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ON THE SYSTEMATIC POSITION OF THE WESTERN GHATS BRONZEBACK *Dendrelaphis chairecacos* (BOIE, 1827) (SQUAMATA: COLUBRIDAE) WITH RANGE EXTENSION TO GUJARAT

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Abstract
We report on the molecular phylogenetic position of the Western Ghats bronzeback, *Dendrelaphis chairecacos* (Boie, 1827), and new sightings from Dangs in Gujarat and Goa State in western India. Based on COI genes sequenced from two samples from Goa and the Dangs, we report that *D. chairecacos* was 5.59–5.60% (the total percentage of divergence is 5.77%), *i.e.* with an intraspecific variation of 0.67% nearly about 0.01%, divergent from *D. tristis* (Indian sample). Our record from the Dangs extends its range northwards by 350 km (from Satara) in the Western Ghats. We also used the geo-referenced and identified photo vouchers posted in citizen science portals to conduct a MaxEnt species distribution modelling for *D. chairecacos* for the first time. Our analysis run based on 27 data points including the new Dangs record and a previously published doubtful record from Yercaud (Southern Eastern Ghats), showed that the probability of occurrence in both these regions was very low (<20%). Areas in Malabar and the Konkan Coastal Plains from Kanyakumari to the Goa Gap had the highest probability of occurrence (>75%). We uphold the taxonomic ambiguity of the individual from Yercaud lacking loreal scale (as *D.* cf. *chairecacos*) and maintain that *D. chairecacos* s.str. is known only from the Western Ghats. We also re-identified a specimen (ZSI-R-22185) from Goa as *D. chairecacos*, which may be its earliest precise record from Goa (in 1969). Thus far based on nine preserved and two uncollected specimens mostly from the southern parts of its range, *D. chairecacos* stands better characterised based on 12 more live specimens, all from the northern parts of its range.

***Keywords*:** bronzeback, Gujarat, Konkan Coast, MaxEnt modelling, new record, sequences, Yercaud

Introduction

The Western Ghats bronzeback, *Dendrelaphis chairecacos* (Boie, 1827) is a medium-sized, non-venomous, diurnal, and arboreal colubrid snake endemic to the Western Ghats of India (van Rooijen & Vogel 2009). This species was recently resurrected from the subjective junior synonymy of the widespread species *Dendrelaphis tristis* (Daudin, 1803) and redescribed after designation of a neotype BMNH 1924.10.13.15 (at the Natural History Museum, London, UK) collected from Kottayam (ca. 9°36′19″N, 76°32′25″E; 5 m a.s.l.), Travancore, Kerala, Southern India. Until the study of van Rooijen & Vogel (2009) the population in the Western Ghats was also considered to be *D. tristis* sensu lato (e.g. Whitaker & Captain 2004).

Since resurrection, a few reports of *D. chairecacos* have been published. Ganesh & Chandramouli (2012) reported it from Gersoppa (14°14′19″N, 74°44′28″E; 50 m a.s.l.) with life-colour photographs. Karthik & Dutta (2020) reported it from Sahyadri Tiger Reserve (17°04′00″–17°19′54″N, 73°40′43″–73°53′09″E; 850 m a.s.l.) near Satara. Here, we report on further individuals of *D. chairecacos* and re-identify historical material from Goa, where it has been implied to occur, as it ranges from Kottayam (van Rooijen & Vogel 2009) to Satara (Karthik & Dutta 2020). Based on first ever molecular sequences, we also report it from the Dangs Forest at the northernmost end of the entire Western Ghats, much further north of the earlier report in Satara. We also assembled *D. chairecacos* record points from online portals to construct a distribution model using the MaxEnt software, a first for this species.

Material and method

We report on the morphology (scored after van Rooijen & Vogel 2009) of 12 live uncollected snakes, comprising 7 males and 5 females [determined by popping method; see Gregory (1983)] observed and documented in The Dangs and Goa from between Nov 2022 and Aug 2023. All measurements were made with vernier calipers except for snout–vent length and tail length which were measured with standard measuring tape. All measurement values were expressed in mm, correct up to one decimal point. Photographs were taken using high-resolution digital cameras. To obtain data for the Max Ent modelling, we perused citizen science portals such as iNaturalist (www.inaturalist.org), Herp Mapper (www.herpmapper.org), and India Biodiversity Portal (www.indiabiodiversity.org) to create a database of field occurrence point records. We performed Species Distribution Modelling (SDM) analysis using MaxEnt (Phillips *et al*. 2006), BioClim (Booth *et al*. 2014), and QGIS (Flenniken *et al*. 2020). Twenty-seven data points were assembled by pooling our own examined materials, occurrence record logs deposited in citizen science portals, and literature reports. Spatial thinning and omitting of near-duplicate points (<2 km apart) were done to reduce clutter and avoid weightage biases in the analysis. Places with obsolete catch-all names that were too imprecise, were omitted. Then a preliminary SDM was conducted using a Maximum Entropy algorithm run on MaxEnt software (Philips *et al*. 2004). We used all the bioclimatic variables downloaded from the BioClim Database, following Joshi & Karanth (2012), though others recommend choosing a correlated set of variables (e.g. Schnase *et al*. 2021). The output map files (GRD and GRI files) were rendered from MaxEnt using Q-GIS software. We rounded off the logistic values of the predictions to the nearest increment of 5 to get better-defined spatial distribution predictions.

Abbreviations. Morphological and morphometric abbreviations recorded in the examined individuals: full head length from the tip of the snout to the posterior of the jaw (FHL), head length from the tip of the snout to the posterior border of the parietal shield (HLP), head width (HW), horizontal diameter of eye (EYED), vertical diameter of eye (EYEDV), distance anterior border of eye to posterior border of nostril (EYEN) distance from the center of the eye to posterior border of the nostril (EYEC-N), interorbital distance (ID), length of parietal shield (LP), width of parietal shield (WP), length of frontal shield (LF), width of frontal shield measured between supraoculars (WF), length of prefrontal shield (LPF), width of prefrontal shield (WPF), length of internasals (LIN), width of internasals (WIN), length of rostral shield (LR), width of rostral shield (WR), maximum width of the vertebral scale at the position of the middle ventral (WVERT), total body length (TBL), snout to vent length (SVL) and tail length (TL), dorsal scales (DS), ventrals (V), subcaudals (SC), supralabials (SL), infralabials (INFL), right and left side (RL), number of infralabials touched by first sublabials (SUBL), number of supralabials in contact with the eye (SLCE), Supraoculars (SO), preoculars

(PRO), postoculars (PO), loreals (L), supralabials in contact with loreal (SLCL), temporals (T), and cloacal scale (AP). CROSS BARS, Cross bars on the fore body present (1); Cross bars on the fore body absent (2); STRIPE1, ventrolateral stripe bright, bordered by one black line (1); ventrolateral stripe bordered by one or two black lines (2); ventrolateral stripe dull, not bordered by black lines (3); ventrolateral stripe absent (4); STRIPE2, postocular stripe thin, occupying the lower edge of the temporal region, ending at or just behind the edge of the jaw (1), postocular stripe broad, occupying the majority of the temporal region and extending onto the neck (2); BS-EYE, black stripe present on the center of the eye (1), black stripe absent on center of the eye (2); BS-PNPRO, black stripe present between postnasal to preocular (1), black stripe absent between postnasal to preocular (2) SLNE, supralabials marked with black streaks between the nasal and the eye (1), supralabials not marked with black streaks between the nasal and the eye (2); VERTEBRAL LINE, distinct throughout the body (1); indistinct or distinct and present only on the neck or forebody (2); completely absent (3); IP SPOT, Inter parietal spot present (1), Inter parietal spot absent (2), Inter parietal spot rudimentary (3).

Genetic Analysis. Genetic data was obtained from two roadkill individuals whose tail tips we sampled. Analysis was done by amplifying a fragment of the cytochrome c oxidase subunit 1 (COI) gene. DNA extraction, PCR amplification, and sequencing were outsourced to Gene Explorer Lab in Ahmedabad, Gujarat. The sequencing of the PCR amplicon was performed using COIF and COIR primers with the BDT v3.1 Cycle Sequencing Kit on an ABI 3500xl Genetic Analyzer. These sequences were submitted to GenBank and compared with published data for *Dendrelaphis* from GenBank, using *Chrysopelea ornata* as the outgroup (following Biakzuala *et al*. 2022; see Sup. Table 1 for details on the sequences and their GenBank accession numbers). Sequence alignment was conducted using ClustalW (Thompson *et al*. 1994) with default settings in MEGA 11 (Tamura *et al*. 2021). A maximum likelihood tree (Guindon *et al*. 2010) was constructed with rapid 1000 bootstrap replications to determine the phylogenetic position of the individuals from Goa and Gujarat (Saitou & Nei 1987, Nei & Kumar 2000). The evolutionary history was inferred by using the Maximum Likelihood method and the Tamura-Nei model (Tamura & Nei 1993). Pairwise differences between sequences were calculated in MEGA 11. This analysis involved 20 nucleotide sequences. Where necessary, we updated the species names of sequences in the NCBI to match the current taxonomy and nomenclature.

Results

Among the regional congeners of *Dendrelaphis* in Peninsular India, *D. chairecacos* differs from others (see van Rooijen & Vogel, 2009; our Sup. Table 2) in having (1) light blue tongue (vs. black tongue in *D. grandoculis*, vs. red tongue in *D. ashoki*, *D. girii* and *D. bifrenalis*); (2) unpatterned or feebly striped dorsum (vs. plain uniform or rarely with traces of crossbars in *D. grandoculis*; bilateral black stripes in *D. bifrenalis*, *D. ashoki*; black temporal streaks covering only head in *D. girii*); (3) one loreal scale on each side of head (vs. 2 in *D. bifrenalis* and *D. girii*). Thus, *D. chairecacos* closely resembles *D.tristis* but differs as follows: (1) 166–179 ventrals (vs. 178–198 in *D. tristis*); 113–132 subcaudals (vs. 117–136 in *D. tristis*); (3) dorsum uniform reddish brown (vs. with a bronze vertebral stripe usually present in *D. tristis*); (4) forebody with prominent cross bars, often in pairs, especially in males (vs. not so in *D. tristis*); (5) usually ventrolateral stripe bright, bordered by one black line (vs. usually ventrolateral stripe dull, not bordered by black lines in *D. tristis*). Thus, here we identify our specimens as *D. chairecacos*. Also, our first-ever molecular phylogenetic sampling recovered clustering of the Dangs (Gujarat) and Goan samples of *D. chairecacos* together, and as sister to *D. tristis*, lending more credibility to the specific distinctions of populations from the Northern Western Ghats.

***Dendrelaphis chairecacos* (Boie, 1827)**

(Figs. 1, 2, 4; Sup. Table 2)

***Morphology*.** The Goan specimens M1-M5 and F1-F4 (*n*=9; 5 males, 4 females; Figs. 1, 2) had the following morphometric features: dorsal scale rows 15:15:9–11; ventrals 170–178; subcaudals 113–127 (111 tail cut); supralabials 9 or 10 with 4,5 or 5,6 or 6,7 touching eye; infralabials 9 or 10 or 11; sublabials 2–3; preoculars 1; postoculars 2; loreal 1; temporals 2+2 or 2+3; anal divided; head length 19.2–26.5mm; head width 9.0–11.2mm; horizontal diameter of eye 5.2–6.0mm; vertical diameter of eye 4.2–5.0mm; distance from anterior border of

eye to posterior border of nostril 4.0–6.5mm; distance from the center of the eye to posterior border of the nostril 6.8–9.5mm; interorbital distance 8.1–9.2mm; length of parietal shield 7.0–8.3mm; width of parietal shield 4.1–5.4mm; length of frontal shield 6.2–7.8mm; width of frontal shield measured between supraoculars 2.1–3.5mm; length of prefrontal shield 3.4–4.6mm; width of prefrontal shield 3.1–4.1mm; length of internasals 3.0–4.9mm; width of internasals 2.9–3.3mm; length of rostral shield 2.1–5.0mm; width of rostral shield 3.0–5.5mm; maximum width of the vertebral scale at the position of the middle ventral 3.1–4.1mm; total body length 873.0–1112.1mm; snout to vent length 587.1–811.1mm; tail length 212.0–349.0mm; maximum body width 36.0–55.2mm; ventrolateral stripe bordered by one or two black lines; postocular stripe thin, occupying the lower edge of the temporal region, ending at or just behind the edge of the jaw; inter-parietal spot present; no light vertebral stripe on back; forebody with black, paired cross bars.

The Dangs specimens (Fig. 2) M6-M7 and F5 (*n*=3; 2 males, 1 female) had the following morphometric features: dorsal scale rows 15:15:9–11; Ventrals 166–168; subcaudals 127–131; supralabials 8 or 9 with 5 or 5,6 touching eye; infralabials 10; sublabials 2–3; preoculars 1; postoculars 2; loreal 1; temporals 2+2 or 2+3; anal divided; head length 19.0–23.0mm; head width 9.0–9.5mm; horizontal diameter of eye 4.0–5.2mm; vertical diameter of eye 3.8–5.5mm; distance from anterior border of eye to posterior border of nostril 3.3–5.5mm; distance from center of eye to posterior border of nostril 6.0–8.0mm; interorbital distance 6.0–9.1mm; length of parietal shield 7.2–8.0mm; width of parietal shield 4.9–5.0mm; length of frontal shield 6.6–7.4mm; width of frontal shield measured between supraoculars 2.2–3.5mm; length of prefrontal shield 3.3–4.6mm; width of prefrontal shield 3.3–4.1mm; length of internasals 3.4–4.0mm; width of internasals 2.9–3.2mm; length of rostral shield 2.4–3.3mm; width of rostral shield 4.4–4.9mm; maximum width of the vertebral scale at the position of the middle ventral 3.3–3.9mm; total body length: 905.0–1110.0mm; snout to vent length: 630.0–822.0mm; tail length: 285.0–288.0mm; ventrolateral stripe bordered by one or two black lines; postocular stripe thin, occupying the lower edge of the temporal region, ending at or just behind the edge of the jaw; inter-parietal spot present; the dorsal bronze stripe is very rudimentary on neck; forebody with black, paired cross bars laterally; tongue blue; eyes black.

***Field Observations*.** In Goa, M3, M2 and F1 were from Bicholim (15°35′75″N, 73°57′47″ E), M1 was from Taliegao (15°26′24″N, 73°47′99″E), F2 was from Vacra (15°14′81″N, 73°57′53″E), M4 is from Guirdolim (15°16′20″N, 74°02′09″E), F3 was from Chandor (15°15′70″N, 74°02′80″E), M5 was from Cuncolim (15°10′20″N, 73°59′55″E), and F4 was from Margao (15°16′96″N, 73°59′09″E). All these areas are situated in the plains and lowlands (<80 m a.s.l.). These snakes were mostly recorded during operations to rescue them, while a few were seen in the field, on trees and bushes, all during daytime. Rescue situations include air-conditioning pipelines (*n*=1), concrete parapet walls (*n*=1), windows of rooms on the first floor (*n*=1), tiled roofs of old houses (*n*=2), and thatched roofs of huts (*n*=2). During fieldwork, live sightings (*n*=2) were obtained on trees and bushes in gallery forests. Roadkills (*n*=3) were recorded on tar roads connecting the town and the Ghat roads. No snake was seen alive crossing roads during our excursions there. Most of the snakes sighted were adults. In one instance, a snake in ecdysis was reported during a rescue situation.

In the Dangs, all the three individuals M6, M7 and F5 were sighted in Ahwa (20°45′48″N, 73°40′11″E) in the hills (500 m a.s.l.). The snake was on a tree at 2m height in the Forest Office Complex, near human habitations, in the morning. M7 was sighted at noon near roadside trees along the Ghat road. F5 was seen in the evening, near a house, where it had probably been in a confrontation with the inhabitants, as it appeared to be wounded.

***Systematic position*.** Our molecular analysis of the COI sequences (PQ658043, PQ658044) of *Dendrelaphis chairecacos* samples from Goa and the Dangs (Gujarat) recovered them as conspecifics, clustering together (nearly 0.01% intraspecific distance; Fig. 3). They were also found to be sister to a *D. tristis* sample from Odisha, India, and *D. subocularis* from China. Genetic comparisons (Sup. Table 3) revealed 5.60% divergence between the Goa sample and *D. tristis*, while the Dangs, Gujarat sample showed 5.59% divergence from *D. tristis* and the total divergence of both the species is 5.77% from *D. tristis*. Both Goa and Dangs, Gujarat samples displayed a genetic divergence of 12.18% and 11.82% respectively from *D. subocularis* from China.

Plate 9

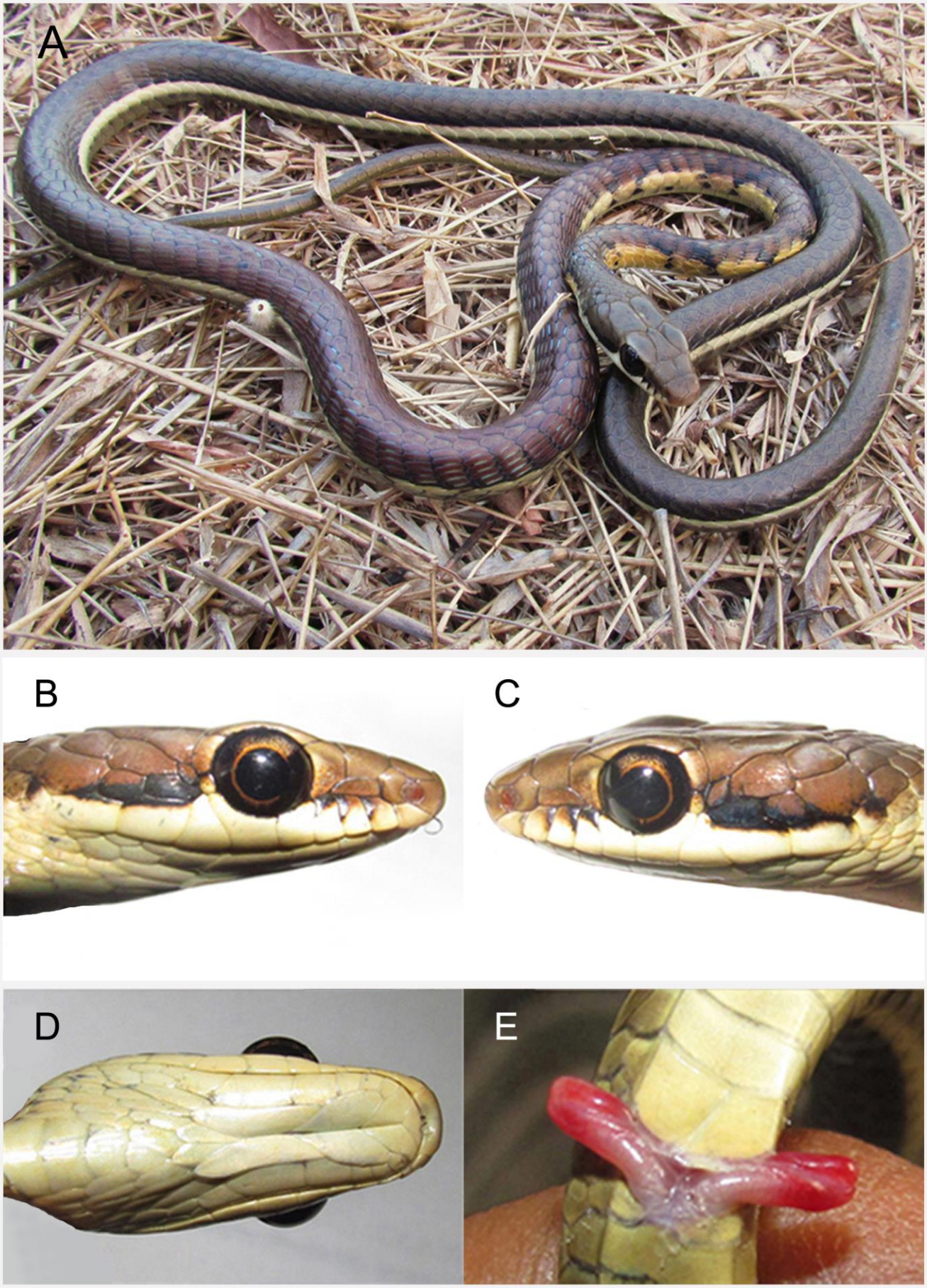

Figure 1. An adult male *Dendrelaphis chairecacos* from North Goa (not collected; M1) with well banded forebody: **(A)** dorsolateral view of full body, **(B)** lateral head (right), **(C)** lateral head (left), **(D)** ventral view of head, and **(E)** ventral view of hemipenes; © Photo: D.S. Parmar.

Plate 10

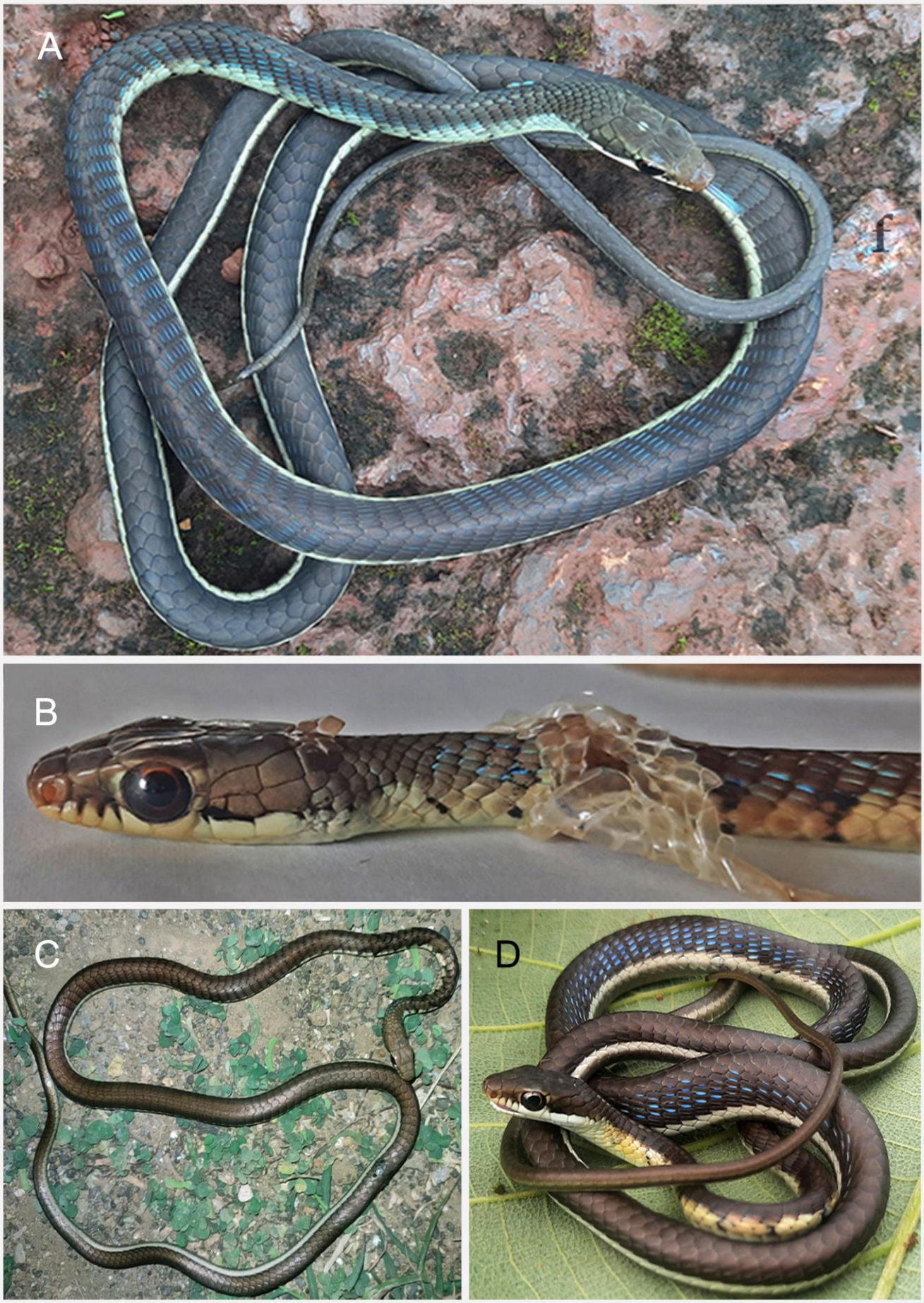

Figure 2. *Dendrelaphis chairecacos* (not collected): **(A)** female (F1) from North Goa with faintly banded forebody showing blue tongue, **(B)** male (M4) from South Goa with shedding skin, **(C)** male and **(D)** female from the Dangs, Gujarat; © Photo: D.S. Parmar / B. Gaykwad.

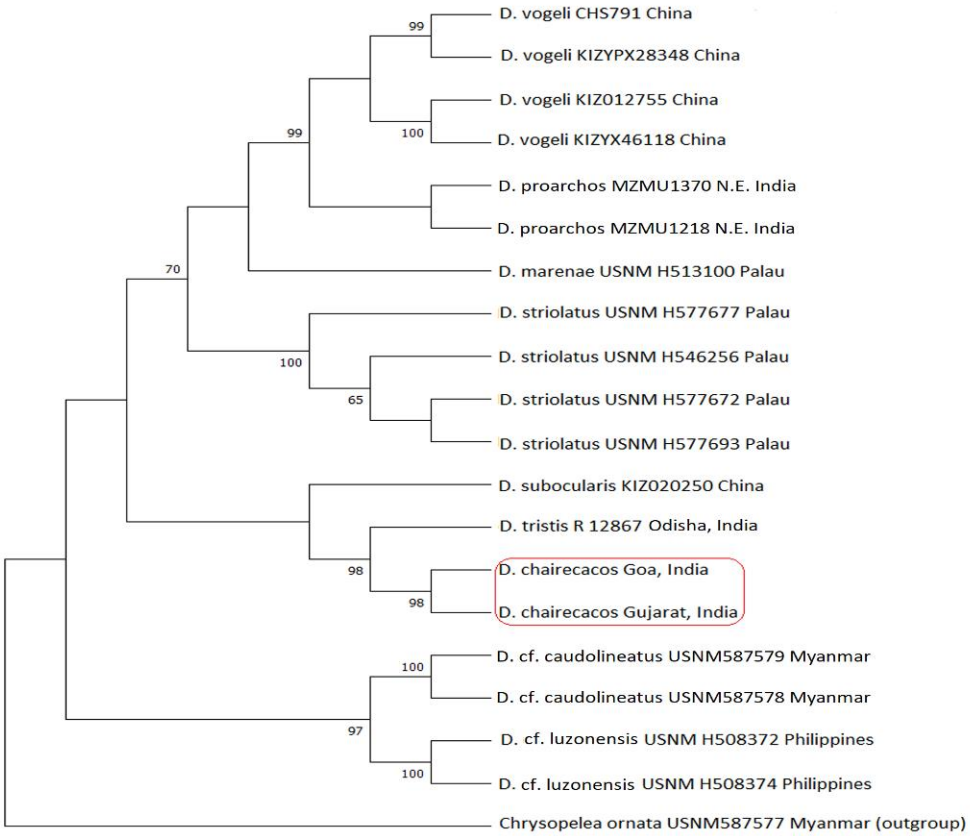

Figure 3. Maximum Likelihood phylogenetic tree showing molecular systematic positioning of *Dendrelaphis chaireacos* samples from Goa and the Dangs, Gujarat, clustering together, with a sister relationship with *D. tristis*, based on COI gene.

Taxonomic re-identifications. Here, we also report on two preserved voucher specimens, hitherto not recognised as representing *D. chairecacos* (Fig. 4). The first specimen is SMNS 2888.1 (Staatliches Museum für Naturkunde Stuttgart), a juvenile from Mangalore that lacks loreal scale on both sides. It has 169 ventrals. Originally labelled as *D. pictus* (sic), this specimen is re-identified here as *D. chairecacos*, with an aberration of lack of loreals. Lack of black lateral stripes on head, neck and forebody plus a much thicker body build clarifies that it is not of the *D. pictus* complex as labelled. The second specimen, ZSI R-22185 (Zoological Survey of India) coll. R.C. Sharma from Concona, Goa on 9 Oct. 1969 is labelled as *D. grandoculis*, a Western Ghats-endemic species (Whitaker & Captain 2004). Our perusal of its three, high-resolution photographs (www.zsicollections.in/search/image/ZSI0000014930) revealed that ZSI R-22185 is surely a specimen of *D. chairecacos*.

Typical diagnostic features (fide van Rooijen & Vogel, 2009) such as black scale sutures in loreal and preocular regions, traces of black paired bands on the forebody that are more visible laterally than dorsally, black postocular streak, black ventrolateral stripe on either side from midbody to tail, clearly indicate that it is indeed a *D. chairecacos*. The lack of a white patch surrounding the eye, plus the presence of black postocular streaks clarify that it is not *D. grandoculis* as labelled. Taken together, these specimens from Mangalore and Goa, are not only the sole recognised preserved materials of *D. chairecacos* from the northern parts of its distribution range (van Rooijen & Vogel 2009) but also those that provide morphological variations (e.g. lack of loreal scale).

Species Distribution Modelling. (Fig. 5). MaxEnt analysis run based on 27 data points produced a prediction map showing the Western Ghats and western plains from Ashambu north to Pune as the realised range of *D. chairecacos*. The highest prediction envelopes (>75% likelihood) were in places near the Mangalore-Udupi region, the Palghat Gap, and the windward slopes of the Periyar Plateau. The next highest prediction (60–75%) covered areas in the Konkan and Malabar Coastal Plains except for the Allepey-Vembanad-Ashtamudi Lake complex. This was followed by much lower predictions of occurrence (40–60%)

Plate 11

Figure 4. *Dendrelaphis chairecacos* **(A)** ZSI R-22185 from Goa, **(B)** an adult from Mangalore, **(C)** SMNS 2888.1 from Mangalore with **(C1-3)** lateral, dorsal, and ventral head profiles; **(D)** an adult topotype from Sabarimalai, **(E)** *D.* cf. *chairecacos* subadult from Yercaud, Shevaroys; © Photo: ZSI /SMNS /S.R. Ganesh

and (20–40%) covering the exposed slopes of the Western Ghats south of Pune. Because there was no precise geo-coordinate data available for the record by Kartik & Dutta (2020), the Sahyadri forests record point could not be used in our analysis. However, the model did predict a 40–60% chance of occurrence in Sahyadri forests and nearby areas (Jaigad, Dapoli). But there was only a low probability of finding the species (<20%) in and around Dangs, further north along the Western Ghats, despite our record from that place. It may be because all three sightings were from one locality, precluding multiple points in the Dangs. Northeastern Sri Lanka, just abutting the Palk Strait was also shown as an area with a low probability of occurrence (20–40%), though it falls outside the realised range of *D. chairecacos* (see van Rooijen & Vogel 2009).

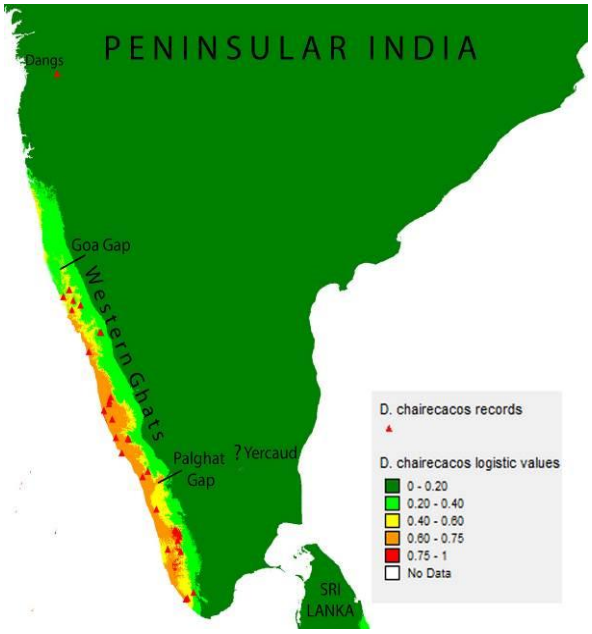

Figure 5. map of the Indian peninsula showing MaxEnt distribution predictions of *Dendrelaphis chairecacos* based on field records (red triangles); colour codes of predictions as shown in the legend. *D.* cf. *chairecacos* from Yercaud (Eastern Gats) indicated with a (?) due to taxonomic uncertainty.

Discussion

So far *D. chairecacos* has been characterised based on nine preserved specimens from Kerala / Tamil Nadu in the southern Western Ghats (Van Rooijen & Vogel 2009), one roadkill from Gersoppa (Chandramouli & Ganesh 2012) and one live adult female from Sahyadri forests (Karthik & Dutta 2020). Here, we furnish morphometric data for twelve live uncollected individuals, three from the Dangs and nine from Goa. Our values for ventrals upper limit (179 vs. 177), and subcaudals lower limit (113 vs.120–132) are slightly different to those reported by van Rooijen & Vogel (2009). Thus, the definition and characterisation of *D. chairecacos* has been further enriched by the additional series of snakes described here. van Rooijen & Vogel (2009) agreed with Wall (1913) in stating that although *D. tristis* is more or less homogenous in colour patterns across most of India, a remarkable dichotomy exists in populations from Maharashtra and Gujarat, which frequently have individuals with a very feeble yellow vertebral stripe and parietal spots. Now, in hindsight, seen in the light of records from the Western Ghats regions of both Maharashtra (i.e. Satara, fide Karthik & Dutta 2020) and Gujarat (The Dangs, this work), they are understood to be *D. chairecacos*. Again, some *D. chairecacos* populations do have mild traces of a yellow vertebral stripe and parietal spots (van Rooijen & Vogel 2009).

Ganesh & Arumugam (2016) reported *Dendrelaphis* cf. *chairecacos* from Shevaroys in the Eastern Ghats, based on a live uncollected juvenile (440 mm total length) documented in Yercaud (11°46′58″N, 78°12′09″ E; 1580 m a.s.l.). This specimen lacked a loreal scale on both sides and was reported to have 153 ventrals (Ganesh & Arumugam 2016). We rechecked our notes and recounted the ventrals in the photo-vouchers of that snake and corrected the number to 173 ventrals. The snake showed traces of a light yellow mid-vertebral stripe on the forebody which became obscure further down the back. Therefore, it shows some resemblance in terms of marginally lower ventral count and obscure vertebral stripe to *D. chairecacos* of the Western Ghats. However, our distribution model did not project any occurrence in the Eastern Ghats. Pending further studies on the Eastern Ghats populations, we advocate maintaining *D. chairecacos* sensu stricto (van Rooijen & Vogel 2009; this work) as endemic to the Western Ghats. Moving forward, we recommend genetic sampling of topotypical *D. chairecacos* from the Southern Western Ghats, to complement the data we have gathered here.

Author contributions

All the authors contributed equally.

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Research permits

Permission to DSP for research in Purna Wildlife Sanctuary.

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Supplement data

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