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43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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continued on the back inside cover

Cover: Leaves and fruits of *Terminalia arjuna* in water colour artwork on cold pressed water colour paper by Bhama Sridharan.

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ARTICLE

Larval descriptions and oral ultrastructures of some anurans (*Duttaphrynus, Minervarya, Nyctibatrachus, Rhacophorus,* & *Polypedates*) (Amphibia) from Wayanad and Vagamon hills, Western Ghats, India

Prudhvi Raj

62-8-26, Sriharipuram, Visakhapatnam, Andhra Pradesh, 530011, India.
prudhvirajg999@gmail.com

Abstract: The external and buccopharyngeal morphologies of tadpoles belonging to six anurans (*Duttaphrynus melanostictus*, *Minervarya agricola*, *Nyctibatrachus periyar*, *Rhacophorus malabaricus*, *R. lateralis*, & *Polypedates pseudocruciger*) from Wayanad and Vagamon hills, in Western Ghats are here-in described. Characterizations of larvae are illustrated by detailed images along with morphometric measurements. Four of the larval descriptions (*M. agricola*, *N. periyar*, *R. lateralis*, & *P. pseudocruciger*) are previously unknown, while two (*D. melanostictus* & *R. malabaricus*) are re-descriptions with additional information. Comparisons with congeners of the respective genera are made. This study is a small step towards advancing our knowledge of anuran larvae and supporting future research form Western Ghats and the adjacent regions.

Keywords: Aquatic, Kerala, morphometry, oral disc, scanning electron microscopy, tadpoles.

Abbreviations: BL—body length (distance from the tip of the snout to the body-tail junction) | DFH—maximum height of dorsal fin | INL—inter-narial distance (measured between the narial apertures) | IOL—inter-orbital distance (measured between the pupils) | LTRF—labial tooth row formula | MBD—maximum body width (at the widest point) | MTH—maximum tail height (including fins and musculature) | MTMW—maximum tail muscle width | NED—distance between eye and narial aperture | NSD—distance between snout and narial aperture | ODD—oral disc rostral width/diameter (maximum width of the oral disc) | SEM— scanning electron microscope | SS—snout to spiracle distance | SV—spiracle to vent length | TL—tail length (length of the tail from body tail junction to tail tip) | TMH—tail muscle height (measured at junction of the body and tail) | VFH—maximum height of ventral fin | VTL—vent tube length.

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Author details: The author is a biologist based at Visakhapatnam, India working on systematics and biogeography of herpetological assemblages from South and South East Asia.

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INTRODUCTION

Western Ghats is a biodiversity hotspot harboring many endemic and unique anuran lineages that are geographically restricted to the region (Myers et al. 2000; Vijayakumar et al. 2019). There are more than 225 species of anurans known from the region of which 80% are endemic (Dahanukar & Molur 2020). Of late, there have been many new taxa described from the region (Dinesh et al. 2021). However, the focus of these works was mainly on their taxonomic and phylogenetic status. The last evaluation of threats for amphibians during Global Amphibian Assessment had found 40% of amphibian fauna from the region threatened with extinction (Biju et al. 2008). Despite recent progress in elucidating anuran diversity in the region, the natural history of most anuran species remains unknown.

Amphibians are unique among tetrapods with their life history characterized by a bimodal lifecycle. Most amphibians have a free-swimming aquatic larval stage that undergoes a major modification in their body plan through metamorphosis (Noble 1927; Orton 1957). Larval anurans are generally referred to as tadpoles. Similar to adults, tadpoles experience selection pressures that tend to shape their ecological and morphological adaptations in aquatic habitats (McDiarmid & Altig 1999). There has been a need to properly identify and characterize anuran larvae (Orton 1953; McDiarmid & Altig 1999; Haas 2003; Altig 2007). However, morphological terminology associated with anuran larvae was standardized only recently (McDiarmid & Altig 1999). In recent times, there has been a growing interest in research on larval morphology of anurans (McDiarmid & Altig 1999; Roelants et al. 2011). However, there are still many knowledge gaps pertaining to the life history patterns of anurans.

With many evolutionary radiations, anurans from Western Ghats can act as a good model group for comparative studies on tadpoles. Western Ghats presents varied landscapes, offering different larval habitats, which have led larval anurans from the region to evolve diverse morphologies (Bossuyt et al. 2004; Das & Dutta 2006). The diversity of larval morphology is not yet fully understood from the region. Of the ~225 species of anurans known from Western Ghats, only 30% have described larval forms (Das & Dutta 2006). This situation is compounded by the fact that very few taxonomic identification keys are available for species-specific larval identification (Raj et al. 2012, 2023). For Western Ghats anurans, there had been a considerable amount of work published on larval anurans in the first half of the 20th century by Annandale (1913, 1918, 1919), Annandale & Rao (1917, 1918), Rao (1914, 1915, 1918, 1922, 1937, 1938), and Ramaswami (1932, 1933, 1934, 1936, 1938, 1940, 1943, 1944). This work follows Bhaduri & Kripalani (1954), Chari (1962), Daniel (1963a,b, 1975), Pillai (1978), Inger et al. (1984), Sekar (1990a,b, 1992), Das (1996), Hiragond & Saidapur (1999), Kuramoto & Joshy (2002), and Dutta et al. (2004). In the past decade, there has been renewed interest in anuran larval studies from the region which resulted in the descriptions of tadpoles for few species (Biju et al. 2011; Raj et al. 2012; Wewelwala et al. 2013; Chandramouli & Kalaimani 2014; Abraham et al. 2015; Priti et al. 2015; Chandramouli et al. 2014; Biju et al. 2016; Senevirathne et al. 2016a,b). However, many of the description are brief and only few species have accurate larval descriptions, and there is a need for more comprehensive work on larval anurans from the region.

The current study presents larval morphologies of some anurans from the Wayanad and Vagamon hills in the Western Ghats. In the current paper, I describe the tadpoles of six species, *Duttaphrynus* cf. *melanostictus*, *Minervarya* cf. *agricola*, *Nyctibatrachus* cf. *periyar*, *Polypedates pseudocruciger, Rhacophorus lateralis*, and *R. malabaricus*. Two of the species, *D.* cf. *melanostictus* and *R. malabaricus,* were described earlier. However, the current descriptions are more detailed and also include the descriptions of buccopharyngeal morphology that are discussed.

MATERIALS AND METHODS

Specimen collection and larval identity

Field sampling was performed on 11 and 17 August 2011 at six locations in the Western Ghats of Kerala State, India: 1) Banasuramala Hills, Kalpetta, Wayanad, 11.62348°N, 75.93157°E, WGS84; 2) Vythiri, near Banasura Sagar Dam, Wayanad, 11.62466°N, 75.99011°E, WGS84; 3) Edatara, Wayanad, 11.62096°N, 75.99955°E, WGS84; 4) Vythiri, near Banasura Sagar Dam, Wayanad, 11.62903°N, 75.96925°E, WGS84; 5) Soochipara, Meppadi, Wayanad, 11.485322°N, 76.151828°E, WGS84; 6) Vagamon, Kottayam, 9.68266°N, 76.90549°E, WGS84 (Figure 1). Tadpoles were collected using an aquarium dip net. The tadpoles were euthanized by immersing them in 6 g/L solution of MS222. All tadpoles were fixed and preserved in 10% formalin, and currently housed at the Laboratory for Conservation of Endangered Species (LaCONES), Centre for Cellular & Molecular Biology (CCMB), Hyderabad, India. Museum catalogue series

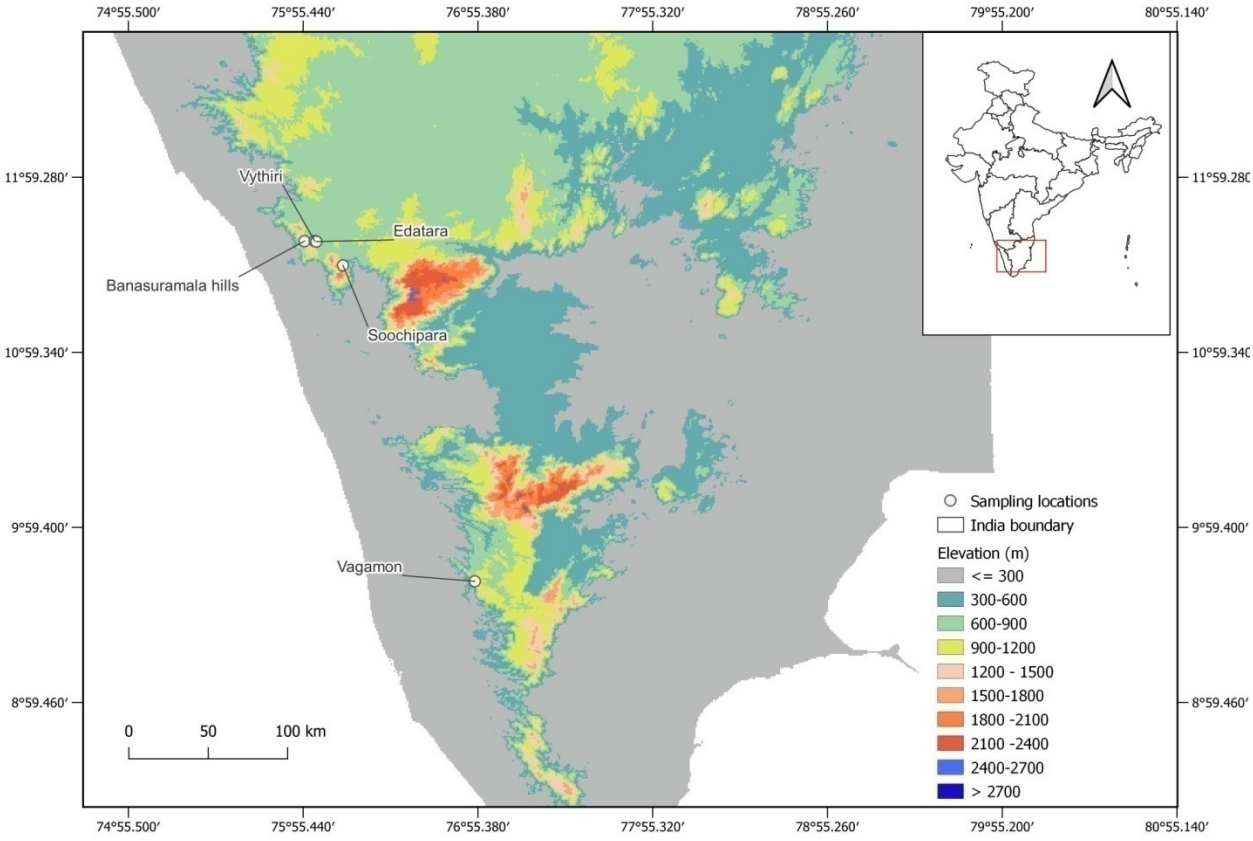

Figure 1. Sampling locations of anuran larvae in the Western Ghats, Kerala, India

of tadpoles examined and data regarding the sampling locations are given along with the descriptions. Freshly preserved tadpoles were photographed using a Nikon D7000 with a macro lens. Tadpoles for three species (*R. lateralis*, *R. malabaricus*, and *P. pseudocruciger*) were reared ex situ until metamorphosis to establish species identity. Due to the unavailability of molecular data, precise species identity of the other three species (*D.* cf. *melanostictus, M.* cf. *agricola*, and *N.* cf. *periyar*) could not be established. However, the taxonomic identity of these three species of tadpoles was based on sympatric adult anurans encountered and collected at the respective sampling locations. Generic-level taxonomy and nomenclature follows Frost (2021), while species definitions follow Das & Ravichandran (1998), Dubois & Ohler (1999), Biju et al. (2011, 2013; but see Abraham et al. 2022), Ganesh et al. (2017), and Chandramouli et al. (2019).

External and buccopharyngeal descriptions for larval anurans are provided based on an advanced larval development stage for each species. Developmental stages of tadpoles were staged using Gosner's table (Gosner 1960). The format of the description and measurements follows Raj et al. (2012). The terminology used in descriptions follows Altig & Johnston (1989) for external morphology, and Wassersug (1976, 1980) and Inger (1985) for buccopharyngeal morphology. Morphology of the buccopharyngeal region for the tadpoles was studied using methylene blue staining and scanning electron microscopy (SEM). For staining of buccopharyngeal structures, 2% Methylene blue solution was brushed on the oral structures. For SEM, methods used by Raj et al. (2012) were followed. External characters were observed using a LEICA EZ4 stereo zoom microscope (8–35 X). Sixteen morphometric measurements were taken using a SPI plastic dial caliper (precision: 0.1 mm).

RESULTS

Genus: ***Duttaphrynus*** Frost, Grant, Faivovich, Bain, Haas, Haddad, de Sá, Channing, Wilkinson, Donnellan, Raxworthy, Campbell, Blotto, Moler, Drewes, Nussbaum, Lynch, Green & Wheeler, 2006

Species: *Duttaphrynus* cf. *melanostictus* (Schneider, 1799).

Larval series examined: WT139/19711

(Banasuramala Hills, Kalpetta, Wayanad, Kerala, India, 11.62348°N; 75.93157°E; WGS84). Tadpoles were collected from a pool that was 1.5–1.8 m in depth. The tadpoles were restricted towards the fringes of the pool taking cover along the emergent vegetation. Tadpoles were found feeding on decaying plant material.

Taxonomic note: Adults of both *Duttaphrynus melanostictus* and *D. parietalis* were recorded from the location where tadpoles were collected. Externally, the tadpoles morphologically resemble those of *D. melanostictus* descriptions (Khan 1965, 1982). However, they vary in few characters, which are discussed. There are no descriptions for tadpoles of *D. parietalis* for comparison.

External morphology: Description of tadpole (Gosner Stage 35): Body oval and elliptical in dorsal and lateral views (Image 1A–B). Dorsal contour is convex and ventral contour of the body is flat or slightly concave at the anterior region and convex at the abdominal region; BL is 40.9% (40.8%–41%) of the total length; MBD is at the middle of the body. The snout is rounded in dorsal and lateral views. Eyes are large; located, and oriented dorsolaterally; the distance between the eye and the nostril represents 27.7% (26.3%–29.4%) of the distance between the eye and the snout. The nostril opening is reniform with the rim elevated, closer to eyes than to snout; placed parallel to the eye in dorsal view; INL is 62.1% (52.9%–71.4%) of IOL; NSD is 16.8% (15.7%–17.9%) of BL. Spiracle sinistral; inner wall of the tube not completely formed; tube orientation is posterolateral and the opening located approximately at the middle of the body; SS is 70.7% (69.7%–71.7%) of BL. Vent tube opening is median and short. Tail tip round; TMH is greatest at body tail junction after which it tapers. The dorsal fin originates at the body tail junction and the ventral fin at the ventral terminus; both the fins are of equal height for most of the length. MTH is at mid-length; TMH is almost equal to MTMW at the tail-body junction. TMH accounted for 34.7% (32.3%–37.1%) of MTH. Dermal pores of the lateral lines on the body faintly

Image 1. *Duttaphrynus* cf. *melanostictus*, Gosner stage 37. External morphology: A—Lateral view| B—Dorsal view | C—Ventral view. Scale = 10 mm. © Prudhvi Raj.

Table 1. Morphometric measurements of *Duttaphrynus* cf. *melanostictus* tadpoles given in mm as mean ± SE.

Gosner stage	IOL	INL	NED	NSD	SS	SV	BL	TL	MBD	MTH	MTMW	TMH	ODD	VTL	DFH	VFH
26(5)	0.7±.03	0.5±.02	0.2±.02	0.7±.03	3.3±.13	1.6±.14	4.6±.22	6.8±.35	2.8±.09	1.8±.06	0.4±.03	0.7±.03	1.3±.07	0.5±.04	0.6±.04	0.7±.03
27(3)	1.2±.11	0.8±.05	0.3±.03	1.0±.08	4.3±.13	2.5±.24	6.1±.33	8.6±.43	3.8±.21	2.4±.13	0.8±.06	1±.05	3.7±1.9	0.8±.05	0.9±.08	0.9±.08
28(3)	1.0±.13	0.8±.06	0.3	1.1	4.5±.13	2.8±.10	6.5±.13	9.1±.83	4.1±.03	3.1±.10	0.9	1.2	1.8±.03	0.8±.07	1.1±.03	1.0±.03
29(2)	1.5±.10	0.9	0.3±.05	1.1±.05	4.6±.10	2.7±.20	6.6±.45	9.5±.20	4.3±.40	2.9±.15	0.9±.05	1.2	1.9±.05	1.0±.05	1.1±.10	1.1±.10
30(4)	1.3±.15	1.0±.09	0.3±.02	1.2±.12	4.6±.31	3.0±.13	7.2±.19	10.5±.32	4.5±.13	3.1±.07	0.9±.08	1.2±.10	1.9±.10	1±.10	1.2±.06	1.0±.09
31(4)	1.5±.07	0.9±.04	0.4±.02	1.2±.08	5.1±.23	2.9±.25	7.1±.15	10.5±.43	4.7±.10	3.3±.07	1±.04	1.2±.08	2.1±.07	1.1±.08	1.2±.04	1.2±.02
32(3)	1.4±.15	1±.05	0.3±.03	1.2±.06	5.3±.32	3.0±.31	7.4±.12	11.6±.39	4.7±.15	3.2±.08	0.9±.08	1.3±.18	1.9±.03	0.9±.03	1.0±.03	1.1±.03
33	1.6	0.9	0.4	1.3	5.2	3	7.2	11.5	4.7	3.6	1	1.3	2.3	0.9	1.2	1.2
34(3)	1.5±.18	0.9±.08	0.4	1.2±.08	5.0±.12	3±.15	7.0±.29	10.7±.17	4.7±.14	3.2±.12	0.9±.06	1.2±.05	1.9±.05	1.1±.05	1.2±.05	1.2±.08
35(2)	1.5±.15	0.9±.05	0.5	1.3±.10	5.4±.15	3.1±.10	7.7±.10	11.1±.20	4.8±.20	3.4±.05	1.3±.35	1.2±.10	2.1±.20	1.2±.10	1.2	1.1±.05
36(4)	1.6±.02	1.0±.07	0.4±.04	1.3±.09	5.4±.09	3.2±.07	7.8±.13	11.0±.23	5.0±.14	3.6±.11	1.0±.02	1.3±.09	2.1±.06	1.1±.08	1.2±.04	1.2±.02
37	1.2	1.1	0.4	1.4	5.9	3.1	8.1	10.9	5	3.6	1.1	1.3	2	0.8	1.5	1.4
38(4)	1.7±.02	1±.07	0.4±.02	1.3±.09	5.1±.12	3.0±.07	7.5±.16	11.3±.23	4.9±.02	3.5±.12	1.0±.02	1.2±.04	2.1±.07	1.1±.08	1.2±.02	1.2±.06
39(2)	1.6±.15	0.9±.05	0.5	1.3±.10	5.1±.10	3.3±.15	7.5±.15	11.2±.85	4.9±.10	3.2±.25	1.1±.10	1.4±.20	2.1±.05	0.9±.10	1.2±.10	1.1±.05
40(2)	1.6±.15	1	0.4±.05	1.3±.10	5.4±.10	3.4±.15	7.6±.20	11.3±.15	4.9±.20	3.1±.10	1.0±.05	1.2±.10	2.1±.05	1.0±.15	1.2	1.2

visible. No glands are present on the outer integument.

Oral disc is anteroventral in location (Image 1C); ODD is 44% (43.1%–45.1%) of the body width; disc emarginated; single row of marginal papillae spread on the lateral corners of the oral disc and none seen on both the labia; four to five submarginal papillae seen at the lateral corners; both labia are of equal size. The labial tooth row formula (LTRF) is 2(2)/3. Order of the length of tooth rows is A-1 > P-1 > A-2 > P-2 > P-3. Jaw sheaths are feeble and both are moderately keratinized. Jaw sheaths are serrated with uniform-sized small serrations; supra-rostrodont is convex, longer with the median slightly broad and tapering to long thin lateral processes; infra-rostrodont is U-shaped, convex laterally and concave medially.

Measurements: Measurements of 42 tadpoles belonging to various Gosner stages (Gosner stages 26–40) are presented in Table 1.

Colouration: In life, tadpoles were black with many closely spaced tiny melanophores and many golden speckles distributed randomly on the outer integument which otherwise are not present in *D. melanostictus* tadpoles; the inner integument had few large melanophores. In lateral view, the flanks were spotted with many tiny melanophores. Ventrally, the integument was transparent with gut coils visible; the throat was spotted on the lateral sides. Both the fins were transparent and the dorsal fin was spotted at the anterior portion. The entire tail muscle was spotted with tiny melanophores, mostly along the posterior region of the tail. Spiracle, oral disc and the vent tube were translucent, however, dotted with few melanophores.

Buccopharyngeal morphology

Buccal roof (Image 2A–B): Prenarial arena of the buccal roof comprises a triangular transverse ridge with tiny papillae on the lateral corners. Internal nares transverse and oriented anteromedially; the gap between the nares narrow and is about half of the length of an individual nare; anterior narial wall pustulose with few tiny pustules and no papilla; posterior wall is tall, smooth with no pustules and valvular. The post narial arena comprises three pairs of papillae arranged in an inverted "v" shape oriented antero-medially. The second and the third post narial papillae are conical and pustulose, with the second papilla being the longest; the first papilla is stubby. Median ridge papilla is triangular with a smooth margin and a bifid tip. There is a single trifid pustulose lateral ridge papilla perpendicular to the median ridge on both sides. Buccal roof arena demarcated with three pairs of long conical papillae present on the lateral border of the roof; about 30 tiny pustules are spread across the entire buccal roof arena. Glandular zone is thick and prominent. The dorsal velum is moderately raised with few tiny projections medially; however, the margin is continuous.

Buccal floor (Image 2C–D): Prelingual arena comprises a single dilated infralabial palp on each side of the posterior lateral corners of the jaw sheath. Each palp is divided into two equal wide projections with many

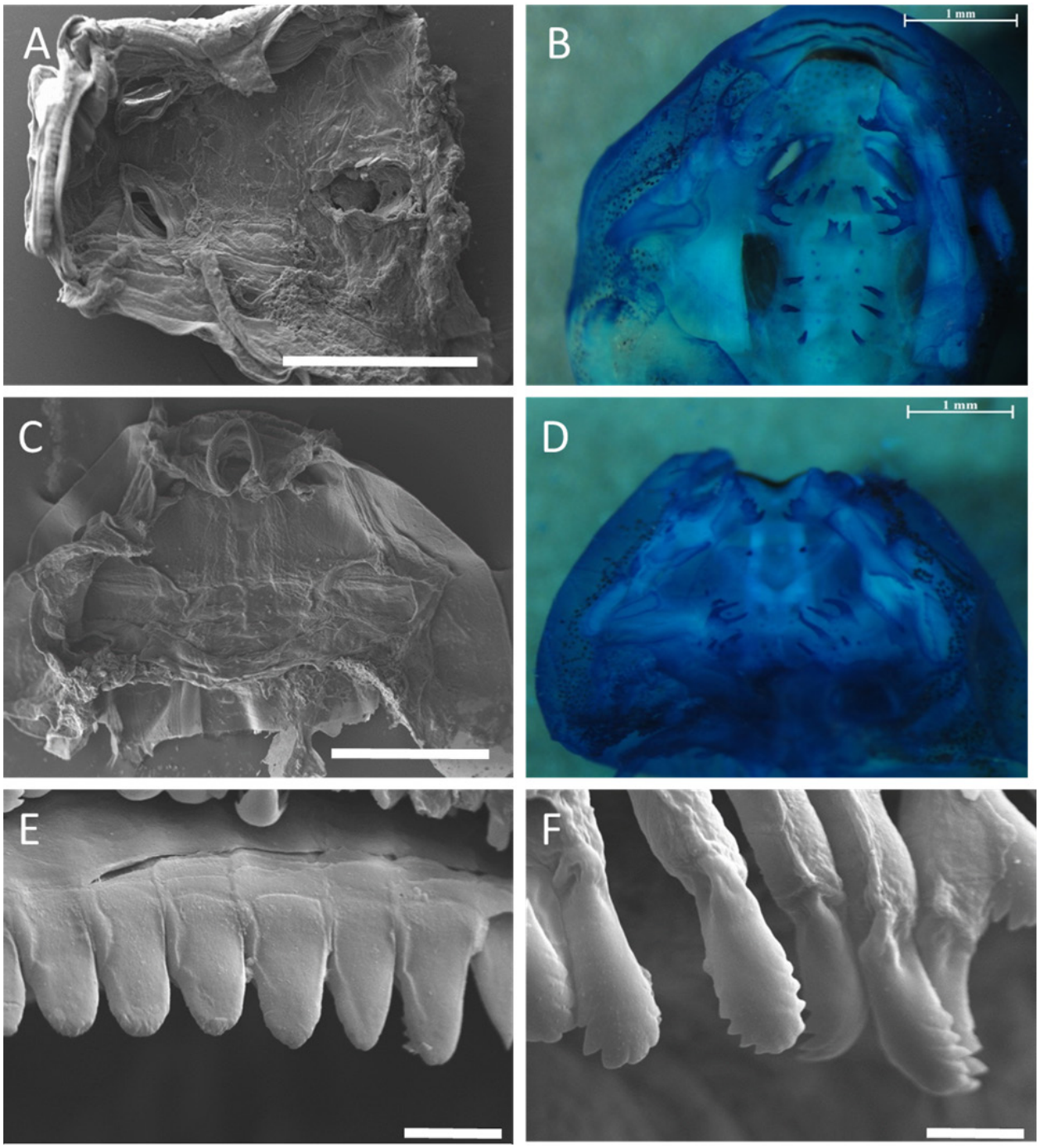

Image 2. ***Duttaphrynus*** **cf.** ***melanostictus,*** **Gosner stage 37. Buccopharyngeal and denticles: A— Buccal roof, SEM photograph, scale = 1 mm | B—Buccal roof, Alcian blue stained photograph, ventral view, scale = 1 mm | C—Buccal floor, SEM photograph, scale = 1 mm | D—Buccal floor, Alcian blue stained photograph, ventral view, scale = 1 mm | E—Individual denticles, scale = .1 mm | F—Jaw sheath serrations = .1 mm. © Prudhvi Raj.**

pustules on the margin. Tongue anlage round and low; two pairs of smooth lingual papillae present, one at the center projecting inwards and the other on the lateral corner of the tongue anlage projecting outwards. Buccal floor arena well defined; anterior region of the buccal floor arena smooth; six long conical papilla commence from the mesad of the buccal floor arena and spread till the posterolateral corners; the second buccal floor arena papilla is the largest and bifid; posterior region of the buccal floor arena composed of 20 pustulations. The buccal pocket opening is narrow and oblique; few pustulations occur in the region between the

tongue anlage and the buccal pockets; no pre-pocket papilla present. Ventral velum smooth with about 10 projections. The outer two projections on either side are widely placed and the rest are concentrated at the center. Median notch is not prominent. The glottis opens immediately posterior to the ventral velum.

Denticles (Image 2E) are closely packed and curved towards the mouth at the apex. The oral angle is more or less straight except for the slightly curved apex. The sheath and the body are broad; about 14–16 long and pointed cusps are present on each denticle. Each serration (Image 2F) on the jaw sheath has a wide base and a rounded head.

Genus: ***Polypedates*** Tschudi, 1838.
Species: *Polypedates pseudocruciger* Das & Ravichandran, 1998.

Larval series examined: WT140/22711 (Vythiri, near Banasura Sagar Dam, Wayanad, Kerala, India, 11.62466°N; 75.99011°E; WGS84). Tadpoles were collected from a pool, which was approximately 1.5 m in depth. The tadpoles were restricted to 0.5–1 m depth of the pool feeding on emergent vegetation occasionally surfacing. Tadpoles of this species were found in pools inhabited by *D.* cf. *melanostictus*, *R. lateralis*, and *R. malabaricus*

Taxonomic note: Fresh metamorphs morphologically matched *P. pseudocruciger*. No tadpole description for this species is available.

External morphology: Description of tadpole (Gosner stage 38): Body oval in dorsal and lateral views (Images 3A–B). Dorsal contour slightly convex with most of the dorsum flattened and ventral contour of body convex and broad at abdominal region; BL is 36.4% of the total length; an indentation is seen immediately behind the eye; MBD at the posterior end of the body. The snout is oblique and rounded in dorsal and lateral views. Eyes are large; located and oriented laterally; distance between the eye and nostril represents 63.2% of the distance between the eye and snout. The nostril opening is oval with the rim elevated, closer to the snout; placed wide

Image 3. ***Polypedates pseudocruciger*****, Gosner stage 37. External morphology: A—Lateral view | B—Dorsal view | C—Ventral view. Scale = 10 mm. © Prudhvi Raj.**

Table 2. Morphometric measurements of *Polypedates pseudocruciger* tadpoles given in mm as mean ± SE.

Gosner stage	IOL	INL	NED	NSD	SS	SV	BL	TL	MBD	MTH	MTMW	TMH	ODD	VTL	DFH	VFH
26(3)	4.7±.08	2±.15	1.7±.03	1.2±.05	6.1±.21	4.9±.20	10.1±.15	17.2±.53	5.1±.08	5.1±.55	1.6±03	2.3±.18	2.2±.03	0.6±.03	2.1±.08	2.1±.08
27(5)	5.5±.16	2.5±.05	2.2±.07	1.2±.05	7.6±.39	6.4±.50	12.5±.59	22.4±1.04	6.7±.41	6.9±.57	2.5±.25	3.1±.08	2.8±.06	0.8±.11	2.2±.17	2.5±.27
28(5)	5.8±.10	2.7±.08	2.5±.10	1.3±.12	7.9±.13	6.7±.18	13.6±.26	23.1±.49	7.2±.18	7.8±.22	2.2±.13	3.4±.14	3±.08	0.9±.19	2.5±.11	2.8±.10
30	5.9	2.9	2.6	1.5	8.7	7.5	14.1	25.2	7.4	8.5	2.3	3.2	3	0.7	3.1	3.1
31(3)	6.2±.05	2.6±.26	2.4±.08	1.4±.15	8.6±.17	7.3±.28	14.6±.35	24.8±.49	7.4±.54	8.5±.24	2.4±.14	3.4±.23	3.1±.20	1.1±.31	2.8±.05	3.2±.15
32(4)	6.5±.11	3.1±.10	2.7±.07	1.4±.11	9.1±.11	7.9±.22	14.8±.34	25±1.29	10.5±2.73	8.5±.08	2.6±.12	3.5±.19	3.1±.02	0.7±.05	2.7±.08	3±.07
33	6.5	3.3	3.1	1.5	9.3	8.8	15.7	27.2	8.6	9.3	3.1	3.9	3.1	1	3.3	4.1
34(3)	6.7±.38	3±.08	2.7±.08	1.7±.03	9.1±.64	8.4±.79	15.6±.54	28.3±1.83	8.3±.24	9.1±.31	3±.20	3.5±.08	2.8±.38	1.2±.31	2.9±.05	3.1±.08
36	6.5	3	2.8	1.5	9.3	7.7	13.9	25.1	7.3	7.8	3	3.7	2.9	2.5	2.5	2.6
38	7	3.2	3.1	1.8	9.3	8.8	17.3	30.2	8.7	8.3	3.4	4.1	3.4	2.3	2.3	2.3
39(4)	7.2±.22	3.1±.16	3.2±.12	1.8±.13	10.3±.33	9.6±.66	16.3±.83	31±1.35	9±.45	8.7±.83	3.2±.18	3.8±.34	3.3±.19	1.5±.52	2.8±.44	2.9±.49
40(5)	7±.14	2.9±.14	2.8±.20	1.8±.06	10.2±.20	9±.49	16.1±.70	32.4±.59	9.7±.21	9.08±.31	3.1±.10	4±.10	3.4±.06	2±.40	3.1±.14	2.9±.08
41(3)	7±.20	2.4±.14	2.8±.03	2±.05	10.4±.12	8.1±.48	16.5±.56	34.7±.48	9.4±.63	8.6±.18	3.5±.29	4.4±.14	3.5±.16	2.1±.12	2.8±.05	3±.08
42(3)	5.9±.25	2.2±.08	2.5±.12	*	*	*	16.2±.26	31.3±1.56	7.1±.23	6.4±.58	3.2±.31	3.3±.14	2.5±.16	*	2.3±.26	1.5±.17

apart and linear to the eye in dorsal view; INL is 45.7% of IOL; distance between the nostril and the snout is 10.4% of BL; naso-lacrimal gland visible between the eye and the nostrils. Spiracle is sinistral with an inner wall of the tube not present; tube orientation is posterolateral and its opening is located below to the lateral median; SS is 53.7% of BL. Vent tube opening is dextral as a small tube and not attached to the tail fin. Tip of the tail acutely pointed; TMH is greatest at the body tail junction and tapers thereafter. The dorsal fin originates anterior to the body tail junction and the ventral fin at the ventral terminus; the ventral fin is taller than the dorsal fin. MTH is at about 1/3rd length from the body tail junction; TMH is about 1.2 times of MTMW at the tail-body junction. TMH accounted for 49.3% of MTH. Lateral line is conspicuous. No glands are present on the outer integument.

Oral disc is at the anteroventral end of the body (Image 3C); ODD is 40.9% of the body width and emarginated. Marginal papillae are single row on the lateral corners of the upper labium and double row on the lower labium; a wide gap is present medially on the upper labium and a small gap medially on the lower labium; three submarginal papillae seen at the lateral corners; both labia are of equal size. The LTRF is 5(2–5)/3(1). Order of the length of tooth rows is P-1 > P-2 > P-3 > A-1 > A-2 > A-3 > A-4 > A-5. Jaw sheaths are well developed and both jaw sheaths are moderately keratinized. Jaw sheaths completely serrated with uniform-sized serration; supra-rostrodont is longer than wide and convex with long lateral process; infra-rostrodont broad U-shaped, convex laterally and concave medially.

Measurements: Measurements of 42 tadpoles belonging to various Gosner stages (Gosner stages 26, 27, 28, 30, 31, 32, 33, 34, 36, 38, 39, 40, 41, 42) are presented in Table 2.

Colouration: In life, tadpoles were olive on the dorsum and the lateral sides, with many tiny melanophores uniformly distributed. In lateral view, the flanks were comparatively lighter than the dorsum. Ventrally, the integument was white and opaque. Dorsal and ventral fins were dirty and translucent with many melanophores; the anterior portion was more spotted than the posterior. Laterally, the tail muscle was white with many melanophores patches of various sizes. Spiracle and oral disc were dotted with few melanophores, and the vent tube was translucent.

Buccopharyngeal morphology

Buccal roof (Image 4A–B): Prenarial arena comprises an arched pustulose ridge with about six pustulations; bordering the ridge are two to three pustules on either side posterolateral to the ridge. Internal nares transverse and oriented slightly posteromedially; both nares separated by a distance of about two-third the length of each nare; anterior narial wall rather smooth with about two to three pustules and a tall, pustulated papilla originating near the lateral corner of the wall; posterior wall tall, smooth and valvular. Post narial arena consists of a tall conical papilla present immediately behind the posterior narial wall oriented medially;

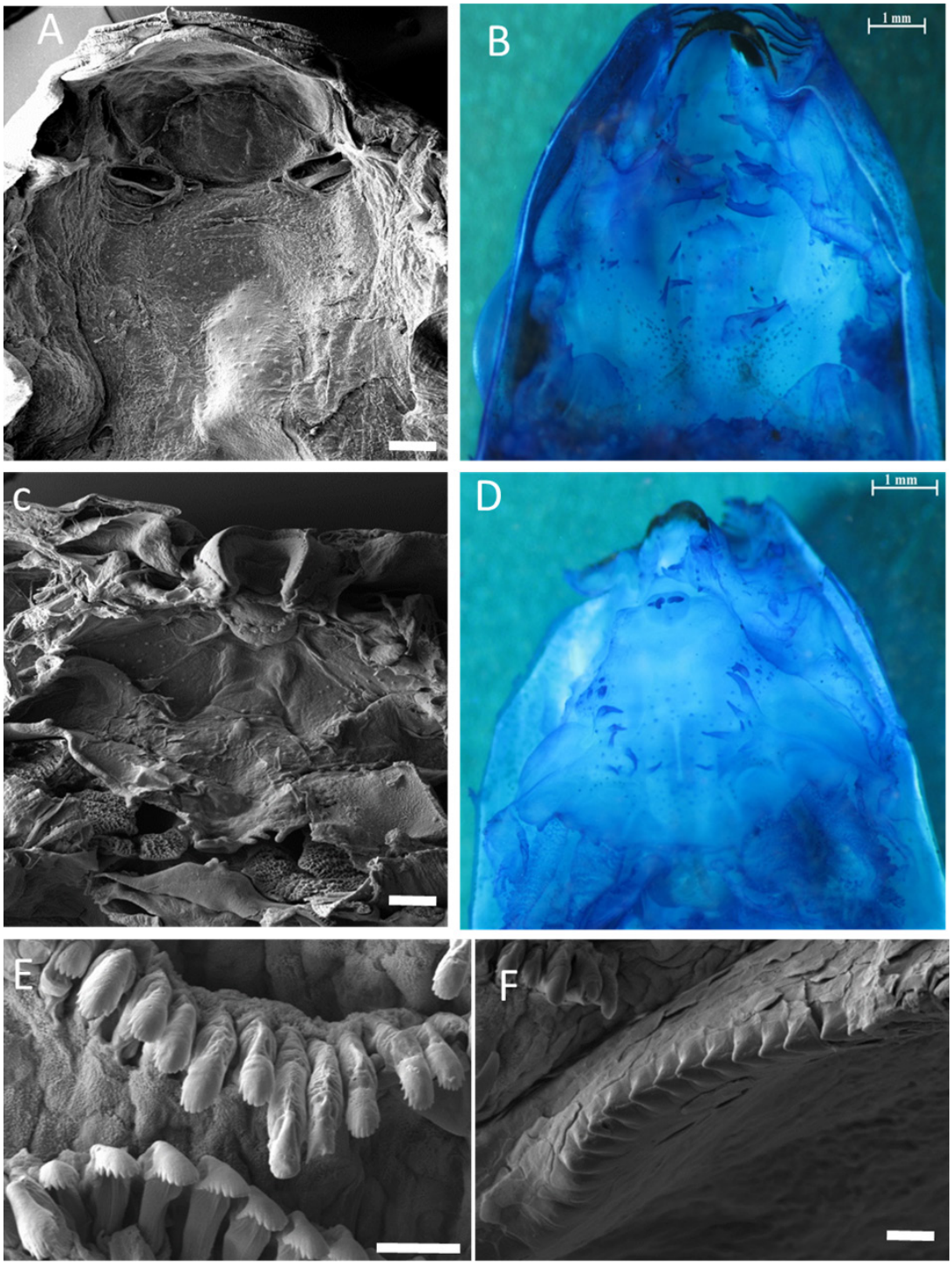

Image 4. ***Polypedates pseudocruciger*****, Gosner stage 38. Buccopharyngeal and denticles A— Buccal roof, SEM photograph, scale = .2 mm | B— Buccal roof, Alcian blue stained photograph, ventral view, scale = 1 mm | C—Buccal floor, SEM photograph, scale = .2 mm | D— Buccal floor, Alcian blue stained photograph, ventral view, scale = 1 mm | E—Individual denticles, scale = .02 mm | F—Jaw sheath serrations = .02 mm. © Prudhvi Raj.**

anterior surface of this papilla is rugose; four pustules are present in front of the median ridge. Median ridge papilla is a triangular flap with a pustulated margin and a long projection medially. A long lateral ridge papilla with a rugose anterior surface is present on the lateral wall on each side perpendicular to the median ridge. Buccal roof arena demarcated with four pairs of long, conical papillae present on the lateral border of the roof; about

50 tiny pustules are spread across the entire buccal roof arena with density higher at the posterior end of the arena. Glandular zone conspicuous; anterior margin of the glandular zone is demarcated by tiny pustules and two to three papillae arranged linearly to the posterior margin of the buccal roof arena. Secretory pits spread throughout the glandular zone. The margin of the dorsal velum is raised, broken medially, and slightly pustulose on the surface.

Buccal floor (Image 4C–D): Prelingual area comprises five pairs of pustules at the anterior end and three pairs of infralabial papillae in the posterior region. Of the three pairs of infralabial papillae, two pairs are located along the posterolateral corners, and the third pair of stubby papillae are located posteromedially between the two posterior papillae; the posterior papillae at the posterolateral corners are elongated and conical with a rugose surface. Tongue anlage broad and raised; two pairs of smooth long lingual papillae are present at the center of the tongue anlage; the inner pair of papillae are longer than the outer. Buccal floor arena delineated by five pairs of buccal floor arena papillae; the buccal floor arena papillae commence from the lateral corners of the floor anterior to the buccal pockets and converge down towards the posteromedial region of the floor, however, the papillae do not meet posteriorly; these papillae are unequal in size, conical and tall; the second papilla from the anterior is the tallest; buccal floor arena composed of about 30 pustulations spread across the floor uniformly. A few papillae and pustules are found beyond the lateral sides of the buccal floor arena. Space between the tongue anlage and the buccal pockets constitutes 14–16 pustulations on each side. Buccal pockets are oblique and wide, orienting linearly towards the anterior; no pocket papillae are present. The region behind the buccal floor arena and the margin of the ventral velum composed of a few pustules sparsely spread medially; ventral velum is wide and sinuate. Ventral velum margin constitutes six projections on each side. The median three projections are closer and concentrated around the center; outer three projections are widely placed apart. Median notch is prominent; the outer margin is granular with many secretory pits. Glottis opens posterior to the ventral velum.

Denticles (Image 4E) are spaced moderately between each other and strongly curved towards the mouth at the apex. The oral angle is straight with a slight curve anteriorly; the sheath is narrow and the body slightly broader; the head is broader with the tip curved. 10–12 short and moderately curved cusps present on each denticle. Serration (Image 4F) on the jaw sheath spaced with a wide base and shot triangular pointed head.

Genus: ***Rhacophorus*** Kuhl & Hasselt, 1822.
Species: *Rhacophorus lateralis* Boulenger, 1883.

Larval series examined: WT142/22711 (Edatara, Wayanad, Kerala, India, 11.62096°N, 75.99955°E; WGS84). Tadpoles were collected from a water tank of about 1 m in depth. The tadpoles were benthic occasionally surfacing. Tadpoles of this species were found along with tadpoles of *P. pseudocruciger* and *R. malabaricus* in some of the pools that were visited during the study.

Taxonomic note: Taxonomic identity of tadpoles was based on fresh metamorphs that morphologically matched taxonomically identified adult *R. lateralis*. No tadpole description for this species is available.

External morphology: Description of tadpole (Gosner stage 36): Snout rounded on both dorsal and lateral profile (Image 5A,B). Body shape oval in both dorsal and lateral views with the body flattened on the dorsum; BL is 36.4% of the total length. Nostril opening is oval-shaped and placed dorsolaterally midway between the eye and the snout; rim of the nasal opening not elevated; NSD is 12.2% of BL. Large bulging eyes oriented dorsolaterally; NED represents 51.1% of the distance between the eye and the snout; INL is 47.1% of IOL. Ventral side is translucent, with the gut coils visible. No glands on the outer integument present. MBD is at the posterior part of the body. Spiracle is sinistral and directed anteroposteriorly, with the inner wall of the spiracle partly formed and attached to the body wall; SS is 52.9% of BL. Vent tube opening is dextral. The tail tapers to a rounded end. The dorsal fin is taller than the ventral fin; MTH is at the mid-length of the tail; TMH is 1.23 times of MTMW at the tail-body junction. TMH accounted for 57.1% of MTH; TMH is tallest at the tail-body junction and continuing till the 1/3rd tail length and thereafter tapering to the tail tip. Origin of the dorsal tail fin at the body tail junction and that of the ventral fin at the ventral terminus. Dermal lines consisting of minute dermal are seen running parallel on either side of the dorsum till the tail tip.

Oral disc (Image 5C) is located terminally at the anteroventral region of the snout. Oral disc is not entire (emarginated) and is bifurcated at the lateral corners; ODD is 27.6% of the body width. Marginal papillae are double rowed on both the labia; distribution of the papillae is not entire with a gap on the upper and lower labia, and papilla distributed till 2/3rd of the labium; papillae on the upper labium is restricted to the lateral

Image 5. ***Rhacophorus lateralis*****, Gosner stage 35. External morphology: A—Lateral view | B—Dorsal view | C—Ventral view. Scale = 10 mm. © Prudhvi Raj.**

corners. Four to six submarginal papillae are present on the lateral corners of the oral disc. The LTRF is 6(3–6)/3(1); two rows of the upper labium (A-1 and A-2) are continuous and the rest bifurcated (A-3 to A-6); the length of each row decreases in descending order from A-1 to A-6; lower labium consisting three-tooth rows of which the P-1 is marginally divided; length of P-1 greater than P-2 row and P-3 being the smallest; tooth rows single. Order of the length of the tooth row is P-1 > P-2 > P-3 > A-2 > A-1 > A-3 > A-4 > A-5 > A-6. Both jaw sheaths are moderately keratinized; uniform-sized minute serrations are present on both the jaw sheaths

Colouration: When freshly collected, the dorsum and the tail were sulphurous-yellow with few tiny melanophores scattered randomly on the dorsum; ventral side was white with no melanophores and translucent. However, the color changed to brown-grey on preservation in 10% formalin. In life, both the dorsal and ventral tail fins were transparent with many blotches present on both fins. The anterior tail fin was dotted with numerous tiny melanophores. Many small blotches were spread across the tail muscle.

Measurements: Measurements of 60 tadpoles belonging to various Gosner stages (Gosner stage 25–Gosner stage 38, 40, 41, 42) are presented in Table 3.

Buccopharyngeal morphology

Buccal roof (Image 6A–B): Prenarial arena of the buccal roof comprises a pustulose transverse ridge arched forward, with the median pustule being the largest. Internal nares transverse and oriented medially, gap between the nares wide with about the length of an individual nare; anterior narial wall pustulose with several tiny pustules and a tall, pustulose papilla stemming from its center; posterior wall is tall, smooth, valvular and smooth. Behind each nare, a tall, broad and

Table 3. Morphometric measurements of *Rhacophorus lateralis* tadpoles given in mm as mean ± SE.

Gosner stage	IOL	INL	NED	NSD	SS	SV	BL	TL	MBD	MTH	MTMW	TMH	ODD	VTL	DFH	VFH
25(3)	2.6±.10	1.6±.18	1.1±.12	1.3±.10	5.7±.12	4.2±.17	8.2±.49	13.0±.49	5.7±.06	4.2±.10	1.3±.12	1.7±.08	2.4±.21	0.9±.08	1.4±.06	1.2±.03
26(2)	3.7±.10	2.4±.05	1.5±.50	1.8±.20	8.3±.25	7.3±.45	12.9±.85	20.9±2.80	7.7±.70	6.3±.95	2.4±.50	2.9±.65	3.1±.55	1.3±.25	2.7±.30	2.1±.50
27(6)	4.0±.18	2.3±.05	1.9±.09	1.8±.10	8.1±.28	6.4±.35	13.1±.49	20.6±.71	8.6±.33	6.5±.27	2.4±.11	2.9±.13	3.4±.13	1.3±.12	2.1±.17	1.8±.16
28(3)	4.8±.10	2.4±.08	2.2±.08	2.1±.05	9.8±.14	7.5±.40	14.5±.54	24.4±1.17	9.7±.34	7.9±.12	2.9±.23	3.7±.17	3.7±.28	1.4±.06	2.7±.13	2.2±.10
29(4)	4.4±.16	2.5±.06	2.1±.08	2.0±.07	9.7±.41	7.9±.48	14.6±.42	25.1±.86	9.4±.40	7.9±.23	3.2±.26	3.6±.08	3.5±.04	1.4±.05	2.6±.14	2.0±.09
30(4)	4.5±.23	2.5±.09	2.1±.06	2.1±.04	9.8±.23	8.3±.45	14.3±.21	25.3±1.23	10.2±.55	8.2±.29	3.1±.29	3.4±.13	4.0±.17	1.4±.09	2.5±.06	2.2±.12
31	4.8	2.6	2.1	2.1	10	7.9	16.7	27.7	10.2	8	3.9	4	4.2	1.5	2.6	2.3
32(2)	4.9±.15	2.6±.10	2.2	2.1	11.3±.25	8.2±.15	16.1±.20	29.3±.25	10.7±.10	8.8±.65	3.6	4.1±.10	4.0±.15	1.2±.05	2.8±.15	2.3±.15
33(2)	4.8±.05	2.7±.10	2.0±.05	2.3±.15	10.8±.25	8.1±.40	15.2±.55	29.9±1.15	11.1±.35	9.1±.50	4.2	4.9	3.9±.05	1.8±.05	2.9	2.1±.10
34	5.6	2.5	2.3	2.4	11.2	10.2	15.9	30.9	11.6	8.2	3.6	4.2	4.3	1.6	2.6	1.9
35(2)	4.8±.10	2.5±.10	2.2	2.0±.05	10.2±.25	9.9±.05	16.6±.60	28.3±.10	12.0±.50	8.9±.10	3.6±.10	4.7±.45	3.2±.15	1.6±.10	2.3±.15	2.2±.20
36	5.3	2.5	2.2	2.1	9.1	8.4	17.2	30	11.2	9.1	4.2	5.2	3.1	1.5	3.2	2.1
37(4)	5.2±.15	2.6±.06	2.2±.15	2.2±.09	10.5±.20	9.2±.12	16.7±.43	29.9±1.33	11.6±.54	9.1±.22	4.2±.06	4.9±.17	3.±.09	1.6±.12	2.4±.04	2.2±.07
38(7)	5.5±.10	2.6±.05	2.2±.04	2.2±.05	10.8±.20	9.4±.44	16.1±.36	30.1±.78	11.2±.21	9.1±.30	3.9±.22	4.6±.18	3.9±.11	1.7±.08	2.8±.12	2.4±.09
40(2)	5.5±.05	2.6±.20	2.3±.05	2.4	11.1±.25	9.1±.40	17.1±.30	31.9±.75	11.5±.25	8.6±.10	4.3±.40	4.7±.20	4.0±.10	1.8±.10	2.7±.05	2.5±.05
41(7)	5.2±.21	2.4±.09	2.1±.11	2.3±.06	11.0±.14	8.6±.36	16.2±.27	30.7±.76	10.7±.34	8.9±.48	3.8±.22	4.0±.25	3.±.15	2.1	2.8±.13	2.2±.17
42(3)	4.7±.15	2.1±.03	2.1±.06	*	*	*	15.8±.63	23.1±2.94	31.0±23.35	4.5±1.02	2.8±.21	3.0±.18	*	*	*	*

curved pustulose papilla is present; the papilla is taller than the papillae on the anterior narial wall and is present immediately behind the posterior narial wall; there are about two to three tiny papillae spread in the post narial arena immediately in front of the median ridge papillae. Median ridge papilla is broad with bifid tip; margin is pustulated. A short and a long, pustulate lateral ridge papilla present perpendicular to the median ridge; the lateral ridge papillae are the longest papillae on the buccal roof. Buccal roof arena demarcated with five pairs of long pustulated papillae present on the lateral border of the roof; about 60 tiny pustules are spread across the entire buccal roof arena. A few non-pustulated smaller papillae are found scattered on the lateral sidewall. A broad glandular zone is present immediately behind the buccal roof arena, with secretory pits present through the glandular zone. The dorsal velum is low and not complete with the medial broken.

Buccal floor (Image 6C–D): Prelingual area comprises of six infralabial papillae, with two long and four tiny papillae on each side; papillae arranged in an oblique row along the margin and lateral sides of the prelingual arena; the second and the posterior papillae are long, broad and pustulose, and the rest of the papillae are diminutive. Tongue anlage round and raised; two smooth lingual papillae present at the center of the tongue projecting outwards. Buccal floor arena is well defined; anterior region of the buccal floor arena smooth; five papilla present on the posterolateral area of the arena; posterior region of the buccal floor arena composed of about 14 pustulations and about six to eight conical papilla evenly spread across on each side of the mesad plane. The buccal pocket opening is wide; region between the tongue and the buccal pockets is coarse with several tiny pustulations; pair of pustulated pre-pocket papilla oriented anteriorly followed by a long, pustulated, curved papillae on the posterior margin of the buccal pocket are present. Ventral velum is smooth with about 12 projections. The outer three projections on either side are widely placed and the rest are concentrated at the center. Median notch is not prominent. Glottis opens slightly posterior to the ventral velum.

Denticles (Image 6E): The denticles are moderately spaced among one another. The oral angle is obtuse; the sheath and the body are narrow; the head is very broad and curved with about 14–16 moderately curved cusps. Each serration (Image 6F) on the jaw sheath is broad with a triangular head.

Species: *Rhacophorus malabaricus* Jerdon, 1870.

Larval series examined: WT138/21711 (Banasuramala hills, Kalpetta, Wayanad, Kerala, India,

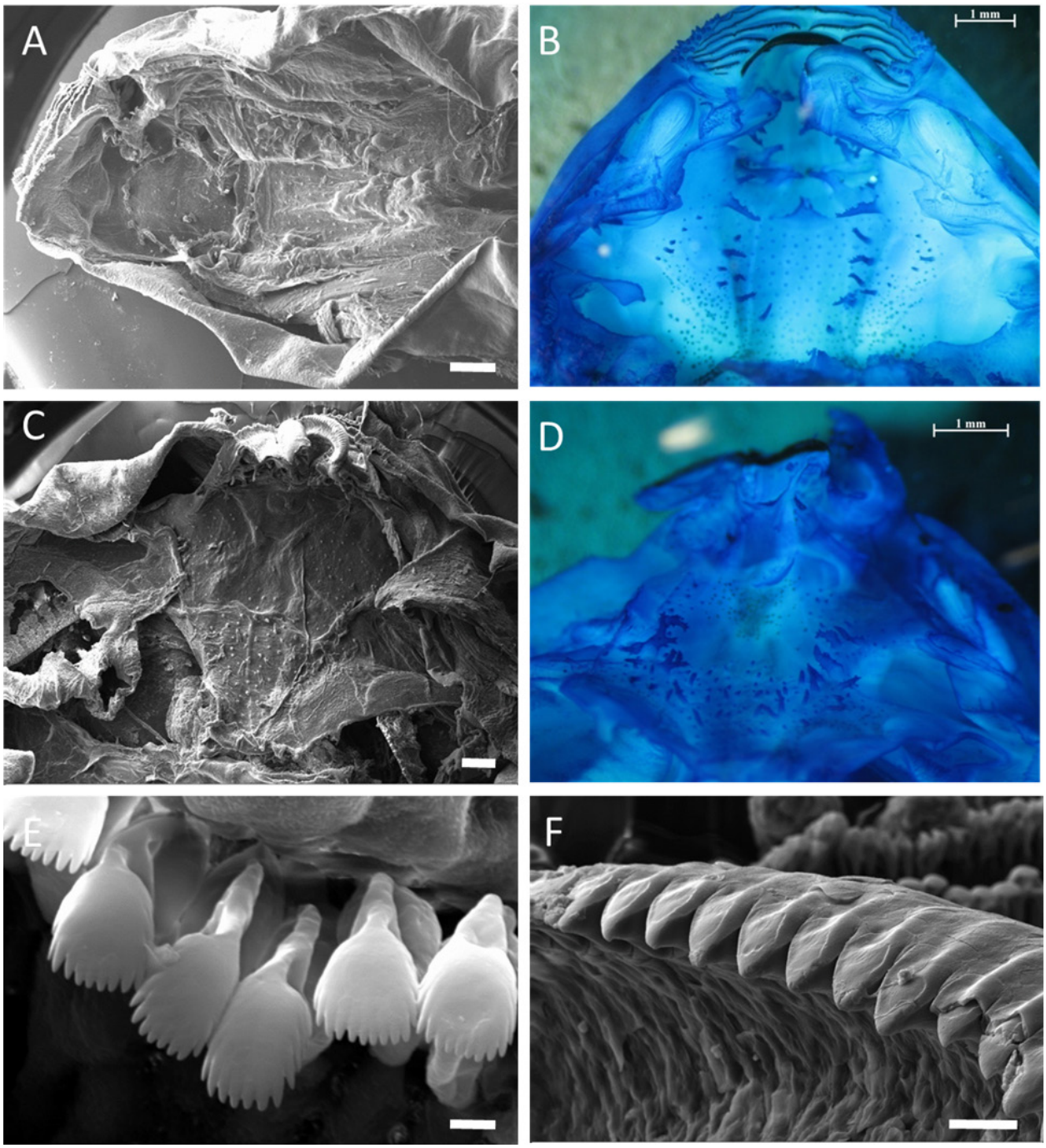

Image 6. ***Rhacophorus lateralis*****, Gosner stage 37. Buccopharyngeal and denticles: A—Buccal roof, SEM photograph, scale = .2 mm | B—Buccal roof, Alcian blue stained photograph, ventral view, scale = 1 mm | C—Buccal floor, SEM photograph, scale = .2 mm | D—Buccal floor, Alcian blue stained photograph, ventral view, scale = 1 mm | E—Individual denticles, scale = .002 mm | F—Jaw sheath serrations = .02 mm. © Prudhvi Raj.**

11.63676°N; 76.0132°E; WGS84), WT143/21711 (Vythiri, near Banasura sagar Dam, Wayanad, Kerala, India, 11.62903°N; 75.96925°E; WGS84). Both the locations were ~10 km apart from each other. Tadpoles were collected from an agricultural water tank that was about 1 m deep. Tadpoles were benthic and fed on benthic detritus material. Tadpoles of this species were found in pools inhabited by *P. pseudocruciger* and *R. lateralis.*

Taxonomic note: Taxonomic identity of tadpoles was based on fresh metamorphs that morphologically matched adult *Rhacophorus malabaricus.* A brief

description on external morphological of tadpoles for this species was made by Sekar (1990a) and the current morphological description matches with the description made earlier.

External morphology: Description of tadpole at Gosner stage 36 (Image 7A–B): Snout is rounded on both dorsal and lateral profile; body is oval; BL is 33.2% (31.6%–36.5%) of the total length. Nostril opening oblong and placed dorsolaterally midway between the snout and the eye; fringe of the nasal opening bulged with the dorsal portion slightly elevated; NSD is 14.8% (12.8%–15.9%) of BL. Large bulging eyes oriented dorsolaterally; NED represents 47% (43.9%–52.6%) of the distance between the eye and the snout; INL is 53.6% (46.1%–56.5%) of IOL. Ventral side translucent with the circular gut coils faintly visible; no glands on the outer integument present. MBD is at the back of the abdomen. Spiracle is sinistral directed antero-posteriorly with the inner wall of the spiracle fully formed but attached to the body wall; SS is 68.1% (64.2%–72.2%) of BL. Vent tube is dextral in opening. The tail tapered to a pointed end. Dorsal and ventral fins are of equal height; TMH is 1.2 times (1–1.4) of MTMW at the tail-body junction; TMH accounted for 55.5% (48.9%–65.8%) of MTH; MTH is at about 1/3 rd of the length. Origin of the dorsal tail fin is at the body tail junction and that of the ventral fin at the ventral terminus. A pair of dermal pore lines run parallel on either side of the dorsum till the tail tip.

Oral disc (Image 7C) is located terminally at the anteroventral region of the snout. Oral disc is not entire (emarginated) and is bifurcated at the lateral corners; ODD is 37.2% (31%– 46.4%) of the body width. Marginal papillae are double rowed on the lower labium and present on the entire lower labium and till the lower quarter of the upper labium (single row). The front portion of the upper labium is without marginal papillae. Three–four submarginal papillae found on the lateral corners of the oral disc. The LTRF is 7(3–7)/3(1), with P1

Image 7. *Rhacophorus malabaricus,* Gosner stage 37. External morphology: A—Lateral view | B—Dorsal view | C—Ventral view. Scale = 10 mm. © Prudhvi Raj.

Table 4. Morphometric measurements of *Rhacophorus malabaricus* tadpoles given in mm as mean ± SE.

Gosner stage	IOL	INL	NED	NSD	SS	SV	BL	TL	MBD	MTH	MTMW	TMH	ODD	VTL	DFH	VFH
25(5)	2.7±.17	1.7±.06	1.1±.06	1.3±.06	5.6±.21	4.0±.19	8.4±.30	13.2±.87	5.2±.17	5.1±.36	1.3±.07	1.9±.18	2.4±.10	0.9±.08	2.1±.13	1.7±.11
26(5)	3.3±.07	2.0±.04	1.5±.08	1.6±.05	7.0±.15	4.9±.21	10.6±.13	17.3±.43	6.2±.23	6.5±.15	1.5±.13	2.6±.13	2.9±.05	0.9±.07	2.3±.06	1.9±.09
27	3.4	2.3	1.6	1.7	7.7	4.9	10.1	17.6	6.5	7	1.6	2.5	3.2	0.9	3.1	2.5
28	3.9	2.3	1.7	1.7	7.3	5.9	12.3	20.9	7.1	7	2	2.6	3.6	1.4	2.5	1.8
29	4.6	2.3	2	2.5	8.4	6.4	12.7	23.3	7.9	6.9	2.1	2.9	3.6	1.1	2.4	2.1
30	4.7	2.5	2	2.1	8.7	7.7	14.7	25.1	8.1	7.7	2.2	3.3	3.6	1.3	2.5	2.1
31(4)	3.1±.33	2.0±.03	1.5±.03	1.5±.15	7.3±.29	6.2±.36	11.5±.35	19.7±.79	7.5±.26	6.8±.25	2.7±.19	3.5±.32	2.6±.14	1.4±.17	2.2±.07	2.0±.11
33	4.9	2.5	2	2.3	8.6	7	14.4	26	8.4	7.7	2.9	4.5	4.1	1.4	2.9	2.4
35(2)	4.8±.15	2.5±.15	1.9±.10	2.2±.15	9.0±.70	8.0±.90	14.5±.10	26.0±.10	9.2±.75	8.1±.10	3.9±.65	4.8±.80	3.4±.40	1.8±.15	2.5±.50	2.0±.45
36(5)	4.6±.18	2.5±.08	1.9±.06	2.1±.09	9.7±.18	8.1±.24	14.3±.27	29.0±1.15	9.4±.33	8.7±.30	3.9±.15	4.4±.52	3.4±.14	1.7±.17	2.9±.09	2.6±.10
37(6)	4.5±.13	2.5±.04	1.8±.07	2.0±.04	9.6±.20	8.2±.34	14.6±.27	30.5±.39	9.9±.24	9.1±.21	4.4±.09	5.5±.12	3.4±.08	1.6±.11	2.8±.12	2.5±.07
38(5)	4.9±.15	2.6±.04	2.1±.14	2.0±.07	9.7±.22	7.8±.27	15.1±.44	30.7±.78	9.9±.38	8.6±.34	4.1±.25	5.1±.34	3.6±.07	1.8±.06	2.9±.12	2.6±.11
40(3)	5.6±.06	2.8±.07	2.1±.03	2.7±.07	11.4±.06	8.6±.48	17.8±.28	31.7±.94	10.7±.20	11.2±.42	4.2±.35	5.2±.13	4.6±.13	1.7±.38	3.9±.19	2.8±.07
41	5.8	2.1	2.2	2	11.7	9.6	16.7	35.6	9.8	8.4	3.6	4.5	3.7		3	2.1
42	4.3	2.3	1.8	1.3			16.7	24.1	7.5	5.8	5.4	3.4	3.1		1.8	1.4

row divided (Image 8C). Upper labium has seven rows of denticles; two undivided upper rows (A-1 and A-2) and five lower rows bifurcating (A-3 to A-7); the length of each row decreases in descending order from A-1 to A-7. Lower labium has three denticle rows, of which the P-1 is marginally divided and which P-3 being the smallest. Tooth rows single. Both the jaw sheaths are moderately keratinized with tiny serrations.

Colouration: Body olive in life, with a dirty white venter containing few scattered melanophores; coloration was lost in preserved specimens. Dorsal side of the body and the tail were mottled with several tiny melanophores. The dorsal tail fin was more mottled than the ventral fin. Ventral side of the body was translucent.

Measurements: Measurements of 44 tadpoles belonging to various Gosner stages (Gosner stage 25–Gosner stage 31, 33, 35–38 and 40–42) are presented in Table 4.

Buccopharyngeal morphology

Buccal roof (Image 8A–B): Prenarial arena composed of a thick pustulated transverse ridge arched forward with uniform-sized pustules. Internal nares transverse and oriented slightly posterior; both nares separated by a distance of about half the length of each nare; anterior narial wall smooth with very few tiny pustules and a tall, pustulated papilla originating at the center; posterior wall is tall, valvular and smooth. A tall, conical and pustulated papilla present immediately behind the posterior narial wall; taller than the papilla on the anterior narial wall; the papilla is the largest of all papillae on the buccal roof. Three tiny papillae spread in the post narial arena immediately in front of the median ridge papilla arrange in an inverted V shape pattern. Median ridge papilla is triangular, having a broad base with a serrated margin. A short and long, pustulate lateral ridge papillae present perpendicular to the median ridge. Both the lateral ridge papillae are pustulated on the anterior face. Buccal roof arena is demarcated with five pairs of short stubby papillae present on the lateral border of the roof; further three pairs of small papillae are found on the lateral wall parallel to the buccal roof arena papillae; about 50–60 tiny pustules are spread across the entire buccal roof arena. A glandular zone is seen immediately behind the buccal roof arena. Observations on the dorsal velum cannot be made.

Buccal floor (Image 8C,D): Prelingual area comprises of five pairs of long infralabial palpillae. Four pairs are located on the posterolateral corners and the fifth pair is located posteromedially of the prelingual area. Size of the papillae on the posterolateral corners follows an ascending order, with the anterior-most palp being the smallest and the posterior palp being the largest and dilated at the tip. All papillae have projections placed equidistantly on their anterior face. Two pairs of papillae are seen just ahead of the tongue anlage oriented medially. Tongue anlage round and raised; anterior portion of the anlage broad and tapers towards the posterior side; two lingual papillae with pustulated tip present at the center of the tongue projecting

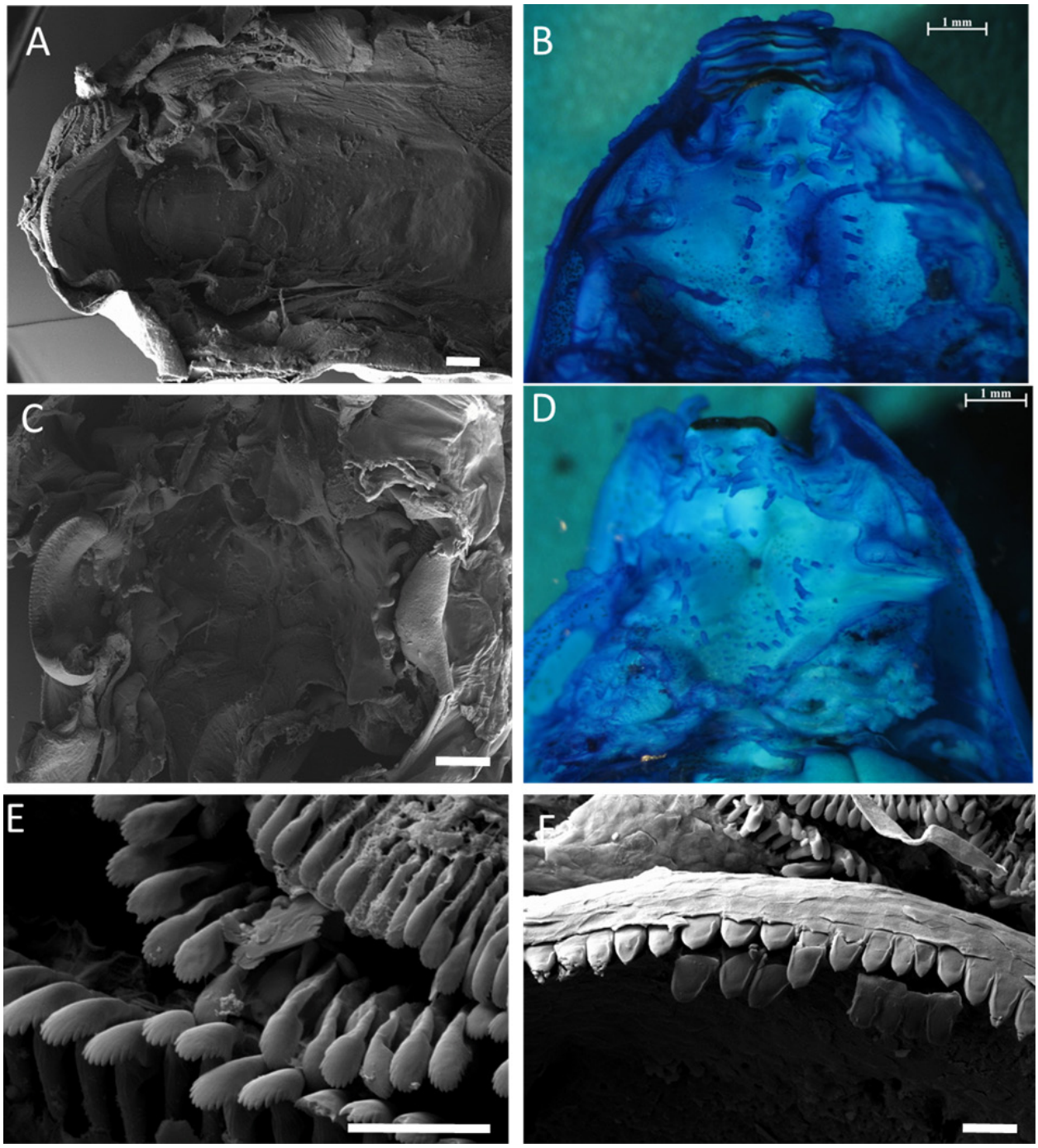

Image 8. ***Rhacophorus malabaricus,*** **Gosner stage 37. Buccopharyngeal and denticles: A— Buccal roof, SEM photograph, scale = .2 mm | B—Buccal roof, Alcian blue stained photograph, ventral view, scale = 1 mm | C—Buccal floor, SEM photograph, scale = .2 mm | D—Buccal floor, Alcian blue stained photograph, ventral view, scale = 1 mm | E—Individual denticles, scale = .02 mm | F—Jaw sheath serrations = .01 mm. © Prudhvi Raj.**

outwards. Buccal floor arena delineated by buccal floor arena papillae; anterior region of the buccal floor arena smooth; five papillae starting from the posterior of buccal pocket and continuing along the posterolateral area on each side of the arena; anterior papillae are long, curved and pustulated; a second row of four papillae present on the laterally to the buccal floor arena papillae; buccal floor arena composed of six–eight papillae and about 40 pustulations. Space between the tongue anlage and the buccal pockets consisting of 12–14 pustulations on each side. Buccal pockets are oblique and wide; a pair of pustulated pre-pocket papillae oriented anteriorly

followed by a long, pustulated, curved papillae on the posterior margin of the buccal pocket are present. Region behind the buccal floor arena and the margin of the ventral velum composed of about 16 pustulations evenly spread across; Ventral velum is wide and sinuate. Margin constitutes six projections on each side. The median three projections are closer and concentrated around the center, outer three projections are widely placed and the rest are concentrated at the center. Median notch is not prominent; the outer margin is smooth with no spicules with many secretory pits visible. Observation on the glottis and brachial baskets could not be made. Glottis opens immediately posterior to the ventral velum.

Denticles (Image 8E): The denticles are moderately spaced between one another. The oral angle is obtuse; the sheath is narrow and the body slightly broader; the head is very broad and curved with about 12–14 moderately curved cusps. Each serration (Image 8F) on the jaw sheath is broad and long with a triangular pointed head.

Genus: ***Minervarya*** Dubois, Ohler & Biju, 2001.
Species: *Minervarya* cf. *agricola* (Jerdon, 1853)

Larval series examined: WT136/20711 (Soochipara, Meppadi, Wayanad, India, 11.485322°N; 76.151828°E; WGS84). Tadpoles were collected from a temporary pool that is less than 0.5 m deep. Substratum in the pool was sandy without any aquatic vegetation.

Taxonomic note: Adults of *Minervarya agricola* were collected at the locality from where the tadpoles were collected. Tadpoles of this species are not described (Ganesh et al. 2017; Chandramouli et al. 2019).

External morphology: Description of tadpole (Gosner stage 38): Body elliptical in dorsal and lateral profiles respectively (Image 9A–B). Dorsal contour convex and ventral contour of the body flat anteriorly with a slight concavity, and convex at abdominal region; BL is 34.3% of the total length; MBD at the middle of the body. The snout is rounded in dorsal and lateral views. Eyes are large; located and oriented dorsolaterally; NED represents 46% of the distance between the eye and snout. The nostril opening is oblong with the rim of the narial opening elevated, nearer to the eyes than the snout; placed wide apart from each other and near to the eye in dorsal view; INL is 46.4% of IOL; NSD is 16.3% of BL. The opening of the spiracle is sinistral; inner wall of the tube is completely formed but attached to the body wall with the aperture free; tube orientation is

Image 9. ***Minervarya*** **cf.** ***agricola*****, Gosner stage 36. External morphology: A—Lateral view | B—Dorsal view| C—Ventral view. Scale = 10 mm. © Prudhvi Raj.**

Table 5. Morphometric measurements of *Minervarya* cf. *agricola* tadpoles given in mm as mean ± SE.

Gosner stage	IOL	INL	NED	NSD	SS	SV	BL	TL	MBD	MTH	MTMW	TMH	ODD	VTL	DFH	VFH
28(3)	1.2±.05	0.7±.03	0.5±.08	0.7±.12	3.5±.26	2.1±.08	5.0±.08	8.2±.39	3.1±.08	2.3±.37	0.7±.03	1.1	1.2±.20	0.7±.08	0.8	0.6±.03
29	1.4	0.8	0.7	1.1	4.1	2.6	6.3	10.7	3.5	2.2	1.2	1.6	1.3	1.2	1	0.7
30	1.4	1	0.8	1	4.2	2.7	6.9	12.3	4.3	2.7	1.1	1.3	1.5	1.1	1	0.7
31(3)	1.8±.17	1.1±.05	0.8±.03	1.1±.03	5.1±.15	3.2±.23	7.4±.29	13.3±.86	4.7±.17	2.9±.17	1.3±.13	1.4±.13	1.4±.03	1.3±.12	1.0±.08	0.8±.05
32(4)	2±.08	1.1±.06	1.0±.06	1.1±.04	5.2±.11	3.2±.14	7.9±.16	14.7±.53	7.4±2.66	3.7±.47	1.9±.54	1.6±.06	1.3±.08	1.5±.17	1.3(±.05)	0.9(±.04)
33(8)	2.0±.06	1.2±.03	1.0±.03	1.3±.04	5.7±.10	3.6±.10	8.5±.12	16.2±.36	5.4±.16	3.5±.07	1.6±.05	1.9±.05	1.4±.04	1.5±.05	1.3±.04	0.9±.04
34(7)	2.1±.06	1.2±.04	1.0±.04	1.3±.03	5.8±.10	3.8±.16	8.5±.13	15.9±.47	5.5±.14	3.8±.09	1.7±.04	1.9±.02	1.5±.06	1.6±.06	1.4±.07	0.9±.05
35(4)	2.1±.10	1.1±.07	1.1±.04	1.2±.02	6.0±.12	3.9±.10	8.6±.18	17.1±.44	5.4±.08	3.7±.04	1.6±.15	2.0±.06	1.5±.06	1.6±.05	1.4±.05	0.9±.04
36(2)	2.3±.25	1.2	1.1±.10	1.3±.10	5.8±.45	3.8±.20	8.9±.30	17.8±.65	5.3±.60	3.9±.15	1.8	2.2	1.6±.05	1.8±.35	1.3	1.1±.10
37	2.2	1.1	1	1.3	5.2	4.6	8.9	15.4	4.9	3.4	1.4	1.9	1.5	1.7	1.2	1
38	2.4	1.3	1.3	1.5	6.1	4.2	9.2	17.6	5.2	4.2	1.8	2.1	1.5	1.7	1.5	1.2
40	2.3	1	1.2	1.3	5.9	5	10.5	17.9	6.3	3.8	1.8	1.7	1.6	1.8	1.5	1
41(2)	3±.10	1.2±.20	1.0±.15	1.4±.40	6.9±.35	4.1±.50	10.2±.95	19.5±1.05	6.3±.35	4.3±.15	2.1±.25	2.2±.15	1.8±.05	1.1	1.4±.05	0.9±.05

posterolateral and its opening is located approximately above the medial of the lateral side of the body; SS is 59.2% of BL. Vent tube opening is dextral and slanting; the right wall is attached posteriorly than to the left wall. Tail tip acute and sharp; musculature is linear till 1/3rd length of the tail after which it tapers. The dorsal fin originates at the body tail junction and the ventral fin at the ventral terminus; the dorsal fin is wider and slightly convex than the ventral fin, which is parallel to tail musculature for most of the length of the tail. MTH is at 2/3rd length from the body tail junction; TMH is 1.16 times of MTMW at the tail-body junction; TMH accounts for 50% of MTH. Lateral line on the body and the tail is visible. No glands are present on the outer integument.

Oral disc is anteroventral in location (Image 9C); ODD is 28.8% of the body width, emarginated; not visible dorsally; single row of marginal papillae spread on lateral corners of the upper labium and double row on the lower labium; medial gaps are seen on both the labia of which the anterior gap is transformed into A-1; no submarginal papillae are present; both labia are of equal size. The LTRF is 2(2)/3(1). Order of the length of denticle rows is A-1 > P-1 > P-2 > P-3 > A-2. Jaw sheaths are well developed and moderately keratinized. Jaw sheaths are completely serrated with small uniform-sized serrations; supra-rostrodont is wide and convex with an arched outline; infra-rostrodont is U-shaped with a concave median.

Measurements: Measurements of 37 tadpoles belonging to various Gosner stages (Gosner stages 28–38, 40, 41) are presented in Table 5.

Colouration: In life, tadpoles were dirty yellow on the dorsum, with many tiny melanophores spread on the dorsal side. Ventrally the belly was dirty yellow with no melanophores and translucent. Laterally, the tail muscle was unicoloured, having a yellow background with many tiny melanophores on the entire length. Dorsal and ventral tail fins were translucent with many tiny melanophores, with the dorsal fin more spotted than the ventral fin; the posterior tip of the tail was pigmented black. Oral disc and the vent tube were translucent with no pigmentation; however, the spiracle was dotted with few melanophores.

Buccopharyngeal morphology

Buccal roof (Image 10A,B): Prenarial arena comprises an arched tri-lobed pustulose median ridge; two pustules are present laterally on either side of the ridge. Internal nares transverse and directed medially; both nares separated by a distance of about half the length of each nare; anterior narial wall studded with few pustules and a short papilla with a rugose margin originating at lateral corner of the wall; posterior wall smooth and valvular with a tiny narial valve projection near to the medial region of the roof. Post narial arena consists of two tall, broad papillae situated immediately behind the posterior narial wall oriented medially; anterior margin of the papilla is rugose. Median ridge papilla is a triangular flap with a pustulated margin. Two flattened lateral ridge papillae pustulated on the anterior margin present perpendicular to the median ridge. The anterior papilla is short and serrated on the margin, while the posterior papilla is longer, broader and bifid with a rugose margin. Buccal roof arena

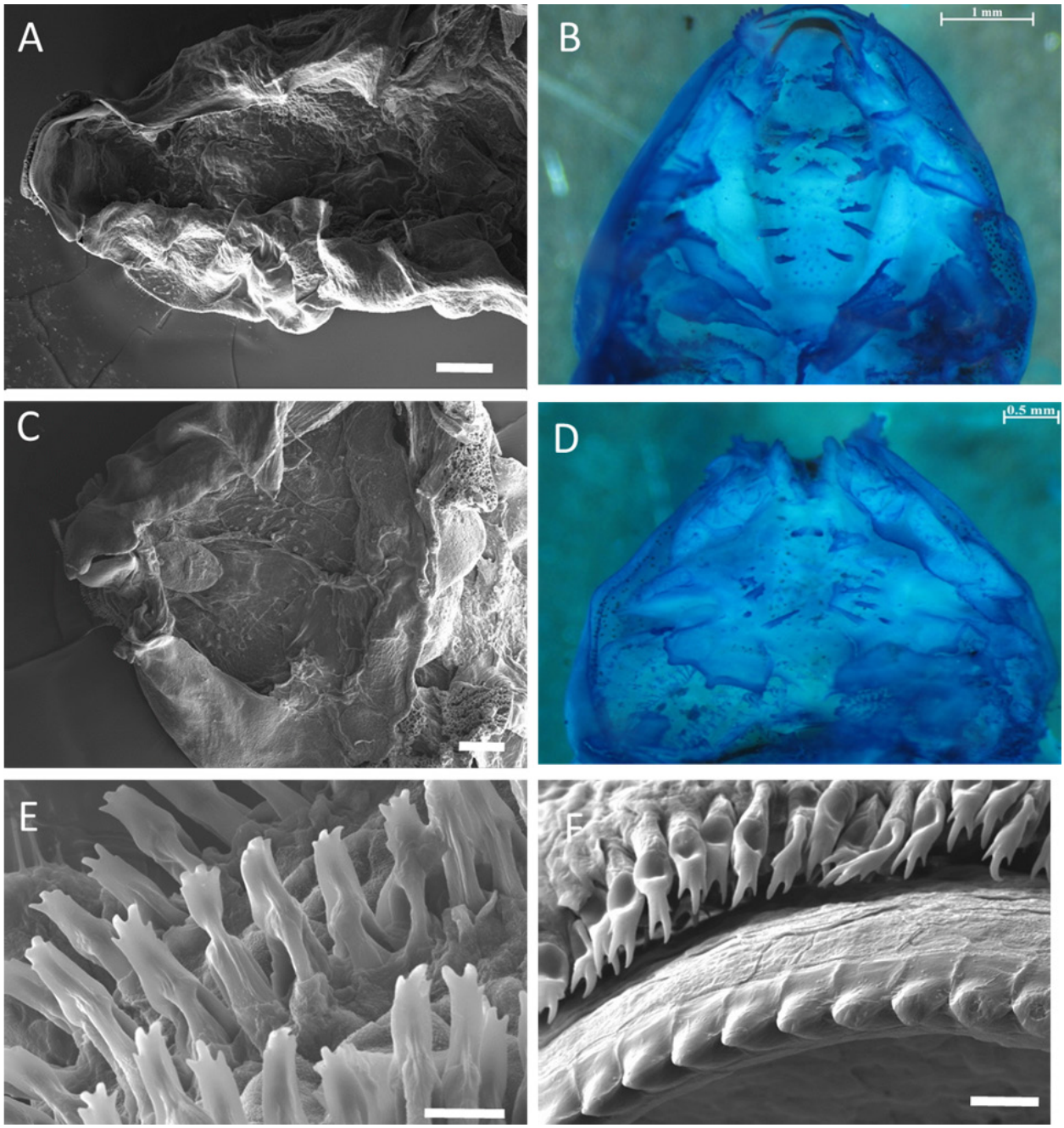

Image 10. ***Minervarya*** **cf.** ***agricola*****, Gosner stage 36. Buccopharyngeal and denticles: A—Buccal roof, SEM photograph, scale = .2 mm | B—Buccal roof, Alcian blue stained photograph, ventral view, scale = 1 mm | C—Buccal floor, SEM photograph, scale = .1 mm | D—Buccal floor, Alcian blue stained photograph, ventral view, scale = .5 mm | E—Individual denticles, scale = .01 mm | F—Jaw sheath serrations = .01 mm. © Prudhvi Raj.**

demarcated with three pairs of long conical pustulated papillae present along the lateral border of the roof; about 30 tiny pustules spread across the entire buccal roof arena. Glandular zone is broad and distinctive, with the anterior margin consisting of pustules; secretary pits sparse and found medially. Dorsal velum margin is conspicuous and oriented posteriorly. The margin of the velum is pustulated and interrupted medially.

Buccal floor (Image 10 C,D): Prelingual area comprises of three pairs of infralabial papillae located along the posterolateral and postero-medial corners; anterior papillae is short with attenuate projections, while the posterior papillae are larger, broader and rugose located at the posterolateral corners of the prelingual

arena; third pair of papillae are located posteromedially between the two posterior papillae on the prelingual arena. Tongue anlage broad and low; two pairs of long conical lingual papillae with pustulated tips are located medially. Buccal floor arena delineated by five pairs of buccal floor arena papillae; the papillae commence anteromedial to the buccal pocket and continue parallel to the mesad plane; all papillae are conical, tall, rugose and of unequal size; the second papilla from the anterior is taller than other papillae; buccal floor arena is smooth with about ten pustules. Space between the tongue anlage and the buccal pockets is free of pustules. Buccal pockets are wide, shallow and transverse orienting towards the mesad; no pocket papillae are present. Region behind the buccal floor arena and the margin of the ventral velum is broad and smooth; ventral velum is wide and sinuate. Ventral velum margin constitutes six projections on each side. The outer three projections are larger and spaced wide apart, while the other three are smaller and concentrated around the center. Median notch is not prominent; the outer margin is smooth with no spicules. Glottis opens posterior to the ventral velum.

Denticles (Image 10E) are moderately spaced and moderately curved towards the mouth at the apex. Oral angle is slightly obtuse. The head of the denticle is short, flattened and slightly curved with 3–4 long, wide, and moderately rounded cusps present on each denticle. Each serration (Image 10F) on the jaw sheath has a short base and a triangular pointed head.

Genus: *Nyctibatrachus* Boulenger, 1882.

Species: *Nyctibatrachus* cf. *periyar* Biju, Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri & Bossuyt, 2011.

Larval series examined: WT145, WT156/151011 (Small stream in tea plantation, Vagamon, Kotayam, India, 9.68266°N, 76.90549°E; WGS84). Tadpoles were collected from a small stream with a muddy substratum.

Taxonomic note: Adults of *Nyctibatrachus periyar* were recorded from the stream where the tadpoles were collected. However, other species of *Nyctibatrachus* are known to occur in the locality where the tadpoles were collected (Biju et al. 2011, but see Abraham et al. 2022; Garg et al. 2017). Tadpoles of *N. periyar* are not described.

Image 11. *Nyctibatrachus* cf. *periyar,* Gosner stage 37. External morphology: A—Lateral view | B—Dorsal view | C—Ventral view. Scale = 10 mm. © Prudhvi Raj.

Table 6. Morphometric measurements of *Nyctibatrachus* cf. *periyar* tadpoles given in mm as mean ± SE.

Gosner stage	IOL	INL	NED	NSD	SS	SV	BL	TL	MBD	MTH	MTMW	TMH	ODD	VTL	DFH	VFH
25(8)	2.2±.17	1.5±.06	0.8±.09	1.1±.09	5.0±.25	4.4±.25	8.7±.49	17.0±.89	5.2±.22	3.6±.17	2.1±.10	2.6±.13	1.6±.11	1.5±.08	1.0±.06	0.7±.04
26(2)	1.6±.25	1.2±.05	0.5±.05	1.2±.05	4.3±.05	3.9±.20	8±.10	14.7±.60	4.0±.15	3.3	1.6±.25	1.7±.05	1.6±.05	1.8	1.2±.10	0.9
27(2)	2.5±.25	1.8±.05	1.3±.45	1.4±.05	6.0±.25	5.4±.50	10.4±.30	21±.60	7.05±.55	4.3±.30	2.6±.05	2.9±.10	2.4±.55	1.7±.05	1.3±.25	0.8±.15
28(2)	2.1±.35	1.5±.30	0.8±.40	1.5±.20	5.5±.80	4.4±.75	9.0±1.15	16.7±2.40	5.8±.95	3.7±.50	2.3±.65	2.7±.85	1.9±.40	1.9	1.3±.20	0.9±.05
29	2.2	1.5	0.6	1.3	4.8	4.2	8.6	16.7	4.5	3.3	1.8	2	1.8	2	1.4	1
30(3)	2.5±.47	1.5±.15	0.8±.15	1.4±.24	5.6±.91	5.1±.88	9.9±1.33	19.0±2.43	5.7±.85	3.9±.48	2.3±.50	2.5±.53	2.0±.20	6.7±4.66	1.1±.08	0.9±.05
31	1.6	1.2	0.5	1.2	4.7	4.1	8.7	15.1	4.3	3.2	1.7	1.9	1.7	1.6	1.3	1.1
35(2)	2.1±.05	1.5	0.7	1.2±.10	4.9±.25	4.5±.25	8.8±.40	18±.40	4.8±.05	3.4±.35	1.9±.10	2.2±.05	1.6±.15	2.0±.05	1.1±.10	0.9±.05
36(2)	2.4±.05	1.4±.05	0.7±.05	1.5	5.7±.20	4.6±.25	9.5±.25	19.3±.25	5.4±.05	4.2±.20	2.1±.05	2.4±.05	1.8±.05	2	1.5±.10	1.1±.10
37(2)	2.4±.15	1.6±.10	0.7±.10	0.8±.25	6±.50	5.5±.40	10.2	18.8±1.10	5.6±.15	3.9±.10	2.3±.20	2.5±.10	1.8±.40	2.2±.30	1.1±.10	0.9±.20
38(2)	2.3±.20	1.6±.05	0.6±.15	1.3	5.7±.45	5.1±.20	10±.20	20.6±.80	5.7±.60	4.2±.25	2.3±.35	2.5±.25	1.8±.05	1.8±.30	1.2±.15	1±.10
39	2.9	1.8	0.9	1.5	6.2	5.1	10.8	22.8	6	4.1	2.6	2.7	1.9	2.2	1.2	0.9
41(5)	2.7±.10	1.5±.05	0.9±.03	1.3±.02	5.7±.08	4.6±.15	9.5±.27	20.0±.76	5.7±.12	4.0±.12	2.4±.08	2.5±.05	1.9±.04	*	1.4±.06	1±.04

External morphology: Description of tadpole (Gosner stage 37): Body elliptical in dorsal and lateral views (Image 11A,B). Dorsal contour convex and ventral contour of body flattened; BL is 35.2% (33.8%–36.5%) of the total length; MBD at mid-length of the body. The snout is rounded in dorsal and lateral views. Eyes are large; located and oriented dorsolaterally; NED represents 46% (42.1%–50%) of the distance between the eye and snout. The nostril opening is oval with the rim elevated; there is a small protuberance at the dorsal most region of the nostril; they are located closer to the eyes than the snout; placed parallel to the eye in dorsal view; INL is 65.3% (65.2%–65.3%) of the IOL. Spiracle sinistral and short; inner wall of the tube completely formed but attached to body wall; tube orientation is posterolateral and its opening located just below the medial on the lateral side of the body; SS is 58.8% (53.9%–63.9%) of BL. Vent tube is dextral with the opening of the aperture towards the right side; both the walls meet each other at the same point. Tail tip acute; musculature is tallest at the body tail junction and tapers to the tip of the tail. The dorsal fin originates behind the body tail junction and the ventral fin at the ventral terminus; the dorsal fin is wider and concave than the ventral fin; MTH is at about mid-length; TMH is 92% (91.1%–93%) of MTMW at the tail-body junction; TMH accounted for 64.1% (63.1%–65%) of the MTH. Lateral line formed by the dermal pores visible. No glands are present on the outer integument.

Moderately large oral disc, which is near ventral in located and opening ventrally (Image 11C); ODD is 32.4% (30% –34.8%) of the body width, emarginated; not visible dorsally; the entire labium is multi-lobed with about eight lobes; the anterior lobe is the largest followed by those on the lateral sides and the posterior; posteriorly, the labium is divided into four lobes. The margins of the labia are with a uniserial row of large marginal papillae spread along the margin of the oral disc; sharp submarginal papillae are seen above the upper jaw sheath as well as on the lobes, both laterally and ventrally; the submarginal papillae above the upper jaw sheath are arranged in two rows and are smaller; the submarginal papillae on the lateral and ventral lobes are larger, fewer and widely placed; about four to five submarginal papillae are seen on each lateral and ventral lobes. No labial tooth rows are present and submarginal papillae are seen in place of denticle rows on the upper labium. Jaw sheaths are well developed and both the jaw sheaths are massively keratinized; supra-rostrodont is longer than wide and convex with long lateral processes; infra-rostrodont is U-shaped, convex laterally and concave medially. Both the jaw sheath are serrated, however, the serrations on the infra-rostrodont are larger than those on the supra-rostrodont.

Measurements: Measurements of tadpoles belonging to various Gosner stages (Gosner stages 25–31, 35–39 and 41) are presented in Table 6.

Colouration: In life, tadpoles were light beige brown with moderate-sized dark brown spots on flanks and dorsum. The inner integument along the lateral sides was found to be dotted with numerous melanophores giving the region a darker appearance than the rest. Ventrally the integument was dirty white and transparent with

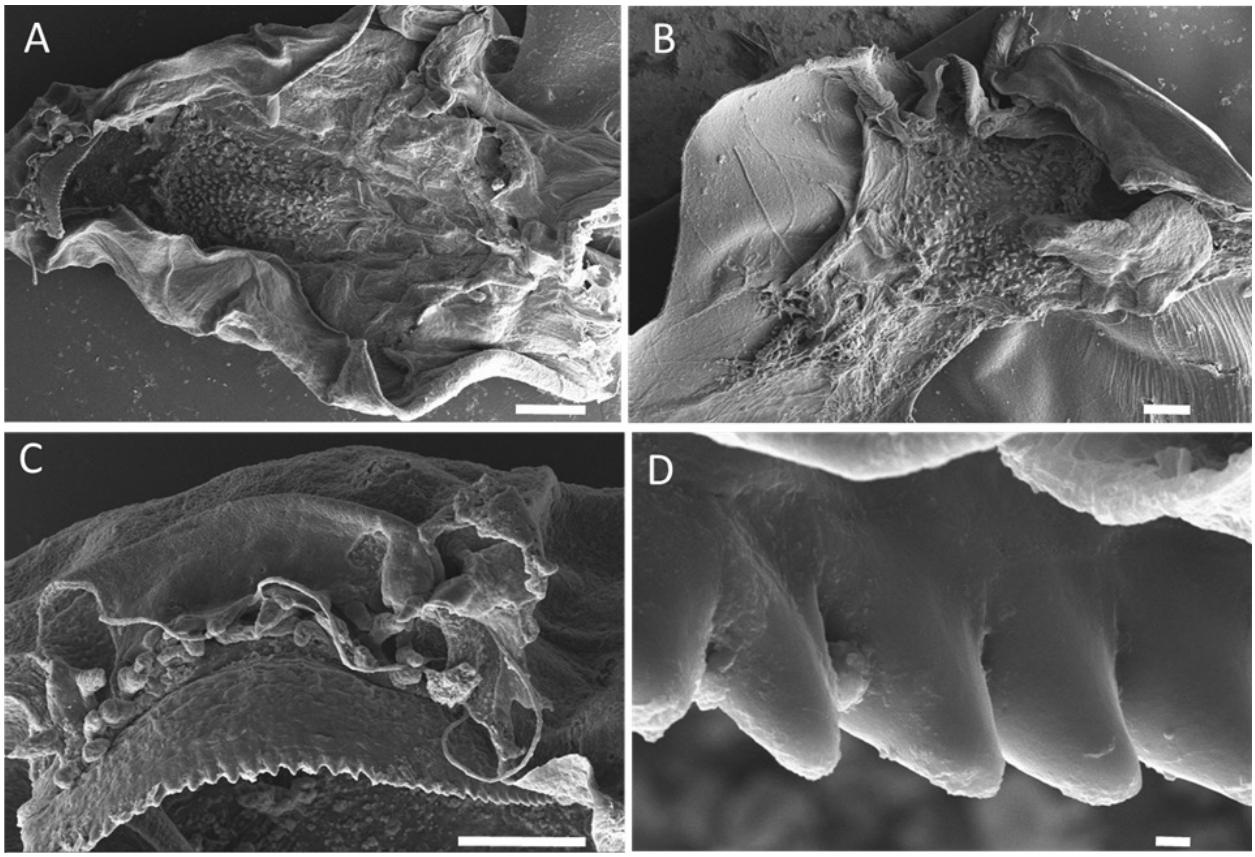

Image 12. ***Nyctibatrachus* cf. *periyar*, Gosner stage 38. Buccopharyngeal and denticles: A— Buccal roof, SEM photograph, scale = .2 mm | B—Buccal floor, SEM photograph, scale = .1 mm | C—Jaw sheath with oral papillae, scale = .1 mm | D—Jaw sheath serrations = .002 mm. © Prudhvi Raj.**

gut visible. The tail muscle has a white background and is mottled with many medium-sized irregular-shaped blotches of moderate-sized melanophores spread across the tail muscles. Dorsal and ventral tail fins were white and translucent with many bands of melanophores, mostly along the posterior region of the tail. Spiracle, oral disc and the vent tube were translucent with no melanophores. Few melanophores were found on the dorsal side of the hind limb.

Buccopharyngeal morphology

Buccal roof (Image 12A): Prenarial arena comprises of nine papillae; about eight papillae are arranged in a diamond shape anteriorly; a short papilla is present along the medial axis posterior to these anterior papillae; all anterior papillae are more or less of equal height. Internal nares transverse and directed medially; both nares broadly separated by a distance of about more than the length of a nare; a short papilla is present medially between the nares; anterior narial wall is pustulose with many tiny pustules and a stubby projection origination at the middle; posterior wall tall, smooth and valvular; two projections of which one is seen at the middle of the wall and the other at the medial end; both the projections are conical and pustulose; the projection seen near the mesad is longer than the projection at the middle of the posterior narial wall. Post narial arena constituted two pairs of papillae arranged behind the posterior narial wall linearly from the mesad plane; all papillae are long with a rugose surface; size wise, the papillae show an ascending order with the papillae near to the mesad plane being slightly shorter and the papillae on the lateral corners being longer. There is no median ridge; however, there are many tiny conical papillae at its location. A long trifid pustulose lateral ridge papillae is present. Buccal roof arena is delineated by about 20 pairs of closely arranged short buccal roof arena papillae. More than 300 pustulations dot the entire buccal roof arena; the posterior region of the buccal roof arena is demarcated by broad bifid papillae on each side. Observations on the glandular zone could not be made and is not prominent as seen in tadpoles of other genus. The dorsal velum is raised and there appears to be a deep grove in front of the margin of the velum; the margin is not entire and broken medially; margin of the velum along the lateral sides had

few tiny projections spaced widely and medially there are numerous projections oriented posteriorly.

Buccal floor (Image 12B): Prelingual area comprises of four pairs of infralabial papillae located along the posterolateral corner of the prelingual area; the first two pairs are moderately long and rugose on the surface; the third pair is trifid and has three thick projections with a rugose surface; the fourth pair has numerous long conical projections (~10). Tongue anlage low and constituted two pairs of papillae; the medial pair of papillae are attached to each other at the base and longer; both pairs of papillae are spread wide apart. The entire floor is dotted with numerous pustules which are bordered anterolaterally by long papillae spread linearly from the lingual arena and posterolaterally by the buccal floor arena papillae; more than 400 pustules are spread across the entire floor; about four to five conical papillae of unequal size are arranged linearly from the lingual arena to the buccal pockets; buccal floor arena is demarcated laterally by about six to eight buccal floor arena papillae; these buccal floor arena papillae are broadly dilated at the tips forming multiple projections. Buccal pockets are small and narrow-oriented anteromedial; no pocket papillae are present. The region between the buccal floor arena and the margin of the velum is smooth. Ventral velum margin is smooth, with about eight to ten long projections mainly concentrated around the medial region on the velum. Glottis opens immediately posterior to the velum.

The serrations (Images 12C–D) on the jaw sheaths are large and, each serration had a wide base and triangular pointed head.

DISCUSSION

Duttaphrynus melanostictus is the most widely distributed toad in southern and southeastern Asia and is a species complex (Dubois & Ohler 1999). Descriptions of morphology for tadpoles of *D. melanostictus* made earlier (Boulenger 1912; Bourret 1942; Kirtisinghe 1957; Daniel 1963a; Khan 1982; Ye et al. 1986; Ray & Tilak 1994; Deuti & Goswami 1995; Chou & Lin 1997; Leong & Chou 1999; Ray 1999; Khan 2001; Anders 2002; Daniel 2002) are brief and do not mention diagnostic features of *D. melanostictus* which distinguish it from other *Duttaphrynus* tadpoles. While resolving the taxonomy of the species is beyond the scope of this paper, morphological comparison for tadpoles is being done with published descriptions of the species and its congeners (Annandale & Rao 1918; Kirtisinghe 1957; Daniel 1963; Khan 1965; Bhati 1969; Inger 1985; Khan & Mufti 1994; Ray 1999; Anders 2002; Khan 2002, 2003a; Daniels 2005; Fei et al. 2005; Inthara et al. 2005; Aran et al. 2012). The external and buccopharyngeal morphologies of the tadpoles of *D.* cf. *melanostictus* are very similar to those of other known *Duttaphrynus* tadpoles. External character states of *D.* cf. *melanostictus* tadpoles that are consistent with other *Duttaphrynus* tadpoles are: oval body with a rounded head; dorsolateral eyes; spiracle opening sinistral; vent tube opening medial; a lanceolate feeble tail with a rounded tip; emarginated oral disc with five tooth rows (2/3). Likewise, *Duttaphrynus* tadpoles share the following buccopharyngeal character states: a prominent transverse semicircular or triangular ridge in the prenarial arena; pustulose anterior narial wall with no papilla; smooth posterior narial wall; a triangular median ridge; branched lateral ridge of papilla; a prominent glandular zone with an elevated dorsal velum; dilated infralabial papillae; two pairs of lingual papillae; well-defined buccal floor arena; projections on the ventral velum. Tadpoles of *D.* cf. *melanostictus* can be diagnosed on the basis of: dark coloured tadpole (uniformly pigmented with black melanophores and speckled with gold); tail musculature black with fins translucent; spiracle with partially formed inner wall; emarginated oral disc with marginal papillae spread only at the lateral corners; labial tooth row formula is 2(2)/3 with the order of tooth rows length being A1>P1>A2>P2>P3; triangular prenarial ridge; trifid lateral ridge papillae; buccal roof arena demarcated by three pairs of papillae; a pair of bifid dilated infralabial papillae; buccal floor arena demarcated by six long conical papilla; both arenas with 20–30 pustulations.

On mainland India, 12 species of *Polypedates* are known to occur, among which tadpoles of *Polypedates maculatus, P. taeniatus* and *P. teraiensis* have been described. *P. pseudocruciger* and *P. occidentalis* are endemic to the Western Ghats. Tadpoles of *P. pseudocruciger* are similar to those attributed to the nektonic morphotype tadpoles of *Polypedates* (Inger 1985; Mohanty-Hejmadi & Dutta 1988; Grosjean 2004; Haas & Das 2008; Chakravarty et al. 2011). External character states of *P. pseudocruciger* tadpoles that are consistent with other *Polypedates* tadpoles are: an anteroventral oral disc; LTRF with multiple tooth rows and strongly keratinized jaw sheaths; body cylindrical with eyes positioned laterally and widely spaced nares; spiracle opening sinistral; vent tube opening dextral; tail fins arched and tapper posteriorly. Buccopharyngeal character states of *P. pseudocruciger* tadpoles that are consistent with other *Polypedates* tadpoles are:

broad buccal roof and floor; an arched prenaial ridge; elongated pre and postnarial papillae oriented medially; median ridge low; buccal roof and buccal floor arena delineated by papillae; presence of glandular zone; tongue anlage with lingual papillae; oblique buccal pockets; ventral velum with projections on margin of velum. Diagnostic characters of *P. pseudocruciger* tadpoles are: body colouration olive with many tiny melanophores on dorsal and lateral sides; tail fins with numerous melanophores, more spotted at the anterior end of the tail; nasal opening oval shaped and elevated; inner wall of spiracle absent; emarginated oral disc with marginal papillation having a wide gap on the upper labium and a small gap on the lower labium; three submarginal papillae at the lateral corners; LTRF is 5(2–5)/3(1); order of the length of tooth rows is P-1>P-2>P-3>A-1>A-2>A-3>A-4>A-5; a pustulated arched ridge arched with about six pustulations; nares separated by a distance of about two-third the length of each nare; median ridge with a pustulated margin and a long medial projection; prelingual area comprising of five pairs of pustules and two pairs of infralabial papillae; two pairs of smooth long lingual papillae; buccal floor arena delineated by five pairs buccal floor arena papillae with 30 pustulations in the arena.

Four species of *Rhacophorus* are endemic to the Western Ghats, of which tadpoles for two species are being described in the current study. Tadpoles of *R. lateralis* and *R. malabaricus* have similar morphological features to those attributed to pond-type *Rhacophorus* (Grosjean & Inthara 2016; Vassilieva et al. 2016). External character states of *R. lateralis* and *R. malabaricus* tadpoles that are consistent with other *Rhacophorus* tadpoles are: an anteroventral oral disc; LTRF with multiple tooth rows and strongly keratinized jaw sheaths; body ovoid with eyes oriented dorsolateral; spiracle opening sinistral; vent tube opening dextral; robust muscular tail. The above characters of *Rhacophorus* tadpoles can be attributed to a benthic feeding larval morphotype (Altig & Johnston 1989). The LTRF 7(3–7)/3(1) of *R. malabaricus* tadpoles from the current description matches with the LTRF for the species given by Sekar (1990a). Similarly, comparisons of tadpole buccopharyngeal morphology with congeners revealed broad similarities (Inger 1985; Grosjean & Inthara 2016). Buccopharyngeal character states of *R. lateralis* and *R. malabaricus* tadpoles that are consistent with other *Rhacophorus* tadpoles are: broad buccal roof and floor; prenarial arena bearing a broad prenarial ridge; elongated postnarial papillae oriented medially; presence of an elevated median ridge; buccal roof and buccal floor arena delineated by papillae; presence of glandular zone; prelingual arena bearing infralabial papillae; tongue anlage with lingual papillae; oblique buccal pockets; ventral velum with projections on margin of velum. Diagnostic characters of *R. lateralis* tadpoles are: body colouration sulphurous yellow with few tiny melanophores dorsally; and tail fins with many blotches; nasal opening depressed; spiracle with the inner wall partly formed and attached to the body wall; emarginated oral disc with marginal papillation having a wide gap in the upper labium and six submarginal papillae at the lateral corners; Labial Tooth Row Formula (LTRF) is 6(3–6)/3(1); a pustulated arched ridge arched forward with the median pustule being the largest in the prenarial arena; nares widely separated by a distance of about the length of each nare; median ridge with a bifid tip; six pairs of infralabial papillae with the second and the fourth papillae large and pustulose; buccal floor arena delineated by five pairs buccal floor arena papillae with 14 pustulations in the arena. Likewise, diagnostic characters of *R. malabaricus* tadpoles are: body and tail olive-coloured, and mottled with several tiny melanophores dorsally; nasal opening elevated; spiracle with the inner wall fully formed but attached to the body wall; emarginated oral disc with marginal papillation having a wide gap on the upper labium and four to five submarginal papillae at the lateral corners; LTRF is 7(3–7)/3(1); a pustulated arched ridge arched forward with uniform sized pustules in the prenarial arena; nares narrowly separated by a distance of about half the length of each nare; median ridge with a serrated margin; four pairs of infralabial papillae with the fourth pair largest and dilated; buccal floor arena delineated by five pairs of buccal floor arena papillae with 16 pustulations in the arena.

The tadpoles of cricket frogs of Asia sensu lato (including the genera *Fejervarya* and *Minervarya*) have been studied earlier (Heyer 1971; Dutta 1997; Leong & Chou 1999; Leong 2005; Stuart et al. 2006). However, detailed morphological descriptions are few. Only recently was systematics of cricket frogs from South and Southeast Asia resolved by phylogenies using multiple molecular markers, which resulted in extensive changes in the taxonomy of the group (Kuramoto et al. 2008 "2007"; Ohler et al. 2009; Purkayastha & Matsui 2012; Dinesh et al. 2015; Howlader et al. 2016; Garg & Biju 2017, 2021; Raj et al. 2018). External character states of *M.* cf. *agricola* tadpoles that are consistent with other cricket frog tadpoles are: an elliptical body with a moderate tail; anteroventral oral disc; marginal papillation of oral disc having medial gaps on both

labia; two labial tooth rows on the upper labium and three rows on the lower labium; dorsolateral eyes; spiracle opening sinistral with the inner wall of the tube completely formed but attached to the body wall; opening of anal tube dextral; fin heavily pigmented only at the distal end. Buccopharyngeal character states of *M.* cf. *agricola* tadpoles that are consistent with other Cricket frog tadpoles are: elongated buccal roof and floor; an arched prenarial ridge; median ridge low; buccal roof and buccal floor arena delineated by papillae and with many pustulations in the arena; tongue anlage with lingual papillae; oblique buccal pockets; ventral velum with projections on margin of velum. Externally, the current description broadly agrees with the descriptions made by Khan (1982, 2003b) and Khan & Mufti (1994) on the general morphology of *Fejervarya*; however, the taxonomic identity of those tadpoles needs to be ascertained. The external larval morphology of various cricket frog species is perplexing since most species have similar body colouration patterns and LTRF. The buccopharyngeal character states in the current descriptions differ from those made by Khan (1991, 1996) in having a tri-lobed pustulose prenarial ridge, nares separated by a distance of half the length of each nare, two pairs of tall post narial papillae and two flattened lateral ridge papillae and having two pairs of infralabial papillae.

Tadpoles of *Nyctibatrachus* species were described earlier (Annandale 1918, 1919; Bhaduri & Kripalani 1955; Pillai 1978) but comparative studies on morphology could not be made using those descriptions. In recent times, detailed morphological descriptions on *Nyctibatrachus* tadpoles were made by Priti et al. (2015). One of the most prominent characters of *Nyctibatrachus* tadpoles is having a multilobed oral disc that is devoid of labial teeth but with keratinized jaw sheaths. Other morphological characters shared by tadpoles of the genus are: an elliptical body with a robust tail; dorsolateral large eyes; acute tail tip; sinistral spiracle; Vent tube opening dextral. Diagnostic characters of *N.* cf. *periyar* tadpoles are: eight lobed oral discs with the anterior lobe largest; two rows of submarginal papillae immediately above the upper jaw sheath; body light beige brown with moderate-sized dark brown spots on flanks and dorsum, and tail mottled with many medium-sized irregular-shaped blotches. Descriptions on larval buccopharyngeal morphology for *Nyctibatrachus* species are unavailable and therefore no comparisons could be made. Tadpoles of *Nyctibatrachus* are morphologically highly derived with unique oral morphology. Unlike tadpoles of other groups, the oral disc labia of *Nyctibatrachus* tadpoles are divided with multiple folds and are devoid of keratodonts that are replaced by conical papillae. This ecomorphological guild is referred to as "psammonic" and is shared by tadpoles of very few anuran groups that are adapted to live in habitats with predominantly sandy substratum (Altig & Johnston 1989). Since, labial tooth row formula cannot be used for larval identity of *Nyctibatrachus* tadpoles, taxonomic identity using oral structures is found to be challenging. Further comparative works on tadpoles of this genus can help to identify characters that can be useful for taxonomic identification. Also, with the buccopharngeal morphology, tadpoles of *N.* cf. *periyar* is unique in have numerous papillae and pustulations spread across the buccal roof and buccal floor arenas. This character of having numerous BRA and BFA papillae/pustulations is shared with psammonic tadpoles of *Boophis picturatus* (Grosjean et al. 2011) that live in habitats with sandy substrate. Recently, from Western Ghats, tadpoles of *Micrixalus* were found to have derived morphology with reduced oral structures similar to that of *Nyctibatrachus* (Senevirathne et al. 2016b). This warrants the need for more studies to understand the unique larval morphologies of these groups from Western Ghats.

Anuran larvae unlike their adult forms are generally overlooked in scientific works and are therefore poorly understood. There has been a call for research on anuran larval forms for long to understand their morphology, both at the assemblage and guild level they occupy, internal anatomy, and developmental patterns. Such information can be helpful in resolving anuran systematic issues, understanding inter-species competition, improving inventorisation of anurans and conservation efforts. Also, in the past forty years, many tadpole studies had focused on describing internal oral structures that are phylogenetically informative. Larval characters are useful to investigate the systematic relationships among anurans (Sokol 1975; Maglia et al. 2001; Haas 2003; Púgener et al. 2003) and can be helpful in getting a greater resolution for presently known systematic relationships.

The current paper describes six species, of which two are re-descriptions. Larval forms of *D.* cf. *melanostictus*, *P. pseudocruciger*, *R. lateralis*, *R. malabaricus*, and *M.* cf. *agricola* were collected from lentic pools. Species other than *P. pseudocruciger* have typical lentic/benthic forms (Altig & Johnson 1989) with spheroid bodies and dorsolateral eyes and an anterolateral mouth, while tadpoles of *P. pseudocruciger* have a typical lentic/nectonic form have laterally oriented eyes. Larvae of *N.*

cf. *periyar* are of lotic/benthic form with spheroid bodies and dorsolateral eyes, and an anterolateral mouth.

Identification of anuran larvae in Western Ghats has been a challenge due to the poor availability of morphological characterization for anuran larvae from the region. Most of the published descriptions of tadpoles from the region were mainly done nearly a century ago and needs thorough review. In recent times, systematics and taxonomy of many anurans from this region had been resolved (Dinesh et al. 2015; Garg & Biju 2017, 2021). External morphology of tadpoles is conserved within a group (genus) and using additional characters like those of the buccopharyngeal region would help in improving species diagnosis and resolving problems in anuran systematics problems (Wassersug 1976; Das 1994). Knowledge on anuran larval morphology can be useful in understanding the diversification patterns and evolution of anurans in the region. Further comparative morphological and developmental studies of larval anurans from the region will likely provide many evolutionary insights since many endemic anuran lineages are known to occur in Western Ghats. Most endemic lineages from the region like *Indirana* (semi-terrestrial tadpoles), *Micrixalus* (fossorial tadpoles), *Nasikabatrachus* (Rheophilous tadpoles), and *Nyctibatrachus* (psammonic tadpoles) tend to have derived tadpoles. Many of these tadpoles morphotypes are rarely seen elsewhere and it is also interesting to find such morphotypes only in these ancient lineages from the region. Since life history patterns for much of the anuran fauna from Western Ghats remain insufficiently understood, larval descriptions from the current study make a significant contribution to the knowledge of the biology of these species. This study opens the door to future studies on larval anurans from the region, which are necessary to understand life history patterns of species. Knowledge of larval forms (morphology and ecology) will be helpful in assessing conservation priorities for anurans of the region, thereby aiding in the conservation of biota in Western Ghats.

REFERENCES

Abraham, R.K., J.K. Mathew, V.P. Cyriac, A. Zachariah, D. Raju & A. Zachariah (2015). A novel third species of the Western Ghats endemic genus *Ghatixalus* (Anura: Rhacophoridae), with description of its tadpole. *Zootaxa* 4048(1): 101–113. https://doi.org/10.11646/zootaxa.4048.1.6

Abraham, R.K., R. Rao, A. Zachariah & R.M. Brown (2022). Integration of ecology, larval phenotypes, and mate-recognition signals with molecular and morphological data indicate taxonomic inflation in *Nyctibatrachus* (Anura: Nyctibatrachidae). *Ichthyology & Herpetology* 110: 526–546.

Altig, R. & G.E Johnston (1989). Guilds of anuran larvae: relationships among developmental modes, morphologies and habitats. *Herpetological Monograph* 3: 81–109. https://doi.org/10.2307/1466987

Altig, R. (2007). A primer for the morphology of anuran tadpoles. *Herpetological Conservation and Biology* 2: 71–74.

Anders, C. (2002). Class Amphibia (Amphibians), pp. 133–348. In: Schleich, H.H & W. Kästle (eds.). *Amphibians and reptiles of Nepal. Biology, Systematics, Field guide*. Koeltz Scientific Books, Koenigstein.

Annandale, N. (1913). Some new and interesting Batrachia and lizards from India, Ceylon and Borneo. *Records of the Indian Museum* 9: 301–307.

Annandale, N. (1918). Some undescribed tadpoles from the hills of Southern India. *Records of the Indian Museum* 15: 19–23.

Annandale, N. (1919). The tadpoles of *Nyctibatrachus pygmaeus* and *Ixalus variabilis*: a correction. *Records of the Indian Museum* 16(4): 302.

Annandale, N. & C.R.N. Rao (1917). Indian tadpoles. *Proceedings of the Asiatic Society of Bengal* 13: 185–186.

Annandale, N. & C.R.N. Rao (1918). The tadpoles of the families Ranidae and Bufonidae found in the plains of India. *Records of the Indian Museum* 15(1): 25–40.

Aran, S., C. Chuaynkern, S. Duengjai & Y. Chuaynkern (2012). Morphology of some tadpoles in Khon Kaen University, Khon Kaen Province. *Journal of Wildlife in Thailand* 19: 41–73.

Bhaduri, J.L. & M.B. Kripalani (1954). *Nyctibatrachus humayuni*, a new frog from the Western Ghats, Bombay. *The Journal of the Bombay Natural History Society* 52: 852–859.

Bhati, D.P.S. (1969). Normal stages in the development of the larvae of *Rana tigrina*, Daud. and *Bufo andersonii* Bouleng. *Agra University Journal of Research* (*Science*) 18(1): 1–13.

Biju, S.D., R. Kamei, G. Bhatta, V. Giri, N. Cox, I. Das & F. Bossuyt (2008). Diversity and conservation status of the Western Ghats amphibians, pp. 80–82. In: Stuart, S.N, M. Hoffmann, J.S. Chanson, N.A. Cox, R. Berridge, P. Ramani, B.E. Young (eds). *Threatened Amphibians of the World*. Lynx Edicions, Barcelona.

Biju, S.D., I.V. Bocxlaer, S. Mahony, K.P. Dinesh, C. Radhakrishnan, A. Zachariah, V. Giri & F. Bossuyt (2011). A taxonomic review of the Night Frog genus *Nyctibatrachus* Boulenger, 1882 in the Western Ghats, India (Anura: Nyctibatrachidae) with description of twelve new species. *Zootaxa* 3029: 1–96. https://doi.org/10.11646/zootaxa.3029.1.1

Biju, S.D., R.G. Kamei, S. Mahony, A. Thomas, S. Garg, G. Sircar & R. Suyesh (2013). Taxonomic review of the tree frog genus *Rhacophorus* from the Western Ghats, India (Anura: Rhacophoridae), with description of ontogenetic colour changes and reproductive behaviour. *Zootaxa* 3636: 257–289.

Biju, S.D., G. Senevirathne, S. Garg, S. Mahony, R.G. Kamei, A. Thomas, Y. Shouche, C.J. Raxworthy, S. Meegaskumbura & I.V. Bocxlaer (2016). *Frankixalus*, a new rhacophorid genus of tree hole breeding frogs with oophagous tadpoles. *PLoS ONE* 11(1):1–17. https://doi.org/10.1371/journal.pone.0145727

Boulenger, G.A. (1912). *A vertebrate fauna of the Malay Peninsula from the Isthmus of Kra to Singapore including the adjacent islands. Reptilia and Batrachia*. Taylor and Francis, London, 294 pp.

Bourret, R. (1942). *Les Batraciens de l'Indochine. Mémoires de l'Institut Océanographique de l'Indochine*, Hanoi, 547 pp.

Bossuyt, F., M. Meegaskumbura, N. Beenaerts, D.J Gower, R. Pethiyagoda, K. Roelants, A. Mannaert, M. Wilkinson, M.M. Bahir, K. Manamendra-Arachchi, P.K.L. Ng, C.J. Schneider, O.V. Oommen & M.C. Milinkovitch (2004). Local endemism within the Western Ghats-Sri Lanka biodiversity hotspot. *Science* 306: 479–481. https://doi.org/10.1126/science.1100167

Chandramouli, S.R. & A. Kalaimani (2014). Description of the larvae of Günther's toad *Duttaphrynus hololius* (Günther, 1876) (Anura:Bufonidae) with notes on development and oral ultra-structure. *Alytes* 31: 3–12.

Chandramouli, S.R., D. Ankaiah, V. Arul, S.K. Dutta & S.R. Ganesh

(2019). On the taxonomic status of *Minervarya granosa* (Kuramoto, Joshy, Kurabayashi & Sumida, 2008) and the distribution of *M. agricola* (Jerdon, 1853) Amphibia: Anura: Dicroglossidae. *Asian Journal of Conservation Biology* 8: 84–87.

Chakravarty, P., S. Bordoloi, S. Grosjean, A. Ohler & A. Borkotoki (2011). Tadpole morphology and table of developmental stages of *Polypedates teraiensis* (Dubois, 1987). *Alytes* 27: 85–115.

Chari, V.K. (1962). A description of the hitherto undescribed tadpole of, and some field notes on the Fungoid Frog, *Rana malabarica* Bibron. *The Journal of the Bombay Natural History Society* 59(1): 71–76.

Chou, W.H. & J.Y. Lin (1997). *Tadpoles of Taiwan. Special Publication*, National Museum of Taiwan, Taipei, 98 pp.

Dahanukar, N. & S. Molur (2020). JoTT Checklist of Amphibians of the Western Ghats (v1.0), 01 January 2020. https://threatenedtaxa.org/index.php/JoTT/checklists/amphibians/westernghats.

Daniel, J.C. (1963a). Field guide to the amphibians of Western Ghats. Part 1. *The Journal of the Bombay Natural History Society* 60: 415–438.

Daniel, J.C. (1963b). Field guide to the amphibians of Western Ghats. Part 2. *The Journal of the Bombay Natural History Society* 60: 690–702.

Daniel, J.C. (1975). Field guide to the amphibians of Western Ghats. Part 3. *The Journal of the Bombay Natural History Society* 72(2): 506–522.

Daniel, J.C. (2002). *The book of Indian reptiles and amphibians*. Bombay Natural History Society, Oxford University Press, Mumbai, Delhi, Calcutta and Chennai, 238 pp.

Daniels, R.J.R. (2005). *Amphibians of peninsular India*. Universities Press (India) Private Limited, Hyderabad, 268 pp.

Das, I. (1994). The internal oral morphology of some anuran larvae from south India: a scanning electron microscopic study. *Amphibia-Reptilia* 15(3): 249–256. https://doi.org/10.1163/156853894X00029

Das, S. (1996). Morphometric, growth and development of *Tomopterna rolandae* (Anura: Ranidae). *Zoos' Print* 11(8): 42–43.

Das, I. & S.K. Dutta (2006). Sources of larval identities for amphibians of India. *Hamadryad* 31(2): 152–181.

Das, I. & M.S. Ravichandran (1998). A new species of *Polypedates* (Anura: Rhacophoridae) from the Western Ghats, India, allied to the Sri Lankan *P. cruciger* Blyth, 1852. *Hamadryad* 22: 88–94.

Deuti, K. & B.C.B. Goswami (1995). *A field guide to the amphibians of West Bengal plains*. World Wide Fund for Nature– India, Calcutta, 53 pp.

Dinesh, K.P., S.P. Vijayakumar, B.H. Channakeshavamurthy, V.R. Torsekar, N.U. Kulkarni & K. Shanker (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. *Zootaxa* 3999 (1): 79–94. https://doi.org/10.11646/zootaxa.3999.1.5

Dinesh, K., B. Channakeshavamurthy, P. Deepak, A. Ghosh & K. Deuti (2021). Morphological groupings within *Euphlyctis* (Anura: Dicroglossidae) and description of a new species from the surroundings of Thattekad Bird Sanctuary, Kerala, India. *Zootaxa* 4990(2): 329–353. https://doi.org/10.11646/zootaxa.4990.2.7

Dubois, A. & A. Ohler (1999). Asian and Oriental toads of the *Bufo melanostictus*, *Bufo scaber* and *Bufo stejnegeri* groups (Amphibia, Anura): a list of available and valid names and redescription of some name-bearing types. *Journal of South Asian Natural History* 4: 133–180.

Dutta, S.K. (1997). A new species of *Limnonectes* (Anura: Ranidae) from Orissa, India. *Hamadryad* 22(1): 1–8.

Dutta, S.K., K. Vasudevan, M.S. Chaitra, K. Shankar & R.K. Aggarwal (2004). Jurassic frogs and the evolution of amphibian endemism in the Western Ghats. *Current Science* 86(1): 211–216.

Fei, L., C.Y. Ye, Y.J. Jiang & F. Xie (2005). *An illustrated key to Chinese amphibians*. Sichuan Publishing Group, Sichuan Publishing House of Science and Technology, Chengdu, 340 pp.

Frost, D.R. (2021). Amphibian Species of the World: An Online Reference. Version 6.1. https://amphibiansoftheworld.amnh.org/index.php. Accessed 4 May 2023.

Ganesh, S.R., S.K. Dutta & S.R. Chandramouli (2017). On the taxonomy and nomenclature of common Indian Cricket Frog *Rana agricola* Jerdon, 1853 (Amphibia: Dicroglossidae). *Asian Journal of Conservation Biology* 6: 107–113.

Garg, S. & S.D. Biju (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

Garg, S. & S.D. Biju (2021). DNA barcoding and systematic review of Minervaryan frogs (Dicroglossidae: *Minervarya*) of Peninsular India: Resolution of a taxonomic conundrum with description of a new species. *Asian Herpetological Research* 12: 345–370. https://doi.org/10.16373/j.cnki.ahr.210023

Garg, S., R. Suyesh, S. Sukesan & S.D. Biju (2017). Seven new species of Night Frogs (Anura, Nyctibatrachidae) from the Western Ghats Biodiversity Hotspot of India, with remarkably high diversity of diminutive forms. *PeerJ* 5(e3007): 1–50. https://doi.org/10.7717/peerj.3007

Gosner, K.L. (1960). A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica* 16: 183–190.

Grosjean, S. (2004). Apport des caractères larvaires à la phylogénie des Amphibiens Anoures. Cas de deux familles: les Megophryidae et les Ranidae. PhD Thesis. Muséum national d'Histoire naturelle, Paris, 261 pp.

Grosjean, S., R.D. Randrianiaina, A. Strauß & M. Vences (2011). Sand-eating tadpoles in Madagascar: morphology and ecology of the unique larvae of the tree frog *Boophis picturatus*. *Salamandra* 47: 63–76.

Grosjean, S. & C. Inthara (2016). Molecular identifications and descriptions of the tadpoles of *Rhacophorus kio* Ohler & Delorme, 2006 and *Rhacophorus rhodopus* Liu & Hu, 1960 (Amphibia: Anura: Rhacophoridae). *Zoosystema* 38: 267–282. https://doi.org/10.5252/z2016n2a5

Haas, A. (2003). Phylogeny of frogs as inferred from primarily larval characters (Amphibia: Anura). *Cladistics* 19: 23–90. https://doi.org/10.1111/j.1096-0031.2003.tb00405

Haas, A. & I. Das (2008). Larval identities of *Ansonia hanitschi* Inger, 1960 (Amphibia: Bufonidae) and *Polypedates colletti* (Boulenger, 1890) (Amphibia: Rhacophoridae) from East Malaysia (Borneo). *Salamandra* 44: 85–100.

Heyer, W.R. (1971). Descriptions of some tadpoles from Thailand. *Fieldiana*: *Zoology* 58: 83–91.

Hiragond, N.C. & S.K. Saidapur (1999). Description of tadpole of *Rana temporalis* from South India. *Current Science* 76(3): 443–444.

Howlader, M.S.A., A. Nair & J. Merilä (2016). A new species of frog (Anura: Dicroglossidae) discovered from the mega city of Dhaka. *PLoS ONE* 11:1–23. https://doi.org/10.1371/journal.pone.0149597

Inger, R.F. (1985). Tadpoles of the forested regions of Borneo. *Fieldiana*: *Zoology new series* 26: 1–89.

Inger, R.F., H.B. Shaffer, M. Koshy & R. Bakde (1984). A report on a collection of amphibians and reptiles from the Ponmudi, Kerala, south India. *Journal of the Bombay Natural History Society* 81(3): 551–570.

Inthara, C., V. Lauhachinda, J. Nabhitabhata, Y. Chuaynkern & P. Kumtong (2005). Mouth part structures and distribution of some tadpoles from Thailand. *The Thailand Natural History Museum Journal* 1(1): 55–78.

Khan, M.S. (1965). A normal table of *Bufo melanostictus*. *Biologia* 11(1): 1–39.

Khan, M.S. (1982). Key for the identification of amphibian tadpoles from the plains of Pakistan. *Pakistan Journal of Zoology* 14: 133–145.

Khan, M.S. (1991). Morphoanatomical specialization of the buccopharyngeal region of the anuran larvae and its bearing on the mode of larval feeding. PhD Thesis, University of the Punjab, Lahore, 92 pp.

Khan, M.S. (1996). Oropharyngeal morphology of tadpole of southern

cricket frog *Rana syhadrensis* Annandale, 1919 and its ecological correlates. *Pakistan Journal of Zoology* 28: 133–139.

Khan, M.S. (2001). Notes on cranial-ridged toads of Pakistan and description of a new subspecies (Amphibia: Bufonidae). *Pakistan Journal of Zoology* 33(4): 293–298.

Khan, M.S. (2002). Riparian tadpoles of Punjab, Pakistan: *Bufo stomaticus* Lütken, 1862. *Bulletin of the Chicago Herpetological Society* 37(12): 216–219.

Khan, M.S. (2003a). The larval hyobranchial skeleton of five anuran species and its ecological correlates (Amphibia: Anura) / Das larvale Hyobranchialskelett von fünf Anurenarten und seine ökologischen Entsprechungen (Amphibia: Anura). *Herpetozoa* 16(3/4): 133–140.

Khan, M.S. (2003b). Morphology of the *Limnonectes* tadpole, with notes on its feeding ecology and on the breeding habits of *Limnonectes* frogs in riparian Punjab. *Bulletin of the Chicago Herpetological Society* 38(9): 177–179.

Khan, M.S. & S.A. Mufti (1994). Oral disc morphology of amphibian tadpole and its functional correlates. *Pakistan Journal of Zoology* 26(1): 25–30.

Kirtisinghe, P. (1957). *The Amphibia of Ceylon*. Privately published, Colombo, 112 pp.

Kuramoto, M. & S.H. Joshy (2002). Tadpoles of *Indirana beddomii* (Anura: Ranidae). *Hamadryad* 27(1): 71–77.

Kuramoto, M., S.H. Joshy, A. Kurabayashi & M. Sumida (2008). The genus *Fejervarya* (Anura: Ranidae) in central Western Ghats, India, with descriptions of four new cryptic species. *Current Herpetology* 26: 81–105. https://doi.org/10.3105/1881-1019(2007)26[81:TGFARI]2.0.CO;2

Leong, T.M. (2005). Larval systematics of the Peninsular Malaysian Ranidae (Amphibia: Anura). PhD Thesis. National University of Singapore, Singapore, 214 pp.

Leong, T.M. & L.M. Chou (1999). Larval diversity and development in the Singapore Anura (Amphibia). *The Raffles Bulletin of Zoology* 47(1): 81–137.

Maglia, A.M., L.A. Púgener & L. Trueb (2001). Comparative development of anurans: using phylogeny to understand ontogeny. *American Zoologist* 41: 538–551. https://doi.org/10.1093/icb/41.3.538

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B da Fonseca & J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858. https://doi.org/10.1038/35002501

McDiarmid, R.W. & R. Altig (1999). *Tadpoles: the biology of anuran larvae*. University Chicago Press, Chicago, London, 444 pp.

Mohanty-Hejmadi, P.M. & S.K. Dutta (1988). Life history of the common Indian Tree Frog *Polypedates maculatus* (Gray, 1834) (Anura: Rhacophoridae). *The Journal of the Bombay Natural History Society* 85(3): 512–517.

Noble, G.K. (1927). The value of life-history data in the study of the evolution of the Amphibia. *Annals of New York Academy of Science* 30: 31–128.

Ohler, A., K. Deuti, S. Grosjean, S. Paul, A.K. Ayyaswamy, A.F. Ahmed & S.K. Dutta (2009). Small-sized dicroglossids from India, with the description of a new species from West Bengal, India. *Zootaxa* 2209: 43–56. https://doi.org/10.5281/zenodo.189799

Orton, G.L. (1953). The systematics of vertebrate larvae. *Systematic Zoology* 2: 63–75. https://doi.org/10.2307/sysbio/2.2.63

Orton, G.L. (1957). Larval evolution and frog classification. *Systematic Zoology* 6(2): 79–86.

Pillai, R.S. (1978). On *Nyctibatrachus major* Boul. (Ranidae) with a description of its tadpole. *Bulletin of the Zoological Survey of India* 1(2): 135–140.

Priti, H., K.V. Gururaja & G. Ravikanth (2015). Morphology, natural history and molecular identification of tadpoles of three endemic frog species of *Nyctibatrachus* Boulenger, 1882 (Anura: Nyctibatrachidae) from Central Western Ghats, India. *Journal of Natural History* 49(43): 1–15. https://doi.org/10.1080/00222933.2015.1034212

Púgener, L.A., A.M. Maglia & L. Trueb (2003). Revisiting the contribution of larval characters to an analysis of phylogenetic relationships of basal anurans. *Zoological Journal of the Linnean Society* 139: 129–155. https://doi.org/10.1046/j.1096-3642.2003.00075

Purkayastha, J. & M. Matsui (2012). A new species of *Fejervarya* (Anura: Dicroglossidae) from Mawphlang, northeastern India. *Asiatic Herpetological Research* 3(1): 31–37. https://doi.org/10.3724/SP.J.1245.2012.00031

Raj, P., K. Vasudevan, D. Veerappan, R. Sharma, S. Singh, R.K. Aggarwal & S.K. Dutta (2012). Larval morphology and ontogeny of *Nasikabatrachus sahyadrensis* Biju & Bossuyt, 2003 (Anura, Nasikabatrachidae) from Western Ghats, India. *Zootaxa* 3510: 65–76. https://doi.org/10.11646/zootaxa.3510.1.4

Raj, P., K.P. Dinesh, A. Das, S.K. Dutta, N.B. Kar & P.P. Mohapatra (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: 1–21.

Raj, P., K. Vasudevan, R.K. Agarwal, S.K. Dutta, G. Sahoo, S. Mahapatra, R. Sharma, S.J. Janani, N.B. Kar & A. Dubois (2023). Larval morphology of selected anuran species from India. *Alytes* 39–40: 1–140.

Ramaswami, L.S. (1932). Some cranial characteristics of Indian Engystomatidae (Anura). *Current Science* 1(6): 167–168.

Ramaswami, L.S. (1933). The vertebral column of some South Indian frogs. *Current Science* 1(10): 306–309.

Ramaswami, L.S. (1934). Contributions to our knowledge of the cranial morphology of some ranid genera of frogs. *Proceedings of the Indian Academy of Sciences* 1B: 80–95.

Ramaswami, L.S. (1936). The morphology of the Bufonid head. *Proceedings of the Zoological Society of London* 106: 1157–1169. https://doi.org/10.1111/j.1469-7998.1936.tb06305

Ramaswami, L.S. (1938). Connections of the pterygoquadrate in the tadpoles of *Philautus variabilis* (Anura). *Nature* 142: 577.

Ramaswami, L.S. (1940). Some aspects of the chondrocranium in the tadpoles of South Indian frogs. *The Half-Yearly Journal of the Mysore University* 1(1): 15–41.

Ramaswami, L.S. (1944). The chondrocranium of two torrent-dwelling anuran tadpoles. *Journal of Morphology* 74(3): 347–374. https://doi.org/10.1002/jmor.1050740303

Rao, C.R.N. (1914). Larva of *Rana curtipes*, Boul. *Records of the Indian Museum* 10(4): 265–267.

Rao, C.R.N. (1915). Notes on some south Indian Batrachia. I. The larvae of *Microhyla rubra* and *Rana breviceps*. *Records of the Indian Museum* 11: 31–38.

Rao, C.R.N. (1918). Notes on the tadpoles of Indian Engystomatidae. *Records of the Indian Museum* 15(1): 41–45.

Rao, C.R.N. (1922). Notes on Batrachia. *Journal of the Bombay Natural History Society* 28(1&2): 439–447.

Rao, C.R.N. (1937). On some new forms of Batrachia from S. India. *The Proceedings of the Indian Academy of Sciences* 6(6): 387–427.

Rao, C.R.N. (1938). Tadpoles of a genus not recorded from India. *Current Science* 6(9): 455–456.

Ray, P. (1999). Systematic studies on the amphibian fauna of the district Dehradun, Uttar Pradesh, India. *Memoirs of the Zoological Survey of India* 18(3): 1–102.

Ray, K. & R. Tilak (1994). Amphibia, pp. 55–75. In: Ghosh, A.K. (Ed.) *Fauna of conservation area 5: Rajaji National Park*. Zoological Survey of India, Calcutta.

Roelants, K., A. Haas & F. Bossuyt (2011). Anuran radiations and the evolution of tadpole morphospace. *Proceedings of the National Academy of Sciences of the United States of America* 108(21): 8731–8736. https://doi.org/10.1073/pnas.1100633108

Sekar, A.G. (1990a). Observations on the developmental stages of the tadpoles of the Malabar Gliding Frog *Rhacophorus malabaricus* Jerdon, 1870 (Anura: Rhacophoridae). *Journal of the Bombay Natural History Society* 87(2): 223–226.

Sekar, A.G. (1990b). Notes on morphometry, ecology, behaviour and food of tadpoles of *Rana curtipes* Jerdon, 1853. *Journal of the Bombay Natural History Society* 87(2): 312–313.

Sekar, A.G. (1992). Morphometry, habitat, behaviour and food of the tadpoles of Leith's frog *Rana leithii*. *Journal of the Bombay Natural*

History Society 89(2): 259–261.

Senevirathne, G., A. Thomas, R. Kerney, J. Hanken, S.D. Biju & M. Meegaskumbura (2016a). From clinging to digging: The postembryonic skeletal ontogeny of the Indian Purple Frog, *Nasikabatrachus sahyadrensis* (Anura: Nasikabatrachidae). *PLoS One* 11(3):1–23, e0151114. https://doi.org/10.1371/journal.pone.0151114

Senevirathne, G., S. Garg, R. Kerney, M. Meegaskumbura & S.D. Biju (2016b). Unearthing the fossorial tadpoles of the Indian Dancing Frog family Micrixalidae. *PLoS One* 11(3): 1–18, e0151781. https://doi.org/10.1371/journal.pone.0151781

Sokol, O.M. (1975). The phylogeny of anuran larvae: a new look. *Copeia* 1975: 1–24. https://doi.org/10.2307/1442399

Stuart, B.L., Y. Chuaynkern, T. Chanard & R.F. Inger (2006). Three new species of frogs and a new tadpole from eastern Thailand. *Fieldiana Zoology* 111: 1–19.

Vassilieva, A., S. Gogoleva & N. Poyarkov (2016). Larval morphology and complex vocal repertoire of *Rhacophorus helenae* (Anura: Rhacophoridae), a rare flying frog from Vietnam. *Zootaxa* 4127: 515–536. https://doi.org/10.11646/zootaxa.4127.3.6

Vijayakumar, S.P., R.A. Pyron, K.P. Dinesh, V.R. Torsekar, A.N. Srikanthan, P. Swamy, E.L. Stanley, D.C. Blackburn & K. Shanker (2019). A new ancient lineage of frog (Anura: Nyctibatrachidae: Astrobatrachinae subfam. nov.) endemic to the Western Ghats of Peninsular India. *PeerJ* 7: 1–28. https://doi.org/10.7717/peerj.6457

Wassersug, R.J. (1976). Oral morphology of anuran larvae: terminology and general description. *Occasional Papers of the Museum of Natural History the University of Kansas Lawrence, Kansas* 48: 1–23.

Wassersug, R.J. (1980). Internal oral features of larvae from eight anuran families: functional, systematic, evolutionary and ecological considerations. *Miscellaneous publication, Museum of Natural History, University of Kansas* 68: 1–146.

Wewelwala, K., A.I. Alagiyawadu, G.K. Kodituwakku & M.M. Bopage (2013). Redescription of the tadpole of *Kaloula taprobanica* (Anura: Microhylidae) from Sri Lanka. *Zootaxa* 3716(1): 98–100. https://doi.org/10.11646/zootaxa.3716.1.8

Ye, R.Q., X.F. Hong & X.D. Chen (1986). Early stages of the embryonic development in *Bufo melanostictus*. *Acta Herpetologica Sinica new series* 5(3): 185–188.

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