Rediscovery of *Boulengerula denhardti* Nieden 1912 (Amphibia: Gymnophiona: Caeciliidae) in Meru County, Kenya

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The dearth of information on caecilian amphibians is most likely due to a lack of directed field studies. Here we report the rediscovery of a population of *Boulengerula denhardti* nearly a century after its description by Nieden in 1912. Morphological examination of seven specimens suggests that they are closer to the type of *B. denhardti* than to any other member of the genus. Nieden's type locality has been widely interpreted as the Tana River Delta, although searches there have not revealed specimens of this species. The locality of the material described herein comes from Ngaia Forest, Meru County, Kenya, approximately 420 km, northwest of the Tana Delta. We discuss dispersal in caecilians and their likely use of riverine corridors. We speculate that more species in this genus are likely to be found in Kenya.

Key words: Gymnophiona, East Africa, Kenya, soil megafauna, body elongation.

Terrestrial caecilians are tropical, limbless, primarily fossorial amphibians. Their subterranean habits make them difficult to find and consequently they are poorly represented in museum collections so that most of the species remain poorly known.

However, some caecilians appear to be abundant, and the relative ease of their collection has resulted in a great advancement of our understanding of their reproduction, trophic niche and morphology (e.g. Wake 1980; Exbrayat & Delsol 1985; Gudynas *et al.* 1988; Himstedt & Fritzsch 1990; Ducey *et al.* 1993; Himstedt & Simon 1995; Exbrayat & Morel 2003; Delêtre & Measey 2004; Gaborieau & Measey 2004).

The genus *Boulengerula* Tornier is the most widespread and speciose caecilian genus in Africa, with seven nominate species as well as additional taxa awaiting description (Loader *et al.* 2011). Two species were known only from the holotype: a single specimen of both *B. denhardti* and *B. fischeri* (Nussbaum & Hinkel 1994; Wilkinson *et al.* 2004), but a targeted search for *B. fischeri* in 2006 revealed 20 more specimens (Measey *et al.* 2011). This followed other 'rediscoveries' of caecilians in this region after long periods without collection (Malonza & Müller 2004; Measey 2006) and prompted us to conduct targeted fieldwork that involved digging for caecilians.

Boulengerula denhardti is the other member of the East African genus which was known only from the holotype and which lay in synonomy (with *Schistometopum gregorii*) for nearly 70 years (Wilkinson *et al.* 2004). The resurrection of *B. denhardti* sparked interest in caecilians of the Tana River region but despite targeted searches in the area (e.g. Wilkinson *et al.* 2004; Malonza *et al.* 2006), no caecilians were found. In February 2007, one of us (S.S.) collected a single *Boulengerula* specimen during a short visit to Ngaia forest, a mid-altitude forest fragment in the Nyambene Hills, eastern Kenya, which has been tentatively identified from a photograph (see Loader *et al.* 2011). In May 2008, V.M. re-visited the forest and collected six more specimens, which we detail here, as well as describing the habitat characteristics of this species.

Ngaia Forest (also known as Ngaya or *Ngaja* in the local Kimeru language) is a mid-altitude (1100–1500 m a.s.l.) forest located on the extreme lower northeastern slopes of the Tertiary volcanic Nyambene Hills, Meru County in Eastern Province. Owing to the steep slopes, there is no standing or flowing water inside the forest. The soils are loose and well drained. Scattered volcanic lava rock boulders are common on the surface in many parts of the forest. There are two rainy seasons in the area; long rains from March to May and short rains from November to December. Human population around the forest is relatively high with constant

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*Author for correspondence. E-mail: john@measey.com movement through the forest that has created an extensive network of footpaths.

Field sampling of caecilians in 2008 was accomplished by use of time-limited searches of one-person hour (see Measey 2006). During the searches we explored the following microhabitats with a forged metal blade (*jembe*): under leaves, leaf-litter debris, decomposing tree stumps, under rocks and logs. In 2008, we found six more caecilians in different parts of the forest (00°19.06′N, 38°00.06′E, 1300 m; 00°23′19.3″N; 38°01′.41.6″E; 1334 m; 00°22′18.0″N; 38°01′16.1″E; 1232 m; Fig. 1) between 21 and 27 May. Caecilians were anaesthetized using a solution of MS222, fixed in a 10% solution of formalin and stored in 70% ethanol.

Measurements were made to the nearest 0.01 mm with Mitutuyo callipers, except total length, which was measured to the nearest mm by stretching the specimen along a ruler. Vertebral counts were made from digital images of radiographs. Specimens are deposited in the herpetology collection of the National Museums of Kenya (NMK/A/4824; NMK/A/4954/1–6). We did not consider it necessary to examine the holotype of *B. denhardti* as it has been recently and comprehensively examined and the measurements reported in Wilkinson *et al.* (2004).

All specimens that we measured had annuli counts above 150 (see Table 1), the threshold given for *B. fischeri* or *B. denhardti* in the key to species of *Boulengerula* by Wilkinson *et al.* (2004), and the single specimen for which dentition was examined (NMK/A/4954/1) appeared to have two intramandibular (or splenial) teeth. However, for its high vertebral number, this species is not especially long (mean excluding juvenile 225.3 mm), and is well within the range of species with far smaller annular and vertebral counts (Nussbaum & Hinkel 1994). In their description, Nussbaum & Hinkel (1994) commented on the extremely slender body of *B. fischeri,* which attains a body elongation index of 102 (mean 80.8; Measey *et al.* 2011). Specimens of *B. denhardti* collected also appear to be very slender, with a maximum body elongation index of up to 82 (mean 67.1), within the range of *B. fischeri.*

Morphological and meristic measurements do not clearly identify the specimens we collected as *B. denhardti.* Neither the number of primary annuli (mean 155.9; range 152–158) nor the total number of vertebrae (mean 156.6; range 151–160) fall within the range of the holotype (161 and 168, respectively Wilkinson *et al.* 2004). It is therefore possible that the specimens we detail here are that of an as yet undescribed species, and not *B. denhardti.* However, our sample size is small and although these characteristics are often diagnostic, they are known to vary intraspecifically. For example, a sample of 14 *B. fischeri* had a range of primary annuli 185–197 and a vertebral range of 192–205 (Measey *et al.* 2011). If *B. denhardti* had a similar or greater range of annular and vertebral counts, the holotype and our collection would be within the known intraspecific variation (for *B. fischeri*). Other measurements taken by Wilkinson *et al.* (2004) may vary due to the extreme desiccation of the holotype compared to our freshly preserved collection. On balance, as the specimens we collected do not fall in the diagnosis of any other described *Boulengerula,* and as their morphology does not clearly contradict the diagnosis given by Wilkinson *et al.* (2004), we tentatively identify these specimens as *B. denhardti.*

In life, *Boulengerula denhardti* appears most similar to *Boulengerula niedeni* being thin with a dorsal purple/brown hue and a paler venter. Its colour changes anteriorly and is characterized by a pinkish dorsal head and a flesh-pink throat. The single juvenile collected was pinkish, with a little pigmentation similar to adults. The degree of pigmentation in caecilians is believed to be related to the amount of above-ground displacement (Wollenberg & Measey 2009).

The stated locality of the holotype of *B. denhardti* was Tana River area, and this has been assumed to mean the Tana River Delta (see Wilkinson *et al.* 2004). Our collection locality lies far from the Tana River Delta (approximately 420 km, northwest, Fig. 1). However, Nyambene Hills, Meru County, and the forest where these specimens were collected fall within the catchment of the Tana River, and it is not unlikely that even if the holotype was collected in the Delta, they could be the same species. Caecilians are known to move down rivers on flotsam, and this method has been speculated to be the route that these and other amphibians reached offshore volcanic islands on freshwater paths (Measey *et al.* 2007b). Loader *et al.* (2011) also commented on the highland to lowland distribution of a single clade of *Boulengerula* cf. *uluguruensis* from the Uluguru Mountains to the Coastal Forests of Kazizumbwi to the southeast of Dar es Salaam, a distance of approximately 200 km. Molecular data showed that these animals were more closely related than specimens in the neighbouring mountain of Malundwe, only 40 km away.

Table 1. Morphometric (in mm) and meristic data for *Boulengerula denhardti* from Wilkinson *et al.* (2004) and a collection from Ngaia Forest, Meru County, Kenya. Specimen numbers are from Museum für Naturkunde der Humboldt-Universität zu Berlin (ZMB – as measured by M. Wilkinson) and National Museums of Kenya (NMK). Sex is coded as indeterminate (i), female (f), male (m) and juvenile (j).

Specimen numbers: Sex:	ZMB 22350 (MW) i	NMK A/4954/1 f	NMK A/4954/2 m	NMK A4954/3 j	NMK A/4964/4 m	NMK A/4964/5 f	NMK A/4954/6 m	NMK A/4824 f
Total length	213	243	178	112	232	223	221	255
Total annuli	161	156	157	158	152	158	154	156
Total vertebrae	168	159	159	159	151	160	152	156
Distance between tip of snout and jaw angle	3.9	4.0	4.0	3.5	4.7	4.1	3.9	4.6
Distance between tip of lower jaw and jaw angle	3.4	2.9	3.1	2.6	3.5	3.1	3.1	3.1
Head width at level of jaw angles	2.9	2.8	2.5	2.2	3.2	3.4	2.9	3.3
Head width at anteriormost nuchal collar groove	3.0	3.3	2.8	2.3	3.2	3.3	2.9	3.1
Distance between tip of snout and anteriormost nuchal collar groove	5.3	5.2	4.6	4.2	5.3	5.1	5.0	5.5
Length of first nuchal collar, measured laterally	1.8	1.3	1.0	1.0	1.6	1.5	1.3	1.8
Length of second nuchal collar, measured laterally	1.9	1.1	1.4	0.9	1.5	1.7	1.1	1.3
Distance between anterior margin of upper lip and tip of snout	1.3	1.1	1.2	1.0	1.4	1.0	1.0	1.5
Distance between tentacle and naris	2.0	1.4	0.6	0.9	1.3	1.2	1.1	1.1
Distance between tentacles	2.8	2.3	1.8	1.3	2.3	2.1	2.2	2.6
Distance between nares	1.5	1.6	1.0	1.0	1.7	1.2	1.5	1.5
Distance between naris and jaw angle	3.3	3.5	3.3	3.2	4.9	3.7	3.9	3.8
Distance between naris and tip of snout	0.9	0.7	0.6	0.6	0.7	0.7	0.7	0.8
Distance between naris and margin of upper lip	1.0	1.0	1.0	0.9	1.2	0.9	1.1	1.4
Distance between tentacle and jaw angle	1.5	2.1	2.4	1.9	2.3	2.3	2.3	2.0
Distance between tentacle and tip of snout	2.5	1.9	1.6	1.6	2.0	1.7	1.7	2.1
Distance between tentacle and margin of upper lip	0.4	0.3	0.4	0.3	0.3	0.2	0.3	0.3
Width at midbody	3.5	3.4	3.2	2.2	3.3	3.2	3.3	3.1
Width at anterior margin of terminal shield	3.0	3.6	2.6	2.0	3.3	2.8	2.7	3.2
Length of terminal shield, measured laterally	1.9	2.2	1.8	1.1	2.6	2.1	2.3	2.5
Circumference at midbody	10.0	12.6	9.8	9.3	12.5	13.2	13.9	12.4
Circumference 5 annuli anterior to terminal shield	8.0	10.4	8.9	7.5	11.2	11.3	11.0	11.3

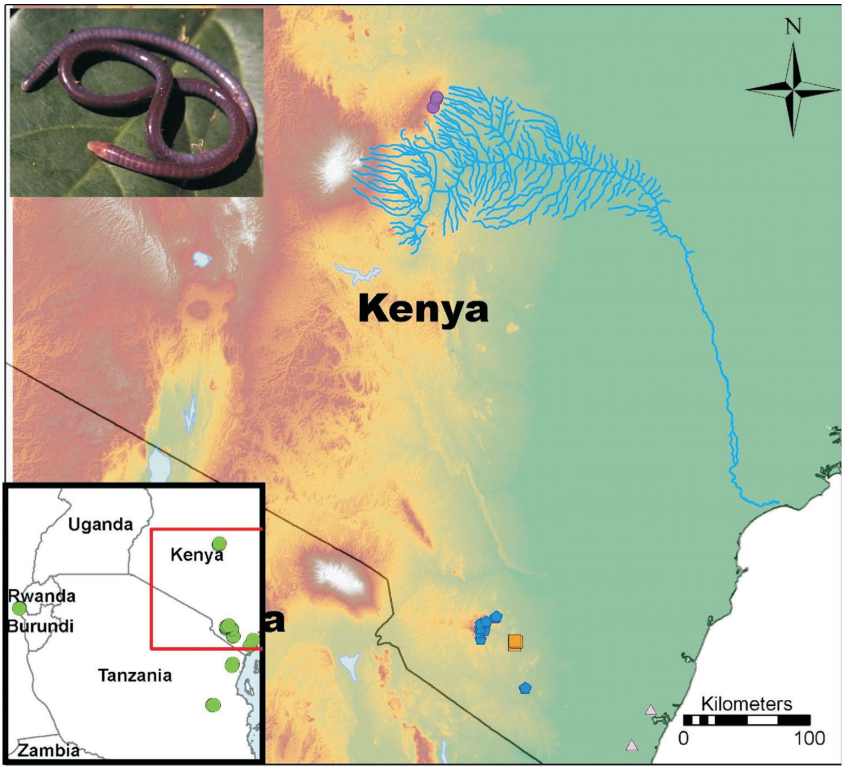

Fig. 1. The collection locality of *Boulengerula denhardti* (●) on the slopes of Nyambene Hills, Meru County, Kenya. The position of the Tana River and associated upper tributaries is shown (solid lines) demonstrating the direct relationship between the collection localities of *B. denhardti* and the Tana River Delta, 420 km southeast, at the coast. Collection localities for other Kenyan *Boulengerula* are shown: *B. taitanus* (Taita Hills: ⬟), *B. chamgamwensis* (Chamgamwe and Shimba Hills: ▲) and *B. neideni* (Sagalla Hill: ■). Upper inset shows an image of the extremely elongate *B. denhardti* in life (image S. Spawls) and below the relative position of *B. denhardti* as the most northerly member of the genus.

However, the former are connected to the coastal forests by the Ruvu River corridor running to Bagamoyo, while the latter have no riverine corridor. Measey *et al.* (2007a) also highlighted the importance of riverine dispersal for a leaf-litter frog, and Blackburn & Measey (2009) speculated that forested river corridors and coastal forests might have allowed movements of leaf litter frogs between mountain blocks in the Eastern Arc.

Seasonal variation in the abundance of *Boulengerula* in the surface soils has been reported (Measey & Barot 2006). It is noteworthy that the two separate collections were both made during a relatively dry period after the normal rainy seasons, and this may have made animals relatively harder to find due to reduced surface soil moisture. Inside the forest caecilians were found in loose and soft soil, rich in organic deposits mainly under or within decomposing logs, or leaf-litter debris. These microhabitats are similar to those preferred by other Kenyan *Boulengerula* species (Malonza & Measey 2005; Malonza & Müller 2004). Outside the forest no efforts were made to search for caecilians in the farmlands. Farms with suitable habitats did border the forest on the upper (western) part and these were planted mainly with Khat (known locally as Miraa; *Catha edulis* (Vahl.) Endl.) and banana plants, regularly associated with caecilians (see Measey 2006). We consider that it is likely that *B. denhardti* occurs in farmlands and elsewhere in the Nyambene Hills.

The rediscovery of this Kenyan endemic caecilian species far inland from its expected locality in the Tana River Delta provides a fresh challenge. Other isolated montane-forested hills in eastern Kenya and even other mountain ranges in northern Kenya may harbour caecilians. The southern slopes of Mt Kenya are of particular interest in being in the same catchment of the Tana River (Fig. 1). We encourage researchers to look again along the entire length of the Tana River and its tributaries to discover whether this or other species can be found there. Moreover, we suggest that this rediscovery, together with other recent finds (Malonza & Müller 2004; Measey *et al*. 2011), shows that an absence of directed field work is the reason for an historical dearth of information on caecilian amphibians.

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