



On the absence of *Ichthyophis sikkimensis* Taylor, 1960 (Amphibia: Gymnophiona: Ichthyophiidae) in the Western Ghats of peninsular India

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We examined two specimens of short-tailed, unstriped *Ichthyophis* Fitzinger, 1843 collected in 1949 from the Anamalai Hills of the Western Ghats of peninsular India. One of these specimens was identified previously as the peninsular Indian *I. subterrestris* Taylor, 1960, the other as *I. sikkimensis* Taylor, 1960, a species known otherwise only from Nepal and the Indian states of Sikkim and West Bengal, approximately 2,200 km to the northeast. We find that the two specimens in question are conspecific, that both have been misidentified and that the pair together probably belong to an undescribed species. Our conclusion that *I. sikkimensis* does not occur in peninsular India removes a major biogeographic anomaly.

Key words: biogeography, microCT, northeast India, phallodeum, taxonomy, *Uraeotyphlus*

INTRODUCTION

Substantial progress has been made in Indian caecilian systematics this century, including the discovery and description of new taxa (e.g., Giri et al., 2003, 2004, 2011; Bhatta et al., 2004, 2007a, b, 2011; Gower et al., 2004, 2008; Wilkinson et al., 2007; Kamei et al., 2009, 2012, 2013; Kotharambath et al., 2012, 2015; Agarwal et al., 2013), recognition of new synonymies (Gower et al., 2007, 2013; Kamei & Biju, 2016), clarification of phylogenetic relationships (e.g., Gower et al., 2002a, 2011, 2016; Wilkinson et al., 2002; Roelants et al., 2007; Kamei et al., 2012; San Mauro et al., 2014) and revisions of higher-level classification (Kamei et al., 2012; Wilkinson et al., 2011). However, identification of caecilians can be challenging and the distributions of many species remain poorly circumscribed (e.g., Kotharambath et al., 2012, 2015; Gower et al., 2013). In some cases, this precludes satisfactory conservation assessments and/or understanding of biogeographical patterns. One such case is illustrated by the ichthyophiid *Ichthyophis sikkimensis* Taylor, 1960.

Ichthyophis sikkimensis was described on the basis of a holotype and three paratypes, from the northeast Indian states of Sikkim and West Bengal. Unlike most other Indian *Ichthyophis*, *I. sikkimensis* lacks a longitudinal,

lateral yellow stripe. The only other unstriped Indian *Ichthyophis*, *I. bombayensis* Taylor, 1960, is restricted to the Western (and possibly southern Eastern) Ghats region of peninsular India (Gower et al., 2007; Ramaswami, 1947) and differs from *I. sikkimensis* most notably in having a much longer tail. Since Taylor's description, *I. sikkimensis* has remained very poorly known. Taylor (1961) summarised his description of the previous year, and Taylor (1968) was again restricted to the type series for characterising the species.

In their then comprehensive treatment of Indian caecilians, Pillai & Ravichandran (1999) challenged the previous understanding that *I. sikkimensis* was restricted to northeastern India by reporting one specimen from the Western Ghats (see also Ravichandran, 2004), approximately 2,200 km to the south and west. Pillai & Ravichandran (1999: 52) remarked that "*Ichthyophis sikkimensis* was hitherto thought to be a Himalayan species confined to Sikkim and Darjeeling" and that "The present record of this species from the Western Ghats of Kerala is surprising and underlines the extreme scantiness of our present knowledge on the distribution of caecilians." Anders (in Schleich & Kästle, 2002) accepted Pillai & Ravichandran's identification and mapped the presence of *I. sikkimensis* in the Western Ghats as well as northeast India and Nepal (providing the first report

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Fig 1. Unstriped *Ichthyophis* specimens collected by A.F. Hutton from Injiparai Estate. A) BNHS 7 (TL c.290 mm). B) BNHS 17 (TL c. 260 mm).

for the latter country). In contrast, Dutta (2003 “2002”; see also Ohler et al., 2004) doubted the conspecificity of the Western Ghats and northeast Indian (Sikkim and West Bengal) unstriped *Ichthyophis*. Dutta argued that the Western Ghats specimen was damaged to the extent of preventing observation of key characters that could potentially confirm Pillai & Ravichandran’s identification of it as *I. sikkimensis*. Dutta further suggested (seemingly on biogeographic grounds) that the specimen was instead likely to be *I. bombayensis* or an undescribed species. To the best of our knowledge, no detailed reassessment of the Western Ghats specimen reported by Pillai & Ravichandran (1999) has been undertaken. Here we report that this material is not *I. sikkimensis*, but instead is likely an undescribed species. Thus, there is no evidence that *I. sikkimensis* occurs in peninsular India.

MATERIALS AND METHODS

Total length was measured to the nearest millimetre (mm) with a ruler, and circumferences to the nearest mm with a ruler and thread. Other measurements were made to the nearest 0.1 mm with vernier calipers. Sex was determined by examination of gonads through a midventral incision. We follow Kamei et al. (2009) in using TN/TE to designate the ratio of the distances between the tentacular aperture and the naris and eye. Phallosome terminology follows Gower & Wilkinson (2002b).

The contentious material in question is housed in the collections of the Bombay Natural History Society, Mumbai, India (BNHS). We also examined the holotype of *I. sikkimensis* from the collection of the California Academy of Sciences, San Francisco, USA (CAS 64216), and two of three paratypes, one from the collection of the Natural History Museum, London, UK (BMNH 87.11.2.28) and one from the Zoologisches Museum, Berlin, Germany (ZMB 50546). The condition of the skull of BMNH 87.11.2.28 was investigated with high-resolution x-ray computed tomography as reported by

Gower et al. (2010), with scanning parameters of 145 kV and 100 μ A, and reconstructed voxel size of 11 μ m. Scans were rendered as surface meshes and examined using Meshlab, a tool developed with the support of the 3D-CoForm project (<http://meshlab.sourceforge.net/>). We have examined type specimens of all species of *Ichthyophis* described from peninsular India.

RESULTS

BNHS 17 (Fig. 1) is the Western Ghats specimen considered to be an *Ichthyophis sikkimensis* by Pillai & Ravichandran (1999). It was collected by A. F. Hutton, on 22 August, 1949 from Injiparai Estate, Anamalai and is now in bad condition. The specimen is in two parts, the front of the head is absent, the tongue is detached from the jaws, the tail end is badly damaged, the skin is loose, and many scale pockets are open and empty. BNHS 7, a second specimen of unstriped *Ichthyophis* was collected by Hutton at the same time and place as BNHS 17. Pillai & Ravichandran (1999) referred BNHS 7 to *I. subterrestris* Taylor, 1960, a species subsequently relegated to the synonymy of *I. bombayensis*, (see Gower et al., 2007), and used it as an exemplar on which they based their “description” of *I. subterrestris*. BNHS 7 is also in bad condition (Fig. 1) and currently is in three pieces. Despite this, its morphology conflicts with its referral to *Ichthyophis subterrestris* (= *I. bombayensis*) and it is clearly not a representative of that species because it has a much shorter tail, with approximately three times fewer annuli posterior to the vent. Some morphometric and meristic data for both the BNHS specimens and for examined type material of *I. sikkimensis* are presented in Table 1.

The two BNHS specimens are very similar to each other as far as can be determined (Table 1). We find no evidence that they represent more than one species of relatively short-tailed, unstriped *Ichthyophis*. Beyond their lack of lateral stripes, the two specimens resemble

Table 1. Meristic and morphometric data for the holotype (CAS 64216) and two paratypes (BMNH 87.11.2.28; ZMB 50546) of *Ichthyophis sikkimensis* and for two *Ichthyophis* sp. (BNHS 7 and 17) from Injiparai Estate. Scales reported as: number of rows of scales in pocket (approximate depth of pocket relative to length of one local annulus). The format 'X–Y' designates the shortest distance between features 'X' and 'Y'.

	CAS 64216	BMNH 87.11.2.28	ZMB 50546	BNHS 7	BNHS 17
Total length	297	255	255	290	260
Midbody width	12.1	11.5	8.8	18.7	8.9
Midbody circumference	33	34	27	50	36
Annular grooves (AGs)	288	290	282	356	295
AGs behind vent	4	5	6	4	3?
Scales in posterior AGs	2–3 (1.5)	3 (1.25–1.5)	3 (1.25–1.5)	-	3 (1.5)
Premaxillary-maxillary teeth	51	46	45	43	>45
Vomeropalatine teeth	48	42	41	47	>38
Outer mandibular teeth	46	42	38	40	39
Inner mandibular teeth	20	20	c.19	c.20	16
Eye–Naris	4.9	3.7	3.5	5.7	-
Eye–Tentacular aperture	1.6	1.5	1.2	2.4	1.8
Tentacular aperture–Naris	3.1	2.9	2.7	4.5	2.8
TN/TE	1.9	1.9	2.3	1.9	1.6
Distance between eyes	5.9	6.0	5.5	7.0	5.4
Distance between nares	3.5	3.1	2.8	2.4	-
Snout tip–first nuchal groove	12.2	10.5	11.4	16.0	12.2
Maximum width of head	8.4	7.9	7.7	11.7	8.9
Length of first collar	3.5	3.1	2.9	4.7	4.7
Length of second collar (C2)	3.6	3.1	3.9	5.2	4.9
Transverse grooves on C2	2	3	2 or 3	1	1 or 2

I. sikkimensis in several respects including the number of annular grooves and the approximate number, disposition, size and shape of teeth (Table 1). However, BNHS 7 and 17 differ from *I. sikkimensis* in having (1) small, generally isolated scales associated even with

anteriormost annular scale pockets (versus scales absent anteriorly), (2) proportionately longer and wider heads, and, less substantially in (3) fewer premaxillary-maxillary than vomeropalatine teeth, and (4) having the eye slightly closer to top of head than to upper lip in lateral

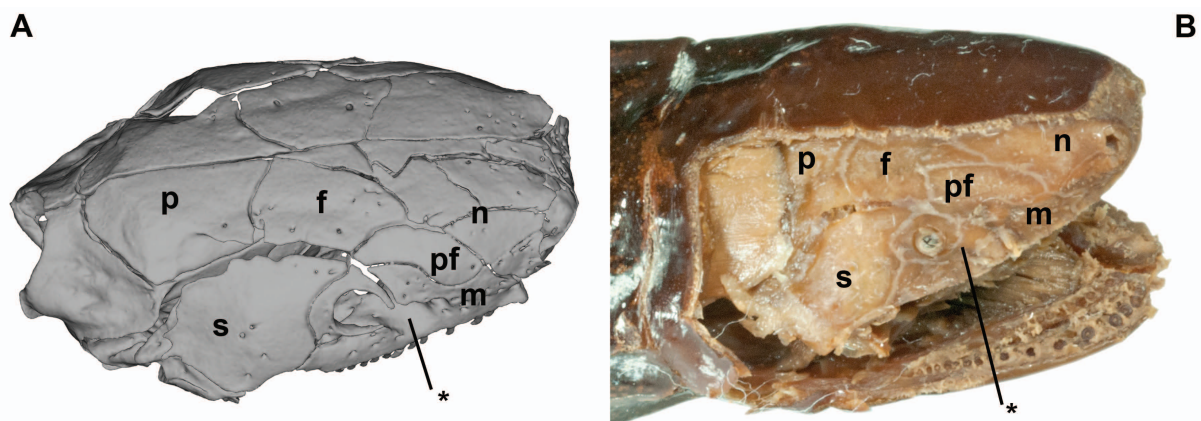


Fig. 2. Comparison of the skull of A) a paratype of *Ichthyophis sikkimensis* (BMNH 87.11.2.28), and B) *Ichthyophis* sp. (BNHS 7) from Injiparai Estate. Figure shows the *I. sikkimensis* specimen to have a larger upper temporal fenestra between squamosal (s) and parietal (p) and frontal (f), and a tentacular groove (indicated by *) that is open rather than partly roofed by bone. BNHS 7 also has a distinctive L-shaped suture between the frontal and prefrontal (pf), and more substantial contact between the nasal (n) and maxillopalatine (m). Right nasal and frontal of BMNH 87.11.2.28 are fractured. Image in part A is a volume reconstruction of microCT data. For head sizes of these specimens see Table 1.

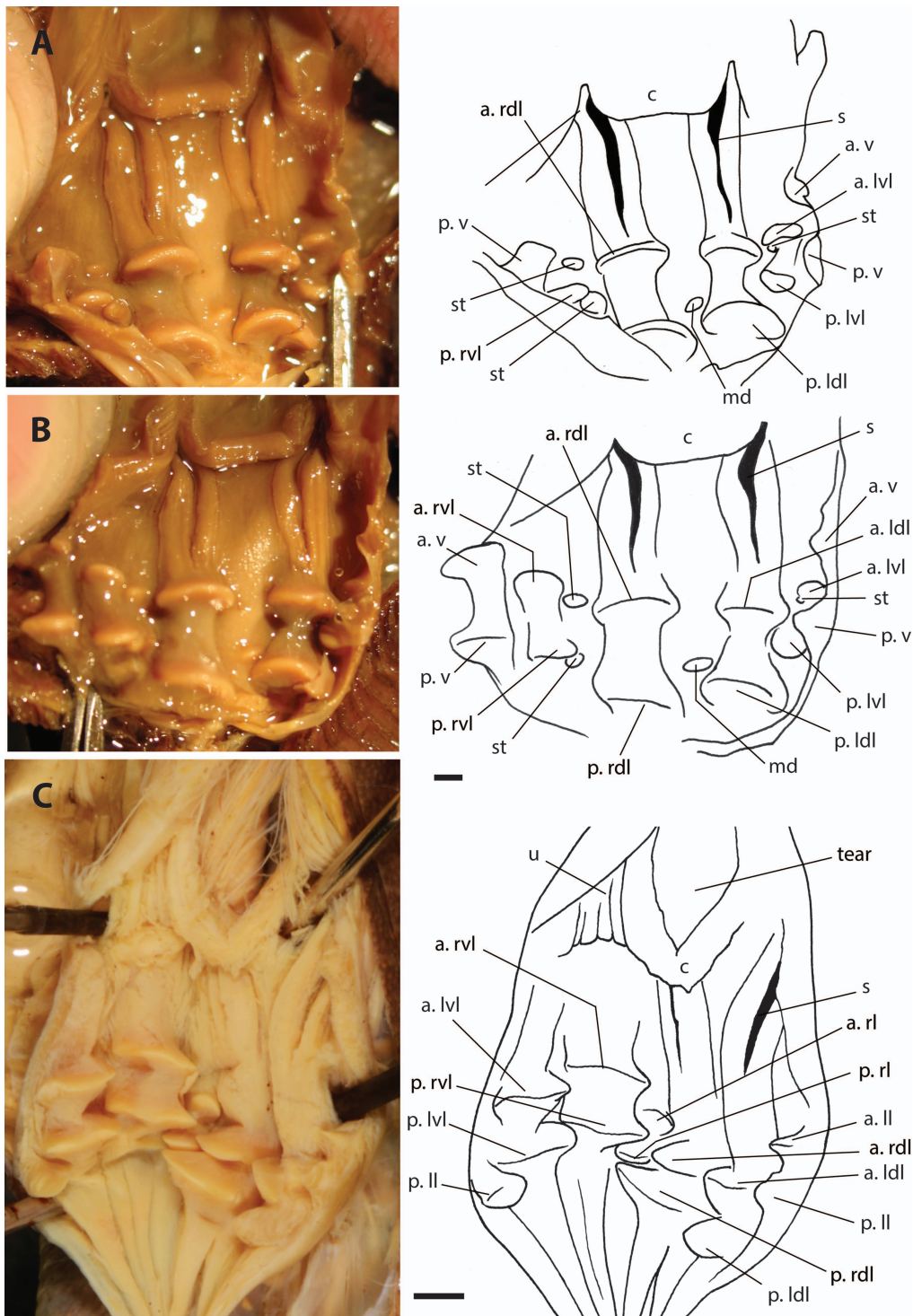


Fig. 3. Comparison of anterior part of phallosome of *Ichthyophis* sp. (BNHS 7) (parts A and B) and a paratype of *Ichthyophis sikkimensis* (BMNH 87.11.2.28) (part C). All views are of the internal surface of the phallosome *in situ*, with anterior to the top of the figure. Incision in BNHS 7 runs slightly to the left of midventral (through the midventral ridge); incision in BMNH 87.11.2.28 runs partly through the left lateral ridge. Figure parts A and B are slightly different views of the same specimen: in A the a. v is obscured by a thumb, the a. rl obscured by the p. v. Abbreviations as follows: a. ldl = anterior thickening of left dorsolateral ridge; a. ll = anterior thickening of left lateral longitudinal ridge; a. lvl = anterior thickening of left ventrolateral ridge; a. rdl = anterior thickening of right dorsolateral longitudinal ridge; a. rl = anterior thickening of right lateral ridge; a. rvl = anterior thickening on right ventrolateral longitudinal ridge; a. v = anterior thickening of ventral ridge; c = colliculus; md = thickening of mid-dorsal longitudinal ridge; p. dl = posterior thickening of left dorsolateral ridge; p. ll = posterior thickening of left lateral ridge; p. vl = posterior thickening of left ventrolateral longitudinal ridge; p. rd = posterior thickening of right dorsolateral longitudinal ridge; p. rl = posterior thickening of right lateral longitudinal ridge; p. rvl = posterior thickening of right ventrolateral longitudinal ridge; p. v = posterior thickening of ventral ridge; s = major sulcus on dorsolateral ridge; st = supernumerary thickening; tear = tear in the tissue; u = urodeum. Scale bar approximately 1 mm (applies to all figure parts).

view (versus equidistant or slightly closer to lip).

Additionally, there are several cranial differences between BNHS 7 and the BMNH paratype of *I. sikkimensis* (Fig 2). These differences include (1) relatively broad (versus more narrow) contact between nasals and maxilloplatinates and concomitant greater (versus lesser) separation of the prefrontals and septomaxillae, (2) upper temporal fenestra more narrow (versus more broadly open), (3) tentacular canal at least partly roofed in bone (versus open), and (4) having a distinctive L-shaped (versus gently curved) suture between the prefrontals and frontals. It is possible that some of these cranial features vary ontogenetically, but taken at face value the differences are not insubstantial. The open or closed nature of the tentacular canal, and the L-shaped or more curved nature of the suture between frontal and prefrontal were found by Wilkinson et al. (2014) to vary inter- but not intraspecifically among small samples of three striped *Ichthyophis* species. Wilkinson et al. (2014) reported that the size of the upper temporal fenestra varied intraspecifically among the same sample.

BNHS 17 is a female and BNHS 7 a male. The phallodeum of BNHS 7 differs notably from that of *I. sikkimensis* (Fig. 3) in having (1) major sulci that extend posteriorly almost to the anterior tuberosities of the dorsolateral ridges (versus a large gap between the sulci and anterior dorsolateral tuberosities); (2) a shorter distance (relative to length of anterior phallodeal chamber) between the tuberosities on the dorsolateral ridges and the colliculus, and between the anterior and posterior tuberosities on each dorsolateral ridge; (3) anterior ends of dorsolateral ridges widely (versus narrowly) separated at colliculus; (4) having a midventral ridge and lacking a pair of 'lateral' ridges; (5) having a middorsal tuberosity; (6) tuberosities on the ventrolateral ridge that are more posteriorly positioned relative to the dorsolateral ridge tuberosities, such that the posterior tuberosities of the ventrolateral ridges are posterior to the anterior tuberosity of the dorsolateral ridge (versus anterior to the dorsolateral ridge tuberosities); (7) supernumerary tuberosities on the posterolateral edges of the tuberosities of the ventrolateral ridges. We are convinced that BNHS 7 has a midventral longitudinal ridge, but there are alternative interpretations of the ridges lying between this and the dorsolateral ridge on each side. We identify (Fig. 3A, B) a ventrolateral (but no lateral) ridge on each side, with small supernumerary tuberosities on the posterolateral edge of the posterior tuberosity of the right ventrolateral ridge, and on the posterolateral edge of the anterior tuberosity of both the right and left ventrolateral ridge. These supernumerary tuberosities could, instead, be interpreted as (asymmetric) features of weakly expressed lateral ridges, or the ventrolateral ridges that we identify could be interpreted as homologous with the lateral ridges (Fig. 3C) of *I. sikkimensis* instead. Either way, the differences in phallodeal morphology between BNHS 7 and *I. sikkimensis* are substantial.

One of us (O.V.O.) visited Injiparai Estate on 9 August, 2003. This is a tea estate on the southwestern outskirts of Valparai. One or two people dug soil with bladed

hoes for approximately four hours. Digging took place in marginal habitats with moist and/or shaded soil, away from cultivated tea. Only a single caecilian was encountered, an *oxyurus*-group (see Gower & Wilkinson 2007) *Uraeotyphlus* Peters, 1879.

DISCUSSION

Based on differences in soft and hard anatomy, BNHS 7 and 17 are neither *Ichthyophis sikkimensis* nor *I. subterrestris*. Although, not all of these differences may prove to be distinctive following examination of additional material, taken together they are numerous and substantial enough to convince us of our taxonomic conclusions. The initial identification of BNHS 17 as *I. sikkimensis* was made by R. A. Nussbaum (as reported by Pillai & Ravichandran, 1999) based only on photographs (R.A. Nussbaum, pers. comm.) and is not surprising given the superficial similarity to this species. More surprising to us is that this identification was seemingly not questioned by Pillai & Ravichandran (1999) given the obvious implications for biogeography and knowledge of caecilian distributions, and also that BNHS 7 was misidentified by Pillai & Ravichandran (1999) as *I. subterrestris* despite the great difference in tail length. Our conclusion that BNHS 17 is not *I. sikkimensis* removes a notable South Asian biogeographic disjunction or anomaly, and highlights the importance of taxonomy in understanding distribution patterns and, consequently, for assessing conservation status (see also Kotharambath et al., 2012; Gower et al., 2015).

Given their poor condition, it could be argued that BNHS 7 and 17 might have had lateral stripes in life that have subsequently faded in imperfect preservation (see Kamei & Biju, 2016 for such a case). In any case, the two specimens do not resemble closely any of the five nominal species of striped *Ichthyophis* known from peninsular India. For example, compared with BNHS 7 and 17, *I. beddomei* Peters, 1880 has a much smaller and more pointed head; *I. tricolor* Annandale, 1909 and *I. beddomei* have tentacles relatively much further from the eye (TN/TE < 1.25: Wilkinson et al., 2007); *I. longicephalus* Pillai, 1986 has more inner mandibular teeth (> 20) in a longer row relative to dentary series, and more scale rows posteriorly (Kotharambath et al., 2012); *I. kodaguensis* Wilkinson, Gower, Govindappa & Venkatachalaiah, 2007 has more inner mandibular teeth (> 24), more scales, and broader and less widely separated choanae; *I. davidi* has many more inner mandibular teeth (> 28) and tentacular apertures relatively further from the eye (TN/TE < 1.4: Bhatta et al., 2011). Two other of Hutton's specimens in BNHS (BNHS 9 and 10; collected 1943) reportedly from Injiparai were identified as the striped species *I. beddomei* by Pillai & Ravichandran (1999). These now also rather poorly preserved specimens bear no indication of a stripe. They are relatively short-tailed but differ clearly from BNHS 7 and 17 (and from *I. sikkimensis*) in, for example, having multiple rows of scales in anteriormost annular scale pockets and in having TN/TE ratios of less than 1.5, with the tentacular apertures relatively further from

the lip. If BNHS 9 and 10 were striped in life then, based on head shape and size, we consider it more likely that they are *I. tricolor* than *I. beddomei*. Another caecilian in the collection of the Natural History Museum, London, BMNH 1950.1.4.81, is an additional Hutton caecilian specimen. The handwritten label on the jar and in the catalogue appear to state “Iryiparai Estate, Lalparai P.O., Anamallai Hills, Coimbatore District”, which we suspect is Injiparai (not Iryiparai) Estate and Valparai (not Lalparai). Initially identified in the BMNH catalogue as *I. glutinosus*, this is instead a previously unreported specimen of a *malabaricus*-group *Uraeotyphlus* Peters, 1879.

BNHS 7 and 17 differ also from the other species of unstriped *Ichthyophis* reported from South Asia. The Sri Lankan *I. orthoplicatus* Taylor, 1965, has more scales in anterior annular scale pockets and perhaps more inner mandibular teeth relative to total length (Nussbaum & Gans, 1980).

We conclude that BNHS 7 and 17 most likely represent an undescribed species of *Ichthyophis* (or at least one not currently known to occur in India) that is superficially similar to *I. sikkimensis*. These two specimens are in such poor condition that we strongly recommend that they are not used as the basis for the description of a new species, especially in the absence of, for example, data on the rest of the skull, mandible and axial skeleton (that could be obtained non-invasively). Further fieldwork in the vicinity of Injiparai Estate, and collection and careful examination of (especially) unstriped *Ichthyophis* from here is clearly warranted. Assuming that the locality data are correct, the presence of more than one species of *Ichthyophis* (at least one of them seemingly undescribed) and both *malabaricus*- and *oxyurus*-group *Uraeotyphlus* species makes Injiparai a diverse and interesting historical caecilian locality worthy of further exploration.

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