*Zootaxa* 5027 (2): 254–268
https://www.mapress.com/j/zt/


**Article**

ISSN 1175-5326 (print edition)
**ZOOTAXA**
ISSN 1175-5334 (online edition)

https://doi.org/10.11646/zootaxa.5027.2.6
http://zoobank.org/urn:lsid:zoobank.org:pub:9D7A5B57-D489-4788-92A0-2C85C275A62B

# A new species of the genus *Hemiphyllodactylus* Bleeker, 1860 (Squamata: Gekkonidae) from Goa, India

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## Abstract

We describe a distinct new species of the genus *Hemiphyllodactylus* based on three specimens collected from semi-urban areas in Goa state of India. The new species can be easily distinguished from all peninsular Indian congeners by its small body size (SVL up to 32.4 mm), having 16–18 dorsal scales and 13 or 14 ventral scales at mid-body contained within one longitudinal eye diameter, nine or ten precloacal pores separated by 1–5 poreless scales from a series of 10–12 femoral pores on each thigh in males, lamellar formula of manus 2222 and of pes 2323 & 2333, as well as subtle colour pattern differences. Mitochondrial sequence divergence confirms the distinctiveness of the new species, which is not closely allied to either the South Indian or Eastern Ghats clades of Indian *Hemiphyllodactylus* and appears to be a member of a third Indian *Hemiphyllodactylus* clade. *Hemiphyllodactylus goaensis* **sp. nov.** is the first member of the genus to be described from the northern Western Ghats region as well as Goa state, and also only the second Indian *Hemiphyllodactylus* known from < 100 m asl. *Hemiphyllodactylus goaensis* **sp. nov.** extends the known distribution of the genus in western India ~ 560 km north in aerial distance and highlights that the genus is more widely distributed than previously thought and most likely contains numerous undescribed species. We also provide final museum numbers for type specimens of *H. arakuensis* and the holotype of *H. kolliensis*.

**Key words:** Biodiversity Hotspot, conservation, distribution, diversity, slender geckos, taxonomy

## Introduction

The genus *Hemiphyllodactylus* Bleeker is represented in peninsular India by a radiation that includes seven named and at least six unnamed species, contained in two deeply divergent clades in southern India and the Eastern Ghats (Agarwal *et al.* 2019, 2020a; Mohapatra *et al.* 2020). These nocturnal geckos are poorly represented in collections on account of their small size (Indian species < 41 mm; Agarwal *et al.* 2020a) and patchy distribution. Indian *Hemiphyllodactylus* have small distributional ranges similar to other members of the genus and are largely distributed in montane forest habitats (~600–1700 m asl.) (Zug 2010; Grismer *et al.* 2013, 2015, 2017, 2020; Sukprasert *et al.* 2018; Sung *et al.* 2018; Agarwal *et al.* 2019). The only Indian species known from low elevations is the recently described *H. minimus* Mohapatra, Khandekar, Dutta, Mahapatra & Agarwal 2020, from lowland coastal Odisha (<100 m asl.).

As a part of an ongoing project on the herpetofauna of Goa, Maharashtra and Karnataka, we obtained three individuals of a *Hemiphyllodactylus* species from two different localities in semi-urban areas of North Goa and South Goa districts. This represents the first record of the genus from Goa and the northern Western Ghats region. Given how restricted in distribution members of the genus are, we sequenced the mitochondrial ND2 gene and examined the morphology of these specimens in detail. The Goan *Hemiphyllodactylus* turned out to be deeply divergent in

 *Accepted by A. Bauer: 26 Jul. 2021; published: 31 Aug. 2021*

ND2 sequence data and can be diagnosed against all known Indian congeners using morphological data. We describe this divergent lineage as *Hemiphyllodactylus goaensis* **sp. nov.**.

## Materials and methods

**Morphological data.** Specimens of the new species used in this study are deposited in the collection of the Bombay Natural History Society, Mumbai (BNHS); other institutional acronyms include the Centre for Ecological Sciences, Bangalore (CES G, CES L); Museum and Research Collection Facility at National Centre for Biological Sciences, Bangalore (NCBS/NRC-AA). Comparative data for seven previously described peninsular Indian congeners were collected from the types (*Hemiphyllodactylus arakuensis*, *H. jnana* Agarwal, Khandekar, Giri, Ramakrishnan & Karanth*, H. kolliensis, H. minimus, H. nilgiriensis* Agarwal, Bauer, Pal, Srikanthan & Khandekar and, *H. peninsularis* Agarwal, Bauer, Pal, Srikanthan & Khandekar) and topotypic *H. aurantiacus* (Beddome) specimens (Appendix 1). We took counts and measurements under a ZEISS Stemi 305 stereo dissecting microscope, on the right side of the body for bilateral characters. The terminology and methodology used to define characters follows Agarwal *et al.* (2019). The following measurements were recorded using a Mitutoyo digital vernier calliper (to the nearest 0.1 mm): snout vent length (SVL), tail length (TL), tail width (TW), trunk length (TRL), body height (BH), body width (BW), forearm length (FL), crus length (CL), head length (HL), head width (HW), head height (HH), eye diameter (ED), naris to eye distance (EN), snout to eye distance (SE), ear to eye distance (EE), ear length (EL), internarial distance (IN) and, interorbital distance (IO).

Meristic characters recorded included: internasal scales (INS), supralabials (SL), infralabials (IL), chin scales (CS), dorsal scales around the midbody contained within one eye diameter (ABS), ventral scales at midbody contained within one eye diameter (VS), femoral pores (FP), precloacal pores (PP), poreless scales between the precloacal and femoral pores on each side (SB PP&FP); subdigital lamellae wider than long on the first finger (LAMF1), subdigital lamellae wider than long on the first toe (LAMT1), the lamellar formula (LAMF/T) and, the basal lamellar formula (BLAMF/T).

**Molecular data.** Tissue samples were preserved in 100% ethanol and DNA extraction, PCR amplification and sequencing were outsourced to Medauxin, Bangalore. Primers used to target the protein coding ND2 gene for amplification were L4437 and H5934 (Macey *et al.* 1997), with the former used for sequencing, with an annealing temperature of 50° C. These were added to an alignment including all published sequences of Indian *Hemiphyllodactylus* and their sister clade from southeast Asia (after Agarwal *et al.* 2019; Table 1); with ClustalW (Thompson *et al.* 1994) used for alignment with default settings as implemented in MEGA 5.2 (Tamura *et al.* 2011). Uncorrected pairwise p-distance with the partial deletion option was calculated in MEGA and the best fit models of sequence evolution were picked using the Bayesian Information Criteria in PartitionFinder 2 (Lanfear *et al.* 2012). The ND2 data partitioned by codon position was picked for both Maximum Likelihood (ML) and Bayesian Inference (BI). A ML phylogeny was reconstructed using the GTR + G model for each partition in RAxML HPC 8.2.10 (Stamatakis, 2006) implemented on the CIPRES Science Gateway (http://www.phylo.org/; Miller *et al.* 2010) with 10 independent ML runs and support assessed with 1000 non-parametric bootstraps. A partitioned BI phylogeny was built using the models selected by PartitionFinder (ND2 codon position, cp, 1 = HKY+I, cp2 = TVM+I, cp3 = TIM+G) with model parameters unlinked across partitions. The analysis was run for 1,000,000 generations sampling every 1,000 generations with two parallel runs with four chains each (one cold and three hot) and convergence determined based on standard deviation of split frequencies (<0.01). The first 25% of trees were discarded as burn-in and a Maximum Clade Credibility tree was built using TreeAnnotator 1.10.4 (Drummond *et al.* 2012).

**TABLE 1.** Sequences used in this study. Abbreviations for museum and voucher collections are as follows: AK, Akshay Khandekar field series; AMB, Aaron Bauer field series; BNHS, Bombay Natural history Society, Mumbai; CYL01, R. Chaitanya field series; CES G (Karanth lab field series) and CES L (Kartik Shanker lab field series) at the Centre for Ecological Sciences, Bangalore; FMNH, The Field Museum of Natural History, Chicago; IAG, Ishan Agarwal field series; NCBS-BH, National Centre for Biological Sciences, Bangalore; ZMKUTHA, Kasetsart University, Thailand.

| Species | Tissue voucher | Locality | GenBank Accession |
|---|---|---|---|
| *Hemiphyllodactylus arakuensis* | CES G068 (BNHS 2275) | India, Andhra Pradesh, Visakhapatnam district. Araku | MK570109 |
| *Hemiphyllodactylus aurantiacus* | AMB (no number) | India, Tamil Nadu, Salem district, Yercaud | MK570111 |
| *Hemiphyllodactylus aurantiacus* | AK 237 (BNHS 2548) | India, Tamil Nadu, Salem district, Yercaud | MK570110 |
| *Hemiphyllodactylus goaensis* **sp. nov.** | BNHS 2847 | India, Goa, South Goa district, Goa University campus | MZ703636 |
| *Hemiphyllodactylus jnana* | CES G470 | India, Karnataka, Kolar district, Kolar | MK570115 |
| *Hemiphyllodactylus jnana* | CYL01 (BNHS 2556) | India, Tamil Nadu Vellore district, Yelagiri | MK570114 |
| *Hemiphyllodactylus jnana* | CES G173 | India, Tamil Nadu, Hosur district, Aiyur | MK570113 |
| *Hemiphyllodactylus jnana* | CES G174 | India, Karnataka, Urban district, NCBS, Bangalore | MK570112 |
| *Hemiphyllodactylus kolliensis* | AK 276 (BNHS 2554) | India, Tamil Nadu, Namakkal district, Kolli Hills | MK570117 |
| *Hemiphyllodactylus kolliensis* | CES G138 | India, Tamil Nadu, Namakkal district, Kolli Hills | MK570116 |
| *Hemiphyllodactylus minimus* | NCBS-BH667 | India, Odisha, Ganjam district, Jhadeswar Shiva Temple | MT966315 |
| *Hemiphyllodactylus nilgiriensis* | CES L467 | India, Tamil Nadu, Nilgiris district, Nilgiris | MK570126 |
| *Hemiphyllodactylus nilgiriensis* | CES L466 | India, Tamil Nadu, Nilgiris district, Nilgiris | MK570125 |
| *Hemiphyllodactylus nilgiriensis* | IAG033 | India, Tamil Nadu, Coimbatore district, Coimbatore | MK570124 |
| *Hemiphyllodactylus peninsularis* | CES L482 (BNHS 2633) | India, Tamil Nadu, Tirunelveli district, Kalakad RF | MK570127 |
| *Hemiphyllodactylus IN 1* | IAG018 | India, Odisha, Kandmahal district, Daringbadi | MK570118 |
| *Hemiphyllodactylus IN 2* | CES G277 | India, Odisha, Gajapati district, Devagiri, | MK570119 |
| *Hemiphyllodactylus IN 3* | IAG011 | India, Odisha, Gajapati district, Mahendragiri, | MK570120 |
| *Hemiphyllodactylus IN 4* | CES G270 | India, Andhra Pradesh, Visakhapatnam district, RV Nagar | MK570121 |
| *Hemiphyllodactylus IN 5* | CES G228 | India, Karnataka, Chitradurga district, Challakere | MK570122 |
| *Hemiphyllodactylus IN 6* | CES G509 | India, Andhra Pradesh, Tirupati district, Tirumala | MK570123 |
| *Hemiphyllodactylus flaviventris* Sukprasert, Sutthiwises, Lauhachinda & Taksintum | ZMKUTHA_ TM001204N | Thailand, Chanthaburi | MG322161 |
| *Hemiphyllodactylus indosobrinus* Eliades, Phimmachak, Sivongxay, Siler & Stuart | FMNH 258695 | Laos, Pakxong, Champasak | JN393935 |

## Results

**Molecular data.** We generated a partial fragment of the ND2 gene (579 nucleotides) which was translated to amino acids to ensure no nuclear copies of mitochondrial genes were inadvertently sequenced. Topologies for the BI and ML phylogenies were very similar except for the position of the *Hemiphyllodactylus* from Goa. In the ML phylogeny, the *Hemiphyllodactylus* from Goa occupies a unique position within the Indian species, falling outside the two major *Hemiphyllodactylus* clades (South Indian and Eastern Ghats clades), and sister to the South Indian clade, albeit with poor support (< 70 bootstrap support, BS; Figure 1). In the BI phylogeny the Goan *Hemiphyllodactylus* is recovered as sister to other Indian *Hemiphyllodactylus* (not shown). The South Indian clade has poor BS (<70) and high posterior probability (1.0), unlike in previous studies (Agarwal *et al.* 2019; Mohapatra *et al.* 2020). The Goan *Hemiphyllodactylus* shows uncorrected pairwise ND2 divergence of 16.6–20.5 % with previously described Indian species (Table 2). It also differs from the other species by a suite of morphological data and we describe it as a new species below.

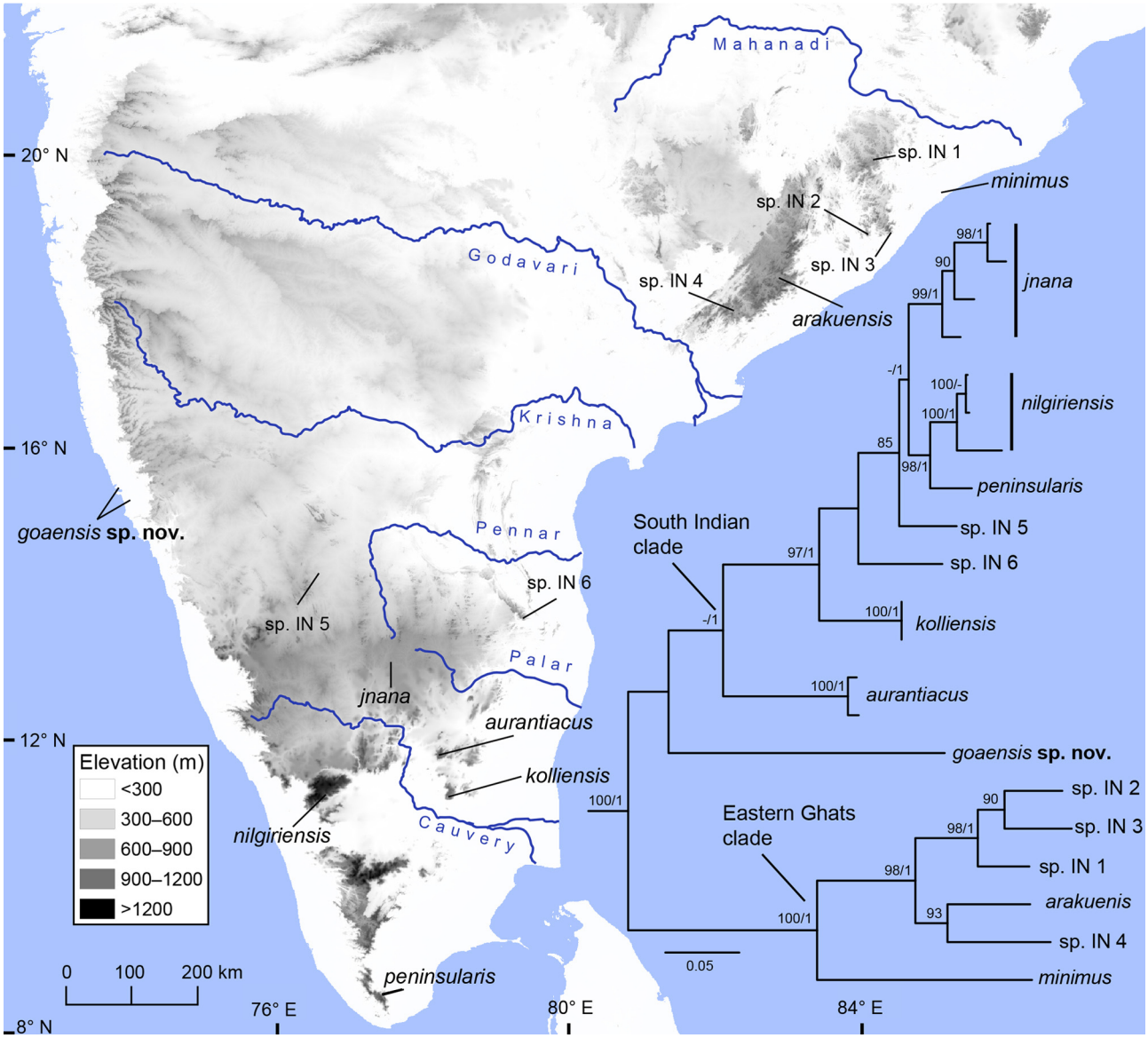


**FIGURE 1.** Type localities of Indian species of *Hemiphyllodactylus* and distribution of *Hemiphyllodactylus goaensis* **sp. nov.** (northern locality is type locality and southern is the other known locality) with major east-flowing rivers marked in blue; inset, maximum likelihood phylogeny of the *aurantiacus* group with bootstrap support > 70% and posterior probability of 1 shown at nodes (outgroups not shown).

**TABLE 2.** Uncorrected pairwise ND2 sequence divergence between described Indian *Hemiphyllodactylus*.

| | Species | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 1 | *Hemiphyllodactylus goaensis* **sp. nov.** (*n*=1) | | | | | | | |
| 2 | *Hemiphyllodactylus arakuensis* (*n*=1) | 20.5 | | | | | | |
| 3 | *Hemiphyllodactylus aurantiacus* (*n*=2) | 16.6 | 19.7 | | | | | |
| 4 | *Hemiphyllodactylus jnana* (*n*=4) | 17.4 | 21.6 | 13.9 | | | | |
| 5 | *Hemiphyllodactylus kolliensis* (*n*=2) | 16.8 | 17.7 | 12.9 | 9.1 | | | |
| 6 | *Hemiphyllodactylus minimus* (*n*=1) | 18.9 | 16.0 | 19.2 | 20.9 | 17.7 | | |
| 7 | *Hemiphyllodactylus nilgiriensis* (*n*= 3) | 18.6 | 20.8 | 14.8 | 6.7 | 10.4 | 21.7 | |
| 8 | *Hemiphyllodactylus peninsularis* (*n*=1) | 18.5 | 20.6 | 13.9 | 6.0 | 9.6 | 20.6 | 5.1 |

## Taxonomy

### *Hemiphyllodactylus goaensis* sp. nov.

Figures 1–6; Table 3.

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**Holotype.** BNHS 2846, SVL 30.2 mm, adult male, from Goa University, Taleigao, (15.46032°N, 73.83583°E; *ca.* 50 m asl.), North Goa district, Goa, India, collected by Dikansh S. Parmar on 22 November 2020.

**Paratypes.** BNHS 2847, SVL 25.6 mm, sub-adult male, same data as holotype except coordinates (15.46041°N, 73.83544°E; *ca.* 50 m asl.), collected by Dikansh S. Parmar on 18 March 2020; BNHS 2848, SVL 32.4 mm, adult female, from near Chandor, (15.26089°N, 74.04367°E; *ca.* 10 m asl.) South Goa district, Goa, India, collected by Rinku Kumar Gupta on 09 September 2020.

**Etymology.** The specific epithet is a toponym for Goa state, to which the new species is currently restricted to.

**Suggested common English name.** Goan slender gecko.

**Diagnosis.** *Hemiphyllodactylus goaensis* **sp. nov.** can be diagnosed from congeners by the unique combination of snout-vent length up to 32.4 mm (*n*=3); five or six chin scales; postmentals not enlarged; 10–12 supralabials and 10 or 11 infralabials; 16–18 dorsal scales and 13 or 14 ventral scales at mid-body contained within one longitudinal eye diameter; four or five subdigital lamellae on the digit I of manus and pes; lamellar formula of manus 2222; lamellar formula of pes 2323 and 2333; males with nine or ten precloacal pores separated by 1–5 poreless scales from a series of 10–12 femoral pores on each thigh (*n*=2); no plate-like enlarged subcaudals; head with dark postorbital streak and longitudinal markings on nape, dark postorbital streak more or less well-defined and may continue until hindlimb insertions, longitudinal markings on nape extending just past forelimb insertions; dorsal pattern of broken dark longitudinal markings and light and dark speckling; postsacral marking with light-coloured anteriorly projecting arms indicated by broken streak extending anterior to hindlimb insertions; belly stippled with black.

**Comparison with peninsular Indian congeners.** *Hemiphyllodactylus goaensis* **sp. nov.** can be distinguished from all other Indian congeners on the basis of the following differing or non-overlapping characters: males with nine or 10 precloacal and 10–12 femoral pores (*versus* males with eight or nine precloacal and two or three femoral pores in *H. arakuensis*, six or seven precloacal and 6–8 femoral pores in *H. aurantiacus*, nine or 10 precloacal and six or seven femoral pores in *H. jnana*, nine precloacal and eight femoral pores in *H. kolliensis*, nine or 10 precloacal and six or seven femoral pores in *H. minimus*, eight or nine precloacal and 7–9 femoral pores in *H. nilgiriensis*, and 11 precloacal and 11 femoral pores in *H. peninsularis*); males with 1–5 poreless scales between precloacal and femoral pores (*versus* 11–14 in *H. arakuensis*, 9–11 in *H. aurantiacus*, 10–12 in *H. jnana*, and 7–9 in *H. nilgiriensis*); 16–18 mid-body dorsal scales in one eye diameter (*versus* 13–16 in *H. arakuensis* and *H. aurantiacus*, and 20 in *H. peninsularis*); 13 or 14 mid-body ventral scales in one eye diameter (*versus* 9–13 in *H. aurantiacus*, 10–13 in *H. kolliensis*, and eight or nine in *H. minimus*); lamellar formula of pes 2323 and 2333 (*versus* 2333 or 3333 in *H. arakuensis*; 2233, 2333 and 3333 in *H. aurantiacus*; 2222 in *H. jnana*, *H. kolliensis*, *H. nilgiriensis* and *H. peninsularis*; 2332 or 2333 in *H. minimus*,).

**Description of the holotype.** The holotype is in good condition except for a small 2.1 mm vertical cut on sternum region. Adult male, SVL 30.2 mm. Head short (HL/SVL 0.19), elongate (HW/HL 0.79), slightly depressed

(HH/HL 0.44), distinct from neck (Figure 2). Prefrontal region flat; canthus rostralis smoothly rounded, snout rounded in dorsal profile (Figure 3A). Snout short (SE/HL 0.45); slightly longer than eye diameter (ED/SE 0.59); scales on snout, canthus rostralis, forehead and interorbital region homogenous in shape, granular; scales on the snout and canthus rostralis slightly larger, conical and pronounced than those on occipital, forehead and interorbital regions, two rows bordering supralabials slightly larger and elongated (Figure 3A, C). Eye small (ED/HL 0.27); pupil vertical with crenulated margins; supraciliaries small, slightly mucronate, gradually increasing in size towards anterior of the orbit, those at the anterior end of orbit largest; ear opening roughly oval (greatest diameter 0.4 mm), eye to ear distance greater than diameter of eye (EE/ED 1.37); rostral wider than deep (rostral width/ height 3.0), undivided; single large supranasal above naris on each side, separated medially by three slightly smaller internasal scales; three postnasal on left side and two on right, marginally smaller in size than supranasals; rostral in contact with naris, supralabial I, supranasals and three small internasal scales on each side; naris small, circular; external naris surrounded by supranasal, rostral, supralabial I and three postnasals on left side and supranasal, rostral, supralabial I and two postnasals on right (Figure 3C). Mental subtriangular, bordered laterally by infralabial I on either side and posteriorly by three slightly enlarged chin scales; five scales touching internal edge of infralabials and mental from juncture of second and third infralabials on either side (Figure 3B). Labials large, supralabial I and infralabial I largest, gradually decrease in size posteriorly; supralabials (to midorbital position) eight on left and seven on right side; 11 supralabials (to angle of jaw) on left and 10 on right side; infralabials (to angle of jaw) 10 on left and 11 on right side (Figure 3C).


**FIGURE 2.** *Hemiphyllodactylus goaensis* **sp. nov.** (holotype, BNHS 2846): (A) dorsal view of body, (B) ventral view of body. Scale bars 10 mm; photos by Akshay Khandekar.

Body relatively stout (BW/SVL 0.15), marginally elongate (TRL/SVL 0.52), ventrolateral folds indistinct (Figure 2A). Scales on dorsal aspect of head and neck granular, slightly smaller than those on snout and forehead, those on dorsum slightly smaller than those on snout, flat and subimbricate; 18 scales contained within one eye diameter. Ventral scales much larger than dorsals, smooth, subequal, imbricate, subcircular, gradually increasing in size posteriorly, except three or four rows above cloaca which are much smaller; 14 scales contained within one eye diameter; gular region with much smaller, somewhat pointed, granular scales, becoming slightly larger, flattened and juxtaposed on anterior and lateral aspects. Scales on palm and sole flat and subcircular; scales on dorsal and ventral aspect of limbs flat, subequal and imbricate, those on anteriolateral aspect of thigh largest (Figure 2B). Forelimbs and hindlimbs short, stout; forearm short (FL/SVL 0.09); tibia short (CL/SVL 0.11). Digits with well-developed lamellar pad; digit I vestigial, without claw; digits II–V well developed, with free terminal phalanx arising from within lamellar pad, ending in a unsheathed, recurved claw; lamellar pads of all digits with basal series of undivided, transverse lamellae, expanding into large triangular apical lamellae, which are deeply notched except terminal lamella which is undivided; proximal lamellae/lamellar formula II–V: 2-2-2-2 (manus) and 2-3-3-3 (pes); basal lamellae of digits II–V: 3-5-5-4 (manus) and 4-5-6-3 on left and 4-5-4-5 on right (pes); transversely expanded lamellae on digit I: four on both manus and pes.

Tail regenerated, not segmented; tail much shorter than snout vent length (TL/SVL 0.49) (Figure 2); scales on dorsal aspect of tail much larger than those on mid-body of dorsum, smooth, flat, subcircular and subimbricate, largest on dorsal side, gradually decreasing in size laterally. Scale on ventral side of the tail almost twice the size of those on the dorsal side of tail, smooth, flat and subimbricate. Two distinct hemipenial bulges at tail base, clearly visible when viewed laterally and ventrally; two enlarged, subequal postcloacal spurs on both sides, anterior one is largest. Angular series of nine precloacal pores separated from a series of 12 (left) and 10 (right) femoral pores by two (left) and five (right) poreless scales.

**Colouration in life (holotype;** Figure 4A). Ground colour of dorsum of head, body and limbs light brown suffused with pink (dirty brown in preservative). Indistinct dark preorbital streak, two indistinct dark, discontinuous postorbital streaks that terminate beyond forelimb insertion, most well defined behind head to just beyond forelimb insertions (especially in preservative). Dorsum of occipital region and body with faint dark longitudinal markings and scattered light speckles. Limbs with dark and light speckling; few scattered orange spots near hindlimb insertions and on hindlimbs and tail. Postsacral marking yellowish cream, chevron-shaped, flanked anteriorly and laterally by black chevron; light anteriorly projecting arms indicated by broken yellow streaks extending anterior to hindlimb insertions (cream coloured in preservative). Regenerated tail finely speckled with dark and light markings; venter of tail off-white. Throat moderately and lateral edges of belly strongly stippled with dark spots and numerous dark scales, underside of limbs and precloacal region strongly pigmented.

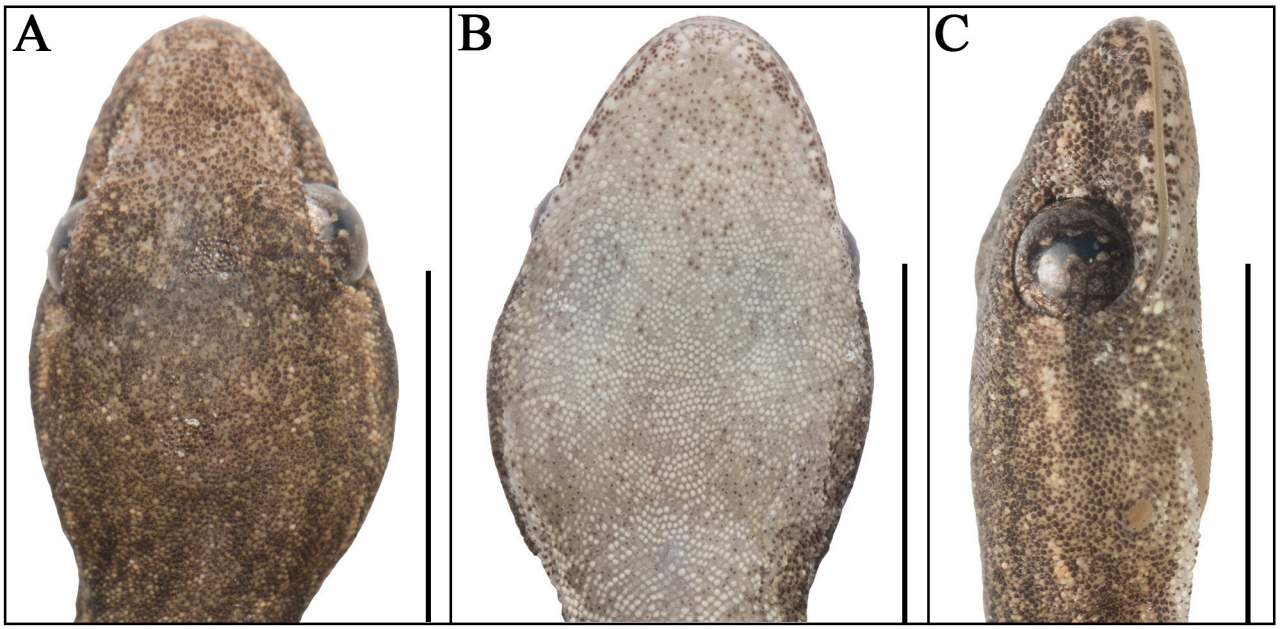


**FIGURE 3.** *Hemiphyllodactylus goaensis* **sp. nov.** (holotype, BNHS 2846): (A) dorsal view of head, (B) ventral view of head, (C) lateral view of head. Scale bars 5 mm; photos by Akshay Khandekar.


**FIGURE 4.** live photos of *Hemiphyllodactylus goaensis* **sp. nov.** (A) male holotype, BNHS 2846, and (B) female paratype BNHS 2848. Photos by Akshay Khandekar.

**Variation and additional information from paratypes.** Mensural and meristic data for the type series is given in Table 3. There is a single sub-adult male (25.6 mm) and a single adult female (32.4 mm). Both paratypes resemble the holotype except as follows: female paratype BNHS 2848 with elongated calcium deposits on either side of the neck (Figure 4B), and fourth terminal phalange of left pes missing. Four chin scales bordering mental posteriorly in BNHS 2848; four chin scales bordering infralabial II in BNHS 2847. Female paratype BNHS 2848 with original (except the tip which is regenerated) and complete tail, shorter than body (TL/SVL 0.69); male paratype also with original but incomplete tail (tail length 7.2 mm); no caudal segments (Figure 5). Original tail bright orange ventrally

in paratypes, light orange dorsally with four indistinct dark bands in female paratype BNHS 2848. Postorbital streak well defined in BNHS 2848, discontinuous but extending beyond hindlimb insertions; dorsal longitudinal markings on neck; BNHS 2847 with dark preorbital streak, indistinct dark longitudinal markings and rows of longitudinally arranged light spots on dorsum of body. Calcium deposits on lateral sides of neck in BNHS 2848 cream coloured. Postsacral marking orange in both paratypes.

**TABLE 3.** Measurements (mm) and meristic data for the type series of *Hemiphyllodactylus goaensis* **sp. nov.** Abbreviations as listed in Materials and Methods. * = tail incomplete; L & R = Left & Right; abs. = absent.

| Type | Holotype | Paratypes | |
|---|---|---|---|
| Specimen number | BNHS 2846 | BNHS 2847 | BNHS 2848 |
| Sex | M | M | F |
| SVL | 30.2 | 25.6 | 32.4 |
| TL | 14.9 | 7.2* | 22.5 |
| TW | 2.3 | 1.8 | 2.3 |
| TRL | 15.8 | 11.0 | 15.8 |
| BH | 2.5 | 2.2 | 2.4 |
| BW | 4.8 | 3.2 | 5.4 |
| HL | 5.9 | 5.3 | 6.8 |
| HW | 4.7 | 4.0 | 5.2 |
| HH | 2.6 | 2.7 | 2.7 |
| FL | 2.9 | 2.3 | 3.0 |
| CL | 3.5 | 2.8 | 3.9 |
| ED | 1.6 | 1.4 | 1.7 |
| NE | 2.2 | 1.9 | 2.2 |
| SE | 2.7 | 2.4 | 3.1 |
| EE | 2.2 | 2.0 | 2.5 |
| EL | 0.4 | 0.2 | 0.3 |
| IN | 0.9 | 0.9 | 1.0 |
| IO | 1.5 | 1.2 | 1.7 |
| SL L & R | 11 & 10 | 12 & 10 | 11 & 10 |
| IL L & R | 10 & 11 | 10 & 10 | 11 & 10 |
| INS | 3 | 2 | 3 |
| CS L & R | 5 & 5 | 5 & 6 | 5 & 5 |
| ABS | 18 | 16 | 18 |
| VS | 14 | 14 | 13 |
| FP L & R | 12 & 10 | 11 & 11 | abs. |
| PP | 9 | 10 | abs. |
| SBPP & FP L & R | 2 & 5 | 1 & 2 | abs. |
| LAM1F L & R | 4 & 4 | 4 & 4 | 5 & 5 |
| LAM1T L & R | 4 & 4 | 5 & 5 | 5 & 5 |
| LAMF | 2-2-2-2 | 2-2-2-2 | 2-2-2-2 |
| LAMT | 2-3-3-3 | 2-3-2-3 | 2-3-3-3 |
| BLAMF II–V L & R | 3-5-5-4 | 4-5-5-5 & 4-5-6-4 | 4-5-6-4 |
| BLAMT II–V L & R | 4-5-6-3 & 4-5-4-5 | 5-5-7-5 | 4-5-4-4 |

**Distribution and natural history.** This species is only known from two localities in Goa, where it was found as a human commensal. Specimens were collected by visual encounter at night from Goa University (North Goa district) and Chandor (South Goa district). On 18 March 2020 at 23:40 hrs, 1st individual (BNHS 2847) was found

on a wall on the second floor of a building ~48 feet above the ground and ~10 feet above floor level. Second individual (BNHS 2848) was found in Chandor (South Goa) on 9 September 2020 at 2130 hrs it was found dwelling on a wooden curtain rod (approximately seven feet from the ground). Third individual (BNHS 2846) was found on 22 November 2020 at 2028 hrs on a wall approximately seven feet from the ground.


**FIGURE 5.** Paratypes of *Hemiphyllodactylus goaensis* **sp. nov.** Scale bar 10 mm; photo by Akshay Khandekar.

**Behaviour and Diet.** All specimens showed tail wagging behaviour and after a short stride or slow walk they also exhibited leaping behaviour. *Hemiphyllodactylus goaensis* **sp. nov.** are moderate to slow in movement but active hunters, in captivity they preyed upon small crickets, small moths, bugs and cockroaches. When larger insects

(double in size than head of geckos) were offered, the geckos would grab them in their mouths and shake their heads with vigorous movements to tear the insects into pieces in order to eat them. Individual BNHS 2846 shed its skin in an almost single complete piece on 13 December 2020 at 2008 hrs, and four days preceding this the colouration became dull and during this period it did not prey upon offered insects.

**Note.** Recently, Agarwal *et al.* (2019) described three new species of Indian *Hemiphyllodactylus* (*H. arakuensis*, *H. jnana*, and *H. kolliensis*) and provided additional morphological data for *H. aurantiacus* based on freshly collected topotypic specimens. However, they did not provide museum numbers for the three new species nor for the topotypic *H. aurantiacus* specimens. Subsequently, Agarwal *et al.* (2020a) described two more species from Tamil Nadu and also provided museum numbers for topotypic *H. aurantiacus*, *H. jnana* and the paratypes of *H. kolliensis*. In the present work, we provide updated museum numbers for for all the *Hemiphyllodactylus* material dealt with by Agarwal *et al.* 2019, 2020a (Table 4).

**TABLE 4.** List of updated museum numbers for recently described Indian *Hemiphyllodactylus* giving type status, and original and updated museum numbers for [a], Agarwal *et al.* (2019); and [b], Agarwal *et al.* (2020a). Museum abbreviations are as follows: Bombay Natural history Society, Mumbai (BNHS); Centre for Ecological Sciences, Bangalore (CES G, CES L); National Centre for Biological Sciences (NCBS-BH).

| Species | Type status | Original number | Updated numbers |
|---|---|---|---|
| *H. arakuensis* | Holotype | G 446[a] | NRC-AA-1139 |
| *H. arakuensis* | Paratype | G 442[a] | NRC-AA-1140 |
| *H. arakuensis* | Paratype | G 443[a] | NRC-AA-1141 |
| *H. arakuensis* | Paratype | G 444[a] | NRC-AA-1142 |
| *H. arakuensis* | Paratype | G 445[a] | NRC-AA-1143 |
| *H. arakuensis* | Paratype | G 447[a] | NRC-AA-1144 |
| *H. arakuensis* | Paratype | G 448[a] | NRC-AA-1145 |
| *H. arakuensis* | Paratype | G 449[a] | NRC-AA-1146 |
| *H. aurantiacus* | Topotype | AK 237[a] | BNHS 2548 |
| *H. aurantiacus* | Topotype | AK 238[a] | BNHS 2549 |
| *H. aurantiacus* | Topotype | AK 239[a] | BNHS 2550 |
| *H. aurantiacus* | Topotype | AK 240[a] | BNHS 2551 |
| *H. aurantiacus* | Topotype | AK 241[a] | BNHS 2552 |
| *H. aurantiacus* | Topotype | AK 242[a] | NCBS-BH703 |
| *H. aurantiacus* | Topotype | AK 243[a] | NCBS-BH704 |
| *H. aurantiacus* | Topotype | AK 244[a] | BNHS 2553 |
| *H. aurantiacus* | Topotype | AK 245[a] | NCBS-BH705 |
| *H. aurantiacus* | Topotype | AK 246[a] | NCBS-BH706 |
| *H. aurantiacus* | Topotype | AK 247[a] | NCBS-BH707 |
| *H. jnana* | Holotype | AQ 191[a] | NCBS-BH709 |
| *H. jnana* | Paratype | AQ 186[a] | NCBS-BH710 |
| *H. jnana* | Paratype | AQ 187[a] | NCBS-BH711 |
| *H. jnana* | Paratype | AQ 188[a] | NCBS-BH712 |
| *H. jnana* | Paratype | AQ 189[a] | NCBS-BH713 |
| *H. jnana* | Paratype | AQ 190[a] | NCBS-BH714 |
| *H. jnana* | Paratype | AQ 192[a] | NCBS-BH715 |
| *H. jnana* | Paratype | AQ 193[a] | NCBS-BH716 |
| *H. jnana* | Paratype | AQ 194[a] | NCBS-BH717 |
| *H. jnana* | Paratype | AQ 195[a] | NCBS-BH718 |
| *H. jnana* | Paratype | CYL 01[a] | BNHS 2556 |

*.....continued on the next page*

**TABLE 4.** (Continued)

| Species | Type status | Original number | Updated numbers |
|---|---|---|---|
| *H. jnana* | Paratype | CESL 014[a] | CESL 014 |
| *H. jnana* | Paratype | G 470[a] | CESG 470 |
| *H. kolliensis* | Holotype | CES G138[a] | NRC-AA-1147 |
| *H. kolliensis* | Paratype | AK 276[a] | BNHS 2554 |
| *H. kolliensis* | Paratype | AK 277[a] | BNHS 2555 |
| *H. kolliensis* | Paratype | AK 278[a] | NCBS-BH708 |
| *H nilgiriensis* | Holotype | BNHS 2632[b] | BNHS 2632 |
| *H nilgiriensis* | Paratype | BNHS 2436[b] | BNHS 2436 |
| *H nilgiriensis* | Paratype | BNHS 2437[b] | BNHS 2437 |
| *H nilgiriensis* | Paratype | CESL 467[b] | CESL 467 |
| *H. peninsularis* | Holotype | BNHS 2633[b] | BNHS 2633 |

## Discussion

*Hemiphyllodactylus goaensis* **sp. nov.** is the eighth Indian species of the genus and 47th globally. The new species is also among the smallest known species of the genus at 32 mm SVL, with only *H. minimus* marginally smaller (SVL up to 31 mm) and only two other Indian species that do not exceed an adult size of 35 mm SVL (*H. nilgiriensis* and *H. peninsularis*; Agarwal *et al.* 2020a; Mohapatra *et al.* 2020). *Hemiphyllodactylus goaensis* **sp. nov.** is also only the second Indian species to have a lowland distribution, after *H. minimus* from the eastern coastal lowlands of Odisha (Mohapatra *et al.* 2020). This new species extends the range of the genus to the northwest by ~330 km (from the locality of *H.* sp. IN 5; Challakere, Karnataka) as well as by ~560 km along the Western Ghats (from the type locality of *H. nilgiriensis*; Coimbatore, Tamil Nadu). *Hemiphyllodactylus goaensis* **sp. nov.** is currently considered as endemic to Goa.

The new species appears to represent a third clade of *Hemiphyllodactylus*—the broad distribution of the genus in India now mirroring that of *Cyrtodactylus* (*Geckoella*), with an Eastern Ghats clade (corresponding to the *G. nebulosus* complex), a south Indian clade (*G. collegalensis* complex) and a northern Western Ghats clade (*G. albofasciatus*-*G. deccanensis* complex) (Agarwal & Karanth 2015). It remains to be seen how widespread *Hemiphyllodactylus* is in the northern Western Ghats and if the genus occurs in central Indian forests where members of the *G. nebulosus* complex are found. *Cnemaspis* is the third genus which has an overlapping distribution in peninsular India, found across the Western Ghats and hills of south India but not known from the northern eastern Ghats (Agarwal *et al.* 2020b).

*Hemiphyllodactylus goaensis* **sp. nov.** is currently known from two localities in Goa: Goa University, North Goa and Chandor, South Goa that are about 30 km straight line distance apart. All specimens were found in similar microhabitats, in human habitation dwelling on walls. The surrounding habitat is open with scattered vegetation. Goa University is located on a flat, coastal, lateritic outcrop with seasonally dry grasslands with shrubs and trees namely *Ficus religiosa* L., *Ficus arnottiana* (Miq.) Miq., *Bombax ceiba* L., *Ceiba pentandra* (L.) Gaertn., *Mangifera indica* L., *Syzygium cumini* L., *Syzygium caryophyllatum* (L.) Alston, *Careya arborea* Roxb., *Pithecellobium dulce* (Roxb.) Benth., *Acacia auriculiformis* A.Cunn. ex Benth., *Acacia mangium* Willd., *Ziziphus mauritiana* Lam., *Ziziphus rugosa* Lam., *Cassia fistula* L., *Calycopteris floribunda* (Roxb.) Lam. (Figure 6) and the second locality is a semi-urban residential area. We are conducting additional sampling to understand the distribution and diversity of the genus *Hemiphyllodactylus* to determine if there is more than one species in Goa and other regions of the northern Western Ghats. In addition, we are trying to understand the natural habitats of *Hemiphyllodactylus goaensis* **sp. nov.**, that has so far only been collected from human habitation. *Hemiphyllodactylus goaensis* **sp. nov.** is the first gecko as well as the first species of animal described from Goa University. This indicates the richness of the university campus as well as the diversity of reptiles in Goa which has been poorly studied. There are no specific threats to the species in Goa University campus except for construction, and sometimes the burning of vegetation which may lead to habitat loss for the species.

**FIGURE 6.** Habitat of *Hemiphyllodactylus goaensis* **sp. nov.** from Goa University, Taleigao, North Goa district, Goa, India. Photo by Dikansh S. Parmar.


## Acknowledgements

We thank the Funding agency Ministry of Environment and Forest and Climate Change (MoEF & CC), for providing funds for the project "Diversity of Herpetofauna of Goa, Maharashtra and Karnataka". Authors would also like to thank Principal Chief Conservator of Forests (Wildlife) and Chief Wildlife Warden of Goa and the Goa Forest Department for necessary facilities and permits, snake rescuer Rinku Kumar Gupta for providing us a female specimen, and Rahul Khot, Assistant Director, Natural History Collection Department, Bombay Natural History Society for providing us specimen voucher numbers. Vinayak R Khanolkar helped identify the tree species at localities of the new species. AK thanks Satpal Gangalmale for his assistance during description and Tejas Thackeray of Thackeray Wildlife Foundation, Mumbai (TWF) for his support. We are thankful to Evan Quah and Pratyush Mohapatra for their comments on the earlier version of the manuscript, from which the paper has improved.


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**APPENDIX 1.** Specimens examined. Museum abbreviations are as follows: Bombay Natural history Society, Mumbai (BNHS); Centre for Ecological Sciences, Bangalore (CES G, CES L); National Centre for Biological Sciences (NCBS-BH); andZoological Survey of India, Jabalpur (ZSI-CZRC).

*Hemiphyllodactylus arakuensis*: holotype, CES G446 (adult male); paratypes, CES G445, CES G447, BNHS 2275 (adult males); CES G442, CES G443, CES G444, CES G448, CES G449 (adult females).

*Hemiphyllodactylus aurantiacus*: topotypic material, BNHS 2551–BNHS 2553, NCBS-BH705–NCBS-BH707 (adult males); BNHS 2548–BNHS 2550, NCBS-BH703 and NCBS-BH704 (adult females).

*Hemiphyllodactylus jnana*: holotype, NCBS-BH709 (adult male); paratypes, NCBS-BH710, NCBS-BH711, CES G470 (adult males), NCBS-BH712–NCBS-BH718, CES L014, BNHS 2556 (adult females).

*Hemiphyllodactylus kolliensis*: holotype, CES G138 (adult male); paratypes, BNHS 2554, BNHS 2555, NCBS-BH708 (adult females).

*Hemiphyllodactylus minimus*: holotype, ZSI-CZRC-7112 (adult male); paratypes, ZSI-CZRC-7113, NCBS-BH667, BNHS 2523 (adult males), ZSI-CZRC-7114, BNHS 2520, BNHS 2521, NCBS-BH665, NCBS-BH665, BNHS 2522, BNHS 2524 (adult females).

*Hemiphyllodactylus nilgiriensis*: holotype, BNHS 2632 (adult male); paratypes, BNHS 2436, BNHS 2437 (adult males), CES L467 (adult female).

*Hemiphyllodactylus peninsularis*: holotype, BNHS 2633 (adult male).