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A New Species of *Fejervarya* (Anura: Dicroglossidae) from Mawphlang, Northeastern India

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Abstract A new Dicroglossid species is described from Mawphlang, Meghalaya, northeastern India. The new species differs from all the congeners occurring in this region in body size and call characteristics. It is larger than *Fejervarya syhadrensis* and *F. nepalensis*, but smaller than *F. teraiensis*. It overlaps *F. pierrei* in snout-vent length, but clearly differs from it in advertisement call, with much shorter note duration, much longer inter note interval, and much lower dominant frequency. Paucity of genetic information and underestimation of species diversity in this region are discussed.

Keywords new species, *Fejervarya*, Amphibia, Anura, Mawphlang, India

1. Introduction

The genus *Fejervarya* (Bolkay, 1915) is represented by 32 species worldwide (Frost, 2011; Howlader, 2011). India has a rich diversity of frogs of this genus with 19 known species, most of which occur in Western Ghats. By contrast, only five species [*F. limnocharis* (Gravenhorst, 1829), *F. nepalensis* (Dubois, 1975), *F. pierrei* (Dubois, 1975), *F. syhadrensis* (Annandale, 1919), and *F. teraiensis* (Dubois, 1984)] have been listed as members of *Fejervarya* from northeastern India (Ahmed *et al*., 2009; Mathew and Sen, 2010). These authors, however, noted that *F. limnocharis* from this region might represent an unnamed species as suggested by the results of recent phylogenetic studies where *F. limnocharis* has been restricted to East and Southeast Asia (Toda *et al*., 1998; Biju, 2001; Veith *et al*., 2001; Djong *et al*., 2007; Matsui *et al*., 2007).

During our field survey in Meghalaya, we collected five frogs that are superficially very similar to *F. "limnocharis"* shown in Mathew and Sen (2010). Unfortunately, the morphological descriptions by Mathew and Sen (2010) are inconsistent and lack measurements, even standard size (SVL), although the size can be a good indicator for classification in frogs of the genus *Fejervarya* that are otherwise very morphologically similar. The frogs in question are surely larger than *F. syhadrensis* and *F. nepalensis*, but smaller than *F. teraiensis*. In both sexes, SVL of these frogs overlaps but tends to be larger than that of *F. pierrei*, but they completely differ in advertisement calls. We thus describe the *Fejervarya* from Meghalaya as a new species.

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2. Materials and Methods

Five specimens collected from Mawphlang (Figure 1), East Khasi Hill District, Meghalaya, India (25°26'42.68" N, 91°45'10.99" E, 1824 m a.s.l.) are preserved in 70% ethanol and deposited in the Zoological Survey of India, North Eastern Regional Centre, Shillong, Meghalaya (ZSI). Measurement data were taken from these preserved specimens following Matsui (1984) and Borthakur *et al*. (2007), with a dial caliper measured to the nearest 0.02 mm.

Morphometric characters include: 1) snout-vent length (SVL); 2) head length (HL); 3) snout length (SL); 4) snout-nostril length (S-NL); 5) nostril-eye length (N-EL);

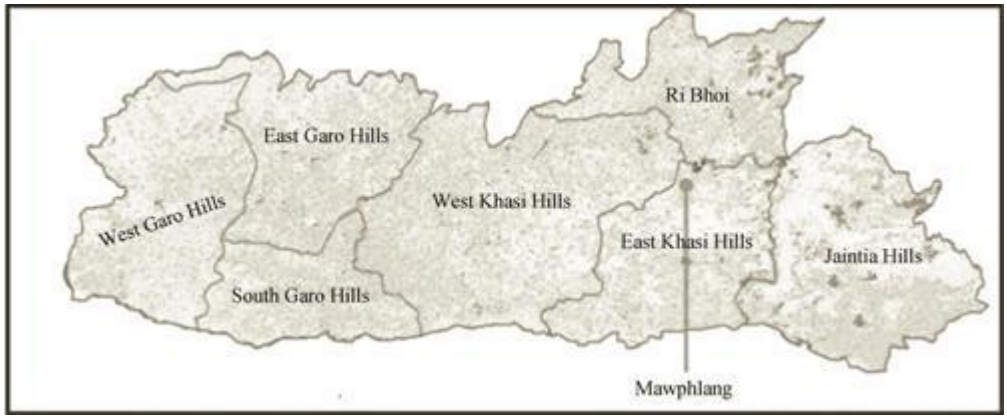

Figure 1 Map of Meghalaya State of India showing the place of occurrence of *Fejervarya sengupti* sp. nov.

6) eye length (EL); 7) tympanum-eye distance (T-ED); 8) tympanum diameter (TD); 9) head width (HW); 10) internarial distance (IND); 11) interorbital distance (IOD); 12) upper eyelid width (UEW); 13) forelimb length (FLL); 14) hindlimb length (HLL); 15) tibia length (TL); 16) inner metatarsal tubercle length (IMTL); and 17) outer metatarsal tubercle length (OMTL). Additionally, we also measured: (18–21) finger length (I-IV FL); and (22–26) toe length (I-V TOEL). We followed the system of description of toe-webbing states used by Savage (1975).

Call recordings were made in the field using a Sony Cybershot camera (model: DSC-W35) on video mode. Calls were analyzed with SoundEdit Pro (MacroMind- Paracom, Inc.) software package on a Macintosh computer, as described elsewhere (Matsui, 1997).

3. Description of the New Species

***Fejerverya sengupti* sp. nov.**

Holotype: V/A/NERC/ZSI/1100 (formerly Jayaditya Purkayastha field series JP0196), adult male (Figure 1) from Mawphlang, East Khasi Hill District, Meghalaya, India (25°26'42.68" N, 91°45'10.99" E, 1824 m a.s.l.), collected by Jayaditya PURKAYASTHA on 15 July 2011.

Paratypes: One male (V/A/NERC /ZSI/1101) and three females (V/A/NERC/ZSI/1099, V/A/NERC/ZSI/1102, and V/A/NERC/ZSI/1103), data same as the holotype.

Etymology: We name the new species in honour of Dr. Saibal SENGUPTA, the first author's mentor and one of the pioneer workers in the field of herpetology in northeastern India after the independence of India.

Diagnosis: A medium-sized *Fejervarya*, with SVL being 33.4 and 35.7 mm in two males and 32.5–53.2 mm in three females; tympanum large,diameter about three-fifth to three-fourth eye diameter; relative length of fingers in ascending order usually II < I < IV < III; toe web formula I1–2 II 1–2½ III 2–3 IV2½–1½ V; a cream vertebral line medially from snout to vent, and from posterior side of thigh to tarsus; forearm with prominent red spots; males with widely separated dark vocal sac markings on throat; advertisement call consisting of a long series of partially pulsed notes, each lasting 64 ms with time interval of 305 ms in between, and dominant frequency of 3300 hz.

Description of holotype (measurements in mm): Body moderately stocky (Figure 2), SVL 35.7; head wider (14.5) than long (12.4); snout elongate (6.3), rounded, longer than eye (4.6); tympanum round, diameter (2.8) about three-fifith that of eye, and separated from eye by half of tympanic diameter (1.5); canthus rostralis oblique, loreal concave; nostril closer to eye (2.9) than to snout tip (3.2); interorbital convex, narrower (2.0) than internarial (2.7) and upper eyelid width (3.1).

Forelimb relatively long (25.7); fingers relatively short, with remnant of web in between; relative lengths in ascending order II (6.56) < I (6.96) < IV (6.98) < III (9.54); tips bluntly rounded; supernumerary tubercles absent (Figure 3).

Hindlimb long (65.4), tibiotarsal articulation of adpressed limb reaching snout tip; tibia relatively long (20.4), heels overlapping when limbs are held at right angles to body; toes long with rounded tip; relative length in ascending order I (7.0) < II (10.6) < V (15.3) < III (16.1) < IV (21.2); toe webbing moderate, formula I1–2 II 1–2½ III 2–3 IV2½–1½ V; inner metatarsal tubercle large (2.6) and elongate; outer metatarsal tubercle oval, small, half of inner one (1.3); subarticular tubercles well developed (Figure 3).

Figure 2 Dorsal (A), ventral (B), and lateral (C) views of the male holotype of *Fejervarya sengupti* sp. nov. (ZSI No. 10) after preservation. Not to scale.

Dorsal surface granulated, scattered with skin folds, more or less arranged transversely and some running dorsolaterally; a supratympanic fold from eye to armpit; side of trunk coarsely granular; limbs dorsally tuberculated; ventral surface smooth except for coarsely granulated cloacal and femoral regions; distinct nuptial pads, gray in color and velvety in structure, covering dorsal and median surfaces of the first finger from its base to point between subarticular tubercle and finger tip; skin on throat side modified for vocal sac; "Fejervaryan" line present from axilla to groin and across breast.

Colour in life: Dorsum greenish beige with large dark blotches forming transverse bands, including interorbital bar; a cream vertebral line medially from snout to vent, and from posterior side of thigh to tarsus; loreal with dark markings below canthus; upper lip with dark bars; supratympanic fold and upper half of tympanum surrounded by a brown band; dorsolaterally greenish yellow; a red blotch on vertebral line just behind eye; forearm with prominent red spots, nearly touching subtympanic orange streak; limbs dorsally greenish beige with wide, dark brown crossbars; tips of digits red; ventral surface uniformly cream with widely separated black markings on throat; cloacofemoral region cream suffused with red; "Fejervaryan" line distinct, dark grey; webs reddish brown.

Colour in preservative: Dorsal colour turns into grayish brown, red blotches on the dorsum and forelimb fade out, and the orange colour of the supratympanic fold becomes dull.

Variation: Small sample size prohibites statistical comparisons, but females tends to have narrower head and internarial space, and shorter snout, forelimb, and tibia, relatively longer SVL than males (Table 1). Head is longer than wide, and nostril is closer to snout than to eye in each male and female individual, and interorbital space is wider than internarial and upper eyelid widths in two females. Relative length of fingers in ascending order is II < I < IV < III in four individuals; Females lack black markings on throat, and nuptial pads on the first finger. The narrow vertebral line is invariably seen in the type series (Figure 4).

Advertisement call: The advertisement call recorded at an ambient temperature of 22 ºC (Figure 5) consists of a long series of partially pulsed notes. The note repetition rate is about 2.46–3.58 (mean ± SD = 2.94 ± 0.54) notes per s. Each note lasts about 62–69 (mean ± SD = 64.4 ± 2.3, n = 12/three males) ms, and the time interval between two notes varies from 273–354 (mean ± SD = 304.6 ± 27.4) ms. Dominant frequency lies at 3150–3450 (mean ± SD = 3261.5 ± 110.2) hz, and harmonics are at 1850–1950 hz and at 4150–4250 hz. The call has slight frequency and intensity modulations.

Figure 3 Ventral views of the right hand (A) and foot (B) of the male holotype of *Fejervarya sengupti* sp. nov. (V/A/NERC/ZSI/1100). Not to scale.

Distribution: *Fejervarya sengupti* sp. nov. is currently only known from its type locality Mawphlang, Meghalaya, northeastern India (Figure 1).

Natural history: The type series of *F. sengupti* sp. nov. were collected from among the bushes near water potholes. These potholes stay filled up with water in the rainy season (April to October) because of the continuous monsoon rain that this region receives. From early evening (ca 18:00 h) calling males could be heard. Fewer calls could be also heard inside forested areas (sacred groves). Amplecting pairs were observed around water bodies. Females, when stressed or handled, produced a very peculiar infant-like high pitched sound.

Comparisons: Because most of the described congeneric species occupy ranges far from northeastern India where the new species occurs (See the Discussion below), comparisons with four species from this region (*F. syhadrensis*, *F. nepalensis*, *F. teraiensis*, and *F. pierrei*) would be pertinent.

Fejervarya sengupti sp. nov., with SVL being 33.4–35.7 mm in males and 32.5–53.2 mm in females, is larger than *F. syhadrensis* [23.3–31.5 mm in males and 26.8–42.5 mm in females: Dubois (1975) as *Rana*; Borthakur *et al*. (2007); Kuramoto *et al*. (2007)] and *F. nepalensis* [23.0–37.8 mm in males and 31.2–42.3 mm in females: Dubois (1975) as *Rana*, Borthakur *et al*. (2007)], but is smaller than *F. teraiensis* [40.1–50.5 mm in males and 51.6–61.2 mm: Matsui *et al*. (2007); SVL (19.5–49.2 mm in males and 25.5–40.6 mm) given by Borthakur *et al*. (2007) apparently for juveniles]. The new species overlaps *F. pierrei* in SVL [24.7–41.2 mm in males and 33.1–46.0 mm in females: Dubois (1975) as *Rana*; Borthakur *et al*. (2007)], but clearly differs from it in advertisement call characteristics. The call of *F. sengupti* is a series of long, multi-pulsed notes like that of the holotype of *F. pierrei* from Nepal (Grosjean and Dubois, 2011) and the note rate is also similar (both 2.9 notes per s). However, the note duration is much shorter (64 ms *vs*. 258 ms in *F. pierrei*), inter note interval is much longer (305 ms *vs*. 92 ms in *F. pierrei*), and dominant frequency is much lower (3260 Hz *vs*. 4200 Hz in *F. pierrei*)

Figure 4 A female paratype of *Fejervarya sengupti* sp. nov. in life from its type locality in India.

Table 1 Measurements in *Fejervarya sengupti*. SVL (Mean ± 1 SD, in mm) and medians of ratios of other characters to SVL, followed by ranges in parenthesis. See text for character abbreviations.

	Male	Female		Male	Female
n	2	3	n	2	3
SVL	34.6 (33.4-35.7)	43.5 + 10.4 (32.5-53.2)	RUEW	8.1 (7.5-8.6)	7.8 (6.1-8.1)
RHL	36.2 (34.9-37.6)	37.9 (30.0-37.9)	RED	11.5 (10.1-12.9)	9.8 (7.9-11.4)
RHW	37.9 (35.2-40.6)	32.5 (31.6-34.5)	RTD	7.2 (6.7-7.8)	6.9 (5.9-7.4)
RSL	18.5 (17.7-19.3)	15.7 (14.1-17.4)	RFLL	71 (70.0-72.0)	59.9 (59.3-60.4)
REND	8.8 (8.1-9.5)	7.5 (5.8-8.6)	RHLL	181.2 (179.2-183.2)	159.7 (154.9-180.7)
RNSD	8.2 (7.3-9.0)	7.3 (6.8-7.6)	RTL	56.5 (55.9-57.1)	47.5 (42.0-54.4)
RTED	4 (3.8-4.3)	4.2 (4.1-5.2)	RIMTL	7.7 (7.3-8.1)	7 (6.5-8.3)
RIND	7.4 (7.4-7.5)	6.9 (6.5-7.1)	ROMTL	3.3 (3.1-3.6)	3.4 (2.7-3.9)
RIOD	6.2 (5.7-6.7)	7.9 (5.8-8.1)			

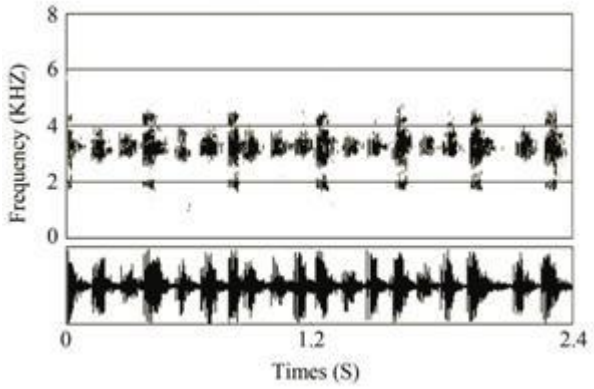

Figure 5 Sonogram of an advertisement call of *Fejervarya sengupti* sp. nov

From the other species known in the regions nearby, *F. sengupti* differs in body size; from *F. orissaensis* (Dutta, 1997) from India [males 33.4–35.7 mm *vs*. 36.2–47.2 mm in *F. orissaensis* Dutta (1997) as *Limnonectes*] and *F. asmatii* from Bangladesh [SVL 29.1–33.4 mm: Howlader (2011)]. Although *F. brevipalmata* (Peters, 1871) and *F. keralensis* (Dubois, 1981), both with body size [21.2–47.0 mm: Dutta (1997) as *Limnonectes*, and 28.3–59.8 mm: Dutta (1997) as *Limnonectes*, respectively] similar to *F. sengupti* are reported from northeastern India, workers have cast substantial doubt on their presence (See Bauer *et al*., 1995; Boulenger, 1905 "1904"; Choudhury *et al*., 2002). Furthermore, *F. altilabris* (Blyth, 1856) from Myanmar, *F. frithii* (Theobald, 1868) from Bangladesh, *F. assimilis* (Blyth, 1852), *F. brama* (Lesson, 1834), *F. sauriceps* (Rao, 1937), and *F. parambikulamana* (Rao, 1937) from India seem to be invalid (Matsui *et al*., 2007).

4. Discussion

From the recent discovery of four new species of *Fejervarya* from the Western Ghats of southwestern India (Kuramoto *et al*., 2007), it is not surprising that *F. sengupti* is further added to Indian members of the genus *Fejervarya*. It is most plausible that several unnamed species of this genus are also present in northeastern India (Prakash, 1995).

From the region of northeastern India, Chanda (1994) reported only *F. limnocharis*. He examined many specimens and listed the SVL of this species from 47.5 mm to 60 mm. Unfortunately, there is no useful information in the given description, and remarks include citations from previous reports. Probably, *F. limnocharis* described by Chanda (1994) might include several species or mostly based on *F. teraiensis*, which has a large body size. Later publications listed five species of *Fejervarya* (*F. limnocharis*, *F. nepalensis*, *F. pierrei*, *F. syhadrensis*, and *F. teraiensis*) from this region (Ahmed *et al*., 2009; Mathew and Sen, 2010), although Borthakur *et al*. (2007) omitted *F. limnocharis* in their list of Assam. As already noted, no true *F. limnocharis* is believed to be a member of the Indian fauna.

Results of recent molecular phylogenetic studies strongly suggest that *Fejervarya* is composed of East- Southeast Asian and South Asian clades (Kurabayashi *et al*., 2005; Kotaki *et al*., 2010), with their boundaries roughly in the region surrounding northeastern India

(northern Thailand, Myanmar, and Bangladesh). As far as we are aware, several described and undescribed species have been reported from this region in addition to the five species seen in northeastern India. Kotaki *et al*. (2010) listed *Fejervarya* sp. hp2 (Three Pagoda Pass, Thailand), *Fejervarya* sp. hp3 (Pilok, Thailand), and *Fejervarya* sp. hp5 (Assam), while Islam *et al*. (2008) reported occurrence of three unnamed species (Large, Medium, and Small types) from Bangladesh, of which one may be identical with *F. asmati* (Howlader, 2011). Similarly, the relationship of Kotaki *et al*.'s (2010) *Fejervarya* sp. hp5 and *F. sengupti* is unknown. However, because Borthakur *et al*. (2007) did not find *F. limnocharis*, which is most probably *F. sengupti* in Assam, *Fejervarya* sp. hp5 seems to be specifically distinct from *F. sengupti*.

Of the species occurring in this region, *Fejervarya* sp. hp2 (Three Pagoda Pass, Thailand) and *Fejervarya* sp., large type (Bangladesh) belongs to the East-Southeast Asian clade, while *F. pierrei*, *F. syhadrensis*, *Fejervarya* sp. medium type (Bangladesh), *Fejervarya* sp. Small type (Bangladesh), *Fejervarya* sp. hp3 (Pilok, Thailand), and *Fejervarya* sp. hp5 (Assam) are grouped in the South Asian clade (Islam *et al*., 2008; Kotaki *et al*., 2010). However, genetic allocation is undetermined for *F. nepalensis* and *F. teraiensis.* Similarly, we have still no chance to examine genetic properties of *F. sengupti*. Strictly, genetic division into two clades does not conform to geographic division as exemplified *F. orissaensis*, which is grouped in the East-Southeast Asian clade in spite of its distribution in eastern India. Nevertheless, molecular phylogenetic studies are surely useful in determining taxonomic status of these morphologically fairly uniform frogs, and future studies on the genus *Fejervarya* from the boundary region including northeastern India are strongly required.

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