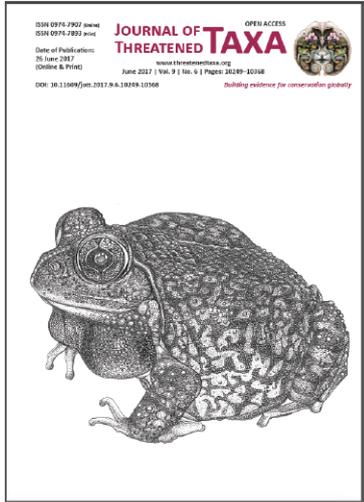


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ARTICLE

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Abstract: *Sphaerotheca pashchima*, a new species of burrowing frog, is described from western India. It can be diagnosed from all its congeners based on a combination of characters including interorbital width less than upper eyelid width, snout to nostril distance less than half of eye diameter, nostril nearer to snout than to eye, internarial distance greater than inter orbital distance, snout rounded, dorsum rough and warty, finger 2 length equal to or less than finger 4 length, finger 1 less finger 3 length, outer metatarsal tubercle absent, tibio tarsal tubercle absent, length of inner metatarsal tubercle more than three times the inner toe length and reduced webbing. We also provide 16S rRNA gene sequence for *S. pashchima* sp. nov. and show that it is genetically distinct from species of *Sphaerotheca* for which genetic data is available.

Keywords: Amphibia, molecular phylogeny, taxonomy.

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Author Contribution: AP, SS, NiD, SL and KJ collected specimens; AP and NeD diagnosed the species; AP, SS, NiD and NeD generated morphometric and genetic data; NeD performed genetic and morphometric analysis; AP and NeD wrote the manuscript with inputs from SL, SS, NiD and KJ.

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For **Acknowledgements** see end of this article.



INTRODUCTION

Genus *Sphaerotheca* was described by Günther (1859). Vences et al. (2000) provided the genetic basis for the validity of genus *Sphaerotheca* and characterized it as a generalized pond breeder, which lay large number of single eggs into shallow, often temporary pools; keratodont formula 1:1+1/3; a broad upper gap in the marginal papillae of tadpoles; absence of derived shape of the dorsal ilium processes; presence of three free distal tarsals; omosternum moderately forked; distinct sesamoid present; short second finger as compared with the first finger; and nuptial pads not black. Genus *Sphaerotheca*, which is endemic to South Asia, includes eight valid species under three morphological groups (Dahanukar et al. 2017), viz., Breviceps group: *S. breviceps* (Schneider, 1799), *S. maskeyi* (Schleich & Anders, 1998), and *S. rolandae* (Dubois, 1983); Dobsoni group: *S. dobsonii* (Boulenger, 1882), *S. pluvialis* (Jerdon, 1853), and *S. swani* (Myers & Leviton in Leviton et al., 1956); and Leucorhynchus group: *S. leucorhynchus* (Rao, 1937), and *S. strachani* (Murray, 1884).

Both Dubois (1983) and Dutta (1986) considered the widely distributed species *S. breviceps* as a species complex. Dutta (1986) suggested presence of at least one more undescribed species in this complex, while Vences et al. (2000) mentions that “a further species from Goa, western India, is about to be described by A. K. Sarkar (pers. comm.)”. No such species, however, has been described from Goa, or western India in general, till date.

While studying the specimens previously identified as *S. breviceps* from Western Maharashtra, Gujarat and Karnataka, and comparing them with type and topotypic material of *S. breviceps* and other available names under *Sphaerotheca*, we realized that the western Indian specimens are morphologically distinct. This species is described as *S. pashchima* sp. nov.

MATERIALS AND METHODS

Specimen collection

Specimens of the new species were collected from western Maharashtra, Gujarat and Karnataka states, India. The specimens were collected from a variety of habitats, including agricultural fields, semi arid grasslands and temporary rainwater pools in semi-evergreen forests. Specimens were preserved in 100% ethanol and transferred to 70% ethanol for long term preservation.

Museum details

Specimens studied are in the Indian museum collections of the Bombay Natural History Society (BNHS, Mumbai), the Zoological Survey of India (ZSI, Kolkata), the Zoological Survey of India, Western Regional Centre (ZSI-WRC, Pune), the Wildlife Information Liaison Development (WILD, Coimbatore), the Abasaheb Garware College, Zoology Research Laboratory (AGCZRL, Pune), and the Institute of Natural History Education and Research (INHER, Pune); the Museum für Naturkunde (ZMB), Berlin, Germany; the California Academy of Sciences, Stanford University collection (CAS-SU), San Francisco, USA; the Zoologische Staatssammlung München, Germany; and the Natural History Museum (BMNH), London, UK.

Morphometry

Measurements were taken to the nearest 0.1mm using a digital calliper (Ocean Premium measuring instruments) and include: Length of specimen from snout to the visible tip of urostyle (SUL), head length (HL), head width (HW), nostril to snout distance (SN), inter narial distance (IN, measured between the centre of the nares), horizontal diameter of the eye (EL), eye to snout distance (SL), eye to nostril distance (EN), shortest distance between eyes (IUE), upper eyelid width (UEW), tympanum diameter (TYD), distance from tympanum to the back of the eye (TYE), length of hand (HAL), F1 to F4 (Finger 1 to Finger 4 length from the base of the sub-articular tubercle), length of forelimb (FLL), length of femur (FL), length of Tibia (TL), foot length (FoL, measured from the base of the inner metatarsal tubercle to the tip of the 4th toe), T1 to T5 (Toe1 to Toe5 length from the base of the respective sub-articular tubercle), and Inner metatarsal tubercle length (IMT). Webbing formula was determined following the method provided by Savage & Heyer (1967) with modifications by Myers & Duellman (1982).

Statistical analysis

All morphometric characters showed positive linear correlation with SUL. Therefore, to remove size bias, statistical analysis of the morphometric data was performed on size adjusted measurements by taking all measurements as percent of SUL. We used morphometric data of species other than the new species from Dahanukar et al. (2017). Multivariate normality of the data was checked using Doornik & Hansen (2008) omnibus. Discriminant analysis (DA) was performed to understand whether related species form significantly different clusters (Huberty & Olejnik 2006) in the genus

Sphaerotheca. Mahalanobis distances (Harris 2001) between pair of individuals were calculated and were used for computing Fisher's distances (distance between the centroids of the clusters, divided by the sum of their standard deviations) between two clusters to check if the clusters were significantly different. Statistical analysis was performed in PAST 3.12 (Hammer et al. 2001).

Molecular analysis

Thigh muscle tissue was harvested from 16 specimens of the new species (marked by asterisk in Table 1). Tissues were preserved in absolute ethanol. DNA extraction, PCR amplification of 16S rRNA gene and sequencing protocols followed Padhye et al. (2014). Sequences were analysed by the BLAST tool (Altschul et al. 1990) for similar sequences in NCBI Genbank database (www.ncbi.nlm.nih.gov). Sequences generated in the current study are deposited in GenBank under the accession numbers KY215979–KY215994. New sequences were added to the database used by Dahanukar et al. (2017) for genetic analysis. Gene sequences were aligned using MUSCLE (Edgar 2004). Pair wise raw phylogenetic distances were calculated in MEGA 6 (Tamura et al. 2013). Maximum likelihood phylogenetic tree was built using IQ-TREE software (Nguyen et al. 2015) where the best nucleotide substitution model was analysed based on the minimum Bayesian Information Criterion (BIC) value (Schwarz 1978; Nei & Kumar 2000). Reliability of the phylogenetic tree was estimated with ultrafast bootstrap support (Minh et al. 2013) for 1000 iterations. Phylogenetic tree was edited in FigTree v1.4.2 (Rambaut 2009).

Comparative material and data sources

Sphaerotheca breviceps: Lectotype, ZMB 55005, male (29.9mm SUL) and paralectotype, ZMB 3351 (33.9mm SUL), eastern India (only photographs examined); BNHS 6004, male (29.6 mm SUL), BNHS 6005, female (33.5mm SUL), WILD-16-AMP-645, male (31.6mm SUL), WILD-16-AMP-646, female (34.8mm SUL), ZSI-WRC A/1546, male (31.7mm SUL), ZSI-WRC A/1547, female (30.0mm SUL), INHER-AMPHIBIA-46, female (34.4mm SUL) and INHER-AMPHIBIA-49, male (27.8mm SUL), 15.xi.2015, India: Tamil Nadu: Nagapattinam District, Tranquebar (=Tharangambadi), Karaikal (11.062°N, 79.813°N, elevation 16m), coll. N. Dandekar and S. Sulakhe; WILD-16-AMP-647, sub adult (26.6mm SUL) and BNHS 6006, sub adult (24.8mm SUL), 26.ix.2014, India: Jharkhand: Dhanbad District, Maithon (23.776°N, 86.809°E, 150m), coll. A.D. Padhye; ZSI 18744, male (48.3mm SUL), Madras, coll. J. Henderson.

Sphaerotheca dobsonii: WILD-16-AMP-648, female

(43.0mm SUL), ZSI-WRC A/1548, female (38.0mm SUL) and BNHS 6007, female (45.5mm SUL), 1-vi-2000, India: Maharashtra: Pune District, Tamhini (18.477°N, 73.427°E, 897m), coll. A.D. Padhye; INHER-Amphibia-86, male (55.1mm SUL), 25.vi.2016, India: Maharashtra: Pune District, Tamhini (18.477°N, 73.427°E, 897m), coll. N. Dandekar & M. Ketkar; INHER-Amphibia-151, female (35.0mm SUL), WILD-16-AMP-651, female (34.3mm SUL) and BNHS 6008, female (42.5mm SUL), 31.vii.2016, India: Maharashtra: Ratnagiri District, Devi-Hasol (16.742°N, 73.432°E, 159m), coll. A.D. Padhye; INHER-Amphibia-144, female (37.0mm SUL), WILD-16-AMP-652, female (41.5mm SUL), WILD-16-AMP-653, female (46.0mm SUL), BNHS 6009, female (42.9mm SUL) and BNHS 6010, female (31.7m SUL), 29-vii-2016, India: Maharashtra: Ratnagiri District, Bankot (17.980°N, 73.065°E, 46m), coll. S. Sulakhe et al.

Sphaerotheca pluvialis: Neotype, ZSI A9074, female (45.1 mm SUL), 10.vi.1998, India: Tamil Nadu: Thiruidisoolam near Pattaravakkam (12.696°N, 80.030°E), coll. Romulus Whitaker; ZSI 18743, female (51.9mm SUL), Madras, coll. J. Henderson; ZSI 12515, male (46.5mm SUL), southern India, coll. E. Gerard; ZSI 2681, female (45.4mm SUL), Sri Lanka, coll. E.F. Kelaart.

Sphaerotheca swani: Holotype, CAS-SU 15371, male (42.3mm SUL), 22.vi.1954, Dharan, eastern Nepal, at an altitude of 1,000 feet, coll. L.W. Swan (only photographs examined).

Sphaerotheca maskeyi: Holotype, ZSM 106/91-2, 8.vii.1991, Chitwan Jungle Lodge, Royal Chitwan National Park, Central Nepal, at an altitude of approx. 300m, coll. H.H. Schleich and T.M. Maskey (only photographs examined, available online at <http://www.biologie.uni-ulm.de/cgi-bin/herbar.pl?herbid=109475&sid=T&lang=d>, accessed on 17 February 2017); ZSI 16127, female (43.7mm SUL), Chinpore (=Chainpur) Nepal. Additional data from Schleich & Anders (1998).

Sphaerotheca rolandae: Holotype, BMNH 1973.3024, Kurunegala, Sri Lanka, altitude 60m, latitude 7°29'N, longitude 80°22'E (only photographs examined); ZSI 17630 and ZSI 17632, Bangalore, India, coll. C.R. Narayan Rao (only photographs examined). Further details from Dubois (1983) and Dutta & Manamendra-Arachchi (1996).

Data for *Sphaerotheca leucorhynchus* from Rao (1937) and *S. strachani* from Murray (1884). Data for *Rana variegata*, a synonym of *S. breviceps*, was obtained from Gravenhorst (1829).

RESULTS

***Sphaerotheca pashchima* sp. nov.**
(Images 1, 2a)

urn:lsid:zoobank.org:act:A7E4CA0A-6CF3-4578-BDF5-C2F76F6AF0CE

Suggested common name: Western Burrowing Frog

Holotype: BNHS 6000, male (41.0mm SUL), 05.vi.2016, India: Maharashtra: Saswad-Waghapur Road, Ambodi Village (18.350°N, 74.041°E, 747m), coll. S. Sulakhe et al.

Paratypes: BNHS 6001, female (46.3mm SUL), BNHS 6002, female (43.9mm SVL), same data as holotype; BNHS 6003, female (42.5mm SUL), WILD-16-AMP-643, sub adult (29.8mm SUL) and ZSI-WRC A/1544, sub adult (24.6mm SUL), 20.ix.2014, India: Gujrat: Veghai Road, Ahwa-Dang (20.764°N, 73.676°E, 395m), coll. N. Modak; WILD-16-AMP-642, male (43.6mm SUL), 26.ix.2015, India: Maharashtra: Saswad-Waghapur Road, Ambodi Village (18.350°N, 74.041°E, 747m), coll. S. Sulakhe et al.; WILD-16-AMP-641, sub adult (19.4mm SUL), 20.x.2014, India: Maharashtra: Ahmednagar District: Karjat, near

Rehekuri Wildlife Sanctuary (18.530°N, 74.990°E, 634m), coll. A.D. Padhye; WILD-16-AMP-644, female (35.5mm SUL), 01.vi.2000, India: Maharashtra: Pune: Tamhini (18.477°N, 73.427°E, 897m.), coll. A. Padhye; ZSI-WRC A/1545, male (43.3mm SUL), 05.vi.2016, India: Maharashtra: Kutwalwadi, near Mayureshwar Wildlife Sanctuary (18.348°N, 74.357°E, 660m), coll. S. Sulakhe et al.; BNHS 6012, female (32.9mm SUL) and ZSI-WRC A/1550, sub-adult (28.5mm SUL), 29.vi.2016, India: Karnataka: Near Yellapur (14.979°N, 74.731°E, 547m), coll. A.D. Padhye et al.; BNHS 6011, male (44.2mm SUL), 29.vi.2016, India: Karnataka: Dharwad-Halliylal-Yellapur Road (15.349°N, 74.868°E, 603m), coll. A.D. Padhye et al.; ZSI-WRC A/1549, sub-adult (29.8mm SUL), 29.vi.2016, India: Karnataka: Yellapur-Halliylal Road (15.160°N, 74.758°E, 458m), coll. A.D. Padhye et al.; BNHS 6013, female (50.5mm SUL), 03.vii.2016, India: Maharashtra: Raigad District, Kolad (18.403°N, 73.321°E, 54m), coll. N. Dandekar & S. Bhawe; BNHS 6014, male (55.7mm SUL), 03.vii.2016, India: Maharashtra: Talekhar near Phansad (18.470°N, 72.990°E, 2m), coll. M. Ketkar & M. Kulkarni; BNHS 6015, male (40.8mm SUL), 17.vii.2016,

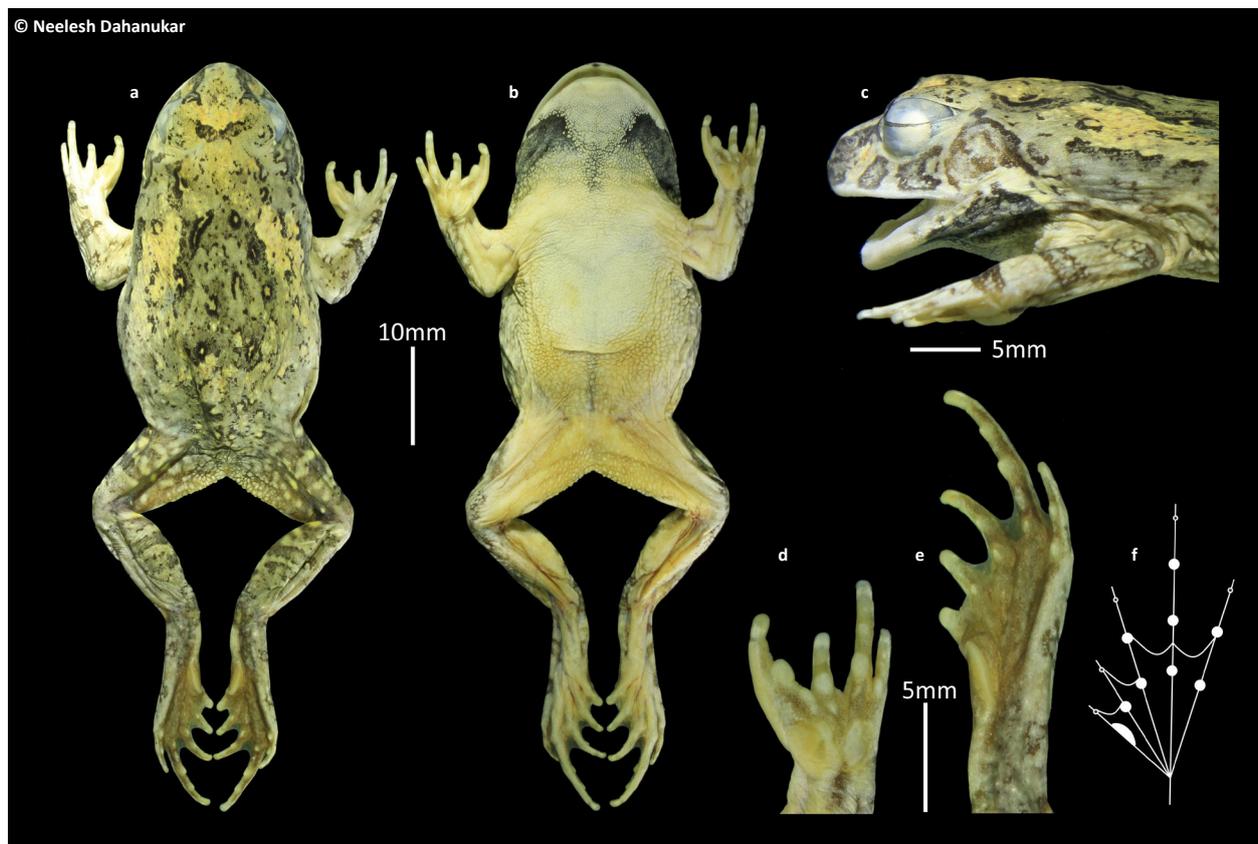


Image 1. *Sphaerotheca pashchima* sp. nov. holotype (BNHS 6000, male, 41.0mm SUL)—(a) dorsal, (b) ventral and (c) lateral profile, (d, e) details of left hand and foot, (f) Webbing pattern on foot. Empty dots indicate phalangeal articulation without tubercle. Solid circles indicates sub-articular tubercles. Crescentic solid structure on first toe indicates inner metatarsal tubercle.

India: Maharashtra: Akole near Sangamner (19.518°N, 73.923°E, 639m), coll. N. Dandekar et al.; BNHS 6016, male (42.6mm SUL), 14.vii.2016, India: Maharashtra: Wada near Jawhar (19.687°N, 73.183°E, 85m), coll. N. Dandekar et al.; BNHS 6017, female (40.6mm SUL), 16.vii.2016, India: Maharashtra: Chinchli to Salher fort road (20.747°N, 73.973°E, 820m), coll. N. Dandekar et al.; BNHS 6018, female (49.4mm SUL), 16.vii.2016, India: Gujarat: Dang District, Waghai-Ahwa road (20.709°N, 73.709°E, 302m), coll. N. Dandekar et al.; BNHS 6019, female (43.1mm SUL), 16.vii.2016, India: Gujarat: Dang District, Ahwa-Chinchli road (20.765°N, 73.972°E, 804m), coll. N. Dandekar et al.

Diagnosis: *Sphaerotheca pashchima* sp. nov. differs from all other congeners based on the following combination of characters: interorbital width less than upper eyelid width; snout to nostril distance less than half of eye diameter; nostril nearer to snout than to eye; internarial distance greater than inter orbital distance; snout rounded; dorsum rough and warty; finger 2 length equal to or less than finger 4 length; finger 1 less finger 3 length; outer metatarsal tubercle absent; tibio tarsal tubercle absent; length of inner metatarsal tubercle more than three times the inner toe length; and webbing formula I1-2II1-3III2-3½IV3½-2V.

Description of the Holotype: (BNHS 6000, male, Image 1) (all measurements in mm) Medium sized frog (SUL 41.0); head wider than long (HW 16.9 > HL 13.7); snout longer than horizontal diameter of eye (SL 6.1 > EL 5.6); pupil diamond-shaped; outline of snout rounded dorsally as well as laterally; snout not protruding beyond the mouth ventrally; nostrils nearer to snout than to the eye (SN 2.7 < EN 3.5); tympanum about ¾rd the diameter of eye (TYL = 3.6; EL = 5.6), very close to eye; supra-tympanic fold distinct; upper eyelid width about ¾rd the horizontal diameter of eye (UEW = 3.3; EL = 5.6); upper eyelids slightly granular; Inter narial width greater than shortest distance between eyes (IN 4.6 > IUE 2.7); canthus rostralis distinct; loreal region slightly concave and oblique; buccal cavity shallow, vomerine teeth in two sharply oblique rows at the anterior border of choanae; tongue thin, bifid, without papilla.

Dorsal skin granulated, slightly warty; ventral and lateral skin granular.

Length of forelimb greater than length of hand (FLL 10.0 > HAL 8.8); finger lengths from shortest to longest - F2 (2.8) < F4 (3.1) < F1 (3.6) < F3 (4.6); palmar tubercles present, outer palmar tubercle single, sub-articular tubercles moderate, supernumerary tubercles present, single; fingers without web or fringe of skin.

Hind limbs long; femur slightly longer than tibia (FL

15.4 > TL 15.6); foot length (FoL 15.6); toe lengths from shortest to longest are - T1 (0.9) < T2 (2.3) < T3 (3.9) < T5 (4.4) < T4 (8.0); inner metatarsal tubercle large, very prominent, compressed, shovel shaped, inserted obliquely at the base of the first toe, which it largely exceeds in length - T1 (0.9) < IMT (3.9); outer metatarsal tubercle absent; supernumerary tubercles absent; sub-articular tubercles moderate; tarsal fold and outer phalangeal fringe absent; webbing formula I0-1II1-2III2-3½IV3½-2V.

Coloration: In life (Image 2a), yellowish-brown above with dark patches, dorso-lateral yellowish patches behind the shoulders, inverted V-shaped mark on the back, yellowish band between eyes followed by a dark band, limbs cross barred, upper jaw laterally shows dark vertical bars, tympanum mottled, white spot behind tympanum at the angle of jaws, ventral side creamy white with two dark patches at the positions of vocal sacks, yellowish marbling in the groins. In preserved (Image 1), similar to that in life except greyish above with small dark patches and two dorso-lateral bright creamy patches behind the shoulders.

Etymology: 'Pashchim' (Sanskrit), means 'west' and is used to signify the distribution of the species in western India. Name is noun in apposition.

Variation: Morphometric variation is provided in Table 1. Color variation as per Image 2. Dorsal colour may vary from dark brown to yellowish-brown with or without reddish granulation; with or without dark brown spots or patches; middorsal line maybe present; limbs usually with irregular dark cross-bands; groin and hinder side of thigh marbled dark brown and yellow, lower parts white.

Genetic analysis: Model selection suggested transition model with gamma distribution (TIM2e+G4, lnL = -1893.27, df = 51, BIC = 4111.45) as the best nucleotide substitution model. *Sphaerotheca pashchima* sp. nov. formed a monophyletic group distinct from *S. breviceps*, *S. dobsonii*, *S. pluvialis* and misidentified species from Myanmar (see Dahanukar et al. 2017) in maximum likelihood analysis (Fig. 1). *S. pashchima* differed from *S. breviceps* by a raw genetic distance of 8.3–11.7 %, from *S. dobsonii* by 6.5–9.5 %, from *S. pluvialis* by 6.3–8.3 % and from misidentified species from Myanmar by 7.6–10.9 % (Table 2).

Morphological analysis: Size adjusted morphometric characters were not significantly different from multivariate normal (Doornik & Hansen omnibus, Ep = 64.38, P = 0.1164). *S. pashchima*, *S. breviceps*, *S. dobsonii* and *S. pluvialis* formed distinct clusters in DA (Fig. 2). *S. pashchima* was significantly different from



Image 2. *Sphaerotheca pashchima* sp. nov. in life. (a) holotype (BNHS 6000, male, 41.0mm SUL) from Ambodi Village, (b) from Kutwalwadi (specimen not collected), (c) from Mayureshwar Wildlife Sanctuary (specimen not collected), and (d) from Akole near Sangamner (BNHS 6015, male, 40.8mm SUL).

S. breviceps (Fisher's distance $F = 17.42$, $P < 0.001$), *S. dobsonii* (Fisher's distance $F = 21.53$, $P < 0.001$) and *S. pluvialis* (Fisher's distance $F = 45.28$, $P < 0.001$) (Fig. 2 inset). *S. pashchima* differed from the remaining three species based on relatively higher values of characters such as IMT, EL, IN, TYD and HL and relatively lower values of characters such as FL, IUE, HW, TYE, FoL, T4L, T5L, T3L, T1L, T2L, F1L and F2L (Fig. 2).

Habitat and ecology: *S. pashchima* is found widely distributed in western India. It inhabits variety of habitats from high to low rainfall areas. In high rainfall areas it is sympatric to *S. dobsonii*. It is also found in semi arid and arid parts of Deccan plateau. In semi arid and arid areas it breeds in temporary rain water pools immediately after the first flash rains. Adults gather in large numbers at potential breeding habitats. Tadpoles are bottom dwelling and frequently come to the surface of water for breathing. Juveniles are cannibalistic; a larger one devours the smaller one of its own species.

Comparisons: *S. pashchima* differs from the species of Leucorhynchus group by absence of outer metatarsal tubercle (vs. present) and from the species of Dobsonii

group in length of inner metatarsal tubercle more than three times the inner toe length (vs. less than 2 times). *S. pashchima* belongs to *breviceps* group of species because of absence of outer metatarsal tubercle and length of inner metatarsal tubercle more than two times the inner toe length.

Within the *breviceps* group, *S. pashchima* differs from *S. breviceps* by following set of characters: second finger equal to or less than fourth finger (vs. second finger longer than fourth finger), interorbital distance less than the width of upper eyelid (vs. equal to or more than upper eyelid), internarial distance greater than interorbital distance (vs. internarial distance less than inter orbital distance), snout rounded (vs. truncated), and webbing formula $I1-2II1-3III2-3\frac{1}{2}IV3\frac{1}{2}-2^*V$ (vs. $I1-2II1\frac{1}{2}-2\frac{1}{2}III2\frac{1}{2}-3\frac{1}{2}IV4-2^*V$). Further, raw genetic distance between widely distributed *S. pashchima* and *S. breviceps* is 8.3–11.7% (Table 2).

S. pashchima differs from *S. rolandae* by following set of characters: first finger longer than second and fourth (vs. first finger shorter than second and fourth); tibio tarsal tubercle absent (vs. tibio tarsal tubercle present);

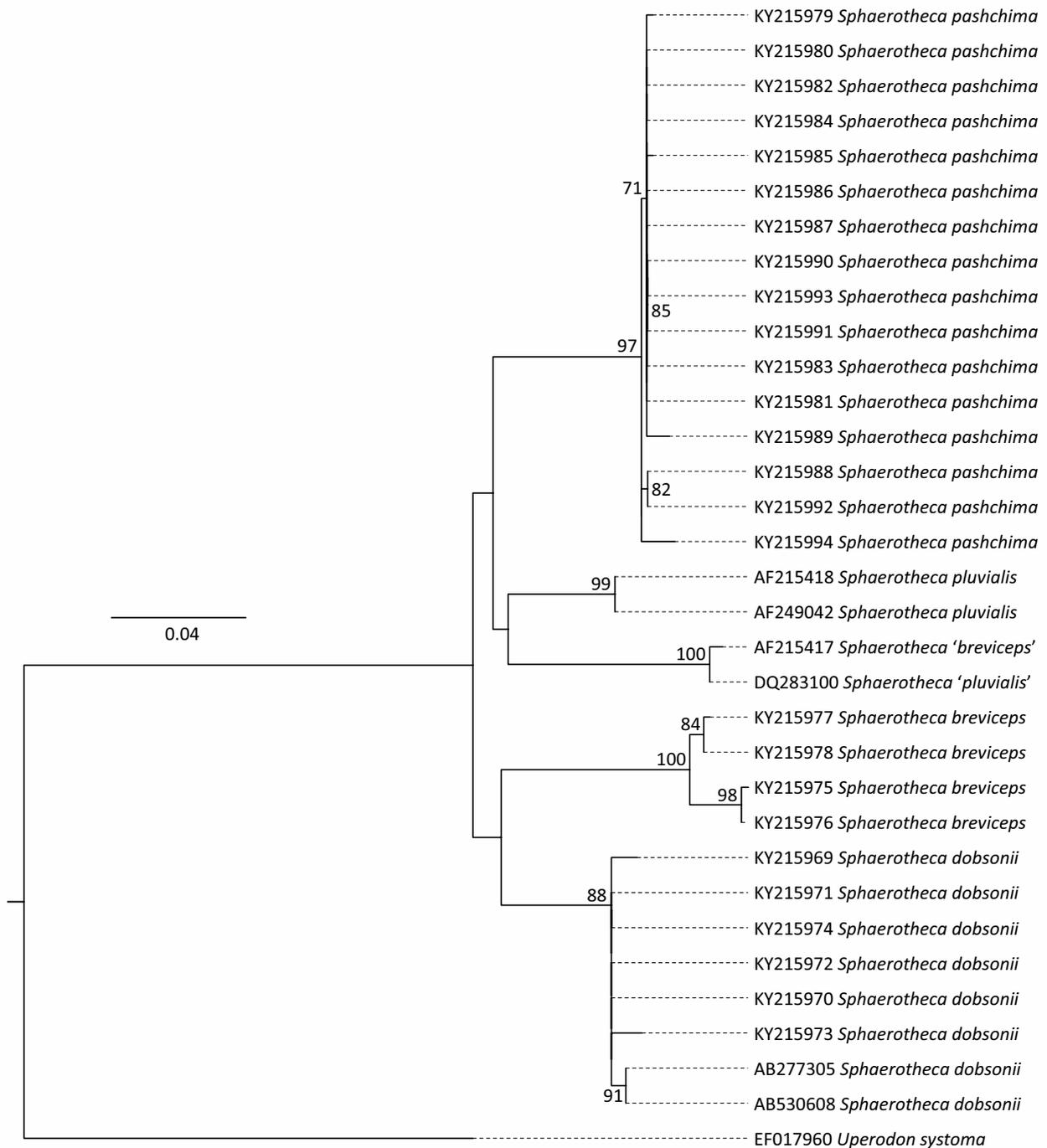


Figure 1. Maximum likelihood analysis of 16S rRNA partial gene sequence. Species in single quotes are misidentified species from Myanmar (see Dahanukar et al. 2017 for more details). *Uperodon systema* is used as an outgroup. Values along the nodes are percent bootstrap for 1000 iterations. Bootstrap values less than 50 are not shown.

and webbing formula I1-2II1-3III2-3½IV3½-2*V (vs. I1-2II1½-2½III2*-3½IV4*-2*V).

S. pashchima differs from *S. maskeyi* by the following set of characters: first finger shorter than third (vs. first finger longer than third), second finger equal to or less than fourth finger (vs. second finger longer than fourth finger), snout to nostril distance less than half of

horizontal diameter of eye (vs. more than half horizontal diameter of eye), dorsum rough and warty (vs. dorsum smooth), nostrils nearer to the tip of snout (vs. nostrils closer to eye) and webbing formula I1-2II1-3III2-3½IV3½-2*V (vs. I1-2*II1½-3*III2*-3½IV3½-2*V).

Dahanukar et al. (2017) tentatively put *Rana variegata* Gravenhorst, 1829 as a synonym of *S.*

Table 1. Morphometric data (in mm) of *Sphaerotheca pashchima* sp. nov. holotype [H] and paratypes [P] of males (M), females (F) and sub-adults (SA). Vouchers with asterisk were used for genetic analysis.

Voucher	SUL	HL	HW	SN	IN	EL	SL	EN	IUE	UEW	TYD	TYE	HAL	FIL	F2L	F3L	F4L	FLL	FL	TL	FoL	T1L	T2L	T3L	T4L	T5L	IMT
BNHS 6000 (M)[H]	41.0	13.7	16.9	2.7	4.6	5.6	6.1	3.5	2.7	3.3	3.6	1.5	8.8	3.6	2.8	4.6	3.1	10.0	15.4	15.3	15.6	1.0	2.3	3.9	8.0	4.4	4.1
BNHS 6011 (M)[P]*	44.2	15.0	19.2	2.9	4.4	7.4	7.0	3.2	3.2	4.5	3.4	1.4	10.7	4.6	3.4	5.7	3.7	10.8	17.3	18.8	20.7	1.3	3.8	5.9	11.1	5.2	4.4
BNHS 6014 (M)[P]*	55.7	18.7	21.7	3.2	4.9	7.8	7.5	4.0	3.3	5.4	3.8	2.1	11.6	5.5	4.0	6.4	4.6	13.1	22.5	22.5	22.5	1.3	2.9	6.4	11.7	6.0	5.5
BNHS 6015 (M)[P]*	40.8	14.4	17.6	2.2	4.1	6.3	5.8	2.9	2.6	3.7	3.2	1.1	9.1	4.4	3.1	5.0	3.3	10.0	19.0	16.9	16.5	1.3	3.0	5.7	9.4	4.2	4.4
BNHS 6016 (M)[P]*	42.6	13.5	16.4	2.8	4.4	6.4	6.4	3.0	3.4	4.0	2.6	1.0	9.6	4.5	3.2	5.6	3.8	9.5	17.9	17.1	18.8	1.0	3.0	5.4	9.2	5.1	4.2
ZSI-WRC A/1545 (M)[P]	43.3	15.2	18.8	2.5	4.3	7.1	6.3	3.0	3.2	4.1	2.8	0.8	8.7	3.4	2.8	4.5	3.0	10.2	18.0	16.6	18.0	1.0	2.6	4.7	9.4	4.8	4.4
WILD-16-AMP-642 (M)[P]*	43.6	14.3	18.4	3.0	3.9	6.7	6.9	3.2	3.0	4.6	3.1	2.3	10.8	3.6	3.0	5.2	3.4	12.6	19.9	17.9	19.9	1.1	2.9	5.3	9.8	4.9	4.5
BNHS 6001 (F)[P]	46.3	16.0	18.4	2.9	4.5	6.5	6.8	3.2	2.9	4.4	3.8	1.1	10.2	4.6	3.4	6.0	3.9	10.3	17.6	17.5	19.0	1.2	2.8	5.5	10.1	5.6	5.0
BNHS 6002 (F)[P]	43.9	14.4	17.2	2.8	4.4	6.2	6.1	3.0	2.2	4.2	2.8	1.0	10.3	4.1	2.9	5.7	3.9	10.5	17.4	14.9	14.0	1.1	1.9	4.7	3.4	3.0	5.0
BNHS 6003 (F)[P]*	42.5	15.7	17.7	2.8	3.9	6.2	6.6	3.4	3.2	4.3	3.0	2.1	10.7	3.6	3.7	5.7	4.3	10.8	18.8	19.1	22.0	1.2	3.5	5.9	11.2	6.3	4.9
BNHS 6012 (F)[P]*	32.9	11.9	11.7	2.3	3.0	5.0	4.9	2.4	2.4	3.1	2.2	0.9	7.6	3.2	2.7	3.8	2.8	6.7	10.5	12.6	13.3	1.0	2.4	4.4	6.9	3.8	3.2
BNHS 6013 (F)[P]*	50.5	17.3	20.1	3.0	4.2	7.4	6.9	3.3	3.3	4.3	3.3	1.7	11.0	4.4	3.8	5.8	3.9	11.8	18.7	20.1	21.5	1.5	4.1	6.2	11.0	5.2	4.8
BNHS 6017 (F)[P]*	40.6	14.3	15.8	2.5	3.9	6.0	5.6	2.8	3.3	3.4	2.8	1.0	9.3	4.3	3.2	5.2	3.3	8.2	16.2	16.1	17.7	1.4	3.0	5.2	9.1	4.8	4.8
BNHS 6018 (F)[P]*	49.4	16.0	18.7	2.8	4.7	7.4	7.7	3.2	3.2	3.7	3.0	0.9	11.4	5.0	3.8	6.0	3.6	11.1	19.8	20.2	20.6	1.3	3.4	6.0	10.5	5.8	4.3
BNHS 6019 (F)[P]*	43.1	14.2	16.4	2.6	3.9	6.1	6.1	2.8	3.3	3.7	2.8	1.0	8.7	4.2	3.0	4.5	3.5	9.0	16.5	17.3	17.2	1.3	2.8	4.7	8.4	4.4	4.2
WILD-16-AMP-644 (F)[P]*	35.5	12.4	14.5	1.9	3.5	5.5	5.3	2.5	3.2	3.3	2.6	1.3	9.2	3.6	2.3	4.1	2.4	9.8	16.9	17.6	17.4	1.2	2.3	4.7	8.0	4.5	4.2
WILD-16-AMP-641 (SA)[P]*	19.4	7.3	8.2	1.3	2.3	3.7	3.6	1.7	1.9	2.0	1.2	0.7	4.7	1.9	1.3	2.4	1.6	4.4	8.1	8.3	8.0	0.4	1.2	2.6	4.2	2.0	1.5
WILD-16-AMP-643 (SA)[P]*	29.8	11.5	13.1	1.9	3.0	4.7	4.6	2.2	2.9	2.9	2.0	1.1	6.9	3.2	2.3	4.2	2.5	8.8	12.2	12.3	13.9	0.8	1.8	3.7	7.6	3.4	3.3
ZSI-WRC A/1544 (SA)[P]	24.6	9.8	11.2	1.6	2.6	4.2	3.8	1.7	2.0	2.8	1.7	1.0	6.5	2.8	1.6	3.9	2.2	6.1	12.1	11.0	11.8	0.7	1.8	3.5	6.5	3.1	2.5
ZSI-WRC A/1549 (SA)[P]*	29.8	10.5	11.9	2.2	2.7	4.8	4.5	2.2	2.5	2.6	1.3	0.9	6.5	3.0	1.8	3.6	2.6	6.5	10.8	11.8	11.6	0.9	2.2	3.5	6.0	3.5	2.9
ZSI-WRC A/1550 (SA)[P]*	28.5	9.8	11.3	2.0	2.9	4.3	4.2	2.1	2.1	2.6	1.4	0.8	6.9	3.1	2.4	3.6	2.5	6.3	10.7	11.8	11.9	0.8	2.2	3.6	6.4	3.2	2.4

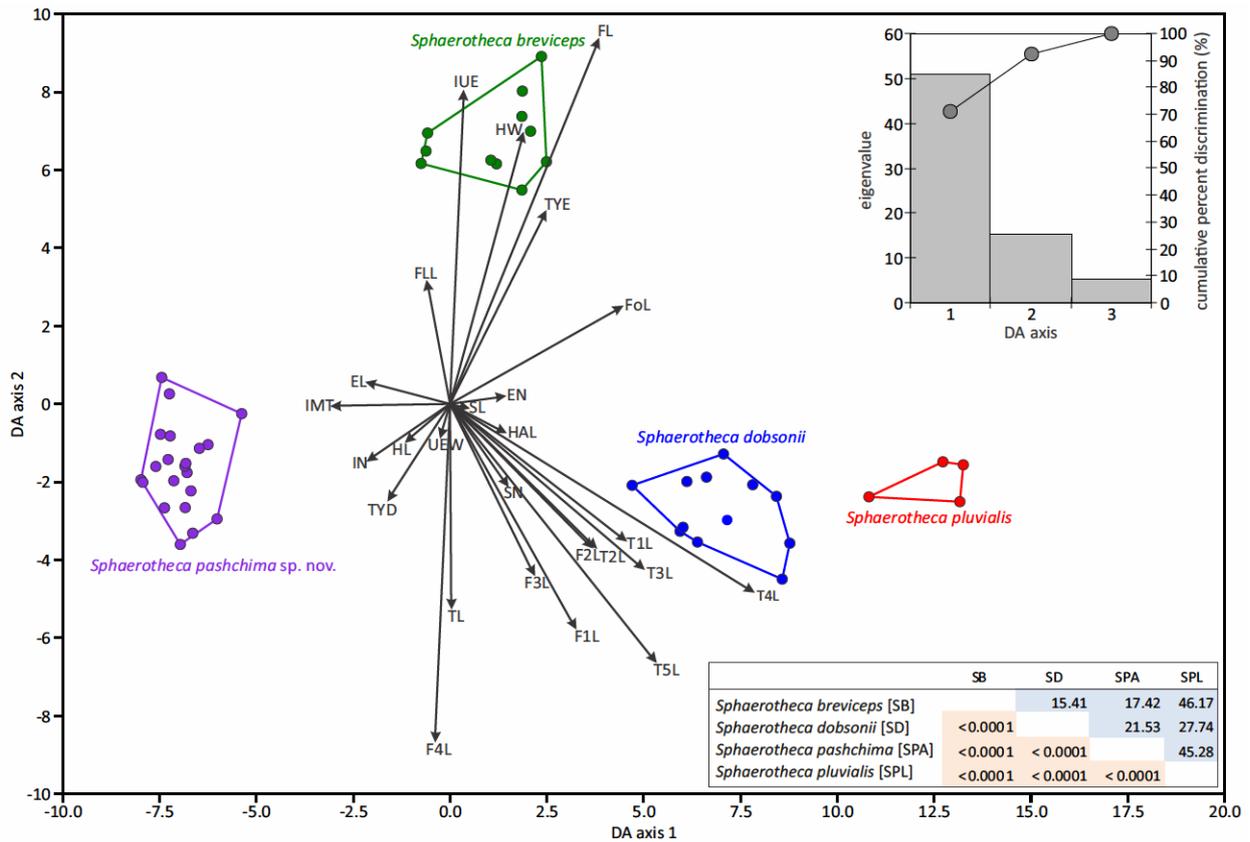


Figure 2. Discriminant analysis biplot of size adjusted morphometric characters. Pairwise Fisher's distances (blue cells) and associated P values (red cells) are provided in the inset at right down corner. Scree plot explaining the percent discrimination explained by each discriminant axis is shown in the inset at upper right corner.

Table 2. Percent pairwise uncorrected raw distances expressed as minimum–maximum based on 16S rRNA partial gene sequence. Values in square brackets are intra species distances. *Sphaerotheca* sp. are misidentified species from Myanmar (see Figure 2 and Dahanukar et al. 2017).

Species	Spa	Sdo	Sbr	Spl	Ssp
<i>Sphaerotheca pashchima</i> (Spa)	[0.0–1.0]				
<i>Sphaerotheca dobsonii</i> (Sdo)	6.5–9.5	[0.0–2.0]			
<i>Sphaerotheca breviceps</i> (Sbr)	8.3–11.7	7.1–10.9	[0.2–2.2]		
<i>Sphaerotheca pluvialis</i> (Spl)	6.3–8.3	5.6–8.0	7.9–8.3	[0.0]	
<i>Sphaerotheca</i> sp. (Ssp)	7.6–10.0	8.1–10.5	9.1–9.6	7.1–7.5	[0.4]

breviceps. The original description of *Rana variegata* is not detailed, however, based on the figure provided by Gravenhorst (1829, Tab. VIII, Fig. I), *S. pashchima* differs from *R. variegata* in having a larger inner metatarsal tubercle (IMT more than three times T1L vs. less than three times) and 3½ phalanges free on inner side of fourth toe (vs. 3 phalanges free).

Distribution: Western parts of peninsular India from the states Gujarat, Maharashtra and Karnataka (Image 3).

DISCUSSION

Dahanukar et al. (2017) provide a review of the species under the genus *Sphaerotheca* and identify three morphological groups for eight valid species in the genus. They also assign genetic barcode for *S. breviceps*, *S. dobsonii* and *S. pluvialis* so as to aid future studies in unambiguous identification of these three species. We describe *S. pashchima* sp. nov. from the *S. breviceps* group, which is morphologically distinct from all its congeners. We also provide genetic barcode as identity of the new species.

It is essential to note that earlier reports of *S. breviceps* by Padhye & Ghate (2002), Padhye et al. (2002), Dharne et al. (2004), Dahanukar & Padhye (2005), and Padhye & Ghate (2012) should be attributed to *S. pashchima* sp. nov. based on current study.

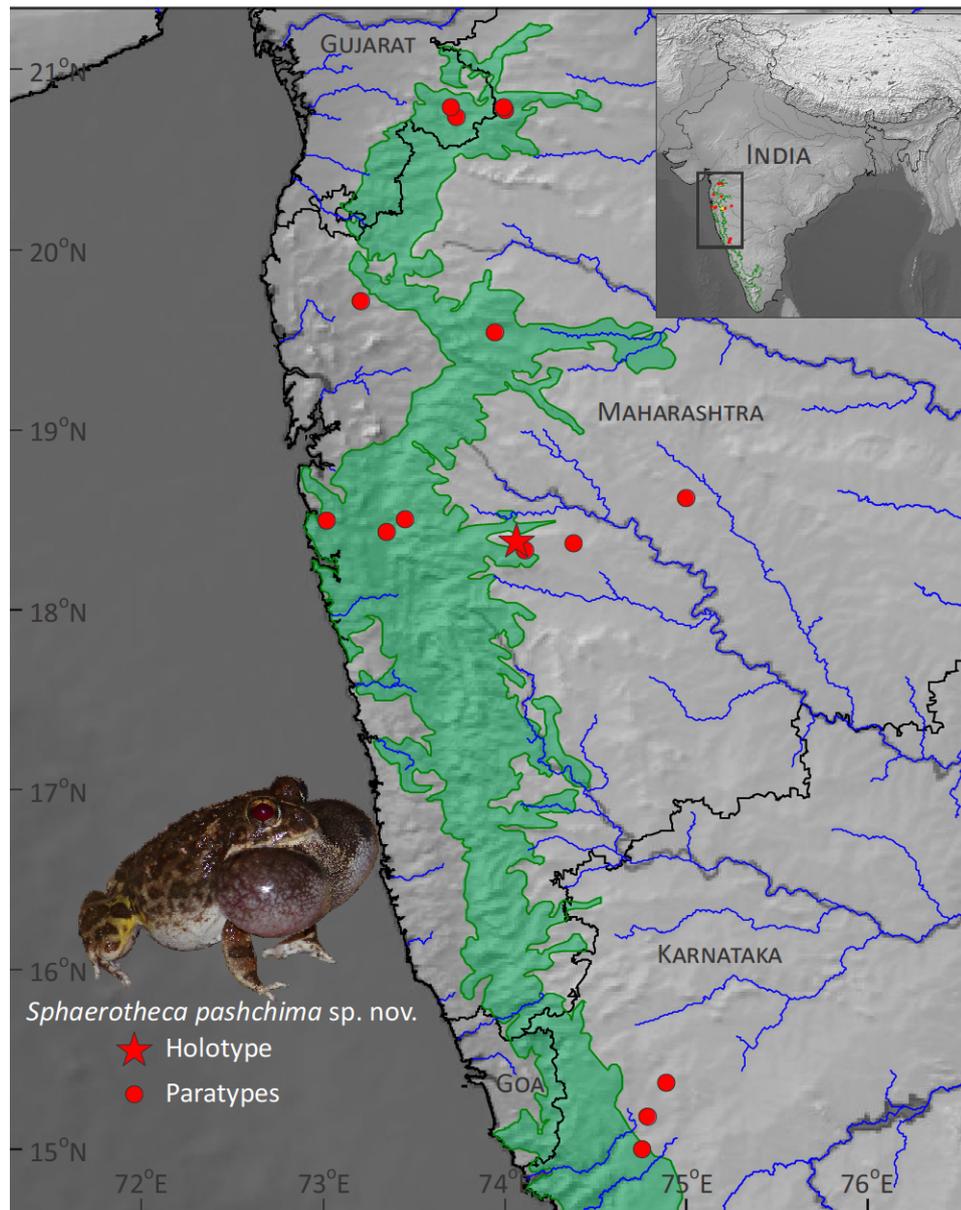


Image 3. Distribution of *Sphaerotheca pashchima* sp. nov. Western Ghats mountain ranges are shown in green.

Dahanukar et al. (2017) mention that the sequence GU191122 for specimen identity as *S. rolandae* from Rajasthan is not of good quality and with several gaps; however, partial sequence comparison suggests that the species is misidentified and is likely to be *S. pashchima* sp. nov. indicating its presence in Rajasthan.

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***Sphaerotheca pashchima*, a new species of burrowing frog (Anura: Dicroglossidae) from western India**

-- Anand Padhye, Neelesh Dahanukar, Shauri Sulakhe, Nikhil Dandekar, Sunil Limaye & Kirti Jamdade, Pp. 10286–10296

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