

## Taxonomic reassessment of the Common Indian Wolf Snakes *Lycodon aulicus* (Linnaeus, 1758) complex (Squamata: Serpentes: Colubridae)

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**Abstract.** We studied the population systematics of the group of the Common Indian wolf snake (*Lycodon aulicus* s. lat.) based on a series of specimens from throughout most of their geographic range. Two discrete species-groups could be discerned based on head dimensions, collar band pattern, hemipenial morphology and frontal-preocular-prefrontal-suproocular scale contact configurations (with outliers). The first one contains specimens agreeing with the morphology of the name-bearing type of *Lycodon aulicus*; the other includes specimens agreeing with the morphology of *Lycodon anamallensis* (so far within the synonymy of *L. aulicus*), which is here revalidated at species-level. We formally report the presence of the presumed Sri Lankan endemic *Lycodon osmanhilli* group taxa in the Indian peninsula and we synonymise *L. osmanhilli* with the senior nomen *L. anamallensis* which is based on an Indian specimen. Our series of specimens show clear and sometimes non-overlapping geographical variations in ventral, subcaudal scale counts and relative tail lengths within both species.

**Key words.** Collar band, head dimension, Indian peninsula, Sri Lanka, Wolf Snakes.

### INTRODUCTION

The common Indian wolf snake *Lycodon aulicus* (Linnaeus, 1758) is a non-venomous, mainly nocturnal, oviparous colubrid snake found in the Indian subcontinent (Whitaker & Captain 2004). It is one of the commonest and most ‘well-known’ snakes in tropical Asia. It was described by Carolus Linnaeus in his *Systema Naturae*. Subsequently, Patrick Russell, the “father of Indian Ophiology”, included this species in his treatise (Russell 1796). It is understood to be widespread, human-commensally and common in almost all herpetological literature (e.g., Whitaker & Captain 2004). But yet, as often the case with such ‘well-known’ South Asian snakes like the Rock Python *Python molurus* (see Wulf & O’Shea 2010), the Spectacled Cobra *Naja naja* (see Wüster 1998a), the Russell’s Viper *Daboia russelii* (see Wüster 1998 b), the Bronzeback Tree Snake *Dendrelaphis tristis* (see Vogel & Van Rooijen 2009) and the Keelbacks *Xenochrophis piscator* and *Amphiesma stolatum* (see Vogel & David 2012; Guo et al. 2014), the taxonomy of *Lycodon aulicus* is still far from being resolved and the variation is not well known.

This species was originally described based on the holotype NHR Lin-21 (formerly MAFR), a 250 mm long specimen (Mus. Drottn.) supposed to come from “America”. The type specimen is still extant in the Royal Museum of Stockholm, formerly the Museum Adolphi Friderici. The type locality was later proved to be in error and was corrected to ‘India’ by Kramer (1977). Laurenti (1768) allocated this species to the genus *Natrix*, as *Natrix aulica*.

Duméril et al. (1854) transferred *Natrix aulica* to the genus *Lycodon*, as *Lycodon aulicum*.

Cantor (1839) described *Lycodon subfuscus* based on a single specimen from Bengal, in north-eastern India. Cantor (1839) also described *Lycodon atropurpureus* based on a single specimen from “Mergui”, now Myeik, in southern Myanmar. Günther (1864) described *Lycodon anamallensis* based on a single specimen from the Anamallay Hills of the Western Ghats, in peninsular India. Later Wall (1909) described the subspecies *Lycodon aulicus oligozonatus* based on specimens from Cannanore (in Malabar Coast) and Bellary (in Deccan plateau), in southern India. All these four nomina were synonymised by Smith (1943) with *Lycodon aulicus* (Linnaeus, 1758). Taylor (1950) described *Lycodon osmanhilli* based on two specimens (a holotype and a paratype) from Colombo in Sri Lanka. Günther (1864) and Boulenger (1893) listed several ‘varieties’ of *L. aulicus*. As can be seen from the list of synonyms which were based on specimens from ‘India’, Bengal, Colombo and Mergui and the generic transfers from across late 18<sup>th</sup> century to mid 20<sup>th</sup> century (Wallach et al. 2014), the *Lycodon aulicus* complex has had a rather controversial taxonomic and nomenclatural history.

Except for *Lycodon osmanhilli*, all of the above-mentioned nomina are currently considered to be subjective junior synonyms of *Lycodon aulicus* (see, for example, Whitaker & Captain 2004; Uetz 2016). Wallach et al. (2014) considered *L. osmanhilli* a synonym of *L. aulicus* as well, but other authors (Das & De Silva 2005; Somaweera 2006) considered it a valid species. While the validity of *Lycodon osmanhilli* is still being discussed,

recently Pyron et al. (2013), in their molecular phylogeny, showed that *Lycodon osmanhilli* is distinct from *L. aulicus*. Their phylogenetic tree revealed that *L. aulicus* is the sister taxon of *L. zawi* Slowinski, Pawar, Win, Thin, Gyi, Oo & Tun, 2001 from the Indoburmese region, while *L. osmanhilli* is the sister taxon of *L. capucinus* (Boie, 1827) of Southeast Asia (Pyron et al. 2013). Siler et al. (2013) even synonymized *L. capucinus* with *L. aulicus*, although they did not examine Indian or Sri Lankan material, a hypothesis not followed here and by later workers (Vogel & Harikrishnan 2013; Wallach et al. 2014).

Ganesh & Chandramouli (2011) remarked on two syntopic morphotypes of the *Lycodon aulicus* complex from Coromandel Coast and enumerated morphological differences. They pointed out differences in general body colouration, head dimensions and band pattern between the two morphotypes and stated that one of the morphs resembled the Sri Lankan endemic *L. osmanhilli*. Our further examination of a series of preserved specimens from several localities, including the type specimens, revealed consistent differences, as suggested earlier (Ganesh & Chandramouli 2011). In this work, we reassess the systematics of *Lycodon aulicus* sensu auctorum and provide formal taxonomic and nomenclatural implications.

## MATERIALS & METHODS

For this study we investigated a total of 74 specimens of the complex of *Lycodon aulicus* originating from Mauritius and Pakistan in the west, across India on to Myanmar in the east, Nepal in the north and Sri Lanka in the south, thus essentially covering the Indian subcontinent. Several live examples were also examined. Specimens were examined for external morphological characters. Forty-four morphological characters were recorded for each specimen. Not all of these characters were useful to distinguish between species in this study, but all of them were compared because they may be useful for further taxonomic actions. Measurements, except body and tail lengths, were taken with a slide-caliper to the nearest 0.1 mm; all body measurements were made to the nearest millimetre. The number of ventral scales was counted according to Dowling (1951). Hemipenial morphological definitions and terminologies follow Dowling & Savage (1960). Half ventrals were counted as one. The first scale under the tail meeting its opposite was regarded as the first subcaudal, the terminal scute was not included in the number of subcaudals. The dorsal scale rows were counted at one head length behind head, at midbody (i.e., at the level of the ventral plate corresponding to a half of the total number of ventrals), and at one head length before vent. We considered infralabials being those shields that were completely below a supralabial. Values for paired

head characters are given in left/right order. Temporal scales were defined as the scales of which more than half of the area lies in front of an imaginary line that extends from the apex of the last supralabial to the posterolateral corner of the parietal. Ratio of the length of (complete) tail to the total length of the snake (i.e., from snout tip to tail tip) is calculated as relative tail length. The pale bands on the body and tail were counted on one side, usually the right side. Hardly visible or incomplete bands were counted as one band; bands that were fused (often forming an "X") were counted as two. The collar on the neck was not counted and bands covering the anal shield were added to the bands of the body. Sex of preserved specimens was determined by dissection of the ventral tail base, while that of live individuals was examined to the extent possible by gentle anal palpation. Statistical tests were carried out in MS Office Excel and PAST software (Hammer et al. 2000).

**Abbreviations.** Avg. – average; BMNH: The Natural History Museum, London, UK. – CAS: California Academy of Sciences Museum, California, USA. – CSPT/S: Chennai Snake Park Museum, Chennai, India. – FMNH: Field Museum of Natural History, Chicago, USA. – NHMW: Naturhistorisches Museum Wien, Vienna, Austria. – MHNG: Muséum d'Histoire Naturelle, Geneva, Switzerland. – SMF: Naturmuseum Senckenberg, Frankfurt Am Main, Germany. – UPZM: Univ. of Peradeniya Zoology Museum, Sri Lanka. – ZFMK: Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany. – ZMB: Zoologisches Museum Berlin, Germany.

## SYSTEMATICS

### *Lycodon aulicus* (Linnaeus, 1758)

*Coluber aulicus* Linnaeus, 1758

*Natrix aulica* – Laurenti, 1768

*Lycodon subfuscus* Cantor, 1839

*Lycodon atropurpureus* Cantor, 1839

*Lycodon aulicum* – Duméril, Bibron & Duméril, 1854

*Lycodon aulicus oligozonatus* Wall, 1909

*Ophites aulicus* – Wall, 1921

*Lycodon aulicus* – Smith, 1943; Daniel, 2002;

Whitaker & Captain, 2004; Goonawardene et al. 2006

*Lycodon travancoricus* (not of Beddome, 1871) –

Rao et al. (2005)

*Lycodon aulicus* morph1 – Ganesh & Chandramouli, 2011

*Lycodon aulicus* – (in part.) Wallach et al. (2014)

**Material examined.** *Males* ( $n=25$ ): **Myanmar:** NHMW 21699.1 Bhamo; CAS 215387 Sagaing; **Nepal:** FMNH 62427, Tansing; BMNH 1936.7.2.2 Mae Dist, Doons; BMNH 80.11.10.138 Nepal; **India:** BMNH 1908.5.23.15

Diburgash, Assam; FMNH 165108 Junganathpur, West Bengal; FMNH 8650 Central province near Chanda; FMNH 60647 Central province, Balaghat dist; BMNH 82.8.26.22 Kinelly (=Kimdey) hills, [Andhra Pradesh]; BMNH 74.4.29.958 Wynads, [Kerala] India; ZMB 1790 Bengal; BMNH 1904.10.18.5 Cannannore, Malabar; NHMW 37406:1 Ahmednagar, Maharashtra; NHMW 37406:2 Ahmednagar, Maharashtra; **Sri Lanka**: FMNH 123906 Ceylon; ZFMK 52137 Kitulgala; ZFMK 52511 Kitulgala; NHMW 21689:5–7 Sri Lanka; NHMW 14487:2–3 Sri Lanka; **Indian Ocean Islands**: ZFMK 29976 Mauritius; ZMB 8158 Isla Bourbon?; NHMW 21699.5 Ainoi islands in Hawaii.

*Females (n=34)*: **Myanmar**: CAS 205000 DNA tested, Rakhin; CAS 245960 Tanintharyi; CAS 219800 Ayeyarwadi; NHMW 14483 Myanmar; ZMB 11625 Myanmar; NHMW 21702.2 Pegu, ; ZMB 10258 Minhla; BMNH 1928.1.4.1 Rangun; **Pakistan**: SMF 64484 Lahore, W-Pakistan; **Nepal**: BM 1984.1216 Royal Chitwan; FMNH 83090 Kathmandu; **India**: CAS-SU 12263 Bistrampur, Madhya Pradesh; FMNH 165107 West Bengal, Howrah Dist.; FMNH 161469 West Bengal, Barnijunoh; NHMW 14487.1 'Alakan'; ZMB 1791 Bengal; ZMB 9956 Ajmere, Rajasthan; ZMB 1806 Calcutta; NHMW 14488 Kolkata; BMNH 1921.6.15.3 Bangalore, Karnataka; SMF 32463 Agra; ZMB 1791 Bengal; BMNH 1955.1.3.11 Mysore, 3500 ft, Karnataka; BMNH 1936.1.3.4 Namakal, Tamil Nadu; BMNH 1924.10.13.9 Punakanaat, 700 ft, Travancore, Kerala; BMNH 69.8.28.94 Matheran, Maharashtra; **Sri Lanka**: FMNH 123907 Ceylon, Trincomalee; ZFMK 52510 Sri Lanka; NHMW 21689:1–3 Sri Lanka; NHMW 14487:1 Sri Lanka; **Indian Ocean Islands**: ZFMK 21766 Mascarenes, Reunion, Manapany; ZFMK 29977 Mauritius.

**Diagnosis (redefined herein)**. A species of *Lycodon* inhabiting the Indian subcontinent, characterised by (1) a wide and large head, (2) a distinct creamy white collar-mark on head across parietal scales converging towards snout-tip, (3) a dark blackish-brown body with creamy white cross bars in life, (4) preocular usually contacting frontal, (5) supraocular usually not contacting prefrontal, (6) a fairly elongate hemipenis with smaller flounces and spines, (7) supralabials white, usually 9 on each side, (8) divided anal scale, (9) scale rows 17:17:15, (10) ventrals: 180–215 and subcaudals: 57–78 pairs, (11) relative tail length 0.15–0.20.

**Description and variation (Fig. 1)**. A medium-sized (avg. 500 mm total length, our longest specimen was a female with 719 mm [BM 1924.10.13.9 from Punakanaat, 700 ft, Travancore, S India]) snake with heavy thickset, stoutly built head and rather robust cylindrical trunk. Rostral scale scarcely visible from above; nasals small, sutured, in contact with 1<sup>st</sup> and 2<sup>nd</sup> supralabials; interna-

sals large, higher than broad; prefrontals vertically oblong, as large as frontal, in broad contact with loreal and preocular; anterior end of prefrontal not half as wide as posterior end, but only slightly smaller; frontal triangular, slightly larger than supraocular, usually in clear contact with preocular; anterior end of frontal not twice as wide as posterior end; supraocular not in contact with prefrontal; postoculars 2, small; temporals usually 2+3+3; supralabials usually 9, 3<sup>rd</sup> to 5<sup>th</sup> touching eye; parietals very large, subequal in length to its distance from internasals; infralabials horizontally elongate, 10–11; 1<sup>st</sup> to 5<sup>th</sup> touching genials; anterior genials larger than posterior genials; body scales smooth and glossy, imbricate, with mild apical pits; dorsal scales in 17:17:15 rows around body; prefrontals usually 1–3; ventrals 180–205 (avg. 191.3) in males and 186–208 (avg. 199.4) in females, angulate laterally; anal scale divided; subcaudals 61–78 pairs (avg. 68.8) in males and 57–74 pairs (avg. 64.5) in females; relative tail length on average 0.186 in males (0.172–0.204) and 0.168 in females (0.146–0.191). Hemipenis fairly thin, cylindrical and short, extending up to 10<sup>th</sup> subcaudal scale, mildly forked near tip; pedicle slightly narrower than hemipenial lobe head; hemipenial head not quite bilobed; sulcal lips broader and ornamented with thick pointed spiny flounces, visible heavily on asulcate side and mildly on sulcate side. Sri Lankan specimens, in both the sexes, have shorter tails, and a lower number of ventral and subcaudals scales compared to peninsular Indian specimens and Indoburmese (here understood as the region from Northeast India upto Burmese peninsula) specimens that had the longest tails (see Table 1).

**Colouration in life**. Dorsum blackish-brown or dark brown, never without tinge of black; a series of about 8–40 creamy white cross bars either wholly complete across the dorsum, or broad on the vertebral row then diverging or disintegrating into two arms laterally; band width covers 2–4 dorsal body scales; interband distance typically covers 10–15 dorsal body scales; bands more thick and prominent on forebody, obscure or absent on hindbody, rarely completely absent, except for traces of white collar mark; underside, upper lip, lower lip, throat and chin pure white, slightly pinkish in juvenile specimens; tongue rosy pink; iris totally black, pupil not visible.

**Remarks**. Linnaeus (1758) is his original description of *Coluber aulicus*, mentioned 'vertex albus' meaning 'white crown of head' in Latin. The subsequent taxa described by Cantor (1839) were based on specimens in conformity with Linnaeus' (1758) description. As explained in Ganesh & Chandramouli (2011), Smith (1943), Daniel (2002), Whitaker & Captain (2004) and Goonawardene et al. (2006), correctly described *Lycodon aulicus* sensu stricto in their accounts of *Lycodon aulicus* although they did not recognize the two differ-



**Fig. 1.** *Lycodon aulicus* adult in life (a) from Sri Lanka, Photo: Dushantha Kandambi; (b) entire – dorsal view, dark morph; (c) entire – dorso-lateral view, light morph; (d) entire – dorsal view, (e) head – dorsal view, (f) head – lateral view, (g) mid-body profile view, all live adult specimens from Mayiladuthurai, India. Photos: S. R. Ganesh & S. R. Chandramouli (h) hemipenis of preserved specimen CAS (California Academy of Sciences) 215387 from Sagiang Divsn., Myanmar. Photo: Gernot Vogel.

**Table 1.** Geographical variation within the *Lycodon aulicus* and *L. anamallensis* groups. Min-max ranges and mean values (within parenthesis) are provided.

Characters	<i>Lycodon aulicus</i> s. str.			<i>Lycodon anamallensis</i>	
	Indoburma m=5, f=11	Peninsular India m=11, f=15	Sri Lanka m=9, f=6	Peninsular India m=3, f=5	Sri Lanka m=2, f=5
Ventrals (males)	182–205 (193.0)	180–206 (196.1)	180–186 (182.9)	174–186 (180.7)	184–186 (186.0)
Subcaudals (males)	68–72 (70.0)	65–74 (69.8)	61–70 (65.9)	63–64 (63.5)	71–73 (72.5)
Rel. tail length (males)	0.182–0.204 (0.195)	0.175–0.187 (0.183)	0.172–0.188 (0.181)	0.195–0.197 (0.196)	0.185–0.200 (0.192)
Ventrals (females)	186–207 (197.5)	191–215 (201.5)	190–202 (195.5)	186–197 (193.6)	195–204 (200.4)
Subcaudals (females)	56–74 (64.0)	57–73 (65.7)	57–67 (60.8)	60–74 (67.5)	63–71 (67.4)
Rel. tail length (females)	0.154–0.189 (0.175)	0.146–0.191 (0.167)	0.149–0.159 (0.155)	0.176–0.185 (0.181)	0.172–0.180 (0.175)

ent morphotypes. Goonawardene et al. (2006) also dealt with *L. osmanhilli*. Wall (1909) misunderstood Linnaeus' definition of this species and went on to name this same morphotype as his new subspecies *Lycodon aulicus oligozonatus* and remarked it to be rare in southern India. *Lycodon aulicus* is found throughout the Indian subcontinent including Nepal, Pakistan, Bhutan, Bangladesh, Myanmar, Sri Lanka and the mainland India (but not the Andaman and Nicobar Islands). It is also found in Mauritius and the Hawaiian Islands.

#### *Lycodon anamallensis* Günther, 1864

*Lycodon aulicus* 'typica' – Wall, 1909

*Ophites anamallensis* – Wall, 1923

*Lycodon osmanhilli* Taylor, 1950 **syn. nov.**

*Lycodon aulicus* (not of Linnaeus, 1758) –

Whitaker, 1978; Das, 2002; Das & De'Silva, 2005;

Rao et al. (2005)

*Lycodon* cf. *aulicus* morph2 –

Ganesh & Chandramouli, 2011

*Lycodon aulicus* (in part.) Wallach et al. (2014)

**Material examined.** *Males* ( $n=5$ ): **India:** BMNH 1904.10.18.2 Cannanore, Malabar, south India; BMNH 1904.10.18.4; Cannanore, Malabar, South India; CSPT/S-28b Madras, India; **Sri Lanka:** FMNH 25927 **Ceylon:** Colombo; MHNG 1198.70 Sri Lanka.

*Females* ( $n=10$ ): **India:** BMNH 1946.1.14.92 Holotype of *Lycodon anamallensis* Anamallays; BMNH 1904.10.18.3 Cannanore, Malabar, Kerala; BMNH no number Madras; BMNH 1924.10.13.7 Mundakayan,

Trawancore, Kerala; CSPT/S-28a Madras; **Sri Lanka:** ZFMK 32253 Sri Lanka; UPZM-17a&b Peradeniya, Kandy; MHNG 744.7 Ceylon; NHMW 21689.4 Ceylon.

**Diagnosis (see also Taylor, 1950).** A species of *Lycodon* presently known from peninsular India and Sri Lanka, characterised by (1) a thin and small head, (2) absence of collar-mark on head; but the first 'band' passing across neck > 7–10 scales away from parietals, and converging towards tail, (3) a reddish-brown body with yellow or cream (never quite white) cross bars in life, (4) preocular usually not contacting frontal, (5) supraocular usually contacting prefrontal, (6) a shorter hemipenis with numerous long frounces and spines, (7) supralabials creamy with a median brown spot, usually 9 on each side, (8) bifid anal scales, (9) scale rows 17:17:15, (10) ventrals: 174–204 and subcaudals: 60–73 pairs, (11) relative tail length 0.14–0.20.

**Description and variation (Figs. 2–4).** A small to medium-sized (avg. 400 mm) snake with a thin head and neck, trunk and tail subcylindrical to slightly depressed. Rostral scale scarcely visible from above, nasals more or less pierced by nostril, partly sutured, in contact with 1<sup>st</sup> supralabial; internasals distinctly larger than nasals, in broad contact with preocular and loreal; loreal one on each side (two on each side in the nominotypical holotype); prefrontals longer than wide, each prefrontal as large as frontal, usually in contact with supraocular; anterior end of prefrontal distinctly half as wide as posterior end; frontal pentagonal, produced posteriorly, slightly larger than supraocular; anterior end of frontal distinctly



**Fig. 2.** Holotype of *Lycodon osmanhilli* KUMNH (Kansas University Museum of Natural History) 24141; (a) entire – dorsal view; (b) entire – ventral view; (c) jar label. Photos: Peter Uetz.

twice as wide as posterior end; frontal usually not in contact with preocular; parietals long, but distinctly smaller than its distance from internasals; postoculars 2; preocular 1, half as long as loreal; temporals usually 2+3+4; supralabials 9, 3<sup>rd</sup> to 5<sup>th</sup> contacting eye; infralabials usually 10–11, horizontally elongate, usually 1<sup>st</sup> to 5<sup>th</sup> touching anterior genials; anterior genials larger than posterior genials; prefrontals 1–3; ventrals 174–188 (avg. 186.0) in males and 186–204 (avg. 197.0) in females, angulate laterally; anal scale divided; subcaudals 63–73 pairs (avg. 67.8) in males and 60–72 pairs (avg. 66.6) in females; average of relative tail length 0.194 in males and 0.172 in females. Hemipenis short and stout, reaching only 7<sup>th</sup>–8<sup>th</sup> subcaudal scale; mildly forked near tip; pedicel barely visible through elongate spines, hemipenial lobe head greatly broader than pedicel, unilobed, flattened, circular and disc-like; sulcal lips ornamented with heavy and elongate spines, many as long as two subcaudal scales; sulcus spermaticus duct barely visible on both sulcate and asulcate sides, being obscured by the spiny flounces. Sri Lankan specimens, in both the sexes have higher ventral and in males higher subcaudal scale counts than peninsular Indian specimens (see Table 1).

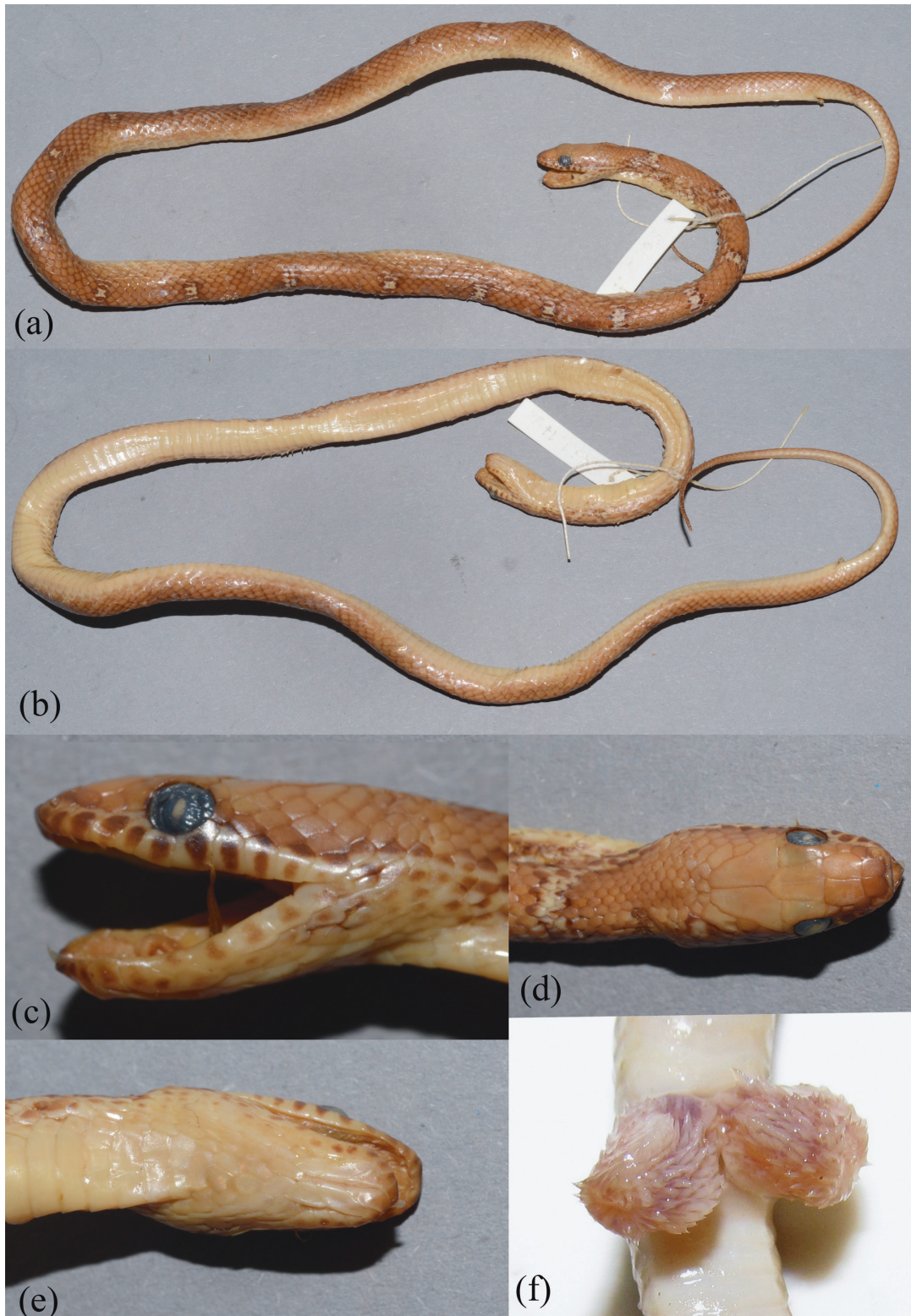
**Colouration in life.** Dorsum fawn brown or reddish-brown, never with a tinge of black; a series of about 15–32 yellowish-white or cream coloured cross bars, either wholly complete across the dorsum, or broad on the vertebral row and diverging or disintegrating into

two arms laterally, bands sometimes speckled inside with background colour; bands more thick and evident on forebody, obscure or absent on hindbody, rarely altogether absent; upper lip, lower lip, throat and chin pale pinkish white dotted with brown, venter uniformly white, pinkish-cream in juvenile specimens; tongue rosy pink; iris totally black, pupil mildly or not visible.

**Remarks.** Günther (1864) described *Lycodon anamallensis* based on a single specimen from the Anamallay Hills, Western Ghats, peninsular India, deposited in Col. R. H. Beddome's collection. Our re-examination of the holotype and additional preserved and living examples from India and Sri Lanka revealed that all specimens except the holotype have only one loreal scale on each side of head and divided anal scales. Therefore, we concur with Smith's (1943) remarks that the presence of double loreals on each side of head and undivided anal scale recorded in both Indian and Sri Lankan specimens are outliers and part of intraspecific variation (see also Wall, 1923). Taylor (1950) described *Lycodon osmanhilli*, discerning it from *L. aulicus* principally based on the character of the preocular separated from frontal. Our examination reveals that the holotype of *L. anamallensis* has its frontal separated from preocular on one side but contacting the preocular on the other side. However, our examination of both living and preserved specimens reveals that the holotype of *L. anamallensis* might be termed as a partial outlier in this character too. Nonetheless, preoc-

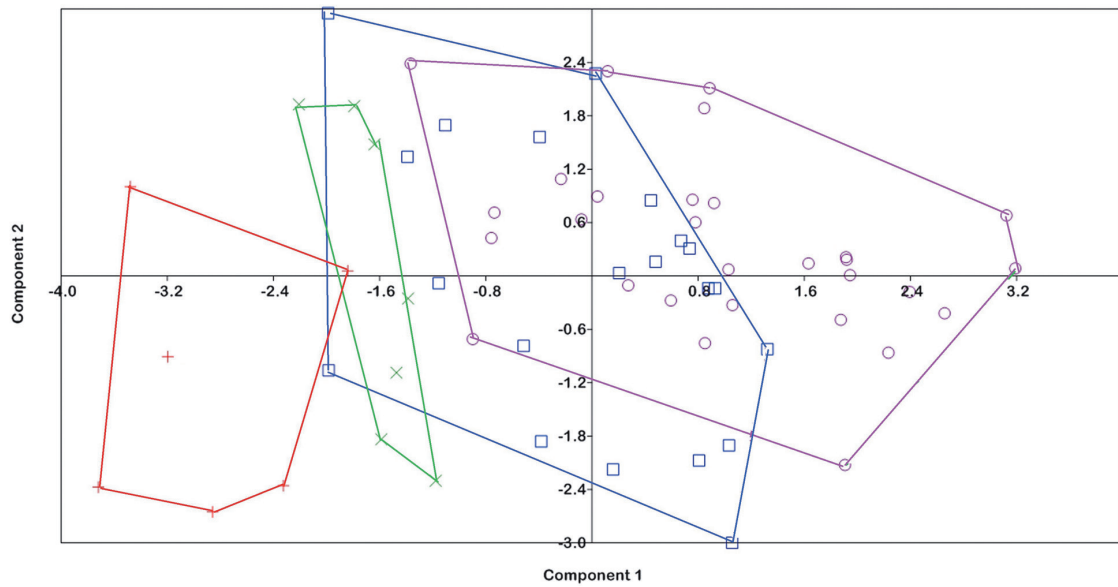


**Fig. 3.** *Lycodon anamallensis* in life (a) adult from Nuwalapitiya, Sri Lanka, Photo: Gernot Vogel; (b) adult from Madras, India; (c) adult, band-less morph from Mayialduthurai, India; (d) adult with eggs; (e) a neonate from Madras; (f) head – lateral view; (g) head – dorsal view, of specimen from Mayiladuthurai, India. Photos: S. R. Ganesh & S. R. Chandramouli.

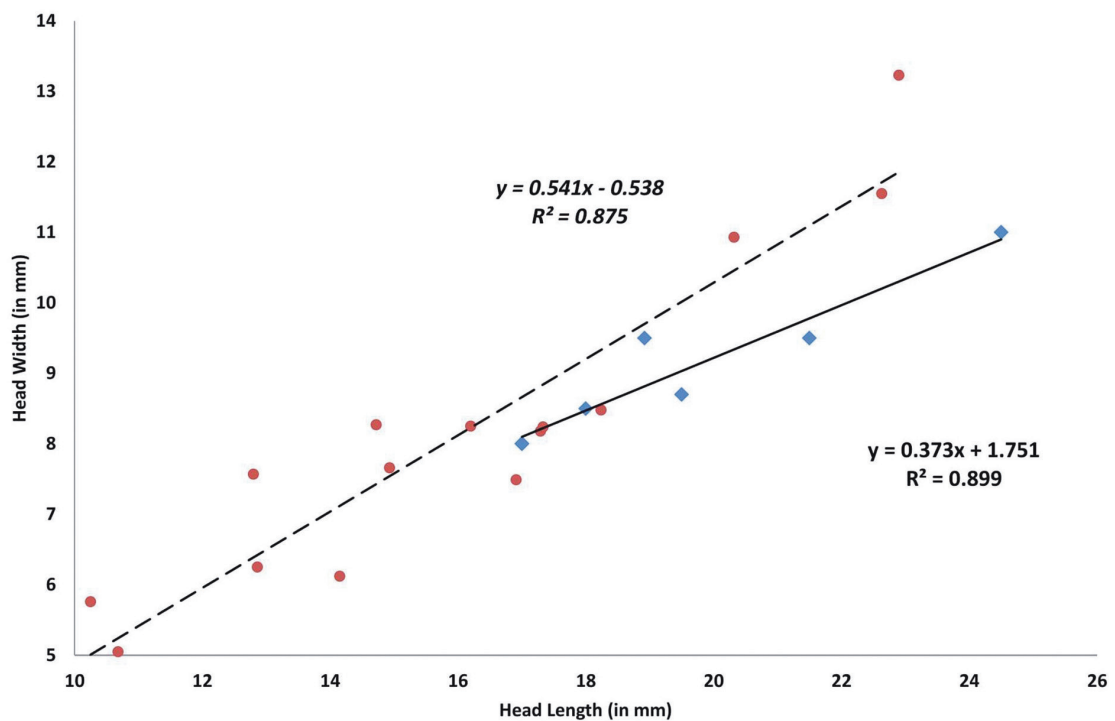


**Fig. 4.** *Lycodon anamallensis* (a-e) Holotype, BMNH 1946.1.14.92, from Anamallays, India; (a) entire – dorsal; (b) entire – ventral; (c) head – lateral; (d) head – dorsal; (e) head – ventral views Photos: Gernot Vogel; (f) Non type CSPT/S-28a hemipenis of specimen from Madras, India Photo: S.R. Ganesh





**Fig. 5.** Principal Component Analysis plot showing rather mild separation of the taxa *L. anamallensis* (green cross – females, red plus – males) and *L. aulicus* (pink circles – females and blue squares – males).



**Fig. 6.** Regression biplot depicting differences in head length vs. head width ratios for *L. aulicus* s. str. (dotted line) and *L. anamallensis* (normal line).

**Table 2.** Comparison of diagnostic characters of peninsular Indian and Sri Lankan *Lycodon* species (except the strongly keeled-scaled *L. carinatus*, endemic to Sri Lanka). Data for other taxa sourced from Smith (1943), Whitaker & Captain (2004), and Mukherjee & Bhupathy (2007).

Characters	<i>Lycodon aulicus</i>	<i>L. anamallensis</i>	<i>L. striatus</i>	<i>L. flavicollis</i>	<i>L. flavomaculatus</i>	<i>L. travancoricus</i>
<b>Collar</b>	Present	Absent	Present	Present	Present (spot)	Obscure
<b>Dorsal ground colour</b>	Brown (rarely blackish)	brown	Blackish brown	Brown	Blackish brown	Blackish brown
<b>Colour of bands</b>	Creamy white	Yellowish white	White (with yellow mid-spot)	Yellow	Yellow	Yellow (rarely yellowish white)
<b>Supralabials</b>	9 (very rarely 8 or 10) <sup>1</sup>	9 <sup>2</sup>	8 (rarely 9)	9	9	9
<b>Anal</b>	2	2	2	2	2	1
<b>Ventrals</b>	180–215	174–204	154–166	210–224	165–183	176–206
<b>Subcaudals</b>	56–78	60–73	35–50	65–72	53–63	64–76
<b>Hemipenis</b>	Reaching 10 <sup>th</sup> subcaudal scale; not quite forked; smaller spiny flounces	Reaching 8 <sup>th</sup> subcaudal scale; mildly forked; broad spiny lobe head	Reaching 10 <sup>th</sup> subcaudal scale; mildly forked; distal 1/3 <sup>rd</sup> flounced, spinose at tip	Cylindrical, not forked at tip, lacks spines	Reaching 15 <sup>th</sup> subcaudal scale; forked at tip, mildly spinose	Reaching 12 <sup>th</sup> subcaudal scale; forked at tip; lobe head / pocket smooth
<b>Distribution</b>	Indian subcontinent	Peninsular India & Sri Lanka	Indian subcontinent	Western Ghats (low Nilgiris)	Northern Western Ghats	Hills of peninsular India

<sup>1</sup> 8 in 1 out of 120 cases, 10 in 3 out of 120 cases with two of these occurring on a specimen from Reunion

<sup>2</sup> In the holotype there are 10 supralabials on the left side, but it can easily be seen that one supralabial is split

ular-frontal separation is still a very typical character for *L. anamallensis* and is diagnostic when used in conjunction with other characters mentioned above.

As explained in Ganesh & Chandramouli (2011), the accounts of *Lycodon aulicus* sensu auctorum by Whitaker (1978), Das (2002), Das & De'Silva (2005) and Rao et al. (2005) refer to *Lycodon anamallensis*. Das & De Silva (2005) did so in their book covering Sri Lankan snakes, despite recognizing *L. osmanhilli*. Earlier, Wall (1909) had apparently mistaken the original concept of *L. aulicus* [s. str.] and after having discerned this *L. anamallensis* morphotype, called it *Lycodon aulicus typica* (contra Linnaeus, 1758) and remarked it to be quite common in southern India, commoner than *L. aulicus* as redefined herein. As currently understood, *L. anamallensis* is known to occur in peninsular India (roughly as far north as 21°N) and Sri Lanka. Based on our specimen examinations, *L. anamallensis* is absent in the Indian Ocean Islands like Mauritius, Reunion and the Hawaii.

Our Principal Component Analysis (Fig. 5) run based on 15 characters from 63 specimens, including 13 *L. anamallensis* specimens (7 m, 6 f) and 50 *L. aulicus* specimens (29 m, 21 f) revealed a mild separation of these forms with outliers, indicating their degree of crypsis to a certain extent. Of the 15 variables analysed, 7 had ei-

genvalues > 1, ranging from 1.03 in Component 7 to up to 2.61 in Component 1. They explained a variance of 99.18%. Component 1 was loaded on relative tail length, ventral and subcaudal scale counts, while Component 2 was loaded on head-scale configuration, collar and band patterns and supralabial markings. As can be seen by the PCA plot, *L. anamallensis* (green cross – females, red plus – males) and *L. aulicus* (pink circles – females and blue squares – males) appear fairly separated. There is a zone of overlap between the females of *L. anamallensis* and the males of *L. aulicus*. This explains the crypsis in this complex well. However, when analysed for head dimension, i.e., head length vs. head width ratio, there is a clear separation of these two taxa (Fig. 6). The regression analyses indicate substantial differences in head dimensions: for *L. aulicus* s. str.  $y = 0.541x - 0.538$   $R^2 = 0.875$ ; for *L. anamallensis*  $y = 0.759x - 4.645$   $R^2 = 0.933$ .

## DISCUSSION

These two species, *L. aulicus* (Linnaeus, 1758) and *L. anamallensis* Günther, 1864, principally differ in head dimensions, collar and band patterns, sex-specific relative tail lengths, hemipenial morphology (see Tables 1, 2)

as well as in genetics (Pyron et al. 2013). These two species are largely sympatric over their geographic ranges in the Indian peninsula (Whitaker & Captain 2004; Das 2002; this work), leaving little doubt to their specific distinction.

Our examination of voucher specimens also revealed distinct and sometimes non-overlapping geographical variation in relative tail lengths, and ventral and subcaudal scale counts between populations within *L. aulicus* and *L. anamallensis* (see Table 1). However, it has to be noted that each of such geographically-concordant variant populations do fall within the corresponding morphotypes outlined above. Additionally, our material did not reveal these geographically-correlated clinal differences within populations of *L. aulicus* s. str. and *L. anamallensis* to be large enough to warrant any further splitting within these two species for the moment. Therefore, we for now refrain from naming each of these individual populations of *L. aulicus* from Nepal, Myanmar, peninsular India and Sri Lanka, and of *L. anamallensis* from peninsular India and Sri Lanka. We conservatively maintain this stance for future investigations.

Additionally, we think that the dilution of these clearly discernible morphotypes representing two distinct species under the name *L. aulicus*, mainly in the Indian peninsula, has caused confusion about the identification and distribution of this group of snakes. In Sri Lanka, however, the situation is different since the thin-headed form had been called as *L. osmanhilli* and was usually regarded as non-conspecific with *L. aulicus* (see Somaweera 2006). But recently Wallach et al. (2014) disregarded these variations and included *L. osmanhilli* in the synonymy of *L. aulicus* and worsened the situation. Pyron et al. (2013), in their genetic analysis, showed that *L. aulicus* and *L. osmanhilli* (i.e., from now on, a synonym of *L. anamallensis*) are not only genetically distinct, but actually belong to different clades, with *L. aulicus* clustering with *L. zawi* and *L. osmanhilli* clustering with the eastern species *L. capucinus*. As shown these two species are easily diagnosable by the characters mentioned above.

#### KEY TO SOUTH ASIAN LYCODON

- 1a. Body scales strongly keeled ..... *L. carinatus*
- 1b. Body scales not strongly keeled ..... 2
- 2a. Anal scale entire ..... *L. travancoricus*
- 2b. Anal scales divided ..... 3
- 2a. Ventrals < 200, body more black than brown ..... 4
- 3b. Ventrals > 200, body more brown than black ..... 5
- 4a. Usually 8 supralabials, reticulations white or with yellow mid-spots ..... *L. striatus*
- 4b. Usually 9 supralabials, reticulations always yellow ..... *L. flavomaculatus*
- 5a. Yellow collar always present, no other pattern, ventrals not angulate laterally ..... *L. flavicollis*

- 5b. Collar present or absent, body uniform or banded, ventrals angulate laterally ..... 6
- 6a. Collar present, touching the parietals, converging towards snout tip ..... *L. aulicus*
- 6b. Collar absent, first band far away from parietals, converging towards tail ..... *L. anamallensis*

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