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Correspondence

Wannabe Ranid: Notes on the morphology and natural history of the Lemaire's Toad (Bufonidae: *Sclerophrys lemairii*)

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In 1901, G.A. Boulenger described as *Bufo lemairii* a very unusual toad from Pweto, Lake Meru in southern Zaire [= Democratic Republic of the Congo (hereafter DRC)]. This taxon was later transferred to *Amietophrynus* by Frost et al. (2006), and subsequently to *Sclerophrys* by Ohler & Dubois (2016). *Sclerophrys lemairii* is known from the eastern half of Angola, northern Botswana, central and southwestern Republic of the Congo, northeastern Namibia, and western and northern Zambia (IUCN SSC Amphibian Specialist Group 2013). It is associated with permanent waters such as swamps, flood plains, and smaller ponds or pools (Pitman 1934, Haacke 1982, Du Preez & Carruthers 2009, Bittencourt-Silva 2014) associated with the Okavango, Zambezi, and Congo River catchments. It is found within an altitudinal range of 900–1,830 m a.s.l. (Schimdt & Inger 1959, Bittencourt-Silva 2014).

Over the last few decades, many authors have referred to this unusual toad as possessing the appearance of a 'ranid' frog: "Habitus raniform…" (Schimdt & Inger 1959: 21), "…had the appearance of hybrids between a toad and a ranid frog" and "…pointed head and relatively long legs…." (Haacke 1982: 11), "Fairly large toad with *Rana*-like appearance, produced by relative narrow head, large tympana, and long toes" (Poynton & Broadley 1988: 464); or "…similar in shape to River Frogs, head narrow and pointed" (Du Preez & Carruthers 2009: 144).

In May 2012, April 2013 and June 2015, the authors had the opportunity to survey the Cubango and Cuito River catchments in southeastern Angola (Brooks 2012, Brooks 2013, Conradie et al. 2016). In May 2012 a single female specimen was found wandering the extensive floodplain north of Menongue on the Cuebe River (-14.42972 S, 17.82658 E); this record expands the known distribution of the species westwards in Angola. During the April 2013 and June 2015 surveys, we found adults at the margins of main river channels at two sites on the lower Cuito River around M'Pupa Falls (-17.51328 S, 20.06111 E and -17.48933 S, 20.05386 E); this expands the known distribution southwards in Angola. Both records represent new Caundo Cubango provincial records. Here we observed and collected a good series of *S. lemairii* to test whether the species indeed has a more general 'ranid' external morphology compared to other, more typical 'bufonid' species. We also provide here additional natural history information, including the first call analysis and description of the tadpole.

Measurements were taken of *Sclerophrys lemairii* (n = 40) deposited in the collections of the Port Elizabeth Museum (PEM) and South African Institute for Aquatic Biodiversity (SAIAB). For comparison, we chose taxa representing the fully aquatic lifestyle (*Amietia angolensis*, *Ptychadena subpunctata*, *Strongylopus fasciatus*), semi-terrestrial lifestyle (*Sclerophrys funerea*, *S. gutturalis*, *Phrynobatrachus natalensis*, *Poyntonophrynus vertebralis*, *Tomopterna cryptotis, Vandijkophrynus gariepensis*), and fully terrestrial lifestyle (*Arthroleptis stenodactylus*, *Breviceps adspersus*) (see Appendix 1). Measurements were taken to the nearest 0.1 mm using digital callipers under a Nikon SMZ1270 dissecting microscope for the following eight morphological characters (used in the principle component analysis): snout–urostyle length (SUL, from tip of snout to vent); head length (HL, from posterior end of mandible to tip of snout); head width (HW, measured at corner of mouth just behind eyes); thigh length (THL, from vent to knee); tibia length (TL, from knee to heel); foot length (FL, measured from heel to tip of longest toe); front arm length (FAL, elbow to tip of longest finger); and front upper-arm length (FUAL, elbow to metatarsal tubercle). All measurements were taken on the right side of the body by the senior author for consistency. Only adult material was considered for this study. Sexes were not separated for statistical analy-

Table 1. Principle component loadings for all variables measured. See text for an explanation of abbreviations.

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
SVL	0.360	-0.240	-0.349	-0.283	0.587	-0.401	0.299	-0.127
HL	0.370	-0.003	-0.318	-0.114	0.064	0.146	-0.850	0.021
HW	0.347	-0.421	-0.459	0.155	-0.556	0.223	0.303	0.135
THL	0.357	0.327	0.098	0.330	-0.232	-0.684	-0.053	0.351
TL	0.348	0.464	-0.043	0.187	-0.109	0.123	0.135	-0.762
FL	0.352	0.414	0.057	0.025	0.335	0.525	0.255	0.498
FAL	0.333	-0.518	0.557	0.472	0.236	0.103	-0.093	-0.113
FUAL	0.360	-0.052	0.491	-0.718	-0.330	-0.013	0.041	-0.018
Standard deviation	2.663	0.764	0.322	0.312	0.222	0.178	0.159	0.128
Proportion of variance	0.887	0.073	0.013	0.012	0.006	0.004	0.003	0.002
Cumulative proportion	0.887	0.960	0.972	0.985	0.991	0.995	0.998	1.000

sis, but a Box-Cox transformation was applied to the dataset to correct for any skewness, and each variable was centred and scaled in the *Caret* preProcess function in R (Box & Cox 1964, R Development Core Team 2014). In order to assess the morphological similarity between *S. lemairii* and the other selected species, a principal component analysis (PCA) was conducted on the transformed data using the *ggbiplot* package in R (Wickham 2009).

Morphological descriptions and labial tooth row formulae (LTRF) of tadpoles, in general, follow McDiarmid & Altig (1999) and Altig (2007). Tadpole developmental stages are based on Gosner (1960). The following measurements of tadpoles were taken to the nearest 0.1 mm under a Nikon SMZ1270 dissecting microscope with digital callipers: total length (TL, distance from snout to tail tip); body length (BL, distance from snout to body-tail junction, a coronal line that abuts the caudal edge of the body); tail length (TAL); maximum body height (BH); maximum body width (BW); basal tail muscle width (TMW); maximum tail height (MTH); tail muscle height (TMH), interorbital distance (IOD, measured from centres of orbits); internarial distance (IND, measured from centres of narial apertures); nasal orbital axis (NOD, measured perpendicular from IND to IOD); snout to nostril axis (SND, measured from tip of snout to the perpendicular line of the IND); snout to orbital axis (SOD); snout to spiracle (SS, measured on a line parallel to the long axis of the body); eye diameter (ED); and oral disc width (ODW, the widest transverse distance).

Advertisement calls were recorded in the field using a NAGRA ARES-ML recorder with a Sony F-V4T Microphone and analysed using Sound Ruler Acoustic Analysis (Version 0.9.6.0) at default settings (Gridi-Papp 2007). General recording settings were set at 44.1 kHz sample ratio, 16 bits resolution, and FFT length 256. The following standard measurements were taken: call duration in seconds (s); number of pulses in a call; and dominant and fundamental frequencies in Hertz (Hz).

Our PCA (Table 1, Fig. 1) indicates that *S. lemairii* is morphologically more similar to typical aquatically adapted species (*Amietia angolensis*, *Ptychadena subpunctata*, *Strongylopus fasciatus*) than to typical terrestrial or semi-terrestrially adapted species (*Sclerophrys funerea*, *S. gutturalis*, *Arthroleptis stenodactylus*, *Breviceps adspersus*, *Phrynobatrachus natalensis, Poyntonophrynus vertebralis*, *Tomopterna cryptotis*, and *Vandijkophrynus gariepensis*). This is especially true in the length of the hind limbs (TL, FL, and THL), which are longer in *S. lemairii* and other aquatic species, while the width of the head (HW) and front arm length (FAL) place it closer to typical Bufonidae (Fig. 1). The first two principle components (PC) explain 96% of the total variation (see Table 1), however, when SVL and HL are removed from the PCA, the remainder of the variables provide the same general results as the first two PC's, indicating a definite intermediate position between terrestrial and aquatically adapted species. These morphological adaptations would allow these toads to live and breed in floodplain habitats. Longer toes allow for better movement through vegetation and anchoring in floating vegetation. The longer limbs may enable them to leap and, together with pointed nose, to dive faster into the water and so avoid possible predation.

Breeding has been recorded at different times of the year, i.e., September 1979 (Xungana, Botswana: Haacke 1982), 29 April 2014 (Lukwakwa, Zambia: Bittencourt-Silva 2014), mid-May (Bangweulu Swamps, Zambia: Pitman 1934), April and June (Upemba NP, DRC: Schmidt & Inger 1959), and 16–17 April 2013 (this paper). One single male was observed calling on 11 June 2015 at M'Pupa Falls, southern Angola, well after seasonal flooding has receded. Bittencourt-Silva (2014) described sexual dimorphism and dynamic dichromatism in a breeding population from Lukwakwa, Zambia. Males would turn from their normal colouration (i.e., light brown with pairs of dark, paraventral patches – see Du preez & Carruthers (2009)) to olive and then bright yellow during breeding periods, afterwards, they would revert to their normal coloration. Haacke (1982) also referred to the yellowish colour of breeding males and red markings on the back and thighs of females, stating that this yellow colour was similar to the colour plate in Schmidt & Inger (1959: pl. 1, fig. 1). On 16 and 17 April 2013, we recorded the same male dichromatism as described above. Adding to these previous observations, we record that there seems to be some degree of male dominance in that the more dominant males turn from olive to bright yellow and call from the most central position while collected females all had the normal coloration. Satellite (sneaker) males were observed 1–2 m from the dominant males, where they intercepted females as they approached a dominant calling male. Both dominant male and satellite males were observed perched on floating grass adjacent to slow-flowing water (Fig. 2). The single male recorded on 11 June 2015 also exhibited the yellow coloration, although no other males or females were observed. Adult males have darkened to black nuptial pads on the first and second fingers (Bittencourt-Silva 2014) as well as the third finger (Schimdt & Inger 1959). A darkened nuptial pad was only recorded on the first finger during the current study.

The following call description is based on a single male recorded while perched on floating vegetation at M'Pupa Falls, Angola, on 17 April 2013 around 21:00 h at 15°C air temperature (Fig. 3). The call sounds like a very short "chuckle", which is repeated up to eight times in less than 10 s at a rate of 1.1 calls per second with a dominant frequency at 1,636 Hz and a fundamental frequency at 818 Hz. The call duration is 0.44 ± 0.02 s and separated from the next call by 0.7 ± 0.14 s (n=8). Each call comprises 20–30 pulses, which are grouped in four clusters of 6–10 pulses each. This is very different from the call described by Channing (2001), who stated a call duration of only 0.06 s and containing three pulses at a frequency of 2.5–4.1 kHz. This call is thus much shorter and more highly pitched and may therefore represent a different type (i.e., territorial, distress, warning or release call, etc.).

The tadpole of *S. lemairii* was previously unknown (see Channing et al. 2012). On the evening of 17 April 2013, two pairs of *S. lemairii* (Fig. 2D) in amplexus were collected and allowed to spawn in a 25-litre bucket with some grass and water taken from the site of capture. The two clutches of single-string eggs hatched after 2–4 days. We did not record the clutch size, but Bittencourt-Silva (2014) estimated 2670 eggs per female. Free-swimming stage was reached after five days and the larvae were thereafter fed daily with either fish flakes or boiled lettuce leaves under ambient conditions, initially in the field and later at the PEM herpetology laboratory. Water was exchanged daily and replaced with dechlorinated water. One or two tadpoles were preserved every 4–5 days in 10% formalin to compile a full developmental series. Tadpoles started reaching metamorphosing stages on Day 112 (e.g., Gosner stages 41–42). The remaining tadpoles were all preserved on Day 146 (approaching five months), with one tadpole still at Gosner stage 26. At Gosner stage 41, the maximum TL was 25.4 mm at 10.0 mm BL. Fully metamorphosed froglets measured 9.2 ± 0.9 mm.

The following tadpole description is based on a single tadpole from the SAIAB 101032 lot at Gosner stage 35. Additional measurements, covering different Gosner stages, are provided in Table 2. All measurements are in mm.

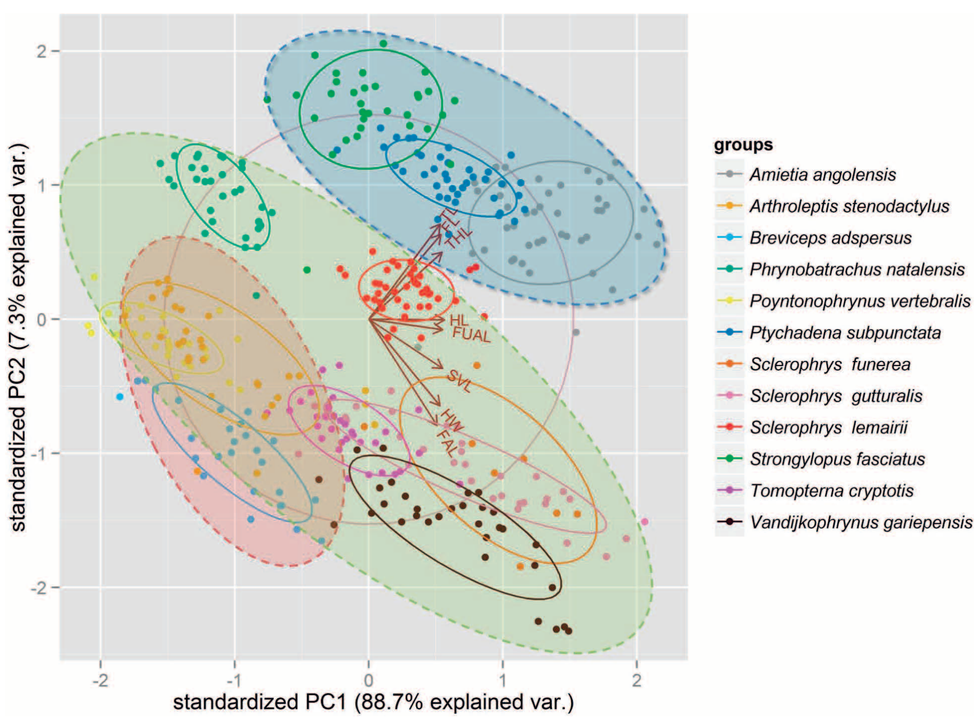

Figure 1. Principal Component Analysis of morphological divergence between species; only the first two PCs are shown (blue eclipse – aquatic group; green eclipse – semi-terrestrial group; red eclipse – fully terrestrial group). See text for explanations of abbreviations used.

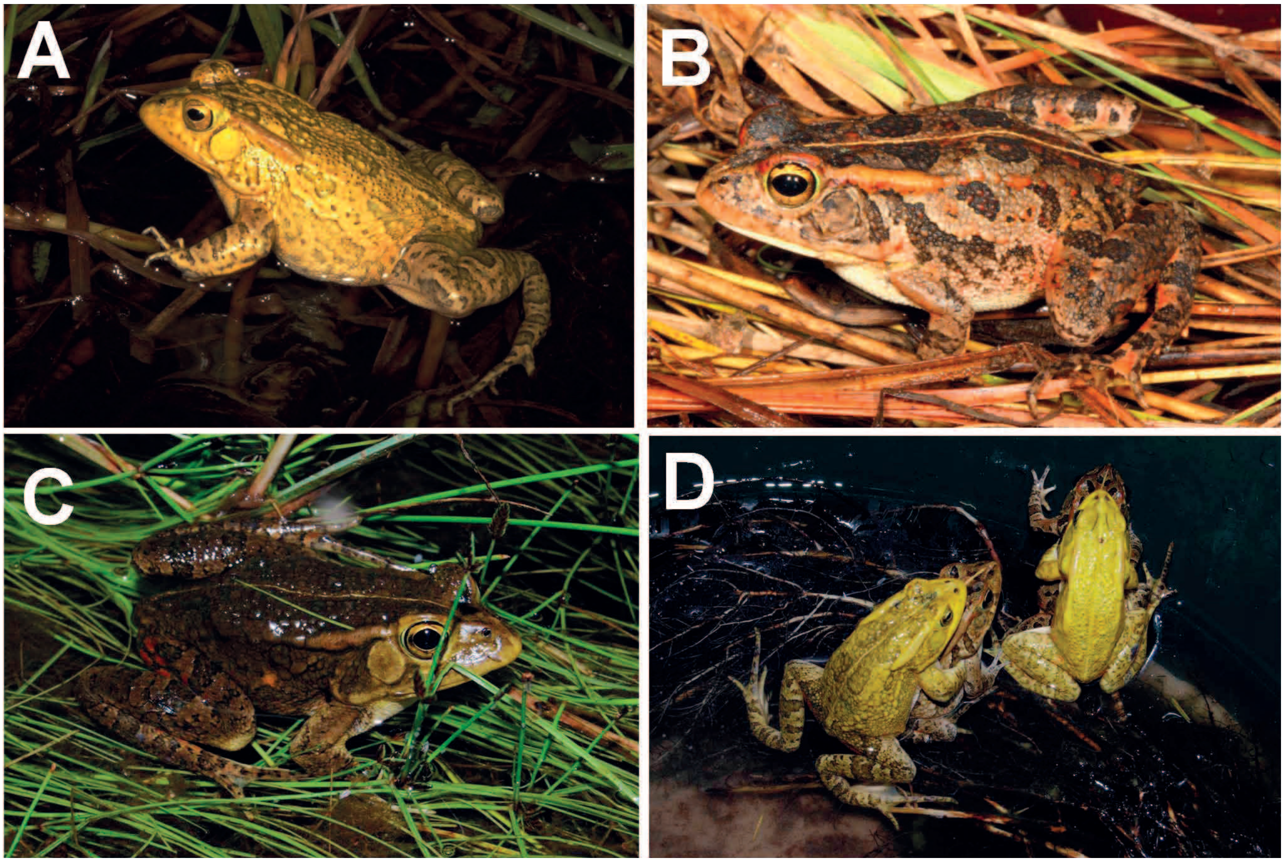

Figure 2. *Sclerophrys lemairii* from M'Pupa Falls, southern Angola. (A) breeding male; (B) adult female; (C) satellite (sneaker) male; (D) two pairs in amplexus.

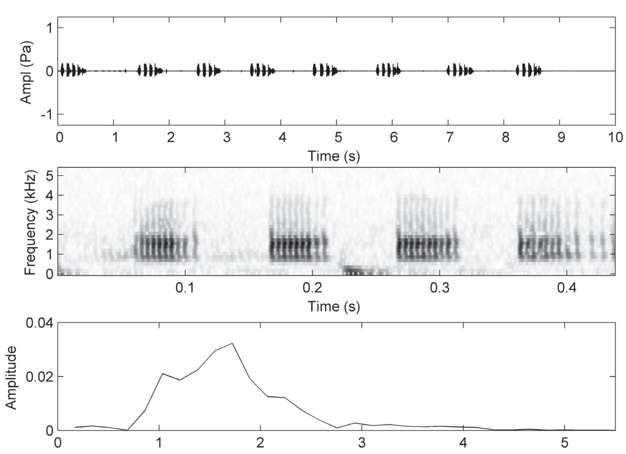

Figure 3. Advertisement call of *Sclerophrys lemairii* from M'Pupa Falls, Angola. (Top) oscillogram of a series of eight calls; (centre) spectrogram of a single call; (bottom) frequency graph of a single call.

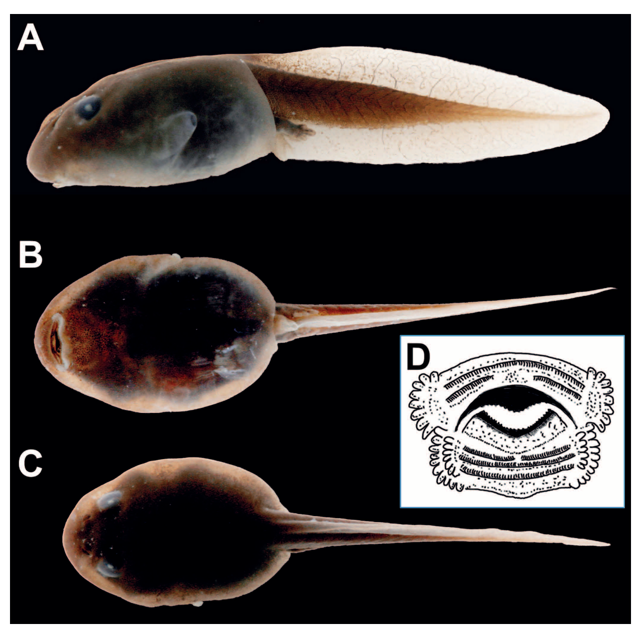

Figure 4. A tadpole of *Sclerophrys lemairii* (SAIAB 101032) from M'Pupa Falls, Angola. (A) lateral view; (B) ventral view; (C) dorsal view; (D) line drawing of LTRF).

Table 2. Measurements of tadpoles in the SAIAB 101032 series in mm ± standard deviation.

Gosner stage	25 (n=11)	26 (n=11)	27 (n=6)	28 (n=1)	31 (n=4)	32 (n=3)	33 (n=2)	34 (n=2)	35 (n=7)	36 (n=3)
Total length (TL)	9.4±1.1	13.2±1.8	17.0±0.7	17	19.7±2.1	19.9±0.4	20.5±0.2	22.5±1.5	22.6±1.0	22.4±1.3
Body length (BL)	4.2±0.4	5.6±0.8	7.2±0.2	7.4	8.0±1.6	8.6±0.4	9.0±0.2	9.7±0.2	9.7±0.4	9.8±0.5
Tail length (TAL)	5.4±0.4	7.6±1.0	9.8±0.6	9.6	11.7±0.5	11.2±0.4	11.5±0	12.8±1.3	12.9±0.8	12.6±1.0
Body height (BH)	1.9±0.2	3.0±0.5	4.0±0.3	4	4.7±0.1	4.5±0.3	4.9±0.2	5.3±0.2	5.1±0.4	5.1±0.1
Tail height (MTH)	2.0±0.2	2.8±0.3	3.7±0.2	3.2	4.5±0.3	4.4±0.2	5.2±0.5	5.1±0.2	4.9±0.3	4.7±0.4
Tail Muscle height (TMH)	0.7±0.1	1.0±0.1	1.4±0.1	1.1	1.6±0.1	1.7±0.1	1.9±0.1	1.8±0.0	1.9±0.1	1.8±0.1
Eye diameter (ED)	0.4±0.1	0.5±0.1	0.6±0.0	0.5	0.9±0.2	0.8±0.2	0.7±0.1	0.8±0.0	0.9±0.1	0.9±0.0
Snout to spiracle (SS)	2.7±0.2	3.6±0.5	4.7±0.3	4.5	5.6±0.2	5.6±0.2	5.8±0.4	6.4±0.3	6.1±0.3	6.1±0.3
Body width (BW)	2.3±0.4	3.6±0.6	5.0±0.6	5	5.9±0.1	5.9±0.4	6.4±0.1	6.7±0.2	6.7±0.4	6.6±0.5
Tail muscle width (TMW)	0.5±0.1	0.8±0.2	1.0±0.1	1	1.3±0.1	1.2±0.1	1.4±0.1	1.5±0.2	1.5±0.1	1.5±0.1
Interorbital distance (IOD)	0.8±0.1	1.2±0.2	1.5±0.1	1.4	1.9±0.1	1.9±0.2	2.0±0.0	2.0±0.1	2.0±0.2	1.9±0.0
Internarial distance (IND)	0.5±0.1	0.6±0.1	0.8±0.1	0.6	0.9±0.1	1.0±0.1	1.0±0.1	1.0±0.1	1.1±0.1	1.0±0.1
Nasal orbital axis (NOD)	0.4±0.1	0.5±0.1	0.7±0.1	0.8	0.7±0.1	0.7±0.2	0.8±0.1	0.9±0.0	0.8±0.1	0.8±0.0
Snout to nostril axis (SND)	0.4±0.1	0.7±0.1	0.8±0.1	0.8	1.0±0.1	0.8±0.1	0.9±0.0	0.9±0.1	1.0±0.1	1.0±0.2
Snout to orbital axis (SOD)	0.8±0.1	1.2±0.2	1.5±0.2	1.6	1.6±0.0	1.4±0.4	1.6±0.0	1.7±0.0	1.8±0.2	1.7±0.2
Narial diameter (ND)	0.2±0.0	0.3±0.0	0.3±0.0	0.4	0.4±0.0	0.8±0.7	0.4±0.1	0.5±0.0	0.5±0.1	0.5±0.1
Oral disc width (ODW)	1.0±0.2	1.3±0.2	1.6±0.1	1.5	1.9±0.2	2.0±0.0	1.8±0.0	2.0±0.0	2.0±0.2	2.0±0.1

Lateral view (Fig. 4A): Body round and plump, nearly as high as wide (BH/BW 0.8); snout oblique; mouth directed near ventral; nasals oval in shape, very small, positioned dorsally, situated midway between eyes and snout (SND/NOD 1.1); eyes small (ED 11% of BL), round in shape, positioned dorsolateral; spiracular tube sinistral, tubular, small, joined to body wall, positioned laterally, and situated closer to vent than snout (SS 63% of BL); spiracular opening oval, directed slightly upwards, at the height of the middle of the lower part of the caudal muscle; tail one and a half times the body length (TAL/BL 1.4) and nearly two thirds of total length (TAL/TTL 0.6), tail musculature narrow (TMH 38% of BH and 42% of MTH), tapering gradually to a sharply pointed tip; tail fins of moderate size, deepest midway down tail, terminating in a bluntly rounded tip; upper fin not extending onto body, slightly convex to the end of the tail; lower fin slightly convex to the end of tail. Ventral view (Fig. 4B): Eyes not visible in ventral view; vent tube marginal, medial and short, with an oval opening. Dorsal view (Fig. 4C): Body oval, nearly as wide as high (BW/BH 1.2), widest just in front of the spiracular opening; snout rounded; nasals tightly spaced; interorbital distance double the internarial distance (IOD/IND 2.0); tail muscle width 27% of body width (TMW/BW 0.25). Oral disc (Fig. 5D): Positioned and directed nearly ventrally, moderately large (ODW 37% of BW); LTRF: 2(2)/3(1), third posterior row nearly equal in length to first and second rows; jaw sheaths narrow, moderately pigmented, encapsulated and rounded; lateral process moderately short; a double row of lateral papillae at corners of mouth, dorsal and ventral gaps free of papillae (up to 80% free); posterior corners with no submarginal papillae; lateral margins of oral disc slightly indented. All Gosner stages, except for late stages (stage 42 onwards), showed the same oral disc configuration. Coloration (preserved): Body darkly pigmented, brown, eyes and iris dark, dorsum dark, venter paler with scattered darker iridophores interiorly adjacent to mouth, intestine not visible through the skin; tail musculature slightly pigmented, lighter towards the tip; fins with scattered spots and veins, but mostly translucent. Measurements: TL 22.6; BL 9.5; TAL 13.2; BH 5.0; BW 6.2; TMW 1.7; MTH 4.5; TMH 1.7; IOD 2.0; IND 1.0; NOD 0.8; SND 0.9; SOD 1.6; SS 6.0; ED 1.0; ND 0.4; ODW 2.3.

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Appendix 1

List of material examined in this study (PEM – Port Elizabeth Museum; SAIAB – South African Institute for Aquatic Biodiversity; WC – Werner Conradie Collection):

Amietia angolensis: PEM A910, 10313, 10317–18, 10325–10327, 10355, 10375, 1906–1909, 1912–1921, 2820–2828, 2830, 2832–2834, 2837, 8017–18, 8093, 9136; SAIAB 87877,118963, 187402; WC 1505, 1507, 1521.

Sclerophrys funerea: PEM A9042, 10007, 10012–13, 10023, 10026, 10031, 10067.

Sclerophrys gutturalis: PEM A6429, 8057, 8073, 8078, 8085–86, 8089–8092, 8463, 8465–8470, 8916, 9083, 9514–9518, 10004, 10008, 10014, 10266, 10267–10269, 10412, 10777, 10950.

Sclerophrys lemairii: PEM A2585, 9046–9048, 10413, 10818–10829; SAIAB 101019 (2), 101031 (10), 101032 (10), 190459 (tadpoles).

Arthroleptis stenodactylus: PEM A6652, 6661, 6956, 6959, 6976–77, 6979, 7304, 7389, 7394, 7572–73, 7995, 9396–9398, 9401–9406, 9413, 11001, 11014, 11018, 11022, 11026, 11030, 11047–48, 11056, 11080.

Breviceps adspersus: PEM A829, 2346, 2355, 2373, 2382–2384, 2411, 2851–3854, 4723, 4724, 4729, 4800, 7989–7993, 8002, 8007, 9431, 9433–34, 9444.

Phrynobatrachus natalensis: PEM A10286–87, 10312, 10320–21, 10323, 10334–35, 10341, 10345–10349, 10358, 10377, 10378, 10410–11, 10424, 10463–10465, 6992, 6994, 9166–9169, 9172–9174.

Poyntonophrynus vertebralis: PEM A752, 1623, 1625, 1796, 1801, 3164–3166, 3169–3182, 3185, 3187–3192, 4850, 6876, 6891.

Ptychadena subpunctata: PEM A1085, 10359–10364, 10366–10368, 10794, 10796–97, 10799, 10800, 10802–3, 10806–7, 10901–10916, 10948, 10964–10967.

Strongylopus fasciatus: PEM A72, 98, 100, 344, 675, 875.1, 875.2, 408–81, 4083–4085, 4093, 4097–98, 4100, 4111, 5365, 5373, 5385, 5404,7962, 10131, 10169, 10171, 10173, 10176, 10188, 10709, 11161, 11167, 11168.

Tomopterna cryptotis: PEM A998–9, 1030–1040, 1076–1081, 1820, 2341, 2385, 3841, 3850, 4253–54, 7515–16, 7994, 9429–30, 9446.

Vandijkophrynus gariepensis: PEM A527, 561, 646, 663, 717, 1730, 1875, 2222, 2791, 4615, 5653, 8817, 8826, 8843, 8846, 8848–49, 8858, 8860, 8863, 9451–52, 9460–9462, 9666, 9671, 9781, 9784–85, 10740–41.