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First report of *Fejervarya moodiei* (Taylor, 1920) (Amphibia: Anura: Dicroglossidae) from the state of West Bengal, India

Debayan Gayen[1*] and Kaushik Deuti[2]

[1]*PG Department of Conservation Biology, Durgapur Government College, Durgapur-71321, Paschim Bardhaman, West Bengal, India*
[2]*Zoological Survey of India, F.P.S. Building, 27 JL Nehru Road, Kolkata, West Bengal, India*
[*]*Corresponding author*✉: *debayangayen123@gmail.com*

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Abstract

Taylor's Mangrove crab-eating Frog, *Fejervarya moodiei* (Taylor) which was reported first from the Indian Subcontinent in 2016, is being reported for the first time from West Bengal State, eastern India, based on collections comprising a total of three specimens from South 24 Parganas District from 1983 to 2008, and photographic record of an uncollected specimen in 2019. The species is compared with *Fejervarya cancrivora* Gravenhorst, with which it is mostly confused.

Key words: Brackish Water Frog, Bali Island, Kalinagar, Marichjhapi, Namkhana, Sunderban Biosphere Reserve

Introduction

India harbours 447 species of amphibians belonging to three orders, 16 families and 67 genera, of which 77 are considered as threatened according to the IUCN Red List of Threatened Species (Dinesh et al., 2020). The genus *Fejervarya* Bolkay, 1915 had been the subject for extensive research in the recent years (Howlader et al., 2016; Garg and Biju, 2017; Sanchez et al., 2018) and presently, erstwhile members of the genus are allocated to the genera *Minervarya* Dubois, Ohler and Biju, 2001 and *Fejervarya* Bolkay, 1915, as per Sanchez et al. (2018). The genus *Fejervarya* Bolkay, 1915 is represented by four species in India (Dinesh et al., 2020), of which *Fejervarya orissaensis* Dutta, 1997 has been reported from the State of West Bengal (Mahapatra et al., 2019).

Satheeshkumar (2011) reported *Fejervarya cancrivora* Gravenhorst, 1829 from Veerampattinam of the mangroves of Pondicherry; Pillai (1991), Harikrishnan et al.(2012) and Chandramouli et al. (2015) reported the species from the Andaman and Nicobar Islands and Jena et al. (2013) reported it from the Bhitarkanika mangroves in Odisha. However, recent studies by Deuti et al. (2016) and Chandramouli et al. (2020) clearly indicates that it is not *F. cancrivora* Gravenhorst, 1829 but *Fejervarya moodiei* Taylor, 1920 that is present in the Indian Subcontinent.

Fejervarya moodiei is a mid-sized frog which inhabits the mangrove areas and was previously misidentified as *Fejervarya cancrivora*. Later the populations of *F. cancrivora* from Trat and Khulna were designated as *F. moodiei* (mangrove type) by Kurniawan et al. (2011). The type locality for *F. cancrivora* is in Java, Indonesia and presently it can be found in Bangkok and Cholburi provinces of Thailand, West Malaysia, Kalimantan (Borneo), Sumatra, West and Central Java, and Bali in Indonesia, with some introduced populations in Papua New Guinea and Guam (Frost, 2021). Whereas, *F. moodiei* was first described from Manila, Luzon in Philippines and presently it occurs in various regions of South and Southeast Asia namely, Odisha, Pondicherry and Andaman Islands in India, southern China, Vietnam, Thailand, Myanmar, Malaysia and Luzon Island in the Philippines (Frost, 2021). It was first reported from India by Deuti et al. (2016) and its confirmed reports are known only from a handful of locations till date-Bhitarkanika mangroves and Bichitrapur mangroves (Odisha), Pondicherry mangroves (Pondicherry UT) (Deuti et al., 2016) and Andaman Islands (Chandramouli et al., 2020). This species has not been yet reported from West Bengal, which may be due to the fact that not many studies were done on the amphibians of the Sunderban mangroves and the coastal regions

(Mukherjee, 1975; Mandal and Nandi, 1989; Varadaraju, 2009) and the researchers may have overlooked this species.

Here, we report this species from the State of West Bengal for the first time with collection of three specimens housed in the collection of Zoological Survey of India (ZSI) and photographic evidences of live uncollected specimens from the district of South 24 Parganas.

Material and Methods

The present study was conducted with the uncollected specimens of *Fejervarya moodiei* from South 24 Parganas district of West Bengal and specimens housed in ZSI, Kolkata, India. Morphological characters of the specimens were measured using Mitutoyo™ digital callipers (to the nearest 0.1 mm). The species was identified following the description of Chandramouli et al. (2020). The second author had the opportunity of examining and measuring five specimens of the Crab-eating Frog (*Fejervarya cancrivora*) at the Department of Systematics et Evolution, Museum National d'Histoire Naturelle, Paris, France in 2013. These measurements are used to compare with that of *F. moodiei* of the present study. The location of the places from where the specimens of *F. moodiei* were collected and those given in the literatures are given in Figure 1.

Principal Component Analysis (PCA) was performed on 22 morphometric variables according to Chandramouli et al. (2020) from specimens of both *F. moodiei* (n= 3) and *F. cancrivora* (n= 5), using PAST 3.0. Before doing the PCA, a normality test was done for all the variables. PCA factor scores for Principal Components (PC) with eigenvalues >1.0 were reported. Factor scores of the first two components were visualized on scatterplots to assess the degree of morphological differentiation between specimens of the two species.

Photographs in the wild were taken during night time of May 2019 with a digital camera (Nikon Coolpix B700). Coordinates were recorded as latitude and longitude in decimal degrees and the map is generated using ArcGIS software version 10.2.2.

Materials Examined: *Fejervarya moodiei:* 3 ex: ZSI K-2795 from Marichjhapi, South 24 Parganas, West Bengal (22.106º N, 88.954º E) collected on 13 November 1988 by R. A. Khan; ZSI K-710 from Kalinagar, South 24 Parganas, West Bengal (22,172º N, 88,463º E) collected on 27 October 1983 by S. C. Soren; ZSI KN-2714 from Namkhana, South 24 Parganas (21.770º N, 88.232º E) collected on 5 April 2008 by T. K. Chatterjee.

Fejervarya cancrivora: 5 ex: MNHN 1891.95 from Borneo; 1998.0005 from Ao Phany Nga, Phang Nga Province, Thailand; 1891.93 from Borneo; 1998.4456 from Java, Indonesia; 1891.84 from Borneo.

Various abbreviations used in the study are as follows: SVL- Snout-Vent Length, HL- Head Length, HW- Head Width, SL- Snout Length, EN- Eye-Nostril Distance, NS- Nostril-Snout Distance, ED- Eye Diameter, TD- Tympanum Diameter, ET- Eye-Tympanum Distance, IN- Internarial Distance, IO- Interorbital Distance, F1- Length of first finger, F2- Length of second finger, F3- Length of third finger, F4- Length of fourth finger, FL- Femur Length, TL- Tibia Length, T1- Length of first toe, T2- Length of second toe, T3- Length of third toe, T4- Length of fourth toe, T5- Length of fifth toe, IMT- Length of Inner Metatarsal Tubercle; ZSI- Zoological Survey of India, MNHN- Museum National d'Histoire Naturelle, Paris, France; K and KN- Registration numbers, Eig.- Eigenvalue, Cum.- Cumulative, Var.-Variance.

Results and Discussion

Diagnosis

Medium to large body size, absence of rictal gland, absence of supralabial line, presence of distinct and glandular supratympanic fold from posterior edge of upper eyelid along upper margin of tympanum and then obliquely down to shoulder and presence of spots around the throat helped us in assigning this species to *Fejervarya* and not *Minervarya*.

The species can be differentiated from its congeners through the possession of the following: mid-sized body; presence of multiple, interrupted, feeble longitudinal skin folds on the dorsum and along the lateral sides; an inverted V shaped fold of skin on the dorsum; a pair of dark colored Fejervary lines (lines on the ventral side seen in case of Fejervaryan frogs) on the ventral region between axilla and groin; dorsally positioned nostrils closer to the snout tip; a supratympanic fold from the postorbital region to the shoulder; well-developed webbing on toes extending between tips of toes III and V to the distal subarticular tubercle of toe IV; an evident inner metatarsal tubercle and the absence of an outer metatarsal tubercle (Fig. 2).

The description and measurements of the collected specimens (Table 1) are given below.

Size

Medium size (SVL= 48.7 ± 7.1) terrestrial frogs.

Head

Head large, almost as long (HL= 15.3 ± 1.6) as wide (HW= 15.6 ± 1.5), depressed; snout blunt and rounded with snout tip projected slightly beyond the mandible, canthus rostralis smoothly curved, nostrils directed upward and nearer to the snout tip (NS= 3.4 ± 0.9) than to the eye (EN= 4.8 ± 0.9); tympanum distinct and smaller than the eye (TD= 3.6 ± 1.1, ED= 5.4 ± 0.2); inter-orbital distance (IO= 6.3 ± 2.3) greater than the inter-narial distance (IN= 3.8 ± 1.2); a well-developed supratympanic fold runs from behind the eye broadening to the shoulder.

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Table 1: Measurement data for three specimens of *Fejervarya moodiei* Taylor, 1920 from the collections of Sundarban Regional Centre, Zoological Survey of India, Canning, South 24 Parganas, India. All measurements are in mm.

Specimen Number	**ZSI K- 2795**	**ZSI K-710**	**ZSI KN-2714**	**Mean± SD**
Locality	Marichjhapi, South 24 Parganas	Kalinagar, South 24 Parganas	Namkhana, South 24 Parganas	
Date of Collection	13.11.1988	27.10.1983	05.04.2008	
Collector's name	R.A. Khan	S.C. Soren	T.K. Chatterjee	
SVL	56.8	43.7	45.7	48.7±7.1
HL	17.1	14.4	14.3	15.3±1.6
HW	17.4	14.6	14.9	15.6±1.5
SL	8.5	6.7	7.8	7.7±0.9
EN	5.8	4.2	4.4	4.8±0.9
NS	4.4	2.8	2.9	3.4±0.9
ED	5.6	5.3	5.2	5.4±0.2
TD	4.9	2.9	3.0	3.6±1.1
ET	3.3	1.5	1.5	2.1±1.0
IN	5.0	3.7	2.7	3.8±1.2
IO	8.3	6.8	3.7	6.3±2.3
F1	6.1	5.6	5.5	5.7±0.3
F2	5.7	5.0	5.3	5.3±0.4
F3	7.5	7.3	7.1	7.3±0.2
F4	5.0	5.7	5.8	5.5±0.4
FL	20.0	18.5	20.3	19.6±1.0
TL	26.0	22.5	23.1	23.9±1.9
T1	5.1	4.2	5.1	4.8±0.5
T2	7.1	7.8	7.7	7.5±0.4
T3	9.5	11.1	12.0	10.9±1.3
T4	15.0	16.2	15.4	15.5±0.6
T5	11.8	11.7	10.7	11.4±0.6
IMT	3.4	2.6	2.3	2.8±0.6

Table 2: Measurement data for five specimens of *Fejervarya cancrivora* from Department of Systematics et Evolution, Museum National d'Histoire Naturelle, Paris, France. All measurements are in mm.

Specimen Number	**1891.95**	**1998.0005**	**1891.93**	**1998.4456**	**1891.84**
Locality	Borneo	Thailand	Borneo	Java, Indonesia	Borneo
SVL	74.9	73.4	95.4	109.2	71.6
HL	24.3	24.2	31.9	32.5	24.2
HW	26.5	24.4	34.7	36.4	24.5
SL	13.0	12.8	17.6	17.5	13.3
EN	7.4	7.7	10.8	9.8	7.8
ET	2.9	3.5	6.0	6.2	3.4
ED	9.9	7.1	9.7	10.4	8.0
TD	6.2	4.8	7.5	4.8	5.2
IO	3.5	5.0	5.7	5.6	4.5
IN	4.6	5.0	5.9	5.7	4.8
F1	11.4	12.4	15.5	17.0	11.3
F2	9.6	11.4	12.3	14.8	8.8
F3	12.3	13.4	15.1	18.7	12.4
F4	9.6	8.3	13.0	12.5	9.3
FL	35.2	29.2	42.4	42.2	30.9
TL	38.8	36.4	50.0	55.1	38.1
T1	11.4	9.5	12.7	12.8	9.6
T2	12.2	15.1	19.0	18.3	12.8
T3	22.4	21.0	30.4	27.6	21.6
T4	34.6	34.9	46.0	42.6	33.0
T5	24.9	24.3	32.6	31.3	25.9
IMT	3.4	5.0	5.1	6.4	4.0

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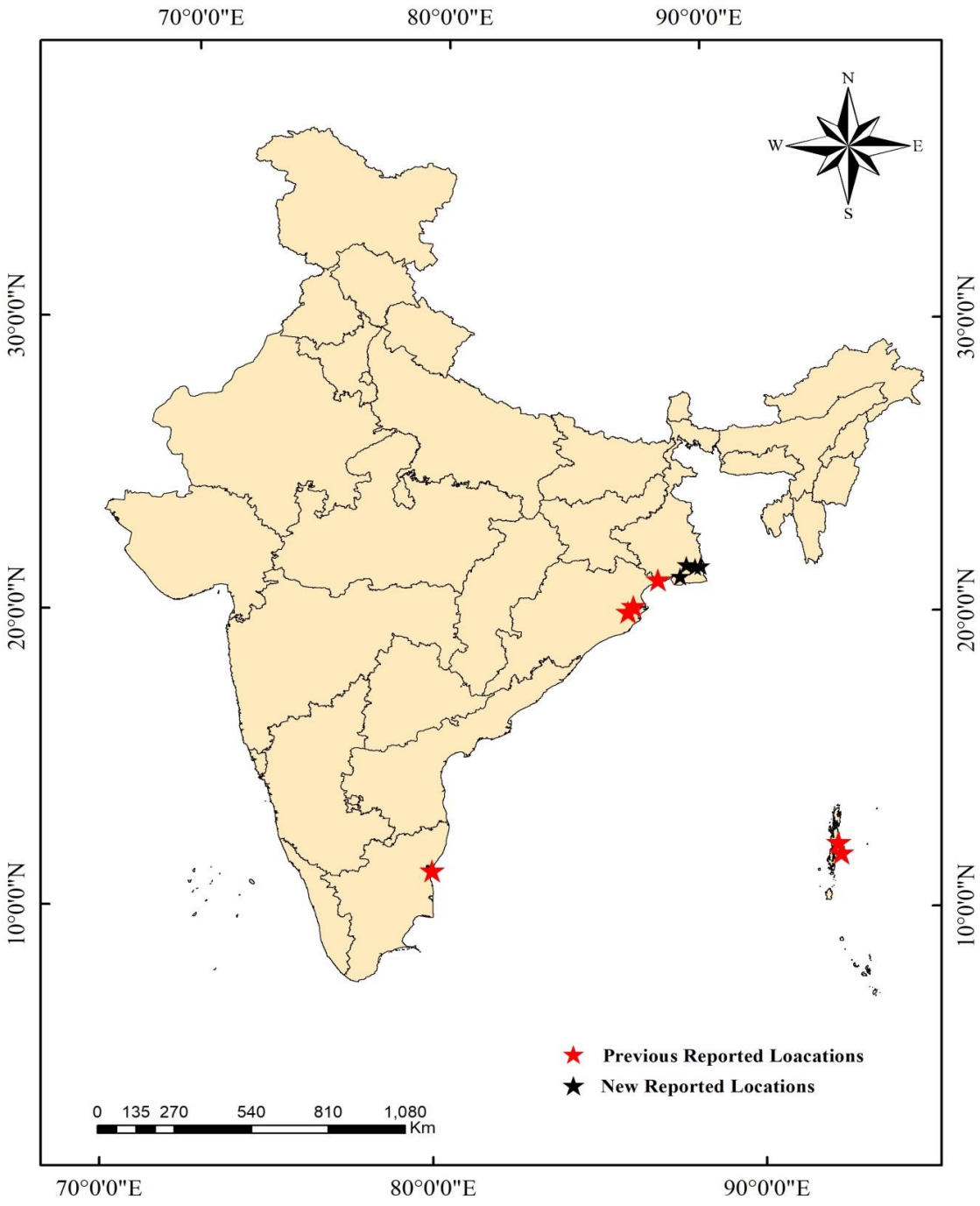

Figure 1: Distribution map of *Fejervarya moodiei* Taylor, 1920 in India (red markings include the previous known locations of the species from India, such as Pondicherry Mangroves, Bhitarkanika mangroves and Bichitrapur mangroves in Odisha and Andaman Islands. Black Marking include localities such as Namkhana, Kalinagar, Marichjhapi and Bali Island of West Bengal reported during the present study.

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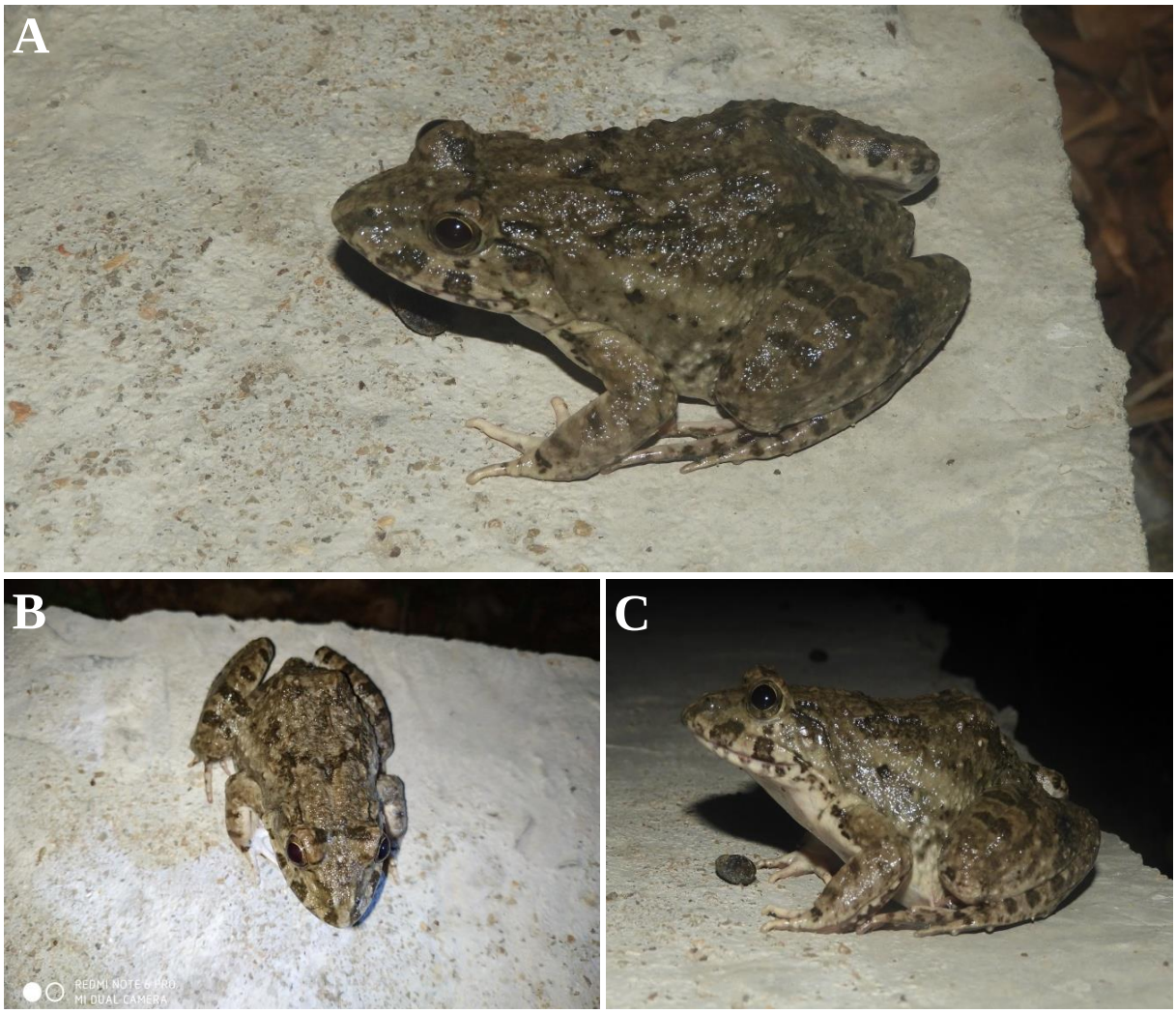

Figure 2: Specimen of *Fejervarya moodiei* in life (uncollected) from Bali Island, South 24 Parganas, West Bengal observed on 28 May, 2019. A and C- Side view of the frog and B- Top view showing the dorsal side of the frog.

Forelimbs

Forelimbs short and robust, without webbing; relative length of the fingers III>I>IV>II; short inner and outer metacarpal tubercles present at the base of the palm.

Hindlimbs

Hindlimbs thick and fleshy; shank longer than the thigh (FL= 19.6 ± 1.0), TL= 23.83 ± 1.84); tarsus short, toe tips rounded, relative toe length IV>V>III>II>I, inner metatarsal tubercle present (IMT= 2.8 ± 0.6), outer metatarsal tubercle absent.

Color

Dorsal color grayish brown with dark markings; a dark brown inter-orbital band and a W- shaped marking present on the back; dorsum with short interrupted glandular folds, lips with dark bars and tympanum darker than the background; venter dirty white with small gray blotches.

Habitat

All specimens observed or collected during the present study are from the mangrove habitats, where they appeared common. Mostly seen during evenings, when they emerge from crab holes on mud banks.

On 28 May, 2019, the first author observed a single individual (gender unknown) of this species in the muddy banks of Bali Island, South 24 Parganas, West Bengal (22º5'33"N, 88º46'13"E). The specimen was not collected but photographed (Fig. 2). On 6 March, 2020 another individual was observed at the same location.

Fejervarya moodiei showed morphometric differentiation from *F. cancrivora*. Principal Component Analysis (PCA) for the specimens of both the species (*F. moodiei*, n= 3; *F. cancrivora*, n= 5) recovered six Principal Components (PC) with eigenvalues >1.0 that accounted for 99.9% of the total variance. PC1 explained 96.8% variance, PC2 explained 2.2% variance, PC3 explained 0.4% variance, PC4 explained 0.25% variance, PC5 explained 0.13% variance and PC6 explained 0.09% variance and the remaining factors explained 0.1% of the variations (Table 3). Projections of the factor planes 1 and 2 showed distinct clusters for the two species (Fig. 3).

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The present report represents the first record of *F. moodiei* from the State of West Bengal, based on collected specimens and photographic evidence and extends its range up to Sunderban mangrove area of South 24 Parganas district, southern West Bengal. Further studies, employing morphological and molecular approaches are needed in order to uneveil various more interesting facts about this lesser known anuran species.

Table 3: Variance explained by Principal Components (PC) with eigenvalues of >1.0 based on Principal Component Analysis of 22 morphometric variables from specimens of *Fejervarya moodiei* and *Fejervarya cancrivora*.

Variable	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6
SVL	0.63375	-0.59864	0.039395	-0.03697	-0.13225	0.15838
HL	0.19589	0.01539	0.06903	0.21418	0.027854	-0.02787
HW	0.23832	-0.02462	-0.13384	0.16236	0.13691	0.061092
SL	0.11641	0.047123	-3.05E-05	0.097208	0.040044	-0.06131
EN	0.0644	0.018194	0.04903	0.24855	0.02642	0.04272
ET	0.045989	-0.08433	0.056004	0.21074	0.1638	-0.00561
ED	0.057112	0.031966	-0.25027	-0.04341	-0.25331	0.001062
TD	0.031404	0.071166	-0.11477	0.44247	-0.21087	0.24666
IO	-0.0085954	-0.17999	0.22697	0.5359	0.13151	-0.11698
IN	0.024539	-0.03573	0.095576	0.24951	-0.13003	-0.00449
F1	0.1245	0.031239	0.18426	-0.13417	-0.02279	0.030964
F2	0.098365	-0.02658	0.24287	-0.28739	-0.06127	0.31785
F3	0.11438	-0.03307	0.20304	-0.35509	-0.09715	-0.1562
F4	0.083485	0.080149	-0.13903	-0.01619	0.29199	-0.1522
FL	0.26664	0.17668	-0.59528	-0.00308	0.10063	0.21674
TL	0.33729	-0.10447	-0.1609	-0.12084	0.17185	-0.49226
T1	0.096247	0.10865	-0.13792	-0.05998	-0.31344	0.19088
T2	0.12788	0.11338	0.34882	-0.03439	0.47996	0.18756
T3	0.21212	0.35005	-0.085068	-0.03928	0.38185	-0.04884
T4	0.34115	0.52597	0.29384	0.038525	-0.13419	0.27322
T5	0.24517	0.33533	0.15917	0.11412	-0.39984	-0.55021
IMT	0.035682	-0.06116	0.20106	-0.03562	-0.01003	-0.00426
Eig	1275.09	29.4326	5.37875	3.41883	1.75718	1.13133
Var	96.826	2.235	0.40844	0.25961	0.13343	0.085909
Cum. Var	96.826	99.061	99.46944	99.72905	99.86248	99.948389

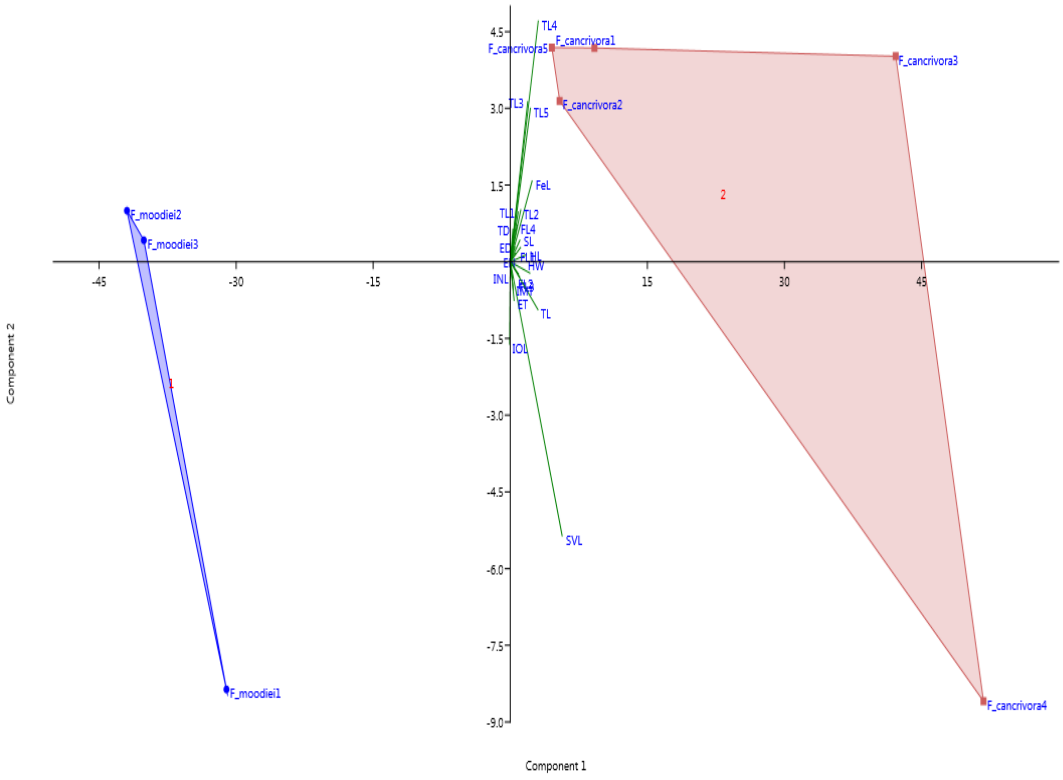

Figure 3: Principal Component Analysis showing morphometric differentiation between *Fejervarya moodiei* and *Fejervarya cancrivora* based on 22 morphological characters.

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Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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