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A new species of *Fejervarya* Bolkay, 1915 (Anura: Dicroglossidae) from the northern Western Ghats parts of Maharashtra, India

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Abstract

In the recent past the systematic position and taxonomy of genus *Fejervarya*, Bolkay is undergoing changes in its systematic position due to fairly good amount of phylogenetic resolution, cryptic morphological characters and lack of systematic sampling for phylogenetic studies across the range of distribution. In our sampling in the northern Western Ghats, we encountered a new lineage sister to the phylogenetic cluster which comprises the 'Rufescens complex'. This new lineage is described here as new species *Fejervarya marathi* **sp. nov.** based on distinctness in a combination of morphological characters, genetic distance and geography. The problems in morphological groupings for the *Fejervarya* frogs of the Western Ghats in the recent studies are discussed with the sub-clade composition based on geography in the phylogenetic tree.

Key words: Cryptic species, *Fejervarya*, Marathi, northern Western Ghats

Introduction

The Western Ghats of India is one of the global biodiversity hot-spots in South Asia harboring highly endemic amphibian fauna (Bossuyt *et al*. 2004; Gunawardene *et al*. 2007; Garg & Biju, 2017). In the last decade, more than 100 species of amphibians have been described from the Western Ghats (AmphibiaWeb, 2018; Frost, 2018). Among the Indian amphibians (total 419), more than 60% species are endemic to the Western Ghats (Frost, 2018). It is believed that there are numerous undescribed species of amphibians in the Western Ghats (Garg & Biju, 2017). Additional surveys and sampling in different seasons across the Western Ghats could unearth more amphibian diversity as well as information on the geographic distribution of species.

In the recent past, the identity and the phylogenetic position of the genus *Fejervarya* Bolkay belonging to the family Dicroglossidae Anderson has been in a state of flux (Dinesh *et al.* 2015, 2017; Raj *et al.* 2018; Sanchez *et al.* 2018). At present, the genus *Fejervarya* comprises a total of 51 species distributed in South and South-East Asia (Frost, 2018) and in India, the genus is represented by 34 species (Dinesh *et al*. 2017; Frost, 2018; Raj *et al.* 2018). Many frog species of the genus *Fejervarya* are widely distributed and have great similarities in their morphology (Kotaki *et al*. 2010; Dinesh *et al*. 2015; Garg & Biju, 2017). Adding to morphological crypsis, there are many taxonomic issues associated with the frogs of this genus, such as the loss of type specimens, incomplete descriptions of species, which have led to uncertainty about the identity of species (for detailed accounts see Garg & Biju, 2017; Dinesh *et al*. 2017 and Raj *et al.* 2018) and their range of distribution. Moreover, the specific breeding activity, secretive life cycle and short breeding period of many of the members of this genus might have acted as a limiting factor in the discovery of the new species and delineation of the distribution range (Dinesh *et al*. 2017; Garg & Biju, 2017; Raj *et al.* 2018).

During our regular monsoon field visits in the northern Western Ghats, we collected a set of samples morphologically assignable to the genus *Fejervarya* based on the generic morphological characters established by Bolkay (1915) and Dubois *et al.* (2001) for the genus (Dinesh *et al*. 2015), but not matching with the descriptions

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of known members of the genus. Further phylogenetic analysis confirmed our generic allocation and the possibility of a new lineage sharing a clade relationship with the 'Rufescens group' of fejervaryan frogs (Garg & Biju, 2017; Dinesh *et al.* 2017). The new species is diagnosable on multiple axes, and is described herein as *Fejervarya marathi* **sp. nov.** The temporal structure and spectral properties of the call of *Fejervarya marathi* **sp. nov.** are provided to distinguish it from the other sympatric *Fejervarya* frogs.

Recently, Sanchez *et al.* (2018) allocated the fejervaryan frogs from South Asia to the genus status *Minervarya* based on large scale phylogenetic studies, resurrecting the genus from junior synonymy as per the principle of priority of the ICZN Code (Dinesh *et al.* 2015). There is morphological character crypsis and character sharing across the genus *Fejervarya, Minervarya* and *Sphaerotheca*. For example, Sanchez *et al.* (2018) have mentioned the presence of "fejervaryan lines" as a shared character between the members of *Fejervarya* and *Minervarya* but absent in *Sphaerotheca*. Similarly "shovel shaped" inner metatarsal tubercle is a shared characters between the members of *Minervarya* (as proposed in Sanchez *et al.* 2018) and *Sphaerotheca* but absent in *Fejervarya*. Within the genus *Minervarya* considered by Sanchez *et al.* (2018), there are shared derived characters among the members / within sub clades like the presence of white lower lip, rictal gland and shovel shaped inner metatarsal tubercle (see discussion below). There are problems in categorizing the generic level morphological characters for the genus *Fejervarya, Minervarya* (as proposed in Sanchez *et al.* 2018) and *Sphaerotheca*.

Accordingly we are treating the new species under the genus *Fejervarya* Bolkay, 1915 as the genus *Fejervarya* is monophyletic with respect to the genus *Sphaerotheca* in the present study and earlier studies of Dinesh *et al.* (2015, 2017), Garg & Biju, (2017) and Raj *et al.* (2018).

Materials and methods

The field visits were made during the monsoon period of northern Western Ghats, Pune, Maharashtra (Fig. 1). Male and female specimens were collected during the peak breeding activity. Photographs of the live individuals were taken in controlled conditions. Specimens were euthanized using MS 222, thigh muscle tissues were dissected for genetic studies and stored in molecular grade ethanol. The frogs were initially fixed in 4% neutral formalin for 48 hours and later preserved in 70% alcohol.

Habitat details and natural history observations were recorded at the collection site during multiple field visits in the peak season of activity. Advertisement calls of males were recorded using digital audio recorder (Tascam DR-05) connected to the microphone (Polsen SCL-1075) with a foam windscreen (sampling rate 44.1 kHz, 16-bit resolution). The microphone was directed towards vocal sac of the calling male and the distance between calling males and microphone was kept ~30 cm. For call description, we used terminologies described by Köhler *et al*. (2017). Call was analyzed for three temporal (call duration, number of notes in the call, number of pulses per note) and two spectral (dominant frequency and fundamental frequency) properties using Raven Pro version 1.5 (Charif *et al*. 2010). Dominant and fundamental frequencies were identified by selecting the highest energy bands and using maximum frequency function in the spectrogram view (FFT window—512, contrast—90 and brightness—45).

For the phylogenetic studies, total genomic DNA was extracted from the ethanol preserved tissue using DNeasy blood and tissue kit (Qiagen, Valencia, CA, USA) following the manufacturers protocol. From the purified eluted DNA, the mitochondrial (mt) 16S rRNA gene (Simon *et al*. 1994) and nuclear (nu) tyrosinase gene (Bossuyt & Milinkovitch, 2000) were amplified. The amplified PCR products were purified using QIAquick® PCR Purification Kit and Sanger sequencing was done using ABI 3500 XL platform (Applied Biosystems). MEGA 6 (Tamura *et al.* 2013) was used for generating uncorrected pairwise genetic distances. For generating a Maximum Likelihood (ML) tree, RaxML (Silvestro & Michalak, 2012) was used with data partition for all the genes under GTR+GAMMA+I model by running 1000 thorough bootstraps and the final consensus tree was visualized by FigTree v1.4.0. During the construction of the phylogenetic tree, we used the sequences from Dahanukar *et al*. (2017), Dinesh *et al*. (2015, 2017), Garg & Biju, (2017) and Raj *et al*. (2018) with our newly generated sequences for the mt 16s rRNA and nu tyrosinase gene for the undescribed species of *Fejervarya* (See Appendix I).

For morphological studies, metric measurements were taken with a Mitutoyo vernier caliper (to the nearest 0.1 mm) and the meristic information was recorded with the Leica MZ75 microscope (Table 1). To carry out a multivariate Principal Component Analysis (PCA), a total of 12 morphometric characters (marked with * in Table

1) were transformed to their relation to SVL for the new species with the data for the species *F. cepfi* from Garg & Biju (2017), *F. syhadrensis* from Dinesh *et al*. (2017) and *F. granosa* from our field collections. For PCA analysis, PAST version 3.16 was used (Hammer *et al*. 2001).

For the diagnosis and establishment of the new species, multiple criteria including phylogeny, genetic distance, geographic isolation and morphological character differences were considered following Vijayakumar *et al*. (2014). Abbreviations followed Dinesh *et al.* 2017.

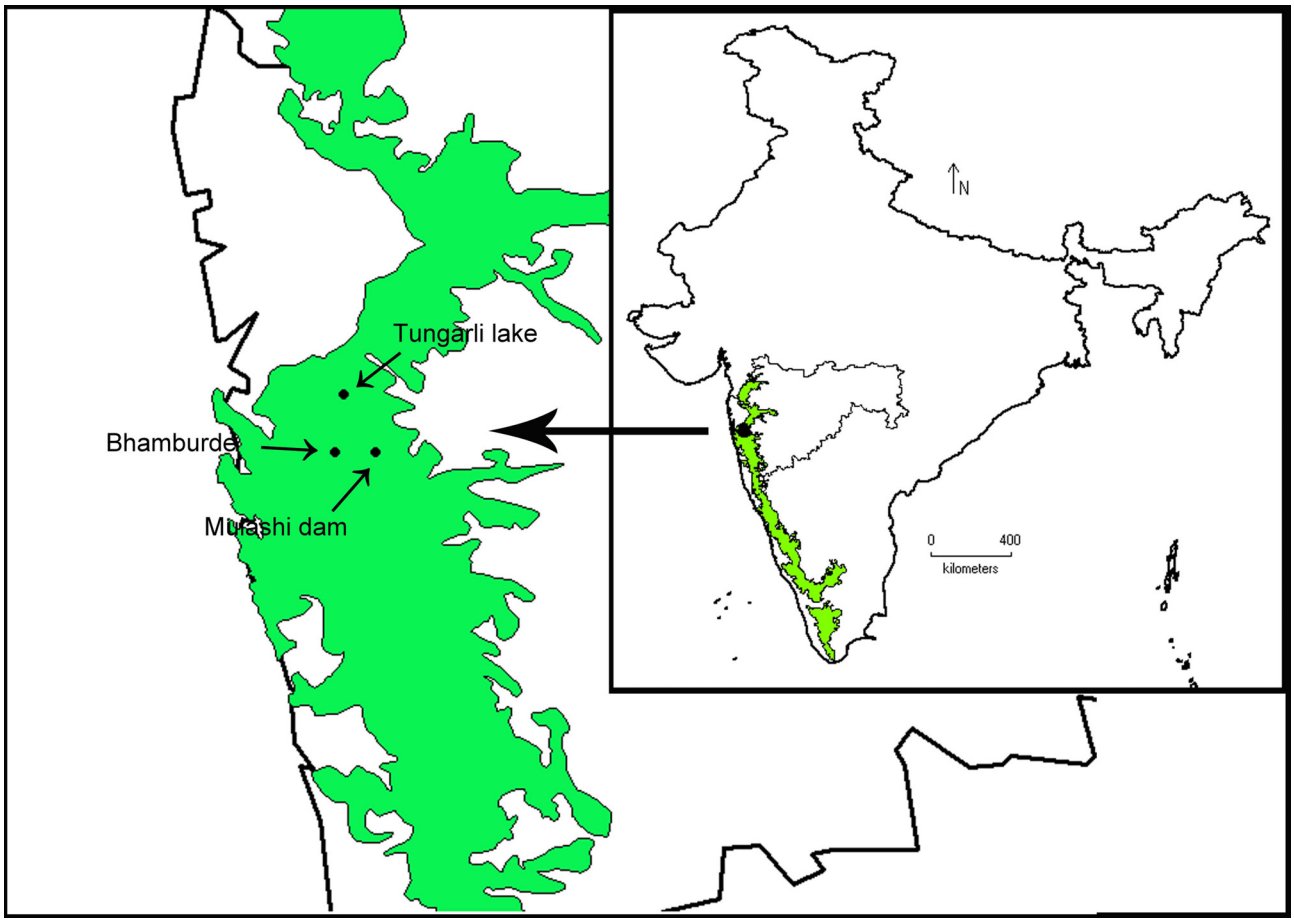

FIGURE 1. Map showing collection localities of *Fejervarya marathi* **sp. nov.**

Results

Generic allocation. The new species is assignable to the genus *Fejervarya* based on the morphological characters (small to large sized frogs with pointed to rounded snout; relatively small tympanum; elongated to shovel shaped inner metatarsal tubercle; small to large webbing between toes; with or without rictal glands and presence of fejervaryan lines on the ventral side of the body) (Table 4) assigned by Bolkay (1915) and Dubois *et al*. (2001) and the phylogenetic position within the larger *'Fejervarya* clade' (Fig. 2) (Dinesh *et al*. 2015, 2017; Raj *et al.* 2018).

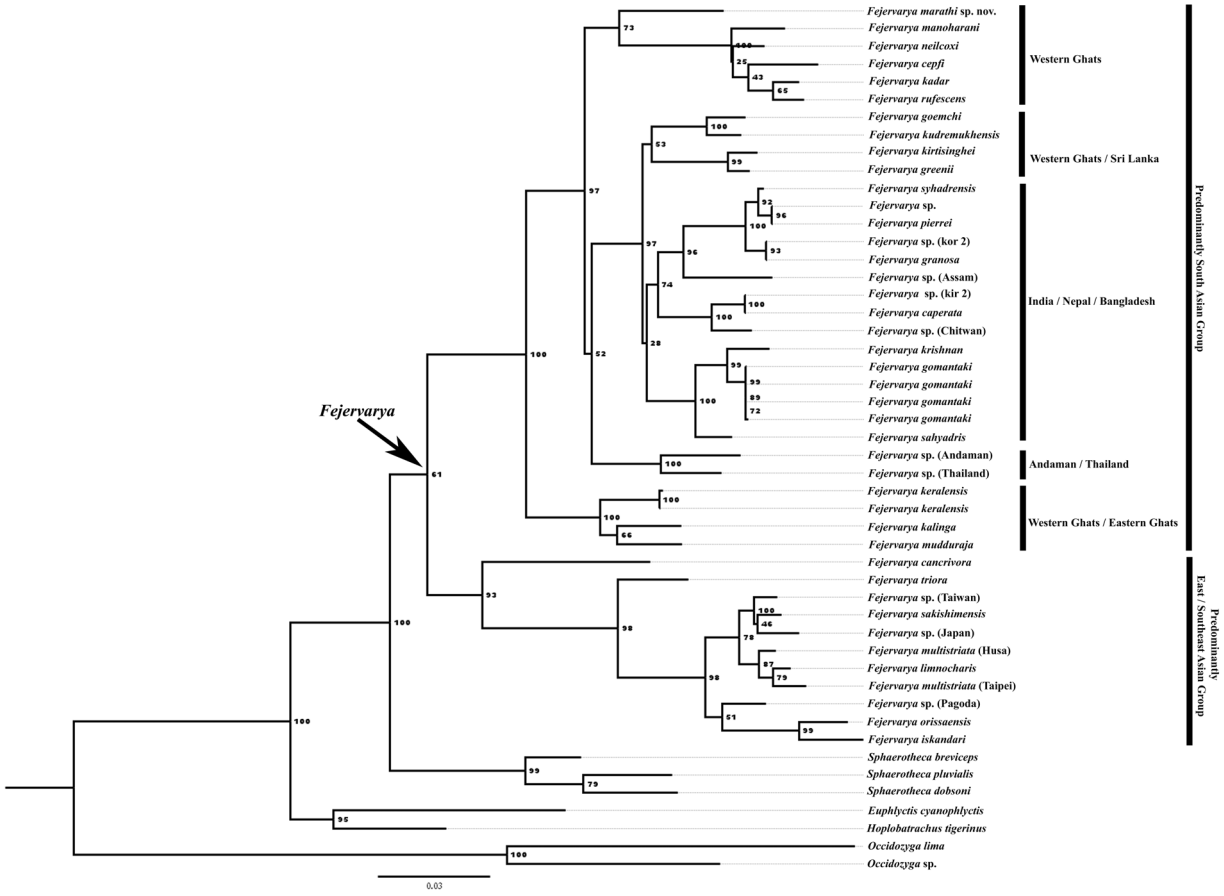

FIGURE 2. Maximum Likelihood tree based on 5429 bp of mitochondrial (16S and 12S) and nuclear genes (BDNF, Rhod, Tyr, RAG-2, NCX1, and CXCR4).

Species Description

Fejervarya marathi sp. nov.

(Table 1, 2 and 3; Fig. 2, 3, 4,5, 6, 7 and 8)

Holotype. ZSI/WRC/A/2121 (SVL 38.3 mm) an adult male collected by Samadhan Phuge, Ramnath Andhale and Kalyani Bhakare in July 2017 from Bhamburde village (N 18.5509; E 73.3790, 670 amsl), Pune , Maharashtra.

Paratypes. ZSI/WRC/A/2122 (SVL 46.8 mm) and ZSI/WRC/A/2123 (SVL 41.7 mm) adult females collected by Samadhan Phuge, Ramnath Andhale and Kalyani Bhakare in July 2017 from Bhamburde village (N 18.5509; E 73.3790, 670 amsl), Pune , Maharashtra.

Lineage Diagnosis. *Fejervarya marathi* **sp. nov.** can be diagnosed as a member of the fejervaryan clade (Fig. 2) (Dinesh *et al*. 2015, 2017; Raj *et al.* 2018), showing a sister relationship with a clade comprising the species *F. rufescens*, *F. manoharani*, *F. neilcoxi*, *F. kadar* and *F. cepfi* exhibiting high genetic divergence (10.6% to 11.3%) for 16s rRNA. Among the members of the sister clade, *F. cepfi* is sympatric with the new species. The new species is distinct from its sympatric phylogenetic sister (*F. cepfi*) species in morphology (Fig. 8) and can be distinguished from *F. cepfi* in having larger adult male size of SVL 34.6–38.3, n=4 (vs. medium adult male size of SVL 29.9 mm to 33.1 mm, n=2 in *F. cepfi*); lower HW/SVL ratio of 0.319 to 0.331, n=4 (vs. higher HW /SVL ratio of 0.369 to 0.375, n=2 in *F. cepfi*); lower IN/SVL ratio of 0.068 to 0.073, n=4 (vs. higher IN/SVL ratio of 0.076 to 0.084, n=2 in *F. cepfi*); higher NE/SVL ratio of 0.085 to 0.094, n=4 (vs. lower NE/SVL ratio of 0.054 to 0.060, n=2 in *F. cepfi*); higher SL/SVL ratio of 0.167 to 0.174, n=4 (vs. lower SL/SVL ratio of 0.145 to 0.154, n=2 in *F. cepfi*); higher EL/

SVL ratio of 0.118 to 0.127, n=4 (vs. lower EL/SVL ratio of 0.106 to 0.114, n=2 in *F. cepfi*); lower IUE/SVL ratio of 0.041 to 0.070, n=4 (vs. higher IUE/SVL ratio of 0.076 to 0.080, n=2 in *F. cepfi*); higher TYD/SVL ratio of 0.062 to 0.074, n=4 (vs. lower TYD/SVL ratio of 0.054 to 0.060, n=2 in *F. cepfi*); inner metatarsal tubercle rounded and fleshy (vs. inner metatarsal tubercle shovel shaped in *F. cepfi*); webbing between toes medium (vs. webbing between toes small (touching second subarticular tubercle on toe IV) in *F. cepfi*).

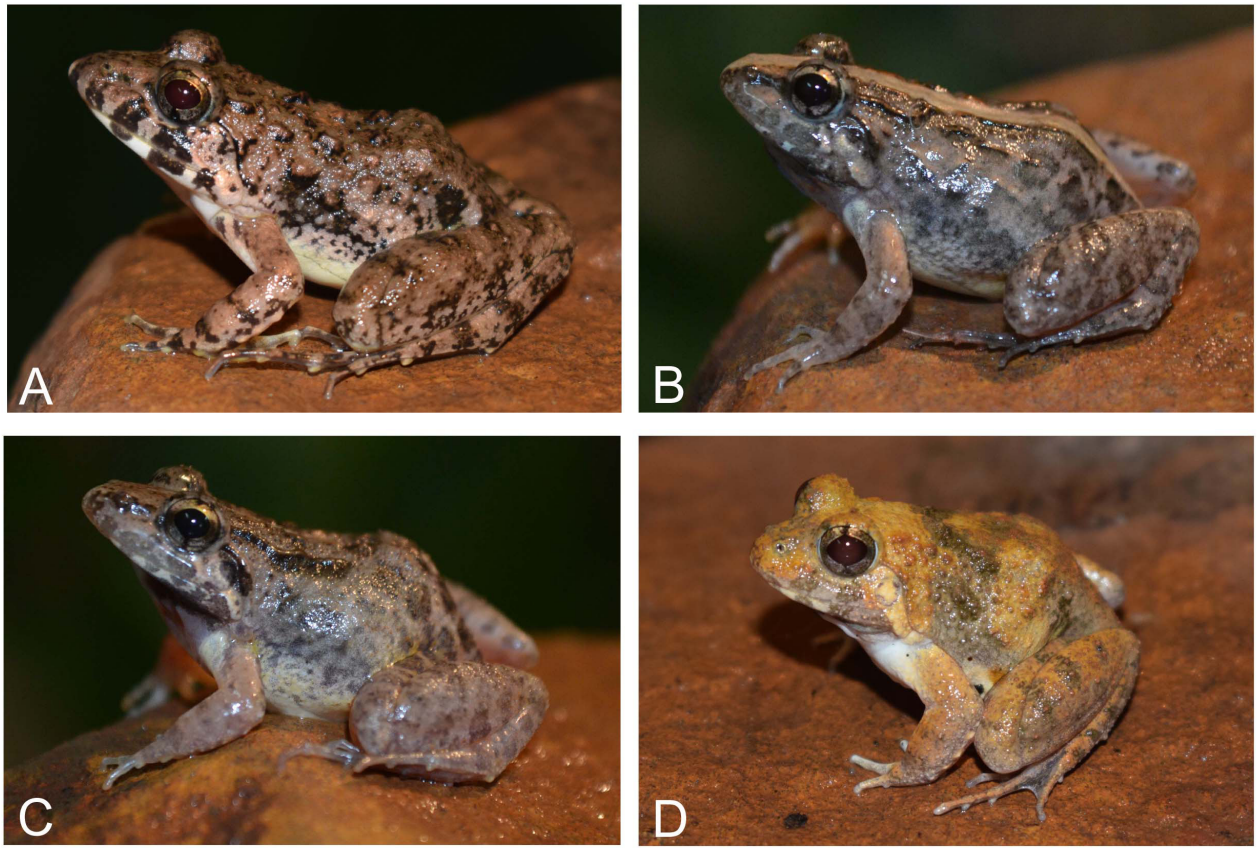

FIGURE 3. (A) Holotype (male) of *Fejervarya marathi* **sp. nov.** in life; and three sympatric frog species (B) *Fejervarya syhadrensis*, (C) *Fejervarya granosa* and (D) *Fejervarya cepfi*.

Field diagnosis. ***Morphology***. In the field, there are no morphologically confusing congeneric sympatric species for *Fejervarya marathi* **sp. nov.** and it can be identified based on the combination of morphological characters including medium to large adult size (male SVL = 34.6 to 38.3 mm, n=4; female SVL = 41.7 to 48.3 mm, n=4); elongated lean body; head length more than head width; pointed snout; inter orbital space equal to upper lid; fore arm length sub equal to hand length; first finger longer than the second; tibio-tarsal articulation reaching the nostrils; femur length less than tibia length; webbing between toes medium (I 1-2½ II 2-3 III 2-2½ IV 2-1 V); inner metatarsal tubercle round, fleshy; glandular tuberculated dorsum; throat and belly smooth; upper lip barred extensively compared to the lower lip and presence of rictal glands. In the comparison section the new species *Fejervarya marathi* **sp. nov.** is compared with its sympatric congeneric species *F. cepfi*, *F. syhadrensis* and *F. granosa*.

Geography. *Fejervarya marathi* **sp. nov.** is distributed in the northern Western Ghats parts of Pune, Maharashtra (around Bhamburde village, Tungarli lake Lonavala and Mulashi dam at an altitude 590-700 m from the sea level). Among the members of its phylogenetic sister clade, the new species is sympatric with *F. cepfi* and allopatric in distribution with the rest of the species, *F. rufescens*, *F. manoharani*, *F. kadar* and *F. neilcoxi*.

Description of Holotype ZSI/WRC/A/2121 (Fig. 3, 4 and 5)**.** A large sized fejervaryan frog (SVL = 38.3 mm) with elongated lean body; head length larger than head width (HL = 14.5 mm; HW = 12.2 mm); snout sharply pointed (SL = 6.6 mm) in both dorsal and ventral view and more than eye diameter (EL = 4.9 mm); canthus rostralis angular, loreal region flat, inter orbital space flat (IUE = 1.6 mm) less than upper lid (UEW = 3.3 mm) and internarial distance (IN = 2.7 mm); distance between back of eyes 1.5 times more than front of eyes (IFE = 5.8 mm;

IBE = 8.7 mm); nostrils oval, nearer to tip of snout; symphysial knob moderate, 'W' shaped; tympanum distinct visible below the supratympanic fold (TYD = 2.4 mm); vomerine ridges present with 2 to 3 spinose teeth; tongue bifid without a papilla.

Fore arm slender, short (FLL = 7.7 mm) and sub equal to hand (HAL = 8.9 mm); fingers short and thin rounded, without any dermal fringes; first finger longer than the second (FL1=3.8 mm, FL2=3.2 mm, TFL =5.1 mm), tips blunt, rounded without any enlarged discs, webbing between fingers absent; subarticular tubercles distinct (one each on finger 1 and 2, and two each on finger 3 and 4) , rounded and pre-pollex tubercle distinct (two on either side), supernumerary tubercles absent.

Hind limbs long, strongly overlapping when folded at right angles to the body and tibio-tarsal articulation reaches nostrils; femur length less than tibia length (FL = 16.6 mm; TiL = 20.3 mm); foot length is 1.92 times tarsus length (FOL = 22.7 mm, TAL = 11.4 mm), relative toe length I<II<V<III<IV (FTL = 13.7 mm); webbing between toes medium (I 1-2½ II 2-3 III 2-2½ IV 2-1 V) webbing touching below the second subarticular tubercle of toe IV; inner metatarsal tubercle (IMT = 1.2 mm) medium rounded and fleshy; outer metatarsal tubercle minute, bulbous; supernumerary tubercles absent and tarsal tubercle absent.

Overall skin on the dorsum glandular with tubercles, finely granular with minute ridges on the upper eyelid, flanks and belly smooth; ventrally smooth on throat and belly. Rictal gland present at the mouth commissural region below the tympanum. Raised short elongated glandular ridges on either side the back of the dorsum.

In life, color on the dorsum light brown, mottled blackish patch from the back of the tympanum till the groin covering the sides of belly, tympanic region cream brownish in colour. Upper lip, lower lip, fore arm and hind limbs barred. Back of thighs reticulated with brown and light yellow. Ventral region creamish white, blackish fejervaryan lines on either side of the belly conspicuous only in life.

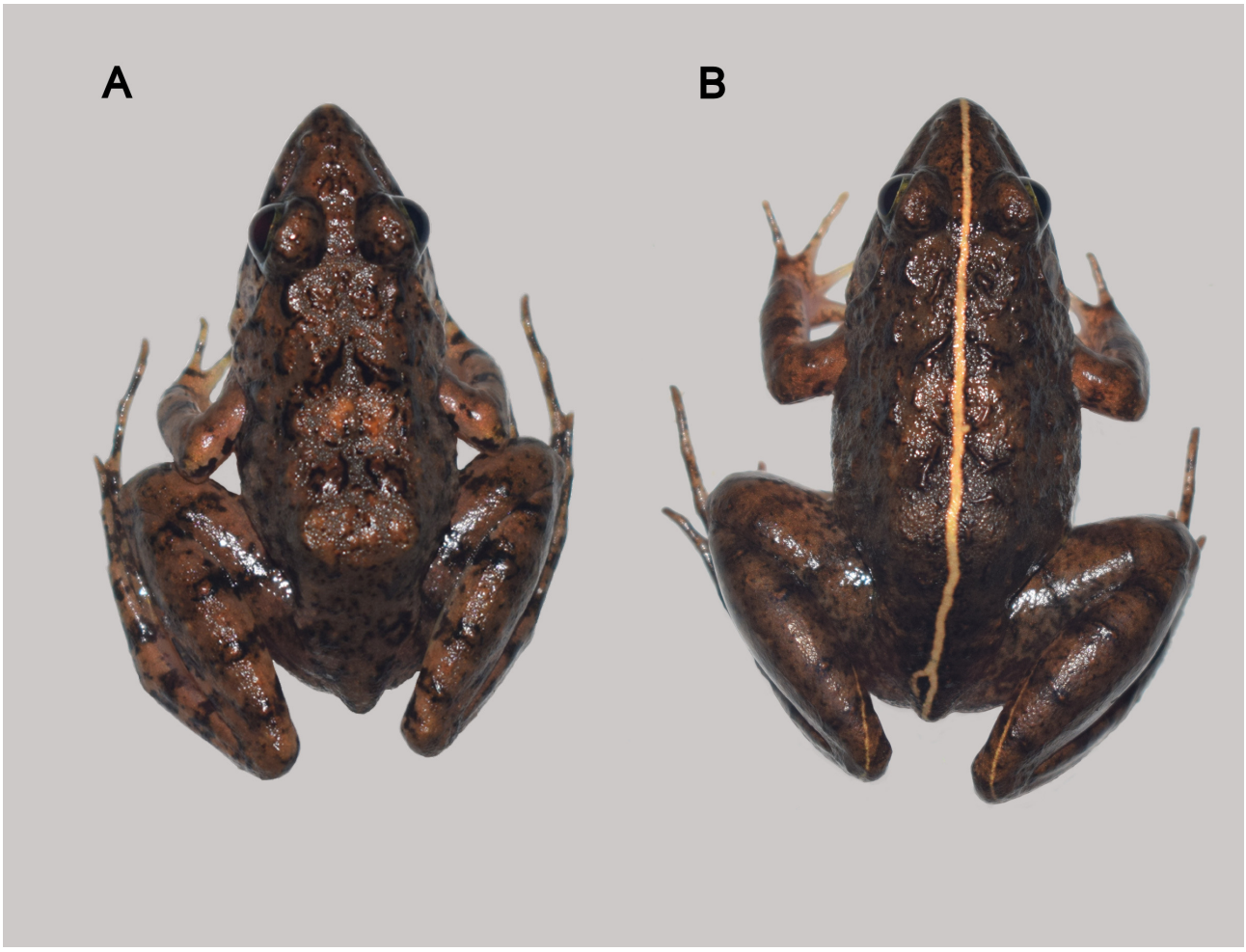

FIGURE 4. Dorsal view of holotype (A) and paratype (B) in life. Note the mid-dorsal line on the paratype.

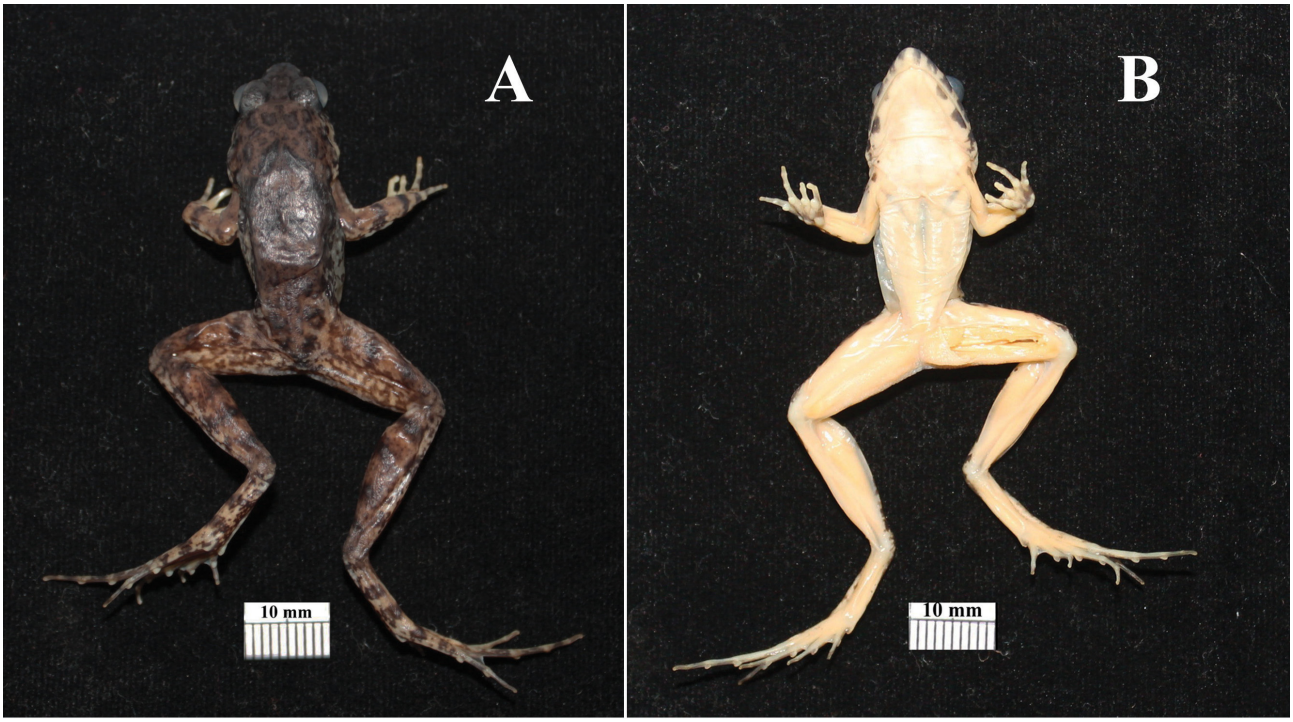

FIGURE 5. Dorsal and ventral view of Holotype in preservation.

In preservative, color on the dorsum more blackish brown, mottled pattern from the back of the tympanum till the groin covering the sides of belly. Region between the eyes and tympanum, half of the tympanum and the region of rictal gland with cream white patch. Upper lip, lower lip, fore arm and hind limbs barred. Back of thighs reticulated with brown and creamish white, ventral region creamish white (Fig. 5).

Secondary sexual characters. Males have blackish external vocal sacs on the throat region which is conspicuous only in life; no thumb pads on the first finger. Males are smaller than the females among the breeding pairs (Fig. 6A).

Additional information from paratypes and variations. Morphometric data are given in the Table 1. Paratypes range from 41.7 mm to 46.8 mm and reference collections range from 34.6 mm to 48.3 mm. In the external morphological characters, mid dorsolateral line was not a consistent character (there is a presence of white mid dorsolateral stripe from tip of snout to back of vent in paratypes (Fig. 4B) and absent in the holotype (Fig. 4A)).

Etymology. The specific epithet is derived from the indigenous language "Marathi" which is one of the predominant language used in the northern Western Ghats. The species epithet is treated as noun in apposition to the generic name. Suggested common name 'Marathi *Fejervarya* frog'.

Distribution and natural history. *Fejervarya marathi* **sp. nov.** is distributed in the northern Western Ghats parts of Pune district, Maharashtra. The new species was seen around Bhamburde village, Tungarli lake near Lonavala and Mulashi dam (Fig. 1) in the month of July (2016 and 2017). All the three localities are situated at altitude 590-700 m from the sea level. Natural history observations were made during the second week of July 2016 at Bhamburde village. The frogs were seen around the pools, grasslands and in the paddy fields, and they were found to be locally abundant. Males of *Fejervarya marathi* **sp. nov.** started calling around 19:00 h generally when there is break in rain spell. During late night, male and female frogs were seen in axillary amplexus (Fig. 6A). We observed an amplecting pair laying eggs at the edge of the very shallow temporary pool (Fig. 6B). In one instance, we observed a crab predating on the eggs (Fig. 6C) of the new species. In the span of one week, most of the breeding activity was over. During our next visit (third week of July 2016) to the same site, we could not see any calling males, amplexus or the freshly laid egg clutches; however, a few large sized adults were seen around.

***Vocalization*.** We used a note centered approach to describe the call (Köhler *et al*. 2017). The call of *Fejervarya marathi* **sp. nov.** is complex and lasts for a duration of 45.51 sec (Fig. 7A). A typical call of *Fejervarya marathi* **sp. nov.** is composed of a series of 24 notes with increasing number of pulses (Fig. 7A, B and C). Analysis

of the temporal structure of the call revealed a pulsed nature of the notes. The first note of the call comprises a single pulse, and number of pulses increases in successive notes (Fig. 7B and C). The call contains a maximum number of notes with 4 to 5 pulses (Fig. 7 A and C). In a series of notes excluding the first 1/3 portion of the call, the number of pulses in the notes may vary from 4 to 5. The spectrogram showed two peak frequencies, dominant frequency (2.8 KHz) and fundamental frequency (1.3 KHz; Fig. 7B and C). We noted 24ºC temperature and 99.99% humidity at the recording site while recording the call.

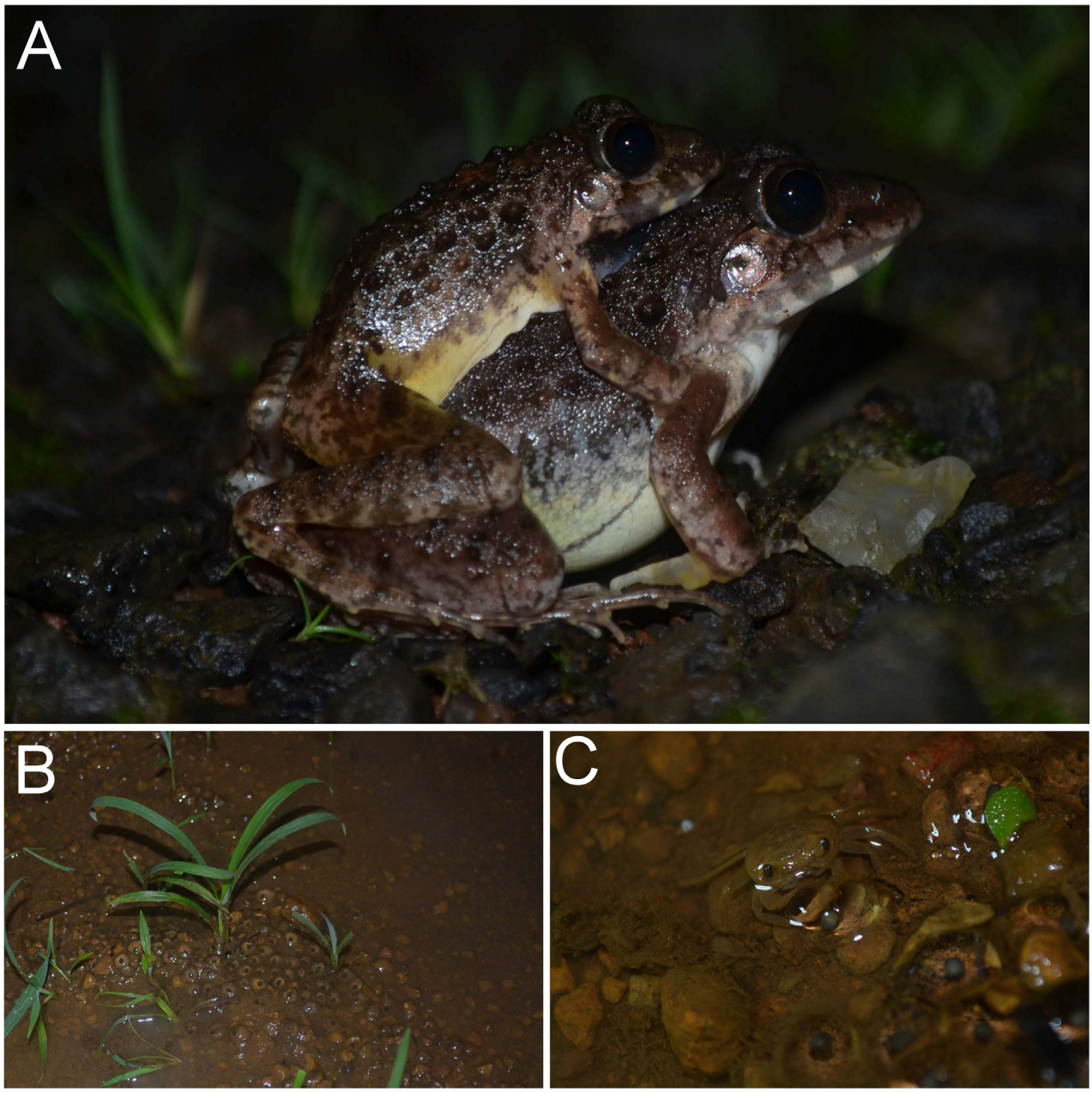

FIGURE 6. Natural history of *Fejervarya marathi* **sp. nov.** (A) Amplecting pair, (B) egg mass attached to grass, (C) crab predating eggs.

Comparisons. *Fejervarya marathi* **sp. nov.** is distinct from congeneric species in a combination of morphological characters, medium to large adult size (male SVL = 34.6 to 38.3 mm, n=4; female SVL = 41.7 to 48.3 mm, n=4); elongated lean body; head length more than head width; pointed snout; inter orbital space equal to upper lid; fore arm length sub equal to hand length; first finger longer than the second; tibio-tarsal articulation reaching the nostrils; femur length less than tibia length; webbing between toes medium (I 1-2½ II 2-3 III 2-2½ IV 2-1 V) webbing touching below the second subarticular tubercle of toe IV; inner metatarsal tubercle round, fleshy;

glandular tuberculated dorsum; throat and belly smooth; upper lip barred extensively compared to the lower lip and presence of rictal glands. Additionally, we provide morphological comparisons with its sympatric species *F. cepfi* (see lineage diagnosis), *F. syhadrensis* and *F. granosa* (Fig. 3 and Fig. 8).

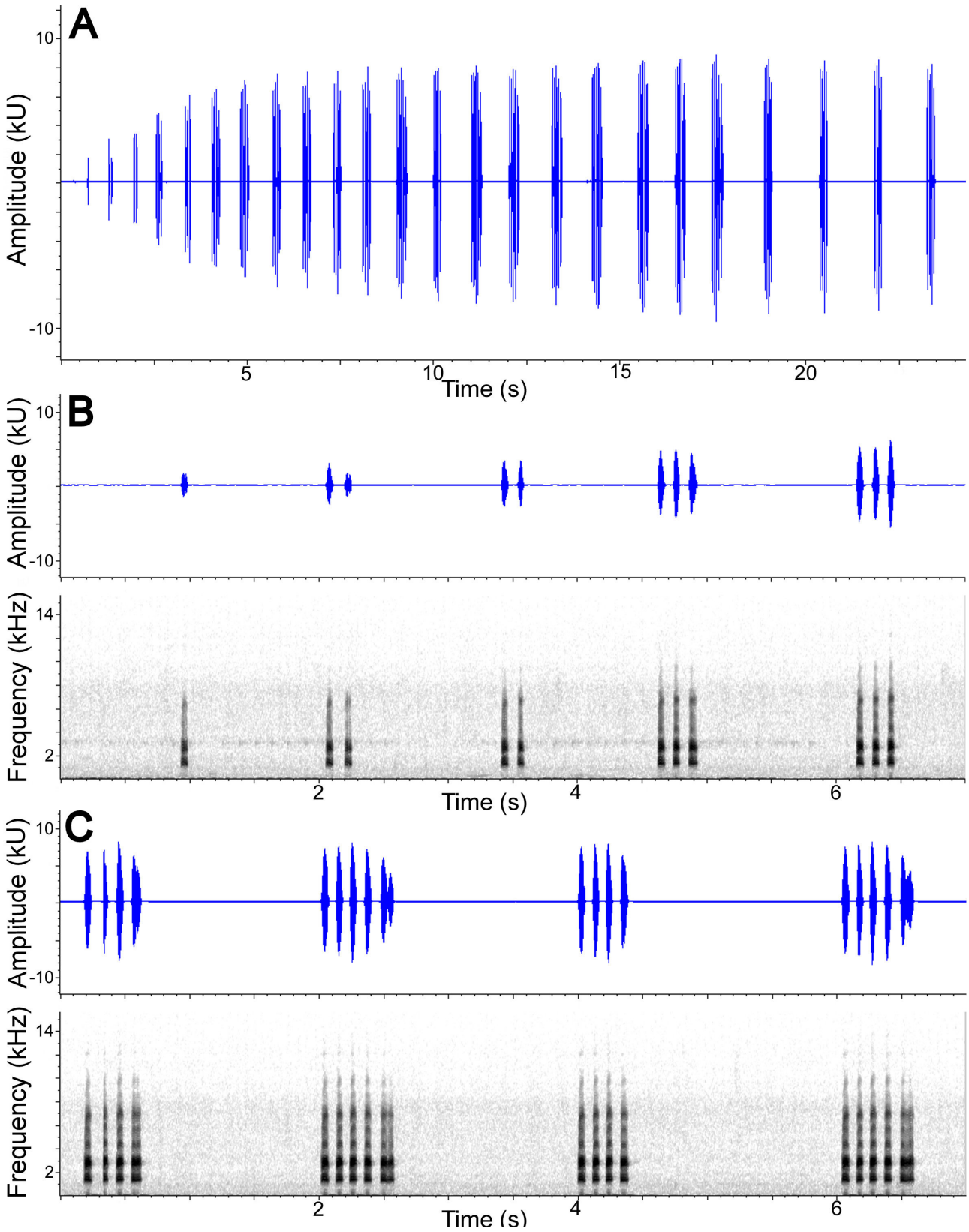

FIGURE 7. Call structure of *Fejervarya marathi* **sp. nov.** (A) Complete call, (B) microtemporal structure and spectrogram of first five notes (of Fig. 8A) in call, and (C) microtemporal structure and spectrogram of 11 to 14 notes (of Fig. 8A) in call.

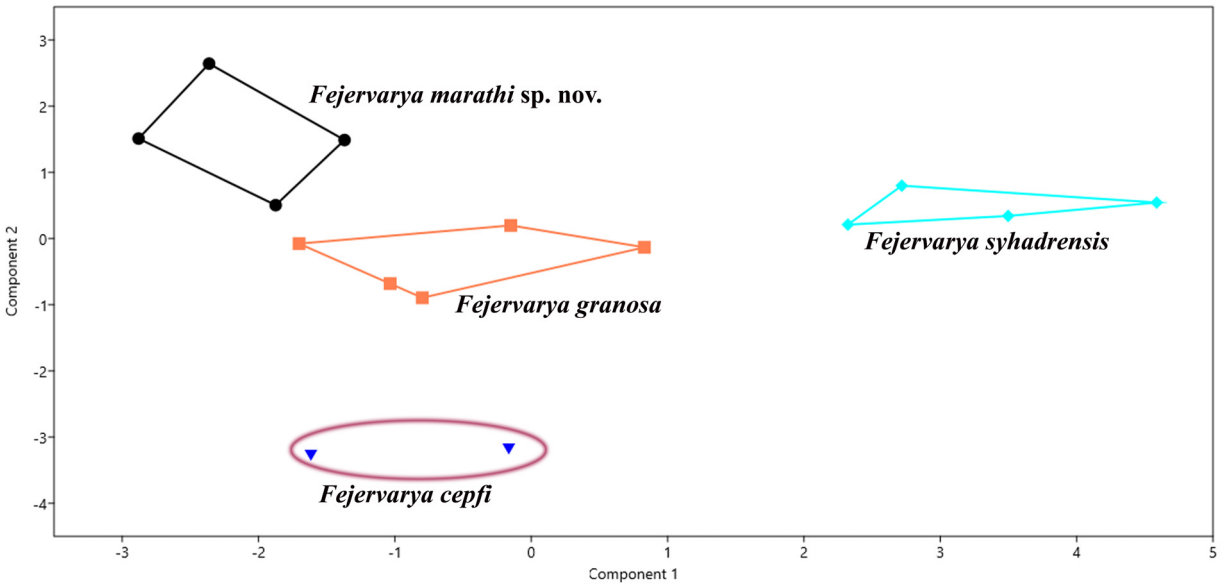

FIGURE 8. Multivariate Principal Component Analysis for male individuals using 12 morphometric characters marked as * in Table 1 transformed to their ratio to SVL for *Fejervarya marathi* **sp. nov**., *F. syhadrensis*, *F. granosa*, *F. cepfi*.

Multivariate Principal Component Analysis (PCA) comparing this species with the sympatric species suggests a considerable morphological separation between *Fejervarya marathi* **sp. nov.** and others (*F. cepfi, F. syhadrensis* and *F. granosa*) (Fig. 8). PC1 accounted for 43.61% variance and PC2 accounted for 20.83% variance (Table 2).

Fejervarya marathi **sp. nov.** can be distinguished from *F. syhadrensis* in having larger adult male size of SVL 34.6–38.3, n=4 (vs. medium adult male size of SVL 28.5–30 mm, n=4 in *F. syhadrensis*); lower HW/SVL ratio of 0.319 to 0.331, n=4 (vs. higher HW/SVL ratio of 0.351 to 0.357, n=4 in *F. syhadrensis*); higher HL/SVL ratio of 0.369 to 0.377, n=4 (vs. lower HL/SVL ratio of 0.320 to 0.336, n=4 in *F. syhadrensis*); lower IN/SVL ratio of 0.068 to 0.073, n=4 (vs. higher IN/SVL ratio of 0.098 to 0.130, n=4 in *F. syhadrensis*); higher MN/SVL ratio of 0.306 to 0.328, n=4 (vs. lower MN/SVL ratio of 0.221 to 0.237, n=4 in *F. syhadrensis*); higher MFE/SVL ratio of 0.222 to 0.237, n=4 (vs. lower MFE/SVL ratio of 0.158 to 0.197, n=4 in *F. syhadrensis*); higher MBE/SVL ratio of 0.142 to 0.151, n=4 (vs. lower MBE/SVL ratio of 0.084 to 0.103, n=4 in *F. syhadrensis*); higher SL/SVL ratio of 0.167 to 0.174, n=4 (vs. lower SL/SVL ratio of 0.159 to 0.161, n=4 in *F. syhadrensis*); lower EL/SVL ratio of 0.118 to 0.127, n=4 (vs. higher EL/SVL ratio of 0.140 to 0.157, n=4 in *F. syhadrensis*); lower IUE/SVL ratio of 0.041 to 0.070, n=4 (vs. higher IUE/SVL ratio of 0.073 to 0.083, n=4 in *F. syhadrensis*); lower FLL/SVL ratio of 0.196 to 0.201, n=4 (vs. higher FLL/SVL ratio of 0.422 to 0.435, n=4 in *F. syhadrensis*); webbing between toes medium (webbing touching below the second subarticular tubercle of toe IV) (vs. webbing between toes low (touching between first and second subarticular tubercle on toe IV) in *F. syhadrensis*); dorsum glandular with ridged folds (vs. dorsum smooth with irregular longitudinal folds but not glandular in *F. syhadrensis*).

Fejervarya marathi **sp. nov.** can be distinguished from *F. granosa* in having larger adult male size of SVL 34.6–38.3, n=4 (vs. medium adult male size of SVL 26.7–30.4 mm, n=5 in *F. granosa*); lower IN/SVL ratio of 0.068 to 0.073, n=4 (vs. higher IN/SVL ratio of 0.075 to 0.089, n=5 in *F. granosa*); lower IUE/SVL ratio of 0.041 to 0.070, n=4 (vs. higher IUE/SVL ratio of 0.075 to 0.080, n=5 in *F. granosa*); lower IFE/SVL ratio of 0.151 to 0.163, n=4 (vs. higher IFE/SVL ratio of 0.171 to 0.178, n=5 in *F. granosa*); lower WBS/SVL ratio of 0.279 to 0.304, n=4 (vs. higher WBS/SVL ratio of 0.341 to 0.372, n=5 in *F. granosa*); lower WFG/SVL ratio of 0.084 to 0.127, n=4 (vs. higher WFG/SVL ratio of 0.262 to 0.306, n=5 in *F. granosa*); webbing between toes medium (webbing touching below the second subarticular tubercle of toe IV) (vs. webbing between toes low (touching the first subarticular tubercle on toe IV) in *F. granosa*); dorsum glandular with ridged folds (vs. dorsum smooth with granular rounded tubercles in *F. granosa*).

TABLE 1. Morphometric data (in mm) for the type series and reference collections of *Fejervarya marathi* **sp. nov.**

	ZSI/WRC/ A/2121#	ZSI/WRC/ A/2124&	ZSI/WRC/ A/2125&	ZSI/WRC/ A/2126&	Average ± SD (Range)	ZSI/WRC/ A/2122$	ZSI/WRC/ A/2123$	ZSI/WRC/ A/2127&	ZSI/WRC/ A/2128&	Average ± SD (Range)
Sex	Male	Male	Male	Male		Female	Female	Female	Female	
SVL	38.3	37.7	37.1	34.6	36.9 ± 1.64 (34.6–38.3)	46.8	41.7	48.3	44.4	45.3 ± 2.88 (41.7–48.3)
HW*	12.2	12.2	12.2	11.4	12.0 ± 0.40 (11.4–12.2)	15.6	14.1	16.4	15.0	15.3 ± 0.96 (14.1–16.4)
HL*	14.5	14.0	13.7	13.0	13.8 ± 0.59 (13.0–14.5)	16.5	15.8	17.0	17.2	16.6 ± 0.61 (15.8–17.2)
IN*	2.7	2.6	2.6	2.5	2.6 ± 0.06 (2.5 -2.7)	3.2	3.6	3.1	3.5	3.3 ± 0.24 (3.1–3.6)
NE*	3.6	3.3	3.2	3.1	3.3 ± 0.23 (3.1–3.6)	4.4	4.2	4.1	4.0	4.2 ± 0.17 (4.0–4.4)
MN	12.6	11.5	11.6	10.9	11.6 ± 0.69 (10.9–12.6)	13.5	13.6	14.0	14.0	13.8 ± 0.28 (13.5–14.0)
MFE	8.8	8.4	8.7	8.2	8.5 ± 0.28 (8.2–8.8)	9.5	10.2	10.4	10.5	10.2 ± 0.48 (9.5–10.5)
MBE	5.5	5.4	5.6	4.9	5.4 ± 0.31 (4.9–5.6)	6.1	7.2	6.6	6.6	6.6 ± 0.42 (6.1–7.2)
SL*	6.6	6.5	6.2	6.0	6.3 ± 0.27 (6.0–6.6)	8.1	7.9	8.1	8.4	8.1 ± 0.19 (7.9–8.4)
EL*	4.9	4.5	4.7	4.2	4.6 ± 0.29 (4.2–4.9)	5.1	5.0	4.9	5.4	5.1 ± 0.19 (4.9–5.4)
IUE*	1.6	2.1	2.6	2.0	2.1 ± 0.42 (1.6–2.6)	2.1	1.8	2.1	2.5	2.1 ± 0.28 (1.8–2.5)
UEW	3.3	3.0	2.8	2.6	2.9 ± 0.31 (2.6–3.3)	4.3	3.9	3.9	3.8	4.0 ± 0.22 (3.8–4.3)
IFE	5.8	5.9	5.8	5.6	5.8 ± 0.10 (5.6–5.9)	7.1	7.0	6.8	7.2	7.0 ± 0.16 (6.8–7.2)
IBE	8.7	8.5	8.7	8.0	8.5 ± 0.34 (8.0–8.7)	10.0	10.4	10.7	10.4	10.4 ± 0.31 (10.0–10.7)
TYD*	2.4	2.3	2.4	2.6	2.4 ± 0.13 (2.3–2.6)	2.8	2.9	2.7	3.1	2.9 ± 0.20 (2.7–3.1)
TE	1.3	1.8	1.9	1.6	1.7 ± 0.24 (1.3–1.9)	2.2	2.3	2.6	2.0	2.3 ± 0.22 (2.0–2.6)
FLL*	7.7	7.4	7.3	7.0	7.3 ± 0.29 (7.0–7.7)	9.1	8.8	9.7	9.2	9.2 ± 0.38 (8.8–9.7)
HAL*	8.9	8.5	7.6	7.8	8.2 ± 0.64 (7.6–8.9)	10.7	9.9	10.0	11.0	10.4 ± 0.52 (9.9–11.0)
FL1	3.8	3.5	3.2	4.1	3.7 ± 0.40 (3.2–4.1)	4.2	4.6	4.2	5.0	4.5 ± 0.37 (4.2–5.0)
FL2	3.2	3.2	3.1	3.1	3.2 ± 0.08 (3.1–3.2)	4.0	3.8	4.0	4.6	4.1 ± 0.35 (3.8–4.6)
TFL	5.1	4.8	4.3	4.1	4.6 ± 0.47 (4.1–5.1)	6.2	5.5	5.7	6.9	6.1 ± 0.63 (5.5–6.9)
AGL	16.2	17.4	19.2	16.2	17.2 ± 1.42 (16.2–19.2)	21.9	16.8	24.7	21.8	21.3 ± 3.30 (16.8–24.7)
WBS	10.7	11.5	11.2	10.3	10.9 ± 0.51 (10.3–11.5)	15.8	12.9	17.4	14.2	15.1 ± 1.95 (12.9–17.4)
WFG	3.5	3.2	4.7	3.8	3.8 ± 0.67 (3.2–4.7)	4.6	4.2	5.1	6.5	5.1 ± 1.01 (4.2–6.5)
ShL/FL*	16.6	15.2	16.9	16.1	16.2 ± 0.73 (15.2–16.9)	22.4	22.0	19.7	20.9	21.2 ± 1.22 (19.7–22.4)
TiL	20.3	19.7	19.1	20.2	19.8 ± 0.57 (19.1–20.3)	25.5	23.9	25.0	26.5	25.2 ± 1.10 (23.9–26.5)
Tal	11.4	9.2	9.7	10.9	10.3 ± 1.03 (9.2–11.4)	13.1	12.3	12.3	13.4	12.8 ± 0.57 (12.3–13.4)
FOL*	22.7	20.5	19.8	19.1	20.5 ± 1.55 (19.1–22.7)	26.0	24.0	24.4	26.1	25.1 ± 1.06 (24.0–26.1)
FTL	13.7	12.3	11.5	12.1	12.4 ± 0.92 (11.5–13.7)	15.5	14.5	15.1	15.5	15.2 ± 0.50 (14.5–15.5)
ITL	4.0	4.0	3.6	3.8	3.8 ± 0.23 (3.6–4.0)	5.1	4.5	5.1	5.0	4.9 ± 0.26 (4.5–5.1)
IMT	1.2	1.5	1.3	1.5	1.4 ± 0.13 (1.2–1.5)	2.1	1.4	2.1	2.0	1.9 ± 0.34 (1.4–2.1)

* data used for PCA analysis; # holotype; $ paratype; & other referred specimens

TABLE 2. Factor loadings of Principal Component Analysis for male individuals for a total of 12 morphometric characters marked as * in Table 1 transformed to their ratio to SVL.

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10	PC 11	PC 12
HW	0.22891	-0.4064	0.11064	0.28295	0.26254	0.60556	-0.2258	0.16038	0.26156	0.06543	-0.296	-0.1322
HL	-0.3628	-0.0801	0.17253	0.42299	0.20296	0.17537	0.11209	0.19469	-0.1618	0.12635	0.54835	0.43365
IN	0.41736	-0.0772	0.07706	-0.0421	0.07633	0.19078	0.28367	0.08144	-0.4693	-0.4509	0.35274	-0.3672
NE	0.18183	0.51985	0.19058	-0.1262	0.06548	0.28655	0.13746	0.02718	-0.167	0.68925	0.02001	-0.1872
SL	-0.1112	0.35785	0.52753	0.18046	-0.0897	0.10599	0.44933	-0.0691	0.36195	-0.3726	-0.2277	0.03274
EL	0.37286	0.27059	-0.0907	-0.0538	0.22827	0.01311	-0.2608	-0.2671	0.53838	-0.1102	0.52304	0.09718
IUE	0.24632	-0.4006	0.23154	-0.2662	-0.2304	-0.2527	0.3216	0.43567	0.36398	0.25935	0.20917	0.02654
TYD	0.26275	0.24141	0.39035	0.27369	-0.1096	-0.3427	-0.5477	0.41311	-0.1746	-0.0935	-0.0691	0.03759
FLL	0.39244	0.1229	-0.2071	-0.1969	0.17504	0.1009	0.18861	0.18162	-0.1505	-0.1107	-0.2939	0.72013
HAL	0.28572	-0.0191	-0.2073	0.42546	-0.7564	0.1879	0.05224	-0.2206	-0.0217	0.09771	0.06924	0.14247
ShL/FL	0.30312	-0.2303	0.16522	0.37582	0.34879	-0.4576	0.22713	-0.4689	-0.1107	0.22929	-0.1378	0.01837
FOL	0.01123	0.25233	-0.5568	0.42552	0.1732	-0.1911	0.2719	0.43699	0.19518	0.00575	-0.0529	-0.2697
Explained variance (%)	43.61	20.83	15.58	8.85	4.03	3.47	1.40	0.99	0.53	0.43	0.18	0.02
Eigenvalue	5.23	2.50	1.87	1.06	0.48	0.41	0.16	0.11	0.06	0.05	0.02	0.003

TABLE 3. Morphological groups proposed by Garg & Biju, 2017 (modified after Dinesh *et al.* 2017) for the members of the *Fejervarya* in the Western Ghats

	Nilagirica group	**Syhadrensis group**	**Rufescens group**	**Sahyadris group**
Size	medium to large adult size (male SVL 32.0–50.0 mm, female SVL 36.0–65.0 mm)	medium adult size (male SVL 25.0–31.0 mm, female SVL 27.0–42.0 mm)	medium adult size (male SVL 28.0–35.0 mm, female SVL 32.0–36.0 mm)	small adult size (male SVL 17.0–22.0 mm, female SVL 21.0–24.0 mm)
Body	elongate or robust body; head longer than wide or sub-equal; presence of rictal glands at labial commissural of the mouth	elongate body; head longer than wide	stout body; head wider than long or sub-equal; presence of rictal glands at labial commissural of the mouth	slender body; head longer than wide; presence of rictal glands at labial commissural of the mouth and a white horizontal band along the upper lip
Webbing	large webbing between toes (beyond the first subarticular tubercle on either side of toe IV).	medium webbing between toes (beyond the second subarticular tubercle but not beyond the first subarticular tubercle on either side of toe IV)	small webbing between toes (beyond the third subarticular tubercle but not beyond the second subarticular tubercle on either side of toe IV)	basal webbing between toes (slightly above the basal subarticular tubercles on all toes)
Inner metatarsal tubercle	long and cylindrical	long and cylindrical	shovel-shaped	long and cylindrical
Skin	dorsal skin with prominent folds, either continuous or discontinuous, with glandular warts or prominent granulations; dorsal chevron present; groin and thigh with prominent reticulations	dorsal skin with prominent discontinuous skin folds, with or without scattered granular projections; dorsal chevron present; groin without reticulations; thigh with faint reticulations	dorsal skin with glandular projections, spines or warts, but without longitudinal skin folds; dorsal chevron present; groin without reticulations; thigh with or without faint reticulations	dorsal skin with weakly developed longitudinal skin folds or granulations; dorsal chevron absent; groin without reticulations; thigh with faint reticulations
Members represented from the Western Ghats	*F. brevipalmata, F. keralensis, F. kudremukhensis, F. mudduraja, F. murthii, F. mysorensis, F. nilagirica, F. parambikulamana, F. sauriceps* and *F. goemchi*	*F. caperata, F. granosa, F. syhadrensis, F. modesta* and *Fejervarya marathi* **sp.nov.**	*F. cepfi, F. kadar, F. manoharani, F. neilcoxi* and *F. rufescens*	*F. sahyadris, F. gomantaki* and *F. krishnan*

Discussion

Dinesh *et al*. (2015) recognised two major groups within the larger clade *Fejervarya*, a group of *Fejervarya* species having their distribution predominantly in East / Southeast Asia, and another group of *Fejervarya* species having their distribution predominantly in South Asia. Since then, a total of 8 new species have been reported from India (Garg & Biju, 2017; Bahuguna, 2017; Dinesh *et al*. 2017; Raj *et al*. 2018) of which genetic information is not available for *F. jhilmilensis*. In our recent phylogenetic studies of the clade of *Fejervarya* species having their distribution predominantly in South Asia, five distinct sub-clades could be discerned; a sub-clade with species restricted to the Eastern Ghats and the Western Ghats (mostly medium to large sized species); a sub-clade with species restricted to the Western Ghats (mostly medium to large sized species with or without a shovel shaped inner metatarsal tubercle); a sub-clade with species distribution in Andaman Islands and Thailand (mostly medium sized species); a sub-clade with species distribution in the Western Ghats and Sri Lanka (mostly large sized species) and a sub-clade with species distribution in India, Nepal and Bangladesh (mostly small to medium sized species, with or without lower white lip and rictal glands) (Fig. 2).

Garg & Biju (2017) have recognized four morphological groups for the *Fejervarya* frogs of the Western Ghats, 'Nilagirica group', 'Syhadrensis group',' Sahyadris group' and 'Rufescens group' (Table 3). The new species *Fejervarya marathi* **sp. nov.** could not be assigned to the 'Rufescens group' as it lacks shovel shaped metatarsal tubercle in spite of being sister to the Rufescens complex phylogenetically. It is considered under the 'Syhadrensis group' based on the dorsal skin pattern and webbing, but the presence of a rictal gland in the new species is a new character for the group (Table 3). Likewise *F. goemchi* is considered under the 'Nilagirica group' based on the size and skin characters in spite of the presence of the rictal gland. With respect to the morphological character groupings for the *Fejervarya* frogs in the Western Ghats, there are multiple shared, derived morphological characters across the morphological groups.

A brief examination of species descriptions from the northern Western Ghats for the family Dicroglossidae suggest that in 1919, Annandale (1919) has described *Fejervarya syhadrensis* (as *Rana limnocharis syhadrensis*) from the Puna (now Pune) and the Satara districts of the state Maharashtra; in 2015, Dinesh *et al*. described *F. gomantaki* from Goa; Garg & Biju (2017) described *F. cepfi* from Amboli of Sindhudurg district of Maharashtra and Dinesh *et al*. (2017) described *F. goemchi* from Goa (Table 4). Interestingly, in the northern Western Ghats, all the small to medium sized *Fejervarya* frogs have a wide range of distribution; *F. granosa* described from the central Western Ghats is reported here from the type locality of the new species; *F. syhadrensis* described from Pune is distributed in Goa (Dinesh *et al*. 2017); *F. cepfi* described from Amboli is reported here from the type locality of the new species. Due to size variations and other clear cut morphological character availability, field identification of the *Fejervarya* species within the northern Western Ghats is quite simple.

In the present study, we have provided temporal call structure and spectral properties of *Fejervarya marathi* **sp. nov.** which may be helpful in distinguishing it from other *Fejervarya* frogs. In addition to the genetic and morphological characters, call properties of males can be helpful in diagnosing the species in the field, especially in the case of sympatric cryptic species (Garg & Biju, 2017; Köhler *et al*. 2017; Garg *et al*. 2018).

Fejervarya marathi **sp. nov.** is currently known from the northern Western Ghats of Pune District with limited specific locations. Therefore we suggest that *Fejervarya marathi* **sp. nov.** be included in the "Data deficient" category of the IUCN Red List warranting further species based explorative surveys. Our field observations revealed that *Fejervarya marathi* **sp. nov.** has a short breeding period. The short breeding period and secretive life cycle of *Fejervarya* frogs are the two major difficulties in the discovery of new species and determining the distribution range of these species (Garg & Biju, 2017). In addition, unpredictable sporadic monsoon showers could also be a major factor that can hamper sampling efforts. Further studies with thorough sampling from multiple localities are necessary for fully understanding the actual diversity of frogs of the genus *Fejervarya*.

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TABLE 4. Extant valid species of *Fejervarya* in the Western Ghats with type locality details

	Species	Type locality	
1	*Fejervarya marathi* sp. nov.	Bhamburde village, Pune	Northern Western Ghats
2	*Fejervarya syhadrensis* (Annandale, 1919)	Khandalla, Poona (now Pune)	
3	*Fejervarya cepfi* Garg and Biju, 2017	Amboli, Sindhudurg	
4	*Fejervarya goemchi* Dinesh, Kulkarni, Swamy and Deepak, 2018	Surla, Goa	
5	*Fejervarya gomantaki* Dinesh, Vijayakumar, Channakeshavamurthy, Torsekar, Kulkarni and Shanker, 2015	Chigule, Belgaum	
6	*Fejervarya modesta* (Rao, 1920)	Jog, Shimoga	Central Western Ghats
7	*Fejervarya mysorensis* (Rao, 1922)	Jog, Shimoga	
8	*Fejervarya krishnan* Raj, Dinesh, Das, Dutta, Kar and Mohapatra, 2018	Jog, Shimoga	
9	*Fejervarya rufescens* (Jerdon, 1854)	Manipal, Udupi	
10	*Fejervarya sahyadris* (Dubois, Ohler, and Biju, 2001)	Gundia, Hassan	
11	*Fejervarya kudremukhensis* Kuramoto, Joshy, Kurabayashi, and Sumida, 200)	Kudremukh, Chickkamagaluru	
12	*Fejervarya sauriceps* (Rao, 1937)	Wattekole, Coorg	
13	*Fejervarya mudduraja* Kuramoto, Joshy, Kurabayashi, and Sumida, 2007	Talapu, Coorg	
14	*Fejervarya caperata* Kuramoto, Joshy, Kurabayashi and Sumida, 2007	Karnoor, Dakshina Kannada	
15	*Fejervarya granosa* Kuramoto, Joshy, Kurabayashi and Sumida, 2007	Talapu, Dakshina Kannada	
16	*Fejervarya neilcoxi* Garg and Biju, 2017	Parambikulam, Palakkad	Southern Western Ghats
17	*Fejervarya parambikulamana* (Rao, 1937)	Parambikulam forests, Palakkad	
18	*Fejervarya nilagirica* (Jerdon, 1854)	Wayanad and Neelgherries	
19	*Fejervarya murthii* (Pillai, 1979)	Naduvattom, Nilgiris	
20	*Fejervarya brevipalmata* (Peters, 1871)	Southern Western Ghats	
21	*Fejervarya kadar* Garg and Biju, 2017	Vazachal, Thrissur	
22	*Fejervarya manoharani* Garg and Biju, 2017	Chathancod-Bonnacaud, Thriuvananthapuram	
23	*Fejervarya keralensis* (Dubois, 1981)	Malabar (uncertain specific locality) but from South of Palghat Gap	

References

AmphibiaWeb (2018) Amphibiaweb: information on amphibian biology and conservation. Berkeley: University of California. Available from: http://www.amphibiaweb.org/ (accessed 14 May 2018)

Annandale, N. (1919) The fauna of certain small streams in the Bombay Presidency: Some frogs from streams in the Bombay Presidency. *Records of the Indian Museum*, 16, 109–161.

Bahuguna, A. (2017) New species of *Fejervarya limnocharis* (Amphibia: Anura: Dicroglossidae) complex from conservation area, Jhilmil Jheel, Haridwar, Uttarakhand, India. *Biosystematica*, 10 (2), 11–23.

Bolkay, S.J. (1915) Beiträge zur Osteologie einiger exotischer Raniden. *Anatomischer Anzeiger*, 48, 172–183.

https://doi.org/10.5962/bhl.part.17101
Bossuyt, F., Meegaskumbura, M., Beenaerts, N., Gower, D.J., Pethiyagoda, R., Roelants, K., Mannaert, A., Wilkinson, M., Bahir, M.M., Manamendra-Arachchi, K., Ng, P.K.L., Schneider, C.J., Oommen, O.V. & Milinkovitch, M.C. (2004) Local endemism within the Western Ghats-Sri Lanka biodiversity hotspot. *Science*, 306 (5695), 479–481.
https://doi.org/10.1126/science.1100167
Bossuyt, F. & Milinkovitch, M.C. (2000) Convergent adaptive radiations in Madagascan and Asian ranid frogs reveal covariation between larval and adult traits. *Proceedings of the National Academy of Sciences of the United States of America,* 97 (12), 6585−6590.
https://doi.org/10.1073/pnas.97.12.6585
Charif, R.A., Waack, A.M. & Strickman, L.M. (2010) *Raven Pro 1.4. User's Manual*. Cornell Lab of Ornithology, Ithaca, 367 pp.
Dahanukar, N., Sulakhe, S. & Padhye, A. (2017) Identity of *Sphaerotheca pluvialis* (Jerdon, 1853) and other available names among the burrowing frogs (Anura: Dicroglossidae) of South Asia. *Journal of Threatened Taxa*, 9 (6), 10269–10285.
https://doi.org/10.11609/jot.3358.9.6.10269-10285
Dinesh, K.P., Vijayakumar, S.P., Channakeshavamurthy, B.H., Torsekar, V.R., Kulkarni, N.U. & Shanker, K. (2015) Systematic status of *Fejervarya* (Amphibia, Anura, Dicroglossidae) from South and SE Asia with the description of a new species from the Western Ghats of Peninsular India. *Zootax*a, 3999 (1), 79–94.
https://doi.org/10.11646/zootaxa.3999.1.5
Dinesh, K.P., Kulkarni, N.U., Swamy, P. & Deepak, P. (2017) A new species of *Fejervarya* Bolkay, 1915 from the lateritic plateaus of the Goa parts of the Western Ghats. *Records of the Zoological Survey of India*, 117 (4), 301–314.
http://doi.org/10.26515/rzsi/v117/i4/2017/121293
Dubois, A., Ohler, A. & Biju, S.D. (2001) A new genus and species of Ranidae (Amphibia; Anura) from southwestern India. *Alytes*, 19, 53−79.
Frost, D.R. (2018) Amphibian species of the world: An online reference. Version 6.0. Electronic Database. American Museum of Natural History, New York, USA. Available from http://research.amnh.org/herpetology/amphibia/index.html (accessed 14 May 2018)
Garg, S., Senevirathne, G., Wijayathilaka, N., Phuge, S., Deuti, K., Manamendra-Arachchi, K., Meegaskumbura, M. & Biju, S.D. (2018) An integrative taxonomic review of the South Asian microhylid genus *Uperodon*. *Zootaxa*, 4384 (1), 1–88.
https://doi.org/10.11646/zootaxa.4384.1.1
Garg, S. & Biju, S.D. (2017) Description of four new species of Burrowing Frogs in the *Fejervarya rufescens* complex (Dicroglossidae) with notes on morphological affinities of *Fejervarya* species in the Western Ghats. *Zootaxa*, 4277 (4), 451–490.
https://doi.org/10.11646/zootaxa.4277.4.1
Gunawardene, N.R., Daniels, A.E.D., Gunatilleke I.A.U.N., Gunatilleke, C.V.S., Karunakaran, P.V., Nayak, K.G., Prasad P.S., Puyravaud, P., Ramesh, B.R., Subramanian. K.A. & Vasanthy, G. (2007) Asian biodiversity crises: a brief overview of the Western Ghats—Sri Lanka biodiversity hotspot. *Current Science*, 93 (11), 1–6.
Hammer, O., Harper, D.A.T. & Ryan, P.D. (2001) PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, 4 (1), 1–9. Available from: http://palaeo-electronica.org/2001_1/past/issue1_01.htm (Accessed 10 Jan. 2019)
Köhler, J., Jansen, M., Rodríguez, A., Kok, P.J.R., Toledo, L.F., Emmrich, M., Glaw, F., Haddad, C.F.B., Rödel, M. & Vences, M. (2017) The use of bioacoustics in anuran taxonomy: theory, terminology, methods and recommendations for best practice. *Zootaxa,* 4251, 1–124.
https://doi.org/10.11646/zootaxa.4251.1.1
Kotaki, M., Kurabayashi, A., Matsui, M., Kuramoto, M., Djong, T.H. & Sumida, M. (2010) Molecular phylogeny of the diversified frogs of genus *Fejervarya* (Anura: Dicroglossidae). *Zoological Science*, 27 (5), 386–395.
https://doi.org/10.2108/zsj.27.386
Raj, P., Dinesh, K.P., Das, A., Dutta, S.K., Kar, N.B. & Mohapatra, P.P. (2018) Two new species of cricket frogs of the genus *Fejervarya* Bolkay, 1915 (Anura: Dicroglossidae) from the Peninsular India. *Records of the Zoological Survey of India*, 118 (1), 1–21.
https://doi.org/10.26515/rzsi/v118/i1/2018/121436
Sanchez, E., Biju, S.D., Islam, M.M., Hasan, M., Ohler, A., Vensis, M. & Kurabayashi, A. (2018) Phylogeny and classification of fejervaryan frogs (Anura: Discroglossidae). *Salamandra*, 54 (2), 109–116.
Silvestro, D. & Michalak, I. (2012) raxmlGUI: A graphical front-end for RAxML. *Organisms Diversity & Evolution*, 12 (4), 335–337.
https://doi.org/10.1007/s13127-011-0056-0
Simon, C., Frati, F., Beckenbach, A., Crespi, B., Liu, H. & Flook, P. (1994) Evolution, weighting and phylogenetic utility of mitochondrial gene sequences and a compilation of conserved polymerase chain reaction primers. *Annals of the Entomological Society of America*, 87 (6), 651–701.
https://doi.org/10.1093/aesa/87.6.651
Tamura, K., Stecher, G., Peterson, D., Filipski, A. & Kumar, S. (2013) MEGA6: Molecular Evolutionary Genetics Analysis Version 6.0. *Molecular Biology and Evolution*, 30 (12), 2725–2729.
https://doi.org/10.1093/molbev/mst197
Vijayakumar, S.P., Dinesh, K.P., Prabhu, M.V. & Shanker, K. (2014) Lineage delimitation and description of nine new species of bush frogs (Anura: *Raorchestes*, Rhacophoridae) from the Western Ghats Escarpment. *Zootaxa*, 3893 (4), 451–488.
https://doi.org/10.11646/zootaxa.3893.4.1

APPENDIX I. GenBank accession numbers for the dicroglossid taxa used in the construction of Maximum-likelihood tree based on 5429 bp of mitochondrial and nuclear genes (16s, 12s, BDNF, Rhod, Tyr, RAG-2, NCX1, and CXCR4)

Species	16S	12S	BDNF	Rhod	Tyr	RAG-2	NXC1	CXCR4
***Fejervarya marathi* sp. nov.**	MH370483*	-----	-----	-----	MH370484*	-----	-----	-----
***Fejervarya kalinga* (India)**	MG870107.1	MG870105.1	-----	-----	-----	-----	-----	-----
***Fejervarya krishnan* (India)**	MG870108.1	MG870106.1	-----	-----	-----	-----	-----	-----
***Fejervarya goemchi* (India)**	MG800344.1	-----	-----	-----	-----	-----	-----	-----
***Fejervarya cepfi* (India)**	KY447308.1	-----	-----	-----	-----	-----	-----	-----
***Fejervarya kadar* (India)**	KY447312.1	-----	-----	-----	-----	-----	-----	-----
***Fejervarya manoharani* (India)**	KY447315.1	-----	-----	-----	-----	-----	-----	-----
***Fejervarya neilcoxi* (India)**	KY447318.1	-----	-----	-----	-----	-----	-----	-----
***Fejervarya rufescens* (India)**	KY447322.1	-----	-----	-----	-----	-----	-----	-----
***Fejervarya keralensis*(India)**	JX573181.1	-----	-----	-----	-----	-----	-----	-----
***Fejervarya keralensis* (India)**	GQ478322.1	-----	-----	-----	-----	-----	-----	-----
***Fejervarya gomantaki* (Goa, India)**	KR781087.1	-----	------	------	KT004441	------	------	------
***Fejervarya sahyadris* (Aralam, India)**	AB530604.1	-----	------	------	------	------	------	------
***Fejervarya sahyadris* (Aralam, India)**	AB530605.1	-----	------	------	------	------	------	------
***Fejervarya kudremukhensis* (Kudremukh, India)**	AB488898.1	AB488875.1	AB489059.1	AB489035.1	AB489014.1	AB488994.1	AB488933.1	AB488916.1
***Fejervarya greenii* (Hakgala, Sri Lanka)**	AB488891.1	AB488868.1	AB489053.1	AB489029.1	AB489008.1	AB488988.1	AB488927.1	AB488910.1
***Fejervarya kirtisinghei* (Hakgala, Sri Lanka)**	AB488890.1	AB488867.1	AB489052.1	AB489028.1	AB489007.1	AB488987.1	AB488926.1	AB488909.1
***Fejervarya* sp. hp4 (Chitwan, Nepal)**	AB488889.1	AB488866.1	AB500239.1	AB500262.1	AB500268.1	-----	AB500251.1	AB500245.1
***Fejervarya caperata* (Mudigere, India)**	AB488894.1	AB488871.1	AB489055.1	AB489031.1	AB489010.1	AB488990.1	AB488929.1	AB488912.1
***Fejervarya* sp. hp5 (Assam, India)**	AB488900.1	AB488877.1	AB489061.1	AB489037.1	AB489016.1	AB488996.1	AB488935.1	AB488918.1
***Fejervarya syhadrensis* (India)**	AY882955.1	-----	------	------	------	------	------	------
***Fejervarya pierrei* (Chitwan, Nepal)**	AB488888.1	AB488865.1	AB489051.1	AB489027.1	AB489006.1	AB490160.1	AB488925.1	AB488908.1
***Fejervarya* cf *syhadrensis* (Matale, Sri Lanka)**	AB488892.1	AB488869.1	AB500237.1	AB500260.1	AB500267.1	-----	AB500250.1	AB500244.1
***Fejervarya granosa* (Mudigere, India)**	AB488895.1	AB488872.1	AB489056.1	AB489032.1	AB489011.1	AB488991.1	AB488930.1	AB488913.1
***Fejervarya* sp. hp3 (Pilok, Thailand)**	AB277300.1	AB277284.1	-----	-----	-----	-----	-----	AB277313.1
***Fejervarya* sp. hp6 (Andaman Islands, India)**	AB488899.1	AB488876.1	AB489060.1	AB489036.1	AB489015.1	AB488995.1	AB488934.1	AB488917.1

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APPENDIX 1. (Continued)

Species	16S	12S	BDNF	Rhod	Tyr	RAG-2	NXC1	CXCR4
***Fejervarya mudduraja* (Madikeri, India)**	AB488896.1	AB488873.1	-----	AB489033.1	AB489012.1	AB488992.1	AB488931.1	AB488914.1
***Fejervarya multistriata* (Husa, China)**	AB488884.1	AB488862.1	AB500234.1	AB500257.1	AB500265.1	AB500252.1	AB500248.1	AB500242.1
***Fejervarya limnocharis* (Java, Indonesia)**	AB277302.1	AB277286.1	AB489044.1	AB489020.1	AB277354.1	AB488980.1	AB277327.1	AB277315.1
***Fejervarya multistriata* (Taipei, Taiwan)**	-----	AB488862.1	AB500235.1	AB500258.1	AB500266.1	AB500253.1	AB500249.1	AB500243.1
***Fejervarya iskandari* (Java, Indonesia)**	AB277303.1	AB277287.1	AB489045.1	AB489021.1	AB277355.1	AB488981.1	AB277328.1	AB277316.1
***Fejervarya orissaensis* (Orrisa, India)**	AB277304.1	AB277289.1	AB500236.1	AB500259.1	AB277356.1	-----	AB277329.1	AB277317.1
***Fejervarya* sp. hp2 (Three Pagoda Pass, Thailand)**	-----	-----	AB500238.1	AB500261.1	-----	AB500254.1	AB277323.1	AB277308.1
***"Fejervarya limnocharis"* (Hiroshima, Japan)**	AB488887.1	AB488864.1	AB489050.1	AB489026.1	AB489005.1	AB488986.1	AB488924.1	AB488907.1
***"Fejervarya limnocharis"* (Orchard Island, Taiwan)**	-----	-----	AB500233.1	AB500256.1	AB500264.1	-----	AB500247.1	AB500241.1
***Fejervarya sakishimensis* (Iriomote Island, Japan)**	AB488886.1	AB488863.1	AB489049.1	AB489025.1	AB489004.1	AB488985.1	AB488923.1	AB488906.1
***Fejervarya triora* (Ubon Ratchatani, Thailand)**	AB488883.1	AB488860.1	AB489046.1	AB489022.1	AB489003.1	AB488982.1	AB488922.1	AB488905.1
***Fejervarya cancrivora* (Salangor, Malaysia)**	AB488882.1	AB488859.1	-----	-----	-----	-----	-----	-----
***Sphaerotheca breviceps* (India)**	-----	-----	-----	AF249110.1	DQ282927	-----	-----	-----
***Sphaerotheca dobsoni* (India)**	AB277305.1	AB277290	-----	-----	AB277357.1	-----	AB277330.1	AB277318.1
***Sphaerotheca pluvialis*(India)**	AF249042.1	AF161039	-----	-----	-----	-----	-----	-----
***Hoplobatrachus tigerinus* (India)**	AB290412.1	-----	AB489063.1	AB489039.1	AB277358.1	-----	AB277331.1	AB277319.1
***Euphlyctis cyanophlyctis* (India)**	AB272604.1	-----	AB489062.1	AB489038.1	AB489017.1	-----	AB488936.1	AB488919.1
***Occidozyga* sp. (Malaysia)**	-----	-----	AB489067.1	AB489043.1	AB489019.1	-----	AB488938.1	AB488921.1
***Occidozyga lima* (Malaysia)**	-----	-----	AB489066.1	AB489042.1	AB489018.1	-----	AB488937.1	-----

* sequences generated for the present studies