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PRELIMINARY STUDY ON THE CRANIOMANDIBULAR MEASUREMENTS OF THE LESSER RICEFIELD RAT, *RATTUS LOSEA* (RODENTIA: MURIDAE) FROM TAIWAN

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ABSTRACT: A preliminary study was conducted on craniomandibular measurements in the lesser ricefield rat (*Rattus losea*) collected from Taiwan, using traditional morphometrics. A relatively larger mean size was detected in males for 18 (69.23%) measurements, among a total of 26 morphometric characteristics.. A relatively larger mean size was detected in males for 18 (69.23%) measurements. The condylobasal length ranged from 35.35 to 40.28 mm (mean: 37.65, SD: ± 1.63) in males and 36.38 to 39.12 mm (mean: 37.50, SD: ± 1.02) in females. The mandibular length varied from 19.62 to 23.95 mm (mean: 21.40, SD: ± 0.32) in males and 20.48–22.08 mm (mean: 21.04, SD: ± 0.52) in females. Two-sample univariate analysis indicated non-significant difference between the sexes for all measurements. In overall measurements, the length of the nasal bone was comparatively longer than the length of the frontal, parietal, and inter-parietal bone. Most characteristics of the skull (72%) showed a significant correlation with condylobasal length. Although the first principal component (PC) accounted for 58.24% of the total variance, scatter plots of the principal components showed that male and female values largely overlapped. Finally, we discussed the morphological characteristics of the *R. losea* skull in relation to the patterns of other *Rattus* species.

Key words: Morphological characteristics, *Rattus losea*, Sexual monomorphism, Skull, Traditional morphometrics.

INTRODUCTION

The lesser ricefield rat (*Rattus losea*) is a medium-sized murine species native to east and southeast Asia, such as China, Laos, Taiwan, Thailand, and Vietnam (Musser and Carleton 2005). It is probably nocturnal and mainly terrestrial, and typically inhabits grass, scrub, mangroves, cultivated rice fields, gardens, and other human modified areas (Adler 1995; Musser and Carleton 2005). It is commensal to humans and is largely dependent on agricultural crops (Adler 1995). It feeds mainly on grains and is probably herbivorous

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(Musser and Carleton 2005; Alpin 2016). It damages the crops and carries ticks that transmit Lyme disease (Shih *et al.* 1998; Brown *et al.* 2005).

Morphometrics provide a quantitative approach to measure and analyze the morphological characteristics and variations in living organisms (Elewa 2004; Biswas and Motokawa 2023; Tuli 2023). It enables researchers to determine and compare morphological structures within and/or between species (Elewa 2004; Meiri and Liang, 2021; Biswas and Motokawa 2023). Morphological characteristics are specific features or elements that illustrate the structural patterns of an organism (Cheverud *et al.* 1979). Among the different morphological features, body size is one of the most important characteristics of animals. It can significantly affect the behavior of an organism and its progression within its ecological niche (Glazier 2021; Tuli 2023).

Morphological patterns of skulls in small mammals have been extensively studied by many researchers (Bronner *et al.* 2007; Suzuki *et al.* 2012, Shintaku and Motokawa 2016; Biswas *et al.* 2020; Biswas and Motokawa 2019, 2023), who have focused on different aspects of morphological variations such as geographical variation, age variation, sexual dimorphism, and static variation. Although most mammalian species generally share a common morphological pattern (rostral variation tends to be larger than that of neurocranium) in the major component of the skull (Suzuki *et al.* 2012; Biswas and Motokawa 2019), each species may have specific morphological characteristics related to their evolutionary history and ecological requirements. Therefore, single-species studies are important to assess the morphological patterns of structural organization of the animal (Biswas and Motokawa 2023).

The ecological aspects of *R. losea* have been studied by some scientists (Brown *et al.* 2005; Chen *et al.* 2017, 2023), who focused mostly on population dynamics, habitat preference and bioacoustics features. However, no study has been conducted on morphological aspects of the skull of *R. losea*. Morphological studies of the skull can facilitate a deeper understanding of an individual's structural characteristics. Moreover, skull, the collection of bones, may provide the natural history of an animal's life (Elbroch 2006). In this study, we therefore analyzed the craniomandibular characteristics in the lesser ricefield rat (*Rattus losea*) using traditional morphometrics that can be used as a reference in morphological studies.

MATERIAL AND METHODS

Studied specimens and morphological characteristics: To measure the morphological characteristics, we used 16 specimens (08 males and 08 females) of adult *R. losea*, The studied specimens were collected from Taiwan and deposited in the Zoological collection of the Kyoto University Museum, Kyoto

University, Japan with the following number: M11618, M11619, M11621, M11622, M11623, M11624, M11625, M11627, M11628, M11629, M11637, M11638, M11639, M11640, M11641, M11651. Based on the eruption of molar teeth, we considered the specimens to be adult (Elbroch 2006; Biswas and Motokawa 2019, 2023). For the cranium, we measured 22 parameters: Condylobasal length (CBL), greatest length of skull (GLS), basal length (BL), short lateral facial length (SL), length of nasal bone (LN), length of incisive foramen (LIF), maximum width of the nasal bone (MWN), palatal length (PL1), breath of rostrum (BR), zygomatic breadth (ZB), least breadth between the orbits (LBO), length of frontal bone (LFB), parietal length (PL2), interparietal length (IPL), greatest neurocranium breadth (GNB), greatest breadth of the occipital condyles (GBO), length of upper molar row in alveoli (LMR1), greatest palatal breadth (GPB), post palatal length (PPL), height from akrokranion to basion (HAB), length of palatal bridge (LPB) and length of auditory bullae (LAB) (Fig. 1). For the mandible, four parameters were measured: length from the condyle (LC), length from the angular process (LA), length of lower molar row in alveoli (LMR2) and aboral height of the vertical ramus (AHR) (Fig. 1), following previous studies on other rodent species (Biswas and Motokawa 2019, 2023). Among the cranial measurements, SL, LN, LIF, MWN, PL1, BR, LMR1, GPB and LPB were classified as rostral variables and LFB, PL2, IPL, GNB, GBO, PPL, HAB, and LAB were considered braincase variables (Biswas and Motokawa 2019, 2023; Biswas et al. 2020). All measurements were taken with a digital slide caliper to the nearest 0.01 mm (Biswas and Motokawa 2019, 2023; Biswas *et al.* 2020).

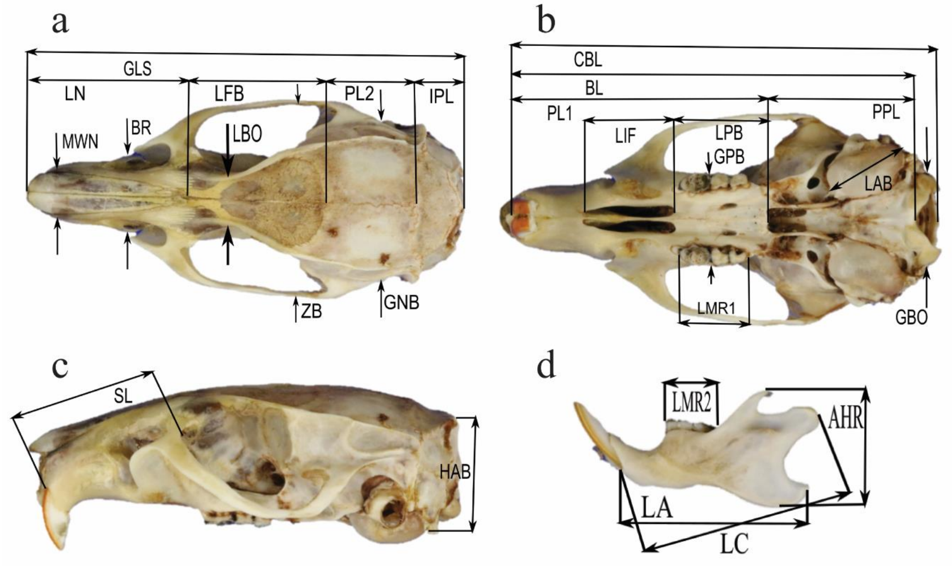

Fig.1. Morphological characteristics of the skull [dorsal (a), ventral (b), lateral (c) view of the cranium, and the mandible (d)] measured in *Rattus losea.* The explanation of measurements is presented in the section of material and methods.

Statistical analyses: The summary statistics [mean (M), standard deviation (SD) and range] were calculated using morphological measurements of the overall specimens, and males and females separately (Table 1), following previous studies (Suzuki *et al.* 2012; Biswas and Motokawa 2019, 2023; Biswas *et al.* 2020). Two-sample non-parametric test (Mann –Whitney *U* test) was used to assess the significance of sex differences in morphological measurements (Biswas *et al.* 2020; Biswas and Motokawa 2023). The correlation coefficients of overall skull traits were calculated against CBL as an independent variable (Biswas and Motokawa 2019). To evaluate intraspecific variation, we performed the principal component analysis (PCA) based on the correlation matrix of log-transformed skull measurements (Motokawa *et al.* 2003). We performed all statistical analyses using the software PAST (ver. 4.10) (Hammer *et al.* 2001).

RESULTS AND DISCUSSION

Patterns of sex differences: Males were found to be slightly larger than females in 18 (69.23%) measurements of the skull in *R. losea* (Table 1). Males showed larger mean values for CBL, BL, SL, LIF, MWN, PL1, BR, LBO, LFB, PL2, GNB, LMR1, GPB, LAB, LC, LA, LMR2, AHR (Table 1). Besides, females showed larger mean values for GLS, LN, ZB, IPL, GBO, PPL, HAB, LPB (Table 1). These results indicated that females are slightly larger than males in the cranium length and width, although males showed larger size in most measurements. In contrast, our results implied that males are larger than females in the mandibular length and height. However, the Mann-Whitney *U*-test demonstrated non-significant differences between sexes in all skull variables (Table 1).

These patterns indicate the absence of secondary sexual dimorphism or sexual monomorphism in the craniomandibular structure of *R. losea*. Previous study also demonstrated non-significant sexual dimorphism in other *Rattus* species (*R. rattus* and *R. norvegicus*) for body weight, body length, tail length, and most skull characteristics (Islam *et al.* 2021). Patterns of sexual dimorphism in rodents are thought to be associated with sexual selectin or mating systems (Wolff 2007). Although multiple paternity has been described in other *Rattus* species (*R. rattus* and *R. norvegicus*) (King *et al.* 2014; Costa *et al.* 2016), no data are available for *Rattus losea*. Species that have a promiscuous mating system (female mates with more than one male) generally lack sexual dimorphism (Schulte-Hostedde *et al.* 2004). Therefore, extensive studies using more sample sizes are needed to elucidate the evolutionary aspects of sexual monomorphism in the craniomandibular morphology of *R. losea*.

Patterns in overall measurements: As male and female showed non-significant difference in the craniomandibular measurements, we considered

Table 1. **Results of the summary statistics of morphological measurements (mm) in the skull of the *Rattus losea* (SD: standard deviation, n: sample size, U: Mann-Whitney *U*)**

Variables	**All (n = 16)**		**Male (n =08)**		**Female (n = 08)**		**Sex differences**	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	*U*	*P*
CBL	37.58 ± 1.31	35.35–40.28	37.65 ± 1.63	35.35–40.28	37.50 ± 1.02	36.38–39.12	32.0	0.958
GLS	39.88 ± 1.31	37.43–41.99	39.81 ± 1.62	37.43–41.99	39.96 ± 1.01	38.72–41.45	32.0	0.958
BL	35.82 ± 1.46	33.65–39.18	35.92 ± 1.82	33.65–39.18	35.72 ± 1.10	34.31–37.34	31.0	0.958
SL	13.58 ± 0.77	12.32–15.15	13.62 ± 0.86	12.32–15.15	13.54 ± 0.73	12.58–14.52	29.5	0.833
LN	14.50 ± 0.77	13.29–16.08	14.41 ± 0.93	13.29–16.08	14.58 ± 0.84	13.32–15.95	28.5	0.753
LIF	7.85 ± 0.46	6.96–8.83	7.93 ± 0.50	7.48–8.83	7.77 ± 0.43	6.96–8.48	32.0	0.958
MWN	4.20 ± 0.27	3.78–4.82	4.28 ± 0.26	4.01–4.82	4.12 ± 0.26	3.78–4.45	21.5	0.293
PL1	22.37 ± 1.03	20.75–25.03	22.46 ± 1.36	20.75–25.03	22.28 ± 0.64	21.38–23.18	31.5	1.000
BR	5.87 ± 0.31	5.49–6.45	6.00 ± 0.33	5.51–6.45	5.74 ± 0.24	5.49–6.18	17.5	0.141
ZB	19.34 ± 0.89	17.93–21.12	19.30 ± 0.93	17.93–20.78	19.39 ± 0.91	18.42–21.12	30.0	0.875
LBO	5.54 ± 0.38	4.88–6.12	5.57 ± 0.33	4.96–5.96	5.51 ± 0.45	4.88–6.12	31.0	0.958
LFB	12.74 ± 0.70	11.75–13.95	12.76 ± 0.74	11.87–13.81	12.73 ± 0.70	11.75–13.95	31.0	0.958
PL2	7.85 ± 0.47	6.84–8.68	8.02 ± 0.33	7.72–8.68	7.68 ± 0.54	6.84–8.56	13.0	0.052
IPL	5.31 ± 0.43	4.71–5.96	5.23 ± 0.46	4.78–5.96	5.40 ± 0.41	4.71–5.90	27.0	0.363
GNB	15.84 ± 0.56	14.74–16.75	15.98 ± 0.71	14.74–16.75	15.70 ± 0.36	15.26–16.32	21.5	0.293
GBO	8.26 ± 0.27	7.85–8.75	8.25 ± 0.29	7.88–8.62	8.27 ± 0.26	7.85–8.75	31.0	0.958
LMR1	6.44 ± 0.30	5.95–6.92	6.54 ± 0.32	5.95–6.92	6.35 ± 0.15	6.12–6.64	18.0	0.160
GPB	7.96 ± 0.33	7.55–8.64	7.98 ± 0.40	7.55–8.64	7.94 ± 0.27	7.68–8.48	31.5	1.000
PPL	13.49 ± 0.52	12.77–14.28	13.48 ± 0.54	12.77–14.26	13.51 ± 0.54	12.78–14.28	31.5	1.000
HAB	9.55 ± 0.31	9.02–10.08	9.53 ± 0.36	9.02–10.08	9.56 ± 0.29	9.11–9.89	28.5	0.752
LPB	8.13 ± 0.37	7.55–8.52	8.12 ± 0.42	7.55–8.52	8.15 ± 0.33	7.82–8.65	30.0	0.875
LAB	7.40 ± 0.27	6.95–7.85	7.45 ± 0.32	6.95–7.85	7.35 ± 0.21	7.11–7.68	24.5	0.462
LC	21.22 ± 1.01	19.62–23.95	21.40 ± 0.32	19.62–23.95	21.04 ± 0.52	20.48–22.08	26.0	0.564
LA	19.63 ± 0.81	18.19–21.58	19.80 ± 1.07	18.19–21.58	19.46 ± 0.44	18.88–20.04	22.0	0.318
LMR2	6.36 ± 0.25	5.81–6.92	6.43 ± 0.33	5.81–6.92	6.28 ± 0.12	6.15–6.52	16.5	0.115
AHR	12.60 ± 0.61	11.58–13.95	12.55 ± 0.70	11.64–13.95	12.25 ± 0.50	11.58–13.23	21.5	0.293

overall patterns for further description. The nasal length (mean: 14.50; SD: ± 0.77) was relatively longer than the length of the frontal (mean: 12.74; SD: ± 0.70), parietal (mean: 7.85; SD: ± 0.47), and inter-parietal bone (mean: 5.31; SD: ± 0.43) in overall skull measurements (Table 1). These patterns are strongly consistent with those described in other *Rattus* species (Islam et al. 2021). Moreover, *R. losea* was found to be similar or slightly larger than the black rat (*Rattus rattus*), while shorter than the brown rat (*Rattus norvegicus*) for the craniomandibular length and width (Islam *et al.* 2021). The CBL was reported 37.2 mm ± 2.7 for *R. rattus* and 46.8 mm ± 4.1 for *R. norvegicus* (Islam *et al.* 2021). ZB was described 18.2 mm ± 1.0 for *R. rattus* and 22.4 mm ± 2.3 for *R. norvegicus* (Islam *et al.* 2021).

Patterns of bivariate correlation in overall measurements: Out of 25 skull traits, significant correlation coefficients were found in 18 variables (GLS BL, SL, LN, LIF, PL1, BR, ZB, LBO, LFB, GNB, GPB, PPL, LPB, LC, LA, LMR2, and AHR) against CBL (Table 2). Non-significant correlation was detected in the remaining 7 variables (MWN, PL2, IPL, GBO, LMR1, HAB, and LAB) (Table 2). The correlation coefficients ranged from 0.325 (GBO) to 0.993 (BL) (mean: 0.703, SD: ± 0.224, n =25) (Table 2).

Table 2. Results of the Pearson correlation coefficients of overall skull characteristics in *Rattus losea*. The condylobasal length (CBL) was used as an independent variable (*r* = Pearson correlation coefficient)

Abbreviation	*r*	*P*
GLS	0.967	< 0.001
BL	0.993	< 0.001
SL	0.943	< 0.001
LN	0.791	< 0.001
LIF	0.745	< 0.001
MWN	0.441	0.088
PL1	0.938	< 0.001
BR	0.777	< 0.001
ZB	0.763	< 0.001
LBO	0.611	< 0.05
LFB	0.717	< 0.05
PL2	0.428	0.098
IPL	0.370	0.159
GNB	0.825	< 0.001
GBO	0.325	0.219
LMR1	0.495	0.513
GPB	0.926	< 0.001
PPL	0.952	< 0.001
HAB	0.336	0.203
LPB	0.712	< 0.01
LAB	0.336	0.204
LC	0.883	< 0.001
LA	0.862	< 0.001
LMR2	0.616	< 0.05
AHR	0.812	< 0.001

Patterns of variation in overall measurements: Principal component analysis based on the correlation matrix revealed that the first four principal components (PC 1, PC 2, PC 3, and PC 4) accounted for 58.24%, 9.31%, 8.59%, and 4.60% of the variance, respectively (Table 3). All variables showed positive loadings on PC 1 (Table 3). PC 1 demonstrated high factor loadings (> 0.060) for 20 (76.92%) variables: CBL, GLS, BL, SL, LN, LIF, PL1, BR, ZB, LBO, LFB, GNB, LMR1, GPB, PPL, LPB, LC, LA, LMR2, and AHR (Table 3), most of which were traits related to rostrum and cranial length. PC 2 showed high factor loadings for 2 variables: IPL (negative) and LAB (Positive) and PC 3 also explained high factor loadings for 2 variables: GBO and HAB (negative) (Table 3). Scatter plots using the scores for PC 1 and PC 2, PC 2 and PC 3, PC 1 and PC 3, and PC 3 and PC 4 demonstrated that the male and female values largely overlapped (Fig. 2).

Table 3. Principal component analysis in *Rattus losea* based on the correlation matrix of log-transformed skull characteristics [High factor loadings are shown as bold (> 0.600)]

Variables	**PC 1**	**PC 2**	**PC 3**	**PC 4**
CBL	0.978	-0.007	0.126	-0.126
GLS	0.946	-0.021	0.104	-0.164
BL	0.971	0.005	0.115	-0.154
SL	0.913	-0.070	0.310	0.020
LN	0.781	0.286	0.059	-0.102
LIF	0.733	0.117	-0.111	0.023
MWN	0.452	0.403	0.586	0.361
PL1	0.917	-0.040	0.057	-0.191
BR	0.861	0.053	-0.088	0.116
ZB	0.832	-0.381	-0.035	0.176
LBO	0.612	-0.511	0.347	0.128
LFB	0.720	-0.527	0.036	0.060
PL2	0.369	0.528	0.275	-0.344
IPL	0.342	-0.759	0.283	0.071
GNB	0.869	0.016	-0.028	0.029
GBO	0.447	-0.169	-0.664	0.297
LMR1	0.616	0.194	-0.182	0.590
GPB	0.931	-0.007	-0.104	-0.098
PPL	0.930	-0.093	0.224	-0.103
HAB	0.425	0.180	-0.730	-0.232
LPB	0.683	-0.052	0.023	-0.349
LAB	0.313	0.638	0.385	0.296
LC	0.946	0.037	-0.258	0.024
LA	0.908	0.205	-0.163	-0.092
LMR2	0.668	0.192	-0.352	0.166
AHR	0.876	0.119	-0.122	0.089
Eigenvalue	15.14	2.42	2.23	1.20
Variance (%)	58.24	9.31	8.59	4.60

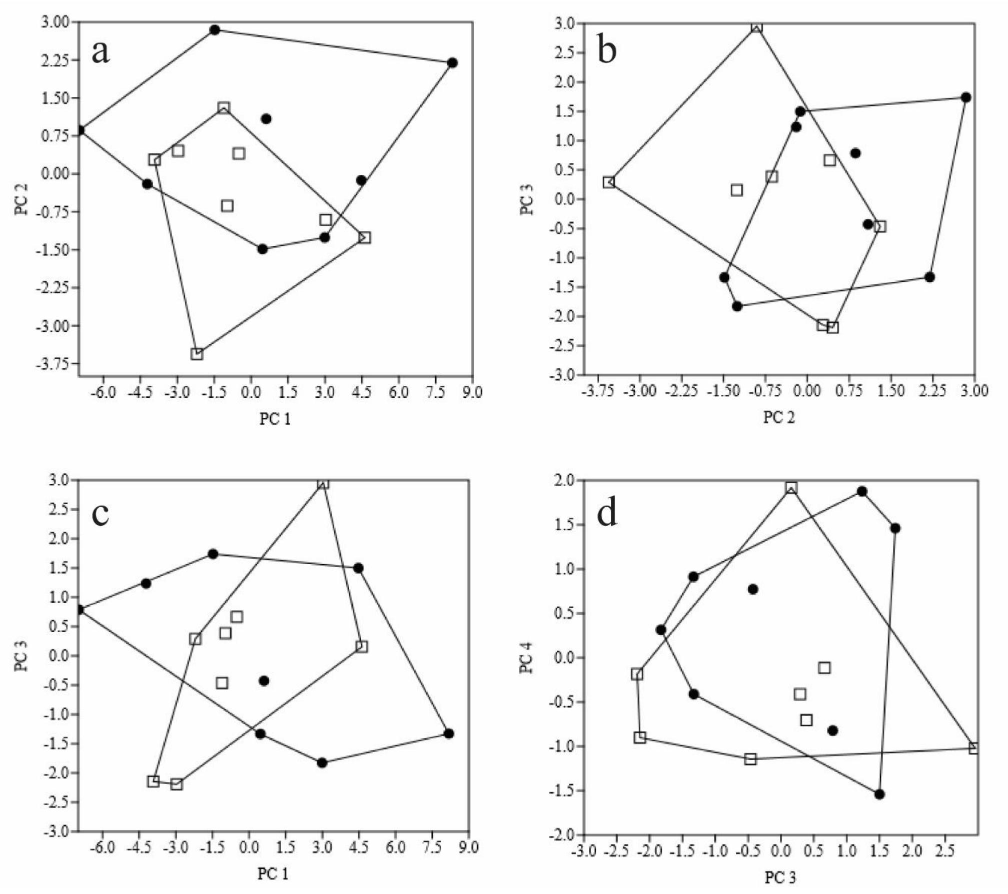

Fig. 2. Scatter plots of the first and second (a), second and third (b), first and third (c), and third and fourth (d) principal component scores for the craniomandibular characteristics in *Rattus losea*. Male and female specimens are represented by solid and open circles, respectively.

Our results indicate that 18 (72.0%) skull characteristics showed a significant correlation against condylobasal length. Most of the rostral variables (77.78%) showed significant correlation with CBL, while 66.67% braincase variables showed non-significant correlation. Principal component analysis also showed similar pattern with that of the correlation coefficients of the skull traits. PC 1 showed high factor loadings (> 0.600) for 20 variables (76.92%). Most rostral variables (88.89%) showed high factor loadings in PC 1, whereas 55.56% braincase variables exhibited low factor loadings. These patterns are strongly consistent with other murid rodents (Lin and Shiraishi 1992; Biswas and Motokawa 2019). These patterns have been suggested to be associated with growth-related events, somatic patterns in the rostrum and neural patterns in the braincase (Moore 1966, 1981; Biswas and Motokawa 2019).

Moreover, the mode of life of a species can be reflected by morphological characteristics (Biswas and Motokawa 2019). The larger correlation coefficient and high factor loadings in both mandibular length (LC and LA) and height (AHR) may indicate a similar structural strength for the major mandibular components. This pattern could imply a relatively low and elongated mandible with long diastema (Elbroch 2006). A long diastema could decrease mechanical advantage of mandibular muscles by increasing out-liver arm, indicating a predominantly granivorous diet (Elbroch 2006; Jones and Law 2018).

CONCLUSION

In conclusion for the first time the present study characterized morphological features of craniomandibular morphology in *R. losea*. We found sexual monomorphism for craniomandibular morphology in *R. losea*. Although most measurement showed significant correlation with condylobasal length, skull segments showed variation in correlation patterns. Our preliminary results on the craniomandibular measurements in *R. losea* may serve as a reference in future morphological studies.

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