# Notes on the distribution and abundance of the caecilian *Boulengerula uluguruensis* (Amphibia: Gymnophiona: Caeciliidae) in the Uluguru Mountains, Tanzania

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## Abstract

*Boulengerula uluguruensis* is a terrestrial caeciliid caecilian described from the Uluguru Mountains of Tanzania. We investigated the relative abundance of *B. uluguruensis* in agricultural and forested habitats at the beginning of the rainy season. This caecilian was found over a wide altitudinal range (450–1175 m a.s.l.), and in many land cover types (including natural forest, plantation forest and small scale agriculture), and different soil textures (including very compact soil). Based on quantitative and semi-quantitative surveys, *B. uluguruensis* is more abundant than any other subterranean lower vertebrate in this area, with densities up to 0.4 individuals $m^{-2}$ in some agricultural plots. The hypothesis proposed, that *B. uluguruensis* is more abundant in agriculture than their native forest, could not be conclusively tested during this brief visit, although the data that were collected do not indicate to the contrary. Likewise, the size of animals from forest and agricultural populations could not be objectively compared.

*Key words:* biodiversity surveys, subterranean predators, population density

## Résumé

*Boulengerula uluguruensis* est un caecilian caeciliid terrestre décrit des montagnes d'Ulguru en Tanzanie. Nous avons relevé l'abondance relative du *B. uluguruensis* dans des habitats agricoles et boisés au début de la saison des pluies. Ce caecilian fut trouvé dans une grande envergure d'altitude (450 to 1175 m asl), et dans plusieurs genres de couverture des terres (y compris forêt naturelle, plantation, et agriculture à petite échelle), et differenté textures du sol (y compris sol de forte densité). Basé sur des enquêtes quantitatives et semi- quantitatives, le *B. uluguruensis* fut plus abondant que toute autre vertébré souterrain dans cette région, avec une densité jusqu'à 0,4 individus par $m^2$ dans quelques terrains agricoles. Notre visite fut trop brève pour que nous puissions vérifier l'hypothèse avancée que *B. uluguruensis* est plus abondant dans l'agriculture que dans la forêt native dont ils sont indigènes, bien que les données accumulées ne montrent pas le contraire. De la même manière, la taille des animaux provenant des populations forestières et agricoles n'a pas pu être comparé objectivement.

## Introduction

Little has been written on the distribution and abundance of caecilians, but general texts suggest that many species are rare and of restricted range (e.g. Taylor, 1968). Two of the six families of caecilians have been recorded from East Africa, the globally distributed Caeciliidae Rafinesque-Schmaltz, and Scolecomorphidae Taylor an African endemic. Two genera of caeciliids are known, the first, *Boulengerula* Tornier, is an East African endemic with six currently recognized species (Wilkinson *et al.*, 2004). The second genus, *Schistometopum* Parker is represented by two species, one of which occurs in East Africa. The

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scolecomorphids have three currently described species in East Africa, all of which are reported to occur in the Uluguru Mountains, together with the caeciliid *Boulengerula uluguruensis* Barbour and Loveridge (Nussbaum, 1985; Nussbaum & Hinkel, 1994).

Although East African caecilians have previously raised little more than taxonomic interest, some ecological work on the abundant *Boulengerula taitanus* Loveridge, from the Taita Hills in Kenya, has given limited insight into the life history of these animals (Wood *et al.*, 1975; Glaser, 1985; Hebrard, Maloiy & Alliangana, 1992; Gaborieau & Measey, 2004; Measey, 2004). Measey (2004) made quantitative surveys of *Boulengerula boulengeri* Tornier and *B. taitanus*, finding that densities reached almost 1 animal per $m^2$ for *B. boulengeri* in secondary forest, and 0.57 animals per $m^2$ for *B. taitanus* in agriculture. While no significant difference was found between densities of *B. boulengeri*, *B. taitanus* were found to be at higher densities in small-scale agriculture, and were significantly smaller, than animals found in forest. As well as using data from randomized surveys, Measey (2004) calculated relative frequencies from semi-quantitative data; the number of animals caught per person hour per area searched. Although the two methods were found to be related, some important discrepancies suggested that both methods should be used when surveying subterranean herpetofauna.

Few articles have mentioned *B. uluguruensis* since its description (Barbour & Loveridge, 1928), when several collection localities were recorded: Bagilo, Nyange, Vituri and Mkarazi, all in the Uluguru Mountains (Fig. 1). Nussbaum & Hinkel (1994) remarked that another specimen (collected by Emmrich) had been found outside the Uluguru Mountains, at Divue River Gorge, Nguru Mountains, a range quite separate from the Ulugurus (Fig. 1), and a record exists from Mkungwe, an outlying hill east of the Ulugurus (N. Doggart, J. Lovett, B. Mhoro, J. Kiure & N. Burgess, unpublished data). Gower, Loader & Wilkinson (2004) mentioned a large collection at Tegetero mission in the Ulugurus: '200+ *B. uluguruensis*, many earthworms, and the four *Typhlops uluguruensis*'. They also noted that despite seven person hours digging, 'no *B. uluguruensis*' were found in forest, commenting that their presence in adjacent forest is yet to be established.

The current study was instigated to follow-up the reports of Gower *et al.* (2004): first to investigate the relative abundance of *B. uluguruensis* at Tegetero mission, and second to establish its presence and abundance in naturally forested habitat.

## Materials and methods

The Uluguru Mountains in East Tanzania range from around 150 m a.s.l. on their south-eastern margin, and extend to 2638 m at their highest point. They form one of the component blocks of the Eastern Arc Mountains (Fig. 1), an exceptionally rich area of biodiversity and endemicity under the direct climatic influence of the Indian Ocean (Lovett, 1998). The natural vegetation is evergreen moist forest; with the eastern slope of the mountains receiving rain in excess of 3000 mm a year with at least 100 mm of rain every month (a per-humid climate). The present-day landscape comprises a mosaic of natural forest, plantation forest, banana plantations, low-intensity agricultural plots, residential and abandoned areas. Characteristics of individual sample sites within this area are given in Table 1.

Measurements of soil texture, soil and air temperature, soil penetration and soil pH were made as per Measey (2004). At Tegetero mission, profiles of soil temperature were recorded by inserting a temperature probe laterally 7.5 cm into the soil under the leaf litter, and then at 5 cm intervals to a depth of 30 cm in a vertically cut section of soil *in situ*. Shade was estimated with regard to the total area searched or surveyed over a site. Locality and altitude measurements were made with a Garmin 12XLS GPS (Garmin, Olathe, KS, U.S.A.).

### *Semi-quantitative surveys*

Timed searches were made, normally for 2 h, for as many animals as possible to be found in an approximated area. Microhabitats targeted for digging were: under fallen and decaying logs, densely shaded areas, areas of accumulated leaf litter or organic matter, and in close proximity to any animal captured. However, the emphasis was to dig into soil to an approximate depth of 0.3 m. A simple index was calculated from this data directly relating the number of animals caught with the area searched (although not necessarily excavated) and person hours taken (i.e. individuals per person hour per area; see Measey, 2004).

### *Quantitative surveys*

Like Measey (2004), we only carried out quantitative surveys within habitats where caecilians were found on that occasion, and within 100 m of that occurrence. This meant that a period of searching in targeted microhabitats

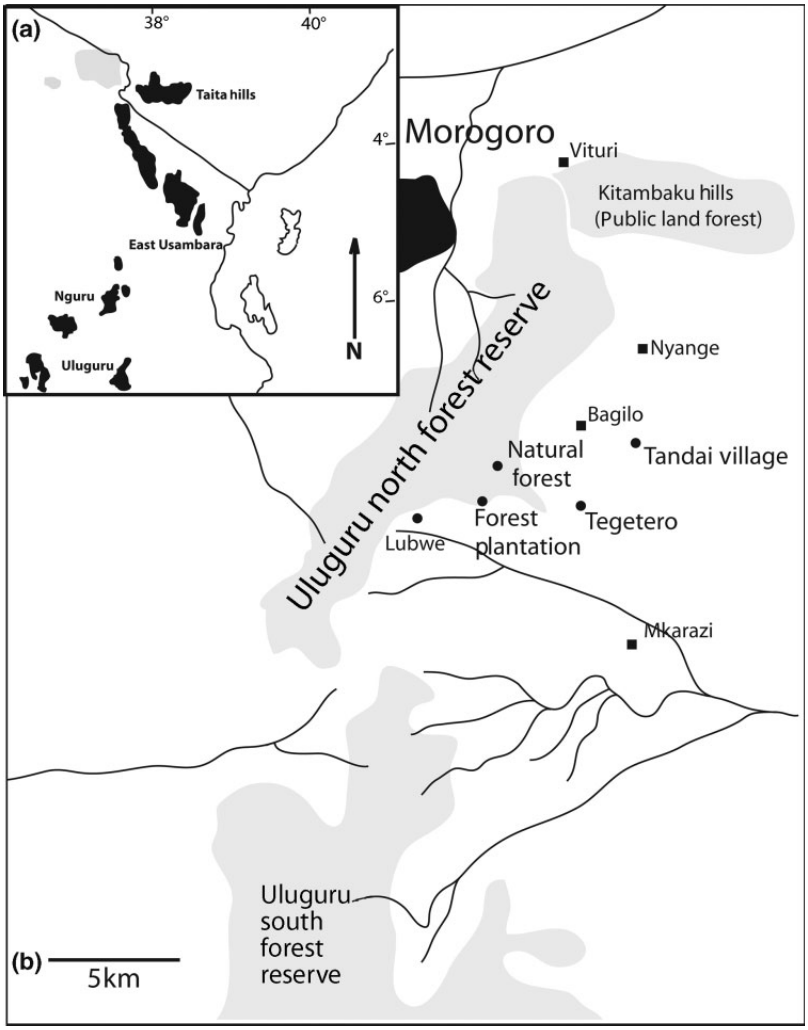


**Fig 1** (a) The position of the Uluguru Mountains in the Eastern Arc (black shading) and other mountains (light shading) of Tanzania (south) and Kenya (north). (b) Sampling sites in the Ulugurus in relation to the Uluguru North Forest Reserve (circles), and those mentioned by Barbour & Loveridge (1928, open squares), and major drainage systems

(see above) was necessary prior to a quantitative survey, and that this was only carried out should a specimen be found.

A 10 by 10 m survey grid was produced by a 20 m length of rope set at right angles with contrasting markers tied at 1 m intervals. Five 1 $m^2$ quadrats were selected using random co-ordinates inside each of three grids per survey site. For other equipment used and a detailed description of the methodology see Measey (2004).

## Results and discussion

On consultation, indigenous people readily distinguished *B. uluguruensis* from earthworms, which are given separate names in Kiluguru: 'Songosi' and 'Finge', respectively. However, in Kiswahili, no words are known to distinguish these two groups or any other subterranean lower vertebrates from earthworms. This is similar to distinctions made in Kisambaa for *B. boulengeri*, but not for *B. taitanus* in Kitaita (Measey, 2004). Indigenous people showed a dislike to handle or even touch specimens (unlike for example earthworms), but did not believe them to be dangerous.

*Boulengerula uluguruensis* was found to be present in all sites searched, although qualitatively our perception was that their abundance was higher in agriculture than in forest. This is reflected in the results of timed searches (Table 2b). Doggart *et al.* (unpublished data) found *B. uluguruensis* in Mkungwe forest reserve in a biodiversity survey in 2000. It is presumed that animals were found in

**Table 1** Site descriptions of surveys for *Boulengerula uluguruensis* in the Uluguru Mountains (see Fig. 1)

| Site name | Date and time visited | Co-ordinates | Altitude (m) | Habitat type | Shade (%) | Air temperature (°C) | Soil temperature (°C) | Soil pH | Soil texture | Soil penetration (kg cm$^{-2}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Tegetero mission | 27 November 2003, 14.00 hours | S 06°55.03′, E 37°43.16′ | 1100 | Mixed agriculture | 50 | 28.1 | 22.5 | 6.20 | Sandy clay loam | 4.4 |
| Uluguru North Forest Reserve | 28 November 2003, 13.00 hours | S 06°56.39′, E 37°42.45′ | 1410 | Natural forest | 100 | 21.6 | 18.9 | 6.82 | Sandy loam | >8.3 |
| Uluguru North Forest Reserve | 29 November 2003, 12.00 hours | S 06°56.90′, E 37°42.77′ | 1390 | Plantation (*Grevillea robusta*) | 80 | 23.5 | 20.5 | 7.17 | Sandy loam | 4.4 |
| Lubwe village | 29 November 2003, 10.30 hours | S 06°56.95′, E 37°42.49′ | 1175 | Mixed agriculture | 10 | – | – | – | Sandy loam | 5.7 |
| Tandai village | 28 November 2003, 16.00 hours | S 06°55.03′, E 37°45.55′ | 450 | Around residential area. Banana and grassland | 15 | 26.7 | 25.7 | 7.76 | Sandy clay loam | >8.3 |

forest as they list this species to be dependent on primary forest. Natural forest proved the most difficult habitat for finding caecilians, indeed the only timed search (29 November 2003) yielding no *B. uluguruensis* was in natural forest (Table 2b). As only two specimens were found in natural forest the hypothesis, that forest populations of *B. uluguruensis* are sparser, or of a bigger size than those found in agriculture (see above), could not be tested. Interestingly, one of the animals found in forest was the largest individual found during the study (a male with total length 240 mm). The other was the smallest found (a juvenile with total length 110 mm); and while the large male was found at about 20 cm deep into compact soil, the smallest animal was found in an accumulation of rotting wood and leaf litter.

In agriculture, nearly all the *B. uluguruensis* were found well into the hard red soil, rather than in the surface layers (leaf litter, roots, or in the A horizon of black soil, Fig. 2). It is known that some caecilians are able to generate considerable burrowing force through the use of a hydrostatic system, apparently more powerful than a vertebral-driven system (O'Reilly, Ritter & Carrier, 1997). A single animal was found under a fallen banana trunk in Tegetero Mission; otherwise all animals required excavation from the soil. Several *B. uluguruensis* were found at the base of banana plants, not uncommon when collecting caecilians (e.g. Measey *et al.*, 2003a; Measey, 2004). In Tandai Village, this was the only microhabitat in which caecilians were collected. A survey which was made at the same site found no animals, partly confirming our suspicions that at this lower altitude, animals were more patchily distributed (see Measey *et al.*, 2003b). Given the amount of banana cultivation which occurs in these lower altitudinal areas, it may mean that *B. uluguruensis* is more abundant here than we report.

Most randomized surveys took around two person hours to perform, usually carried out with one jembe and at least two people. In shaded areas it was not easy to predict where caecilians would occur, and this resulted in similar numbers being found with the two survey techniques (Table 2). However, where there was no shade from trees, digging at the base of banana plants yielded the only caecilians caught, both at Tegetero mission and Tandai. The reason for the apparently higher densities of *B. uluguruensis* in the plantation forest compared with natural forest is not clear, although a similar situation was observed for *B. taitanus* in Kenya (Measey, 2004). Canopy cover in the plantation was incomplete, compared with the complete canopy in natural forest. A decrease in canopy

**Table 2** Density and mass of *Boulengerula uluguruensis* found in surveys in the Uluguru Mountains. For detailed site descriptions see Table 1. (a) In quantitative surveys five 1 $m^2$ quadrats were randomly assigned and sampled in each of three 100 $m^2$ grids, giving a total of 15 $m^2$. (b) Results of timed searches in agricultural and forested habitats

| Date | Site | Altitude | Type | Number of animals found | Number of empty quadrats | Density ($m^2$) | Biomass ($g\ m^{-2}$) |
|---|---|---|---|---|---|---|---|
| (a) | | | | | | | |
| 27 November 2003 | Tegetero Mission | 1000 | Agriculture | 6 | 9 | 0.4 | 0.43 |
| 28 November 2003 | Uluguru North Forest | 1050 | Natural forest | 0 | 15 | 0 | 0 |
| 28 November 2003 | Tandai | 450 | Agriculture | 0 | 15 | 0 | 0 |
| 29 November 2003 | Uluguru North Forest | 1100 | Plantation forest | 1 | 14 | 0.07 | 0.11[a] |
| | | | | Number of estimated animals found | Area searched ($km^2$) | Time taken (person hours) | Animals $h^{-1}\ km^{-1}$ |
| (b) | | | | | | | |
| 27 November 2003 | Tegetero Mission | 1000 | Agriculture | 7 | 0.00 | 4 | 50.52 |
| 28 November 2003 | Uluguru North Forest | 1050 | Natural forest | 2 | 0.25 | 9 | 0.44 |
| 28 November 2003 | Tandai | 450 | Agriculture | 4 | 0.00 | 1.5 | 596.28 |
| 29 November 2003 | Uluguru North Forest | 1100 | Plantation forest | 2 | 0.00 | 6 | 21.08 |
| 29 November 2003 | Lubwe village | 1175 | Agriculture | 2 | 0.00 | 1 | 282.84 |
| 29 November 2003 | Uluguru North Forest | 1100 | Natural forest | 0 | 0.10 | 4.5 | 0.00 |

[a]Estimated from size of incomplete animal (actual mass unknown).

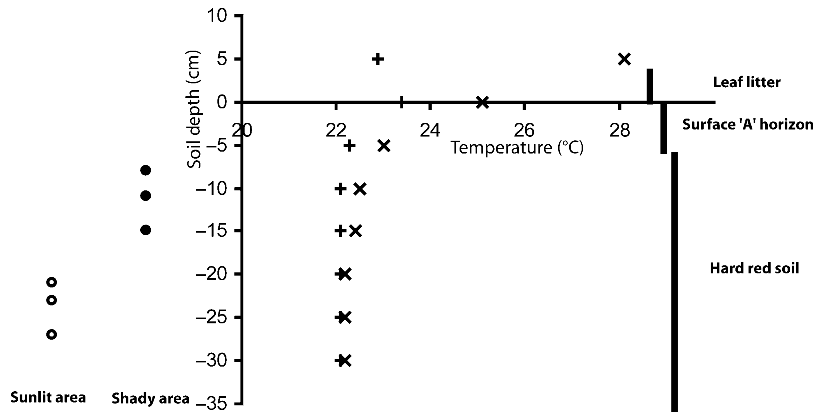


**Fig 2** Depth of *Boulengerula uluguruensis* found in a quantitative survey at Tegetero mission (left) in open (open circles) and shaded (solid circles) areas. Soil temperature profiles show that shaded areas (crosses) have lower surface temperatures and lower temperatures in the upper levels of soil. Open areas (checks) have a higher temperature until a depth of 20 cm. Bars (to the right) indicate depths of leaf litter, rich organic soil and deeper mineral soils

cover would allow more rainfall to directly impact on the soil, as well as allowing sunlight to warm the soil (see Fig. 2). The effect of temperature and rainfall on caecilian abundance are not well known, although most studies agree that animals are more difficult to find in the dry season (e.g. Measey *et al.*, 2003a; Kupfer, Nabhitabhata & Himstedt, 2004).

During the randomized survey at Tegetero mission, we found that animals from quadrats in the shade were more shallow ($\bar{x}$ 11.3 ± 3.51 cm) in the soil than in squares containing animals in full sun ($\bar{x}$ 23.6 ± 3.05 cm; see Fig. 2). Temperature profiles of the soil show that in open areas soil temperature reached a minimum of 22.2°C at a depth of 20 cm, while in the shade a minimum temperature of 22.1°C was reached at 10 cm. Exposed tropical soils can reach very high surface temperatures, but these quickly diminish with increasing depth, so that at around 50 cm depth diel temperatures barely fluctuate, although year round temperatures may continue to vary at considerable depth (Lavelle & Spain, 2001). The hypothesis that caecilians undergo vertical migrations with variations in soil temperature profiles could be tested with both field and laboratory studies.

It is noteworthy that no other caecilian species were found during randomized surveys or timed searches in November 2003. Three other caecilian species are known from the Uluguru Mountains (see above). Gower *et al.* (2004) mention finding one *S. kirkii* after five person digging hours in the natural forest above Tegetero Mission during their visit in May 2002. November represents the start of the rainy season that peaks in March/April, and little rain had fallen prior to the survey time. It is possible that different number of individuals would be found at different times, as has been noted for other caeciliids (Measey *et al.*, 2003b). In the East Usambara Mountains, *S. vittatus* is only known from primary forest, whilst *B. boulengeri* Tornier is found in agricultural, secondary and primary forest habitats (Measey, 2004). However, in the Pare Mountains, the same species is known from forest and agriculture, although no *Boulengerula* species is present (S. Loader, personal communication).

Two *Melanoseps loveridgei* Brygoo and Roux-Estève were found during timed searches in natural and plantation forest (29 November 2003). This black limbless skink is already known from the Uluguru Mountains, although little is known about its ecology (Spawls *et al.*, 2002). A single specimen of *Probreviceps macrodactylus* (Nieden) was also found in natural forest within a quadrat of the quantitative survey on 28 November 2003 (Table 2a). Several other examples of the same species were found whilst making timed searches in the same area, as well as in the plantation forest. This result, whilst not being statistically robust, does allow an idea of relative densities of caecilians and other herpetofaunal taxa. During the quantitative survey at Tegetero Mission (27 November 2003) a single specimen of *Typhlops uluguruensis* was found 14 cm deep in a 1 $m^2$ quadrat that also contained a *B. uluguruensis* (at 21 cm depth, but within a 25 cm lateral distance of the *T. uluguruensis*). Gower *et al.* (2004) commented how the two species resemble one another; both are pink, elongate and limbless. The comparative abundance of these taxa seems to concur with the findings of Gower *et al.* (2004). It is noteworthy that no *T. uluguruensis* were found in natural forest. This does not indicate absence, but perhaps that they, like *B. uluguruensis*, are more abundant in small-scale agricultural settings (see Measey *et al.*, 2003b; Gower *et al.*, 2004).

## Conclusion

The data recorded here are presented with a number of caveats. First, the short time spent doing fieldwork means that few areas were sampled, and consequently the main hypotheses could not be statistically tested. In addition, the timing of this survey represents the beginning of the rainy season, and it has been found in other studies that abundance of caecilians in the top 30 cm of soil can have considerable seasonal variation (Measey *et al.*, 2003b). Despite these caveats, some conclusions can be made about *B. uluguruensis* in the Ulugurus. We confirm their presence in naturally forested areas. We show that they can be abundant in some agricultural areas, reaching a density of up to 0.4 individuals $m^{-2}$ at Tegetero mission. Secondly, that they inhabit a wide altitudinal range (at least from 450 m). Lastly, they appear to be more abundant than any other subterranean lower vertebrates in this area. This is yet another example of a caecilian found to be common in agricultural habitats (e.g. Glaser, 1985; Measey & Di-Bernardo, 2003; Measey *et al.*, 2003a,b; Measey, 2004), and it is remarkable that this order of animals came to be considered so rare (e.g. Duellman & Trueb, 1986; Bhatta, 1997).

Our hypothesis that *B. uluguruensis* is more abundant in agricultural habitats than in their native forest could not be conclusively confirmed during this study, although the data that were collected do not indicate to the contrary. Likewise, the hypothesized size difference between animals from forest and agricultural populations could not be objectively compared. Both hypotheses need further sampling in another visit to determine their validity.

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