Phyllomedusa 24(2):295–312, 2025
© 2025 Universidade de São Paulo - ESALQ
ISSN 1519-1397 (print) / ISSN 2316-9079 (online)
doi: http://dx.doi.org/10.11606/issn.2316-9079.v24i2p295-312

Discovery of a new species of *Gegeneophis* (Gymnophiona: Grandisoniidae) highlights hidden diversity and implications for regional endemism in the Western Ghats, India

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Abstract

Discovery of a new species of *Gegeneophis* (Gymnophiona: Grandisoniidae) highlights hidden diversity and implications for regional endemism in the Western Ghats, India. A new species of *Gegeneophis* is described from the base of the lateritic plateaus of Satara, Maharashtra, India. The new species is described based on morphological characters, metric and meristic measurements, phylogenetic analysis, genetic distances, ASAP analysis, and geographic isolation. Phylogenetic and ASAP analyses suggest the presence of an additional six lineages representing potential new species from the northern and central Western Ghats. The affinities of spatial and temporal distribution of *Gegeneophis* in the northern and central Western Ghats are discussed.

Keywords: Annulocylix caecilian, Legless amphibian, New species description, Northern Western Ghats, Tailless caecilians, Taxonomy.

Resumo

A descoberta de uma nova espécie de *Gegeneophis* (Gymnophiona: Grandisoniidae) destaca a diversidade oculta e as implicações para o endemismo regional nos Ghats Ocidentais, India. Uma nova espécie de *Gegeneophis* é descrita a partir da base dos planaltos lateríticos de Satara, Maharashtra, Índia. A nova espécie é descrita com base em várias linhas de evidência, incluindo características morfológicas, medições métricas e merísticas, análise filogenética, distâncias genéticas, análise ASAP e isolamento geográfico. As análises filogenéticas e ASAP sugerem a presença de seis linhagens adicionais que representam potenciais novas espécies do norte e centro dos Ghats Ocidentais. São discutidas as afinidades da distribuição espacial e temporal de *Gegeneophis* no norte e no centro dos Ghats Ocidentais.

Palavras-chave: Anfíbio ápode, Cecílias sem cauda, Descrição de espécie nova, Ghats Ocidentais setentrionais, Taxonomia.

Received 25 August 2025
Accepted 07 November 2025
Distributed December 2025

Introduction

In India the legless amphibian family Grandisoniidae is represented by two genera, *Gegeneophis* Peters, 1880 “1879” and *Indotyphlus* Taylor, 1960 (Dinesh *et al.* 2024, Frost 2025). The genus *Gegeneophis* is endemic to peninsular India and is represented by 12 species. One species is endemic to the Eastern Ghats, and 11 species are endemic to the Western Ghats (Dinesh 2020, Ramakrishna *et al.* 2023) (Figure 1, Table 1). The two species in the genus *Indotyphlus* are endemic to the northern Western Ghats (Dinesh *et al.* 2024).

The first species of *Gegeneophis* described from the Western Ghats was *Gegeneophis carnosus* (Beddome, 1870) (described as *Epicrium carnosum* Beddome, 1870) from the Periah Peak region of Wayanad, Kerala (Table 1). The species is endemic and has a restricted distribution around the Wayanad hill ranges (Dinesh 2025).

Taylor (1964) described *Gegeneophis ramaswamii* Taylor, 1964 from the Tenmalai forest region of Kollam, Kerala (Table 1). This species is endemic to the southern Western Ghats and has abundant populations south of Shencotah pass (Dinesh 2025).

The first lower-elevation (below 100 m) species of *Gegeneophis* was described as *Gegeneophis krishni* Pillai and Ravichandran, 1999 from Krishna Farms, Gurpur, Dakshina Kannada, Karnataka (Pillai and Ravichandran 1999) (Table 1). The species is a central Western Ghats endemic confined to habitats in the vicinity of the type locality (Dinesh 2025).

The earliest species of *Gegeneophis* lacking secondary annuli was described as *Gegeneophis seshachari* Ravichandran, Gower, and Wilkinson, 2003 from the reaches of Dorle Village, Ratnagiri, Maharashtra (Ravichandran *et al.* 2003) (Table 1). The species is a northern Western Ghats endemic confined to the regions surrounding the type locality (Gower *et al.* 2007, Dinesh 2025).

The first species of *Gegeneophis* having secondaries in the anterior half of the body was described by Giri *et al.* (2003) as *Gegeneophis danieli* Giri, Wilkinson, and Gower, 2003 from the Amboli region of Sindhudurg, Maharashtra (Table 1). *Gegeneophis nadkarnii* Bhatta and Prashanth, 2004 was described from vicinities of the Bondla Wildlife Sanctuary, Goa, by Bhatta and Prashanth in 2004. Because of genetic homogeneity *G. nadkarnii* was treated as a junior synonym of *G. danieli* by Gower *et al.* (2013). *Gegeneophis danieli* is a northern Western Ghats endemic known to inhabit the Amboli region of Maharashtra to northeastern Goa (Dinesh 2025).

Bhatta and Srinivasa (2004) described *Gegeneophis madhavai* Bhatta and Srinivasa, 2004 from lower elevations (150 m) of Doddinaguli, Mudur, Kundapura, Udupi, Karnataka (Table 1). This species is endemic to the central Western Ghats and is known only from the type specimens (Dinesh 2025).

In 2007 two species of *Gegeneophis* were described from northern Western Ghats. *Gegeneophis goaensis* Bhatta, Dinesh, Prashanth, and Kulkarni, 2007 was described from the lower elevations of Ganv Kond, Keri, Sattari, North Goa, Goa (Bhatta *et al.* 2007a), and *Gegeneophis mhadeiensis* Bhatta, Dinesh, Prashanth, and Kulkarni, 2007 was described from the surrounding areas of Rameshwar temple, Chorla, Khanapur, Belgaum, Karnataka (Bhatta *et al.* 2007b) (Table 1). Both species are northern Western Ghats endemics with good populations near the type localities (Bhatta *et al.* 2010, Dinesh 2025).

Gegeneophis pareshi Giri, Gower, Gaikwad, and Wilkinson, 2011, a species with a worm-like pinkish head, was described by Giri *et al.* (2011) from the lower-elevation villages of Kuske near Cotigaon Wildlife Sanctuary, Canacona, South Goa, Goa (Table 1). This endemic species is known primarily from areas adjacent to the type locality (Dinesh 2025).

Kotharambath *et al.* (2012) described *Gegeneophis primus* Kotharambath, Gower, Oommen, and Wilkinson, 2012 from the Cardamom state in the Sugandhagiri region, near Vythiri,

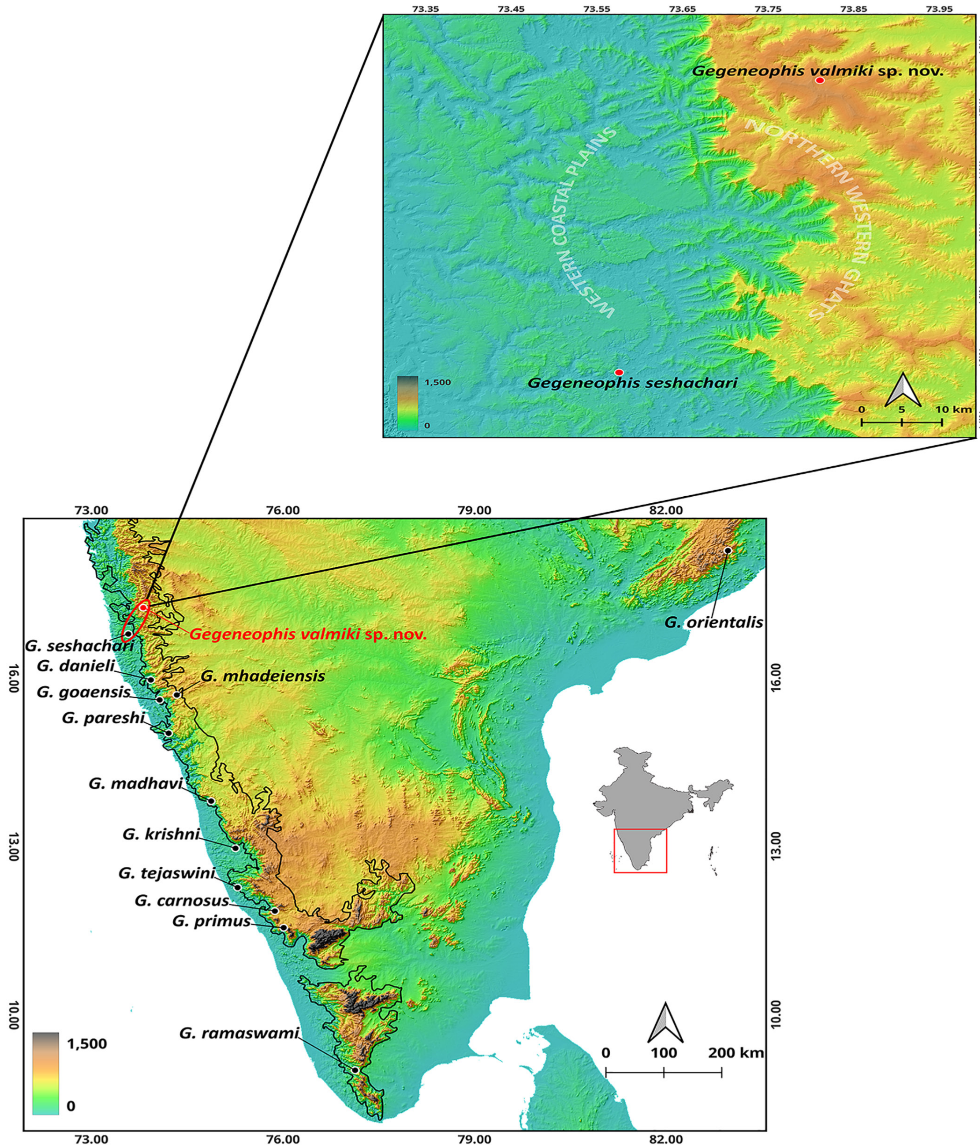

Figure 1. Map showing the type localities of the extant species of *Gegeneophis* in peninsular India and the type localities of phylogenetic sister species *Gegeneophis valmiki* sp. nov. and *Gegeneophis seshachari*.

Pozhuthana, Vythiri, Wayanad, Kerala (Table 1). This endemic species is limited to the locations around the Wayanad hill ranges (Dinesh 2025).

Outside the Western Ghats, the first species of *Gegeneophis* was described from the Eastern Ghats (near Beespuram, Visakhapatnam, Andhra Pradesh) as *Gegeneophis orientalis* Agarwal, Wilkinson, Mohapatra, Dutta, Giri, and Gower, 2013 (Agarwal *et al.* 2013) (Table 1). This species is an Eastern Ghats endemic with a localized distribution in the Andhra Pradesh and Orissa regions (Agarwal *et al.* 2013, Dinesh 2025).

Kotharambath *et al.* (2015) described *Gegeneophis tejaswini* Kotharambath, Wilkinson, Oommen, and Gower, 2015 from Bedoor, Kakkadav Bridge, Cheemeni, Hosdurg, Kasaragod, Kerala (Table 1). This species is endemic to the central Western Ghats and is known only from the type specimens (Dinesh 2025).

A unique pattern occurs among the 11 species of *Gegeneophis* reported from the Western Ghats (Dinesh 2020, Ramakrishna *et al.* 2023). Five species, *G. danieli, G. seshachari, G. goaensis, G. mhadeiensis,* and *G. pareshi* are restricted to the northern Western Ghats region, while another five species, *G. carnosus, G. krishni, G. madhavai, G. primus,* and *G. tejaswini,* are restricted to the central Western Ghats. *Gegeneophis ramaswamii* is the only species restricted to the southern Western Ghats (Table 1).

Table 1. Type locality and annuli (primary and starting of secondary grooves) information for the extant species of *Gegeneophis* from the peninsular India.

Sl. No	Species	Total primary	Secondary starts between	Type locality in peninsular India	Geographic zones
1	*Gegeneophis valmiki* sp. nov.	137–145	absent	Maharshi Valmiki Mandir, Valmiki Plateau, Palashi, Pathan, Satara, Maharashtra	Northern Western Ghats
2	*Gegeneophis seshachari*	122–127	absent	Dorle, Sindhudurg, Maharashtra	
3	*Gegeneophis danieli*	112	5–34	Amboli, Sawanthwadi, Maharashtra	
4	*Gegeneophis mhadeiensis*	117–125	87–98	Chorla Ghats, Surla, Karnataka	
5	*Gegeneophis goaensis*	125–126	38–48	Kheri village, Goa	
6	*Gegeneophis pareshi*	145–150	absent	Kuske near Cotigaon Wildlife Sanctuary, Canacona, South Goa	
7	*Gegeneophis madhavai*	96–97	63–70	Mookambika wild life sanc. Karnataka	Central Western Ghats
8	*Gegeneophis krishni*	125–127	110–114	Gurupur, Dakshina Kannada, Karnataka	
9	*Gegeneophis carnosus*	105–112	99–105	Periah Peak, Wayanad, Kerala	
10	*Gegeneophis primus*	108–112	absent	Sugandhagiri, Vythiri, Wayanad Kerala	
11	*Gegeneophis tejaswini*	125–131	105–115	Bedoor, near Cheemeni, Hosdurg Taluk, Kasaragod Kerala	
12	*Gegeneophis ramaswamii*	109–114	98–103	Tenmalai Bonakad estate, Kerala	Southern Western Ghats
13	*Gegeneophis orientalis*	104–106	95–99	Beespuram, Visakhapatnam District, Andhra Pradesh	Eastern Ghats

Koyna Wildlife Sanctuary in the northern Western Ghats, which is known for tropical evergreen forests and the surrounding Koyna reservoir mosaic-forested ecosystem, is one of the well-suited habitats for caecilians. No species of the genus *Gegeneophis* have been reported previously further north of the Amboli region. During a field survey conducted in and around Koyna Wildlife Sanctuary (Dinesh 2021), a population of *Gegeneophis* was encountered that did not correspond morphologically to any of the extant congeners. Integrative taxonomic studies involving DNA barcode data, and meristic and morphometric studies confirmed the novelty, and this species is herein described as a new species supported with a single gene phylogeny and ASAP (Assemble Species by Automatic Partitioning) species delimitation.

Materials and Methods

Study Species

The field survey was one of the faunistic surveys conducted in search of amphibians in and around the Koyna Wildlife Sanctuary (Dinesh 2021). The specimens were collected from decaying leaf litter in the vicinity of Shri Maharshi Valmiki Mandir during heavy rain in July 2017. A total of seven specimens were collected by hand during daytime searches, which involved digging the soil using a trident and spade. Photographs of live specimens were taken using a Canon camera. The specimens were euthanized using MS-222, and liver tissues were extracted prior to preservation and stored in molecular-grade alcohol for subsequent molecular analysis. The specimens were then fixed in 70% ethanol for morphological studies.

Morphometry

Morphometric measurements were taken using Mitutoyo vernier calipers and an Olympus SZ61 camera-mounted stereomicroscope, except for body length and body circumference, which were measured using a piece of thread and a ruler. Abbreviations and terminology follow Bhatta *et al.* (2007ab). The studied specimens are registered in the National Zoological Collections of the ZSI, WRC, Pune (ZSI/WRC/V/A2782 to 2784).

Principal Component Analysis (PCA) was conducted for eight morphometric characters to compare the new species (*N* = 7) with morphologically similar species lacking secondary annuli, including *G. seshachari* (*N* = 3), *G. pareshi* (*N* = 16), and *G. primus* (*N* = 8) (data taken from original descriptions of *G. seshachari, G. pareshi,* and *G. primus*). All parameters were normalized by dividing the total body length of the specimen (TBL), except for one ratio (length divided by width). PCA was performed using PAST software 4.03 (Hammer *et al.* 2001).

DNA Barcoding

Genomic DNA was extracted from liver tissue using the QIAGEN kit, following the manufacturer's protocol. The gDNA was eluted in 100 µl of AE buffer and quantified using the dsDNA HS Assay Kit (Invitrogen) on a Qubit 2.0 fluorometer. The mitochondrial 16S gene was targeted and amplified using the primers 16SarL (5′-CGCCTGTTTATCAAAAACAT-3′) and 16SbrH (5′-CCGGTCTGAACTCAGATCACG-3′) (Palumbi *et al.* 2002). PCR reactions were carried out in a 25 µl volume, consisting of 2 µl of gDNA (> 100 ng), 12.5 µl of 2X Hot Start Master Mix (Promega), 2.0 µl of $MgCl_2$, 1.0 µl each of forward and reverse primers (10 pmol), and nuclease-free water to reach the final volume.

The thermocycling profile included an initial denaturation at 95°C for 2 min, followed by 35 cycles of 30 s at 95°C, 30 s at 47–52°C, and 30 s at 72°C, with a final extension at 72°C for 5 min. Amplification success was confirmed by gel electrophoresis on a 1.2% agarose gel stained with 0.6 µl of ethidium bromide. PCR products were purified using Invitrogen's PureLink PCR Purification Kit and subsequently outsourced for Sanger sequencing.

Phylogenetic Analysis

The resulting chromatogram files were visualized and manually edited using Chromas v2.6.5 software (Technelysium Pty. Ltd. 2018). A total of 47 sequences provided in Gower *et al.* (2011), along with outgroup sequences, were downloaded from NCBI GenBank. These sequences were aligned and trimmed using the MUSCLE algorithm in MEGA X (Kumar *et al.* 2018). Maximum Likelihood analysis was performed on a dataset comprising 53 sequences of 562 bp, including those generated in this study, using the IQ-TREE multicore version 1.6.12 web server (Trifinopoulos *et al.* 2016). The analysis was conducted with 1000 ultrafast bootstrap replicates under default parameters, and the GTR+F+I+G4 substitution model was auto-selected based on the Bayesian Information Criterion (BIC). The final consensus tree was visualized in FigTree v1.4.0, with *Grandisonia, Praslinia,* and *Hypogeophis* treated as outgroups (Gower *et al.* 2011).

Species delimitation was conducted using the ASAP (Assemble Species by Automatic Partitioning) online tool (Puillandre *et al.* 2021), employing Kimura (K80) genetic distances with a default transition/transversion ratio of 2.0. Partitions were assessed based on the lowest ASAP scores, which indicate well-differentiated and statistically supported groups. The best partition with the lowest ASAP is marked with a red frame. An elevation map was generated using QGIS v3.24 (QGIS Development Team). The sequences generated in this study were submitted to NCBI GenBank (PX475275.1).

Results

The proposed new species, collected from the Valmiki Plateau, Palashi, is geographically located in the central plateau hills of the northern Western Ghats at an elevation of 1000 m (Figure 1). It is isolated by at least 70 km (aerial distance) from one of its sister clade members, *G. seshachari,* which is reported from an elevation of 200 m (Figure 1).

Phylogenetically, the populations from Valmiki Plateau, Palashi were recovered as sister to the clade comprising two unnamed lineages from Kolhapur, one unnamed lineage from Ratnagiri, and the extant species *G. seshachari* (Figures 2 and 3). For the uncorrected pairwise genetic distance the new species was 3.5% divergent from the unnamed lineage from Ratnagiri, 3.9% divergent from *G. seshachari,* 4.8% from one of the unnamed lineages from Kolhapur, and 7% divergent from another unnamed lineage from Kolhapur (Figures 2 and 3). Furthermore, analysis using ASAP indicates that the new lineage is a distinct phylogenetic lineage, supported by the best partition identified with a minimum value (Figure 3).

The populations from Valmiki Plateau were assigned to *Gegeneophis* as done by Peters (1879) and Pillai and Ravichandran (2005). Morphologically, the new species has a unique combination of characters, including primary annular grooves ranging from 137 to 145, absence of secondary grooves, and unsegmented terminal keel (Figures 4, 5, 6). Due to the absence of secondary grooves and a greater number of primary annular grooves, field identification of the new species is easy.

Taxonomy

Gegeneophis valmiki sp. nov.
lsid:zoobank.org:act:7D8A404D-6AC2-4347-8FB5-A12A17B1B13A

Holotype.—An adult male (ZSI/WRC/V/A/2782), collected on 16 July 2017 around the Maharshi Valmiki Mandir (17.2518° N, 73.8104° E, 1000 m); Valmiki Plateau, Paneri, Palashi, Patan, Satara, Maharashtra, collected by A.S. Kalawate and team.

Paratype.—An adult male (ZSI/WRC/V/A/2783), collection details same as holotype.

Etymology.—The species is named after the Maharshi Valmiki temple near the Valmiki Plateau,

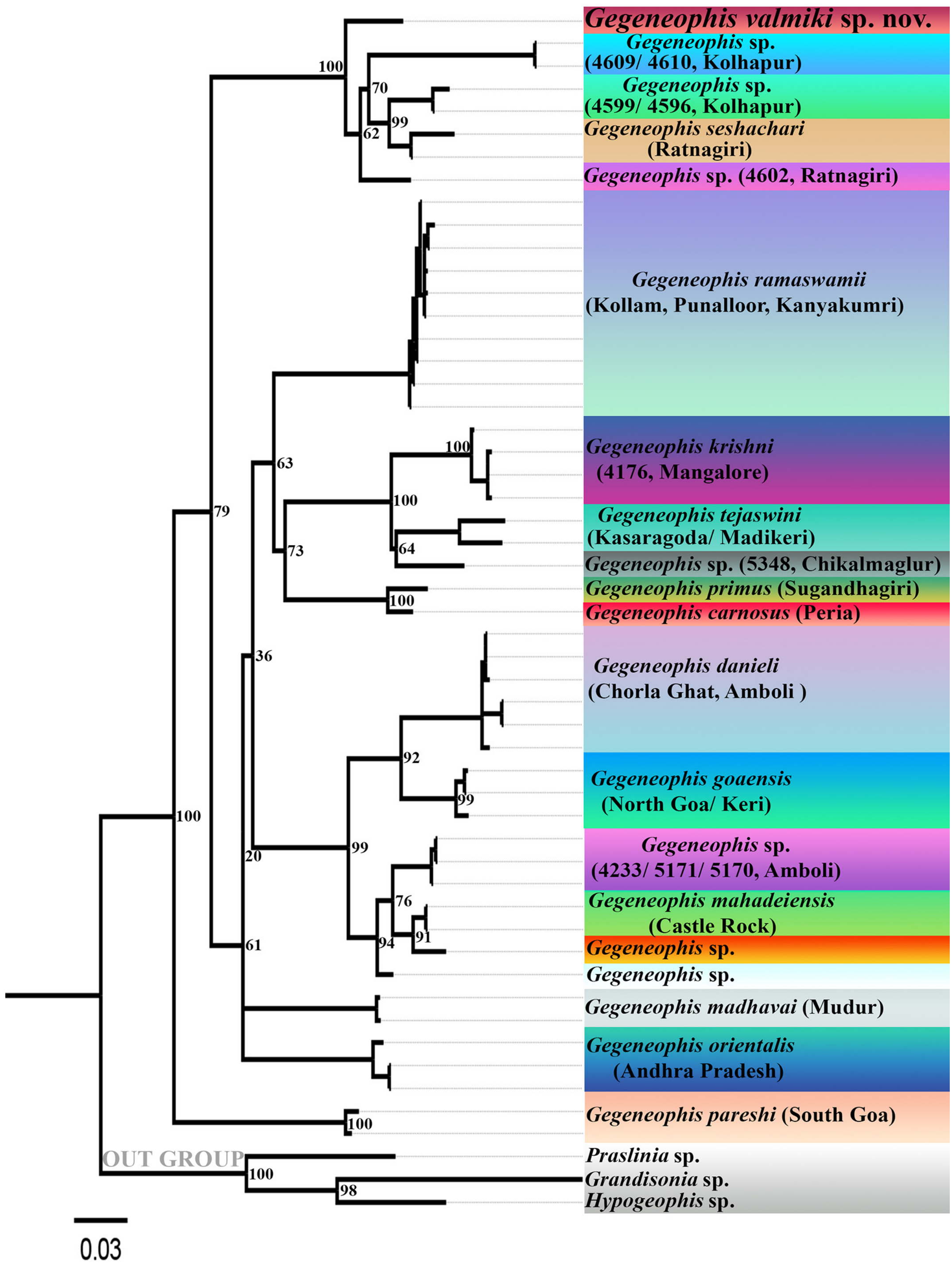

Figure 2. Maximum likelihood tree for the members of *Gegeneophis* based on the mt 16S rRNA (590 bp).

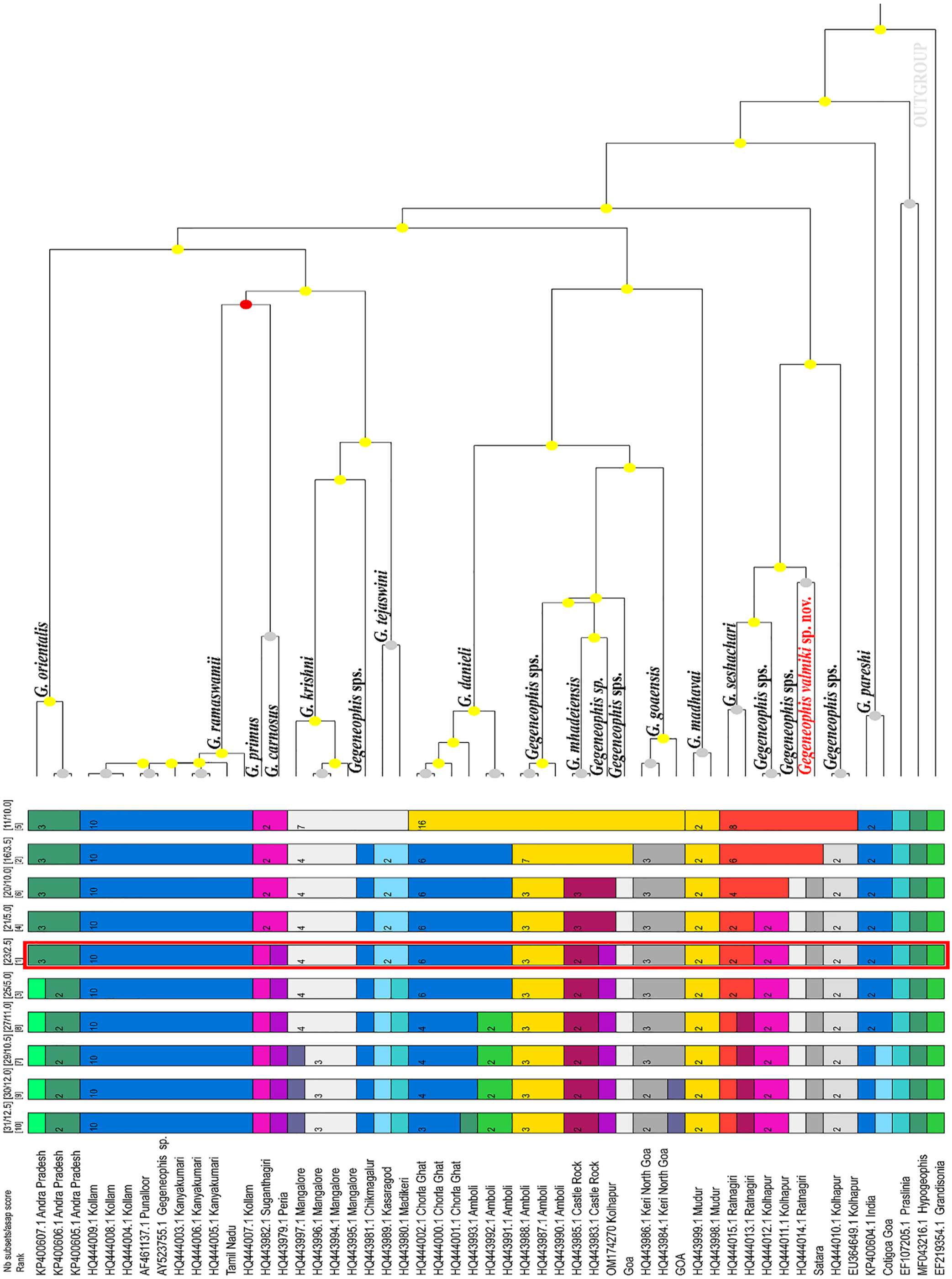

Figure 3. ASAP species delimitation for the genus *Gegeneophis* based on mt 16S rRNA sequences included in this study. The best partition with the lowest ASAP is marked with a red frame.

type locality. Species epithet '*valmiki'* is treated as a noun in apposition to the generic name.

Morphological diagnosis.—A slender vermiform teresomatan *Gegeneophis* having a tentacle between eye and naris, narial plugs open and small. Only primary annuli are distinct and distinguishable with no secondary annular grooves. *Gegeneophis valmiki* sp. nov. has 135 to 145 primary annuli. Diastemata absent between vomerine and palatal teeth. Unsegmented terminal shield without keel and 1 mm long from the last primary groove, transverse vent close to terminal shield (0.2 mm).

Description of the holotype (ZSI/WRC/A/2782) (Figures 5 and 6).—Morphometric and metric details provided in Table 1. Adult male, 192 mm total length, in well-preserved condition. Skin of the fixed specimen soft, smooth, and glandular, slightly glossy due to preservation artefacts. A mid-ventral incision anterior to vent was made for extraction of tissue sample and determination of sex. A few scratches visible on skin on anterodorsal body (made during search for scales). In life body sub-cylindrical, after fixation became slightly dorsoventrally compressed. Circumference at midbody 10.0 mm, with length by circumference ratio of 19.2. Body width almost uniform throughout length; in preserved state body 3.0 mm wide at first annular groove and 4.1 mm at midbody at widest part. Body width decreases to 2.5 mm at region of vent. Body width at 1st nuchal groove 3.2 mm, 2nd nuchal groove 3.1 mm. Distance from tip of snout tip to 1st nuchal groove 4.6 mm, 2nd nuchal groove 4.7 mm, 3rd nuchal groove 5.6 mm. Laterally width of 1st nuchal groove 0.4 mm, 2nd nuchal groove 0.5 mm. Nuchal region broader when compared to another nuchal collar and annular region. Three distinct nuchal grooves visible between the two nuchal collars.

In dorsal view, head tapers obtusely from region of eye to tentacular aperture. Anteriorly head rounded at tip of snout. Head at jaw angle slightly narrower than nuchal region, head length 4.5 mm, head width at jaw angle 2.9 mm. Laterally, top of head straight without protuberances (preservation artefacts). Margin of upper lip slightly arched, snout projects 0.6 mm beyond mouth (Figure 6A). Distance between jaw angle and top of head (1.8 mm) more than distance between the jaw angle and ventral surface of lower jaw (0.9 mm). Anterior margin of lower jaw more narrowly rounded than anterior margin of snout in ventral view. Tiny sub-circular nostrils closer to level of tip of snout (0.2 mm). Internarial distance 1.0 mm, visible laterally but not ventrally, whitish rim around nostrils visible laterally.

In life, tentacles visible laterally (Figure 4), globular in position, 2.9 mm apart. Tentacles situated 1.2 mm from snout, 0.8 mm from nostril, 0.4 mm from margin of upper lip, 0.7 mm from top of head, 2.4 mm from jaw angle (Figure 6B). Tiny eyes situated under bone (width of eye 0.3 mm), visible evidently in life (Figure 4) but not clearly in preserved specimen (Figures 5 and 6B). Eyes dorsolateral in position, interorbital distance 2.6 mm. Distance from eye to nostril 1.9 mm, to tentacle 0.9 mm, to tip of snout 2.2 mm.

Two rows of teeth in upper jaw, two rows of teeth in the lower jaw, all recurved and monocusped. Compared to posterior teeth, anterior teeth smaller. Teeth in posterior region of premaxillary–maxillary and vomeropalatine series almost parallel, vomeropalatine teeth series lacks diastemata. Total premaxillary–maxillary teeth 20, 18 vomeropalatine teeth, 17 dentary teeth, 3 splenial teeth. The premaxillary–maxillary and vomeropalatine tooth rows clearly extend posterior to region of choanae. In anterior view dentary teeth appear larger when compared to premaxillary–maxillary and vomeropalatine teeth, splenials are smallest. Sub-circular choanae smaller in upper palate. Tongue broadly rounded, unattached anteriorly, close to splenial teeth that are separated by a groove from gingivae.

Laterally, second collar region 0.5 mm, equal to first collar region (0.4 mm). First and second nuchal grooves complete around body when compared to third incomplete nuchal groove. One short transverse middorsal groove on

Figure 4. *Gegeneophis valmiki* sp. nov in life from Maharshi Valmiki Mandir, Valmiki Plateau, Paneri, Palashi, Pathan, Satara, Maharashtra, India.

Figure 5. Holotype of *Gegeneophis valmiki* sp. nov. (ZSI/WRC/V/A/2782).

dorsum of first collar between first and second nuchal groove. Middorsal groove present over entire dorsum between second and third nuchal grooves.

Dorsal surface of body dark brown, ventral region light brown. Anterior part of body lighter in color compared to rest of the midbody and posterior part of body. Entire body glandular in texture, annuli marked by whitish grooves. Primary grooves more conspicuous on lateral sides of body when compared dorsally and ventrally. 145 primary annuli present to terminal shield that is 1.0 mm (Figure 6C). Transverse vent 0.2 mm wide, vent surrounded by 11 denticles (Figure 6D).

In life, dorsum and lateral sides of holotype dark slate brown, ventrally lighter brown, anterior part of head light brown, glossy, where tentacles and eyes visible. Annuli and annular groves prominent on lateral sides of body, annular grooves clearly demarcated with distinct glandular dots. In preservation, head region dorsally and ventrally light brown compared to dark brown body color. Annular grooves lighter in color and clearly distinguishable. Disc in vent region whitish both in life and preservation.

Other Variations

The paratype is similar to the holotype in all morphological features except for body size and the number of primary annuli. Variation among the reference collections is provided in Table 2.

Comparisons

Multivariate Principal Component Analysis (PCA) was used for the species of *Gegeneophis* without secondary annular groves (*G. seshachari, G. pareshi, G. tejaswini,* and *Gegeneophis valmiki* sp. nov.). Morphological character separation was analyzed using PC2 and PC3 (Figure 7). In the Principal Component analysis, PC2 accounted for 18.7% variance, and PC3 accounted for 10.4% variance. The combination of total primaries and the appearance of secondaries on the primaries are graphically illustrated (Figure 8) for ease of museum specimen identification.

Among the congeners, *Gegeneophis valmiki* sp. nov. differs from *G. seshachari* in having 137 to 145 primary annuli (*vs.* 122 to 127); *G. valmiki* is known from high-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from coastal plains with an elevation of 30 m at Dorle village, Ratnagiri, Maharashtra).

Figure 6. (**A**) Head, ventral profile; (**B**) Head, lateral side profile; (**C**) Dorsal view of terminal shield, (**D**) Ventral side of body terminus of *Gegeneophis valmiki* sp. nov.

Gegeneophis valmiki sp. nov. differs from *G. pareshi* in having 137 to 145 primary annuli (*vs.* 145 to 150); known from high-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from elevation of of 200 m at Kuske village, Cotigao Wildlife Sanctuary, Goa).

Gegeneophis valmiki sp. nov. differs from *G. primus* in having 137 to 145 primary annuli (*vs.* 108 to 112); known from higher-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from elevations of 800 m at Vythiri Taluk, Wayanad District, Kerala).

Gegeneophis valmiki sp. nov. differs from *G. danieli* in having 137 to 145 primary annuli and the absence of secondary annuli (*vs.* 112 to 114 primary annuli and secondaries starting between 5th to 34th annuli); known from higher-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from elevations

Table 2. Morphometric (in mm) and meristic data for the type series of *Gegeneophis valmiki* sp. nov. #ZSI/WRC/V/; *eight characters used for Principal Component Analysis (PCA).

Reg no.#		**A/2782**	**A/2783**	**A/2784a**	**A/2784b**	**A/2784c**	**A/2784d**	**A/2784e**
Sex		Holotype	Paratype					
Total length	TBL	192	195	190	99	77	146	146
Head length	HDL	4.5	4.5	4.8	3.2	2.2	3.0	2.3
Head width at jaw angle*	HWJ*	2.9	3.0	2.7	1.8	1.7	2.3	1.9
Circumference at mid body*	CMB*	10.0	11.0	10.0	7.0	7.0	10.0	11.0
Width of the body at 1st annular groove	WFA	3.0	3.0	2.7	1.8	1.7	2.4	2.4
Width of the body at broadest region	WBB	4.1	3.9	3.1	1.9	1.8	3.0	2.8
Width of the body at the level of vent*	WBV*	2.5	2.6	2.4	1.3	1.2	2.0	1.8
Length divided by width	LDW	19.2	17.7	19.0	14.1	11.0	14.6	13.3
Length of snout projecting beyond mouth	LSP	0.6	0.7	0.5	0.4	0.7	0.2	0.4
Distance between jaw angle and top of head	DJH	1.8	1.6	1.6	1.3	1.9	0.7	1.5
Distance between jaw angle and ventral surface of lower jaw	DJV	0.9	1.6	1.1	0.7	1.7	1.4	0.8
Distance between jaw angle and tip of lower jaw	DJJ	3.3	3.3	2.9	1.8	3.2	0.9	2.4
Distance between nostrils*	DBN*	1.0	0.7	1.4	0.7	0.6	0.6	0.7
Distance between nostril and snout tip	DNS	0.2	0.3	0.2	0.3	0.3	0.3	0.2
Distance between tentacles*	DBT*	2.9	2.1	3.2	1.6	1.3	1.4	1.8
Distance between tentacle and snout tip*	DTS*	1.2	1.3	1.0	0.9	1.2	1.1	0.9
Distance between tentacle and jaw angle*	DTJ*	2.4	2.5	2.4	1.5	2.7	2.2	1.9
Distance between tentacle and nostril	DTN	0.8	0.8	0.6	0.5	0.7	0.6	0.7
Distance between tentacle and margin of upper lip	DTU	0.4	0.4	0.4	0.3	0.5	0.3	0.2
Distance between tentacle and top of head	DTH	0.7	0.5	0.6	0.6	0.7	0.6	0.7

Table 2. Continued.

Reg no.[#]		**A/2782**	**A/2783**	**A/2784a**	**A/2784b**	**A/2784c**	**A/2784d**	**A/2784e**
Width of eye	WOE	0.3	0.2	0.2	0.1	0.3	0.2	0.2
Distance between eyes	DBE	2.6	2.7	2.7	1.0	1.6	1.0	2.0
Distance from eye to nostril	DEN	1.9	1.7	2.0	1.0	1.7	1.5	1.4
Distance from eye to tentacle	DET	0.9	0.7	1.1	0.3	0.7	0.5	0.5
Distance from eye to snout tip	DES	2.2	2.2	2.3	1.4	2.2	1.8	1.7
Width at 1st nuchal groove	WFN	3.2	3.0	2.9	1.9	1.9	2.9	2.5
Width at 2nd nuchal groove	WSN	3.1	2.8	2.7	1.6	1.5	2.5	2.3
Width at 2nd nuchal groove	LFN	0.4	0.7	0.3	0.3	0.3	1.2	1.0
Length of 2nd nuchal collar (Laterally)	LSN	0.5	0.5	0.3	0.3	0.9	1.5	1.6
Distance between snout tip and 1st nuchal groove	DFN	4.6	4.5	4.5	3.0	3.0	3.9	4.1
Distance between snout tip and 2nd nuchal groove	DSN	4.7	5.1	4.8	3.3	3.4	4.6	4.3
Distance between snout tip and 3rd nuchal groove	DST	5.6	6.0	4.9	3.8	4.5	5.8	5.1
Width of disc surrounding vent*	WDV*	1.2	1.4	3.1	0.6	0.6	1.0	1.2
Length of disc surrounding vent	WDV*	1.1	1.4	2.0	0.5	0.5	1.1	1.2
width of vent	WOV	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Number of denticles surrounding the vent	DSV	11	11	12	6	10	5	6
Number of premaxillary-maxillary teeth	NPM	20	18	19	15	16	17	16
Number of vemoropalantine teeth	NVT	18	18	17	12	14	18	18
Number of dentary teeth	NDT	17	15	19	14	12	17	15
Number of splenial teeth	NST	3	3	4	3	2	3	2
Total number of primary annuli	TPA	145	143	144	137	137	141	144

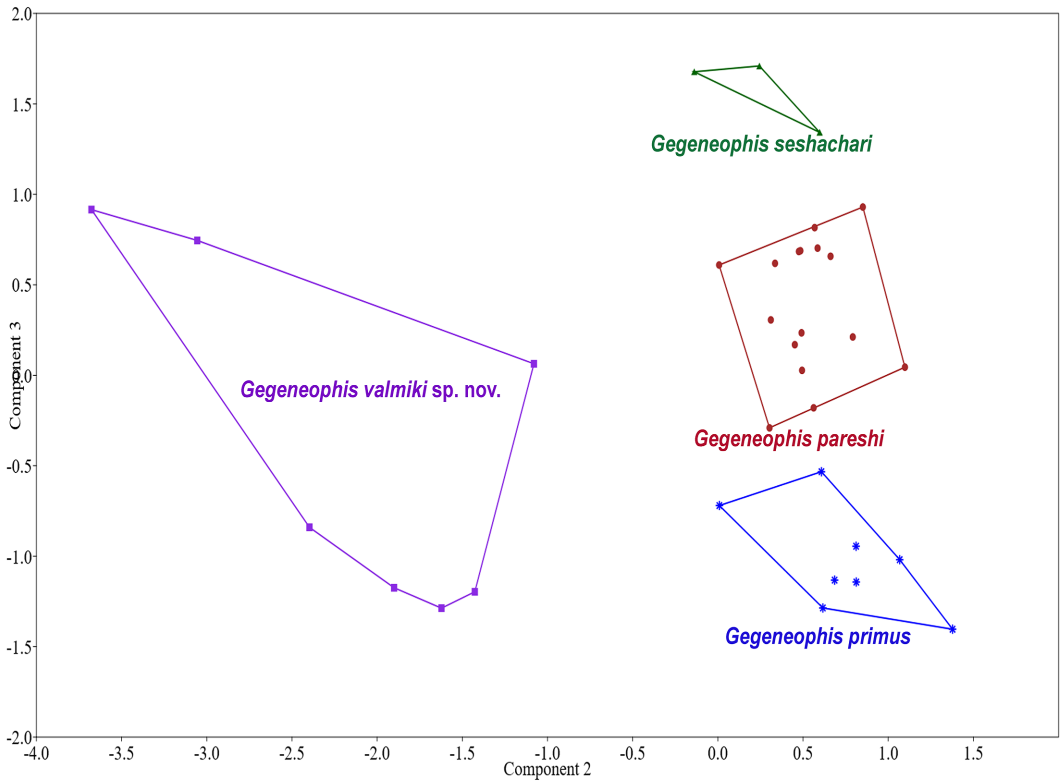

Figure 7. Multivariate Principal Component Analysis scatter plot for the members of *Gegeneophis* without secondary annuli (*Gegeneophis valmiki* sp. nov, *G. seshachari, G. pareshi,* and *G. primus*).

of 850 m at Amboli forest of Western Ghats in Sindhudurg, Maharashtra).

Gegeneophis valmiki sp. nov. differs from *G. goaensis* in having 137 to 145 primary annuli and absence of secondary annuli (*vs.* 125 to 126 primary annuli and secondaries starting between 38th to 48th annuli); known from higher-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from elevations of 50 m at Keri Village, Goa).

Gegeneophis valmiki sp. nov. differs from *G. mhadeiensis* in having 137 to 145 primary annuli and absence of secondary annuli (*vs.* 117 to 125 primary annuli and secondaries starting between 87th to 98th annuli); known from higher-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from elevations of 700 m at Chorla Village, Belgaum, Karnataka).

Gegeneophis valmiki sp. nov. differs from *G. madhavai* in having 137 to 145 primary annuli and absence of secondary annuli (*vs.* 96 to 97 primary annuli and secondaries starting between 63rd to 70th annuli); known from higher-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from elevations of 50 m at Mudur Village, Kundapura, Udupi, Karnataka).

Gegeneophis valmiki sp. nov. differs from *G. krishni* in having 137 to 145 primary annuli and absence of secondary annuli (*vs.* 125 to 127 primary annuli and secondaries starting between 110th to 114th annuli); known from higher-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from elevations of 40 m at Krishna Farms, Gurpur, Dakshina Kannada, Karnataka).

Gegeneophis valmiki sp. nov. differs from *G. tejaswini* in having 137 to 145 primary annuli and absence of secondary annuli (*vs.* 125 to 131 primary annuli and secondaries starting between 105th to 115th annuli); known from higher-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from elevations of 40 m at Bedoor, Cheemeni, Hosdurg, Kasaragod, Kerala).

Gegeneophis valmiki sp. nov. differs from *G. carnosus* in having 137 to 145 primary annuli and absence of secondary annuli (*vs.* 105 to 112 primary annuli and secondaries starting between 99th to 105th annuli); known from higher-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from elevations of 1500 m at Periah Peak, Wayanad, Kerala).

Gegeneophis valmiki sp. nov. differs from *G. ramaswami* in having 137 to 145 primary annuli and absence of secondary annuli (*vs.* 109 to 114 primary annuli and secondaries starting between 98th to 103rd annuli); known from higher-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from elevations of 200 m at Tenmalai forests, Kollam, Kerala).

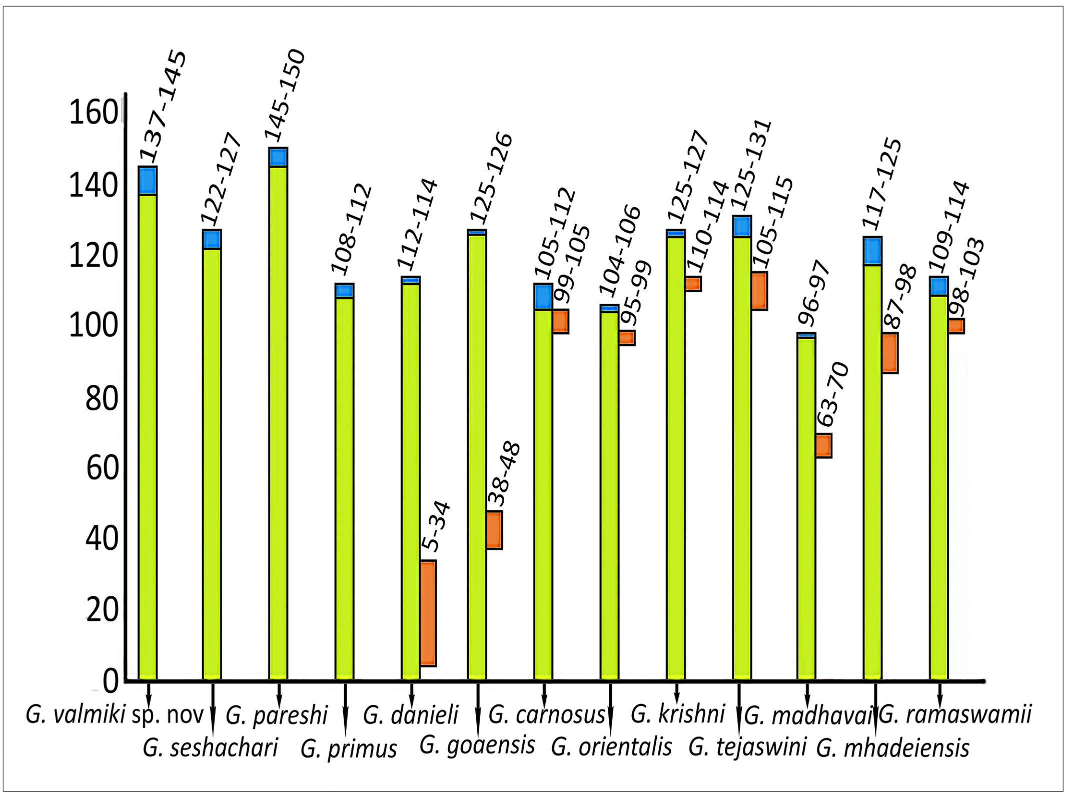

Figure 8. Graphic illustration of number of primary annular grooves and the initiation of secondary annular grooves for the extant 13 species of *Gegeneophis* in the peninsular India. Green bars: primary annuli; Blue bars: range of primary annuli; Orange bars: secondary annular groove starting range.

Gegeneophis valmiki sp. nov. differs from *G. orientalis* in having 137 to 145 primary annuli and absence of secondary annuli (*vs.* 104 to 106 primary annuli and secondaries starting between 95th to 99th annuli); known from higher-elevation mountain plateaus of 1000 m at Palashi, Pathan, Satara, Western Ghats (*vs.* known from elevations of 1200 m at Beespuram, Visakhapatnam, Andhra Pradesh and Deomali, Koraput, Odisha region of the Eastern Ghats).

Discussion

The distribution and patterns of species descriptions in *Gegeneophis* are unique in peninsular India. Among the 13 extant species (including the new species), six have their type localities and ranges in the northern Western Ghats, followed by five species in the central Western Ghats (Table 1, Figure 1). The southern Western Ghats and the Eastern Ghats are each represented by a single species.

Another six new lineages (Figures 2 and 3) are awaiting formal description, of which four are from the northern Western Ghats. This pattern of higher concentration of *Gegeneophis* species in the northern Western Ghats needs to be examined in context of this region as a potential center of origin for species diversity.

Considering the taxonomy of Indian caecilians, tooth count as a reliable taxonomic character is questionable. The number of teeth in caecilians varies with life stage, physiological condition, and dietary preferences within their habitat. For example, Giri *et al.* (2003) reported 30 premaxillary–maxillary, 33 vomeropalatine, 24 dentary, and 6 splenial teeth in their description of *G. danieli.* In contrast, Bhatta *et al.* (2004) documented 20 premaxillary–maxillary, 18 vomeropalatine, 10 dentary, and 5 splenial teeth in the description of *G. nadkarni.* Subsequently, based on molecular data presented by Gower *et al.* (2011), *G. nadkarni* was treated as a junior synonym of *G. danieli* (Gower *et al.* 2013). Now, dentition details for *G. danieli* are 20 to 30 premaxillary–maxillary, 18 to 33 vomeropalatine, 10 to 24 dentary, and 5 to 6 splenial teeth. Similarly, Ravichandran *et al.* (2003) reported 21 premaxillary–maxillary, 20 vomeropalatine, 18 dentary, and 3 splenial teeth in the original description of *G. seshachari.* Gower *et al.* (2007), in their redescription of the species, documented a range of 21 to 23 premaxillary–maxillary, 20 to 22 vomeropalatine, 16 to18 dentary, and 2 to 3 splenial teeth. Age, habitat preference, and diet composition are crucial factors influencing tooth retention in adult caecilians. Under these circumstances the utility of tooth count as a taxonomic character is challenging.

Since 2003, in descriptions of new species of *Gegeneophis* and *Indotyphlus,* more than 20 measurable (metric) characters have been considered. Only a few characters such as the position of the tentacles relative to the nostrils and eyes have proven to be reliable for generic-level differentiation between *Gegeneophis* and *Indotyphlus* (Giri *et al.* 2004). It is apparent that the remaining measurable characters were included as part of formal species descriptions rather than being taxonomically reliable or diagnostic (Figure 7). In contrast, meristic characters, such as the number of primary annuli and the presence or initiation of secondary annular grooves, have proven to be useful (Figure 8). High resolution field photographs are expected to facilitate the use of meristic characters for species identification in the field. Understanding the high species richness in northern Western Ghats using the total number of primaries and secondary annular grooves on the body in combination with geography (Dinesh 2025) may be reliable identification characters for Western Ghats caecilians.

The challenging part of caecilian studies in Western Ghats is the limited number of museum specimens for morphological studies and the limited knowledge of geographical distribution. In India, most of the members of the *Gegeneophis* are treated as either Data Deficient or Not Assessed categories for IUCN Red List status (Ramakrishna *et al.* 2023).

The type locality of *Gegeneophis valmiki* sp.

nov. lies in the vicinity of a temple characterized by perennial streams that provide suitable microhabitats for caecilians. Small scale agricultural practices in the surrounding areas involve the use of cow dung manure in paddy fields. Our field surveys discovered a higher frequency of caecilian encounters around cow manure pits next to forested areas, which are generally rich in organic matter and moisture (Dinesh *et al.* 2024). Because this study represents the northernmost distributional limit of *Gegeneophis* in the Western Ghats, further field explorations are warranted to uncover the potential hidden diversity and to better delineate the distributional range of the genus. Because *Gegeneophis valmiki* sp. nov. is known from only from a single locality, it is recommended that the species be treated as Data Deficient, warranting further field studies.

Acknowledgments

We thank the Director, Zoological Survey of India (ZSI), Kolkata; the Officer-in-Charge, ZSI, WRC, Pune for support and facilities. We are grateful to Mr. Ajay Sagar, Mr. Ram Sundarkanth Salve, and the staff of ZSI, WRC, Pune for their help during field work. We thank Priyanka Swami and Varsha V Kumar, Kartik Shankers lab, CES, IISc, Bangalore, and Shabnam Ansari ZSI, WRC Pune for the wet lab support. KPD is deeply grateful to Dr. Gopalakrishna Bhatta for his guidance and mentorship in caecilian research. The authors are grateful to the anonymous reviewers, Prof. Janalee Caldwell and the Editor-in-Chief for their critical comments that helped improve an earlier version of this manuscript.

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Editor: Jaime Bertoluci