Morphology and ecology of *Microhyla rubra* (Anura: Microhylidae) tadpoles from Sri Lanka

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Abstract.—The life-history, ecology, external and buccal morphology of *Microhyla rubra* (Jerdon, 1854) tadpoles are described. Approximately 400 eggs, ready to hatch, were observed as a single mass and several of these were reared in laboratory. Tadpoles showed several characters that are not seen in most other microhylids: a whip-like tail-end flagellum, a dorsoterminal mouth, a transparent body, absence of flaps and existence of a median notch on upper lip, presence of papillae (or scallops) on lower lip, and a deep ventral tail fin (compared to the dorsal tail fin). *Microhyla rubra* tadpoles also have several features, so far not noted in other microhylids: six papillae (or scallops) on lower oral flap, a crescent-shaped spiracular opening, and an enlarged crest on ventral tail fin. For some characters, such as shape of the oral flaps, we show that there is considerable variation within and between Gosner stages. This species deposits its eggs as rafts in ephemeral pools where water chemistry (bound ammonia, salinity, conductivity, pH, sulphate ion concentration) and temperature are apparently favorable for rapid growth, reducing the risk of predation from fully aquatic predators. Since oxygen concentrations in these habitats are low and free ammonia concentrations are moderately high, occupying surface layers of pools would enable the eggs and tadpoles to overcome these impediments to growth and survival.

Key words. Microhylinae, microhyline tadpoles, morphology, buccal, ecology, *Microhyla rubra*

Introduction

The natural history and reproductive biology of microhylid frogs are poorly known (Wassersug 1980; Donnelly et al. 1990; Lehr et al. 2007). Although descriptions of tadpole characters useful in taxonomy have been described only for a few species, tadpole morphology varies considerably both inter- and intra-specifically (Donnelly et al. 1990). Hence, it is important to study tadpole morphology in greater detail, making inter-species comparisons more useful for phylogenetic and comparative-morphological analyses.

The Red narrow-mouthed frog, *Microhyla rubra*, is widely distributed in the lower elevation regions of Sri Lanka, peninsular India, and Bangladesh, rarely occurring above 500 m asl (Kirtisinghe 1957; Manamendra-Arachchi and Pethiyagoda 2006; IUCN 2004); it is found predominantly in drier parts of these countries. The species is often found under logs, piles of rubble, haystacks, and stones, where comparatively higher moisture levels exist. Small size, nocturnal habits, and cryptic nature of these frogs make them difficult to encounter in the field.

Nonetheless, *Microhyla rubra* is categorized as "Least Concern" by the IUCN, due to its wide distribu-

tion, tolerance of dry environmental conditions, and high population densities.

Despite their abundance, details of the life history of *Microhyla rubra*, especially tadpole characteristics and biology, are still poorly known. Several previous workers (Rao 1918; Parker 1928, 1934; Kirtisinghe 1957, 1958) have described the external morphology of the tadpoles, and Rao (1918) states that they are not transparent. Kirtisinghe, (1957) provided a brief description of the external morphology of the tadpole, including presence of a tail-end flagellum, dorso-terminal mouth, spiracular opening above a notched flap on underside of the belly, and the deep lower crest of the ventral tail fin. Kirtisinghe (1957) provides a drawing of oral flaps, but without a description. Internal buccal morphology is not discussed by any of these researchers.

Here we provide a more complete description of the external morphology of *Microhyla rubra* tadpoles and provide the first description of their buccal morphology. We particularly concentrate on the mouth location, spiracle location, shape of spiracular opening, tail morphology, and mouthparts, as these features are shown to vary considerably among and within microhylids (Donnelly et al. 1990) and are of potential importance in systematics.

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Figure 1. Open and shallow ephemeral pool lined by grass and shrubs, where floating eggs were sampled.

Methods and materials

Location (08°16'49.43" N, 80°28'49.96" E): Several eggs in late embryonic stages were collected (identity of species was not known at time of collection) from an ephemeral man-made pool near Nachchaduwa reservoir in Anuradhapura (Fig. 1). Tadpoles at Stage 24 (Gosner 1960) emerged from these eggs after two days. These tadpoles were raised in the laboratory, with partial daily water changes of dechlorinated water, and periodically sampled until metamorphosis. Tadpoles were fed on boiled egg yolk. Metamorphs were raised an additional month, and identified using taxonomic keys devised for adult frogs (Manamendra-Arachchi and Pethiyagoda 2006). Tadpoles were fixed in 10% buffered formalin for two days and preserved in a 1:1 mixture of 10% buffered formalin and 70% alcohol. Tadpoles are deposited in the collection of the Department of Zoology, University of Peradeniya, Sri Lanka (DZ).

Grillitsch et al. (1993) and McDiarmid and Altig (1999) were followed for external description of tadpoles. For internal oral anatomy, a combination of Khan (2000) and Wassersug (1976) was followed. The surgical method delineated by Wassersug (1976) was used and the following measurements were taken (Fig. 2): maximum height of body (bh), maximum width of body (bw), maximum diameter of eye (ed), maximum height of tail (ht), maximum height of lower tail fin (lf), internarial distance (nn), naro-pupilar distance (np), interpupilar distance (pp), rostro-narial distance (rn), distance from tip of snout to opening of spiracle (ss), distance from tip of snout to insertion of upper tail fin (su), snout-vent length (svl), total length (tl), maximum height of upper tail fin (uf), distance from vent to tip of tail (vt), tail muscle height (tmh), and tail muscle width (tmw). Morphology was observed using a Motic zoom-stereomicroscope (6-50 ×). Tadpoles were measured using digital calipers (measured to the nearest 0.01 mm).

Results

Description of tadpole

External morphology. The following description is based on five Stage 35 tadpoles of *Microhyla rubra* (DZ 1033-37) except where explicitly stated.

In dorsal view, body clearly differentiated into two parts, a longer and wider anterior region (R1) and a narrower posterior region (R2). Anterior region almost twice as long and wide as posterior region (Figs. 2 and 3). Eyes
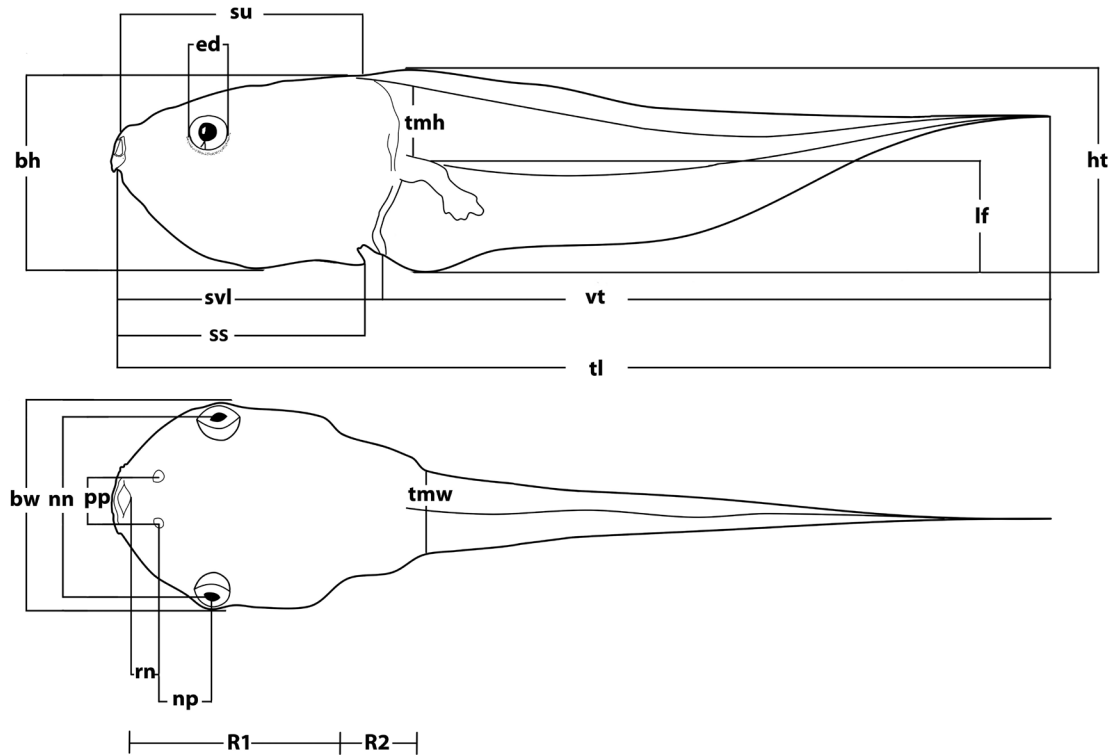
Figure 2. Outline of *Microhyla rubra* tadpoles showing the measurements that were taken.

small (ed/bw = 0.22) and snout rounded. Head and body posterior to eyes with sides parallel to each other, and conjunction of R1 and R2 forms an angle of 137-148°. Eyes directed slightly dorsolaterally, bulbous, and entire eye visible through epidermis due to dearth of pigmentation. Nares closed (nn/pp = 0.21), narial depressions visible, oval, unpigmented to slightly pigmented, located immediately anterior to two small concentrated patches of pigment, anterodorsolaterally directed, and closer to snout tip than to pupils. Nasolacrimal duct apparent. A lateral protruding ridge anterior to eye. Mouth narrow, superior, lower and upper-lips both visible. Tail long, tapering, with a whip-like flagellum (pointed tail tip; Fig. 4).

In profile, R1 wedge-shaped, pointed at snout, anterior-dorsal aspect straight, and anterior-ventral aspect slightly rounded. R2 ventrally rounded and dorsally slightly rounded. Gut contained in R2, overlaid with iridophores (Fig. 3E). A paired gas-filled cavities present dorsolateral to the gut (probably the developing lungs); horizontal dark bar located dorsal to gas-filled cavities. Spiracle mid-ventral, transparent, ends at posterior ventral part of body, dorsally attached to body wall, and ventrally free with a small posteriorly extending flap with medial notch near vent. Ventral tail fin begins at the dorsal attached end of the spiracular opening. Spiracular opening crescent-shaped with anterior portion of the ven-

tral tail fin contained within the spiracle (Fig. 3C). Vent tube in lower tail fin, posterior to spiracle opening. Tail musculature weak, extending to end of tail tip (tail-muscle height/body height = 0.43; tail-muscle width/body width = 0.31), V-shaped myomeres apparent only in posterior two-thirds of tail (Fig. 3A). Dorsal tail fin deeper than ventral tail fin, both fins originate above and below the same vertical point on body. Fins reduced towards end, proximally a deep convex extension of ventral tail fin (lowest crest) distally, a smaller crest towards middle of tail (Fig. 5).

In ventral view, eyes barely visible, but silhouette of eye-ball apparent through unpigmented skin. Extended flap of lower lip visible. Coiled gut visible, positioned slightly to left of midline, overlaid with iridophores. Heart at boundary of R1 and R2.

Oral flaps: upper lip not fleshy (Fig. 3B), with a slight medial notch. Edge of lower lip slightly scalloped, with three projections on each lobe (Fig. 8).

Buccal morphology

Labial keratinized teeth were absent in all individuals examined.

Ventral buccal region. Prelingual arena U-shaped, length greater than width, curved portion of U directed anteriorly toward oral aperture. A pair of dorsally-direct-
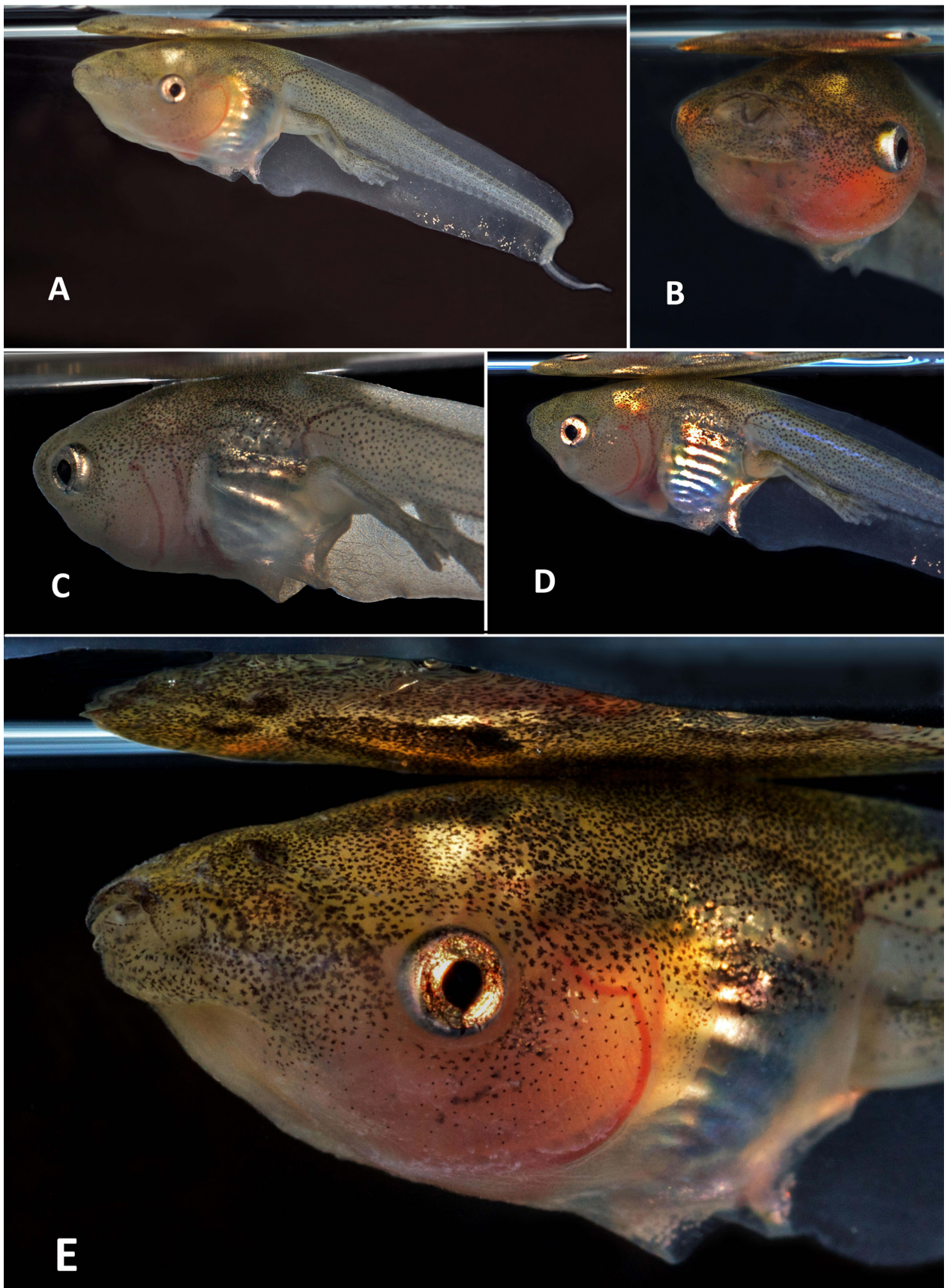
Figure 3. *Microhyla rubra* tadpole (Stage 38) in life showing: (A) the long tail with a distinct flagellum, (B) position of mouth, (C) shape of the spiracle and position of the vent tube in tail, (D) Shape of the convex curvature in ventral fin, and (E) close up of the head and body showing the nasolacrimal duct, distribution of pigmentation, mouth position, and groove on non-fleshy upper lip.
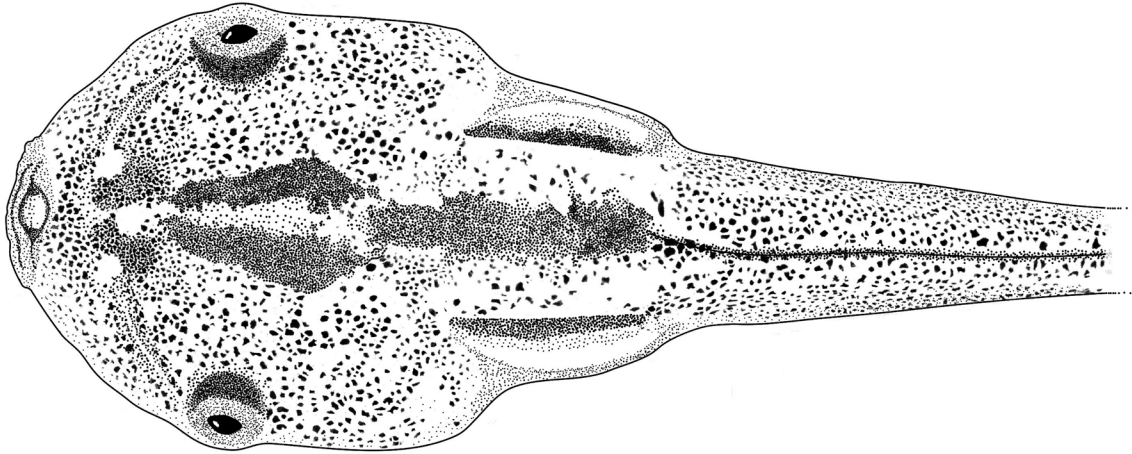
Figure 4. Dorsal aspect of the body and part of the tail of a *Microhyla rubra* tadpole (Stage 35). Scale bar, 1 mm.

ed lateral infralabial papillae of equal size line mouth opening. Fleshy fold on the lateral walls of mouth opening. A fleshy fold on mouth floor posterior to infralabial papillae, directed towards buccal cavity. A pair of lateral buccal pockets in anterior region of buccal floor. A single pair of small papillae on anterior wall of buccal cavity, on either side of mouth aperture, not attached to tongue. Conical, non-papillated tongue anlage, broader anteriorly, without pigment, narrower and free posteriorly, with pigment. Buccal floor arena (BFA) triangular, laterally elevated, medially depressed, forming a narrow passage at the anterior portion of BFA, posterior end of buccal floor much broader than anterior end. Two small and blunt, two large, and one medium-sized symmetrical pairs of conical BFA papillae. Small papillae (length = 0.07 mm) anterior to all others. Medium papillae (length = 0.16-0.19 mm) close to glottis. Large papillae (length = 0.27-0.34 mm) further from glottis, posterior to medium papillae. Single conical large medial preglottal papilla. Buccal pockets long and narrow, sickle-shaped, and

blunt at the blind end. A pair of symmetrical, small blunt proximal prepocket papillae. Pairs of one large conical, three medium conical, four small blunt postpocket papillae. A large conical medially curved distal and sinistral prepocket papilla. A large and medium conical, medially curved, distal dextral prepocket papilla. Trachaea club-shaped, protruding from base of velum, extending to base of BFA, ending in elevated lips. Broad ventral velum without strong spicular support, free margin of velum smooth, covered by secretory pits, and containing a single broad projection above third filter plate (Fig. 6).

Dorsal buccal region. Choanae blind ended. Prenarial arena a posteriorly-directed V-shaped depression. Prenarial papilla, single, medial, small, blunt, placed anterior to narial papilla. Narial papillae hang from narial depression, slightly twisted, long, flat, robust, with three projections towards the anteriorly-directed tip; the middle projection longest. Postnarial ridge slightly serrated. Buccal roof arena (BRA) triangular, broad anteriorly, and lined by postero-lateral BRA border with papillae. Close

Table 1. Means and standard deviations of 12 tadpole body measurements of *M. rubra* at different Gosner stages (26, 31, 33, and 35).

| Characteristics	Stage 26	Stage 31	Stage 33	Stage 35
	n = 2	*n* = 2	*n* = 2	*n* = 6
Body height (bh)	2.45 ± 0.02	3.63 ± 0.01	4.60 ± 0.15	5.54 ± 0.67
Body width (bw)	2.83 ± 0.37	4.47 ± 0.06	5.79 ± 0.21	6.41 ± 0.66
Maximum tail height (th)	2.98 ± 0.32	4.49 ± 0.32	5.24 ± 0.04	6.26 ± 1.07
Inter narial distance (nn)	0.64 ± 0.01	0.89 ± 0.01	1.07 ± 0.02	1.23 ± 0.12
Inter pupular distance (pp)	2.68 ± 0.37	4.20 ± 0.09	5.50 ± 0.22	5.94 ± 0.83
Snout-vent length (svl)	4.24 ± 0.09	5.85 ± 0.30	7.40 ± 0.34	8.67 ± 1.22
Total length (tl)	14.48 ± 1.65	20.59 ± 2.47	26.23 ± 0.55	29.00 ± 3.11
Vent to tail tip length (vt)	10.24 ± 1.75	14.74 ± 2.18	18.83 ± 0.21	20.39 ± 2.01
Tail muscle height (tmh)	1.07 ± 0.13	1.93 ± 0.30	2.23 ± 0.01	2.35 ± 0.24
Tail muscle width (tmw)	0.66 ± 0.01	1.33 ± 0.09	1.69 ± 0.24	1.98 ± 0.29
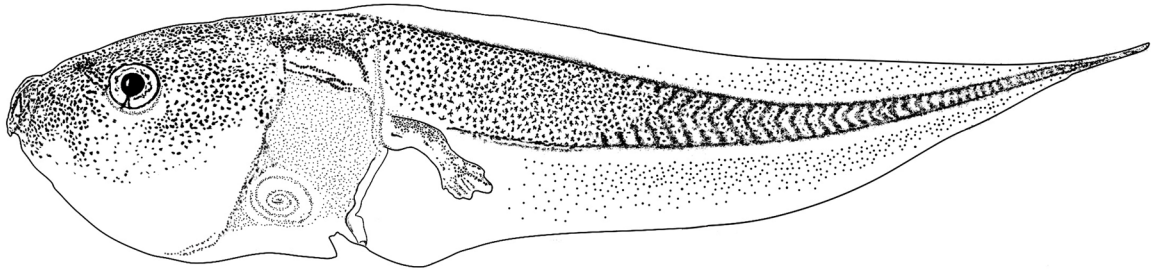
Figure 5. Profile of the whole body of the *Microhyla rubra* tadpole (Stage 35). Scale bar, 1 mm.

to BRA apex, one pair long (length = 0.44-0.47 mm) and pointed; one pair medium (length = 0.14-0.19 mm) and pointed; BRA papillae, lateral to apex; BRA border with a few small (length = 0.04-0.06 mm) BRA papillae. Broad roof glandular area anterior to dorsal velum and dorsal velum gradually thins medially (Fig 7).

Ventral pharynx region. Branchial baskets triangular, half of the filter cavities anterior to the velum, and all three filter plates distinct. A distinctly ridged oval torus present in each filter cavity and subvelar surface with many secretory ridges (Fig. 6).

Color in life. Body transparent and light yellowish grey. In profile, dorsum densely pigmented compared to venter, pink region present between eyes and coiled gut. Iris silver, with dark inverted V-shape at ventral edge. R2 studded with silver iridopores and dark-brown pigment cells (Fig. 3E). Tail fins lightly pigmented in dark brown.

Tail musculature equally pigmented throughout, size of pigment patches reducing posteriorly (Fig. 3A, B, C, and D). Upper margin of the hind limb and toes pigmented (Fig. 3A, C, and D). In dorsal view, densely pigmented areas located near nasal openings, between nasal opening and point of origin of upper tail fin, along the base of the upper tail fin and in the gas-filled cavities. Posterior to nasal markings a red band extends to margin of R1 and R2. Eyeballs apparent and black in color.

Color (preserved). Body semi-transparent to brownish-white, tail lighter color than the body. Pigments on body star-shaped, giving the appearance of powder coating. Higher densities of pigments occur dorsally than ventrally. A median symmetrical dorsal band of dark brown to black melanophores covers the brain region and extend to near the base of eyes and nasal pits. Dark brown to black pigment patches present posteriorly to low-pigmented nasal depressions. Iris silver, with scattered dark patches. Two narrow dark lines originate at dorsal pole of pupil and extend ventrally. Symmetrical black bands over dorsum to gas-filled cavities at the origin of the tail musculature. A dark brown line runs along the top of the tail musculature between dark bands of gas-filled cavities. R2 (Fig. 2) in the body almost covered with iridiophores, giving it a characteristic silvery shine, and black color patches present on this silver region. Reduced pigmentation in the tail musculature and tail fins. Ventrally, heart visible, cream colored, at margin of R1 and R2.

Variation. There is a substantial amount of variation in the lower lip in tadpoles of different developmental stages, and sometimes even within a given developmental stage. At Stage 25 (early stage) for instance, there is a single pair of scallops on the lower lip but these develop into six very distinct papillae (three pairs) by late Stage 25. At Stage 30, the scallops are distinct and there is little variation within the stage. By Stage 35, the scallops are not clearly discernible (and there is little variation within the stage; Fig. 8).The tail-fin shape changes from a simple long triangular shape (Stage 25) to a more complex shape with two crests on the ventral tail fin (anterior crest deeper and crest in middle of tail shallower; Stage 35).
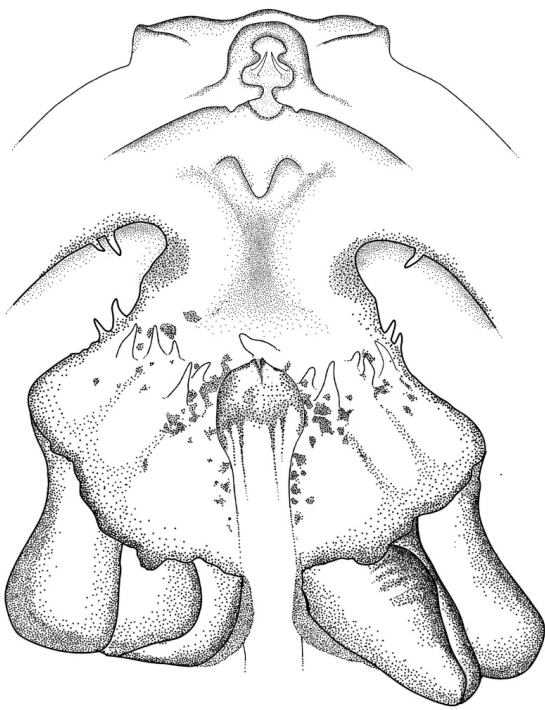

Figure 6. Ventral buccal morphology of the *Microhyla rubra* tadpole (Stage 35). Scale bar, 1 mm.
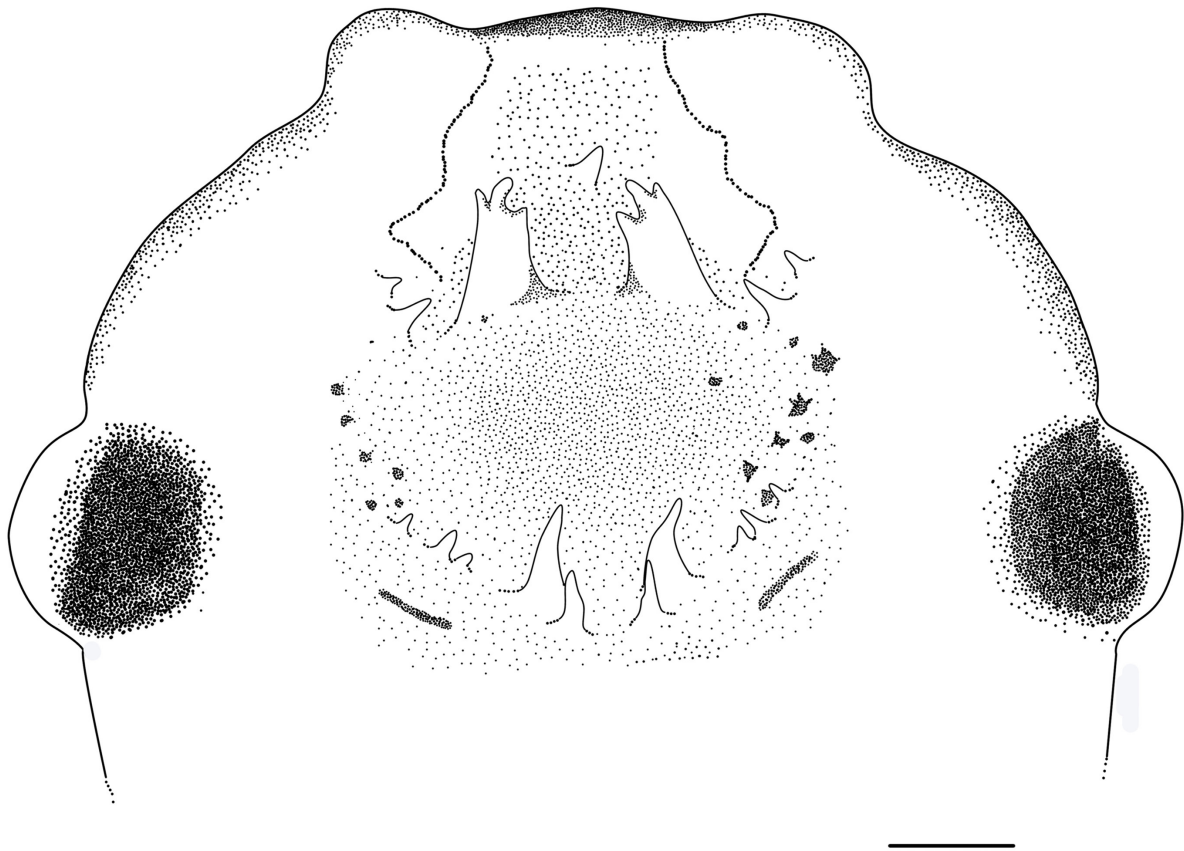
Figure 7. Dorsal buccal morphology of a *Microhyla rubra* tadpole (Stage 35). Scale bar, 1 mm.

Measurements (mm). bh = 5.25; bw = 5.93; ed = 1.26; ht = 5.50; lf = 2.54; nn = 1.12; np = 2.66; pp = 5.54; rn = 1.20; ss = 7.58; su = 7.66; svl = 7.99; tl = 27.04; uf = 0.85; vt = 19.05; tmh = 2.31, and tmw = 1.68. Measurements of tadpoles in Stages 26, 31, 33, and 35 are presented in Table 1.

Ecological notes. We observed a group of late-stage embryos (almost ready to hatch) on the surface of an open pool of water. The pool was man-made (probably excavated clay for brick-making forming the depression which then filled with water), isolated from other water bodies, and exposed to direct sunlight. The pool shore was lined with small shrubs and visible submerged terrestrial shrubs and vegetation, suggestive of recent inundation (Fig. 1). The pool apparently had been filled with rainwater, and was likely ephemeral. The maximum depth of the pool was about 50 cm (most areas shallower) with an area of approximately 100 m². Water quality of the pool (9:50 am): temperature = 26.3 °C; dissolved oxygen = 0.92 mg/l; pH = 6.68; conductivity = 87.8 µS; salinity = 0; $(NO_3^-)N$ = 0.524 mg/l; $(NH_4^+)N$ = 0.46 mg/l; free NH_3 = 0.56 mg/l; fluoride = 0.8 mg/l; total hardness = 275 mg/l; SO_4^{2-} = 0 mg/l. A total of 410 early stage, whitish-gray embryos were observed and several were collected for study.

The larvae of several anuran species were observed in syntopy with the *M. rubra* tadpoles: *Polypedates mac-ulatus*, *Microhyla ornata*, *Fejervarya limnocharis*, a bufonid tadpole of an unidentified species, and *Sphaerotheca rolandae*.

Discussion

Tadpoles of *Microhyla rubra* lack keratinized mouth parts and have a dorsoterminal mouth. Dorsoterminal mouths are not observed among New World microhylid tadpoles, but within old world microhylid tadpoles, both terminal and dorsoterminal mouthparts are observed (Donnelly et al. 1990).

Donnelly et al. (1990) highlighted several microhylids species that lack flaps of the upper lip (*M. rubra* lacks flaps on the upper lip) and other species that lack flaps are *Glyphoglossus molossus*, *Kalaula borealis*, *K. rugifera*, *K. verrucosa*, *Metaphrynella pollicaris*, *Microhyla achatina*, *Mi. anectens*, *Mi. okinavensis*, *Mi. heymonsi*, *Mi. pulchra*, and *Mi. zeylanica*. *Microhyla zelanica* is a Sri Lankan endemic whose tadpole was described by Kirtisinghe (1957); though he did not describe the oral flaps explicitly, his figure shows flaps to be absent on the upper lip. Kirtisinghe (1957) described tadpoles of *M. rubra*, which lack flaps on the upper lip.

Microhyla rubra have six papillae (scallops) on the lower lip but number varies with developmental stage.
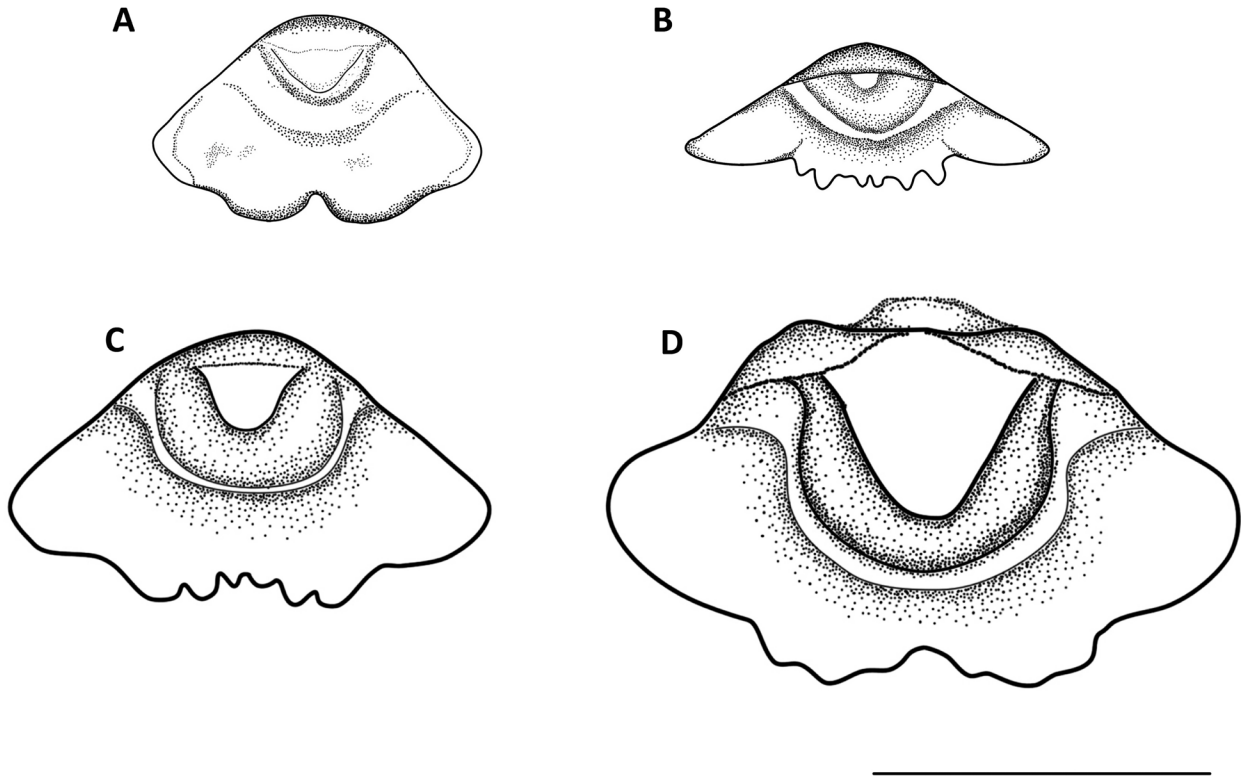
Figure 8. Variation in oral flaps of *Microhyla rubra* tadpoles at various stages of development (A) Gosner stage 25 – early; (B) Gosner stage 25 – late; (C) Gosner stage – 30; (D) Gosner stage – 35. Scale bar, 1 mm.

However, in Kirtisinghe's (1957) diagram of *M. rubra*, the scallops are not discernible (not mentioned as papillae or scallops by Donnelly et al. 1990), but there appears to be more than two, and Kirtisinghe apparently illustrated a late stage (Stage 35 or later) tadpole. Kirtisighe's (1957) diagram of the lower lip of *M. zeylanica* shows five well-distinguished conical papillae. Lower lip papillae, surprisingly, are reported in few other species of microhylids (Donnelly et al. 1990).

The whip-like tail-end flagellum has been reported from nine species of microhylids (Donnelly et al. 1990). Parker (1934) and Kirtisinghe (1957) mention the flagellum in *M. rubra*. Parker (1934) correctly asserts that the flagellum enables these tadpoles to maintain their position in water. In aquaria we observed the tail being waved occasionally but the flagellum being waved almost continuously. These tadpoles have the ability to move the very tail tip, helping maintain their position in the water, probably helping the tadpoles to conserve energy and reducing surface disturbance that may be attractive to predators. Further, buoyancy is perhaps assisted by the air-filled dorsolateral cavities (or developing lungs) in the body (in R2).

A nasolacrimal duct is apparent in Stage 35 tadpoles. Lehr et al. (2007) argue that it is present in all tadpoles, but only apparent in near metamorphs. Enough informa-

tion has not been gathered to support or refute that this duct is present in all tadpoles, but it was only apparent in *M. rubra* tadpoles at an advanced stage. Lehr et al. (2007) recommend that a better description for this character would be to observe whether or not the nasolacrimal duct is pigmented. In *M. rubra*, it is apparent only because it is relatively unpigmented, compared to the background, but in some species it may be apparent because it is more pigmented, compared to the background. We therefore suggest that when this character is assessed, the background pigmentation (relative to the pigmentation on the duct) should be considered.

External nares are open only in late stage microhylid tadpoles (McDiarmid and Altig 1999). Kirtisinghe (1957) highlights this for *M. rubra* and we confirm. We observed that external nares open very late, after front limbs emerge at Gosner stage 41. Nares opened forming a rim by the nasal opening in Gosner stage 42.

Kirtishinge (1957) states that toes are fully webbed in tadpoles. We observed that toes were mostly webbed in tadpoles (having toes), but saw that webbing rapidly diminishes by Gosner stage 42. Webbing is vestigial, conforming to the extent seen in adults, by the one-month old froglet stage (when the study ended).

The ventral tail fin of *M. rubra* is deeper than the dorsal tail fin. Nelson (1972) mentions that *Microhyla*

Figure 9. Newly emerged froglet of *Microhyla rubra* (SVL: 8.31mm).

have deeper ventral fins, and highlights *M. pulchra* and *M. rubra* as having much deeper fins. We confirm this assertion.

The notch apparent on the upper lip, in late stage (Gosner 35), is not depicted in Kirtisinghe (1957).

The spiracle in *M. rubra* opens mid-ventrally, and the opening of the spiracl M. ornata e is crescent-shaped. This shape is most easily observable in live tadpoles (Fig. 3C).

There is substantial variation in oral flaps at various developmental stages (Fig. 8). Most of this variation is portrayed in the amount and prominence of scallops on the lower flap (or labium). Variation within Gosner stages is apparent, especially for early Gosner stages. For instance, at Gosner stage 25, early-stage larvae have only two relatively large scallops on each flap, but by late-stage, size of the individual scallops decreases and number increases up to six. By Gosner stage 30, number of scallops remains at six, however, by stage 35, prominence of these are reduced, and in some specimens, depending on the mouth position upon preservation, it can be difficult to distinguish these scallops. Hence, when tadpoles are described, it is important to note the development of a character periodically over several developmental stages, rather than highlighting characters at only a single stage (often Gosner stage 35 is used), especially from only a single individual.

Rao (1918) described *M. rubra* as being nontransparent, but experience in the field with *M. rubra* tadpoles has shown they are almost as transparent as *M. ornata* tadpoles. Rao (1918) comments that Ferguson (1904) had confused the larvae of *M. ornata* and *M. rubra*. However, without knowing the stage at which the comparisons were made (there was no general agreement on staging tadpoles at the time), it is difficult to endorse Rao's assertion. However, we disagree with Rao's statement that *M. rubra* tadpoles are "not transparent." Kirtisinghe's (1957) description of the Sri Lankan *M. rubra* refers to them as "mostly transparent." However, preservation reduces the transparency of late-stage tadpoles in both species.

We raised *M. rubra* for a month beyond metamorphosis. This enabled us to determine unequivocally that the tadpoles raised were verifiably *M. rubra* (Fig. 9).

Although we sampled for aquatic tadpoles in all habitat types (e.g., man-made irrigation tanks, wells, streams, rivulets, and paddy fields) we only found *M. rubra* tadpoles in ephemeral pools. Several issues could be important for their absence: flowing water, water chemistry, the ephemeral nature of the water body, and predators. The more permanent water bodies are occupied by predatory fish such as *Channa* (Snakehead), *Mystus* (Catfish), and smaller cyprinid fishes that we have observed feeding on the various life history stages of most amphibians. In these ephemeral habitats, such large aquatic predators are absent (Skelly 1996; Eterovick and Barata 2006).

Flowing water makes it impossible to have surface-floating eggs for any length of time. However, the problem with non-flowing water is paucity of oxygen, especially when biomass within the water body is high. One way of overcoming this is to have surface eggs, which not only provides for better access to oxygen, but to higher temperatures, which together facilitate rapid development. Rapid development is important when living in ephemeral pools, to escape desiccation before development is complete (Skelly 1996). The temperatures in the shallow pool (where we found these eggs) were high (26.3 °C) and oxygen levels low (0.92 mg/l; measured at 9:50 am).

Tadpoles that we raised in the laboratory took 77 days to metamorphose. Days to metamorphose in the wild might be lower as the temperature in its habitat is higher (day time lab temperature = 22-24 °C; day time habitat temperature 26-30 °C), probably accelerating development.

M. rubra tadpoles live in water close to the surface and feed on plankton and suspended food particles.

Many aquatic habitats in the dry zone of Sri Lanka are polluted to some degree, and ephemeral pools provide a refuge for amphibians to breed. Activity of the numerous tadpoles together with the decaying biomass conceivably could drive up the unbound ammonia and nitrate concentrations, while reducing the dissolved oxygen concentration. A combination of indiscriminate biocide use, overuse of fertilizer, habitat alteration, and urbanization has changed the freshwater habitats of Sri Lanka dramatically (Steele et al. 1997). Habitat of early-phase paddy fields could conceivably provide an excellent environment for *M. rubra*, although we did not find them there, conceivably due to the overuse of fertilizer and biocides. Sri Lanka-Western Ghats is one of the most populous of the 34 global biodiversity hotspots and this has created a significant impediment to preserving habitats and moderating rapid changes in inimical land use patterns.

Water chemistry of the ephemeral pools indicates that they are not highly polluted. Although free ammonia is fairly high within the pool, bound ammonia (NH_4^+) N, conductivity, salinity, and sulphate-ion concentrations were low. Further studies are needed to assess the tolerance levels of tadpoles and the role of ephemeral pools in providing a refuge for tadpoles of various species.

Although human activities inadvertently create a few ephemeral pools for frogs, they may be drained, filled, and levelled in a surprisingly short period of time. There is a small chance for breeding populations of frogs to establish themselves and survive in these types of habitats. Special consideration (different from those practiced in preserving and managing the forest habitats of Sri Lanka) is needed in managing amphibians of the dry zone of Sri Lanka.

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