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The Tadpoles of *Taudactylus eungellensis* and *T. liemi* and a Key to the Stream-dwelling Tadpoles of the Eungella Rainforest in East-central Queensland, Australia

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Frogs of the genus *Taudactylus* are associated with streams in remnant rainforest regions along the northeast coast of Australia (Cogger, 1992). The ecology and life histories of the six known species are poorly understood, and concern about the conservation status of stream-dwelling frogs in eastern Queensland has stimulated efforts to understand the ecology of these species (McDonald, 1990; Richards et al., 1993; McNellie and Hero, 1994). During a comprehensive research and monitoring program of the amphibians at Eungella National Park in east-central Queensland, Australia, we observed and measured tadpoles of both *Taudactylus eungellensis* and *T. liemi* at several locations. Here we report that the tadpole described as *T. eungellensis* by Liem and Hosmer (1973) had been misidentified; while Liem and Hosmer probably studied tadpoles of both species, the specimen that they illustrated and described was a tadpole of *T. liemi*, a species that was not recognized and described until years after their research had been published (Ingram, 1980).

We describe the tadpole of *T. eungellensis*, present a detailed comparison with the tadpole of *T. liemi*, and provide a key to the stream-dwelling tadpoles of the Eungella rainforest to help distinguish the characters differentiating these and the other tadpoles found in and around the rainforest streams of Eungella National Park.

MATERIALS AND METHODS

Fieldwork in Eungella National Park was conducted during November 1993, and at monthly intervals between March 1994 and July 1996. Eungella National Park is a large block of rainforest (73,000 Ha) in the Clarke Range, west of Mackay. Most of the rainforest is complex mesophyll vine forest, although pockets of simple and complex notophyll vine forests emerge on poorer soils (Winter and McDonald, 1986).

Tadpoles were collected by dipnet at several first to third order streams within the rainforest. Most tadpoles were measured in the field with vernier callipers and released at the point of capture; others were anaesthetised in a dilute chlorotone solution, preserved in 10% formalin, and lodged in the Queensland Museum (QMJ62574-89, *T. eungellensis*; QMJ62590-94, *T. liemi*). To confirm identifications, larvae of each species were reared to metamorphosis in the laboratory. Spe-

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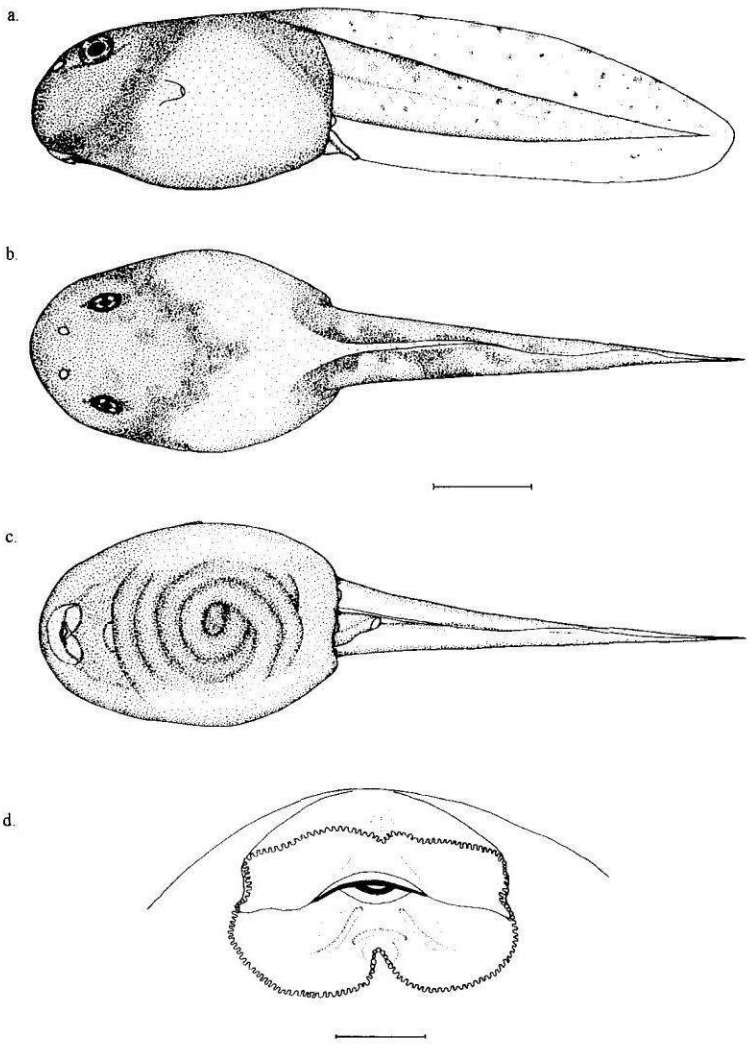

FIG. 1. (a–c): The tadpole of *Taudactylus eungellensis* (Qld Museum No. QMJ 62574; Total length = 36.4 mm, Gosner Stage 26). Scale bar represents 5 mm. (d): The oral disc of *T. eungellensis*. Scale bar represents 1 mm.

cific localities (Australian Map Grid reference, map #8655 Mirani) and altitudes of sites where tadpoles were measured are: for *T. eungellensis*—"Rawson Creek" AMG 702 702, 340 m; "Dooloomai Falls" AMG 695 712, 550 m; Tree Fern Creek AMG 713 693, 260 m; Owen's Creek AMG 725 712, 700 m; and for *T. liemi*—"Dooloomai Falls" AMG 695 712, 550 m; "Sunrise Creek" AMG 575 588, 720 m; "Mount David Creek" AMG 678 744, 980 m; "Mount William Creek" AMG 666 737, 960 m. Site names in quotes were ascribed by us, and may not appear on official maps of the area.

Morphological terminology follows Altig (1970) and Hero (1990), and description of developmental stages follows Gosner (1960). Height of caudal musculature and fins was measured at the mid-length of the tail. Tadpoles were examined and drawn using a binocular microscope with a drawing tube. Features of the oral disc and body morphology were of limited use to distinguish between *T. eungellensis* and *T. liemi*, but pigment patterns in life were a consistently useful feature. The illustrations, therefore, depict pigment patterns that are present in life. Pigment patterns that persist in preserved specimens are also described, although these are less useful for distinguishing between the tadpoles. Color descriptions should be treated with some caution as tadpole color can often be a function of factors such as substrate color or water clarity (Bragg, 1957). A representative specimen of each species is illustrated in Fig. 1a–d (*T. eungellensis*, Qld Mus. No. QMJ 62574) and Fig. 2a–d (*T. liemi*, Qld Mus. No. QMJ 62594). The labial tooth row formulae (LTRF) included with the illustrations are based on observations of all specimens examined or collected, which include tadpoles at most stages of development.

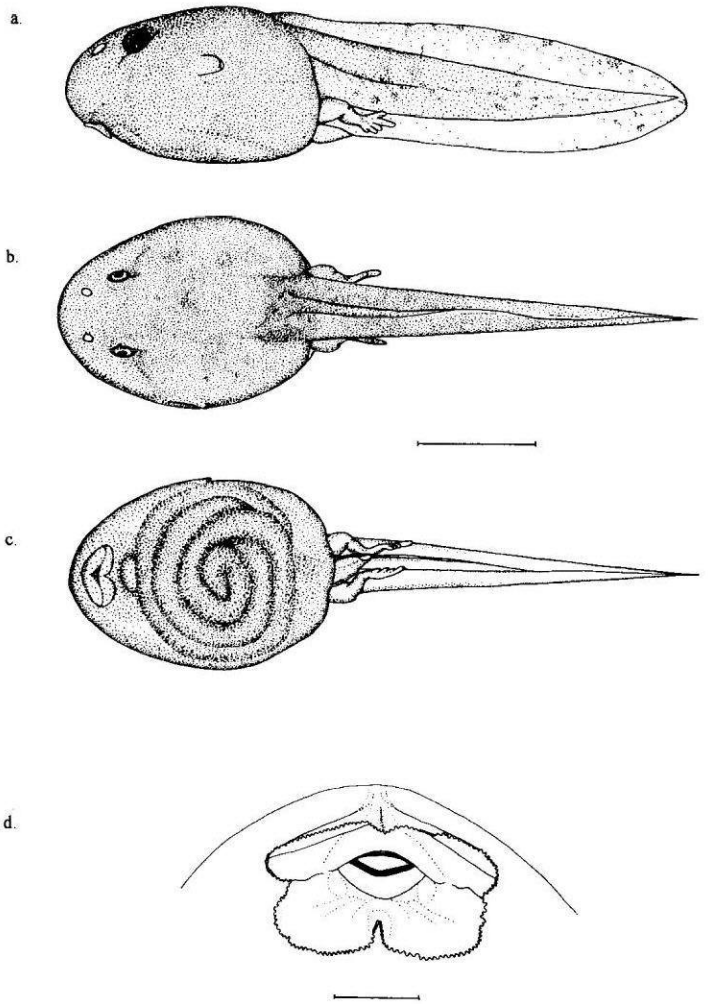

FIG. 2. (a–c): The tadpole of *Taudactylus liemi* (Qld Museum No. QMJ 62594; Total length = 27.15 mm, Gosner Stage 37). Scale bar represents 5 mm. (d): The oral disc of *T. liemi*. Scale bar represents 1 mm.

Habitat and life history notes of the two species are provided to assist identification in the field.

RESULTS AND DISCUSSION

Tadpole measurements from all sites are presented in Table 1.

Identification: *Taudactylus eungellensis* (Liem and Hosmer, 1973):

General.—A tadpole at stage 26 (Fig. 1a–c) had the following measurements (mm): total length = 36.4, body length = 15.6, body width = 10.1, body height = 8.3, tail height = 7.7, interorbital distance (between closest edges) = 3.25, internarial distance = 1.85, eye-naris distance = 1.44. Eyes dorso-lateral, eye diameter = 1.88 (12.05% of body length). Nares dorsal, and midway between tip of snout and anterior edge of eye; narial margin with no rim, slightly indented. Spiracle small, sinistral, lightly pigmented and visible from dorsal view; detached at opening which is directed slightly dorsally. Vent tube dextral, attached to and opening at ventral edge of fin, 1.7 mm posterior of the tail-body junction. Dorsal fin terminates at or just anterior to tail-body junction; dorsal fin taller than caudal musculature at mid-length of tail; ventral fin is not. Tail tip tapers uniformly to blunt end. Tadpoles vary in total length from 12 mm at stage 25 to 42.8 mm at stage 39 (Table 1). Oral disc generally small (3.25 mm wide), almost terminal, with complete single row of small marginal papillae (Fig. 1d). Medially, posterior edge of skirt of papillae folded or indented towards centre of disc. Labial teeth absent on anterior labium, three distinct ridges without labial teeth on posterior labium (LTRF = 0/0). Keratinous jaws pigmented, small; appear thin and weak.

Dorsal.—Light brown (mid-dorsally) to orange-brown (dorso-laterally) dermal pigments on body, with distinctive V-shaped marking from posterior

TABLE 1. Measurements of live tadpoles examined throughout this study.

Species	Stage	SVL (mm) mean	Max	Min	No.	Total (mm) mean	Max	Min	No.
Taudactylus eungellensis	25	10.7	16.0	5.7	429	23.9	38.9	12.0	429
	26	13.0	15.8	9.5	22	30.5	39.7	22.1	22
	27	14.0	16.4	10.5	20	32.7	38.4	24.9	20
	28	14.9	17.1	13.0	15	32.5	39.2	26.1	15
	29	14.0	16.4	10.0	10	32.1	39.3	24.2	10
	30	14.1	16.1	12.6	7	33.2	38.4	29.9	7
	31	14.3	16.4	10.5	14	33.1	39.3	24.3	14
	32	13.9	14.5	13.3	2	30.9	31.4	30.3	2
	33	14.0	15.0	12.6	5	32.5	37.1	29.0	5
	34	14.4	16.9	12.7	10	34.4	37.3	29.7	10
	35	14.0	15.7	11.8	3	33.2	37.7	28.7	3
	36	14.8	17.0	12.8	11	33.7	39.0	25.5	11
	37	15.0	16.9	13.0	9	35.5	37.7	29.5	9
	38	12.9	14.1	12.4	4	31.2	36.7	28.3	4
	39	15.4	17.3	13.7	10	37.0	42.8	33.5	10
	41	14.5			1	38.9			1
	44	11.5			1	26.2			1
Taudactylus liemi	25	7.8	11.9	4.8	38	20.8	33.1	14.0	38
	26	9.4			1	21.5			1
	27	10.5	11.6	9.2	4	27.7	34.0	22.9	4
	28	11.3	12.4	10.6	6	31.5	33.2	28.2	6
	29	9.4			1	25.0			1
	30	10.9	11.4	10.4	3	30.2	32.3	29.1	3
	31	9.4			1	26.7			1
	32	10.0			1	25.6			1
	33	11.7	12.2	11.2	2	29.8	33.3	26.2	2
	35	11.6	11.6	11.5	2	33.1	35.3	30.9	2
	36	11.0	11.7	10.2	2	29.3	30.2	28.4	2
	37	11			1	31.8			1
	38	10.4			1	27.8			1
	39	10.9	11.4	10.4	2	30.4	32	28.8	2
	41	11.1			1	32.5			1
	42	9.5			1	27.5			1
	44	9.4			1	14.4			1

mid-dorsal area forward to mid-lateral points on either side (Fig. 1a–b). Some dark pigment present on posterior walls of body, near base of tail; dark markings less obvious on young tadpoles. Irregular blotches of dark and golden pigments on dorsal surface of caudal musculature, especially anteriorly; most marked in larger tadpoles. Short orange-white pigmented line along edge of dorsal fin at base of tail.

Lateral.—Orange-brown dermal pigments, especially dorsolaterally and laterally; dorsoventrally, pigments become paler. Caudal musculature generally immaculate; only very sparse stippling of dark chromatophores. With small tadpoles, fins appear clear and colorless; as tadpole grows, small dark flecks develop in fins, especially dorsally.

Ventral.—Cardial and branchial region visible through sparsely pigmented dermal layer of ventral body wall. Size of branchial region appears restricted and confined by large intestinal mass. Intestinal coils visible mid-ventrally; visibility obscured laterally by dermal layer of orange/golden chromatophores. Ventral caudal musculature unpigmented.

Preserved specimens lose orange pigments on body and dorsal edge of caudal musculature; dark pigments maintained on remainder of caudal musculature and fins. Diagnostic V-shaped marking lost from dorsal aspect of body. Anterior extensions of caudal musculature partially visible through dorsal dermal layers of body. Intestinal coils completely visible ventrally and laterally. As blood pigments fade, branchial and cardial organs become transparent and obscure. Nares become obvious; eyes partially sink into orbital sockets.

Identification: *Taudactylus liemi* (Ingram, 1980):

General.—A tadpole at stage 37 (Fig. 2a–c) had the following measurements (mm): total length = 27.15, body length = 11.25, body width = 7.82, body height = 6.1, tail height = 6.0, interorbital distance (between closest edges) = 1.84, internarial distance = 1.6, eye-naris distance = 0.65. Eyes dorsolateral, eye diameter = 0.7 (6.2% of body length). Nares dorsal, directed anterodorsolaterally, nearer to anterior edge of eye than tip of snout; narial margin may have shallow rim medially. Spiracle small, sinistral, lightly pigmented, visible from dorsal view, detached at opening which is directed slightly dorsally. Vent tube dextral, attached and opening at ventral edge of fin, 1.8 mm posterior of tail-body junction. Dorsal fin terminates

at or just anterior to tail-body junction; dorsal fin height equals height of caudal musculature at mid-length of tail; height [illegible] pers uniformly to blunt end. Tadpoles vary in total length from 14 mm at stage 25 to 35.3 mm at stage 35 (Table 1). Oral disc generally small (2.7 mm wide), almost terminal, with complete single row of small marginal papillae (Fig. 2d). Medially, both anterior and posterior edges of skirt of papillae folded or indented towards centre of disc. Labial teeth absent from anterior labium; indistinct ridges without labial teeth on posterior labium (LTRF 0/0). Keratinous jaws pigmented; appear thin and weak.

Dorsal.—Body mid-brown to grey-brown with few distinguishing markings. Golden chromatophores throughout dermal surface, never clumped or concentrated. Very sparse pigments anterior to nares, where dermal layer approaches transparency. Obscure transverse narrow dark bar at posterior end of body adjacent to base of caudal musculature. Dorsal surface of caudal musculature has patches of brown and golden pigments, similar to but less striking than *T. eungellensis*. Edge of dorsal fin pigmented. Tadpoles nearing metamorphosis may have obscure X-shaped pattern on dorsal body surface (see illustration in Liem and Hosmer, 1973).

Lateral.—Pale brown dermal pigments; pigment density reduced ventrally. Caudal musculature pale cream to white; very little pigmentation other than sparse stippling of dark chromatophores and subtle markings in grooves of muscle joins. Both fins transparent and colorless, irregular golden and brown chromatophores throughout.

Ventral.—Dermal layer largely free of pigments; caudal and branchial region and intestinal coils clearly visible. May have sparse dermal stippling of golden chromatophores mid-ventrally. Ventral caudal musculature unpigmented.

Preserved specimens lose most pigments on body; dark pigments maintained throughout caudal musculature and fins. Dorsally, especially posteriorly, anterior extensions of caudal musculature visible through skin. Laterally, intestinal coils completely visible. As blood pigments fade, branchial and cardial organs become transparent and obscure. Nares become obvious; eyes partially sink into orbital sockets.

tadpoles swam rapidly for short bursts near the substrate in the lower water column.

[illegible] (pers. obs. of gravid females), but sites of oviposition are unknown. Tadpoles of *T. eungellensis* may be locally abundant, and are found in large and relatively still mid-stream pools, or partially connected stream-side pools. Frogs of *T. eungellensis* have a peak breeding season between January and May, but tadpoles of all sizes and developmental stages may be found throughout the year. Metamorphosis occurs between November and January (unpubl. data).

Little is known of the breeding biology of *T. liemi* but a clump of large unpigmented eggs (79 eggs found on 30 November 1993) and newly hatched tadpoles were found throughout this study under small rocks in seepage areas adjacent to rainforest streams and in remnant pools of intermittent creeks. Tadpoles of *T. liemi* were generally scarce and were found in small remnant pools along intermittent creeks, permanent stream-side pools, seepages, and under water under rocks along slower margins of the stream; only rarely were they found in pools directly connected to a stream. Frogs of *T. liemi* call in suitable conditions throughout the year, especially between August and February. Their calling season peaks around December, and tadpoles are most commonly found between February and September. Metamorphs have been found between October and January (pers. obs.).

Sympatric Species.—Tadpoles of *T. eungellensis* were found in sympatry with *Litoria lesueuri, Mixophyes fasciolatus,* and occasionally *T. liemi*. Tadpoles of *T. liemi* were found in sympatry with *Litoria chloris, L. revelata* and occasionally *T. eungellensis*. The tadpoles of *T. eungellensis, M. fasciolatus* and *L. lesueuri* are stream-dwelling, being found predominantly in mid-stream pools, while tadpoles of *T. liemi, Adelotus brevis, L. chloris,* and *L. revelata* are found in stream-side pools and adjacent seepages. All species can be easily identified using the key provided in Appendix 1.

Frogs of both *T. liemi* and *T. eungellensis* were found in association with *L. chloris, L. lesueuri, M. fasciolatus,* and with each other. In addition, frogs of *T. liemi* were also found in association with *L. revelata,* and very rarely, [illegible]

Species	Stage	N	Mean	Min	Max
Taudactylus eungellensis	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	32	[illegible]	32.1	39.3	24.2
Taudactylus liemi	25	[illegible]	7.8	[illegible]	11.9
	32	[illegible]	10.0	[illegible]	[illegible]
	38	[illegible]	10.4	[illegible]	[illegible]

mid-dorsal area forward to mid-lateral points on either side [illegible]

[illegible]

12% of the body length dorsally. [illegible]

[illegible] If disturbed, [illegible]

Preserved specimens lose orange pigments on body and dorsal edge of caudal musculature; dark pigments

ally. As blood pigments fade, branchial and cardial organs become transparent and obscure. Nares become obvious; eyes partially sink into orbital sockets.

Acknowledgments.—Funding was provided by the Australian Nature Conservation Agency (ANCA), through the Queensland Department of Environment and Heritage (QDEH). Tadpoles were collected under QDEH permits [illegible]

Identification: Taudactylus liemi (Ingram, 1980).

[illegible] tached and opening at ventral edge of fin, 1.8 mm posterior of tail-body junction. Dorsal fin terminates

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APPENDIX 1

Key to the Stream-dwelling Tadpoles of Eungella Rainforest

1A Anterior gap in oral papillae 2
1B No gap in oral papillae 5
2A Three or more anterior tooth rows 3
2B Two anterior tooth rows 4
3A Wide gap in second anterior tooth row; vent tube medial; dark brown pigments; LTRF 4–5[2](3,4,5)/3(1); ventral oral disc . . . . . Striped Marsh Frog, *Limnodynastes peroni*
3B No gap or slight gap in second anterior tooth row; vent tube dextral; pigments nearing black; LTRF 3–4(2–4)/3(1); anterior oral disc . . . . . Tusked Frog, *Adelotus brevis*
4A Spiracle sinistral; intestine obscured by dark or golden brown pigmentation; LTRF 2(2)/3(1); eyes situated dorso-laterally . . . . . Red-Eyed Tree Frog, *Litoria chloris*
4B Darkly pigmented body and tail muscle with silvery-blue sheen; spiracle paragyrinid; intestine covered with silver pigments; LTRF 2(2)/3(1); eyes situated laterally . . . . . Whirring Tree Frog, *Litoria revelata*
5A Labial teeth absent; submarginal papillae absent—*Taudactylus* 6
5B Labial teeth present; submarginal papillae present 7
6A Orange-brown pigments in life, with prominent darker markings across base of tail and posterior portion of body; posterior fold only in labial papillae; eye diameter >12% of body length . . . . . Eungella Torrent Frog, *Taudactylus eungellensis*
6B Grey-brown pigments only; no prominent markings across dorsal side of body; anterior and posterior folds in labial papillae; eye diameter <9% of body length. . . . . Liem's Day Frog, *Taudactylus liemi*
7A Two anterior tooth rows; LTRF 2/3; several rows of submarginal papillae completely surrounding the oral disc; body length at Gosner stage 30 < 12 mm, total length at Gosner stage 30 < 30 mm . . . . . Stony Creek Frog, *Litoria lesueuri*
7B Six anterior tooth rows with three lateral rows on each side of jaw; LTRF 6(3–6)/3(1); few submarginal papillae; body length at Gosner stage 30 > 15 mm, total length at Gosner stage 30 > 45 mm . . . . . Great Barred Frog, *Mixophyes fasciolatus*

NOTE: *Rheobatrachus vitellinus* was also found in the streams of Eungella, but does not have a stream-dwelling tadpole.