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Nesting site characteristics and egg hatching success of Maleo (*Macrocephalon maleo*) in Hungayono Sanctuary, Gorontalo

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Abstract*. Maleo population is decreasing due to the decline in the suitable breeding sites. The establishment of a maleo sanctuary in Hungayono aims to increase the maleo population by protecting its eggs and increasing the success rate of eggs hatched. This study aims to analyze the characteristics of maleo nesting habitats, describe the semi-natural maleo egg hatching management in the sanctuary, and analyze the success rate of maleo egg hatching in Hungayono. The results showed that the Maleo nesting sites were clean of bushes and shrubs, but there were still shades from trees or bamboo. The nesting sites are close to rivers and geothermal sources with mixed soil structures. The natural egg burrows have an average depth of 92,8 cm, a width of 82,7 cm, a temperature of 32,5 °C, and a humidity of 90%. Hungayono has seven hatcheries that utilize geothermal heat to hatch Maleo eggs semi-naturally. The burrows size in the hatcheries was made according to the size of Maleo eggs, with an average depth of 32 cm and width of 10 cm, an average temperature is 32,5 °C and humidity is 90,8%. The incubation period for the semi-natural hatcheries is 60–80 days. Maleo egg hatching success rate reached 60,18% in the medium category.*

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INTRODUCTION

Maleo (*Macrocephalon maleo*) is a megapod bird species endemic to Sulawesi Island (Tasirin *et al.* 2021). Currently, Maleo's population continues to decline due to its nesting site being increasingly threatened by human population growth and changes in land use (Bainta *et al.* 2020; Maulany *et al.* 2021). In nature, Maleo faces the threats of limited habitat suitable for nestings and a challenging breeding process (Bashari *et al.* 2020). Maleo has special needs for its nesting site because of its unique breeding behavior. Maleo will leave its egg in a burrow (Gunawan 2004) and leave it to hatch by itself, therefore, the nesting site chosen by Maleo's are specific. According to Bashari *et al.* (2021), Maleo's place its eggs in sandy or volcanic areas in both lowland and hilly primary forests, with natural heat for hatching process such as solar heat or geothermal.

In 2001, the Bogani Nani Wartabone National Park (BTNBNW) in collaboration with several partners, established supporting facilities for managing Maleo nesting sites, one of which is Hungayono. The purpose of the establishment was to manage the nesting sites, semi-natural egg hatching, Maleo chicks rearing, and Maleo chicks release in their natural habitats (Bashari *et al.* 2020). The establishment of Hungayono facility basically aims to increase maleo population by protecting its eggs and increasing its eggs hatching success using semi-natural incubation.

Information about the characteristics of maleo nesting sites in Hungayono and the management of the Hungayono Sanctuary area in an effort to protect Maleo is very important to be studied because it is one of the aspects considered in improving the quality of the management of Maleo conservation in Bogani Nani Wartabone National Park (TNBNW). Based on this, this study aims to: 1) analyze Maleo nesting site characteristics, 2) describe the management of semi-natural Maleo eggs hatching in Hungayono hatchery, and 3) calculate the success rate of Maleo eggs hatching in Hungayono Sanctuary.

METHOD

Research Location and Time

The research was carried out in June-August 2021 in Hungayono nesting site, Bogani Nani Wartabone National Park (TNBNW), Tulabolo Village, East Suwawa sub-district, Bone Bolango district, Gorontalo Province.

Data Collection Methods

The data collected consisted of 3 groups of data, namely the characteristics of Maleo nesting site, the semi-natural eggs hatching management, and the success rate of Maleo eggs hatching. The details of data collection can be seen in Table 1.

Table 1 Types of data and data collection methods

Data Groups	Data	Collection Methods
Characteristics of Maleo nesting site	Plant diversity	Field observation
	Egg burrows soil structure	Field observation
	Egg burrows size	Field observation
	Egg burrows temperature and humidity	Field observation
	Egg burrows distance from heat source	Observation and interview
Semi-natural eggs hatching management (hatchery)	Maleo eggs search and collection	Observation and interview
	Maleo eggs relocation	Observation and interview
	Preparation of semi-natural egg hatching in hatchery	Observation and interview
	Maleo eggs handling	Observation and interview
	Maleo eggs incubation time	Interview
Success rate of Maleo eggs hatching	The number of eggs relocated	Interview and literature review
	The number of eggs hatched	Interview and literature review
	The number of un-hatched eggs	Interview and literature review

Data Analysis

The data of Maleo nesting site characteristics and Hungayono semi-natural hatchery management were analyzed using descriptive methods. The calculation of the success rate of Maleo eggs hatching in Hungayono hatchery was carried out with reference to Fauziyyah (2016), which was adopted for research needs. The formula is as follows:

$$TL = \frac{a}{b} \times 100\%$$

Explanation:
TL = Eggs hatch rate
a = Number of eggs hatched
b = Number of eggs relocated to hatchery

The criteria used to determine the success rate of the semi-natural Maleo eggs hatching in the Hungayono Sanctuary hatcheries were based on the percentage numbers as follows: 0% to 30% is low, 31% to 60% is moderate, and 61% to 100% is high (Fauziyyah 2016).

RESULT AND DISCUSSION

Characteristics of Maleo Nesting Sites in Hungayono

Hungayono is one of the maleo nesting sites that has been actively managed by TNBNW in collaboration with the Wildlife Conservation Society (WCS) since 2003. Hungayono has a forest area of 8,3 hectares located around the Bone Bolango river and natural heat sources (geothermal). Based on the literature review and the result from interviews, there are five nesting sites in Hungayono, of which only four are currently actively used by Maleo. The details of the maleo nesting sites are presented in Table 2 and Figure 1.

Table 2 Nesting sites distance from the river and natural heat sources

Nesting Ground	Area (ha)	Details	Dominant Plants
Beringin	0,75	Distance from Bone Bolango river is about ±30 m, and natural heat sources are about ±2 m	*Piper aduncum* and *Equisetum hyemale*
Halbolo	1,5	Distance from Bone Bolango river is about ±1 m with natural heat sources on the river bank.	*Calophyllum dioscurii, Senna siamea, Garuga floribunda, Equisetum hyemale, Gigantochloa apus, Schizostachyum lima,* and *Aleurites moluccana*
Alang-alang	0,5	Distance from Bone Bolango river is about ±50 m and from natural heat sources is about ±5 m.	*Imperata cylindrica* and *Schizostachyum lima*
Pinanggobolu	0,75	Distance from Bone Bolango river is about ±150 m and from natural heat sources is about ±50 m	*Anthocephalus macrophyllus, Garuga floribunda, Arecaceae sp,* and *Schizostachyum lima*
Crocodile	-	No longer active due to a landslide in the area	-

Figure 1 (A) Beringin nesting ground, (B) Halbolo nesting ground, (C) Alang-alang nesting ground, and (D) Pinanggobolu nesting ground

Natural geothermal is a factor that is strongly suspected to affect the presence of Maleo in the four nesting sites, in addition to other environmental factors (such as the suitability of the soil structure, temperature, humidity, and the existence of threat) that support the hatching process of Maleo eggs. Froese and Mustari (2019) stated that Maleo lays eggs in soil or sand with natural heat sources. Based on the results of field observations, another factor that affected the presence of Maleo was the condition of the nesting sites that were clean of shrubs but still got sufficient shade from trees and bamboo to make it easier for Maleo to detect the presence of predators, these results were in accordance with Poli *et al.* (2016). Table 3 briefly describes the condition of Maleo nesting sites in Hungayono.

Table 3 Characteristics and conditions of Maleo nesting sites

Characteristics	Conditions
Hungayono	The primary forest is overgrown with trees, herbs, bamboo, and reeds. The location was quite far from the nearest cultivated land.
Nesting sites	Sparse vegetation, clean of shrubs, with shade from trees and/or bamboo
	Close to Bone Bolango river and natural heat sources point
Soil structure	Mixed soil, with gray soil color, Maleo likes sandy soil structure
Heat sources	Geothermal heat

The condition of the Hungayono nesting sites were not much different from Jamili *et al.* (2015), Poli *et al.* (2016), and Santrio *et al.* (2021). The sandy soils in the nesting sites make it easier for Maleo to dig holes or burrows for their eggs (Nafiu *et al.* 2015). In addition, according to Sadjab *et al.* (2020), sand contains iron (Fe) with high thermal conductivity properties, which can affect temperature and humidity of sand based on depth. According to Gunawan (2004) there are several locations favored by Maleo as nesting sites, such as tree buttresses, around fallen trees, in tree root systems, and under canopy cover. The location that is not favored by Maleo was an open area overgrown with reeds (*Imperata cylindrica*) and without shade because these locations do not guarantee safety and ease of digging the burrows (Poli *et al.* 2016).

Maleo egg-laying activity starts at around 06.00 to 10.00 AM Central Indonesian Time (WITA), and if there are disturbances, whether in the form of predators or the presence of a human, Maleo will delay laying their eggs and start again at around 04.00 to 05.00 PM WITA. Santrio *et al.* (2021) stated that Maleo laid their eggs from 09.00 AM to 04.00 PM and was strongly influenced by the conditions of their surroundings. The search for Maleo eggs by Hungayono keepers was carried out every day from around 10.30 AM to 02.00 PM WITA in all nesting sites. The search was conducted by observing signs left behind by Maleo, such as their footprints, the conditions of the soil that looked loose, and whether there were litters or twigs on the egg burrow cover. Gunawan (2000) stated that burrows that might contain Maleo eggs have a neat cover and traces of footprints or feces.

Based on the results of measurement, Maleo egg burrows were found to have different widths and depths but still had a relatively similar temperature and humidity (see Table 4). According to Hafsah *et al.* (2008), the depth and width of the egg burrows were related to soil texture and the strength of the geothermal heat.

Table 4 Natural Maleo egg burrows characteristics

Characteristics	Burrows number-									
	1	2	3	4	5	6	7	8	9	10
Burrows width (cm)	79	26	35	30	82	107	180	110	108	70
Depth (cm)	79	110	76	43	80	95	130	103	130	82
Temperature (^{o}C)	34	32,7	33,8	33,8	32,4	32,3	31,9	31,3	31,9	31
Humidity (%)	93,8	93	93	93,3	87	90,2	83,9	88,5	83,9	87

Based on Table 4, Maleo's egg burrows in Hungayono had a depth ranging from 43 to 130 cm with an average of 92,8 cm and a width ranging from 26 to 183 cm with an average of 82,7 cm. Hafsah *et al.* (2008) stated that Maleo's egg burrows with a depth of 51 to 87 cm from surface can provide optimum temperature and humidity for Maleo embryo development, as well as protect eggs from predators. The depth difference in several Maleo egg burrows in each nesting site were influenced by several factors, including soil structure, burrow temperature, and also the threat of predators. Gunawan (2004) and Nafiu *et al.* (2015) reported that the depth of the egg burrows was one of the efforts made by Maleo to anticipate threats from egg predators.

The measurements of temperature showed that the egg burrows had temperature ranging from 31 to 34°C with an average of 32,5°C, while the humidity of the egg burrows ranging from 83,9 to 93,8% with an average of 90% (see Table 4). The results of these measurements were not much different from Hafsah *et al.* (2008), with a temperature of 33,03°C with a humidity of 68,55%. The depth of Maleo egg burrows in their natural habitat was influenced by natural heat sources such as geothermal. According to Gunawan (2000), nesting sites with geothermal heat sources have varying egg burrows depths depending on the strength of the geothermal. The deeper the egg burrows, the closer it is to geothermal sources, and the higher its temperature.

Semi-Natural Maleo Eggs Hatching Management In Hatchery

The egg-hatching process in the hatchery was carried out semi-naturally using geothermal heat sources, and the burrows were created in soil with mixed texture. Hungayono has seven hatcheries located around the nesting sites, which have been managed since 2004 (Figure 2).

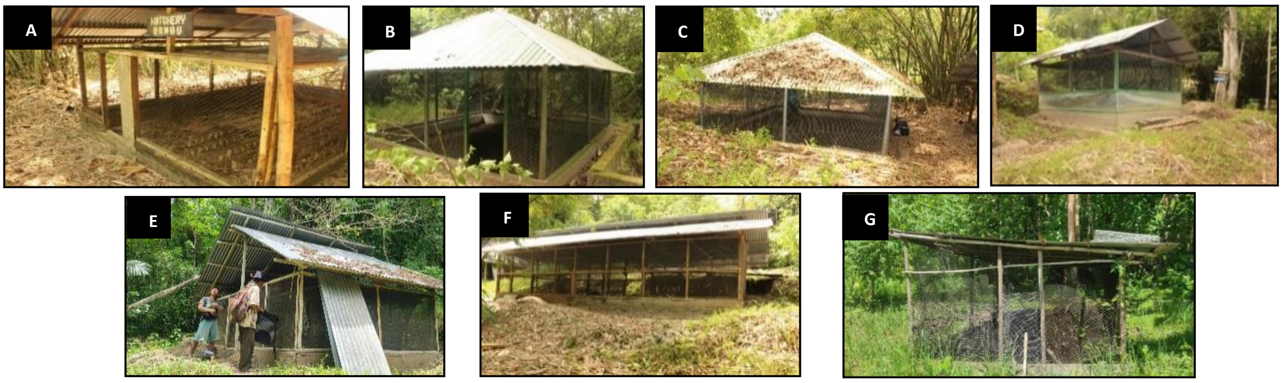

Figure 2 (A) Bamboo hatchery, (B) TN3 hatchery, (C) TN2 hatchery, (D) TN1 hatchery, (E) Fiper hatchery, (F) Florindus hatchery, (G) Emergency hatchery

The egg hatching process was carried out based on the BTNBNW (2020) nesting sites management procedure, including 1) searching and collecting eggs in Maleo natural habitat, 2) setting up artificial (semi-natural) egg burrows, 3) eggs hatching and monitoring the hatching process, and 4) relocating and caring for the Maleo chicks after hatching. The four aspects of the governance stages of hatching eggs in the sanctuary were briefly described below:

1. Searching and Collecting Eggs in Natural Habitat
   This stage was carried out every day by Hungayono keepers from 10.30 AM to 02.00 PM WITA. The eggs found were handled manually, put in a bucket with leaf litter to prevent friction between eggs, then the eggs were brought down to the Sanctuary area for the semi-natural (artificial) hatching process in the hatchery.
2. Semi-Natural Hatchery Preparation
   Maleo eggs obtained from the nesting sites were put into the hatchery by placing them (burying) into the artificial burrows for hatching. Before the egg-burying process was carried out, the burrows were cleaned out from remaining egg shells or gravel, and then the burrows were dug to an average depth of 25 to 40 cm to achieve the appropriate temperature and humidity. The result of measurements of the semi-natural egg-hatching burrows in the hatchery showed that the depth of the artificial burrows was different to achieve

the optimum temperature needed to hatch Maleo eggs, but in general, the width of the artificial burrows had the same size adjusted to the size of Maleo eggs (see Table 5).

Table 5 The characteristics of Maleo manmade burrows in the hatcheries

Hatchery	Width (m) x Height (m)	Burrows size (cm)		Temperature (ºC)	Humidity (%)
		Depth	Width		
Bambu	17,42 x 2,08	33	10	32	91,7
Florindus	34,1 x 3	30	10	32,7	91
Fiper	15,58 x 2,17	40	10	32,3	90,4
TN 1	12 x 2,16	37	10	33,6	93,1
TN 2	17,42 x 2,08	25	10	31,5	88,9
TN 3	17,89 x 2,05	25	10	32,3	90,4
Darurat	12 x 1,8	35	10	33	90

3. Hatching Eggs and Monitoring the Hatching Process

   An important step in the process of semi-natural hatching of eggs in the hatchery after the collection of eggs and the preparation of the burrows was the hatching of eggs. This step begins with burying Maleo eggs into the artificial burrows in the hatchery with the blunt side of the egg facing upwards, which is in accordance to Lembang *et al.* (2018) that stated that in the process of burying eggs, the correct position of laying eggs was to place the egg vertically with its pointed part at the bottom. After that, the eggs were given bamboo sticks which serve as a sign that there is an egg in the burrows, with a distance between eggs of ±14 cm. The burrows were then covered with soil so as to cover the entire egg, and the soil was then patted until it was even but not too dense. The position of the burrows in the hatchery was made following the coordinate system that has been made to make it easier to check whether the eggs have hatched or not (Bashari *et al.* 2020). Furthermore, the monitoring activity was carried out so that the Maleo hatchlings could immediately be handled to avoid the possibility of death.

4. Relocation and Treatment for Maleo Chicks After Hatching

   After the eggs hatched, the chicks were left in the hatchery for around three days, then relocated to the habituation cage. This means that Maleo chicks in the hatchery did not receive immediate treatment from the keeper and were not given any feed. Feeding was only carried out when the Maleo chicks were in the habituation cage. According to Tanari (2007), Maleo chicks that just hatched from their eggs do not need to be fed until they are two days old and still use the food in their bodies. The relocation of Maleo chicks from the hatchery to the habituation cage was carried out using a backpack with a size large enough to accommodate 2-3 chicks.

The treatment for Maleo chicks was only given in the habituation cage in the form of feeding and drinking. If the Maleo chicks were considered strong and agile, they would be released into their natural habitat without any special treatment in their release activities in Hungayono. The habituation cage has been constructed in such a way as to resemble the Maleo's natural habitat so that the Maleo chicks were released only by opening the habituation cage or by expelling Maleo chicks to get out of the habituation cage to their natural habitat.

The measurements of temperature showed that the artificial burrow in the hatchery had temperature ranging from 31 to 33ºC with an average of 32,5ºC and humidity ranging from 88 to 93% with an average of 90,8%. The hatching times ranged from 60 to 80 days. Gunawan (2004) stated that Maleo eggs hatched semi-naturally in-situ take around 60 to 85 days with temperatures ranging from 32 to 34ºC and humidity of 60 to 85%. Hafsah *et al.* (2008) stated that Maleo eggs in their natural habitats needed around 60 to 69 days to hatch with a temperature of 32,90ºC and humidity of 68,41%, while eggs hatched in ex-situ needed around 72 to 86 days of incubation with temperature of 31,68ºC and humidity of 67,52%. Hafsah *et al.* (2008) also stated that hatching Maleo eggs using natural heat sources like geothermal has a relatively constant temperature and humidity compared to ex-situ hatcheries that rely on a solar heat source.

Temperature stability in the semi-natural burrows in the hatcheries is very important because it will determine the success of the hatching process (DuRant *et al.* 2013; Sheavtiyan *et al.* 2014). Hafsah *et al.* (2008) stated that the hatching process of Maleo eggs using geothermal heat has a constant temperature compared to the hatching process using a solar heat source, which has an unstable temperature. This could impact the growth of the embryos causing them to not be able to develop normally. With regard to temperature stability, one of the key factors was the soil structure prepared in each of these semi-natural hatcheries. In this case, from the 7 hatcheries, as presented in table 5 above, it turns out that the location and structure of the soil were different, which was adjusted to the temperature and structure of the soil from which the eggs were collected. This was intended to create semi-natural conditions in the hatcheries that were hoped to guarantee the stability of temperature and soil humidity in the semi-natural artificial burrows.

Semi-Natural Maleo Egg Hatching Success Rate in Sanctuary

According to the data acquired through interviews and literature review, there were 15.510 eggs collected from all of the nesting sites in Hungayono during the period of 2011 to 2020, in which 9.334 (60,18%) eggs successfully hatched in the hatcheries. Based on the criteria for the success rate of hatching eggs from Fauziyyah (2016), Hungayono semi-natural hatcheries achieved a moderate category. Figure 3 below shows a graph of the number of eggs collected and successfully hatched in Hungayono from 2011 to 2020.

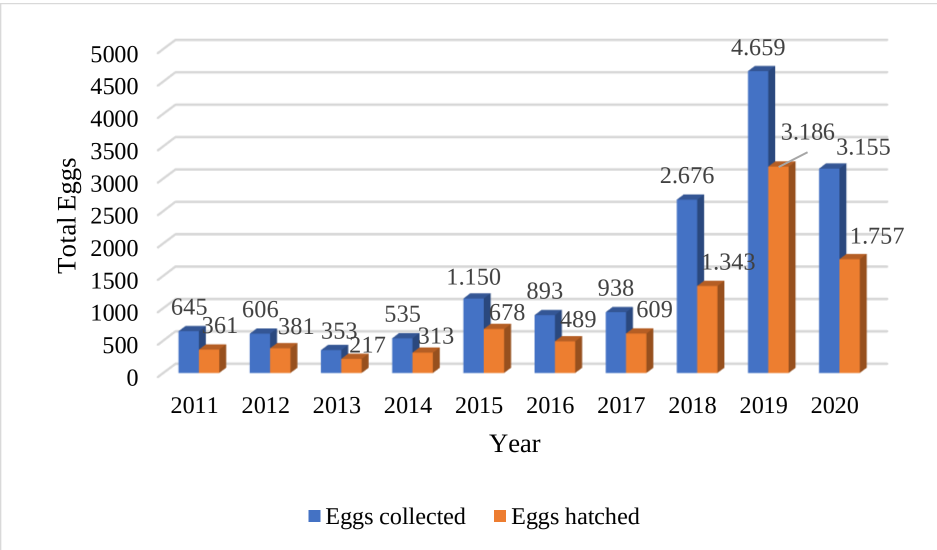

Figure 3 Number of Maleo eggs collected and successfully hatched in the hatchery

Figure 3 shows the development and growth of Maleo eggs in their natural habitat. The eggs increased in line with the improvement in the management of their natural habitat, especially related to controlling threat factors such as egg theft by humans, site security, and maintenance by keepers. Figure 3 also shows that the success rate of semi-natural egg hatching in the hatcheries shows a tendency to increase from year to year, although in general, the average success rate is still moderate. The trend of increased success rate in the hatching of Maleo eggs from year to year was partly due to ongoing efforts to improve management, starting from the stage of collecting eggs, transporting, and relocating eggs to the artificial burrows in the hatcheries, including efforts to maintain stable temperature and humidity during the process of eggs incubation in the artificial burrows in the hatcheries.

A significant increase occurred in 2019 with the total number of eggs collected from nature was as many as 4.659 eggs of which 3.186 eggs (68,38%) were successfully hatched, although the highest percentage of eggs hatched happened in 2013 (76,77%) the number of eggs being collected and hatched was far smaller with only 353 eggs being collected and 217 eggs hatched. An overview of the improvement of egg collection from their natural habitat and efforts to improve the management of Hungayono Sanctuary (hatcheries) in a sustainable manner showed an increase in the success rate of eggs being hatched and also the success of releasing the hatched chicks into their natural habitat. The intervention of Maleo bird management practices is expected to support bird conservation efforts in their natural habitat in Bogani Nani Wartabone National Park.

CONCLUSION

Maleo nesting sites are clean of bushes and shrubs, but there were still shades from trees or bamboo. The nesting sites are close to rivers and geothermal sources with mixed soil structures. The natural egg burrows have an average depth of 92,8 cm, an average width of 82,7 cm, an average temperature of 32,5 ^{o}C, and average humidity of 90%. Hungayono has seven hatcheries that are used for the semi-natural egg-hatching process using geothermal heat. The man-made burrows size in the hatcheries was made according to the size of Maleo eggs, with an average depth of 32 cm and an average width of 10 cm, an average temperature is 32,5 ^{o}C, and an average humidity is 90,8%. The length of the incubation period for the semi-natural hatcheries is 60 to 80 days. Maleo egg hatching success rate reached 60,18% in the medium category.

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