Amphibia-Reptilia

Sexual dimorphism in *Xenodon neuwiedii* skull revealed by geometric morphometrics (Serpentes; Dipsadidae)

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Abstract. Sexual dimorphism in snake head/skull is poorly known, although analyses in other vertebrate groups have already pointed this kind of morphological difference. Herein we evaluated the existence of sexual dimorphism in the skull of *Xenodon neuwiedii* through Geometric Morphometrics (GM). We found that females have larger skulls than males using centroid size data. Considering the ventral view of the palatomaxillary apparatus, compared to females, males tend to have longer maxilla, ectopterygoid slightly laterally shifted, palatine slightly shorter, and longer pterygoid. For the dorsal view, males showed larger snout, more oblique frontoparietal suture, posterior region of the skull more tapered, larger supraoccipital, and larger and more oblique supratemporals. *Xenodon neuwiedii* showed static allometry only for the symmetric component of the dorsal view, with 9.7% of shape variation explained by size. The present study is the first evaluating and describing sexual dimorphism in skull shape for snakes independently of size. We compared our results with other studies and concluded that to accurately perform intraspecific analyses or to better understand sexual and/or natural selection, sexual dimorphism should be considered, even for structures (e.g. skull) that are traditionally not used for this purpose.

Keywords: allometry, female, male, osteology, shape, snake.

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Supplementary material

Table S1. Description of landmarks used in the GM analyses of the (a) dorsal and (b) ventral views of the skull of *X. neuwiedii*.

Landmark	Description
a. Dorsal	
1	Anterior-most point of premaxilla
2,3	Lateral-most point of premaxilla
4	Dorsal-most point of ascending process of premaxilla
5	Anterior-most point of nasals joint
6,7	Anterior-most point of the nasals
8,9	Most posterolateral point of the nasals
10	Rearmost point of nasals joint
11, 12	Lateral-most point of the nasals
13	Anterior-most point of frontals joint
14,16	Anterior-most point of prefrontal-frontal joint
15, 17	Posterior-most point of prefrontal-frontal joint
18, 19	Lateral-most point of frontal-parietal joint
20	Contact between frontals joint and parietal
21, 22	Lateral-most point of postorbital process
23, 24	Most posterolateral points of parietal
25, 26	Lateral-most point of the parietal-supraoccipital joint
27	Posterior-most point of parietal
28, 29	Supraoccipital-prootic-exoocipitals joint
30	Posterior-most point of supraoccipital
31, 32	Posterior-most point of exoccipitals
33	Posterior-most point of exoccipitals joint
34, 36	Anterior-most points of supratemporals
35, 37	Posterior-most points of supratemporals
b. Ventral	
1	Anterior-most point of maxilla
2	Posterior-most point of maxilla

3	Last maxillary tooth
4	Medial-most point of the palatine process of maxilla
5	Anterior-most point of palatine
6	Lateral-most point of maxillary process of palatine
7	Anterior-most point of the basis of choanal process of palatine
8	Medial-most point of choanal process of palatine
9	Posterior-most point of the basis of choanal process of palatine
10	Lateral-most point of the palatine-pterygoid joint
11	Medial-most point of palatine-pterygoid joint
12	Anterior-most point of ectopterygoid-pterygoid joint
13	Posterior-most point of ectopterygoid-pterygoid joint
14	Posterior-most point of pterygoid
15	Last pterygoid tooth
16	First pterygoid tooth
17	Anterior-most point of the medial branch of ectopterygoid
18	Anterior-most point of the lateral branch of ectopterygoid

Table S2. Sum of squares (SS), mean squares (MS), degree of freedom (DF), F statistics, and P-value calculated using ANOVA considering the difference of Procrustes coordinates between two photographs of the same individuals and two landmark digitalisations of the same photograph, for dorsal (D) and ventral (V) views of *X. neuwiedii* skull.

Effect	SS	MS	DF	F	P (param.)
Individual (D)	0.21213729	0.0001554119	1365	10.23	<.0001
Side (D)	0.00171671	0.0000490488	35	3.23	<.0001
Ind*Side (D)	0.02074168	0.0000151954	1365	6.36	<.0001
Photograph (D)	0.00669125	0.0000023897	2800	3.13	<.0001
Landmark (D)	0.00428167	0.000000764	5600		
Individual (V)	0.59360899	0.0004756482	1248	24.54	<.0001
Photograph (V)	0.02480486	0.0000193788	1280	3.63	<.0001
Landmark (V)	0.01365490	0.0000053339	2560		

Supplementary Table 3. Sum of squares (SS), mean squares (MS), degrees of freedom (DF), F statistics, R squared coefficient (RSQ), and P-value of MANOVA considering centroid size, sex, and the interaction between these parameters for the dorsal view of *X. neuwiedii* skull.

	DF	SS	MS	RSQ	F	P
CENTROID	1	0.002571	0.0025710	0.04398	1.9381	0.050
SEX	1	0.006209	0.0062086	0.10621	4.6804	0.001
CENTROID:SEX	1	0.001921	0.0019215	0.03287	1.4485	0.075
Residuals	36	0.047754	0.0013265	0.81694		
Total	39	0.058455				

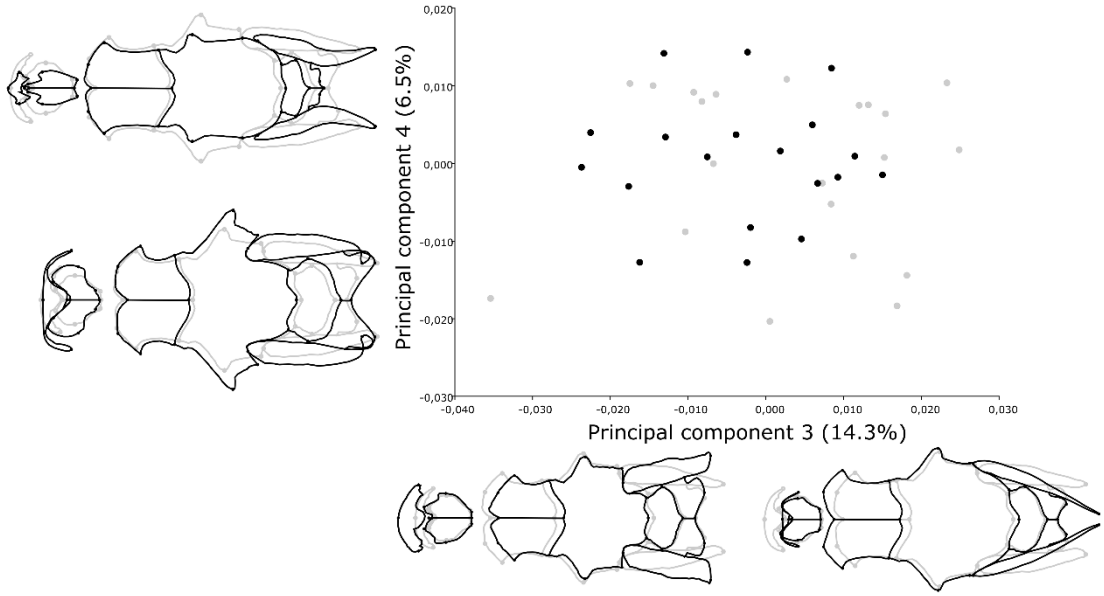

Figure S1. Principal component analysis of symmetric component of the dorsal view of the overall shape of the skull of *Xenodon neuwiedii*. Shapes represent, respectively in anticlockwise, PC4 in 0.1, PC4 in –0.1, PC3 in –0.1 and PC3 in 0.1. Grey dots females; black dots males.

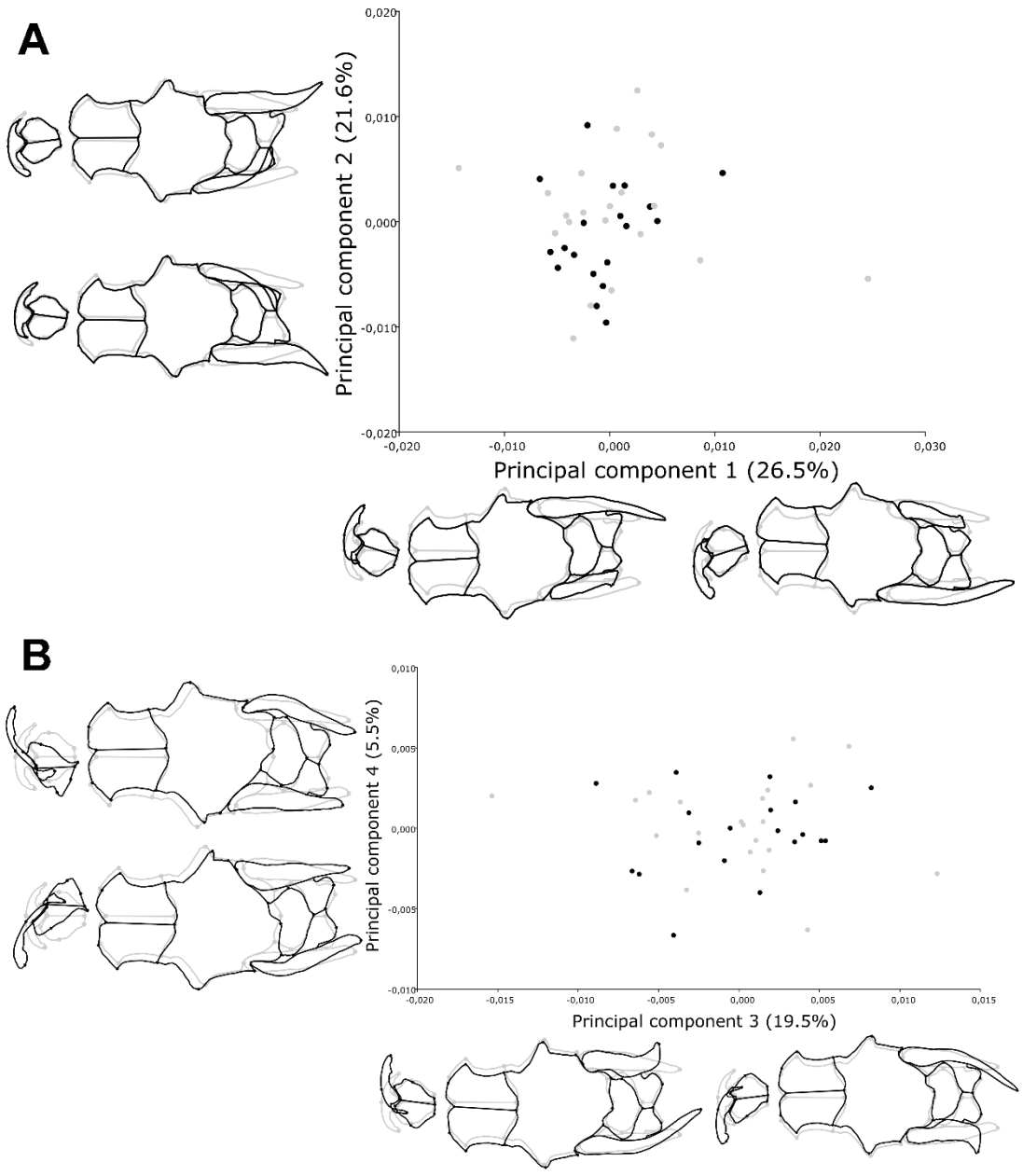

Figure S2. Principal component analysis of asymmetric component of the dorsal view of the overall shape of the skull of *Xenodon neuwiedii*. A – (P1 *vs*. PC2) Shapes represent, respectively in anticlockwise, PC2 in 0.1, PC2 in –0.1, PC1 in –0.1 and PC1 in 0.1. B – (PC3 *vs*. PC4) Shapes represent, respectively in anticlockwise, PC4 in 0.1, PC4 in –0.1, PC3 in –0.1 and PC3 in 0.1. Grey dots females; black dots males.

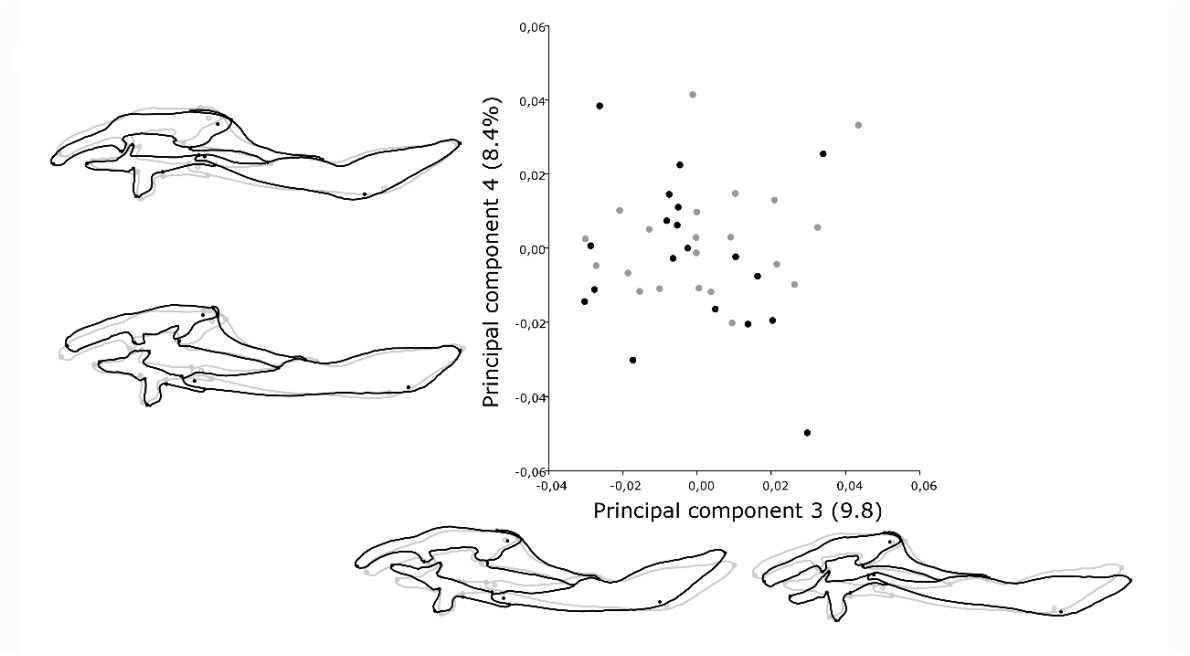

Figure S3. Principal component analysis of the ventral view of the overall shape of the skull of *Xenodon neuwiedii.* Shapes represent, respectively in anticlockwise, PC4 in 0.1, PC4 in –0.1, PC3 in –0.1 and PC3 in 0.1. Grey dots females; black dots males.

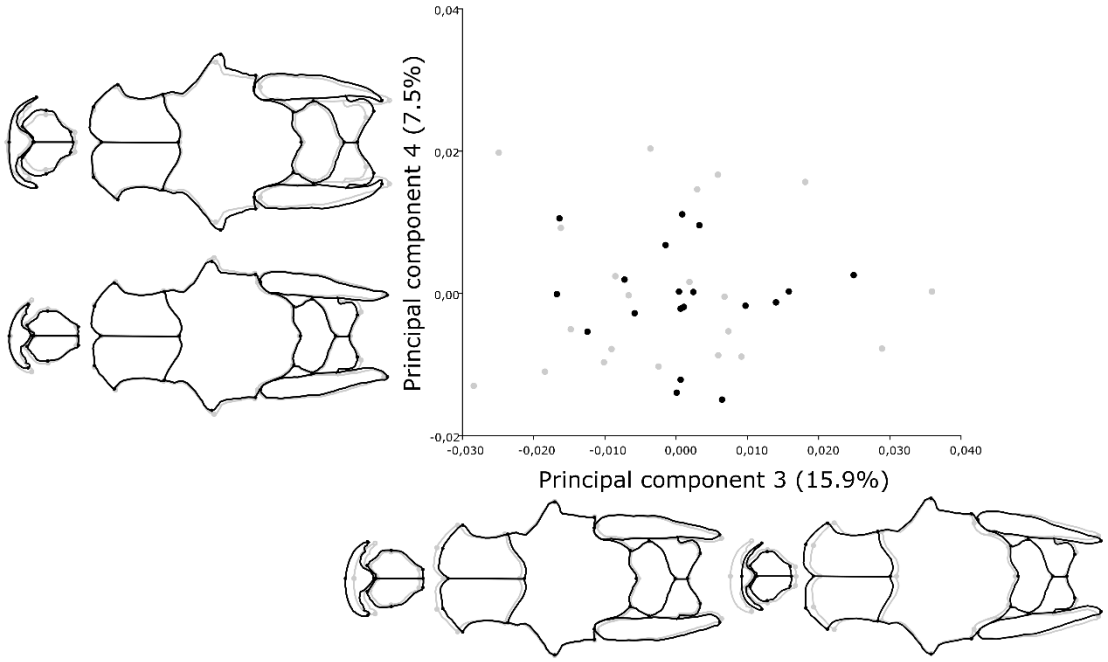

Figure S4. Principal component analysis of size corrected symmetric component of dorsal view of the skull of *Xenodon neuwiedii*. Shapes represent, respectively in anticlockwise, PC4 in 0.04, PC4 in –0.02, PC3 in –0.03 and PC3 in 0.04. Grey dots females; black dots males.