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Characteristics of Maleo bird spawning nests (*Macrocephalon maleo*) in Lake Towuti, South Sulawesi, Indonesia

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Abstract. *Karim HA, Najib NN, Ayu SM, Fidel. 2023. Characteristics of Maleo bird spawning nests (*Macrocephalon maleo*) in Lake Towuti, South Sulawesi. Biodiversitas 24: 690-696.* Maleo birds (*Macrocephalon maleo*) have a habitat in the forest near the beach or in the middle of the forest near the hot springs. However, in Pekaloa Village, East Luwu District, Maleo birds are found in Lake Towuti, South Sulawesi, Indonesia. This, of course, shows that the habitat of Maleo birds on the shore of the lake is new information, especially on the island of Sulawesi. This research was conducted in Pekaloa Village, Towuti Sub-district, East Luwu District, South Sulawesi. This study was conducted to collect data on the characteristics of Maleo Senkawor (*Macrocephalon maleo*) nests. Secondary data collection began from scientific journals and works, as well as discussions with the surrounding community and the TWA manager of Lake Towuti, while primary data was obtained from measurements and direct observation in the field, as well as laboratory analysis. In this study, five nest plots with 13 nest holes were used, and the vegetation analysis used example plots measuring 175 m^2. The characteristics of the nest pit have an average depth of 0.6 m, a surface diameter of 0.41 m, a temperature of 33.6^oC, and a pH of 6.2. Vegetation analysis found eight species around the Maleo Senkawor bird's nest. Vegetation analysis used the density formula: highest frequency density 19.5 and highest frequency 0.57, lowest density 0.02 and lowest frequency 0.14. This study forms the basis of new information in the conservation of Maleo birds with the characteristics of the habitat conditions for nesting Maleo birds, especially in the coastal area of the lake.

Keywords: Habitat spawning, Maleo preservation, megapode

INTRODUCTION

Maleo birds are classified as rare wildlife and are protected by Law Number 5 of 1990 concerning the Conservation of Natural Resources and their Ecosystems, and are protected based on the Decree of the Minister of Environment and Forestry of the Republic of Indonesia Number P.106/ Menlhk/Setjen/Kum.1/6/2018 concerning protected plant and animal species. The existence of the Maleo population is estimated to be decreasing due to habitat destruction (habitat degradation), hunting, and egg collection in nature. This is of particular concern to governments and conservation agencies in protecting and preserving Maleo birds. The 2000-2004 IUCN organization implemented a program primarily to protect Maleo and other megapod birds (Butchart and Baker 2000). The international conservation agency IUCN (International Union For Conservation of Nature) has included this bird in the Endangered category (IUCN 2016).

Meanwhile, CITES (Convention of International Trade in Endangered Species of Fauna and Flora) categorizes Maleo birds in the Appendix I category, which means that these birds are prohibited for trade (CITES 2017). The Maleo bird makes it one of Sulawesi's endemic animals that are endangered and belong to the category of endangered (Santrio et al. 2020). According to BirdLife International (2020), Maleo is an endangered species due to its small, highly fragmented population and continuous rapid decline.

Maleo bird (*Macrocephalon maleo*) is one of the unique endemic birds of Sulawesi Island because it has a large number of eggs. The distribution of Maleo on Sulawesi is quite widespread, especially in Central Sulawesi, North Sulawesi, Southeast Sulawesi, and South Sulawesi (Gusmawan et al. 2018). Some conservation areas that are well-known as Maleo bird habitats in Central Sulawesi include Bakirang Wildlife Sanctuary, Morowali Nature Reserve, Tanjung Matop Wildlife Sanctuary, and Lore Lindu National Park (TNLL) (Froese and Mustari 2019). The latest information on Maleo birds is found in South Sulawesi, located in Pekaloa Village, Towuti Sub-district, East Luwu District. This is based on the exploration conducted by the Faculty of Forestry Team of Andi Djemma University in 2018. Maleo birds are usually found on the beach or in the middle of the forest near the hot spring, but now Maleo birds are found a lot on the shore of the lake. In 2018, information from the public stated that Maleo birds were seen on the shore of Lake Towuti, Pekaloa Village (Karim 2020). This is certainly new information for Maleo bird habitats.

The Maleo is still a rare species that can only live in coastal forests with fine sand and direct sunlight. Maleo birds lay eggs in holes that are cut off from time to time and in open land warmed by geothermal energy or sunlight (Balantukang et al. 2015). The process of breeding Maleo birds is carried out by planting their eggs in hot sand or soil

that has geothermal activity, which then the process of hatching and enlarging the offspring of Maleo birds left to nature (Argeloo 1994; Harris et al. 2014). Maleo bird egg holes are usually located on sun-drenched volcanic and sandy beaches, lakesides, riversides, and along the coast (Santrio et al. 2021). This type of bird is characterized by eggs measuring 5-6 times the size of chicken eggs, incubated with solar or geothermal heat for 2-3 months (BirdLife International 2001). The hatching and enlargement of eggs take place in the soil or sand where the eggs are laid. The Maleo bird chooses to nest in the lowland open forest near or surrounded by the river. Maleo lay eggs in areas that are non-vegetable and higher than rivers or lakes (Nafiu et al. 2015).

Maleo birds are one of the members of the megapode that is threatened with extinction due to one of the impacts of land use changes in the habitat of Maleo birds (Saputra and Yuda 2020). The high change in the activity of forest areas opened for plantations, agricultural activities, and destruction of forests that become the habitat in situ of Maleo birds, causes a decrease in environmental carrying capacity for breeding. Forest damage reduces available habitat and isolates forests from Maleo bird spawning nests (Gunawan 2000). In addition, the decline in the Maleo population due to fragmented habitat conditions makes this species closer to extinction (Indrawan et al. 2012). Maleo bird population decline is also caused by its natural predators, such as lizards, snakes, and eagles (Maulany et al. 2021). Another problem faced is the destruction of habitat due to the exploitation of Maleo eggs, so the population of Maleo will be reduced in the next few years (Santrio et al. 2021).

The existence of spawning sites is very important as a support for the life of Maleo birds. The spawning site not only serves as a reproductive activity but is also a feeding ground for Maleo birds. The condition of the spawning habitat on the shore of Lake Towuti will be new information for Maleo bird conservation. One attempt to prevent the extinction of Maleo bird populations can be made by ex-situ captivity. The habitat conditions in the lake certainly require a database on the characteristics of nesting. This data is essential for the preservation of Maleo in its original habitat. However, the authors limited this study to the physical condition of eggs (sex determinants) of Maleo birds that were not observed in this study and focused only on the environmental characteristics and vegetation of nest-hole habitats. Based on the above background, it is necessary to conduct research on the characteristics of Maleo spawning nests on the shore of Lake Towuti TWA, Pekaloa Village, Towuti Sub-district, East Luwu District, South Sulawesi Province, Indonesia.

MATERIALS AND METHODS

Study area

The research was conducted in the Lake Towuti Natural Tourism Park of East Luwu District, South Sulawesi Province, Indonesia (Figure 1). Data collection was carried out from September to October 2019. The data collected in this study consisted of primary data and supporting data (data components, data types, data collection methods, and data analysis). The tools and materials used in this study are GPS and compass used to determine the coordinates of the research location, binocular tools, DSLR cameras, Pro cameras used for documentation of research objects and activities, and roll meters. Neat ropes are used to create vegetation observation plots. Soil gauges are used to determine the pH and temperature of the soil, digital scales are used to measure Maleo eggs (if found), camping equipment, plastic bags to store unidentified vegetation types, and the label paper, tally sheet, and stationery are used to record research data. The object of the study was a Maleo bird.

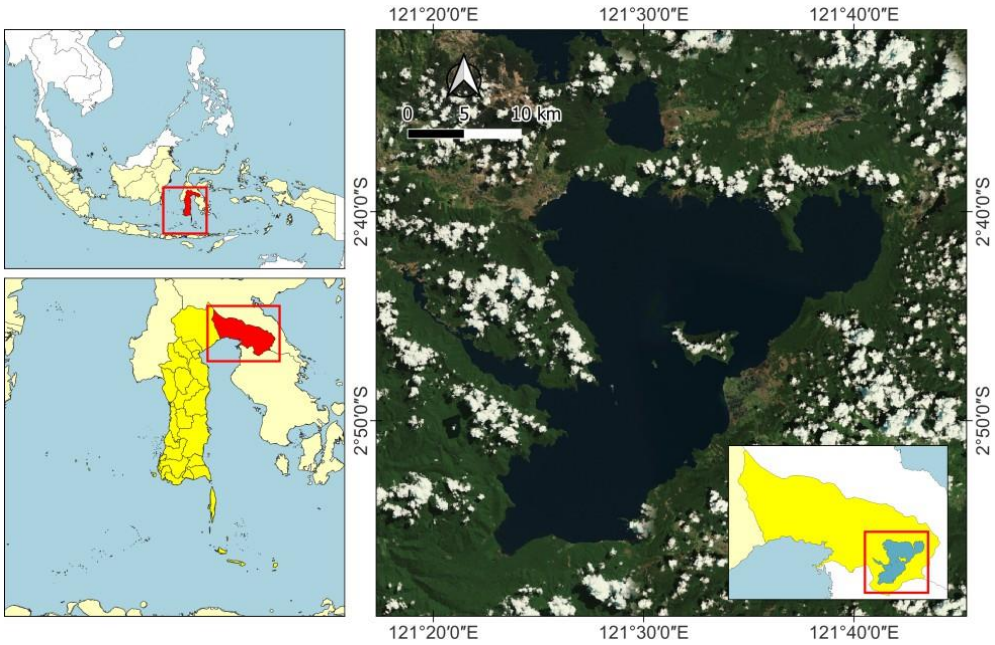

Figure 1. Lake Towuti research location, South Sulawesi, Indonesia

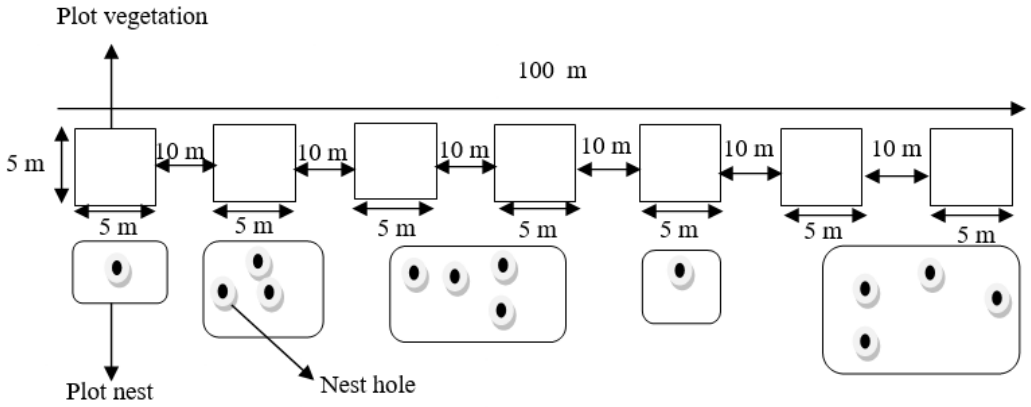

Figure 2. Sketch of the creation of a plot for the collection of vegetation data and the characteristics of the nesting nest

The data collected in this study include Data Characteristics of the Maleo Senkawor Bird Laying Nest, covering the depth and diameter of the nest surface, then soil samples, including texture and pH. Climate, covering soil temperature, vegetation analysis, and Maleo bird egg measurement. This study only focused on the environmental characteristics and vegetation of the habitat in the nesting hole. It was limited without observing the physical condition of Maleo bird eggs (sex determinants).

Field observations to determine the condition of the research area, which is the habitat of the Maleo bird. Based on the results of the Maleo Senkawor bird field survey, conducting lay eggs at 06.00-14.00 while data collection of nest, land, climate, and measurement of eggs is carried out at 14.00-15.00, which is done once in each nest, while the sampling of vegetation is done at 15.00-16.00.

Procedure

The creation of nest plots and vegetation around Maleo nests was carried out by making observations of vegetation plots using the Layered Line Method. This method can be considered as a modification of the multiple plot method or the path method, the 5x5 m Layered Line Method with a 10 m plot spacing systematically created around the seven Maleo nesting plots. Meanwhile, in the creation of nest observation plots, observation plots were made according to the condition of the nest, or irregular plots were made with 5 observation plots (Figure 2). Measurement of nesting characteristics, i.e., depth and diameter. Depth is measured perpendicularly from the ground level to the part of the ground where the Maleo bird eggs are laid using a meter.

Instead, the diameter of the nesting surface is measured perpendicularly twice in each laying hole using a metering tape. Soil includes particle composition and pH. The composition of soil particles was determined by taking soil samples in 13 nesting holes for laboratory analysis. At the same time, pH was measured using a 4-in-1 moisture meter by plugging in the tool and waiting a few minutes for the measurement results. The climate includes the temperature measured by plugging the tool into the nest hole. We wait a few minutes for the measurement results and collect the vegetation data by calculating the number and type of individuals. Maleo eggs were measured using a stroller to measure the length and diameter of the eggs, then weighed the weight of the eggs was using digital scales.

Data analysis

Data analysis, among others: (i) Nesting characteristics such as soil data, climate, and egg measurements are analyzed descriptively in accordance with the results of observations obtained in the field; (ii) About the data of vegetation types around the nest, a vegetation analysis is carried out related to the density and frequency of a type of vegetation in the research plot. Data on vegetation types around Maleo bird nests were further analyzed using the following equation (Knight 1975):

$$\text{Density (K)} = \frac{\text{Number of individuals r of a type}}{\text{Example plot area}}$$

$$\text{Relative density (KR)} = \frac{\text{Number of individuals of a type}}{\text{Total of the entire type}} \times 100\%$$

$$\text{Frequency (F)} = \frac{\text{Number of example squares found in a type}}{\text{Total number of entire measuring compartments}}$$

$$\text{Relative Frequency (F)} = \frac{\text{Frequency of a type}}{\text{Frequency of all species}} \times 100\%$$

RESULTS AND DISCUSSION

Characteristics of Maleo habitat

Lake Towuti is an ancient lake located in Towuti Sub-district, East Luwu District, South Sulawesi Province, Indonesia. 121°20'48"-121°41'11" E and 02°38'22"-02°56'37" S are the coordinates. The Lake Towuti area is part of the Lake Towuti Natural Tourism Park, which is managed by the Natural Resources Conservation Center (BKSDA) of South Sulawesi under the Forestry Development Agency of the Republic of Indonesia. Lake Towuti, Natural Tourism Park, is an ancient tectonic lake with a depth of 203 m, making it the second largest lake in Indonesia after Lake Toba. The maximum area of Lake Towuti is approximately 56,108 ha at an altitude of 293 m. The lake water source comes from several springs and

surrounding water catchment areas that enter the lake through 26 rivers and tributaries.

Based on the geographical location, the spawning habitat is at the coordinate point S 02º39'15.96", BT 121º29'57.48". The coastal area in Lake Towuti, which found several nesting holes, has an average nesting height from the lake. Surface ±1 m, with a land area of Cape Tominanga spawning 1.4 ha, while the area used by Maleo birds is 390.66 m^2 or 0.03 ha, the nearest nesting distance to the edge of the forest is about 100 m and to the lake is about 28 m. Observations at the location of the study indicate that the Maleo persuasion habitat is at the transition boundary (ecotone) between the Tominanga Protected Forest and Lake Towuti TWA. This area is a corridor for Maleo birds to reach their cruising areas. On average, in the dry season, the area around the Maleo Bird spawning area in Tominanga Forest experienced an increase in land due to a decrease in lake water level. This condition is thought to be a new nesting site that Maleo birds can take advantage of. The heat conditions of Maleo bird nesting come from the temperature of the soil. Soil temperature is strongly influenced by weather conditions (such as the length of solar irradiation and rainfall). Therefore, Maleo bird coastal habitat is only used in the dry season at the time of maximum radiation (Gunawan 2000).

The excavation holes of Maleo nests are generally in the shape of an inverted triangle, with the width of the front being smaller than the back (Gunawan 2000). This inverted triangular nest is thought to protect Maleo eggs that are in the ground. There are five nesting plots in the nesting habitat, consisting of 13 active nesting holes. The number of spawning holes can be associated with the availability of a large enough area so that Maleo birds can freely make spawning holes. The large, open spawning area also minimizes the frequency of using the same nesting holes by Maleo parent birds. According to Gunawan (2000), nests in outdoors can generally be found in habitats that are spawning by utilizing solar heat sources.

Plot 1 has an area of 40.8 m^2 with one exploration hole. Plot 2, with an area of 58.4 m^2, has three exploration holes. Plot 3 with an area of 104.5 m^2 has four blast holes, and plot 4 with an area of 11.9 m^2 has one blast hole. In addition, plot 5 with an area of 175 m^2 has two exploration holes. Each laying hole has a distance between the nesting hole and the pit volume, which can be seen in Table 1.

The discovery of all Maleo bird nests on the shore of Lake Towuti is in between the habitat of the lake and the swamp, where reed plants dominate the condition of the land around the spawning nest. The nest hole is in an open pile of black sand and is exposed to direct sunlight throughout the day. Higher heat conductivity in sandy soils than in clay soils (Bockheim et al. 2020). Maleo birds choose a warm location to soak their eggs because the sun's heat can be directly absorbed into the soil, then the soil stores the heat (geothermal heat) that can be tolerated by Maleo birds' eggs during the hatching period (Jamili et al. 2015). According to Gunawan (2000), when compared to hatching in Insitu (geothermal source) at 34ºC from 18 hatched eggs, all hatched. However, to date, there is no information on the impact of blast temperature on the determination of Maleo bird egg sex. The characteristic data observed in the 13 holes of Maleo bird nests can be seen in Table 2.

In the process of conservation and preservation of Maleo birds, one of the important things is to determine the suitability of the habitat for spawning and breeding. Therefore, knowing the characteristics of land suitable for exploration is one of the supports for the conservation of Maleo birds. Based on observations on the shore of Lake Towuti regarding the depth and diameter of the surface of the Maleo hatch hole, almost every hatch hole has a difference in depth, the diameter of surface, temperature, and pH in the hatch hole. This data is very basic and forms the basis of information in the effort to manage in-situ/ex-situ, which includes the protection, restoration, and design of suitable habitats for Maleo birds, as well as the assistance of in-situ and ex-situ egg hatching programs.

Table 1. Volume and distance data between Maleo bird nests in Lake Towuti, South Sulawesi Province, Indonesia

Egg hole	Distance between laying holes (m)	Nest hole volume (m^3)
1	23	1.24
2	3	0.69
3	4.60	0.64
4	3.60	0.70
5	4.80	0.61
6	2.70	0.64
7	2.50	0.79
8	6.40	0.90
9	28	0.81
10	6.20	0.74
11	6.60	0.76
12	4	0.79
13	4	0.57
Total	**92.9**	**9.99**

Tabel 2. Observational data on the characteristics of the Maleo bird's nest in Lake Towuti, South Sulawesi Province, Indonesia

Nest plot	Laying hole	Depth (m)	Surface diameter (m)	Temperature (ºC)	pH
P I	1	0.64	0.45	34	6.0
P II	2	0.55	0.40	34	6.0
	3	0.60	0.37	33	6.5
	4	0.53	0.41	34	6.5
P III	5	0.54	0.38	34	6.5
	6	0.51	0.40	34	6.5
	7	0.55	0.43	34	6.5
	8	0.57	0.45	34	6.0
P IV	9	0.68	0.39	30	6.0
P V	10	0.59	0.40	34	6.5
	11	0.50	0.44	35	6.0
	12	0.60	0.41	34	6.0
	13	0.53	0.37	33	6.0
Average				33.61	6.23

The results of observations on 13 nesting holes carried out on the edge of Lake Towuti showed that the size of the resulting nesting holes was not uniform in diameter and depth of the nesting holes. Pit depth varies from 0.51 m to 0.68 m. The depth of the hole in the North Buton Wildlife Sanctuary shows that the depth of the hole is between 46-60 cm (Santrio et al. 2021). While the results of the nest hole diameter measurement range from 0.37 m to 0.45 m, this difference can be caused by the condition of soil constituent particles, vegetation roots around the Maleo nest, and weather factors. According to Dekker (1988), Maleo will lay eggs deeper when the soil temperature falls after heavy rainfall and shallower after drought.

Maleo generally doesn't dip their eggs but just bury them in a hole and leave them. The following egg-hatching process uses geothermal energy. Maleo has a unique reproductive strategy where for several months each year, couples lay many eggs in communal nesting sites on naturally heated substrates of sun-warmed beach sand or geothermally heated land (Froese and Mustari 2019). The sand-dominated and sun-drenched shore of Lake Towuti is one of the supporting factors for Maleo egg hatching. Therefore, temperature plays an important role in the hatching process. Temperature plays an important role in hardening Maleo bird eggs because if the temperature is too low or too high, it can decrease the percentage of hatching. Widya (2021) states that direct sun exposure occurs throughout the day and dramatically affects soil temperature, so that embryo development in Maleo bird eggs can develop. The temperature is also influenced by the depth of the soil because each nest plot has a different thickness, so the strength of the heat source is also different for each nest (Table 2). On the other hand, the depth of the nest is also related to the safety of the newly hatched Maleo cub. The boy Maleo broke the eggshell and dug a hole in the ground.

From on-site observation, the Maleo nest is located in the open on the shore of Lake Towuti, which is exposed to direct sunlight. Dilawar et al. (2021) showed that the suitable temperature range for the natural hatching of Maleo eggs is 32-35ºC. The results of measurements carried out on the shore of Lake Towuti show that Maleo bird nesting holes have soil temperatures ranging from 30ºC to 35ºC with an average of 33.61ºC. Widnyana et al. (2019) mentioned that the soil temperature suitable for Maleo egg hatching conditions ranges from 33-35ºC. Maleo bird research in West Sulawesi found that the acceptable soil temperature for hatching Maleo eggs was between 32-35°C (Maulany et al. 2021). An important factor that determines the suitability of a place as a spawning nest is the presence of heat sources in the depths of the soil that can be reached by Maleo birds. Temperature differences within tolerance limits (location and heat source) only result in differences in curing time (Gunawan 2000).

From the results of soil acidity measurements (pH) in Maleo bird nests in Lake Towuti ranged from 6.0-6.5, with an average of 6.23, while neutral pH was in the pH range of 6-7. From the observations, it can be assumed that Maleo eggs can tolerate sour soil conditions (pH). This is caused by rapid infiltration, resulting in a lack of organic matter and nesting areas in open sandy soils. The pH diversity in nests is thought not to affect Maleo birds in the selection of nesting habitats but to impact microorganisms in the soil.

The sand in Lake Towuti is different from the sand in other Maleo bird habitats because it is black with small rocks. The results of laboratory tests are known that the composition of soil particles in Maleo nest holes is presented in Table 3. The composition of soil particles in Maleo nesting holes is dominated by sand which is 93.3%, and the smallest percentage is dust. + clay which is 0.6%. According to Froese and Mustari (2019), *Macrocephalon maleo* is an endemic megapode bird in Sulawesi, Indonesia, which lays large eggs in communal nesting sites in sand or naturally heated soil. In addition, the type of sandy soil particle composition affects the excavation of nest holes and hatching eggs because Maleo birds easily dig sand, and sand stores heat, so it makes it easier for eggs to hatch. Non-adherent grain conditions make sandy soil easy to dig, as well as higher heat conductivity in sandy soil than in clay (Gunawan 2000). In addition, the sandy nature of the soil quickly releases water so that it is not affected by puddles. The texture of sandy soil is very important in terms of its ability to withstand water for Maleo bird nests and has many macropores to facilitate air exchange. The texture of sandy soils that tend to be coarse has a lower water-holding ability compared to smooth textured soils (clay) (Bockheim et al. 2020).

Table 3. Soil type texture data for each Maleo egg-laying nest in Lake Towuti, South Sulawesi Province, Indonesia

Explosion hole	Gravel (%)	Sand (%)	Dust + Clay (%)
1	4.4	93.5	0.7
2	5.7	92.8	0.8
3	6.1	92.3	1.1
4	7	94.2	1.1
5	5.1	93.2	0.7
6	6.5	92.3	0.4
7	7.3	93.3	0.4
8	6.1	93.8	0.6
9	5.8	93.0	0.3
10	6.5	93.5	0.5
11	5.7	92.0	0.8
12	7.5	94.3	0.6
13	4.7	93.3	1.0
Average	6.0	93.3	0.6

Table 4. The type of vegetation that grows around Maleo bird nests on the shores of Lake Towuti, South Sulawesi Province, Indonesia

Species name	K	KR(%)	F	FR(%)
Imperata cylindrica	19.5	57.18	0.57	21.34
Fimbristylis bisumbelata	0.12	0.35	0.42	15.73
Cyperus rotundus	5.12	15.01	0.42	15.73
Morinda citrifolia	0.02	0.05	0.14	5.24
Ischaemum rugosum	8.12	23.81	0.28	10.48
Paspalum conjugatum	0.39	1.14	0.14	5.24
Eleusine indica	0.76	2.22	0.28	10.48
Sacciolepis interrupta	0.07	0.20	0.42	5.71

Maleo birds live wildly in shrubs ranging from hot open flat places to dense hills 1200 meters above sea level (Martin et al. 2017). Vegetation around the research site can serve as a place to forage, hide from predators, and affect the temperature of the Maleo nest hole. Vegetation analysis was carried out on the shore of Lake Towuti, precisely at the location around the Maleo blast hole. The Line Layout Method was used with seven 5x5 m squares. The vegetation around the Maleo bird nesting hole is dominated by lower plants, such as reeds (*Imperata cylindrica*) and grasses (*Eleusine indica*), as well as noni trees (*Morinda citrifolia*). According to Santrio et al. (2021), The environmental condition of each hole is influenced by the type of vegetation, namely plants that are the source of Maleo bird food. The presence of grass growing high in the nest provides several advantages for Maleo birds. In addition to being a source of food (seedlings), the vegetation of the spawning habitat also benefits Maleo birds, which can hide from predators during the spawning process. Tasirin et al. (2021) said that the vegetation needs of Maleo birds are generally to eat, rest, hide in nests, shelter from predators, or escape from them.

This study forms the basis for obtaining new information on the condition and characteristics of Maleo bird nesting habitat in the coastal area of the lake. The characteristics of Maleo bird nests in Lake Towuti observed include an average nesting hole depth of 0.56 m and an average nesting diameter of 0.41 m. Maleo birds are indirectly tolerant of the temperature conditions of nesting. Of course, the spawning grounds should be placed to obtain the maximum heat source to soak the eggs. The average temperature of a Maleo nest on the shore of the lake towuti is 33.61ºC. From the results of soil samples, the composition of soil particles shows that Maleo bird nest holes are a type of sandy soil. It benefits Maleo birds in digging and is resistant to the heat conditions of nesting holes. The presence of vegetation around Maleo's nest generally lays eggs for foraging, shelter, or escape from predators. In the future, it is necessary to observe the relationship of nest hole characteristics (temperature, soil, pH, and hole depth) to the sex ratio of Maleo bird eggs.

On the other hand, this study is important for the conservation of Maleo birds because it provides new information regarding the egg-nesting characteristics of Maleo birds in lake habitats. On the other hand, this study can be the basis for the community that the condition and characteristics of Maleo egg nests are very important for the survival of Maleo birds living in the vicinity. One of the problems of population decline, in addition to habitat degradation and fragmentation, is the lack of awareness of people who still use Maleo eggs. In the future, it is necessary to understand the people who live around the nest of eggs about the critical value of endemic animals so that the survival of Maleo birds is maintained.

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