Effects of Meteorological Factors on the Expression of Nesting Behaviour in the Sulawesi Babirusa (*Babyrousa celebensis*)

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ABSTRACT

The impact of environmental stimuli on the expression of nesting behaviour of Sulawesi babirusa (*Babyrousa celebensis*) was explored over a period of 1339 days from 01st August 2006 until 31st March 2010 in a large animal enclosure on Bali, Indonesia. We found that nest building behaviour and the re-use of sleeping nests occurred more frequently in the dry season than the wet season and was clearly influenced by both a drop in the ambient temperature and an increase in wind speed. Additionally, net effective temperature (NET) computed from a combination of ambient temperature, relative humidity, and wind speed indicated a close relation to the nesting behaviour frequency; a decreasing trend of the expression rate of nesting behaviour with increasing NET in the early evening. Moreover, the trend of the expression rate by 12-hr NET fluctuation from 05:00 hr to 17:00 hr was also found out in all seasons. Meanwhile, 24-hr rainfall had a negative impact on the expression rate. These findings suggested that NET was a useful meteorological index to discuss the motivation to exhibit the nesting behaviour of babirusa, and also babirusa probably found thermal comfort in the sleeping nest.

Key words: babirusa, net effective temperature, seasonality, sleeping nest, weather condition

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INTRODUCTION

The babirusa (Genus *Babyrousa*) is a wild pig inhabiting Sulawesi and the neighbouring islands of Indonesia. It comprises of three extant species; Sulawesi babirusa (*Babyrousa celebensis*)[1], Moluccan babirusa (*Babyrousa babyrussa*)[2, 3] and Togian babirusa (*Babyrousa togeanensis*)[4]. The IUCN Red List indicates the population trend as “decreasing” for all three species due to human-caused threats, and Sulawesi babirusa is currently listed as “Vulnerable” [5]. Among the three species,

Sulawesi babirusa is the only species to be maintained in zoological institutions. Global collaboration of conservation efforts has been made for a long-term survival of *in situ* and *ex situ* populations of this species[6]. Simultaneously, zoos holding this species have been encouraged in research activities to expand our knowledge of biology, behaviour and successful management of this species. However, there is a limited number of works carried out at zoos to understand the normal behaviours that they exhibit in their natural ecological environment, for example general behaviour[7, 8], agonistic behaviour[9], and ploughing behaviour[10]. This is probably because of design and spatial restriction of the animal enclosure and appropriate climatic conditions for expression of

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Fig. 1 A Sulawesi babirusa sleeping nest.

A: A male Sulawesi babirusa *Indro* standing in the cogongrass.
B: A sleeping nest created in a depression in the cogongrass by *Indro*. Babirusa Park.

some behaviours in this species.

In the preceding article[11], we described several characteristics of the nesting behaviour of this species, observed in a spacious outdoor enclosure fulfilling the environmental requirements[12, 13], in Bali, Indonesia. In short; 1) Mainly before dusk, but not every day, both sexes of babirusa gather plant matters such as fallen leaves, twigs, grass (Figs. 1 and 2ABC) and occasionally pluck some parts of living trees while standing on the hind limb, and pile them up to build a sleeping nest at their selected sites; 2) After the nest building behaviour of approximately half an hour, they slide headfirst into the nest to sleep (Fig. 2D); 3) Sleeping nests once created are mended with the snout and forelimb to re-use for some days, or used as nest materials of their next sleeping nest.

In the domestic pig (*Sus scrofa*), it is well-known that

Fig. 2 Nesting behaviour of Sulawesi babirusa using leaf-base fibres of round-leaf fountain palm (*Saribus rotundifolius*) and paddy straw provided.

A: A female babirusa *Priska* carrying the leaf-base fibres to the nest site.
B: Subsequently, *Priska* started carrying paddy straw to pile up on the leaf-base fibres.
C: Another female babirusa *Shela* also started carrying paddy straw to build the shared nest.
D: After 30-min nest building, they slid headfirst into the sleeping nest. Bali Zoo.

nest building behaviour is affected directly by season due to environmental temperatures[14]. In the previous reports on the babirusa, there were pieces of observational findings of the response to weather conditions and climatic seasons. According to Guillemard[15], babirusa nests provided shelter from the rain and cold. Babirusa in the Jersey Wildlife Preservation Trust was asleep earlier during the winter[7]. In Antwerp Zoo where babirusa always had free access to their outdoor enclosures through a flapping door, the animals slept in the indoor enclosure for most of their night-time sleeping; they sometimes slept outdoors on hot summer days[8].

In Bali, rainfall exhibits marked seasonal variation caused by the Austral-Asia monsoon; dry months include June-August and rainy months include December-February; there is variation in the transition between these periods. Additionally, it is known that ambient temperature and relative humidity vary more between night and day than between months[16, 17]. Other than the amount of rainfall, some meteorological parameters such as wind direction and wind speed also have distinct differences between the seasons. Taking due note of these climatic conditions at the study site, we recorded the seasonal difference in the frequency of nesting behaviour of the babirusa. The purpose of this article was 1) to examine the effect of meteorological factors on the expression of nesting behaviour in the babirusa and 2) to explore the trigger for nesting behaviour of babirusa.

MATERIALS AND METHODS

Study sites and periods

The study was conducted at Babirusa Park[11, 12], located in a rice-growing area at an altitude of 144 m, Loday village, Bali, Indonesia. The study period was 1936 days long from 01st January 2005 to 20th April 2010.

Animals, enclosures and husbandry

Two pairs of adult Sulawesi babirusa and their six infants (Table 1) kept in the two adjacent spacious outdoor enclosures with their pens (Fig. 3) were observed[11]. Generally, one enclosure accommodated one breeding pair and their infant, and they had *ad libitum* access to the entire area including the pen, grass field, swimming pool and wallowing mud. Animals were fed twice a day at 06:30 hr and 16:00 hr. Sleeping nests, once constructed in the outdoor enclosure, were left untouched unless they were extremely dirty.

Table 1 Sulawesi babirusa observed at Babirusa Park during the period from 01st August 2006 until 20th April 2010.

Name	Sex	Date of birth	Age
Indro	M	17/10/2001	4-8 yrs
Shela	F	07/01/2003	3-7 yrs
April	M	23/04/2003	3-6 yrs
Priska	F	10/10/2003	2-6 yrs
Sherly	F	29/06/2005	1-4 yrs
Karlo	M	19/05/2006	3 mths-3 yrs
Shandro	M	12/08/2006	3 mths-2 yrs
Pindo	M	09/05/2009	5-11 mths
Shergio	M	10/05/2009	5-11 mths
Sherina	F	10/05/2009	5-11 mths

Fig. 3 The layout of Babirusa Park.

Behavioural observations and data collection

A detailed description of the methods used in this study has been noted by Ito et al. (2019)[11]. A total of 12 staff including two authors took turns participating in the data collection. During the 17 hours from 05:00 hr to 22:00 hr every day, at

least five observers per day recorded the following information; date and time, enclosure ID, animal names, oestrous status, nesting place, nest materials, nest material gathering and building behaviour, and resting behaviours. Each behaviour examined in this study was defined as follows: 1) nest material gathering behaviour is “a sequence of behaviour to pick up or pluck plant matters with the mouth to transport them to the nest site”; 2) nest building behaviour is “a sequence of behaviour to create a sleeping nest while manipulating plant matters with the snout and/or forelimb”; 3) re-use of the nest is “a sequence of behaviour to slide into the nest once used for sleeping, including mending the nest once used for sleeping while manipulating plant matters with the mouth and/or forelimb before sliding in”.

Meteorological data collection

From 01st August 2006 until 20th April 2010, ambient temperature (°C) and relative humidity (%) were measured with a thermohygrometer (SK-110TRH II, Sato Keiryoki Mfg, Tokyo, Japan) in the outdoor enclosure every 30 min from 05:00 hr until 22:00 hr. In the same interval, rainfall (mm) was also measured with a tipping bucket rain gauge (Rainew 111, RainWise, ME, USA) from 17th March 2007 until 20th April 2010. Both instruments were installed in the outdoor enclosure where the animal could not reach, and each value was manually recorded by observers of the day. The wind speed (m/sec) adopted was that recorded at the weather station of Bali (<http://www.windguru.cz/62407>). Based on these data, the net effective temperatures (NETs; one of the practical indices of apparent temperature, equivalent perceived by humans, °C) at 05:00 hr, 14:00 hr, and 17:00 hr and at the timing of the nesting behaviour on each observation day were computed using the Misenard formula modified by Gregorcuk[18, 19]:

$$\text{NET} = 37 - \frac{37 - t}{0.68 - 0.0014 \gamma + \frac{1}{1.76 + 1.4v^{0.75}}} - 0.29t \left(1 - \frac{\gamma}{100}\right)$$

where t denotes the ambient temperature in °C, γ the relative humidity in % and v the wind speed in m/sec.

In addition, following consideration of the possibility that the amount of daily fluctuation of NET may affect the expression of nesting behaviour, the 12-hr NET fluctuation was also evaluated. In this study, the 12-hr NET fluctuation was defined as the total amount of the difference between NETs at 05:00 hr and 14:00 hr and in addition, the difference between NETs

at 14:00 hr and 17:00 hr. The onset and termination of the two main seasons, as dry and rainy periods, were determined by three sets of data; monthly precipitation, number of days with rainfall and wind data. We set the length of the two main seasons as three or four consecutive months each, and the remaining months as two transition periods between them. Sunrise occurred in the short period 05:48 hr - 06:34 hr, and sunset occurred in the period 18:06 hr-18:46 hr depending on the month.

Data analysis

The gathering of nest material and subsequent nest building behaviours, as well as the re-use of nests were referred as to ‘nesting behaviour’. Lying behaviour on the bare ground without nest materials was not included in the analyses. Behavioural and meteorological data observed during the 1339 days (44 months from August 2006) were analysed. The data set was divided into two groups, the ‘expression group’ and the ‘non-expression group’ depending on whether or not the nesting behaviour was exhibited by at least one individual each day. Based on 1) our previous findings that the animals most frequently exhibited nesting behaviour for one hour from 17:00 hr to 18:00 hr[11], 2) the availability of wind data that were measured at every hour, and 3) the physiological aspect that existed, but with the unknown time difference/interval (Δt) between “the exposure to external stimuli” and “the expression of the nesting behaviour that we can observe”, we used meteorological data measured at 17:00 hr for the non-expression group. To compare the mean of meteorological data of the two groups, Student’s t -test or Welch’s t -test were applied. To examine the effect of climatic seasons and each meteorological factor on the expression of nesting behaviour, expression rates of nesting behaviour were calculated at each degree of the measured meteorological data. In this study, the nesting behaviour expression rate was defined as the percentage of the number of days when the nesting behaviour was exhibited by at least one individual divided by the total number of observation days. To test for an increasing/decreasing trend in the expression rate, the Cochran-Armitage test[20, 21] was carried out. To secure the precision of this test, the range of the meteorological factors was narrowed to the range where the observed sample number was approximately >40 at each calculation. A statistical difference in the expression rate of nesting behaviour between climatic seasons was examined by the paired sample t -test with individual

Fig. 4 Meteorological monthly data recorded at 17:00 hr during the period from April 2007 until March 2010.

Wind speed and the balance of days with winds blowing from the opposite direction can also be helpful to understand the turning point of the season. In this graph, the easterly wind was defined as that which blew from the direction between the northeast and the southeast, and comparably the westerly wind was defined as that which blew from the direction between the northwest and the southwest. No northerly wind was recorded at 17:00 hr.

pooled data obtained from seven animals; *Indro, Shela, April, Priska, Sherly, Karlo* and *Shandro* (Table 1) who experienced all seasons for more than 12 months in total (368 days of the three dry seasons and 332 days of the three rainy seasons). The influence of rainfall in 24 hours on the nesting behaviour expression was analysed with chi-square test. Statistical analysis was carried out using statistical software R version 2.8.1[22]. *P*-values of less than .05 were considered significant. Statistical results were written along with the APA style.

RESULTS

Meteorological features

The summarised meteorological data observed at 17:00 hr are shown in Fig. 4. Monthly mean ambient temperature at 17:00 hr ranged from 26.4 to 31.0°C. Slightly lower

temperatures were recorded in the middle of the year, mainly in July and August. These months had little rainfall (e.g. 4.6 mm in September 2007) with constantly strong winds from a south-easterly direction. As a consequence, the NET values were relatively low. In contrast, from the end of the year to the beginning of the next year, temperatures were slightly higher, there were many rainy days with much rainfall (e.g. 496.8 mm in December 2007), the wind was from a westerly direction and as a consequence, relatively higher NET values were recorded. The onset and termination of each season in the three years from April 2007 to March 2010 were identified as follows; Dry months were July-October 2007, June-September 2008 and May-August 2009. Rainy months were December 2007-March 2008, November 2008-February 2009 and December 2009-February 2010. The other months comprised

Table 2 Effect of the climatic season on the expression of nesting behaviour.

Animal		Nesting behaviour expression rate (%)	
Name	Sex	Dry season	Rainy season
Indro	M	23.5	7.8
Shela	F	15.9	4.5
April	M	14.0	2.1
Priska	F	22.3	4.8
Sherly	F	16.0	2.7
Karlo	M	13.7	2.3
Shandro	M	17.2	4.8
Mean (SD)		17.5 (3.9)	4.1 (2.0)

the transition periods.

The relative humidity in the early evening showed a wide fluctuation and ranged from 34 to 92%, although in most cases it ranged from 55 to 80%. Seasonal differences in relative humidity recorded at 17:00 hr were small.

Every year, for a short period of around one week in the middle of the rainy season, the study site experienced thunderstorms with more than 10 m/sec of wind speed, referred as “fresh breeze” or stronger on the Beaufort wind force scale 5 to 7.

Effect of the climatic season

The mean nesting behaviour expression rates were 17.5% ($n = 7$, $SD = 3.9$) in the dry season and 4.1% ($n = 7$, $SD = 2.0$) in the rainy season (Table 2). Paired sample t -test indicated a significant difference between the two seasons, $t(6) = 15.01$, $p < .0001$.

Effect of the ambient temperature

Out of 1336 days with available temperature data, nesting behaviour was recorded for 323 days (expression group). Therefore, the overall nesting behaviour expression rate by ambient temperature was 24.2%. The mean ambient temperature measured at the timing of nesting behaviour was 27.6°C ($n = 323$, $SD = 1.6$), while that at 17:00 hr of the non-expression group was 28.6°C ($n = 1013$, $SD = 1.8$). A significant difference was recognised between the two groups, $t(609) = -8.83$, $p < .0001$. In the range of >24 to $\leq 31^\circ\text{C}$, a decreasing trend of the expression rate of nesting behaviour (from 37.8 to 7.6%) with increasing ambient temperature was seen, X^2 (1, $N = 1271$) = 51.81, $p < .0001$ (Fig. 5A). In the dry season, the expression rate of nesting behaviour showed a similar sharp

decline from 56.7 to 21.9% in the range of >25 to $\leq 29^\circ\text{C}$, X^2 (1, $N = 376$) = 15.97, $p < .0001$ (Fig. 5B). In contrast, no more than 22.5% of the rate was shown in the range of >26 to $\leq 31^\circ\text{C}$ in the rainy season (Fig. 5C).

Effect of the relative humidity

The mean relative humidity of the nesting behaviour expression group was 68.2% ($n = 323$, $SD = 7.3$), while that at 17:00 hr of the non-expression group was 67.8% ($n = 1010$, $SD = 8.1$). There was no significant difference between the groups, $t(594) = .81$, $p = .418$, and no specific trend of the expression rate.

Effect of the wind speed

The mean wind speeds experienced by the expression group and the non-expression group were 5.6 m/sec ($n = 323$, $SD = 2.0$) and 4.8 m/sec ($n = 1013$, $SD = 2.1$), respectively. A significant difference between the groups was noted, $t(1334) = 6.11$, $p < .0001$. In the range of >1 to ≤ 7 m/sec of wind speed, the expression rate showed an increase in proportion (from 11.2 to 40.3%), X^2 (1, $N = 1152$) = 49.62, $p < .0001$ (Fig. 4D). During the dry season, wind speed reached 11 m/sec, with the highest frequency of nesting behaviour expression in the range of >5 to ≤ 6 m/sec of wind speed; the increasing trend of the expression rate (from 23.6 to 50.6%) appeared at wind speeds in the range of >3 to ≤ 7 m/sec, X^2 (1, $N = 323$) = 11.66, $p = .0006$ (Fig. 5E). By way of contrast, despite a wider range of wind speeds (up to 15 m/sec), no significant trend of nesting behaviour expression rate was recorded in the rainy season, X^2 (1, $N = 347$) = 0.13, $p = .720$ (Fig. 5F).

Effect of the net effective temperature (NET)

The NET of the nesting behaviour expression group ranged from 14.2 to 26.7°C with a mean of 21.7°C ($n = 323$, $SD = 2.1$). That of the non-expression group ranged from 15.5 to 29.6°C with a mean of 23.0°C ($n = 1007$, $SD = 2.2$). There was a significant difference between the two groups, $t(1328) = -9.78$, $p < .0001$. In the range of >18 to $\leq 27^\circ\text{C}$ of NET, the expression rate of nesting behaviour showed a decreasing trend (from 45.5 to 5.4%), X^2 (1, $N = 1274$) = 68.96, $p < .0001$ (Fig. 5G). Similarly, in the dry season, the decreasing tendency (from 50.0 to 23.8%), X^2 (1, $N = 348$) = 8.17, $p = .0043$ was notable (Fig. 5H). However, a narrow range of the expression rate with maximum 20.8% was recorded in the rainy season (Fig. 5I).

Effect of the 12-hr NET fluctuation

The mean 12-hr NET fluctuation of the expression group was 15.0°C ($n = 323$, $SD = 2.6$), while that of the non-expression

Fig. 5 Stacked histograms of frequency of observation days with and without nesting behaviour, and the rates of expression of nesting behaviour during the period from 01st August 2006 until 31st March 2010.

A-C; Effect of the ambient temperature (°C).

D-F; Effect of the wind speed (m/sec).

G-I; Effect of the net effected temperature (NET, °C).

J-L; Effect of the 12-hr NET fluctuation (°C).

Entire period: A, D, G and J.

Dry season; B, E, H and K.

Rainy season; C, F, I and L.

group was 13.6°C ($n = 1002$, $SD = 2.6$). There was a significant difference between the two groups, $t(1323) = 7.99$, $p < .0001$. The expression rate of nesting behaviour showed an increasing trend (from 5.9 to 42.2%) in the range of >9 to ≤18°C of the NET fluctuation, $X^2 (1, N = 1205) = 62.55$, $p < .0001$ (Fig. 5J). When analysed by season, a similar upward tendency (from

23.5 to 50.0%) was seen in the range of >12 to ≤19°C of the NET fluctuation in the dry seasons, $X^2 (1, N = 368) = 4.75$, $p = .029$ (Fig. 5K), and also the upward tendency (from 0 to 22.2%) was seen in the range of >9 to ≤16°C of NET fluctuation in the rainy season, $X^2 (1, N = 393) = 14.91$, $p = .0001$ (Fig. 5L).

Effect of the precipitation

Annual precipitation was 1933.5 mm in 2008 and 1882.9 mm in 2009. During the period of 1111 days from 17th March 2007 to 31st March 2010, the study site had 451 days with rainfall (≥ 0.5 mm) and 660 days without rainfall. The overall expression rate of nesting behaviour was 24.1% ($n = 268$). The highest rate (27.1%) was seen during the 660 days without rainfall. In the meantime, 19.7% of the expression rate was recorded in the 451 rainy days. The chi-square test indicated a significant difference in the expression rate between the 660 days without rainfall and the 451 days with rainfall, $X^2 (1, N = 1111) = 7.99, p = .0047$. In the limited range of ≥ 0 to ≤ 15 mm of rainfall, a decreasing trend of nesting behaviour expression rate (from 27.1 to 13.3%) was demonstrated, $X^2 (1, N = 1006) = 5.79, p = .0162$.

DISCUSSION

We have shown that climatic seasons and meteorological factors had a significant impact on the frequency of nesting behaviour in babirusa; the expression of nesting behaviour can be understood with the value of NET at 17:00 hr as a meteorological index.

The climatic data measured at the study site (Fig. 4) were typical examples of the two contrasting seasons reported previously [16, 17]. We found that frequent nesting behaviour was displayed particularly in the dry months when windy days continued (Fig. 5E). Although the ambient temperature in the study site changed little throughout the year, evening

'wind chill' in the dry season probably meant that the animals 'felt' cooler than the measured surrounding temperature. Heat is removed from the babirusa body by 1) evaporation after bathing, wallowing or a rain shower, 2) air convection, and 3) conduction into the ground or pen floor when the animal is lying down. Except for the tip of the tail, the skin of the babirusa is only thinly covered with very short hairs [1, 23]. Heat loss from the body is thought to be high in the evening of windy days.

However, there were cases when relatively higher wind speed (> 7 m/sec) did not lead to nest building behaviour (Figs. 5DE). Possible reasons why the strong wind produced a lack of response included 1) caution induced by the strong wind itself, 2) irregular 'wind noises' generated by the wind shaking tree branches, and 3) associated rainstorm reducing motivation to undertake nesting behaviour. When these negative factors were present, the animal returned to the concrete pen which was another good option for a comfortable sleep.

It is widely accepted that humidity affects cutaneous sensation. At a relatively high ambient temperature, high humidity increases the perception of heat. However, our result indicated that the humidity recorded in this study did not affect the frequency of nesting behaviour. Calculations of NET with such ranges of humidity indicated approximately 1°C of the NET rise and drop, respectively (Table 3). In other words, the range of relative humidity measured in this study did not have an impact alone, and always function together with other meteorological factors.

Table 3 Function of ambient temperature, relative humidity and wind speed on the numerical value of net effective temperature (NET).

Function	Ambient temp. (°C)	Relative humidity (%)	Wind speed (m/sec)	NET (°C)
Ambient temp.	30	60	5	24.2
	25	60	5	18.1
	20	60	5	12.1
Relative humidity	25	80	5	19.0
	25	60	5	18.1
	25	40	5	17.3
Wind speed	25	60	10	17.0
	25	60	5	18.1
	25	60	1	20.9
	25	60	0	23.8

NET increased as ambient temperature and relative humidity increase, but decreased with increasing wind speed.

Our observations strongly suggested that low NET conditions in the early evening motivated the animals to build nests (Figs. 5GH). The nests probably provided thermal comfort to the animal. Contrary to the other meteorological indices, the increasing trend of expression rates by 12-hr NET fluctuation was seen in both seasons (Figs. 5KL). Taking the definition of 12-hr NET fluctuation in this study into account, high values of 12-hr NET fluctuation at the study site can be interpreted as the ambient air condition with large amplitude of temperature reached high-temperature state. And, this is a situation where the human can feel hot in the mid-day (14:00 hr), and cool in the early evening (17:00 hr) until the next morning (05:00 hr). Here, the combination of such thermal condition and the animal's response remind us of the 'three-bowls experiment' [24] that is well-known evidence that sensitivity to temperature can alter based on the previous thermal condition. That is, after the adaptation to relatively high temperature, we tend to feel the low-temperature environment to be much cooler (colder) than after the adaptation to low temperature. Recently, the 'three-bowls experiment' can be interpreted with neurophysiological functions of transient receptor potential (TRP) channels including transient receptor potential melastatin 8 (TRPM8) [25, 26]. Therefore, it is probable that babirusa also 'feels' cool in such situations with high values of 12-hr NET fluctuation, and is thereby motivated to make the decision to build a nest for the night's sleep.

The value of NET at 17:00 hr showed an annual cycle with the peak in the rainy season and the trough in the dry season; the expression of nesting behaviour appeared in the trough and corresponded to the dry season (Fig. 6). Some decrease was also seen in the middle of the rainy season. This cyclical pattern was mainly created by the monsoonal wind conditions; the constant, strong easterly wind in the dry season, the westerly monsoon wind in the rainy season and the intervening slowdown of airflow caused by the conversion of wind direction in the transition periods (Fig. 7).

With these meteorological and behavioural evidences, we concluded that

- 1) Drop in the ambient temperature and increase in wind speed are positive meteorological factors to motivate the nesting behaviour for sleep in babirusa. Rainfall is a negative factor.
- 2) The main purpose of their nesting behaviour for sleep was evidently thermal comfort. NET in the early evening

can explain the annual cycle of the nesting behaviour expression rate. 12-hr NET fluctuation is also a useful meteorological index to study the nesting behaviour of babirusa.

- 3) As the result of the combination of the effective weather condition mentioned above, frequent nesting behaviour of babirusa can be observed mainly in the dry season in the study site.

Rainfall had a statistically negative impact on the nesting behaviour of babirusa in this study. When heavy rain completely soaked the ground, babirusa turned to the shelter of the pen. Perhaps babirusa in the wild may select suitable places in the forest to take shelter. During the survey in the Togian archipelago [4], we have recorded a couple of pieces of evidence such as typical babirusa nests created under a large tree growing on the upper part of the wooded hill, and a rock cave called 'babirusa cave' by local farmers. On the other hand, when the rain was gentler, we also recorded nesting behaviour in the outdoor area. We speculated that light rain brought a drop in the ambient temperature and thereby motivated the expression of nesting behaviour. So, even if the same amount of 24-hr rainfall is recorded, babirusa may make a different decision with respect to the selected sleeping site depending on the relative dampness of the ground's surface at that time of day. Should this be so, there is room for further study of soil moisture and babirusa nesting behaviour in the future.

Our unexpected discovery of the large impact that wind speed had upon the frequency of nest building behaviour raised several questions. However, the main question was whether wind might remain the main factor motivating nest building in a forest habitat. Usually, the strong wind of an open environment is much reduced in intensity on the forest floor.

The region where the babirusa occurs has a variety of weather conditions and topography [27]. The local climate is dependent on the distance from the coast, the altitude, and whether it is on the East or the West side. Also, the soil composition and vegetation differ across these same areas. It would be interesting to conduct similar behavioural studies in the wild, viewed from a topographical viewpoint.

The results of the present study have clearly demonstrated a relationship between the expression of nesting behaviour and a variety of environmental conditions. As of March 2018, the Sulawesi babirusa was officially maintained in eight zoos in Indonesia. For example, the altitude of our study site was

Fig. 6 Seasonal variation of the net effective temperature (NET) during the period from 01st August 2006 until 31st March 2010.

This graph was generated from 5680 dots representing data from 1330 days, overlapping NET at 14:00 hr with no wind at 0 m/sec (red dots), NET at 14:00 hr with the wind speed data measured (yellow dots), NET at 17:00 hr (green dots) and NET at 05:00 hr (blue dots) in sequence. In addition, 323 violet dots representing the NET of the expression group were plotted on the uppermost layer. The concentration of violet dots indicates that the expression of nesting behaviour can be seen in the relatively low NET zone.

Fig. 7 Effect of the wind speed on seasonal variation of the net effective temperature (NET) at 17:00 hr during the period from 01st August 2006 until 31st March 2010.

This graph was generated by overlapping NET at 17:00 hr (green dots), NET at 17:00 hr with wind speed less than 3 m/sec (yellow dots) and NET at 17:00 hr with wind speed more than 7 m/sec (violet dots) in sequence. Yellow dots almost correspond to the transition and rainy seasons. Violet dots correspond to the dry season and to the middle of the rainy season.

144 m, while those of other zoos on Java Island, Indonesia range from approximately 9 m to over 1000 m above sea level. Further information from other zoos varying in the natural

environment and enclosure conditions might deepen our understanding of the nesting behaviour of the babirusa.

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原著論文 動物行動学

気象要因がスラウェシバビルサ (*Babirusa celebensis*) の営巣行動発現に及ぼす影響

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要 約

スラウェシバビルサの営巣行動発現に及ぼす環境刺激の影響を調査した。2006年8月から2010年3月までの1339日間にインドネシアの比較的大規模な屋外飼育施設において記録されたバビルサの造巣及び巣の再利用行動と気象データの関係性を分析した結果、その行動は乾季に高頻度に発現され、外気温の低下や風速の上昇の影響を受けることが判明した。また、夕方の体感温度の低下に伴うその行動発現率の増加傾向が認められた。季節を問わず、午前5時から午後5時までの12時間の体感温度の変化量が大きくなるほど、行動発現率の増加傾向もみられた。24時間降水量は営巣行動発現に抑制的であった。バビルサの営巣行動モチベーションは、体感温度を指標として議論でき、バビルサは寝屋に快適な温度環境を見出している可能性が強く示唆された。

キーワード：気象、季節、体感温度、寝屋、バビルサ

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