Zootaxa 3410: 19–34 (2012)
www.mapress.com/zootaxa/
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Article

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

A new species of *Raorchestes* (Amphibia: Anura: Rhacophoridae) from mid-elevation evergreen forests of the southern Western Ghats, India

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Abstract

A new species of the shrub frog genus *Raorchestes* Biju, Souche, Dubois, Dutta and Bossuyt is described as *Raorchestes kakachi* **sp. nov.** from Agastyamalai hill region in the southern Western Ghats, India. The small sized *Raorchestes* (male: 24.7–25.8 mm, n = 3 and female: 24.3–34.1 mm, n = 3) is distinguished from all other known congeners by the following suite of characters. Snout oval in dorsal view; tympanum indistinct; head wider than long; moderate webbing in feet; colour on dorsum varying from ivory to brown, blotches of dark brown on flanks, brown mottling on throat reducing towards vent; inner and outer surface of thigh, inner surface of shank and inner surface of tarsus with a distinct dark brown horizontal band which extends upto first three toes on upper surface. A detailed description, advertisement call features, ecology, natural history notes and comparison with closely related species are provided for the new species.

Key words: Shrub frogs, Agastyamalai, Taxonomy, Acoustics, Western Ghats

Introduction

The Western Ghats of India harbors a high diversity of amphibians, particularly shrub frogs of the genus *Raorchestes* (Biju *et al.* 2010). Molecular phylogenetic work by Biju *et al*. (2010) on the genus *Philautus* resulted in its segregation into *Philautus* Gistel, *Pseudophilautus* Laurent and *Raorchestes*. The genus *Raorchestes* comprises of relatively small frogs (15–45 mm), active at night, vomerine teeth absent, transparent/translucent vocal sac while calling and direct development without free swimming tadpoles (Biju *et al.* 2010; Li *et al.* 2011). Here, we report a new species of *Raorchestes* from Kakachi Tea Estate in the mid-elevation evergreen forests of Kalakad Mundanthurai Tiger Reserve (KMTR) from the Agastyamalai hill range, southern Western Ghats, India, making the total species in *Raorchestes* in Western Ghats to 40.

Material and methods

Study area. The study was carried out in the Kakachi tea estate and the adjacent forests of Kalakad Mundanthurai Tiger Reserve (KMTR). The reserve covers an area of 895 km^2 and is located between 8.416667° N to 8.883333° N latitude and 77.166667° E to 77.583333° E longitude with the altitude ranging from 40 m to 1,800 m amsl. It experiences two monsoons, the southwest (June–September) and the northeast (October–January) receiving a mean annual rainfall of about 3,000 mm (Ganesh *et al.* 1996). Kalakad Mundanthurai Tiger Reserve comprises of a matrix of habitats ranging from thorny scrub forest in the foothills to the wet evergreen forests in higher elevations and has a high diversity and endemism of flora and fauna (Johnsingh 2001). The species described herein was col-

Accepted by M. Vences: 15 Jun. 2012; published: 6 Aug. 2012

lected near roadside streams on riparian vegetation in Kakachi tea estate (8.549167° N latitude and 77.385833° E longitude, 1285 m amsl). This species is also seen in Upper Kodayar (8.530833° N latitude and 77.359722° E longitude, 1300 m amsl, Figure 1) Forests which represent the mid elevation evergreen forest of the Western Ghats comprising of *Cullenia–Aglaia–Palaquium* vegetation series (Ganesh *et al*. 1996).

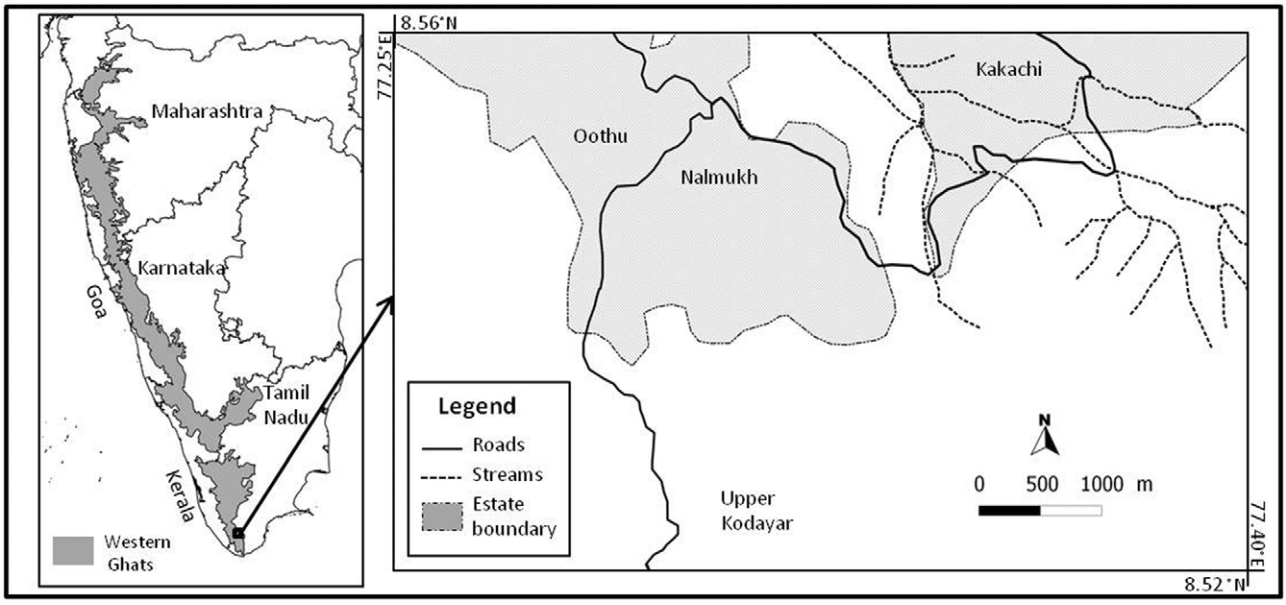

FIGURE 1. Map showing the Western Ghats in peninsular India and details of the type locality of *Raorchestes kakachi* **sp.nov.**

Morphology and morphometry. The new species was compared with published literature for *R. flaviventris*, published literature and personal observations for *R. chalazodes* and examination of type specimens of the remaining 37 valid species of *Raorchestes* from the Western Ghats. The frogs were euthanized and preserved in 70% alcohol. Morphometric measurements were taken using a Mitutoyo® digital caliper to the nearest 0.1 mm. Materials examined are provided in Appendix I. Measurements and terminology follows Biju and Bossuyt (2009). Abbreviations used are as follows: snout–vent length (SVL); head width, at the angle of the jaws (HW); head length, from the rear of the mandible to the tip of the snout (HL); inter upper eyelid width, i.e. the shortest distance between the upper eyelids (IUE); maximum upper eyelid width (UEW); snout length, measured from the tip of the snout to the anterior orbital border of the eye (SL); eye length, i.e. the horizontal distance between the bony orbital borders of the eye (EL); distance from the rear of the mandible to the nostril (MN); distance from the rear of the mandible to the anterior orbital border of the eye (MFE); distance from the rear of the mandible to the posterior orbital border of the eye (MBE); distance between anterior corner of eyes, i.e. the shortest distance between the anterior orbital borders of the eyes (IFE); distance between posterior corner of eyes, i.e. the shortest distance between the posterior orbital borders of the eyes (IBE); largest tympanum diameter (TYD); forelimb length, measured from the elbow to the base of the outer palmar tubercle (FLL); hand length, measured from the base of the outer palmar tubercle to the tip of the third finger (HAL); thigh length (TL); shank length (ShL); foot length, measured from the base of the inner metatarsal tubercle to the tip of the fourth toe (FOL); distance from the heel to the tip of the fourth toe (TFOL).

A few additional morphometric measurements were made based on Gururaja *et al.* (2007) and have been abbreviated as follows: internarial distance, i.e. least distance between the inner margins of nares (IN); nostril–snout distance, i.e. distance between middle of nostril and tip of snout (NS); eye to nostril distance, i.e. distance between anterior-most point of eye and middle of nostril (EN); tympanum–eye distance, i.e., anterior rim of tympanum to posterior of eye (TYE); disc width on fingers I, II, III and IV (FD I, II, III and IV); width of finger I, II, III and IV measured at the base of the disc (FW I, II, III and IV); lengths of fingers I, II, III and IV measured from base of proximal subarticular tubercle to finger tip (FL I, II, III and IV); tibia width, i.e. width of tibia at its widest region (TW); disc width on toes I, II, III, IV and V (TD I, II, III, IV and V); width of toes I, II, III, IV and V (ToW I, II, III, IV and V) measured at the base of disc; length of toes I, II, III, IV and V measured from base of proximal subarticular tubercle to tip of toe (ToL I, II, III, IV and V); length of inner metatarsal tubercle (IMT); distance from

distal edge of metatarsal tubercle to maximum incurvature of web between fourth and fifth toe (MTFF); distance from distal edge of metatarsal tubercle to maximum incurvature of web between third and fourth toe (MTTF); distance from maximum incurvature of web between fourth and fifth toe to tip of fourth toe (FFTF); distance from maximum incurvature of web between third and fourth toe to tip of fourth toe (TFTF). We also measured tongue-length and width (TLW). Intercalary ossification, which is the cartilaginous structure between distal and penultimate phalanges in fingers and toes, was also observed. The presence of an intercalary ossification can be noticed without anatomical sectioning as a glandular projection between phalanges (Daniel 1963).

Abbreviations: Commonly used terminologies have been abbreviated as follows: ATREE (Ashoka Trust for Research in Ecology and the Environment), BNHS (Bombay Natural History Society), CES (Centre for Ecological Sciences), IISc (Indian Institute of Science), KMTR (Kalakad Mundanthurai Tiger Reserve), KSS (K.S. Seshadri), KVG (K.V. Gururaja), NAA (N.A. Aravind), PS (Preeti Saryan), RH (Relative Humidity), RG (R. Ganesan), TA (Tamizalagan), TG (T. Ganesh), ZSIC (Zoological Survey of India, Kolkata), ZSI/SRC (Zoological Survey of India, Southern Regional Centre, Chennai), ZSI/WGRC (Zoological Survey of India, Western Ghats Regional Centre, Calicut).

***Raorchestes kakachi* sp. nov.**
(Figures 2.a–b & 3.a–h; Table 1)
Suggested common name: **Kakachi shrub frog**

Holotype. ZSI/WGRC/V/A/857, an adult male collected by KSS and TA on shrubs at 2 m height from Kakachi, near a stream on 23rd May 2011 during 19:40 hrs (8.549167° N latitude and 77.385833° E longitude, 1285 m amsl).

Paratypes. ZSI/WGRC/V/A/858–859, consists of two males and three females collected in Kakachi. One male was collected by KSS in Kakachi, collection date same as holotype. The other male and a female were collected on 24th May 2011 at 20:51 hrs by KSS & PS (8.530833° N latitude and 77.359722° E longitude, 1300 m amsl). Two females were collected on 24th January 2011 at 20:30 hrs by KSS, NAA, TG and RG on riparian vegetation along a stream.

Diagnosis. Small sized adult *Raorchestes* (male: 24.7–25.8 mm, n = 3 and female: 24.3–34.1 mm, n = 3) diagnosed with the following characters. Absence of vomerine teeth; translucent vocal sac while vocalizing; active during night (observed between 18:00–23:00 hrs); all digits well differentiated with discs having distinct circummarginal grooves; absence of dermal folds and spur in forelimbs and hindlimbs. It is distinguished by all other congeners by the following combination of characters: (i) flat head; (ii) snout oval in dorsal view; (iii) tympanum indistinct; (iv) supra-tympanic fold distinct; (v) head wider than long; (vi) skin granular on throat, chest, belly, flanks, vent and lower parts of thigh; (vii) tuberculate projections on dorsum, upper eye lids, snout, tympanic region, fore limbs and hind limbs; (viii) colour on dorsum varying from ivory to brown, blotches of dark brown on flanks, brown mottling on throat reducing towards vent; (ix) fingers and toes with well developed discs, circummarginal groves folding upwards giving a bifid appearance in dorsal view; (x) intercalary ossification distinct, present between penultimate and distal phalanges of both fingers and toes as a white glandular projection; (xi) moderate webbing in hind limbs; (xii) distinct dark brown horizontal band on inner and outer surface of thigh, inner surface of shank and inner surface of tarsus extending up to first three toes on upper surface; and (xiii) iris colour brown.

Description of holotype (all measurements in mm, Figure 3. a–h): A small sized frog (SVL = 25.8), head wider than long (HW = 9.4; HL = 8.7), snout oval in dorsal view and in profile rounded. Eye length sub-equal to snout length (EL = 3.8; SL = 4.0). Canthus rostralis rounded, loreal region slightly concave. Interorbital space flat, almost equal to upper eyelid width and internarial distance (IUE = 2.6; UEW = 2.7; IN = 2.6). Internarial distance between posterior margins of eyes 1.8 times that of anterior margins (IFE = 5.2; IBE = 9.2). Nostrils oval, without flap, closer to tip of snout than to eye (NS = 1.7; EN = 2.5). Weak symphysial knob. Pineal ocellus absent. Tympanum indistinct, oval, closer to eye (TYD = 1.1; TYE = 0.6), 3.5 times in eye length. Supratympanic fold distinct from back of eye to shoulder. Median sub-gular vocal sac with a pair of openings at the base of lower jaw. Tongue bifid (TLW, length = 5.4; width = 3.9), chordate, sparsely granular. Lingual papilla absent. Eyes moderately large (EL = 3.8), protruding, pupil horizontal.

FIGURE 2.a. *Raorchestes kakachi* **sp. nov.** holotype in life (male, SVL = 25.8 mm; ZSI/WGRC/V/A/857); b. Paratype in life (female, SVL = 34.1; ZSI/WGRC/V/A/858). Photographed in type locality by KSS.

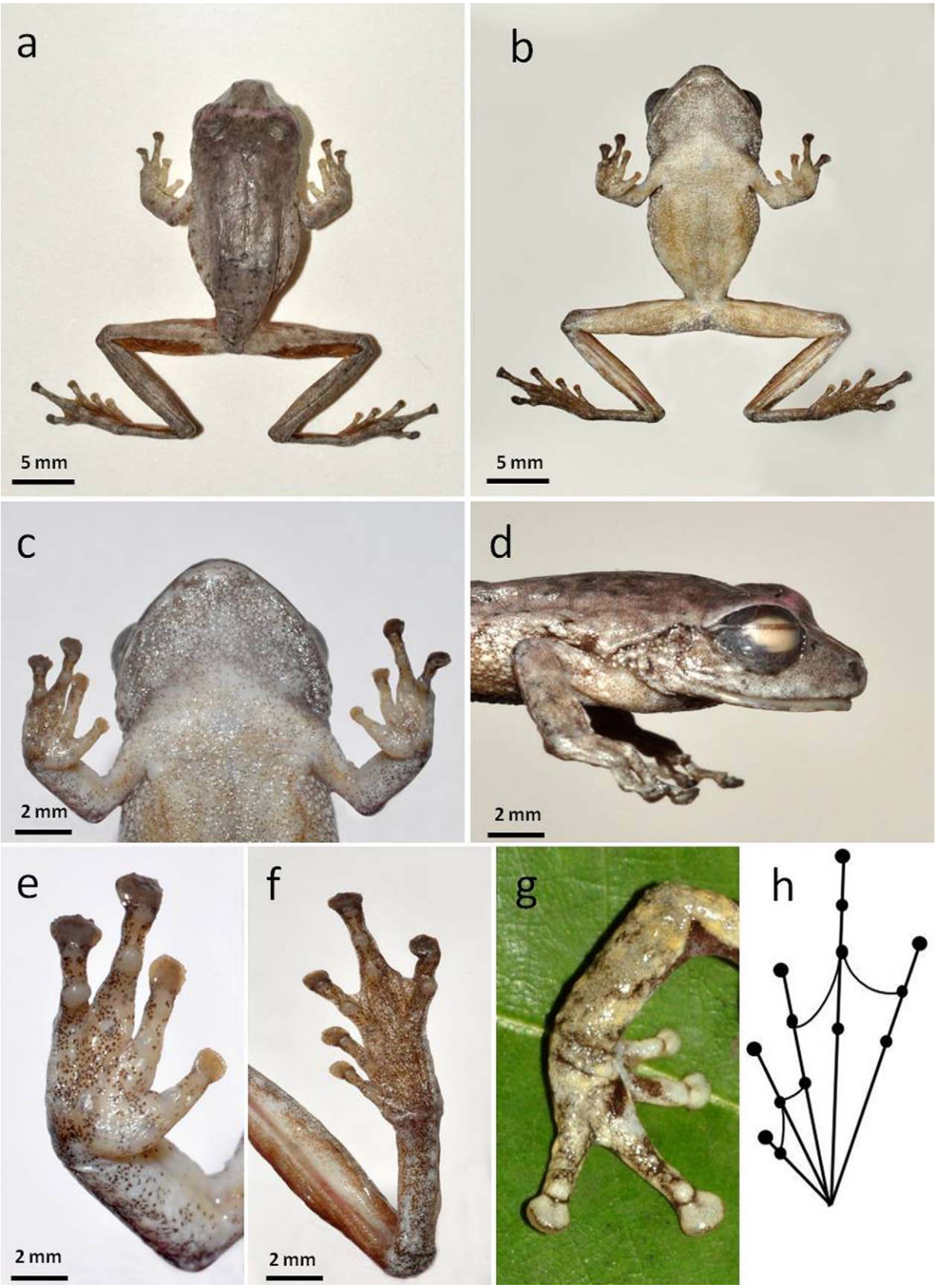

FIGURE 3.a–f. *Raorchestes kakachi* **sp.nov.** holotype in preservative. a. dorsal view ; b. ventral view; c. ventral view of head; d. lateral view of head; e. ventral view of hand; f. ventral view of foot; g. dorso-ventral view of hand in life (female, ZSI/WGRC/V/A/858) and h. schematic diagram of webbing in feet. All photographs by KSS.

FIGURE 4.a–c. Variations in morphology among males of *Raorchestes kakachi* **sp. nov.** from type locality (a & b: not collected, c: 858) d: holotype male calling (857); e. Variation in female (859) & f. amplecting pair (858). Numbers in parenthesis indicate voucher numbers with ZSI/WGRC/V/A as prefix. All photographs by KSS.

Fore limb length shorter than hand length (FLL = 6.6; HAL = 7.2). Relative lengths of fingers I<II<IV<III (FL I = 1.3; FL II = 2.7; FL III = 3.9; FL IV = 2.8). Finger tips with well developed discs (FD I = 0.4, FD II = 0.5, FD III = 0.7, FD IV = 0.7; FW I = 0.8, FW II = 1.0, FW III = 1.5, FW IV = 1.5) with circum marginal grooves, grooves fold upwards, giving bifid appearance in dorsal view, intercalary ossification distinct between penultimate and distal phalanges (Figure 3. g). Dermal fringes weak, on both sides of the fingers. Webbing between fingers absent. Subarticular tubercles distinct (finger: i = 1, ii = 1, iii = 2, iv = 1) rounded and pre–pollex tubercle oval, distinct. Supernumerary tubercles present. Nuptial pad absent.

TABLE 1. Morphometric data of *R. kakachi* sp. nov., holotype and paratypes (Prefix ZSI/WGRC/V/A to voucher specimen numbers)

Voucher specimens Sex Morphometric characters	857 Holotype Male	858 Paratype Male	858 Paratype Male	Average ± SD (Range)	858 Paratype Female	859 Paratype Female	859 Paratype Female	Average ± SD (Range)
SVL	25.8	24.7	24.2	24.9 ± 0.8 (24.2–25.8)	34.1	24.3	28.7	29.0 ± 4.9 (24.3–34.1)
HW	9.4	9.8	9	9.4± 0.4 (9.0–9.8)	12.9	9.0	11.6	11.1 ± 2 (9.0–12.9)
HL	8.7	7.6	8.2	8.1 ± 0.5 (7.6–8.7)	10.7	7.8	9.4	9.3 ± 1.5 (7.8–10.7)
IUE	2.6	3.7	2.6	3.0 ± 0.6 (2.6–3.7)	3.4	3.9	3.8	3.7 ± 0.3 (3.4–3.9)
UEW	2.7	2.2	2.7	2.5 ± 0.3 (2.2–2.7)	3.1	2.4	2.4	2.6 ± 0.4 (2.4–3.1)
SL	4	3.4	3.3	3.6 ± 0.4 (3.3–4)	5.2	3.3	4	4.2 ± 1.0 (3.3–5.2)
EL	3.8	3.7	3.5	3.7 ± 0.2 (3.5–3.8)	4.8	3.3	4.1	4.1 ± 0.8 (3.3–4.8)
MN	7.5	6.6	7.6	7.2 ± 0.6 (6.6–7.6)	10.2	6.8	8	8.3 ± 1.7 (6.8–10.2)
MFE	5.5	4.8	5.3	5.2 ± 0.4 (4.8–5.5)	7.2	4.6	5.7	5.8 ± 1.3 (4.6–7.2)
MBE	2	2	1.5	1.8 ± 0.3 (1.5–2)	2.8	2.1	2.8	2.6 ± 0.4 (2.1–2.8)
IN	2.6	2.4	2.5	2.5 ± 0.1 (2.4–2.6)	3	2.1	2.8	2.6 ± 0.5 (2.1–3)
IFE	5.2	4.7	5	5.0 ± 0.3 (4.7–5.2)	6.7	4.3	4.4	5.1 ± 1.4 (4.3–6.7)
IBE	9.2	7.9	8.8	8.6 ± 0.7 (7.9–9.2)	10.6	8.2	10.8	9.9 ± 1.4 (8.2–10.8)
NS	1.7	1.8	1.5	1.7 ± 0.2 (1.5–1.8)	1.7	1.9	1.5	1.7 ± 0.2 (1.5–1.9)
EN	2.5	2.4	2.4	2.4 ± 0.1 (2.4–2.5)	3.6	2.5	2.8	3.0 ± 0.6 (2.5–3.6)
TYD	1.1	0.8	1.2	1.0 ± 0.2 (0.8–1.2)	1.2	0.9	1.3	1.1 ± 0.2 (0.9–1.3)
TYE	0.6	0.7	0.3	0.5 ± 0.2 (0.3–0.7)	0.7	0.9	0.9	0.8 ± 0.1 (0.7–0.9)
T LW	3.9*5.4	5.2 *7.1	4.3*4.5	4.4 ± 0.66 (3.9–5.2) * 5.6 ± 1.3 (4.5–7.1)	7.7*10. 9	5.2*6.4	6.7* 7.8	6.5 ± 1.2 (5.2–7.7)* 8.3 ± 2.3 (6.4–10.9)
FLL	6.6	5.1	5	5.6 ± 0.9 (5–6.6)	6.9	5.3	6.9	6.4 ± 0.9 (5.3–6.9)
HAL	7.2	7.3	6.8	7.1 ± 0.3 (6.8–7.3)	10.1	7.4	7.7	8.4 ± 1.5 (7.4–10.1)
FD I	0.4	0.5	0.5	0.5 ± 0.1 (0.4–0.5)	0.6	0.5	0.5	0.5 ± 0.1 (0.5–0.6)
FD II	0.5	0.6	0.6	0.6 ± 0.1 (0.5–0.6)	0.7	0.6	0.6	0.6 ± 0.1 (0.6–0.7)
FD III	0.7	0.7	0.6	0.7 ± 0.1 (0.6–0.7)	0.7	0.8	0.7	0.7 ± 0.1 (0.7–0.8)
FD IV	0.7	0.7	0.6	0.7 ± 0.1 (0.6–0.7)	0.8	0.7	0.7	0.7 ± 0.1 (0.7–0.8)
FW I	0.8	0.8	0.5	0.7 ± 0.2 (0.5–0.8)	1.1	0.8	0.6	0.8 ± 0.3 (0.6–1.1)
FW II	1	1	0.9	1.0 ± 0.1 (0.9–1)	1.1	1.2	0.7	1.0 ± 0.3 (0.7–1.2)
FW III	1.5	1.4	1.3	1.4 ± 0.1 (1.3–1.5)	1.8	1.1	1	1.3 ± 0.4 (1–1.8)
FW IV	1.5	0.3	1	0.9 ± 0.6 (0.3–1.5)	1.5	1.1	1	1.2 ± 0.3 (1–1.5)

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TABLE 1. (continued)

Voucher specimens	857 Holotype	858 Paratype	858 Paratype		858 Paratype	859 Paratype	859 Paratype	
Sex	Male	Male	Male		Female	Female	Female	
Morphometric characters				Average ± SD (Range)				Average ± SD (Range)
FL I	1.2	1.8	1.3	1.4 ± 0.3 (1.2–1.8)	2.3	1.5	1.8	1.9 ± 0.4 (1.5–2.3)
FL II	2.7	2.8	2.3	2.6 ± 0.2 (2.3–2.8)	3.5	3.1	3.1	3.2 ± 0.2 (3.1–3.5)
FL III	3.9	3.8	3.8	3.8± 0.0 (3.8–3.9)	4.7	4.3	4.5	2.5 ± 0.2 (4.3–4.7)
FL IV	2.8	3.2	3.0	3.0 ± 0.2 (2.8–3.2)	3.6	3.0	3.4	3.3 ± 0.3 (3.0–3.6)
TL	12.2	12.2	12	12.1 ± 0.1 (12–12.2)	16.2	12	14.9	14.4 ± 2.2 (12–16.2)
ShL	13.1	13.5	12.7	13.1 ± 0.4 (12.7–13.5)	16.9	12.8	15.5	15.1 ± 2.1 (12.8–16.9)
TW	2.5	2.1	2	2.2 ± 0.3 (2–2.5)	3.1	2.6	2.7	2.8 ± 0.3 (2.6–3.1)
FOL	9.3	9.4	9	9.2 ± 0.2 (9–9.4)	13.7	9.1	11.5	11.4 ± 2.3 (9.1–13.7)
TD I	0.4	0.5	0.5	0.5 ± 0.1 (0.4–0.5)	0.6	0.4	0.6	0.5 ± 0.1 (0.4–0.6)
TD II	0.5	0.6	0.6	0.6 ± 0.1 (0.5–0.6)	0.7	0.5	0.7	0.6 ± 0.1 (0.5–0.7)
TD III	0.5	0.6	0.6	0.6 ± 0.1 (0.5–0.6)	0.9	0.5	0.7	0.7 ± 0.2 (0.5–0.9)
TD IV	0.7	0.6	0.6	0.6 ± 0.1 (0.6–0.7)	0.9	0.6	0.8	0.8 ± 0.2 (0.6–0.9)
TD V	0.7	0.5	0.5	0.6 ± 0.1 (0.5–0.7)	0.9	0.6	0.7	0.7 ± 0.2 (0.6–0.9)
ToW I	0.9	0.9	0.4	0.7 ± 0.3 (0.4–0.9)	1.2	0.5	0.2	0.6 ± 0.5 (0.2–1.2)
ToW II	0.9	0.8	0.4	0.7 ± 0.3 (0.4–0.9)	1.1	0.5	0.6	0.7 ± 0.3 (0.5–1.1)
ToW III	0.9	0.9	0.5	0.8 ± 0.2 (0.5–0.9)	1.3	0.6	0.6	0.8 ± 0.4 (0.6–1.3)
ToW IV	0.9	1.2	0.6	0.9 ± 0.3 (0.6–1.2)	1.4	0.6	0.6	0.9 ± 0.5 (0.6–1.4)
ToW V	1	0.8	0.7	0.8 ± 0.2 (0.7–1)	1.4	0.6	0.8	0.9 ± 0.4 (0.6–1.4)
ToL I	1.7	1.7	1.5	1.6 ± 0.1 (1.5–1.7)	2.1	1.5	1.4	1.8 ± 0.5 (1.4–2.1)
ToL II	2.2	2.4	2	2.2 ± 0.2 (2–2.4)	3.5	2.6	2.9	3.0 ± 0.5 (2.6–3.5)
ToL III	3.1	2.9	2.7	2.9 ± 0.2 (2.7–3.1)	5.3	3.2	3.5	4.0 ± 1.1 (3.2–5.3)
ToL IV	5.1	4.9	4.6	4.8 ± 0.2 (4.6–5.1)	8.9	5.0	5.8	6.6 ± 2.1 (5.0–8.9)
ToL V	3.6	3.7	3.5	2.2 ± 0.3 (1.9–2.4)	5.0	3.1	4.3	4.1 ± 1.1 (4.3–5.0)
IMT	0.9	0.9	0.9	0.9 ± 0.0 (0.5–0.7)	1.5	0.7	1	1.1 ± 0.4 (0.7–1.5)
TFOL	16.3	16.3	15.8	16.1 ± 0.3 (15.8–16.3)	22.3	16.2	20.2	19.6 ± 3.1 (16.2–22.3)
MTFF	5.8	4.5	5.4	5.2 ± 0.7 (4.5–5.8)	7.4	5.8	6.2	6.5 ± 0.8 (5.8–7.4)
MTTF	5	3.8	4.9	4.6 ± 0.7 (3.8–5)	6.3	4.8	5.2	5.4 ± 0.8 (4.8–6.3)
TFTF	4.5	3.3	3.6	3.8 ± 0.6 (3.3–4.5)	4.6	3.6	3.7	4.0 ± 0.6 (3.6–4.6)
FFTF	4.2	3	3.2	3.5 ± 0.6 (3–4.2)	4.2	2.7	4.2	3.7 ± 0.9 (2.7–4.2)

Hind limbs long, touch when folded at right angles to body. Shank 5.2 times longer than wide (ShL = 13.1; TW = 2.5), longer than thigh length (TL = 12.2) and longer than foot length (FOL = 9.3). Heel to tip of fourth toe (TFOL = 16.3) 7.8 times longer than fourth toe length (ToL = 2.1). Relative toe length I<II<III≤V<IV (ToL I = 1.7; ToL II = 2.2, ToL III = 3.1; ToL IV = 5.1; ToL V = 3.6). Toes with well develop discs at tip (TD I = 0.4, TD II = 0.5, TD III = 0.5, TD IV = 0.7, TD V = 0.7; ToW I = 0.9, ToW II = 0.9, ToW III = 0.9, ToW IV = 0.9, ToW V = 1.0). Webbing moderate (MTTF = 5.0, MTFF = 5.8, TFTF = 4.5, FFTF = 4.2). First toe (ToL I = 1.7) 1.9 times the length of inner metatarsal tubercle (IMT = 0.9 mm). Outer metatarsal tubercle absent, supernumerary tubercles and tarsal tubercle present (toe: i = 1, ii = 1, iii = 2, iv = 3, v = 2).

Skin: Snout, between eyes, sides of head, fore limb, hind limb and dorsum shagreened. Tuberculate projections on dorsum, upper eye lids, snout, fore limbs and hind limbs. Tympanic region sparsely granular. Venter granular, larger granulation on belly reducing towards throat, flanks and thigh. Lower part of flanks granular. Upper flanks sparely granular. Dorso-lateral folds and macroglands absent.

Colour in life. Male–dorsum pale-yellow brown with small dark irregular lavender spots. Head with a grey band between eyes. Sides of head cream coloured. Dark brown lower margin of supratympanic fold. Vocal sac translucent with granular grey spots. Iris reddish brown, pale blue semi-circular skin fold at the posterior corner of eyes, translucent nictitating membrane, margins speckled with brown. Upper and lower lip cream coloured. Forelimbs cream coloured, shoulder flesh coloured. Venter uniform flesh coloured from chest to vent, throat pale buff, mottled with brown. Flanks straw yellow, interspersed with brown blotches, groin brown. Distinct dark brown horizontal band on inner and outer surface of thigh, inner surface of shank and inner surface of tarsus extending up to first three toes on upper surface. Forelimbs and hind limbs with faint cross bands. Webbing in feet brown.

Colour in preservative. Male–dorsum and head brown. Lateral parts of body light brown. Head with a flesh coloured band between eyes. Forelimb and hand cream coloured with faint cross bands. Irregular black spots throughout dorsum. Flanks dark brown, interspersed with cream blotches which reduce towards groin. Groin brown. Distinct dark brown horizontal band on inner and outer surface of thigh, inner surface of shank and inner surface of tarsus extended up to first three toes on upper surface. Forelimbs and hind limbs with faint cross bands. Webbing in feet brown. Faint cross bands across thigh, shank and tarsus. Venter cream coloured, with brown speckles through out. Throat mottled with brown. Palm and feet with brown speckles (Figure 3. a–f).

Female–head with tetragonal cap, ivory coloured. Lateral parts of body buff with black-brown blotches. Upper half of flanks mottled with brown and cream patches. Distinct dark brown horizontal band on inner and outer surface of thigh, inner surface of shank and inner surface of tarsus extended up to first three toes on upper surface. Venter cream coloured. Throat mottled with brown. Distinct brown cross bands across fore limbs and hind limbs.

Etymology. Named after the locality of holotype–Kakachi. Kakachi is treated as an invariable noun in apposition to the generic name.

Sexual dimorphism. Male–nuptial pad absent; possess a median subgular vocal sac with a pair of openings at the base of the lower jaw; iris colour dark brown. Female–larger than the male (SVL: male–24.9 ± 0.8 mm, n = 3 and female–29.0 ± 4.9 mm, n = 3); ovary large, with creamy white eggs; head with a tetragonal cap like patch, pale pink to grey, iris colour reddish to golden brown. Distinct from that of male, in having dorsum dark grey, interspersed with straw yellow and black marbling throughout. Head with a distinct pale grey tetragonal patch. Sides of head cream-ivory with three dark brown stripes below the eyes till upper lip. Lower margin of supratympanic fold dark brown (Figure 2.b).

Variation (Figure 4. a–c): Details of the morphometric variations observed in 6 individuals is provided in Table 1. Morphologically, the dorsum colouration among males varied from dark brown to buff. One male individual (ZSI/WGRC/V/A 858, Figure 4. c) was with coffee brown dorsum, ivory patches on lower part of tympanic region, loreal region, shoulder, knee and heel. Ivory spots on upper part of flank, lower dorsum, dorsal part of hand and foot. Variations also included distinct cross bands on both forelimbs and hind limbs, straw yellow colouration on the lower dorsum and overall dark reddish colouration on anterior dorsum. In females, the patch on head was uniform. Among immature females, the dorsum colour varied from pale brown to dark brown similar to that of males.

Comparisons. *Raorchestes kakachi* **sp. nov.** can be confused with *R. flaviventris* (Boulenger) and *R. kaikatti* (Biju & Bossuyt) by its overall morphology. However, *R. flaviventris* differs from *R. kakachi* **sp. nov.** in the following characters: tongue with lingual papilla vs. absent, tympanum distinct vs. indistinct, thigh length equal to shank length (ThL = 13.5 mm, ShL = 13.5 mm) vs. thigh length shorter than shank length (male, ThL = 12.1 ± 0.2 mm,

ShL = 13.1 ± 0.4 mm, n = 3; female, ThL = 14.4 ± 2.2 mm, ShL = 15.1 ± 2.1mm, n = 3), webbing between fingers rudimentary vs. absent, dermal fringe on fingers absent vs. present, ventral side grey and dark-brown vermiculated throughout vs. ventral side grey with brown mottling reducing towards vent, forelimbs, tibia and foot, dorsal and posterior part of thigh brown with cream dots vs. distinct dark brown horizontal band on inner and outer surface of thigh, inner surface of shank and inner surface of tarsus extended up to first three toes on upper surface. *R. kaikatti* differs from *R. kakachi* **sp. nov.** in the following characters: head length equal to head width (male, HW = 9.6 ± 0.4, HL = 9.5 ± 0.4 mm) vs. head wider than long (male, HW = 9.4 ± 0.4, HL = 8.1 ± 0.5 mm; female, HW = 11.16 ± 2, HL = 9.3 ± 1.5 mm), thigh length equal to shank length (male, ThL = 12.5 ± 0.9 mm, ShL = 12.3 ± 0.8 mm, n = 5) vs. thigh length shorter than shank length (male, ThL = 12.1 ± 0.2 mm, ShL = 13.1 ± 0.4 mm, n = 3; female, ThL = 14.4 ± 2.2 mm, ShL = 15.1 ± 2.1 mm, n = 3), ventral side greyish white vs. brown mottling, posterior part of thighs and groin brown vs. distinct dark brown horizontal band on anterior and posterior parts of thigh, inner surface of shank and inner surface of tarsus extended up to first three toes on upper surface.

The comparison provided above for *R. kaikatti* is based on the examination of the name bearing types at BNHS but that of *R. flaviventris* are based on original descriptions provided in Bossuyt and Dubois (2001) and Biju and Bossuyt (2009) since the specimen itself is located outside India. Details of name bearing types examined by authors has been provided in Appendix I and major opposing suite of morphological characters of all other species in *Raorchestes* found in the Western Ghats except *R. flaviventris* and *R. kaikatti* are provided in Appendix II.

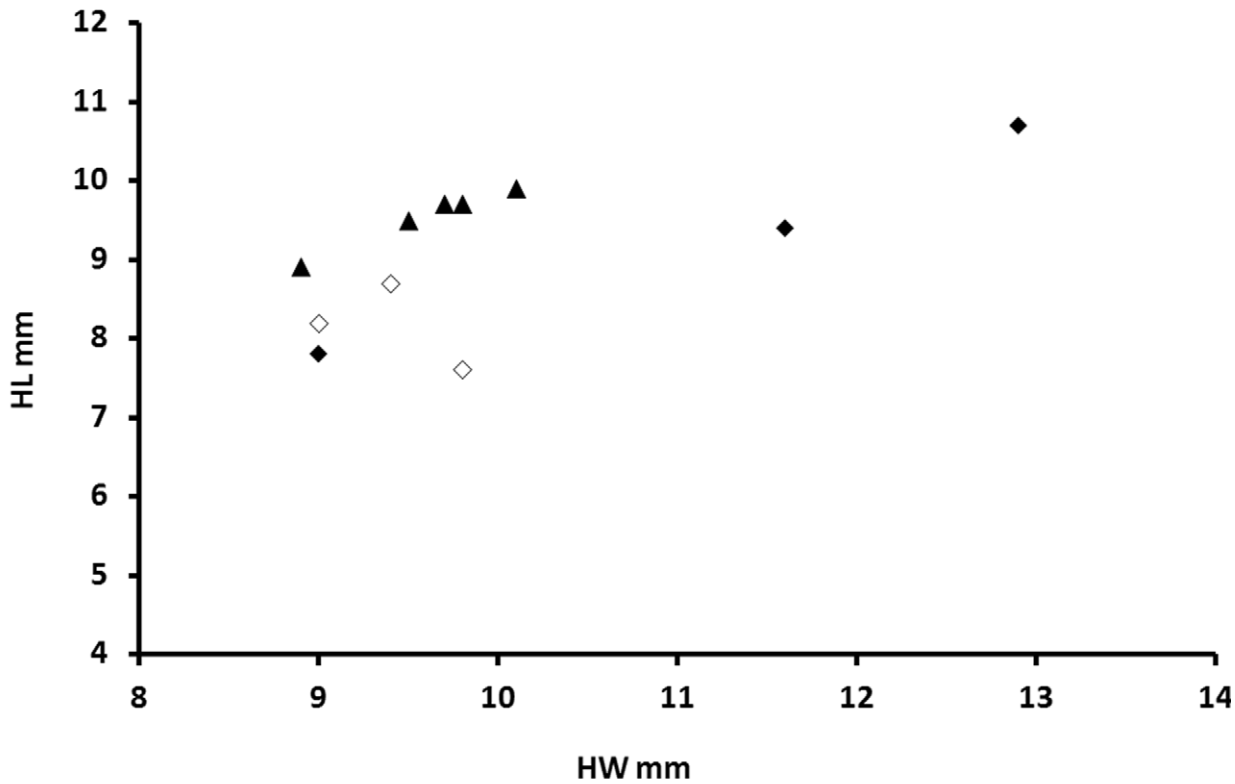

FIGURE 5. Morphometric distinction of two *Raorchestes* species. The head width has been plotted with head length. Closed triangle indicates *Raorchestes kaikatti* (five males: BNHS 4557, 4465, 4417, 4466 and SDB 541, Type locality: Kaikatti) and open diamond indicates *Raorchestes kakachi* **sp. nov.** (three males, ZSI/WGRC/V/A 857,858). Closed diamonds indicates three females (ZSI/WGRC/V/A 858, 859).

Ecology and natural history notes. Two individuals (ZSI/WGRC/V/A/858: one male and one female) of this species were first collected on bushes up to 2 m height along streams on riparian vegetation next to the road in Kakachi by KSS, NAA, TG and RG on 24th January 2011 at 20:30 hrs. Subsequently, on 24th May 2011, a pair (ZSI/WGRC/V/A/859: one male and one female) in axillary amplexus was observed and collected on forest floor in the same location by KSS and PS from 20:49 hrs to 21:30 hrs. The amplecting pair was carried to laboratory where they were observed for egg laying in a terrestrial enclosure. The amplecting pair dismounted and the female laid six eggs and a few more eggs were visible in the abdomen. The eggs were non-pigmented with jelly mass and measured (2.2 mm, n = 3). However, we did not make any further observation on egg development.

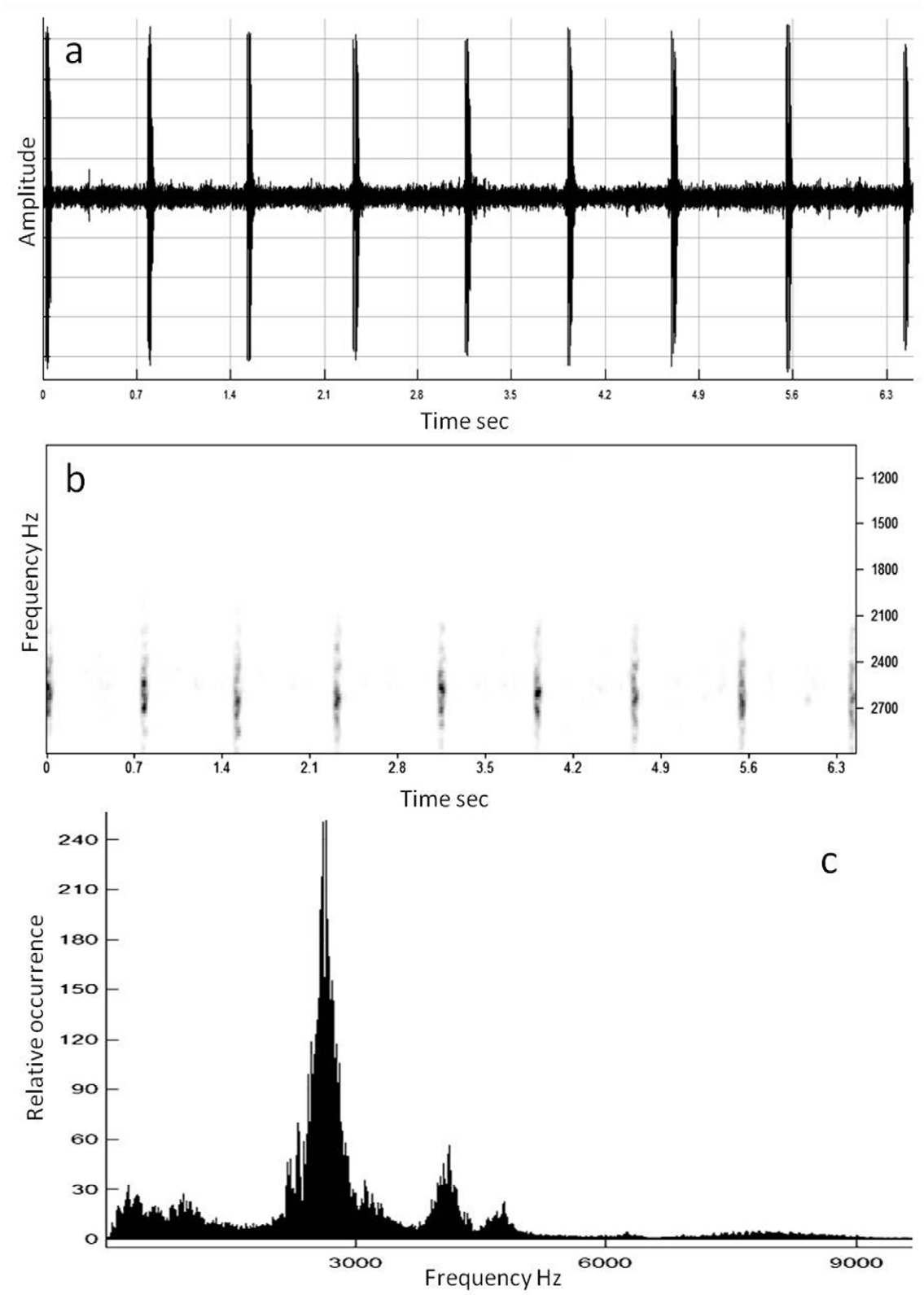

FIGURE 6. Spectrogram of an advertisement call of *Raorchestes kakachi* **sp. nov.** (ZSI/WGRC/V/A/ 857) measuring 6.54 sec in duration recorded from Kakachi on 23rd June 2011 at 19:08 hrs. Dominant frequency of this call 2625 Hz, pulse duration 0.05 sec, pulses 9, pulse rate 1.77 sec^{-1}. a. Amplitude; b. Spectrogram and c. Band width.

Between May and June 2011, three individuals were observed and photographed (not collected) to be foraging in the canopy of *Cullenia exarillata* (32 m) and *Diospyros* sp. (30 m) trees between 19:00–21:15 hrs in forests

around Kakachi and Upper Kodayar. The canopy was accessed at night using modified single rope technique (Perry 1978). Two calling males were collected from 2 m high vegetation along a stream in Kakachi on 24th June 2011. The calls of these two individuals were recorded for analysis. An amplecting pair was observed the next day (25th June 2011) on the same location on roadside tree at 4 m height from 19:23 hrs–21:30 hrs but did not lay eggs. In another location, a male and female were observed in the sub-canopy (ca.15 m) of roadside trees. A male *Ramanella montana* was seen mounting with a female of *R. kakachi* **sp. nov.** for about 5 min after which, the pair disengaged in the same location.

A long term monitoring study by KSS in KMTR using automated sound recorders have recorded the species to be vocalizing in the canopy and on the ground. The vocalization begins at about 18:30 hrs and the number of individuals and their vocalizing intensity reaches a peak between 18:00–20:30 hrs. Initially the calls were heard from the canopy and the frogs were detected on the ground at about 19:00 hrs.

Though many individuals of this frog were observed in the canopy in both Kakachi and Upper Kodayar, the individuals described in this paper were collected on ground and on natural vegetation in estate, either before the frog went up into the canopy or after they descended from there.

Advertisement call analysis. Calls were recorded using Nikon D90 DSLR camera within 20–30 cm from calling males at night (19:00–21:30 hrs). The air temperature and humidity at collection time were (23°C and 86% RH, measured using Kestrel 3500®, data logger). Eight calls from two calling males were analyzed using Audacity Ver.1.3 (Beta) and SIGVIEW 32 Ver.2.3.0. Call terminology was based on Kok and Kalamandeen (2008). Each call had 6–9 pulses (*treek, treek, treek,*…pulses). Average dominant frequency was 2637.25 ± 14.1 Hz (range: 2630–2651 Hz), Call duration was 4.98 ± 0.8 sec (range: 3.4–6.5 sec), inter call duration was 1.46 ± 0.7 sec (range: 0.6–2.2 sec), pulse duration was 0.74 ± 0.07 sec (0.6–0.9 sec), pulse period was 0.05 ± 0.006 sec (range: 0.04–0.07 sec) and pulse rate was 1.54 ± 0.1 sec^{-1} (range: 1.37–1.75 sec^{-1}). Figure 6.a–c illustrates the amplitude, call spectrum and peak frequency of a single call (ZSI/WGRC/V/A 857). A short video clip of the frog vocalizing can be found on Amphibia web, 2012 (http://tinyurl.com/raorchestes-kakachi).

Discussion

Large reserves like the Kalakad Mundanthurai Tiger Reserve supports a rich diversity of flora and fauna showing high levels of endemism (Johnsingh 2001). The reserve has some of the largest tracts of primary evergreen forests in the Western Ghats. It also forms a unique and important component of the Agasthyamalai region wherein studies in the recent past have recorded several new *Raorchestes* species (Anil *et al.* 2011). The rediscovery of *Melanobatrachus indicus*, *Duttaphrynus beddomei* (Vasudevan *et al.* 2001) and *Raorchestes chalazodes* (Ganesan *et al.* 2011) from these forests significantly enhance the importance of KMTR in supporting and conserving amphibian diversity. The species discovery pattern in the Western Ghats has been exponential in the past decade (Aravind *et al.* 2005; Aravind & Gururaja 2011), resulting in discovery/re-discovery of some exceptionally charismatic and unique species (Biju *et al.* 2010; Anil *et al*. 2011; Biju *et al.* 2011; Ganesan *et al.* 2011). However, studies on amphibian ecology, population dynamics and evolution are limited and thus requiring further systematic studies in these areas (Aravind & Gururaja 2011).

Acknowledgements

We thank the PCCF, Field director, Deputy Director, Range forest officers and field staff of Tamil Nadu Forest department for permits and field support. Dr S.D. Biju, Delhi University, taught KSS techniques in field surveys, amphibian identification and specimen preservation; he has been a constant guiding force by provided encouragement and timely suggestions and we are grateful to him. The field surveys were supported by the *Future conservationist* award from the *Conservation Leadership Program* (CLP) and *Save Our Species* (SOS) *Campaign* to KSS and we are thankful for the financial support. We thank Drs. T. Ganesh, R. Ganesan and M. Soubadra Devy (ATREE) for encouragement, support and providing comments on the manuscript.

We thank Dr. Dinesh K.P. (ZSI) for specimen verification. Critical comments from Drs. Karthick Balasubramanian (CES, IISc) and Dinesh K.P. greatly improved the manuscript. We are thankful to both of them. Shri. C.

Radhakrishnan and Dr. Md. Jafer Palot of ZSI extended the museum facilities in Calicut and Dr. Asad Rahmani, Mr. Sameer and Mr. Nayak provided access to specimens in BNHS. Dr. Priyadarshanan Dharmarajan (ATREE) extended microscope facilities; Seena (ATREE) helped KSS in Calicut; Preeti, S. interned with ATREE and took part in field surveys. Prashanth M.B. helped in preparation of the map. Johnson and Tamizalagan (Chian) provided field support during the surveys. Mathivanan, M. and Allwin, J. provided logistical support. Tamil Nadu Electricity board provided accommodation. We are thankful to all of them. We thank two anonymous reviewers and Prof. Miguel Vences for constructive comments on the manuscript.

References

AmphibiaWeb (2012) Information on amphibian biology and conservation. Berkeley, California. Available from: http://www.amphibiaweb.org/cgi-bin/amphib_query?query_src=aw_lists_soundInclude_&special=call&genus=Raorchestes&species=kakachi (Accessed 8 June 2012).

Anil, Z., Dinesh, K.P., Kunhikrishnan, E., Das, S., Raju, V.R., Radhakrishnan, C., Palot, M.J. & Kalesh, S. (2011) Nine new species of frogs of the genus *Raorchestes* (Amphibia: Anura: Rhacophoridae) from southern Western Ghats, India. *Biosystematica*, 5, 21–48.

Aravind, N.A., Ganeshaiah, K.N. & Uma Shaanker, R. (2004) Croak, croak, croak: Are there more frogs to be discovered in Western Ghats? *Current Science*, 86, 1471–1472

Aravind, N.A. & Gururaja, K.V. (2011) *Theme paper on the amphibians of the Western Ghats*. Report Submitted to Western Ghats Ecology Expert Panel, Ministry of Environment and Forests (MoEF), Govt. of India, 29pp.

Biju, S.D. & Bossuyt, F. (2009) Systematics and phylogeny of *Philautus* Gistel, 1848 (Anura, Rhacophoridae) in the Western Ghats of India, with descriptions of 12 new species. *Zoological Journal of the Linnaean Society*, 155, 374–444.

Biju, S.D., Shouche, Y., Dubois, A., Dutta, S.K. & Bossuyt, F. (2010) A ground-dwelling rhacophorid frog from the highest mountain peak of the Western Ghats of India. *Current Science*, 98, 119–1125.

Biju, S.D., Bocxlaer, I.V., Mahony, S., Dinesh, K.P., Radhakrishnan, C., Zachariah, A., Giri, V. & Bossuyt, F. (2011) A taxonomic review of the Night Frog genus *Nyctibatrachus* Boulenger, 1882 in the Western Ghats, India (Anura: Nyctibatrachidae) with description of twelve new species. *Zootaxa*, 3029, 1–96.

Bossuyt, F. & Dubois, A. (2001) A review of the frog genus *Philautus* Gistel, 1848 (Amphibia, Anura, Ranidae, Rhacophorinae), *Zeylanica*, 6, 1–112.

Daniel, J.C. (1963) Field guide to the amphibians of western India, Part I. *Journal of the Bombay Natural History Society*, 60, 415–438.

Ganesh, T., Ganesan, R., Devy, M.S., Davidar, P. & Bawa, K.S. (1996) An assessment of plant biodiversity at a mid elevation evergreen forest of Kalakad Mundanthurai Tiger Reserve, Western Ghats, India. *Current Science*, 71, 379–392.

Ganesan, R., Seshadri, K.S. & Biju, S.D. (2011) Lost! Amphibians of India. Available from http://www.lostspeciesindia.org/LAI2/new1_rediscovered.php (accessed 19th July, 2011)

Gururaja, K.V., Dinesh, K.P., Palot, M.J., Radhakrishnan, C. & Ramachandra, T.V. (2007) A new species of *Philautus* Gistel (Amphibia: Anura: Rhacophoridae) from southern Western Ghats, India. *Zootaxa*, 1621, 1–16.

Johnsingh, A.J.T. (2001) The Kalakad–Mundanthurai Tiger Reserve: A global heritage of biological diversity. *Current Science*, 80, 378–388.

Kok, P.J.R. & Kalamandeen, M. (2008) *Introduction to the taxonomy of the amphibians of Kaieteur National park*. Guyana. Belgian Development Corporation, 278pp.

Li, J.T., Rao, D.Q., Murphy, R.W. & Zhang, Y.P. (2011) The systematic status of Rhacophorid frogs. *Asian Herpetological Research*, 2, 1–11.

Perry, D.R. (1978) A method of access into the crowns of emergent and canopy trees. *Biotropica*, 10, 155–157.

Vasudevan, K., Kumar, A. & Chellam, R. (2001) Structure and composition of rainforest floor amphibian communities in Kalakad Mundanthurai Tiger Reserve. *Current Science*, 80, 406–412.

APPENDIX I.

Details of type specimens examined by KSS and KVG are *R. agasthyaensis* ZSI/WGRC V/A/830, ZSI/WGRC V/A/831; *R. amboli* BNHS 4398; *R. anili* BNHS 4535, BNHS 4276–9, BNHS 4585, BNHS 4404–5; *R. akroparallagi* BNHS 4387; *R. bobingeri* BNHS 4272; *R. bombayensis* ZSIC V/A 18288; *R. chlorosomma* BNHS 4425; *R. chromasynchysi* BNHS 4433; *R. chotta* BNHS 4427; *R. coonoorensis* BNHS 4444; *R. crustai* ZSI/WGRC V/A/847, ZSI/WGRC V/A/848; *R. dubois* BNHS 4251; *R. graminirupes* BNHS 4264–6, BNHS 4587; *R. griet* BNHS 4457; *R. jayarami* BNHS 4459; *R. johnceei* ZSI/WGRC V/A/845, ZSI/WGRC V/A/846; *R. kadalarensis* ZSI/WGRC V/A/832, ZSI/WGRC V/A/833; *R. kani* BNHS 4467; *R. kaikatti* BNHS 4557, 4465, 4417, 4466; *R. luteolus* BNHS 4191; *R. manohari* ZSI/WGRC V/A/828, ZSI/WGRC V/A/829A, ZSI/WGRC V/A/829B; *R. marki* BNHS 4537; *R. munnarensis* BNHS 4481; *R. nerostagona* BNHS 4244; *R.*

ochlandrae ZSI/WGRC V/A/632–7; *R. ponmudi* BNHS 4257; *R. ravii* ZSI/WGRC V/A/840, ZSI/WGRC V/A/841; *R. resplendens* ZSI/SRC VA 1106, BNHS 4087; *R. signatus* BNHS 4487; *R. sushili* BNHS 4544; *R. theuerkaufi* ZSI/WGRC V/A/836, ZSI/WGRC V/A/837A, ZSI/WGRC V/A/837B; *R. thodai* ZSI/WGRC V/A/838, ZSI/WGRC V/A/839; *R. tinniens* BNHS 4496; *R. travancorics* BNHS 4592; *R. tuberohumerus* BNHS 4194; *R. uthamani* ZSI/WGRC V/A/834, ZSI/WGRC V/A/835.

APPENDIX II

List of congeners compared (37 species of *Raorchestes*, except *R. flaviventris* and *R. kaikatti* which are provided in the comparison section of the manuscript) with opposing suite of characters to *R. kakachi* **sp. nov.**

Speices	Opposing characters
R. agasthyaensis Anil, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot & Kalesh	Snout pointed in dorsal view, loreal region acutely flat, tympanum distinct, dark brown colour on canthus rostralis, loreal region and region of supra tympanic fold, forelimb sub-equal to hand length, dermal fringe in finger absent, dorsum with distinct 'Ä' brown mark, iris golden brown, shank sub-equal to thigh length, webbing in feet reduced.
R. anili (Biju & Bossuyt)	Snout pointed in dorsal view, snout length longer than eye diameter, tympanum distinct, canthus rostralis sharp, flanks and groins deep brown with light-grey blotches, anterior surface of thighs and inner side of shanks with light chocolate-brown blotches, alternated with variable sized grey patches, webbing in feet reduced, ventral side grey with brown speckles.
R. akroparallagi (Biju & Bossuyt)	Size very small (male: 19.2–22.5 mm, female: 26–27.3 mm), overall green coloration but with varying morphs of brown to orange, light brown loreal and tympanic region, supratympanic fold indistinct, nuptial pad present, webbing in feet reduced.
R. beddomii (Günther)	Size very small (male: 15.6–23.3 mm, female: 22.9–29.9 mm), dorsum coloration, dorsal side of fore limbs, hind limbs, and loreal and tympanic regions uniformly green, canthus rostralis indistinct, supratympanic fold indistinct, fingers without lateral dermal fringe, webbing in feet reduced, flanks and groin with blue colouration interspersed with yellow.
R. bobingeri (Biju & Bossuyt)	Snout length shorter than eye diameter, canthus rostralis indistinct, loreal region acutely flat, nuptial pad present, webbing in feet complete, body flat, dorsum uniformly granular and green, yellowish upper arm, anterior and posterior surface of thighs light red to dark fleshy red in life.
R. bombayensis (Annandale)	Canthus rostralis sharp, presence of papilla on tongue, distinct nuptial pad, webbing reduced, supernumerary tubercles on feet absent, groin and lateral side brown marbled with creamy white blotches.
R. chalazodes (Günther)	Dorsum, dorsal side of limbs, tympanic region and sides of head uniform green, flanks and groin ashy blue occasionally with few deep blue spots, snout rounded in dorsal view, tympanum and supratympanic fold distinct, supernumerary tubercles on both limbs prominent, ventral sides of lower arm and tarsus prominently granular, iris with golden yellow filling, breaking into four with horizontal and vertical divisions.
R. charius (Rao)	Snout rounded in dorsal view, interorbital space convex, dorsum with small horny spinules, groin and posterior part of thighs uniform brownish black with large yellow blotches, triangular grey snout, webbing in feet whitish.
R. chlorosomma (Biju & Bossuyt)	Tympanum distinct, webbing rudimentary (just above third subarticular tubercle on IV toe), supernumerary tubercles on hand and foot absent, skin on snout, between eyes and upper eyelids smooth, femur without brown band, iris greyish green, groin light grey to brown, vermiculated with black patches of variable size.
R. chotta (Biju & Bossuyt)	Very small size (male: 16.0–17.2 mm, female: 20.5 mm), snout sharply pointed in dorsal view, loreal region acutely concave, canthus rostralis sharp, supratympanic fold indistinct, webbing on feet rudimentary, prominent tubercles on upper eyelid, dark spot on either side of flank near vent, posterior surface of shanks vermiculated.
R. chromasynchysi (Biju & Bossuyt)	Snout pointed in dorsal view, canthus rostralis sharp, tympanum distinct, lingual papilla present on tongue, skin on dorsum smooth, anterior and posterior thigh dark brown and yellow blotches on anterior thigh.

continued next page

APPENDIX II. (continued)

Speices	Opposing characters
R. coonoorensis (Biju & Bossuyt)	Snout longer than eye length, tympanum distinct, dorsum with spinular projections, second subarticular tubercle on third finger double, webbing reduced, dorsum reddish brown colouration, posterior surface of thighs dark brown with variable grey patches.
R. crustai Anil, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot & Kalesh	Snout pointed, throat with black spots, belly glandular, lingual papilla present, tympanum distinct, canthus rostralis sharp, dorsum granular, dark brown bands on anterior and posterior thigh absent. According to Anil *et al*. (2011), webbing one fifth in hand between II and III finger. However, on type examination, no webbing found in hand.
R. dubois (Biju & Bossuyt)	Snout pointed in dorsal view, loreal region acutely concave, tympanum distinct, supratympanic fold distinct, dorsum and lateral side prominently granular, webbing in feet rudimentary, thigh and shank coffee brown and intermingled with light-grey and yellow blotches and ventral side of forelimb coarsely granular.
R. glandulosus (Jerdon)	Snout pointed in dorsal view, prominently granular lateral abdominal area, uniform green dorsum with scattered brown spots, tympanum distinct, webbing at the base of fingers rudimentary, dorsal surface of forearm and loreal region yellow, anterior and posterior surface of thighs yellow.
R. graminirupes (Biju & Bossuyt)	Snout pointed in dorsal view, shorter than diameter of the eye, canthus rostralis sharp, loreal region acutely concave, dorsum shagreened with a few granular projections, a horny ridge from snout to middle of the dorsum passing between the eyes and hindlimbs long, posterior of thighs chocolate brown vermiculated with bluish green, webbing in feet reduced, belly vermiculated with brown specks.
R. griet (Bossuyt)	Snout pointed in dorsal view, tympanum distinct, skin of dorsum with small horny spinules, horny ridges between the eyes, arranged in a triangle directed posteriorly, flank and groin light brown with minute white marbling, posterior part of thighs brown with minute grey spots, webbing in feet rudimentary.
R. jayarami (Biju & Bossuyt)	Dorsum, upper arm and limbs uniform green, snout pointed in dorsal view, supratympanic fold indistinct, nuptial pad weakly present, subarticular tubercles in finger IV-double, lateral region and margin of thigh white, often with bluish black spots, granulation on the ventral side elongated.
R. johnceei Anil, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot & Kalesh	Size moderate (male: 30.6–33.0 mm), snout pointed in dorsal view, tympanum distinct, loreal region acutely flat, loreal region and region of supra tympanic fold dark brown, dorsum bicoloured with two lateral orange yellow stripes with a middle black stripe from back of orbit to vent.
R. kadalarensis Anil, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot & Kalesh	Very small sized (male: 17.2–21.9 mm), snout acutely pointed, loreal region acutely flat, canthus rostralis and upper region of supra tympanic fold dark brown, hind region of the fore arm with brown patch, dorsum with hour-glass shaped mark in occipital region, lower end of the hour-glass shaped mark extending as two lateral brown stripes to groin region, webbing in feet moderate.
R. luteolus (Kuramoto & Joshy)	Snout pointed, elongated body, yellow dorsum with faint brown lines, loreal and tympanic regions golden yellow or yellowish brown, distinct blue colour on the outer margin of eye. Dorsum and upper surface of limbs finely granulated. Venter and vocal sac uniform pale yellow.
R. manohari Anil, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot & Kalesh	Very small size (male: 16.8–17.6), dorsum orange with black spots, snout obtuse in dorsal view, loreal region flat, dorsum uniformly granular and yellowish glandular, dark brown spots on the upper half, iris silvery blue with fine black reticulations.
R. marki (Biju & Bossuyt)	Snout pointed in dorsal view and longer than the horizontal diameter of the eye, canthus rostralis sharp, loreal region acutely concave, tympanum distinct, supratympanic fold distinct, tongue with lingual papilla, horny ridges between the eyes, arranged in a triangle directed posteriorly, flank and groin light grey with minute white marbling, rudimentary webbing in feet.
R. munnarensis (Biju & Bossuyt)	Size moderate (male: 27.8–32.6 mm), snout rounded in dorsal view, loreal region obtusely concave, tongue with a median lingual papilla, tympanum and supratympanic fold distinct, nuptial pad present on first finger, lower jaw golden yellow, groin region light brownish yellow and marbled with brown, ventral colouration light black.

continued next page

APPENDIX II. (continued)

Speices	Opposing characters
R. nerostagona (Biju & Bossuyt)	Size moderate (male: 30.1–34.0 mm), snout rounded in dorsal view, canthus rostralis sharp, loreal region obtusely concave, tympanum and supratympanic fold distinct, tongue with lingual papilla, outer side of forelimb and hind limb with dermal fringe, moderate webbing in hand, shortly spinular projections on upper eyelids, tongue with a pointed papilla, greenish to brown dorsum.
R. ochlandrae (Gururaja, Dinesh, Palot, Radhakrishnan & Ramachandra)	Body elongate and squat, head arched, snout rounded in dorsal and ventral views, pupil with striking golden yellow dentition like marks, belly granular, under parts of forearm and thigh granular, vocal sac un-pigmented, fleshy brown to cream yellow dorsum, two distinct golden yellow lateral bands bordered by dark brown from upper eyelid to the posterior part of flanks.
R. ponmudi (Biju & Bossuyt)	Size large (male: 32.2–38.7mm, female: 43.1 mm), robust body, canthus rostralis sharp, loreal region obtusely concave, tympanum distinct, tongue with lingual papilla, subarticular tubercles prominent, IV1 double, posterior surface of shanks banded, dorsum with 'X' mark, posterior surface of tibia vermiculated.
R. ravii Anil, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot & Kalesh	Snout sharply pointed, dark brown colouration on upper part of nostril, canthus rostralis and region of supra tympanic fold, dorsum with a faint 'H' brown mark, webbing in feet rudimentary**.**
R. resplendens Biju, Shouche, Dubois, Dutta & Bossuyt	Snout rounded, canthus rostralis indistinct, loreal region vertically acute, tympanum distinct, eyes bright red, hind limbs extremely short, webbing in feet rudimentary, dorsum with glandular swellings, deep brick red dorsum with black filling irregular furrows, ground dwelling.
R. signatus (Boulenger)	Snout pointed, tongue with a lingual papilla, flanks and groin flesh white or light-reddish brown, flanks without markings and glandular, some individuals with radiating golden stripes in eye.
R. sushili (Biju & Bossuyt)	Canthus rostralis rounded to sharp, loreal region acute to obtuse, tympanum distinct, anterior part of dorsum shagreened, webbing reduced, back with a dark-brown inverted 'V' shaped marking.
R. theuerkaufi Anil, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot & Kalesh	Snout sharply pointed, canthus rostralis angular, dark brown colour on upper part of the nostril, canthus rostralis, loreal region and region of supra tympanic fold, brick red with irregular black markings on dorsum and limbs, dorsum highly glandular, brick red in colour without any specific pattern, iris copper coloured.
R. thodai Anil, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot & Kalesh	Snout sharply pointed and protruding beyond mouth, tympanum distinct, loreal region flat, glandular dorsum, dorsum golden yellow with a pair of faint thin dorso-lateral brown bands.
R. tinniens (Jerdon)	Very small size (male: 18.4–21.6 mm, female: 25.0–28.0 mm), snout rounded, tongue with lingual papilla, lateral side coarsely granular, flanks and groin dark-brownish black, first two fingers yellow in life.
R. travancoricus (Boulenger)	Canthus rostralis indistinct, supratympanic fold indistinct, webbing in feet rudimentary, dorsum yellow colouration with black streaks, loreal and tympanic regions light brown with a prominent streak on each side of the snout.
R. tuberohumerus (Kuramoto & Joshy)	Very small size (male: 17.7–19.0 mm), head as wide as long, shank shorter than thigh, groin and anterior surfaces of thighs dark brown with yellow blotches, nuptial pad present, humerus bone prominently protruding anterio-ventrally.
R. uthamani Anil, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot & Kalesh	Very small size (female: 19.4–20.1 mm), lingual papilla present, snout rounded, tympanum distinct, pinkish-yellow dorsum, dorsum uniform glandular, disc tips brown colour, iris silvery white with thin black reticulations, webbing less developed.