

Redescription of *Rhacophorus chuyangsinensis* Orlov, Nguyen & Ho, 2008 (Anura: Rhacophoridae) based on new collections from new south Vietnamese provincial records: Lam Dong and Khanh Hoa

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Rhacophorus chuyangsinensis Orlov, Nguyen, & Ho, 2008, which was described based on a type series consisting of three adult males only, is re-described based on extensive new collections from southern Vietnam. Our new records consist of 17 individuals, among them the first two females to become known. In our extended description we deal for the first time with adult female morphology and with so far unknown colour pattern in life. Our new records of *R. chuyangsinensis* for Lam Dong and Khanh Hoa provinces expand the originally known distribution of this species about 81 km to the Southeast of its type locality (Chu Yang Sin National Park, Dak Lak Province, southern Vietnam, 1,600 m a.s.l.). We further add additional information on the natural history of *R. chuyangsinensis*, which inhabits rocky forest streams at altitudes between 1,320–1,600 m a.s.l.

Keywords: Anura: Rhacophoridae: *Rhacophorus chuyangsinensis* - morphology, taxonomy, new distribution data, natural history - Vietnam: Lang Bian Plateau.

INTRODUCTION

Rhacophorus chuyangsinensis was recently described by Orlov *et al.* (2008) based on a type series consisting of three adult males from Kon Tum Plateau, Vietnam. This species was so far known only from the type locality in Chu Yang Sin National Park, Dak Lak Province, Central Vietnam (Nguyen *et al.* 2009). During recent

herpetological surveys in the Southeast of the type locality, viz. in Bi Doup-Nui Ba National Park (Lam Dong Province) and Hon Ba Nature Reserve (Khanh Hoa Province), southern Vietnam (Fig. 1), extensive collections of this species took place, among them the first females known to science and a previously unknown colour pattern. Therefore, we herein provide an extended description of *R. chuyangsinensis* based on our new records from southern Vietnam.

MATERIAL AND METHODS

Specimens were collected in the evergreen forests of Bi Doup-Nui Ba National Park, (Lac Duong District, Lam Dong Province: 12°00'–12°52'N, 108°17'–108°42'E; 600–2000 m a.s.l.) between March and June 2010 (periods of 18–25 March, 26–30 April, 20–24 May, and 07–19 June) and of Hon Ba Nature Reserve (Dien Khanh District, Khanh Hoa Province: 12°02'–12°15'N, 108°57'–109°05'E; approximate 1600 m a.s.l) in September 2010 (period of 10–15 September).

Frogs were collected by hand from 19:00–23:00. After taking photographs, specimens were anaesthetized, fixed in 80% ethanol for few hours, and subsequently preserved in 70% ethanol. Specimens finally were deposited in the collections of the University of Science, Ho Chi Minh City, Vietnam (US); the Vietnam National Museum of Nature (VNMN), Ha Noi, Vietnam and the Zoologisches Forschungsmuseum Alexander Koenig (ZFMK), Bonn, Germany. Adults (♂♂): UNS 00500–00508, VNMN 965, ZFMK91517–91522; Adults (♀♀): UNS 00509, VNMN 969.

Measurements were taken with a digital caliper to the nearest 0.1 mm: SVL (snout-vent length): distance between tip of snout and vent; HW (head width): distance between angles of jaws; HL (head length): distance between angle of jaws and snout tip; SNL (snout length): distance between anterior corner of eye where the upper and lower lids meet together and the tip of snout; NS (distance between nostril and snout tip): distance between middle of nostril and tip of snout; IN (internarial distance): distance between nostrils; IO (interorbital distance): least distance between upper eyelids; UEW (upper eyelid width): greatest width of upper eyelid; ED (eye diameter): horizontal width of eye at its widest point; DFE (distance between front of eyes): distance between anterior points of eyes; DBE (distance between back of eyes): distance between posterior points of eyes; TD (tympanum diameter): horizontal width of tympanum at its widest point; E-T (distance between eye and tympanum): distance between posteriormost point of eye and anteriormost edge of tympanum; distance between axilla and groin (A-G): distance between posterior edge of forelimb at its insertion to body and anterior edge of hind limb at its insertion to body; length of upper arm (UAL): distance between axilla and elbow; length of lower arm (LAL): distance between elbow and posteriormost margin of inner palmar tubercle; length of hand (HAL): distance between proximal edge of palmar tubercle and tip of the third finger; length of thigh (THL): distance between center of knee and center of hindlimb insertion; length of tibia (TBL): distance between center of knee and center of heel; foot length (FOL): distance between base of inner metatarsal tubercle and tip of the fourth toe; tarsus-foot length (TFOL): distance between base of tarsus and tip of the fourth toe; length of finger or toe: distance between posterior margin of most proximal subarticular tubercle or crease of articulation and tip of finger or toe; first finger length



FIG. 1

Map showing the distribution of *Rhacophorus chuyangsinensis* in Vietnam (blue: type locality; red: new records from Lam Dong and Khanh Hoa provinces, Vietnam).

(FFL); first toe length (FTL); width of disc on finger or toe: greatest width of terminal disc on finger or toe; third finger's disc width (TFPW); length of inner metatarsal tubercle (IMTL); length of nuptial pad (NPL); formula of webbing followed Glaw and Vences (2007). The sex of the specimens was superficially determined based on the

absence or presence of male nuptial pads; female sex was proven by the examination of the reproductive organs after dissection. Morphological identification and comparisons followed the original description (Orlov *et al.* 2008).

RESULTS

REDESCRIPTION OF *RHACOPHORUS CHUYANGSINENSIS* ORLOV, NGUYEN & HO, 2008

In the following we provide a detailed morphological description of *R. chuyangsinensis* based on 15 adult males and two adult females from Lam Dong and Khanh Hoa Provinces, southern Vietnam (for measurements see Table 1).

Head approximately as long as wide; snout slightly pointed in dorsal view, pointed and slightly exceeding to mouth in profile; nostril round, and closer to tip of snout than to eye; canthus rostralis distinct; eye diameter 0.7–0.9 times of snout length; interorbital region flat, wider than internarial distance and as large as or little bit larger than width of upper eyelid; tympanum round, not raised above temporal region, with a slightly elevated rim; diameter of tympanum 0.4–0.5 times of eye diameter, distance between eye and tympanum 0.3–0.4 times the tympanum diameter; supratympanic fold distinct, from behind of eye to beyond level of axilla; choanae small, round; vomerine teeth grouped in two oblique rows, beginning nearby anterior edges of the choanae, closer to choanae than to each other; tongue bifid at rear.

Limbs slender; relative lengths of fingers I<II<IV<III; tips of fingers flat, enlarged into round discs with circummarginal grooves; disc of third finger as large as or little larger than the tympanum diameter; fingers incompletely webbed, formula I(1) IIIi(1)e(0.5) IIIi(1.5)e(1) IV(1); narrow, smooth flap of skin present along outside of fourth finger and lower arm, ending at elbow; subarticular tubercles on fingers and toes round, prominent and conspicuous; nuptial pad distinct in males, located on lateral and dorsal aspect of first finger, from near its base to proximal end of penultimate phalanx; length of nuptial pad slightly larger than that of the first finger; discs of toes round with circummarginal grooves, smaller than those of fingers; relative lengths of toes I<II<V<III<IV; toes broadly webbed, formula I(0) IIIi(1)e(0.5) IIIi(1)e(0) IVi(0.5)e(0.5) V(0.5); dermal fringe along outside of fifth toe and foot narrower than that along outside of fourth finger and lower arm, and ending at tibiotarsal articulation with a long, pointed projection; inner metatarsal tubercle flat, oval, its length about one-third to half of that of first toe; outer metatarsal tubercle absent; heels overlapped when legs are held at right angles to body; tibiotarsal articulation extending to anterior edge of eye or between eye and tip of snout.

Skin smooth on dorsal body, head, and limbs; throat, chest, and lower part of flank slightly granular; belly and ventral surface of thigh coarsely granular; posterior cloacal appendix present.

Coloration in preservative. Dorsal surfaces of body and limbs ground yellow to dark brown; dorsal pattern which is yellow in life becomes creamish-white in preservative; nuptial pad white; surfaces of belly, limbs, discs and webbings whitish-cream; the blue color surrounding the black patches on flanks and upper arms is only slightly discernible if at all.

Coloration in life. Back and upper surfaces of limbs pale green or dark brown, with many small white or yellow spots; ventral surface bright yellow without small

TABLE 1. Measurements (mean \pm standard deviation, followed by minimum and maximum in parentheses; in mm) of *Rhacophorus chuyangsinensis* from Bi Doup-Nui Ba National Park, Lam Dong Province and Hon Ba Nature Reserve, Khanh Hoa Province, Vietnam; n: number of specimens. See the methods for abbreviations.

	Males (n = 15)	Females (n = 2)
SVL	37.9 \pm 2.6 (34.8–43.8)	59.1 \pm 1.6 (58.0–60.2)
HL	14.7 \pm 0.7 (13.5–16.1)	21.5 \pm 0.5 (21.2–21.9)
HW	15.0 \pm 0.6 (14.17–16.3)	22.2 \pm 0.4 (21.5–22.9)
SNL	6.0 \pm 0.7 (3.7–6.5)	7.3 \pm 1.6 (6.1–8.4)
NS	2.3 \pm 0.3 (1.8–2.8)	3.4 \pm 0.3 (3.2–3.6)
IN	3.3 \pm 0.2 (2.9–3.5)	4.6 \pm 0.7 (4.1–5.1)
ED	4.9 \pm 0.4 (4–5.4)	5.9 \pm 0.1 (5.9–6.0)
UEW	3.8 \pm 0.6 (2.4–4.6)	3.3 \pm 1.7 (2.1–4.5)
IO	4.5 \pm 0.8 (3.8–7.9)	8.5 \pm 3.5 (6.0–11.0)
DFE	8.3 \pm 0.6 (7.4–9.3)	11.7 \pm 0.8 (11.1–12.3)
DBE	12.9 \pm 1.3 (9.7–14.3)	17.0 \pm 0.7 (16.5–17.5)
TD	2.4 \pm 0.5 (2.0–4.2)	4.1 \pm 0.9 (3.5–4.8)
E-T	1.0 \pm 0.2 (0.6–1.3)	1.9 \pm 0.3 (1.8–2.1)
A-G	20.9 \pm 1.3 (18.5–23.2)	33.5 \pm 1.0 (32.8– 34.2)
UAL	6.9 \pm 0.4 (6.4–7.8)	11.8 \pm 0.6 (11.3–12.2)
LAL	7.2 \pm 0.6 (6.5–8.2)	11.0 \pm 0.1 (10.9–11.1)
HAL	12.1 \pm 0.8 (11.0–13.4)	17.4 \pm 0.2 (17.3–17.5)
TFPW	1.8 \pm 0.3 (2.0–2.8)	3.3 \pm 0.1 (3.3–3.4)
THL	18.9 \pm 1.3 (16.7–20.7)	28.2 \pm 1.2 (27.3–29.0)
TBL	20.1 \pm 1.0 (19.0–21.7)	29.9 \pm 0.5 (29.5–30.3)
FOL	17.1 \pm 2.6 (13.9–24.8)	24.2 \pm 0.1 (24.1–24.3)
TFOL	27.0 \pm 1.4 (24.3–29.2)	39.3 \pm 0.8 (38.7–39.9)
IMTL	1.3 \pm 0.2 (0.9–1.7)	1.6 \pm 0.5 (1.27–1.5)
FTL	3.0 \pm 0.5 (2.2–4.3)	5.6 \pm 2.3 (4.0–7.2)
NPL	3.3 \pm 0.3 (2.8–3.7)	-

spots; thin, light stripes present along canthus rostralis, from tip of snout to middle of the eye; flanks, anterior and posterior surfaces of limbs yellow to orange; axilla, groin, anterior surface of upper arm and thigh, and posterior surfaces of thigh and tibia usually with large, black patches that vary in size and shape; these patches are sometimes surrounded by bright blue color and are more obvious in females (more details are given in the discussion of the sexual dimorphism); webbings on fingers and toes yellow or orange, sometimes with black pattern at base; discs of fingers and toes yellow to orange; posterior cloacal appendix white; long, pointed projection at the heel of the same color as dorsal surface of thigh or yellow; pupil horizontal, black; iris brown, fading into red-orange at the upper and lower parts and surrounded by an inner black and outer blue circle (Fig. 2). Dorsum of some males (UNS00506–00508; ZFMK91517–91519) reddish brown, with two yellow dorsolateral stripes stretching from posterior corner of eye to groin and a medium third yellow stripe extending from behind the middle of the back towards cloaca; in such coloured specimens, also the light snout stripes are more distinctly developed, and sometimes a light stripe between eyes is present, forming a triangle on the dorsal surface of head (UNS00506 & ZFMK91519) (Fig. 2 E & F).

Sexual dimorphism. Female size on average is 1.6 times larger than that of males. The females also differ from males by their flank pattern, which consists of the



FIG. 2

Different color patterns of *Rhacophorus chuyangsinensis* in life. (A-B) female (VNMN965) at day and night time. (C-F) males (C: UNS00500, D: UNS00508, E: ZFMK91518, and F: UNS00506).

same colour than the dorsal pattern, viz. dark reddish brown or ground brown, with many small whitish spots (versus bright yellow flanks in males without small whitish spots). In females the bright bluish color on axilla, groin and front of the forearm is also more obvious and furthermore may even extend towards the middle of the flanks

and cover nearly the whole anterior surface of the forearm (Figs 2A, 2B). In addition, the posterior surface of the thigh and tibia of females is covered with large black, elongated patches.

EXTENDED DIAGNOSIS (AFTER ORLOV *ET AL.* 2008, COMBINED WITH OUR NEW DATA)

A small rhacophorid species with 35.1–44.15 mm SVL in adult males, and 58.0–60.2 mm in adult females; body depressed; head wide and flat, approximately as long as wide; snout somewhat pointed; diameter of the eye 0.7–0.9 times of snout length; iris brown to red-orange at the upper and lower parts, surrounded by inner black and outer blue circle; pupil black, horizontal; tympanum round, small but clearly visible; supratympanic fold extending just beyond level of axilla; back and dorsal surfaces of limbs smooth; throat slightly granulated, belly and ventral surface of thigh coarsely granular; vomerine teeth in two oblique ridges that reach the upper part of the rounded choanas; discs of fingers and toes flat, large, round, with circummarginal grooves; discs on fingers larger than toe discs; fingers incompletely webbed (formula: I(1) IIi(1)e(0.5) IIIi(1.5)e(1) IV(1)); toes extensively webbed (formula: I(0) IIi(1)e(0.5) IIIi(1)e(0) IVi(0.5)e(0.5) V(0.5)); dermal fringe along the outside of the fourth finger and lower arm present; similar ridge of skin present along the outside of the fifth toe and foot, ending at heel, which bears a long, pointed projection; back and dorsal surfaces of limbs pale green to dark green or dark brown, with many small white or yellow spots; belly yellow without spots; webbings on fingers and toes yellow to orange; posterior cloacal appendix white.

NATURAL HISTORY

The new records of *Rhacophorus chuyangsinensis* from Bi Doup-Nui Ba National Park (Lam Dong Province) and Hon Ba Nature Reserve (Khanh Hoa Province) were made nearby or within rocky streams in evergreen forests at elevations between 1,320–1,600 m a.s.l. The frogs were observed during evening and night time sitting on high branches of trees along the streams, approximately 1.5–2 m above the ground. Sometimes these trees were up to 5 m distant from water sources (Fig. 3). On 22 May 2010, we measured environmental temperatures of 19.2–19.5°C, and humidities of 92.4–93.6% at the sites where the frogs were found. One female (UNS00509), which was collected during dry season on 18 March 2010, was gravid and contained large eggs up to 3 mm diameter.

DISCUSSION

Our new rhacophorid records from Bi Doup-Nui Ba National Park (Lam Dong Province) and Hon Ba Nature Reserve (Khanh Hoa Province) were morphologically well assignable to the recently described species *Rhacophorus chuyangsinensis* (Orlov *et al.* 2008). But we also found some differences between the new collections and the type series of *R. chuyangsinensis*. Our new records from Lam Dong and Khanh Hoa provinces had the interorbital distance as large as or slightly larger than the width of the upper eyelid (in contrast to the condition described for two of the three males by Orlov *et al.* 2008); the nuptial pad length was 1.0–1.3 times the first finger length in



FIG. 3

Habitat of *Rhacophorus chuyangsinensis* in (A) Bi Doup-Nui Ba National Park, Lam Dong Province; and (B) Hon Ba Nature Reserve, Khanh Hoa Province, Vietnam.

our new series (versus only half of finger's length according to Orlov *et al.* 2008); the tympanum diameter was nearly half (0.4–0.5) of the eye diameter in the new series (versus tympanum diameter being 0.6–0.7 of eye diameter according to Orlov *et al.* 2008). Based on our new records of *R. chuyangsinensis* we could also show that adult males have a wider range in snout-vent length than it was noted previously (only 42.9–44.2 mm after Orlov *et al.* 2008 versus 35.1–43.8 mm in the new series from Lam Dong and Khanh Hoa). Besides providing first data on the size and the so far unknown colour pattern of the females of this recently described species, the first record of a so far unknown, both triangle-shaped and striped light dorsal colour pattern in male *R. chuyangsinensis* are particularly noteworthy. Because these unusually patterned males occurred in the same microhabitat and because we did not find significant morphological differences compared to normal patterned congeners, we evaluate them as representing the same species. However, future bioacoustic and molecular approaches, which are lacking at time, must confirm the conspecific status of the different colour morphs. Orlov *et al.* (2008) could not document male advertisement calls of *R. chuyangsinensis* during October 2007. Thus, these authors assumed that the species probably does not reproduce at that time of the year. Our first record of a gravid female collected at the end of March 2010 indicates that reproduction at least takes place in the dry season. Beyond an extended distribution range of the species we also could show that this species can also be found at lower altitudes, viz. between 1,320–1,600 m a.s.l.

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