

Application of sexual dimorphism-derived variation in morphometrics and intraspecific interaction likelihood in Sunda pangolin (*Manis javanica*) to increase species encounter rates

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Abstract. Novriyant N, Takandjandji M. 2022. Application of sexual dimorphism-derived variation in morphometrics and intraspecific interaction likelihood in Sunda pangolin (*Manis javanica*) to increase species encounter rates. *Biodiversitas* 23: 2753-2759. Effectively encounters opportunities of Sunda pangolin (*Manis javanica*) in natural habitats is still necessary to have more research. A diversity of pangolins' physical and biological characteristics has been disclosed to facilitate the identification process in natural habitats. However, pangolins are animals that tend to be solitary; they have fast movement, so the area coverage is extensive; this condition complicates the data collection process. It is unknown yet, whether pangolins of different sexes usually exist in the same space and time, either in terms of foraging or other interactions, known as intra-specific interactions. Thus, this study aimed to predict intraspecific interactions of *M. javanica* to increase the encountering of pangolins chance in natural habitats. As many as 29 individual pangolins (14 males and 15 females) be measured its morphometric data. To convincingly justify that morphometric variation can be used as encounter rate opportunities in natural habitats, a series of analyses, i.e., univariate test, correlation analysis, and multiple regression, were applied to this research. Other estimations from feeding activity data were also carried out to detect pangolins' niche width and its overlap according to sexual dimorphism. Univariate analysis shows that overall, the total body length (head to tail) of both males and females does not differ significantly. But, the correlation coefficient indicates the physical character of female and male body length is related to each other (value 0.769**). The resulting regression model indicates that the presence of pangolins in their sex similarity in a particular place tends to be avoided, while there is a 1:1 probability of sexual dimorphism. This also means that males and females can be used as the same individual in ecological observations.

Keywords: Body length, critically endangered species, niche breadth, niche overlap, pangolin measurement

INTRODUCTION

Sunda pangolin (*Manis javanica*) is the only pangolin species in Indonesia. However, the actual distribution of *M. javanica* in Southeast Asia is quite broad and has a close kinship with other Manidae species in Asia (Rode-Margono et al. 2014; Hassanin et al. 2015; Sulaiman et al. 2017; Trageser et al. 2017). Unfortunately, scientific records of the existence of pangolins in nature are still limited. The main problem in estimating the pangolin population is the low encounter rate, even with the help of camera traps (Suzuki et al. 2017; Willcox et al. 2019). Many studies show this; whether pangolin species were studied in Africa (Cameroon and Nigeria) (Angwafo et al. 2019; Maurice 2019; Omifolaji et al. 2020) or other Manidae species in Asia (Sompud et al. 2016, 2019; Challender et al. 2019b). The low encounter is accompanied by high hunting (Challender et al. 2012; Willcox et al. 2019), forcing pangolins, especially *M. javanica*, to be critically endangered under criteria A2d+3d+4d by IUCN Redlist category (Challender et al. 2019a).

Several habitat characters have been studied to increase encounters, ranging from tracing the nature of the prey

habitat of *M. javanica* to the possible ecological strategies it chooses. Regarding prey, *M. javanica* tended to prefer food from the order Hymenoptera (2.40 colonies/ha) rather than the order Isoptera (0.87 colonies/ha), which was easy to find in habitats with dry wood, moss, and hummus in the forest floor so that all suitable habitat components were utilized so that maximum for these various functions (Manshur et al. 2015). Unfortunately, *M. javanica* tends to choose anti-predatory and anti-competitive strategies to acquire prey, so intraspecific interactions have an excellent opportunity for (Manshur et al. 2015). Intraspecific interactions occur between individuals within a species (Classen et al. 2017) used to assess the self-regulatory, self-limiting, or disruptive mechanisms present within the species (van Altena et al. 2016).

Intraspecific interaction and competition can occur if there is a niche overlap in each (Elfidasari 2007; Arellano et al. 2017), in the same opportunity to obtain feed or the same use of space and time. However, niches are thought to differ between sexes and body size within species. In snakes, for example, sex-specific niche adaptation predicts differences in habitat and prey for these species (Shine 1986; Nijman et al. 2012). The possibility encounter of *M. javanica* can be estimated by identifying the niche

differentiation through a daily activity approach related to their range or home range. *M. javanica* is a nocturnal mammal that actively moves and feeds from midnight to 06.00 a.m. (Lim and Ng 2008) in both in-situ and ex-situ areas (Challender et al. 2012; Zhang et al. 2017). Judging from the movements conducted throughout the night, *M. javanica* can explore quite far, such as its relative in the eastern highlands of Brazil, the Giant anteater (*Myrmecophaga tridactyla*), which can prey on ants and termites with an average cruising capability of 1-2 km (Bertassoni et al. 2017; Bertassoni and Ribeiro 2019).

Territory range and species dispersal are affected by moving speed, which considers the body mass of the species (Priatna et al. 2012; Santini et al. 2013; Ofstad et al. 2016). Others state that the morphometric species influence movement. Based on this, male and female *M. javanica* may have their form of adaptation that distinguishes their habitat's use of space and time. However, until now, there has been no report on the relationship between sex and body length of *M. javanica* with activity and the alleged similarity of niches in pangolins. If we find male pangolins in their habitat, will it be easy for us to find females around the exact location? Is it possible that intraspecific competition in *M. javanica* can be used to predict its presence in nature and increase its encounter? To answer these questions, an indicative test of these opportunities is needed. This study analyzes the niche differences between males and females based on pangolins' morphometric approach and daily feeding activity. The analysis results can be used as a data basis to predict whether there are differences in intraspecific niches between male and female pangolins.

MATERIALS AND METHODS

Measurement sample

Morphometric measurements were conducted in 2010, 2012, and 2013 on 29 individuals (14 males and 15 adult females) of Sunda pangolins. There are 2 data source locations of these 29 individuals. One male and two adult females of Sunda pangolins were from in-situ areas in South Sumatra Province (Bismark 2011 data set; unpublished), while 13 males and 13 females were measured directly from the pangolin in captivity. Sex determination was used in this study based on the sign of genitals (Figure 3). This collection was a pioneer captive breeding of *M. javanica* in Indonesia (Novriyanti 2011), located in Binjai City, North Sumatra Province, Indonesia. Unfortunately, now this captivity is no longer operating.

There are three morphological variations of pangolins used to estimate the differences in intraspecific niches based on sex: head length, body length, and tail length. Overall morphometric parameters were determined based on their use in ecology, mainly those closely related to feed acquisition and self-defense activities. The head length was

measured from the front cranial to the back of the body. The body length was calculated from the back cranial to the beginning of the tail. The tail length was determined by measuring the beginning of the tail to the end of the tail. This method is the same as the measurement technique in previous studies (Takandjandji and Sawitri 2016). Each morphological variation that has been measured is marked using colored markers (Figure 1).

Data analysis

All morphometric data obtained through measurement were analyzed using IBM SPSS Statistics 26 with a series of tests as follows: (i) The univariate test was conducted to see the difference and the effect of sexual dimorphism through the difference in mean and standard deviation. (ii) A correlation test. The univariate data result will be compared with the Pearson correlation test; if there is no correlation between Sunda pangolin body length so indicates that there is no differentiation of males and females of Sunda pangolin in direct and fast encounters. The morphometric approach assumes that variations in body size become the primary sexual dimorphism in influencing its existence in nature. The confidence interval used is 95%. The hypothesis used H_0 : there is no significant correlation between the morphometric side of males (head, body, and tail) to females. At the same time, the counter hypothesis (H_1) is a significant and positive correlation between the two sexes of pangolins based on their morphometric differences. Test Statistics are as follows: a) If the significance value of the correlation coefficient (r) (2-tailed) > 0.05 , then H_0 is accepted; and b) If the significance value of the correlation coefficient (r) (2-tailed) < 0.05 , then H_0 is rejected. (iii) Multiple regression tests were conducted to determine whether the total body length of Sunda pangolin males or females influences each other. variants in movement. (iv) Detection of niche width and niche similarity.

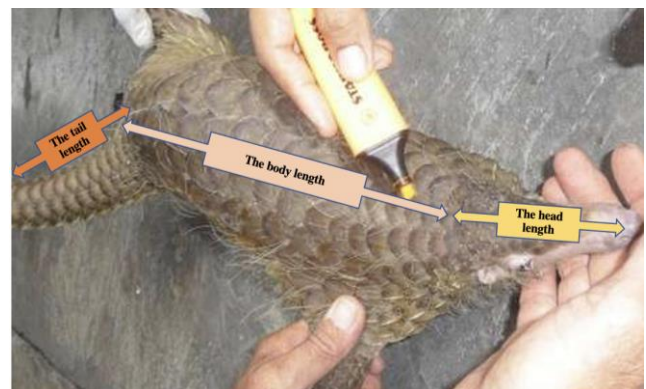


Figure 1. Marking the measurement limits of the pangolin's body (photo: Novriyanti)

Apart from morphometric data, data on feeding activity of pangolins in captivity that have been studied (Novriyanti 2011) were used to detect niche breadth and niche overlap of pangolins by sex. Niche width and niche similarity will show whether the occurrence of encounters of male and female pangolins is independent of increasing the chances of encountering pangolins in the wild. The size of the niche width was analyzed using the Shannon-Wiener formula (F1), then complete with standardization of the Shannon-Wiener niche width (F2). Niche similarity was analyzed using the Morisita Index (F3).

RESULTS AND DISCUSSION

Morphometric variations of sexual dimorphism

In this study, the pangolin is often known as the common Sunda Pangolin or Malayan Pangolin. There was no significant difference in body length between male and female pangolins. The difference in total body length ranges from 2-3 centimeters only. The measure of morphometric data obtained a total body length of pangolin species in this study in 85.5179 ± 13.9486 centimeters or between 71.5693 centimeters and 99.4665 centimeters for Male and 84.2000 ± 13.6863 centimeters or between 70.5137 and 97.8863 centimeters for Female (Table 1). Compared to the same species in Nature Parks (DWNP) Kelantan and Penang, Malaysia (Sulaiman et al. 2017), and elsewhere (Gaubert et al. 2018), the total body length of pangolins in this study was more petite. Even the head-body length of the two sexes has a difference of almost 10 cm compared to the same species in Malaysia. The overall size of the pangolin is also correlated with body mass (Sulaiman et al. 2017), so the weight of the pangolin in this study is also thought to be smaller. Compared to the Indian

pangolin in Sri Lanka (Algewatta et al. 2021), the total body length of the pangolins in this study was also small; the difference was 5-10 cm in males and females. Although the full size is shorter than other pangolin species, the body length of Sunda pangolin to tail is not much different (0.910), even more than that of Indian pangolin, which is only 0.87 (Algewatta et al. 2021).

In this study, the measure of head, body, and tail length variables between male and female pangolins did not show any differences. The head length of both sexes is shorter, so it tends to cluster at a relatively small value, while the body length is more extensive. Its position is close to the tail length distribution, spreading away from the midline (Figure 2). However, the total length of the pangolin's body from the tip of the snout to the end of the tail spreads quite far. This means that the sex differences based on body size are apparent when viewed. However, based on correlation analysis, the total body length of pangolins in different sexes showed a weak relationship even though the probability significance was <0.05 (Pc: 0.631*; sig: 0.015).

Table 1. Pangolin morphometric character (*Manis javanica*)

Variables	Mean (cm)	Std. Deviation (cm)
Male		
Head length	12.2500	2.27655
Body length	34.9107	6.22001
Tail length	38.3571	9.26413
Total body length	85.5179	13.9486
Female		
Head length	11.1833	2.40250
Body length	34.8667	6.10464
Tail length	38.1500	7.32766
Total body length	84.2000	13.6863

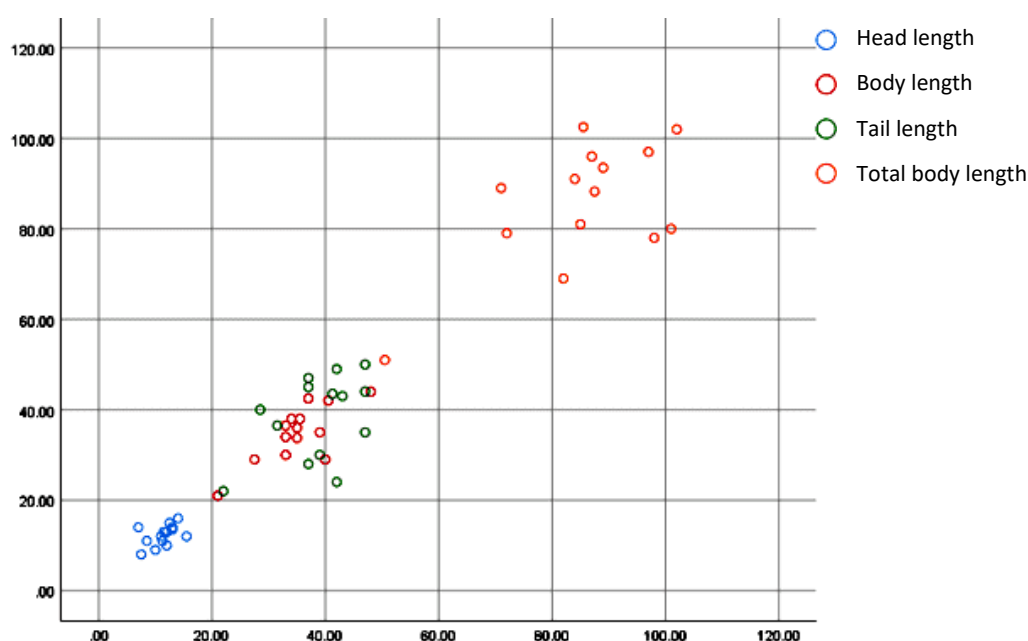


Figure 1. The distribution of the length of the morphometric variation is based on the sexual dimorphism of pangolins (*Manis javanica*)

$$H' = -\sum p_j \cdot \log p_j \dots \dots \dots (F1)$$

$$J = \frac{H'}{\log n} \dots \dots \dots (F2)$$

$$Mo = \frac{2 \cdot \sum p_{ij} \cdot p_{ik}}{\sum p_{ij} \cdot \left(\frac{n_{ij}-1}{N_j-1} \right) + \sum p_{ik} \cdot \left(\frac{n_{ik}-1}{N_k-1} \right)} \dots \dots \dots (F3)$$

Where:

H': the size of the niche according to Shannon-Wiener

P_j: the proportion of individuals who use the jth resource (ni/N)

N: n₁ + n₂ + ... n_s

n: total available feeding activity packages resources

J': a measure of evenness according to the Shannon-Wiener function

H': the size of the niche according to Shannon-Wiener

Mo: Morisita index for niche overlap

p_{ij}, p_{ik}: the proportion of feeding activity-i to the total available feeding activity packages used by pangolin-j

n_{ij}, n_{ik}: the number of feeding activity-i utilized by pangolin-j or pangolin-k

N_j, N_k: total individuals utilized

In sexual dimorphism, a solid relationship (1% error) between the two is indicated by body length (Pc=0.769; sig: 0.001). Male pangolin head length and female tail length showed a vital relationship with a strong significance (Pc: 0.559; sig: 0.038). Meanwhile, if we look at each sex, for example, male pangolins, there is no relationship between measurement variances (Table 2). However, there is a solid relationship between body and tail length in female pangolins. The significance of the relationship between female body length and tail length is almost perfect, with a probability < 0.05.

The finding of insignificant size differences can have implications for the speed of sex estimation indirect observations in nature or measuring using a scale from camera observations. The sex of the pangolin cannot be directly identified based on such encounters. Pangolins must be caught to see their sexual dimorphism, as shown in Figure 3. However, to obtain body length measurements, pangolins must be in a state not curled up. In comparison, the pangolin is a typical round animal. This species has been recorded curled up while inside a tiger; even hunters often find him in a ball-like state (Zhang et al. 2017; Sompud et al. 2019). When found in nature twisting the body, the length of the body can be approximated by the tail length, although in males, there is not an extraordinarily strong relationship between the body and the tail. Meanwhile, a strong relationship between male and female bodies can have implications for the presence of males and females in the exact location with a probability of 1:1.

Intraspecific interaction possibility of pangolin (*Manis javanica*)

Based on the morphometric approach

The coefficient of determination in the multiple regression test will indicate the presence or absence of interaction between the variables measured in each sexual dimorphism. The interaction between the pangolin sexes was fragile as the overall body size (head length+body length+tail length) of pangolin show it (R²<80%) in Table 4. As for each sex, only the female body length variance had the possibility of interaction with other body sizes (R²: 69.0) while the male did not (R²: 24.1%). Thus, the regression model shown is only a model that shows the effect of female body length on other variables, especially with tail length (Table 5).

Table 2. Correlation value between body parts of each sex of pangolin (*Manis javanica*)

		Correlations					
		Male head length	Male body length	Male tail length	Female head length	Female body length	Female tail length
Male head length	Pearson Correlation		0.386	0.230	0.463	0.512	0.559*
	Sig. (2-tailed)		0.173	0.429	0.096	0.061	0.038
	N	14	14	14	14	14	14
Male body length	Pearson Correlation	0.386		0.384	0.120	0.769**	0.462
	Sig. (2-tailed)	0.173		0.175	0.684	0.001	0.097
	N	14	14	14	14	14	14
Male tail length	Pearson Correlation	0.230	0.384		-0.079	0.350	0.448
	Sig. (2-tailed)	0.429	0.175		0.790	0.220	0.108
	N	14	14	14	14	14	14
Female head length	Pearson Correlation	0.463	0.120	-0.079		0.143	0.406
	Sig. (2-tailed)	0.096	0.684	0.790		0.611	0.133
	N	14	14	14	15	15	15
Female body length	Pearson Correlation	0.512	0.769**	0.350	0.143		0.806**
	Sig. (2-tailed)	0.061	0.001	0.220	0.611		0.00001
	N	14	14	14	15	15	15
Female tail length	Pearson Correlation	0.559*	0.462	0.448	0.406	0.806**	1
	Sig. (2-tailed)	0.038	0.097	0.108	0.133	0.000	
	N	14	14	14	15	15	15

Note: *: Correlation is significant at the 0.05 level (2-tailed); **: Correlation is significant at the 0.01 level (2-tailed)



Figure 2. Sexual dimorphism of pangolin. A. Male; B. Female

The allegation of niche similarity based on morphometric variations of pangolin sexual dimorphism is shown in Table 6, with a significance of 0.015 ($p < 0.05$) between the two male and female total body length variables, the probability of their encounter is predictable. By this model (TMBL: Total male body length; TFBL: Total female body length), the increase in male body size will undoubtedly affect the female body size and vice versa.

$$\text{TMBL} = 30.933 + 0.641\text{TFBL} \text{ or } \text{TFBL} = 31.987 + 0.621\text{TMBL}$$

This morphometric difference reflects the adaptation of species occupying the same geographic area and can even measure the vulnerability of populations to anthropogenic activities over time (Irwin et al. 2019). If nature provides abundant feed, all individual pangolins can enjoy it fairly and equitably. The implication is that if a male pangolin is found in a habitat, there is a chance of encountering a female pangolin in a habitat with similar morphometric characteristics.

Based on the feeding activity budget approach

All pangolin activities, especially in captivity, are carried out at night, starting at 18.00 WIB until 24.00 WIB. This daily activity did not change as predicted in natural habitats (Challender et al. 2012, 2019c; Withaningsih et al. 2018). Likewise, there were no differences in activity budgets for male and female pangolins with feeding activities in the food consumption (Clark et al. 2008; Challender et al. 2012).

Based on the standardized Shannon-Wiener niche width calculation, the niche width of male and female pangolins is almost the same because the difference is nearly zero (JA-JB: 0.0001). This means there is no differentiation or specialization in finding prey in nature. In other words, both males and females in natural habitats have the same opportunities and efforts to find their food, namely ants and termites (Withaningsih et al. 2018; Bertassoni and Ribeiro 2019; Chao et al. 2020). The possibility of intraspecific competition is quite large when males and females are together in a food source location.

Table 3. Summary of model fit for sexual dimorphism

Model	R	R Square	Adjusted R square	Std. error of the estimate	Durbin-Watson
Dependent variable: male body length	0.491 ^a	0.241	0.103	5.89092	1.562
Dependent variable: female body length	0.831 ^b	0.690	0.638	3.67249	1.599
Dependent variable: total female body length	0.631 ^c	0.398	0.348	11.08185	2.182

Note: Predictors: (Constant), male tail length, male head length; Predictors: (Constant), female tail length, female head length; Predictors: (Constant), total male body length

Table 4. Regression coefficient and model significance on each female morphometric variable

Model	Coefficients ^a						
	Unstandardized coefficients		Standardized coefficients	t	Sig.	95,0% confidence interval for B	
	B	Std. error	Beta			Lower bound	Upper bound
(Constant)	12.684	5.870		2.161	0.052	-0.105	25.473
Female head	-0.561	0.447	-0.221	-1.255	0.233	-1.535	0.413
Female tail	0.746	0.147	0.895	5.088	0.000	0.427	1.065

Note: Dependent variable: female body

Table 5. Regression coefficient and model significance of pangolin total body length to assess niche similarity based on sexual dimorphism

		Coefficients ^a			t	Sig.	95,0% Confidence Interval for B	
Model		Unstandardized coefficients	Standardized coefficients	Beta			Lower bound	Upper bound
		B	Std. Error	Beta				
Dependent variable: Total male body length	(Constant)	30.933	19.596		1.579	0.140	-11.764	73.629
	Total female body length	0.641	0.228	0.631	2.819	0.015	0.146	1.137
Dependent variable: Total female body length	(Constant)	31.987	19.075		1.677	0.119	-9.574	73.548
	Total male body length	0.621	0.220	0.631	2.819	0.015	0.141	1.101

Meanwhile, based on the analysis of the Morisita Index, the niche overlap of the two sexes is Mo: 1.01 or 101%. This value is so significant that it can be said that with the same niche, intraspecifically male and female pangolins overlap when they are active in nature in getting their prey. The implication in ecology, males and females can be used as the same individual observations because the chance of encountering them in nature is the same.

Pangolins are solitary animals (Challender et al. 2012, 2019a), including foraging in nature. This means that it is scarce to find male and female pangolins together in a location, except for females with un-weaned cubs (Lim and Ng 2008). All analysis tools on morphometric characters show a significant relationship between males and females. There is an influence of the presence of males on females in nature, and vice versa, although not too strong. If there are pangolins of different sexes in the same location, then perhaps there is no tendency to avoid each other, thus increasing the chances of encounters in nature. Meanwhile, same-sex pangolins, especially males, tend to avoid each other. Therefore, the findings of this study suggest that a high chance of intraspecific interactions (Manshur et al. 2015) between individuals of different sexes within the species (Classen et al. 2017) may occur. The opportunity for intraspecific interaction is quite significant because pangolins may be challenging to detect the presence of individuals in their own or other species mainly because the size of their eyes is relatively tiny (Chong et al. 2020). The proof is that it is not uncommon to find a Malayan porcupine (*Hystrix brachyura*) in pangolin nests and use it together (Withaningsih et al. 2018).

This study notes that *M. javanica* originating from Indonesia, especially Sumatra, is smaller than Sunda pangolin species in other locations. However, this finding is also different from previous measurements, which stated that the Sumatran pangolin is the largest. This may have something to do with the degradation of Sumatra's forests (Prabowo et al. 2016) that occurred so that pangolins seek to cohabit and coexist with other species in secondary habitats. In addition, no different niches were found in the sexual dimorphism of pangolins. If nature provides abundant feed, all individual pangolins can enjoy it fairly and equitably. Both males and females in natural habitats have the same opportunity and effort to find their prey. The implication is that if a male pangolin is located in a habitat, there is a chance of encountering a female pangolin in a

habitat with similar morphometric characteristics. This also means that males and females can be used as the same individual observations in ecology. Concerning the management of pangolin species in Indonesia, the standardization of morphometric measurements used for field identification and cladistics needs to be agreed upon by Indonesian pangolin experts/observers. Something that Indian pangolin observers have started (Perera et al. 2020). Thus, pangolin populations can be monitored on a larger scale, technology-based, and quickly to avoid hunting in the wild.

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