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A new species of *Xylophis* Beddome, 1878 (Serpentes: Pareidae) from the southern Western Ghats of India

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Abstract

We reassess the taxonomy of the Indian endemic snake *Xylophis captaini* and describe a new species of *Xylophis* based on a type series of three specimens from the southernmost part of mainland India. *Xylophis deepaki* **sp. nov.** is most similar phenotypically to *X. captaini,* with which it was previously confused. The new species differs from *X. captaini* by having a broader, more regular and ventrally extensive off-white collar, more ventral scales (117–125 versus 102–113), and by lack of flounces on the body and proximal lobes of the hemipenis. Phylogenetic analysis of mitochondrial 16S DNA sequences strongly indicates that the new species is most closely related to *X. captaini*, differing from it by an uncorrected pairwise genetic distance of 4.2%. A revised key to the species of *Xylophis* is provided.

Keywords

Hemipenis, Kanyakumari, molecular phylogeny, snakes, taxonomy, Xylophiinae.

Introduction

The fossorial snakes of the genus *Xylophis* Beddome, 1878 (Pareidae: Xylophiinae) are endemic to the Western Ghats region of peninsular India. The genus comprises four currently recognised species, namely *X. perroteti* Duméril, Bibron and Duméril, 1854, *X. stenorhynchus* (Günther, 1875), *X. captaini* Gower and Winkler, 2007, and *X. mosaicus* Deepak, Narayanan, Das, Rajkumar, Easa, Sreejith and Gower, 2020 (Deepak et al. 2020). The taxonomy of *Xylophis* was static for more than 100 years until the description of *X. captaini* (Gower and Winkler 2007) and *X. mosaicus* (Deepak et al. 2020). Although most species of *Xylophis* are restricted to high elevations of the Western Ghats and with a narrow distributional range (Gower and Winkler 2007; Deepak et al.

Table 1. DNA sequence data for mitochondrial 16S rRNA gene used in phylogenetic analyses. All data previously published except for *Xylophis deepaki* **sp. nov**.

Species	Voucher	GenBank #	Corresponding GenSeq Nomenclature
Xylophis captaini (Pareidae: Xylophiinae)	BNHS 3376	MK340909	genseq-1 16S
Xylophis deepaki **sp. nov.** (Pareidae: Xylophiinae)	ZSI-CZRC-7218	MW832840	genseq-1 16S
Xylophis mosaicus (Pareidae: Xylophiinae)	BNHS 3579	MN970035	genseq-1 16S
Xylophis perroteti (Pareidae: Xylophiinae)	BNHS 3582	MN970037	genseq-3 16S
Xylophis perroteti (Pareidae: Xylophiinae)	CES 2016b	MK340908	genseq-3 16S
Xylophis perroteti (Pareidae: Xylophiinae)	BNHS 3581	MN970036	genseq-3 16S
Xylophis stenorhynchus (Pareidae: Xylophiinae)	CAS 17199	MK340907	genseq-4 16S
Pareas monticola (Pareidae: Pareinae)	ADR 507	MN970033	—
Pareas cf. *formosensis* (Pareidae: Pareinae)	CHS 886	MK194290	—
Achalinus rufescens (Xenodermidae)	CHS 868	MK194279	—
Xenodermus javanicus (Xenodermidae)	FMNH 230073	AF544810	—

2020), *X. captaini* has a wider distribution in the low to mid-elevation regions of the western flank of the southern Western Ghats (Gower and Winkler 2007; Bhupathy et al. 2016). In the original description of *X. captaini*, two specimens from the southernmost limit of the distribution appeared to be outliers with higher ventral counts (see Gower and Winkler 2007). This led us to reassess the taxonomy of *X. captaini* and to examine more specimens from the above mentioned region. In this work, we describe a new species supported by morphological and molecular data and present a new key to identify the congeners.

Materials and Methods

Molecular analysis

We generated DNA sequence data for the mitochondrial 16S rRNA gene (*16S*) for one *Xylophis* specimen (ZSI-CZRC-V-7218) from Melpuram, Kanyakumari district, Tamil Nadu, India. Genomic DNA was extracted from liver tissue stored in absolute ethanol at –20C, using the DNeasy (QiagenTM) blood and tissue kit. We amplified a partial sequence of *16S* using the primers 16Sar-L and 16Sar-H and reported protocols (Palumbi et al. 1991). PCR amplifications were carried out in an S1000TM Thermal Cycler (Bio-Rad, USA). Amplified PCR products were run on a 2% agarose gel and viewed with an Essential V4 (UVITEC Cambridge, UK) gel documentation system. PCR products were Sanger sequenced in both directions at Medauxin Sequencing Services (Bangalore, India). Sequences were aligned using ClustalW in MEGA 5.1 (Higgins et al. 1994; Tamura et al. 2011) with default parameter settings. Uncorrected pairwise genetic distances were calculated using MEGA5. We used PartitionFinder v1.1.1 (Lanfear et al. 2012) with default settings to find the best-fit model of sequence evolution for the single partition used. Ten *16S* sequences for Xylophiinae and four outgroups comprising two species of the subfamily Pareinae (Pareidae) and two of Xenodermidae were downloaded from GenBank (Table 1).

Bayesian (BI) phylogenetic analysis was carried out with MrBayes 3.2 (Ronquist et al. 2012), with default prior settings and implementing the best-fit model (GTR+I+G) determined by PartitionFinder. Four separate runs were set up with eight Markov chains, each initiated from random trees and allowed to run for five million generations, sampling every 100 generations. Analyses were terminated when the standard deviation of split frequencies was less than 0.005, the first 25% of trees were discarded as "burn-in", and trees were constructed under the 50% majority consensus rule. Maximum Likelihood (ML) analysis was carried out with RaxML GUI version 2.0 (Edler et al. 2020) implementing the GTRGAMMA model of sequence evolution, which is recommended over GTR+G+I because the 25 rate categories account for potentially invariant sites (Stamatakis 2006). Support for internal branches in ML and BI trees was quantified using bootstrap (1000 replicates) and posterior probability, respectively. The two xenodermids in the data set were used to root trees following the phylogenetic results of Deepak et al. (2020).

Morphological analysis

In addition to the materials of the species described here, we examined the type material of all species of *Xylophis*, including junior synonyms, except for *X. perroteti* for which we relied on data and photographs presented by Deepak et al. (2020). Total length, circumference, snout-vent length and tail length were measured with thread and a ruler to the nearest 1 mm. Other dimensions were recorded using a Mitutoyo™ digital caliper to the nearest 0.1 mm. Photographs were taken with a Canon EOS 7D (Canon Inc., Taiwan) digital camera mounted with a 100 mm macro lens. Bilateral scale counts separated by a slash are given in left/right order. Ventrals were counted following Gower and Winkler (2007), such that the

Table 2. Meristic and morphometric (in mm) character data for *Xylophis deepaki* **sp. nov**. † indicates data from Ganesh et al. 2012. — indicates data not recorded. Abbreviations for characters follow Gower and Winkler (2007).

Registration number	**ZSI-CZRC-7218**	**BNHS 3383**	**ZSI-SRC-VRS-287**	**BNHS 1762**	**†CSPT/S 77A & B**
Specimen status	Holotype	Paratype	Paratype	Referred specimen	Referred specimens
Sex	Male	Male	Male	Female?	Male & Female
DSR	15:15:15	15:15:15	15:15:15	15:15:15	15:15:15
SL	5/5	5/5	5/5	5/5	5/5
IL	5/5	5/5	5/5	5/5	5/5
TL	136	112	125	115	176–199
tL	16	10.4	15.4	—	10–16
W	3.4	3.1	3.7	—	4.62–4.70
V	123	120	123	c.125	117–118
SC	23	22	20	16	13–18
HL	4.3	3.8	4.4	—	4.75–4.93
Hw	3.6	2.9	3.7	—	4.27–4.55
F-Snt	1.4	1.5	1.5	—	1.87–1.99
PrfL	0.6	0.6	0.6	—	0.51–0.65
F-Snt ÷ PrfL	2.1	2.5	2.3	—	3.06–3.60
FL	2.6	1.9	2.1	—	2.51–2.55
Fw	1.8	1.8	2.0	—	2.23–2.33
PaL	2.2	2.0	2.5	—	2.47–2.62

anterior-most ventral is identified as the anterior-most mid-ventral scale posterior to the mental shield. We followed Günther (1875), Smith (1943) and Gower and Winkler (2007) in identifying the elongate scale contacting the front of the eye as a loreal rather than a preocular. Dorsal scale rows were counted in as short (longitudinally) a transverse zig-zag as possible. Abbreviations for morphological measurements and meristic characters (Table 2) follow Gower and Winkler (2007). The hemipenis of ZSI-CZRC-V-7218 was partially everted during preservation and was further prepared ex-situ following methods described by Zaher (1999), Myers and Cadle (2003), and Zaher and Prudente (2003). Description of hemipenis characters and terminology follows Dowling and Savage (1960), Myers and Campbell (1981), Zaher (1999) and Zaher et al. (2019). The hemipenial morphology of the new species was compared with its congeners based on the data provided by Boulenger (1890), Smith (1943), McDowell (1987), Gower and Winkler (2007) and Zaher et al. (2019). In addition, the hemipenis of *X. mosaicus* (BNHS 3578, not described by Deepak et al. 2020) was also included in comparisons based on an unpublished photograph. The hemipenis was photographed through a stereo-zoom microscope (Leica M2054 A, Heerbrugg, Switzerland) and the measurements were taken using the digital caliper.

Catalogue numbers for voucher specimens bear the following prefixes: BNHS (Bombay Natural History Society, Mumbai, India); CSPT (Chennai Snake Park Trust, Chennai, India); FMNH (Field Museum of Natural History, Chicago, USA); ZSI-CZRC (Zoological Survey of India, Central Zone Regional Centre, Jabalpur, India); ZSI-SRC (Zoological Survey of India, Southern Regional Centre, Chennai, India).

Results

Molecular systematics

Both ML and BI analyses recovered the same set of relationships (Fig. 1) and these are fully congruent with those reported by Deepak et al. (2020). *Xylophis* forms a clade (BI 0.83, ML 48) comprising two main lineages, one clade comprising the species with 13 dorsal scale rows at midbody (*X. perroteti* + *X. mosaicus*) and the other of species with 15 dorsal scale rows (*X. captaini*, *X. stenorhynchus* and the new species described herein). The new species is maximally supported as most-closely related to *X. captaini* (Fig. 1). The uncorrected pairwise genetic distance in *16S* between the new species and *X. captaini* is 4.2% followed by 8% with *X. stenorhynchus*, and 8.6% and 9.6–10.7% with *X. mosaics* and *X. perroteti*, respectively (see Table 3).

Xylophis deepaki sp. nov.

http://zoobank.org/E3969D3B-48CE-4760-8FF9-A65E19A09AD6

Figs 1–5A. Tables 1–2.

Chresonyms

Xylophis perroteti – Rajendran (1985).

Xylophis captaini – Gower and Winkler, 2007 [in part]; Ganesh (2010); Ganesh et al. 2012; Bhupathy et al. 2016 [in part]

Table 3. Uncorrected pairwise distances for mitochondrial 16S rRNA gene among samples used in the phylogenetic analyses.

	Species	1	2	3	4	5	6	7	8	9	10
1	Xylophis captaini										
2	*Xylophis deepaki* **sp. nov.**	0.042									
3	Xylophis mosaicus	0.095	0.086								
4	*Xylophis perroteti* BNH S3582	0.109	0.102	0.051							
5	*Xylophis perroteti* CES2016b	0.101	0.096	0.046	0.000						
6	*Xylophis perroteti* BNHS 3581	0.110	0.107	0.055	0.000	0.006					
7	Xylophis stenorhynchus	0.086	0.080	0.063	0.074	0.070	0.077				
8	Pareas monticola	0.148	0.150	0.112	0.090	0.114	0.090	0.117			
9	*Pareas* cf. *formosensis*	0.119	0.119	0.069	0.087	0.083	0.089	0.091	0.093		
10	Achalinus rufescens	0.126	0.130	0.119	0.137	0.132	0.138	0.112	0.141	0.136	
11	Xenodermus javanicus	0.149	0.151	0.126	0.151	0.151	0.151	0.136	0.124	0.147	0.098

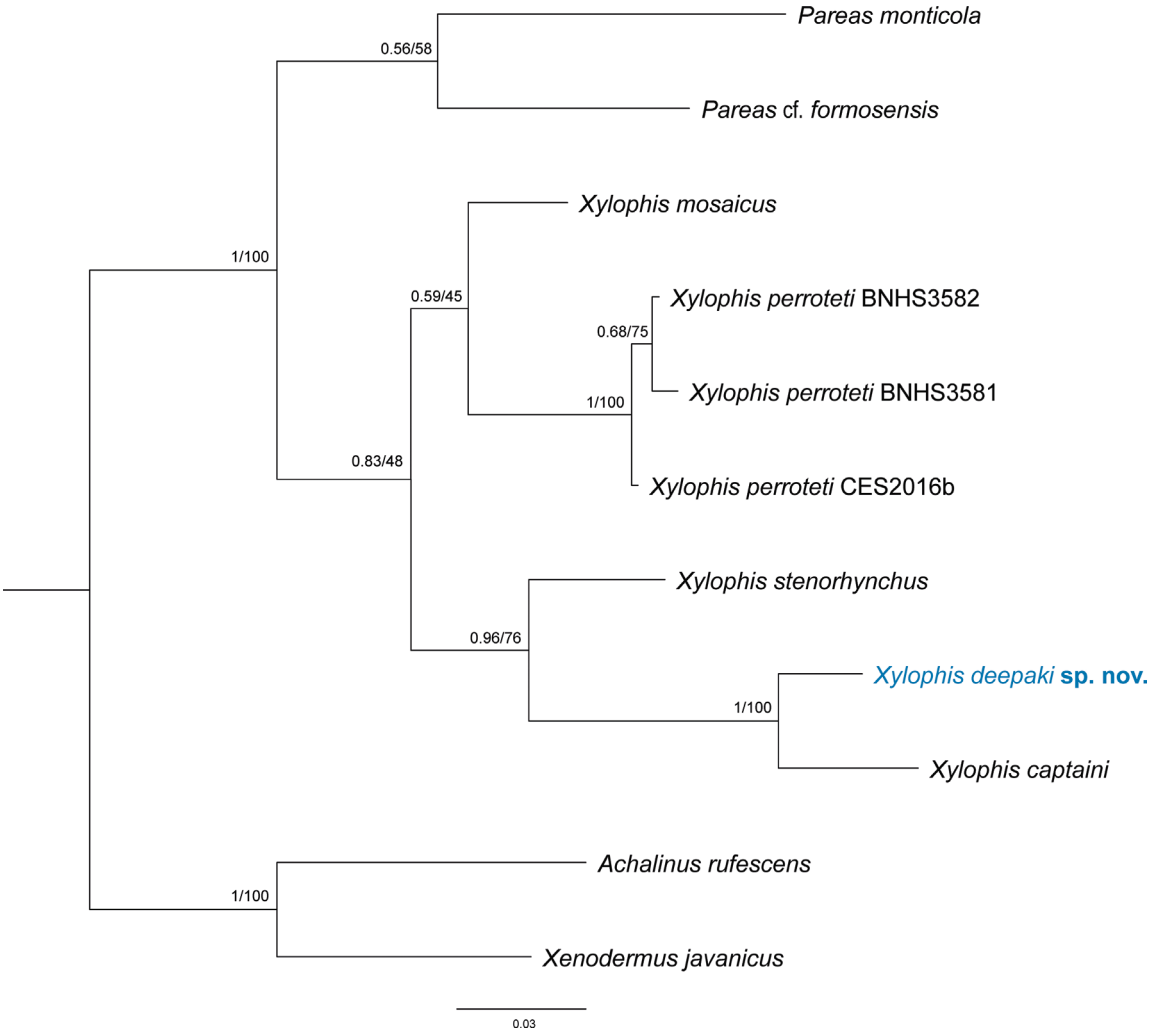

Figure 1. BI Phylogeny showing the phylogenetic relationships of *Xylophis deepaki* **sp. nov.** Numbers at internal branches are posterior probability and ML bootstrap support values, respectively. Scale bar represents substitutions per site.

Type locality. India, Tamil Nadu: close to Marthandam, 8° 20.610'N, 77° 13.092'E, 56 m a.s.l., plantation, 23 November 2016, Surya Narayanan and Pratyush P. Mohapatra leg., see map in Fig. 2.

Type specimens. Holotype male, spirit preserved, with hemipenis in a separate vial, ZSI-CZRC-V-7218 (Figs 3, 4, 5A). Paratype-1, male, collection details as for holotype, ZSI-SRC-VRS-287 (Figs 6 A–D, 5B). Paratype-2, male, collector unknown, from Potugani junction, Kanyakumari Dist., Tamil Nadu (=Pathugani) (8°28.672'N, 77°13.627'E, 240 m a.s.l), collection date unknown, BNHS 3383 (see Gower and Winkler 2007: 316).

Referred specimens (n = 3). BNHS 1762, female (?), collected from Ashambu hills, Tamil Nadu is treated as a referred specimen and not a paratype because of the imprecise locality and poor condition of the specimen. CSPT/S 77a and 77b from Ambadi estate, Kanyakumari District, Tamil Nadu (reported as *X. captaini* by Ganesh et al. 2012) are referred but have not been examined by us.

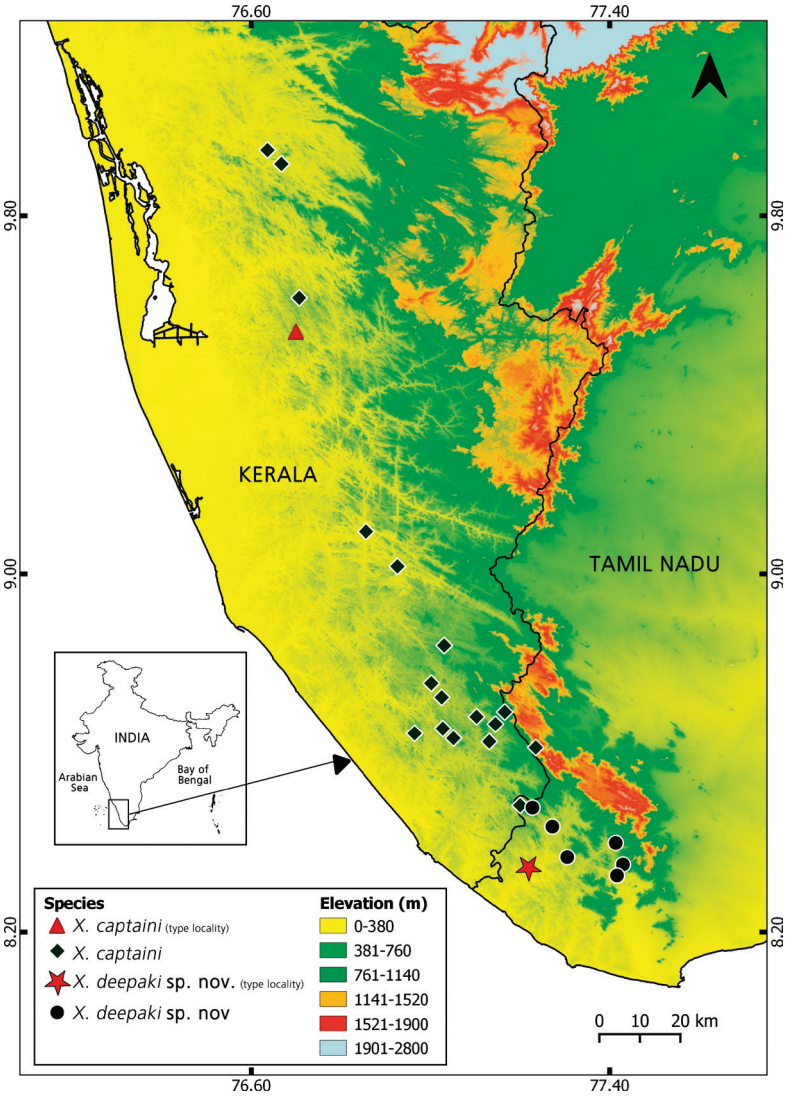

Figure 2. Distribution of *Xylophis captaini* and *X. deepaki* **sp. nov.** in the Western Ghats based on specimens examined in this study and observations of uncollected animals reported in the text.

Diagnosis. The new species is assigned to the genus *Xylophis* based on the anterior-most (three) pairs of infralabial shields reduced to narrow strips, together much smaller than large pair of anterior chin (genial) shields. *Xylophis deepaki* **sp. nov.** is small (maximum known total length 199 mm), with 15 dorsal scale rows at midbody, 117–125 ventrals (n=6), 13–23 subcaudals (n=6), internasal length almost equal to the prefrontal length, a thick and ventrally near-complete off-white collar, and mostly smooth hemipenial body and lobes.

Xylophis deepaki **sp. nov.** differs from *X. perroteti* (including its putative synonym *X. microcephalum*, see Deepak et al. 2020) and *X. mosaicus* in having 15 rather than 13 dorsal scale rows along most of the body. Additionally, the new species has relatively short prefrontals and broad, squarish internasals (vs. long prefrontals and internasals), and a distinct off-white collar band (vs. absent). The hemipenis of *X. deepaki* is smooth with few, ill-defined flounces towards the distal end of the lobes (vs. well-defined longitudinal flounces in *X. perroteti*) and differs from that of *X. mosaicus* in having a short, smooth body and lobes (vs. elongated body, ill-defined 'calyces' and scattered fleshy papillae on the distal part of the body and the lobes).

The new species differs from *X. stenorhynchus* (and its putative synonym *X. indicus*, see Gower and Winkler 2007) in having generally fewer ventrals, 117–125 (vs. 120–135), internasals almost as long as the prefrontals along the midline (vs. substantially shorter than prefrontals), the length of first and second infralabialstogether shorter than the third (vs. about as long as the third infralabial), and a wide off-white collar extending to the ventral surface (vs. narrow and dorsally restricted collar band).

Xylophis deepaki **sp. nov.** differs from its superficially most-similar congener and closest relative, *X. captaini*, in having more ventral scales, 117–125 (vs. 102–113), a wide off-white collar band that extends onto the ventral surface (vs. narrow and dorsally restricted collar band), lacking a dark lateroventral line on the third dorsal scale row on each side (vs. present in *X. captaini*) and in having a largely smooth hemipenis with a protrusion on the hemipenial body (vs. proximal half of each lobe having about eight, approximately transverse fleshy flounces and lacking a protrusion on the body). The new species dif-

Figure 3. Holotype of *Xylophis deepaki* **sp.nov** (ZSI-CZRC-V-7218) in dorsal (A) and ventral (B) views. Scale bar = 10 mm

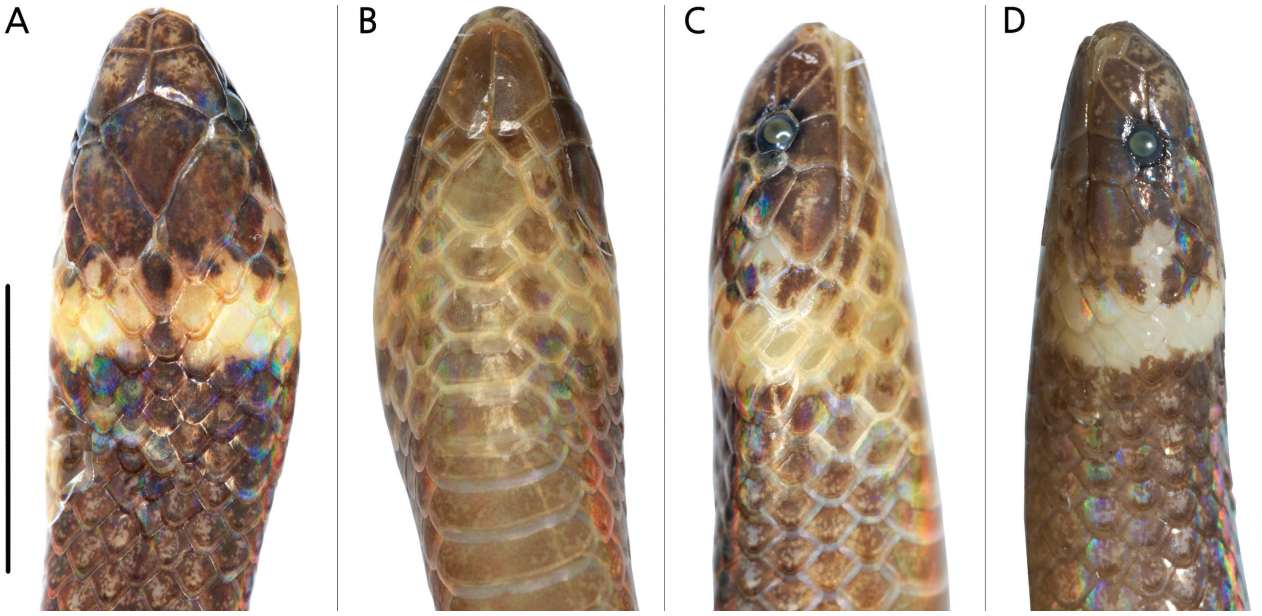

Figure 4. Head of holotype of *Xylophis deepaki* **sp. nov.** (ZSI-CZRC-V-7218) in dorsal (A), ventral (B), right lateral (C) and left lateral (D) views. Scale bar = 10 mm.

fers from congeners by an uncorrected pairwise DNA-sequence difference of > 4% in mitochondrial *16S.*

Description of holotype (ZSI-CZRC-V-7218)**.** Some morphometric and meristic data are given in Table 2. A male specimen, in good condition, a longitudinal ventral incision into coelom extending from 64th to 67th ventral. The body preserved in a loose coil, slightly dorsoventrally flattened, with a small constriction slightly below the midbody caused by overly tight tying of a field tag. Both hemipenes removed for further preparation, stored with the specimen. Colours have not noticeably faded in preservative.

Back of head slightly wider than anterior of the neck and narrowing steadily anteriorly thereafter. Head short, 4.3 mm, and high, 2.6 mm, with steeply domed snout in lateral view. Snout abruptly tapering to blunt, rounded tip in dorsal view. Rounded rostral short in dorsal view, much shorter than the distance between it and prefrontal scales. Nasals undivided, not in contact with each other and each smaller than the rostral that separates them anteriorly. Naris subcircular, situated in the anterior part of the nasal. Paired internasals large, much larger than the nasals and rostral. Prefrontals distinctly larger than the internasals in area and slightly longer along the midline suture (0.7 mm vs. 0.5 mm between internasals). Frontal kite-shaped with the anterior margin slightly convex, no-

Figure 5. *Xylophis deepaki* **sp. nov.** showing colour in life. A. Holotype ZSI-CZRC-V-7218, B. Paratype ZSI-SRC-VRS-287.

ticeably longer (2.6 mm) than broad (1.8 mm) and almost as long as the parietals. Parietals longer than wide, with short midline contact (0.4 mm), much shorter than midline contact between internasals and between prefrontals.

Five supralabials, third and fourth contacting eye; first very small, contacting second supralabial, rostral and nasal; second is a thin strip contacting the nasal, loreal and adjacent supralabials; third taller than long, contacting loreal and adjacent supralabials; fourth slightly larger than the third, contacting postocular, anterior temporal and adjacent supralabials; fifth largest, touching anterior and lower posterior temporal as well as fourth supralabial. Eyes small with a subcircular pupil. One supraocular and one postocular on each side, subequal in size. One anterior temporal, larger than two subequal posterior temporals. Mental short, broad, with a tripartite anterior end. Anterior two infralabials short and thin, second slightly larger. The length of first two infralabials together shorter than the third, and in lateral view falling notably short of halfway along the length of anterior genials. Fourth and fifth infralabials much larger. Pair of anterior genials, large, meeting substantially along the midline. Posterior pair of genials much smaller, contacting briefly along the midline, largely divided by the intervening anteriormost ventral. First unpaired midventral scale (= first ventral, here) between posterior genials, larger than the subsequent ventrals, longer than wide and the subsequent ventral scales are wider than long. Body subcylindrical, ventral surface slightly flattened, Dorsal scales in 15 rows at the level of fifth ventral until the posteriormost ventral. Dorsal scales macroscopically smooth, regularly arranged, evenly sized across the body and apical pits absent. Ventrals scales 123 in number, all similarly proportioned except for anteriormost ventral. Anal shield undivided, larger than the last ventrals, its posterior margin overlaps six scales on each side, including the subcaudals. Subcaudals in 23 pairs. Tail terminates in bluntly tapering, apical, spine-like scute.

Scales on the body and tail iridescent. Head scales match this, except for some of the anterior supralabials and infralabials. Overall, the specimen is in shades of brown mottled with off-white and with a distinct off-

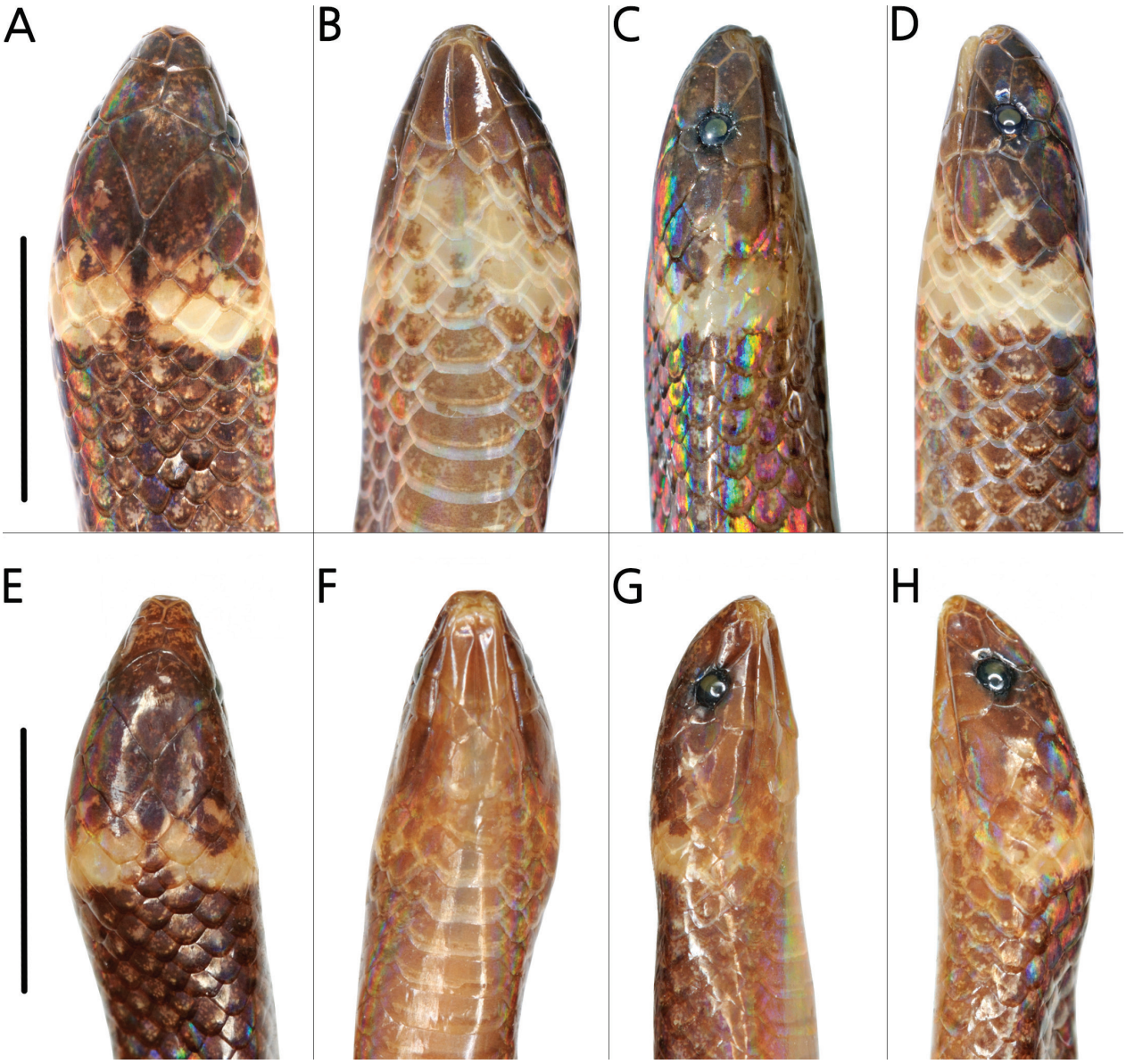

Figure 6. Views of the head of paratypes of *Xylophis deepaki* **sp. nov.** (A–D. ZSI-SRC-VRS-287, E–H. BNHS 3383); dorsal view (A, E), ventral view (B, F), right lateral view (C, G) and left lateral view (D, H). Scale bar = 10mm.

white collar. Ventral surface paler and less mottled than dorsum, and first three ventrals and adjacent scales mottled off-white continuation of the collar. The main body of each ventral and subcaudal scale are fairly uniform, pale brown, sometimes with an indistinct dark proximal margin anteriorly and off-white margin posteriorly. Upper and sides of the head and body-tail junction are darkest parts of the animal, notably darker than the body. Dorsal head scales generally dark brown with distinct irregular off-white mottling on all scales except for darker frontal. First two supralabials and first three infralabials off-white with a small brown patch only on the second supralabial. Other lateral head scales brownish with very little pale mottling except for a substantial off-white patch on the anterior part of the lower posterior temporal. Collar band off-white, approximately two scales wide with slightly irregular anterior and posterior edges, extends laterally on both sides and connected ventrally where it is two to three scales wide but somewhat broken by brown mottling. Three distinct dark lines on the dorsal surface, running from behind the collar to tail tip, all more than half a dorsal scale wide, being one scale wide at the body-tail junction. Distinct dark dorsal stripe up to almost one scale wide, medially along the middorsal line, narrowly breaking the pale collar mid-dorsally. Middorsal line confined to the midline (eighth) scale row and the pair of dorsolateral lines confined to the 5th dorsal scale row on each side. Three thin, indistinct ventrolateral lines run along the first three dorsal scale rows of each side, becoming feeble and almost invisible at the level of approximately the 30th ventral. Between dark longitudinal lines, scales are various shades of mottled pale brown and off-white. In life, the colouration is almost the same as in the preserved condition except for the pale collar which has faded in ethanol-preserved specimens.

Hemipenis (Fig. 7) 8.5 mm in total length, 53% of the tail length, extending to posterior of the 12th subcaudal. Bilobed and deeply forked, for 37.6% of total length. Apical lobes cylindrical and slightly unequal (length and the maximum width of each lobe: 5.3 and 0.9 mm; 4.6 and 0.8 mm, respectively). Hemipenial body unornamented except for a fleshy protuberance on the sulcal side, slightly proximal to the fork, below the sulcus division. The sulcus bifurcates at almost three quarters along the length of the hemipenial body and runs centro-linearly, terminating distally below the apex. In the fully everted hemipenis, the sulcus canal is not exposed but rather enclosed by the lips. The head appears to be rounded and disk-shaped. Towards the distal end, there are 4–8 oblique, inconspicuous flounces on both sides of the sulcus spermaticus. A few scattered microscopic papillae on the flounces at the distal end.

Variation in paratypes. See Table 2 for variation in some meristic and morphometric features. Paratypes generally very similar to holotype. Both paratypes generally in moderate to good condition. In ZSI-SRC-VRS-287 the upper posterior temporals slightly smaller on both sides; the posterior pair of genials separated by a macroscopically indistinct thin slither of the first ventral; the third ventral is the first scale that is wider than long. ZSI-SRC-VRS-287 is preserved in a U-shaped loose coil and lacks any incision into the coelom; head slightly narrower (not an artefact of preservation); frontal more domed anteriorly, making the prefrontal appear shorter along the midline in dorsal view; midline contact between parietals slightly longer than between both internasals and both prefrontals; third supralabial wider along the lower margin; pale collar less distinct ventrally. In BNHS 3383, the posterior margin of the anal shield overlaps five rather than six scales on each side, including the subcaudals.

Etymology. This species is named in honour of the Indian herpetologist Dr Deepak Veerappan, in recognition of his substantial, 21st Century contributions to herpetology, including work on *Xylophis* systematics. We suggest the common name Deepak's wood snake (English).

Distribution and natural history. Based on the limited current knowledge, *Xylophis deepaki* **sp. nov.** is endemic to Tamil Nadu, known from only a few locations along the south-western slopes of the southernmost part of the Western Ghats. Apart from Melpuram, Pathukani, Ambadi estate, and Ashambu hills in Kanyakumari District (vouchered specimens), *X. deepaki* is also known from Kulashekaram, Keeriparai and Thadikarankonam, Kanyakumari District of Tamil Nadu (uncollected, live observations), at elevations of 86–245 m a.s.l.. This region receives an annual rainfall of ca. 1500–2600 mm (Glenna et al. 2018). The lower plains here, including the type locality, are currently dominated by extensive monocultures of rubber (*Hevea brasiliensis* Müll.) and partly teak (*Tectona grandis* L.) plantations. The natural vegetation of this region is of southern tropical dry deciduous

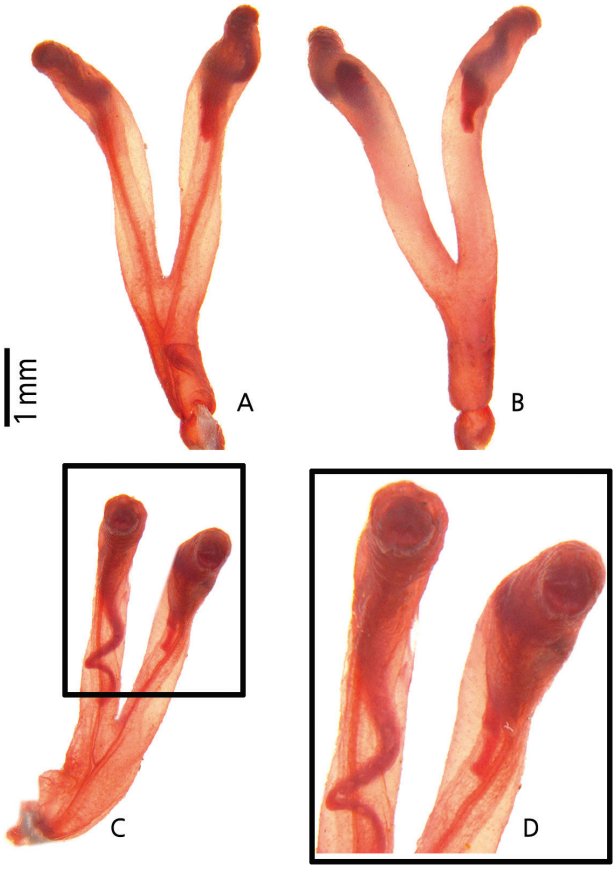

Figure 7. Hemipenis of *Xylophis deepaki* **sp. nov.** (ZSI-CZRC-V-7218). (A) sulcate view of left side; (B) asulcate view of left side; (C) sulcate view of the right side; (D) enlarged view of the distal portion of the sulcate side. Scale bar = 1 mm.

forest with trees such as *Haldina cordifolia* (Roxb.), *Cochlospermum religiosum* (L.), *Dillenia pentagyna* Roxb., *Hydnocarpus laurifolia* (Dennst.), *Hymenodictyon excelsum* (Roxb.) and *Lannea coromandelica* (Houtt.) with mostly red soil and mixed with varying quantity of ferruginous elements (Henry and Swaminathan 1981).

The holotype (ZSI-CZRC-V-7218) and paratype-1 (ZSI-SRC-VRS-287) along with three other individuals (uncollected) were found in a private plantation area consisting of mixed coconut and plantain crops (Fig. 8). These animals were found while digging humus-rich, clay mixed red soil in the farmed land. *Xylophis deepaki* **sp. nov.** appears to be common within its currently known range. One of us (AB) has encountered as many as eight individuals of *Xylophis* cf. *deepaki*. while removing stone debris in a rubber plantation at ca. 14:00hrs in November 2013 at Thadikarankonam, Kanyakumari District, Tamil Nadu and one specimen from Keeriparai, Kanyakumari District, Tamil Nadu was found moving on the surface during rains in a rubber plantation (farmland) at 18:00hrs in October 2014; these records are provisionally treated as likely to be the new species because these localities are close to the type locality of *X. deepaki* **sp. nov.** Rajendran (1985) reports a series of *Xylophis perroteti* found sympatric with *Rhinophis travancoricus* in Ambadi estates near Pechiparai dam, with four individuals of *Xylophis* sp. found while digging along a brook; these are

very far from the known distribution of *X. perroteti* and at much lower elevations (see Deepak et al. 2020), and instead might also represent *X. deepaki* **sp. nov.** based on the locality. Rajendran (1985) stated that the *Xylophis* he observed likely fed on termites, but the basis for that is unclear, and as far as we know, no feeding observations have yet been reported. Gower and Winkler (2007) reported earthworms in the guts of two specimens in *X. captaini*.

Currently, *X. deepaki* **sp. nov.** is not reported from any protected areas and all the known records are from human-modified landscapes such as plantations, except for the record from Ashambu hills. Bhupathy et al. (2016) predicted *X. captaini* to occur in Kanyakumari Wildlife Sanctuary and Kalakkad Mundanthurai Tiger Reserve based on the results from environmental niche modelling, where possibilities of sympatric occurrence of the both *X. captaini* and *X. deepaki* cannot be ruled out. Additionally, the underlying distribution data for *X. captaini* used by Bhupathy et al. (2016) included the southernmost records from Gower and Winkler (2007) that are here shown to instead represent *X. deepaki* **sp. nov.**

Xylophis spp. are not protected under any schedules of the Indian Wild Life (Protection) Act, 1972. We encourage additional studies on their taxonomy, ecology and evaluation of their conservation status of these snakes, which might aid in future amendment of the Act.

Revised key to the species of *Xylophis*

This revised key is based on that presented by Deepak et al. (2020), modified by incorporating *X. deepaki* **sp. nov.** Note that, following Gower and Winkler (2007), the 'first ventral' here is the anteriormost midline ventral scale behind the mental. Gower and Winkler's (2007) and Deepak et al.'s (2020) keys mistakenly used a lower limit of 106 ventrals for *X. captaini*, instead of 102 (Gower and Winkler 2007). Furthermore, ranges of ventrals for one of the species with 15 midbody dorsal scale rows might need modifying if Inger et al.'s (1984) count of 119 for FMNH 217695 (see Discussion) is confirmed and if this specimen can be identified to one of the currently recognised species included in this key.

1 Dorsal scales in 13 rows at midbody; supraocular notably larger than postocular; six or more infralabials **2**
– Dorsal scales in 15 rows at midbody; supraocular and postocular shields subequal in size; five infralabials **3**
2 First ventral separates the posterior genials and contacts the anterior genials ..... ***X. perroteti*** (including its putative junior subjective synonym *X. microcephalum*)
– Posterior genials in midline contact, preventing contact between first ventral and anterior genials ... ***X. mosaicus***
3 Ventrals 120–135; prefrontal shields much longer than internasals; second infralabial notably longer than first, the two together being about as long as the third infralabial ..... ***X. stenorhynchus*** (including its putative junior subjective synonym *X. indicus*)
– Ventrals 106–125; prefrontals and internasals subequal in midline length; second infralabial only marginally longer than first, the two together being shorter than the third infralabial **4**
4 Ventrals 102–113; pale collar restricted to dorsum; hemipenis body with large flounces ..... ***X. captaini***
– Ventrals 117–125; pale collar extends onto venter; hemipenis body without flounces ..... ***X. deepaki* sp. nov.**

Discussion

Our description of *X. deepaki* **sp. nov.** increases the total number of currently recognised *Xylophis* species to five, excluding the two putative synonyms *X. microcephalum* and *X. indicus* (see Gower and Winkler 2007; Deepak et al. 2020). With three of the five currently recognised species being described since 2007 it seems that great advances in *Xylophis* taxonomy have been made. However, these advances are largely restricted to systematics, with very little information available on the precise distributions of each species, or their natural history, population status, feeding and reproductive ecology, and conservation status.

Classification of *Xylophis* under the newly described subfamily Xylophiinae (family Pareidae) based largely on molecular phylogenetics (Ruane and Austin 2017; Deepak et al. 2018) has received support from morphology (Zaher et al. 2019). The latter authors also provided information on the hemipenial morphology of *X. perroteti.* The data on hemipenial morphology of *Xylophis* by Boulenger (1890), Smith (1943), McDowell (1987), Gower and Winkler (2007), Zaher et al. (2019) and the present work, indicates that the hemipenis of *Xylophis* differs substantially from that of other (Pareinae) genera within Pareidae by the absence of calyces on the lobes. The report of calyces at the distal end of the lobes of the hemipenis of *X. stenorhynchus* by Smith (1943) was doubted by Gower and Winkler (2007).

During this study, it was drawn to our attention (V. Deepak, pers. comm.) that the numbers of subcaudals of BNHS 1751 (male *X. mosaicus*) and BNHS 1759 (female *X. perroteti*) were erroneously mixed up by Deepak et al. (2020). We can correct this by reporting that BNHS 1751 has 17/17 subcaudals (not 12/13) and that BNHS 1759 has 12/13 subcaudals (not 17/17) (SN, pers. obs.).

Figure 8. Habitat of *Xylophis deepaki* **sp. nov.** in Melpuram, Kanyakumari Dist., Tamil Nadu, showing some banana and coconut within rubber plantation.

As per our present understanding, *X. deepaki* **sp. nov.** is the only species of *Xylophis* to occur at the far southern end of the Western Ghats, where it is restricted to low and mid-elevations of the southwestern slopes of this mountain range. However, it should be noted that previous confusion with *X. captaini*, and lack of dedicated *Xylophis* surveys (other than those reported by Gower and Winkler 2007 and Bhupathy et al. 2016) makes it likely that the full extent of the distributions of *X. captaini* and *X. deepaki* **sp. nov.** (as well as other congeners) are not yet known.

In addition to new materials reported here, we have identified some of the *Xylophis captaini* specimens (BNHS 1762, BNHS 3383, CSPT 77a, b) previously referred by Gower and Winkler (2007) and Ganesh et al. (2012) as *X. deepaki* **sp. nov.** because of their southerly locality records, high ventral counts and other diagnostic characters. Gower and Winkler (2007) used data from Inger et al. (1984) to refer two specimens (FMNH 217695 and 217696) from Ponmudi, southern Kerala to *X. captaini.* One of these (FMNH 217696) was reported by Inger et al. (1984) as a male having only 102 ventrals (mistakenly reported as 104 by Gower and Winkler 2007) and so is very likely to be *X. captaini*. The other specimen (FMNH 217695) is reported by Inger et al. (1984) as a female with 119 ventrals—we have not examined this specimen directly and its identity is less clear, although Inger et al.'s (1984) colour description for both specimens (narrow collar, dark line on third dorsal scale row) match *X. captaini* more closely than *X. deepaki* **sp. nov.** Inger et al. (1984) reported the two specimens from 145 and 300 m elevations, both higher than the 120 m elevation or lower for the type material of *X. captaini* reported by Gower and Winkler (2007). Bhupathy et al. (2016) reported the elevational range of *X. captaini* to be up to 1,000 m but scalation data or photographs were not presented, so we are unable to check the identity of the *Xylophis* specimens they recorded.

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Competing interests

The authors have declared no competing interests exist.

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