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A new species of *Boulengerula* Tornier (Amphibia: Gymnophiona: Caeciliidae) from an isolated mountain block of the Taita Hills, Kenya

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Abstract

A new species of East African caeciliid caecilian, *Boulengerula niedeni* spec. nov. (Amphibia: Gymnophiona) is described based on a series of 11 specimens from Sagalla Hill, an isolated mountain block of the Taita Hills in southern Kenya. It differs from all other *Boulengerula*, except *B. taitanus* (Loveridge), in being pigmented with whitish marked annular grooves and from *B. taitanus* by its distinctive brownish colouration, an exposed sphenethmoid, a higher mean number of annuli and vertebrae, and different phallus morphology.

Key words: caecilians, taxonomy, herpetology, Eastern Arc Mountains, East Africa, phallus morphology, systematics

Introduction

The caecilian fauna of East Africa currently comprises seven species of caeciliids and three species of scolecomorphids. As currently conceived (Wilkinson *et al.* 2004) the genus *Boulengerula* comprises six species, which makes it the most speciose of all African

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caecilian genera. With the exception of one or two lowland forms, most of the East African caecilian species inhabit the forested mountains of the Eastern Arc, a recognized biodiversity hotspot of global importance (e.g. Myers *et al*. 2000). In 1935, Loveridge described *B. taitanus* from Mt. Mbololo in the Taita Hills complex, Kenya (Fig. 1). This species became subsequently known to also inhabit Dawida, i.e. the main Taita Hills block (e.g. Glaser 1984; Hebrard *et al.* 1992; Gaborieau & Measey 2004; Measey 2004). Recently collected caecilians from Sagalla Hill, an isolated mountain block of the Taita Hills range in the Eastern Arc, differ substantially from *B. taitanus* and all other members of *Boulengerula* in their colouration, phallodeal characters and other morphological features. Here we describe these caecilians as a new species.

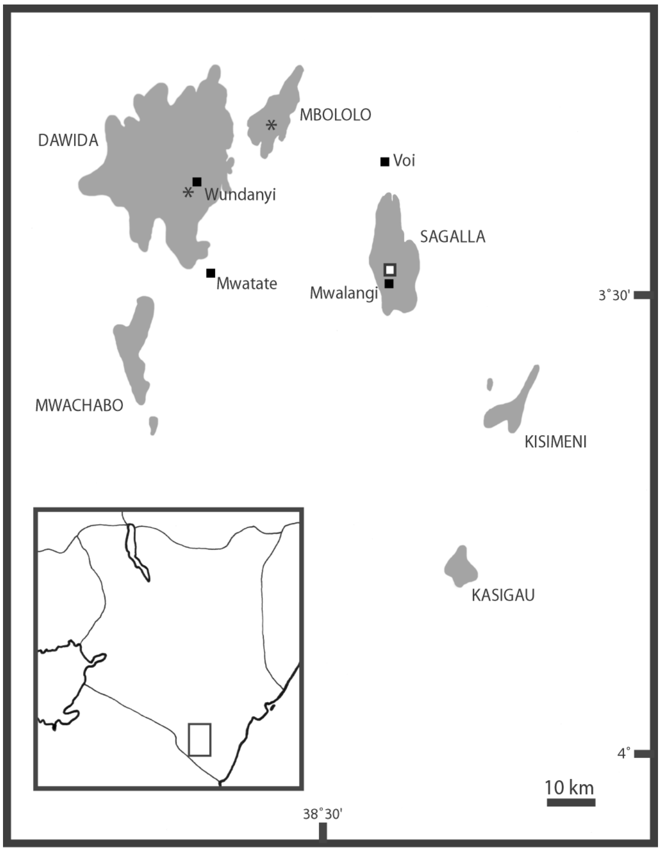

FIGURE 1. Map of the Taita Hills Formation. The inset map shows the position of the Taita Hills in Kenya. The map shows all mountainous areas above 1000m. The open square marks the type locality of *Boulengerula niedeni* and asterisks mark localities of *B. taitanus* used for comparison. Towns are marked with a square. Names written in capital letters refer to mountains, others to towns.

Boulengerula niedeni sp. nov.
(Figs. 2, 3, Table 1)

Holotype: NMK A/4294 National Museums of Kenya, Nairobi, Kenya. A mature female collected approximately 100m behind the matatu (bus) terminus at Mwalangi shopping centre, Sagalla Hills, Taita-Taveta District, Kenya, by Hendrik Müller and David Mwaghania, 23 January 2004. The specimen was dug up from underneath a banana plant on a local shamba (small agricultural holding) at approximately 1080 m above sea level (S03°30.76', E38°34.59').

Paratypes: 10 additional specimens collected 23.01.2004 (BMNH2005.10–11, NMK A/4295) by Hendrik Müller and David Mwaghania and 26.04.2004 (NMK A/4298/1–7) by Patrick K. Malonza from the same locality as the holotype. All specimens were dug up from shambas, mostly in soil underneath bananas or under decomposing organic debris.

Diagnosis: A medium to large *Boulengerula* with the sphenethmoid exposed between the frontals. It differs from all other members of the genus, except *B. taitanus*, in being strongly pigmented, which gives it a brownish appearance in life and dark slate in preservative, with whitish annular grooves. It differs from *B. taitanus* in its distinctive brownish rather than bluish-black colouration, the sphenethmoid being exposed between the frontals, a higher mean number of vertebrae and annuli, and different phallus morphology with broad, flange-like tuberosities of the dorsolateral ridges that are in close proximity dorsomedially.

Description of the holotype: Morphometric and meristic data are given in Table 1. The holotype is in good condition generally. It is slightly dehydrated, which results in a somewhat wrinkled appearance with the ventral side being partly concave. Three patches of artefactual dark discolouration are present on the ventral side of the head and anterior body. There are two midventral longitudinal incisions, the first (13 mm) beginning 24 mm in front of the vent and the second (18 mm) 67 mm in front of the vent.

The natural shape of the body is cylindrical to subcylindrical and appears slightly dorsoventrally compressed (more so in preservative). The body is almost uniform in width, except for the anterior 30 mm where the body gently narrows towards the head. The body also narrows slightly in its last 25 mm towards the vent, from where the body narrows abruptly towards the terminus.

In dorsal view, the head is parabolic, tapering from the first nuchal groove towards the nares, with a slight bulging in the region of the tentacles. Anterior to the nares, it terminates in a rounded but narrow snout tip. In lateral view, the top of the head is almost straight and tapers gently towards the level of the tip of the lower jaw, from where it tapers strongly towards the tip of the snout. The snout is bluntly rounded and has its apex on a horizontal line halfway between naris and tentacle in lateral view. The underside of the snout (rostrum) is slightly concave above the margin of the upper lip. In ventral view, the tip of the lower jaw is more broadly rounded than the tip of the snout. The distance between the jaw angle and the top of the head (at the level of the jaw angle) is slightly greater (but less than one and a half times) than the distance between the jaw angle and the ventral side of the head.

The eyes are not visible and no differentiation in skin pigmentation indicates their position. There is no conspicuous depression or elevation in the region where the eyes would be expected to lie.

The tentacles are short and globular. The tentacular apertures are almost perfectly circular and raised, resulting in an elevated rim around the tentacular orifice. They are encircled by a dark ring and are positioned slightly ventrolaterally on the head. In ventral view, the tentacular apertures are more clearly visible than in dorsal view, where they just about reach the outline of the head. In lateral view, the tentacle is much closer to the margin of the upper lip than to the top of the head and lies on an imaginary straight line between the naris and the jaw angle. The tentacular aperture is positioned almost half way between the anteriormost margin of the mouth and the angle of the jaw, but slightly closer to the anteriormost margin of the mouth.

The nares are very small, subcircular to kidney shaped, and less than 0.1 mm in diameter. They sit at the anterior rim of a very shallow, oval to subcircular depression of 0.26 mm length. In lateral view, the naris is positioned almost equidistant from the upper side, underside, and apex of the rostrum, with the distance to the apex being the smallest and to the underside the largest. The nares are also visible anteriorly and dorsally but not ventrally.

The choanae have an oval shape and no conspicuous choanal valves are visible. The lateral rim of the choana is formed by the vomeropalatine shelf and is slightly raised. The medial rim is not raised. The angles of the jaw are not cut, so tooth counts are approximations. In the holotype, the teeth are arranged in three series. We count 24 premaxillary-maxillary teeth, 22 vomeropalatine, 18 dentary. Of the splenial series, only a single pedicel is present on the right side, the crown being broken off. No traces of splenials were found on the left side. There is no diastema between vomerine and palatine teeth. The flat and featureless tongue is free at its anterior end and not pigmented.

The two nuchal collars appear slightly broader than the adjacent areas. At 2.2 mm the second nuchal collar is slightly longer than the first (1.9 mm, measured laterally). The two nuchal collars are clearly demarcated by three nuchal grooves. The first nuchal groove is largely incomplete dorsally. The second nuchal groove is complete and has a small, forward pointing bend on the dorsal side. The third nuchal groove is interrupted ventrally, with the gap slightly shifted towards the left side. Ventrally, the first and second nuchal grooves are straight, whereas the open ends of the third groove are bent slightly backwards, mirroring the posterior groove of the first annulus. The first nuchal collar has a short transverse groove on the dorsal side, which is only very faintly indicated. A clearly marked, albeit very narrow crease is present on the ventral side. The second nuchal collar also bears a transverse groove, which is much broader than the one on the first collar and clearly indicated. Lateral transverse grooves are present on neither collar.

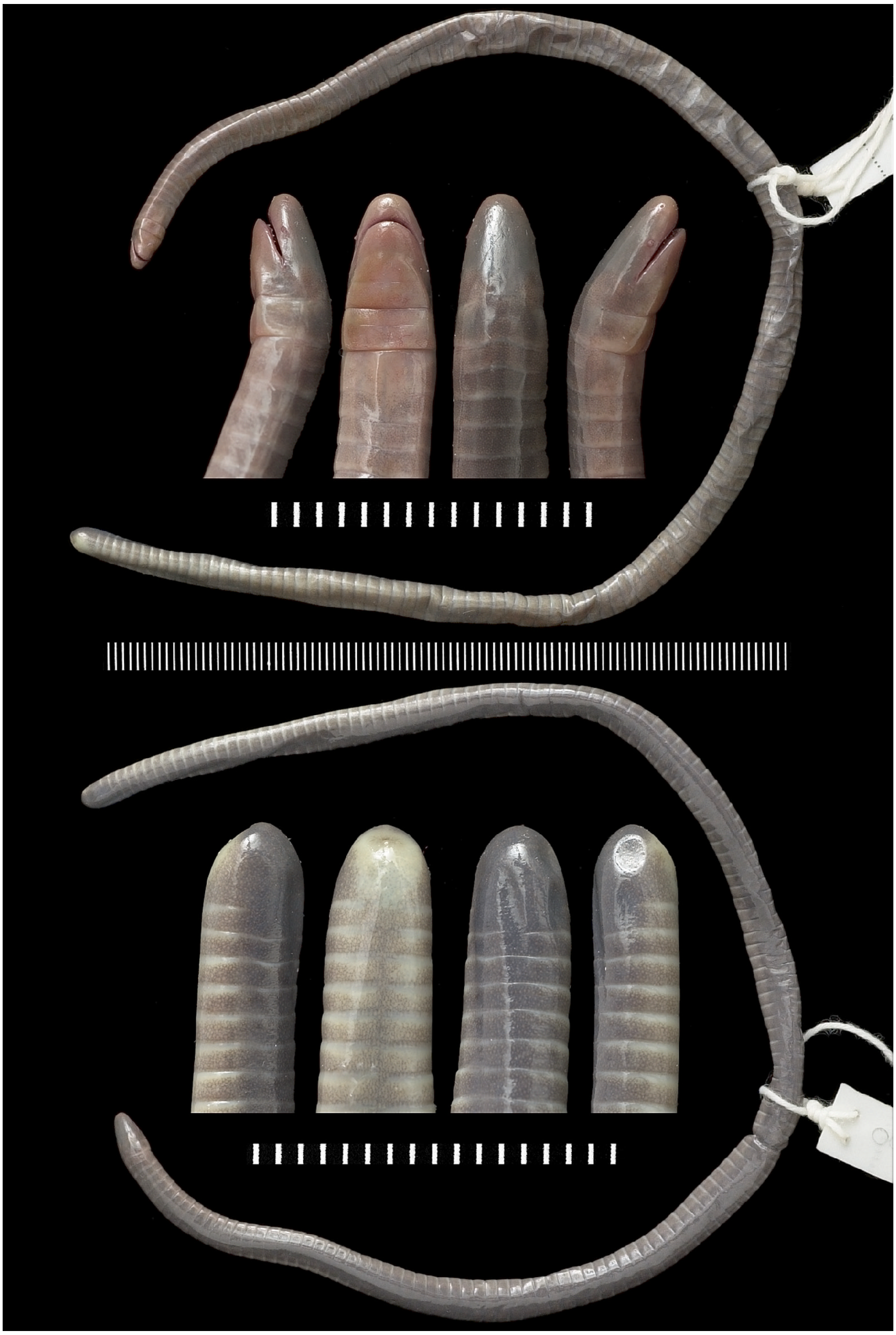

FIGURE 2. Holotype of *Boulengerula niedeni* (NMK A/4294), showing the ventral and dorsal side of the whole specimen. The head and body terminus are shown enlarged in dorsal, ventral and lateral views. Scales are in mm.

TABLE 1. Morphometric and meristic data for holotype and paratypes of *Boulengerula niedeni*. All measurements are in mm and were made to the nearest 0.1 mm under a binocular microscope with ocular micrometers, except for length and circumference, which were measured with a ruler and a piece of thread and a ruler, respectively. Tooth counts marked with an asterisk are approximations.

	NMK A/4294	BMNH 2005.10	BMNH 2005.11	NMK A/4298/7	NMK A/4298/6	NMK A/4298/2	NMK A/4298/3	NMK A/4298/4	NMK A/4298/1	NMK A/4298/5
Sex	f	m	f	indet.	indet.	m	m	j	m	j
Total length	275	228	216	253	245	213	201	121	196	92
Number of primary annuli	144	142	140	143	141	142	142	143	138	-
Head length	5.5	6.0	5.2	5.8	5.4	5.5	4.8	3.6	4.8	3.4
Distance between snout tip and angle of jaws	4.0	4.2	3.7	3.3	4.0	3.9	3.4	2.6	3.5	2.3
Distance between tip of lower jaw and first nuchal groove	4.6	5.0	4.3	5.0	4.6	4.3	3.6	3.0	4.1	2.5
Distance between tip of lower jaw and angle of jaws	3.0	3.4	2.9	3.4	3.2	2.7	2.3	1.8	2.5	1.4
Length of first nuchal collar	1.8	2.0	1.6	2.0	2.1	1.6	1.7	1.3	1.5	1.3
Head width at first nuchal groove	4.0	4.8	3.7	4.6	4.3	4.0	4.2	2.9	3.9	2.5
Head width at angle of jaws	3.8	4.3	3.4	4.1	4.0	3.8	3.5	2.9	3.4	2.4
Distance between external nares	1.5	1.5	1.5	1.5	1.4	1.5	1.4	1.1	1.3	1.0
Distance between tentacles	3.1	3.5	2.9	3.1	3.4	3.1	2.9	2.2	2.7	2.0
Distance between external naris and tentacle	1.6	1.8	1.6	1.8	1.6	1.5	1.3	1.1	1.3	0.9
Distance between tentacle and margin of upper lip	0.3	0.4	0.4	0.3	0.4	0.4	0.4	0.2	0.4	0.3
Distance between external naris and first nuchal groove	5.2	5.6	4.8	5.4	5.3	5.0	4.3	3.3	4.6	3.3
Distance between external naris and angle of jaws	3.6	4.0	3.3	3.6	3.6	3.4	3.0	2.1	3.3	2.2
Distance between tentacle and tip of snout	2.1	2.2	1.9	2.3	2.0	1.8	1.7	1.3	1.5	1.3
Distance between tentacle and angle of jaws	1.8	2.1	1.8	1.8	1.8	1.8	1.5	1.3	1.9	1.2
Distance between snout tip and anterior margin of mouth	1.0	0.9	0.9	1.1	0.8	1.1	0.8	0.7	0.8	0.8
Width at midbody	4.7	4.8	4.8	4.8	6.3	4.2	4.5	3.0	4.3	2.6
Body width at level of vent	2.9	2.9	2.8	3.1	3.7	2.9	3.0	2.2	3.4	2.0
Distance from vent to body terminus	0.8	0.4	0.8	0.8	0.5	0.9	0.7	0.6	0.9	0.3
Circumference at midbody	17	16	12	16	19	18	15	10	13	10
Premaxillary-maxillary teeth	24	23	24	24	25	25	26	22	21	-
Vomeropalatine teeth	22	17*	18	-	19*	-	-	-	-	-
Dentary teeth	18	19	21	21*	20*	20*	18*	-*	17*	-
Splenial teeth	1	2	2	-	-	-	-	-	-	-
Number of vertebrae	150	145	148	152	146	151	150	150	150	146

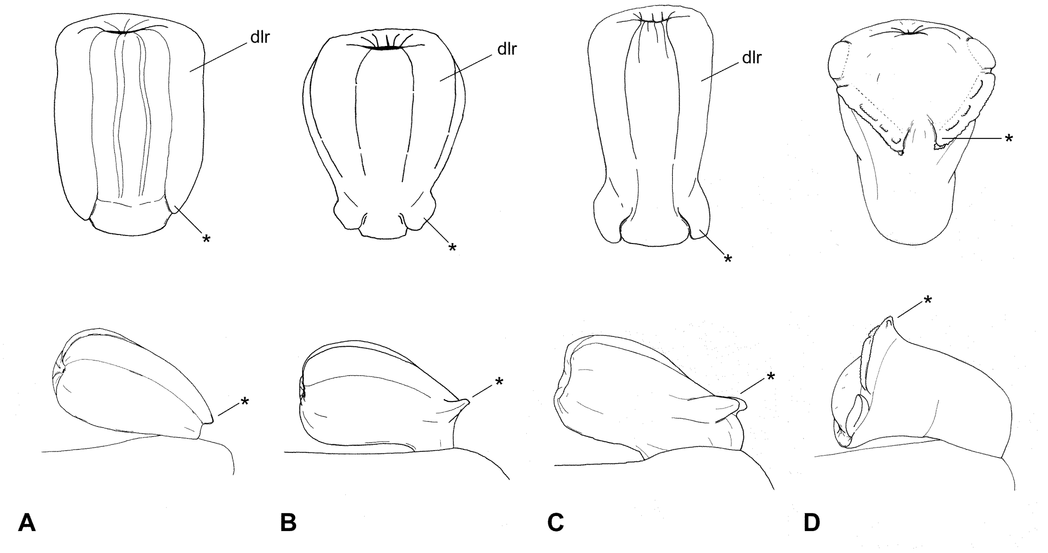

FIGURE 3. Phallus of (A) *Boulengerula boulengeri*, (B) *B. uluguruensis*, (C) *B. taitanus*, and (D) *B. niedeni*, in dorsal (top row) and lateral view. Not to scale. The horns and tuberosities referred to in the text are marked by an asterisk (*), dlr – dorsolateral longitudinal ridge.

In preservative, the annuli are marked by whitish grooves. These markings are most pronounced laterally and ventrolaterally but are lacking on the dorsal side. There are 144 primary annuli. With the exception of the anterior sixth of the body, annular grooves are mostly incomplete dorsally. The last seven annuli prior to the second to last annulus are also well demarcated by dorsally complete annular grooves. Most annuli are interrupted at the ventral midline, except in the anterior and posterior fifths of the body. The body terminus is capped by a terminal shield, which bears no annular grooves posterior to the vent. The annular grooves, separating the terminal shield from the last annulus are short, incomplete dorsally and ventrally, and only visible in lateral and ventral view. The penultimate annulus is also incompletely separated ventrally and dorsally from the last annulus, although to a far lesser extent than the last is from the terminal shield. There are no indications of a subdivision of the primaries by secondary annulation on any part of the body. No attempt was made to search for scales.

The body terminus is formed by a terminal shield of 3.5 mm length (measured laterally). It is rounded in dorsal view and ends in a very bluntly pointed tip. In lateral view, the terminal shield appears slightly thicker than the adjacent part of the body, although this could be an artefact of preservation. The body tapers strongly from anterior of the vent towards the terminal apex. It tapers more strongly from the venter, where the terminal shield is almost planar and angled upwards at about 60 degrees towards the terminal apex, whereas the dorsal side is evenly rounded. The transverse vent lies within a poorly defined, transverse oval disc of about 1.9 by 2.6 mm, 0.8 mm in front of the body terminus. The vent is somewhat irregular within the disc, having a pattern of six anterior and seven posterior denticles, of which the anteromedial is the largest. The anterior denticles appear duplicated in a second internal row, which suggest that the cloaca is slightly prolapsed.

The colour in life is brownish on the dorsum with a clear pinkish-reddish tinge. The ventrum is light brown to pinkish and appears somewhat translucent. The annuli are indicated by white markings, which are faint anteriorly and more pronounced towards the body terminus, giving the flanks a lighter appearance. The head also has a pinkish colouration that only slightly contrasts with the rest of the body. In preservative, the colour has faded to grey dorsally and to light grey ventrally. The flanks are still lighter coloured and give the impression of broad ventrolateral stripes, although the ventral border is not very well defined.

The specimen is a mature female with developing ovarian eggs. Five eggs are visible through the second incision (from the vent) at the ventral side of the specimen. The diameter of one egg is 3.0 x 1.6 mm.

Etymology: This species is named for Fritz Nieden, herpetologist at the Zoologisches Museum Berlin during the early 1910s, for his many contributions to the taxonomy of African amphibians and reptiles. The specific name is a noun in the genitive case.

Additional information from paratypes

Colouration.—Adult specimens of *B. niedeni* exhibit no variation in their colouration and show no obvious differences to the colouration of the holotype as described earlier. The three juvenile specimens however, differ markedly in their colouration from the adult specimens in our sample. All juveniles are unpigmented on the ventral and lateral sides and only possess a dark and narrow dorsal band. Loveridge (1935) and Nussbaum and Hinkel (1994) reported the young of *B. taitanus* to be pink in life. Nussbaum and Hinkel (1994) further reported that the dark colouration of *B. taitanus* develops ontogenetically from a darker, middorsal band, which intensifies and gradually broadens. It appears therefore as if in *B. niedeni* too the adult pigmentation develops some time after hatching, presuming that *B. niedeni* is direct-developing as is known for *B. taitanus* (Nussbaum & Hinkel 1994).

Oral cavity, teeth, and skull morphology.—To gain a better understanding of the morphology of the oral cavity, we cut the jaws of one of the paratypes (BMNH 2005.10). In this specimen, the choanae are oval and about 7 mm x 3.5 mm. The smallest distance between them is 11 mm. The lateral margin of the choana is raised and formed by the gums of the vomeropalatine tooth shelf. The medial rim is not raised. Clearly developed choanal valves are not visible. The teeth are arranged in four series. The premaxillary-maxillary (PMM) series traces a broad arc across the midline anteriorly and extends backwards to the jaw angle. It is continuous except for a slight gap on each side behind the anterior four to five teeth. These gaps are not strictly symmetrical but might demarcate the border between premaxillary and maxillary teeth. The vomerine teeth form a short arc, even broader anteriorly than in the PMM, and end well before the anterior rim of the choanae. The palatine teeth are separated from the vomerine teeth by substantial diastemata. The palatal series begins just behind the anterior rim of the choana and extends to about one tooth position (0.1 mm) behind the posterior-most PMM teeth. Whereas the right side of the palatine series contains eight teeth and is apparently complete, there are no teeth on the left side except what appears to be the posterior-most tooth. It seems as if the teeth are being replaced as a group here (see Taylor 1968). The dental teeth form a continuous arc that extends backwards to the jaw angle. The splenial series consists of a single pair of teeth anteriorly, almost completely hidden within the gums.

The PMM teeth slightly increase in size from the anterior to the 3rd or 4th position, from where they then gradually decrease posteriorly. The vomerine teeth are larger than the palatine teeth and are about the same size as posterior PMM teeth, although the vomerine teeth appear to be more slender. The palatine teeth again are more slender than vomerine teeth. The dentary series has the largest teeth, which increase in size from anterior towards the 4th or 5th position, behind which they are smaller and gradually decrease posteriorly. The splenial teeth are the smallest of all series. The vomerine, palatine, and splenial teeth are bicusped, whereas the PMM and dentary teeth are monocusped. The tongue is free anteriorly but does not cover the splenial teeth. It is unpigmented and gently rounded anteriorly. The anterior part of the tongue is flat and featureless but some longitudinal plicae are present posteriorly.

Another paratype (BMNH2005.11) shows a similar intraoral morphology to BMNH2005.10 except for the diastemata between vomerine and palatine teeth. This specimen exhibits a morphology intermediate between BMNH 2005.10 and the holotype, in that only moderate diastemata are present.

For a preliminary examination of skull characteristics the skin covering the right side of the head was reflected in BMNH 2005.10. In this specimen, the slender, dorsal part of the sphenethmoid is exposed in the skull roof and separates the frontals. The orbital region is completely covered by bone and no trace of an eye is visible.

Phallus morphology.—The terminology for the description of phallus morphology follows Gower and Wilkinson (2002). The phallus is fully or partially everted in four specimens (BMNH 2005.10, NMK A/4298/1, NMK A/4298/2, NMK A/4298/3). There are no obvious longitudinal ridges on the phallus. However, there are large, flange like tuberosities near the apex of the phallus. These are bipartite with a smaller ventrolateral flange and a larger dorsolateral flange that increases in size towards the dorsal side of the phallus, resembling a collar like structure (see Fig. 3D). In lateral view, the flanges are inclined diagonally to almost vertically along the longitudinal axis of the phallus. The dorsolateral flanges have serrated edges and converge towards the dorsal side of the phallus and terminate in pointed, horn-like structures that point dorsally and are only separated by a narrow gap. Besides these main flanges, smaller, pointed or plate-like, serrated accessory protuberances are present and seem to be associated with the dorsolateral ridges. The extent to which the phallus ornamentation, i.e serrations and accessory protuberances, is developed is variable among the specimens.

Body terminus and vent.—The number of cloacal denticles varies in our sample from five anterior and six posterior denticles to six anterior and seven posterior. The largest denticles are usually the one or two medial anterior denticles. A keel on the terminal shield is weakly indicated in some of the specimens but very conspicuously developed in one of the juvenile paratypes (NMK A/4298/5).

Phylogenetic relationships and comparison with other *Boulengerula*

Boulengerula niedeni fits the diagnosis of *Boulengerula* as currently conceived (Nussbaum & Hinkel 1994). Compared to other members of the genus, *B. niedeni* is readily distinguished by its distinctive colouration. Whereas *B. taitanus* is a dark coloured form, most other *Boulengerula* are either unpigmented and appear pink in life, including *B. changamwensis*, *B. fischeri*, *B. uluguruensis*, and (presumably) *B. denhardti*, or show a light bluish grey colouration, like *B. boulengeri*. When comparing *B. niedeni* with other *Boulengerula* species, the closest relative appears to be *B. taitanus*, based on overall phenetic similarity and close geographic proximity of their distributions.

To assess morphological differences between *B. niedeni* and *B. taitanus*, we compared our sample of *B. niedeni* against a sample of 58 *B. taitanus* ranging from 55 mm total length to 345 mm (see Appendix). Although at the upper end, the range of the number of annuli of our sample of *B. niedeni* falls within the range of *B. taitanus*, with 138-144 compared to 124-147 respectively. The mean values for the number of annuli however, are well separated at 141.67 (SD 1.80) for *B. niedeni* and 135.53 (SD 4.67) for *B. taitanus*. When comparing the number of vertebrae (counted from x-rays) in both samples, *B. niedeni* also shows a higher mean number of vertebrae with 149.00 (SD 2.14) as compared to 142.07 (SD 5.20) in *B. taitanus*, although overlap between the ranges does occur (146-152 and 130-153, respectively). However, the ranges of vertebrae number might show greater overlap between the two species once a larger sample of *B. niedeni* becomes available for study.

A comparison of phallus morphology among *B. niedeni*, *B. taitanus*, *B. boulengeri*, and *B. uluguruensis* (Barbour and Loveridge) reveals common patterns but also what we interpret as specific differences (see Fig. 3). *Boulengerula taitanus*, *B. boulengeri*, and *B. uluguruensis* all have dorsolateral longitudinal ridges but differ with regards to the extent of their development. In addition, the four species have differently arranged phallus ornamentation. In *B. boulengeri* the longitudinal ridges are very prominently developed and each ridge terminates close to the base of the phallus in a simple, semidetached pointed tip. In *B. uluguruensis* and *B. taitanus* prominent horn-like tuberosities are present at the end of each ridge and inclined against the longitudinal axis of the phallus. The horn-like tuberosities are smaller and only moderately developed and inclined in *B. uluguruensis,* but *B. taitanus* shows a more pronounced development and a slightly stronger inclination. *Boulengerula niedeni* differs from the other species in having no markedly developed longitudinal ridges. Instead, large, horn-like tuberosities are attached more apically to an otherwise almost smooth phallus. *Boulengerula niedeni* is further unique in that the horn-like tuberosities are in close proximity dorsally and possess elaborate ornamentation. The phallus morphology of *B. denhardti* and *B. fischeri*, both known from only the type specimen, and *B. changamwensis*, which is known from only a few specimens (Malonza & Müller 2004), is currently unknown. At present, the intra- and interspecific variation of phallodeal morphology is poorly understood (Gower & Wilkinson 2002), but the main differences we observed are constant and we interpret them as further evidence that *B. niedeni* is a distinct species. We note however, some variation in the degree of phallus ornamentation in *B. niedeni*, which might reflect seasonal variation.

Discussion

Wilkinson *et al.* (2003) analysed the relationships of African caecilians using mitochondrial DNA sequences. Their phylogeny confidently resolved their only two representatives of *Boulengerula*, *B. boulengeri* and *B. taitanus*, as sister taxa, although Wilkinson *et al.* (2003) pointed out the deep molecular divergence between the two. In their discussion of interrelationships within *Boulengerula*, Wilkinson *et al.* (2004) suggested that the synonymy of *Afrocaecilia* with *Boulengerula*, proposed by Nussbaum and Hinkel (1994), might have been premature. Against this backdrop it is intriguing to note an apparently more similar general phallus morphology with inclined dorsolateral tuberosities in *B. uluguruensis* and *B. taitanus* as compared to *B. boulengeri* (see Fig. 3). This common phallus morphology might be a putative synapomorphy of *Afrocaecilia sensu* Taylor (1968). However, *B. niedeni*, which appears most similar to *B. taitanus* based on external morphology, shows a strikingly different phallus morphology. It seems therefore as if phallus morphology might be a useful character in distinguishing species of *Boulengerula* although further research is necessary to investigate and compare the phallus morphology in other members of *Boulengerula*. The diagnostic value of the phallus has previously been suggested for caecilians (Gower & Wilkinson 2002; Kupfer & Himstedt 2002).

Taylor (1968) and Nussbaum and Hinkel (1994) used the presence of a diastema between vomerine and palatine teeth as a character to diagnose species of *Boulengerula* (*sensu* Nussbaum & Hinkel 1994). The few specimens examined for oral morphology in our comparatively small sample of *B. niedeni* show different states of this character, ranging from a very pronounced diastema as in *B. changamwensis* to no diastema as in *B. taitanus*. It appears therefore as if the presence of a diastema between vomerine and palatine teeth, at least in *B. niedeni*, is much more variable than previously thought. Tooth replacement has been reported in other caecilian species (Taylor 1968) and seems to be the most likely cause for the observed variation in the arrangement of vomeropalatine teeth in our series. Future studies on other *Boulengerula* should investigate the intraspecific variability of this character and our observation suggests that this character should be treated with caution when dealing with very small sample sizes.

Local farmers report *Boulengerula niedeni* to be more abundant during the wet seasons, something previously reported for other East African caecilians (e.g. Loveridge, 1935). All specimens collected during this study were from small-scale agricultural plots (shambas); natural forest has all but disappeared from this isolate (Wilder *et al.* 1998). Our personal experience and published work (e.g. Glaser 1984; Measey 2004) indicate that shambas can be suitable habitats for some caecilian species, including members of the genus *Boulengerula*. However, understanding of what constitutes suitable habitat for caecilians is currently uncertain (Gower & Wilkinson 2005). For example, specimens of *B. taitanus* found in shambas were significantly smaller but more abundant than those inhabiting naturally forested areas of the Taita Hills (Measey 2004). The only known locality for this new species is Sagalla Hill (c. 2900 hectares above 1000m asl), a small mountainous area that is ecologically isolated within the arid Tsavo plain. The currently limited information about *B. niedeni* implies that it should be considered ‘data deficient’ (IUCN 2001). However, as all specimens were collected in an anthropogenically disturbed area on a small, isolated mountain, it is clear that detailed future investigations are needed.

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Appendix

Material Examined

Boulengerula niedeni.–Kenya: Coastal Province: Taita-Taveta District: Sagalla Hill: BMNH 2005.10–11; NMK A/4294; NMK A/4298/1–7.

Boulengerula taitanus.– Kenya: Coastal Province: Taita-Taveta District: Dawida: Wundanyi: NMK A/3110–2 (specimen field numbers: MW501–11, 514, 516–525, 528–41, 544–48, 814); Mt. Mbololo: MCZ 20001, MCZ 20002, MCZ 20004, MCZ 20005, MCZ 20007–12, MCZ 20014, MCZ 20015, MCZ 20017, MCZ 20018, MCZ 20021, MCZ 85094.

Institutional codes: BMNH: The Natural History Museum, London, UK; MCZ: Museum of Comparative Zoology, Harvard, USA; NMK: National Museums of Kenya, Nairobi, Kenya.

References

Gaborieau, O. & Measey, G. J. (2004) Termitivore or detritivore? A quantitative investigation into the diet of the East African caecilian *Boulengerula taitanus* (Amphibia: Gymnophiona: Caeciliidae). *Animal Biology*, 54, 45–56.

Glaser, H. S. R. (1984) Observations on an abundant caecilian, *Afrocaecilia taitana*, in Kenya. *ASRA Journal*, 2, 47.

Gower, D. J. & Wilkinson, M. (2002) Phallus morphology in caecilians and its systematic utility. *Bulletin of the Natural History Museum, London (Zoology)*, 68, 143–154.

Gower, D. J. & Wilkinson, M. (2005) Conservation biology of caecilian amphibians. *Conservation Biology*, 19, 45–55.

Hebrard, J. J., Maloiy, G. M. O. & Alliangana, D. M. I. (1992) Notes on the habitat and diet of *Afrocaecilia taitana* (Amphibia: Gymnophiona). *Journal of Herpetology*, 26, 513–515.

IUCN (2001) *IUCN red list categories and criteria: version 3.1.* IUCN Species Survival Commission, Gland, Switzerland and Cambridge. UK.

Kupfer, A. & Himstedt, W. (2002) New data on the copulatory organs in caecilians (Amphibia: Gymnophiona. *Zoology* 105, Supplement V, 34.

Loveridge, A. (1935) Scientific results of an expedition to rain forest regions in Eastern Africa. I New reptiles and amphibians from East Africa. *Bulletin of the Museum of Comparative Zoology*, 79, 2–19.

Measey, G. J. (2004). Are caecilians rare? An East African Perspective. *Journal of East African Natural History*, 93, 1–19.

Malonza, P. K. & Müller, H. (2004) A rediscovery after two decades: the Changamwe lowland caecilian *Boulengerula changamwensis* Loveridge, 1932 (Amphibia: Gymnophiona: Caeciliidae). *Journal of East African Natural History*, 93, 57–61.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A. B. & Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature*, 403, 853–858.

Nussbaum, R. A. & Hinkel, H. (1994) Revision of East African caecilians of the genera *Afrocae-*

cilia Taylor and *Boulengerula* Tornier (Amphibia: Gymnophiona: Caeciliaidae). *Copeia*, 1994, 750–760.

Taylor, E. H. (1968) *The caecilians of the world: a Taxonomic Review.* University of Kansas Press, Lawrence, 848 pp.

Wilkinson, M., Loader, S. P., Gower, D. G., Sheps, J. A. & Cohen, B. L. (2003) Phylogenetic relationships of African caecilians (Amphibia: Gymnophiona): insights from mitochondrial rRNA gene sequences. *African Journal of Herpetology,* 52, 83–92.

Wilkinson, M., Loader, S. P., Müller, H. & Gower, D. G. (2004) Taxonomic status and phylogenetic relationships of *Boulengerula denhardti* Nieden, 1912 (Amphibia: Gymnophiona: Caeciliidae). *Mitteilungen aus dem Museum für Naturkunde Berlin, Zoologische Reihe*, 80, 41–51.