SALAMANDRA	42	4	231-238	Rheinbach, 20 November 2006	ISSN 0036-3375

A new species of torrent-dwelling *Litoria* (Anura: Hylidae) from the Kikori Integrated Conservation and Development Project area, Papua New Guinea

Stephen J. Richards & Paul M. Oliver

Abstract. A new species of torrent-dwelling *Litoria* is described from lower-montane forest in the Kikori Integrated Conservation and Development Project area of Southern Highlands Province, Papua New Guinea. It is a medium-sized tree frog with spiniform tubercles on the hindlimbs, a green and brown blotched dorsum, and yellow colouration on the hidden surfaces of the thighs. External morphology and call data suggest affinities to *Litoria macki* and *L. spinifera*, but the new species can be distinguished from these taxa by a combination of smaller size, more extensively webbed hands and less tuberculate body, and by its different advertisement call.

Keywords: Hylidae, *Litoria*, vocalisations, new species, Papua New Guinea.

Introduction

The mountains of New Guinea's central cordillera are the result of a complex sequence of uplift events associated with collision of the Australian and Pacific Plates (Pigram & Davies 1987). These events have produced extreme environmental clines and numerous isolated habitat patches, creating a prime environment for extensive and rapid biotic diversification (Heads 2001, 2002). One particularly interesting group that has occupied these steep and perpetually wet mountains are hylid frogs of the genus *Litoria* Tschudi, 1838 that have adapted to life along steep torrential streams. These frogs lay large, unpigmented eggs among or under stones in the stream bed, and have tadpoles with large, suctorial mouthparts (Günther 2006).

The Kikori Integrated Conservation and Development Project (KICDP) in Gulf and Southern Highlands Provinces, Papua New Guinea, encompasses a huge range of habitats, ranging from low altitude coastal mangroves and rainforest to montane moss forest and grasslands. The frog fauna in this area is extremely diverse, and nearly 50 percent of the known taxa are undescribed (Richards 2002). In this paper we describe a new species of torrent-dwelling *Litoria* from lower montane forest in the KICDP area.

Materials and methods

Measurements (to the nearest 0.1mm) were taken with dial calipers and a stereomicroscope fitted with an ocular micrometer, and follow Richards (2001). They are: SVL (snout-vent length), TL (tibia length), HW (head width at tympanum), HL (head length from tip of snout to posterior edge of tympanum), EYE (horizontal eye diameter), TYM (horizontal tympanum diameter), IN (internarial distance), EN (distance between anterior edge of eye and posterior edge of naris), 3FD (transverse diameter of 3rd finger disc) & 3FP (narrowest transverse width of penultimate phalanx), 4TD (transverse diameter of 4th toe disc) and 4TP (penultimate phalanx, as for 3rd finger).

Advertisement calls were recorded with a Sony Pro-Walkman WMD-6C tape recorder and Sennheiser ME66 microphone, and 4 calls from two males were analyzed using the AVISOFT SAS-Lab Pro sound analysis

program. Air temperatures adjacent to calling males were measured with a Miller & Weber quick-reading thermometer. Specimens are deposited in the South Australian Museum (SAMA) and the Natural Sciences Resource Centre of the University of Papua New Guinea (UPNG). We examined comparative material in the collections of the American Museum of Natural History (AMNH), Berlin Zoological Museum (ZMB), British Museum (BM), Museum Zoologicum Bogoriense (MZB), Queensland Museum (QM), South Australian Museum (SAMA), Museum of Comparative Zoology, Harvard University (MCZ) and Museo Civico di Storia Naturale, Genoa (MSNG).

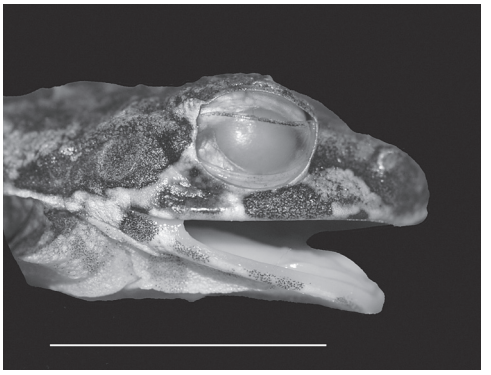

Fig. 1. Lateral view of head of holotype of *Litoria spartacus* sp. n. (SAMA R60290). Scale 10 mm.

Fig. 2. Ventral view of manus and pes of holotype of *Litoria spartacus* sp. n. (SAMA R60290). Scale 10 mm.

Results

***Litoria spartacus* sp. n.**
(Figs 1-6, Tables 1-2)

Holotype: SAMA R60290, adult male, torrential stream adjacent Moro Camp at base of Iagifu Ridge (6°21.833'S, 143°13.481'E, 800 m above sea level), Southern Highlands Province, Papua New Guinea, collected by S. RICHARDS on 16 May 2002.

Paratypes: Same locality as holotype, UPNG8864-5, adult males, collected 24 October 1999, SAMA R60291-2, adult males, collected 16 May 2002, SAMA R60293, adult female, collected 21 October 2001, SAMA R60294-6, adult males, collected 22 October 2001, all collected by S. RICHARDS and D. WEMP; SAMA R61238, Benaria River (6°03.287'S, 142°58.707'E 1345 m above sea level), SHP, Papua New Guinea, collected by S. RICHARDS on 1 May 2005.

Diagnosis: A medium-sized (males 35.8-37.3, a female 51.1 mm SVL), green and brown torrent-dwelling *Litoria* with bright yellow thighs, distinct webbing between fingers 2, 3 and 4, moderately large discs on fingers (3FP/3FD 0.556-0.684) and toes (4TP/4TD 0.524-0.600), small spiniform tubercles on distal edges of tarsi, no spiniform tubercles on body, and an advertisement call consisting of a series of 10-14 loud, bell like notes and lasting up to 18 seconds.

Litoria spartacus sp. n. can be readily distinguished from most other described stream-dwelling New Guinean *Litoria* by the following combination of features: presence of vocal slits in males [absent in *Litoria eucnemis* (LÖNNBERG, 1900), *L. exophthalmia* TYLER, DAVIES & APLIN, 1986 and *L. genimaculata* (HORST, 1838)] (TYLER 1968, TYLER et

	L. spartacus sp. n. (n= 9)		*L. macki* (n=6)		*L. spinifera* (n=12)	
	Mean (SD)	Range	Mean(SD)	Range	Mean (SD)	Range
SV	36.77 (0.701)	35.6-37.5	43.93 (1.36)	42.1-45.7	37.26 (1.29)	35.3-39.4
TL/SV	0.610 (0.016)	0.584-0.626	0.629 (0.016)	0.604-0.650	0.657(0.020)	0.630-0.691
EYE/SVL	0.127 (0.009)	0.112-0.143	0.125 (0.009)	0.114-0.142	0.116 (0.009)	0.107-0.137
EN/IN	0.592 (0.030)	0.551-0.644	0.664 (0.075)	0.592-0.784	0.698 (0.052)	0.615-0.829
HW/SVL	0.342 (0.011)	0.334-0.365	0.340 (0.005)	0.335-0.349	0.352 (0.010)	0.337-0.371
3FP/3FD	0.620 (0.045)	0.556-0.684	0.402 (0.029)	0.370-0.448	0.449 (0.022)	0.409-0.476
4TP/4TD	0.553 (0.021)	0.524-0.600	0.503 (0.015)	0.480-0.520	0.512 (0.032)	0.473-0.588
3FD/SVL	0.053 (0.005)	0.048-0.062	0.064 (0.004)	0.061-0.073	0.058 (0.002)	0.053-0.061
4TD/SVL	0.057 (0.003)	0.053-0.062	0.055 (0.005)	0.050-0.064	0.050 (0.003)	0.047-0.059

Tab. 1. Mean, standard deviation and range for key ratios of *Litoria spartacus* sp. n., and the two most similar species *Litoria macki* and *Litoria spinifera*.

al. 1986); possession of moderately extensive webbing between fingers 2-3-4 [absent or at most basal in *Litoria arfakiana* (Peters & Doria, 1878), *L. bulmeri* (Tyler, 1968), *L. macki* Richards, 2001, *L. micromembrana* (Tyler, 1963), *L. modica* (Tyler, 1968), *L. oenicolen* Menzies & Zweifel, 1974, *L. spinifera* (Tyler, 1968) and *L. wollastoni* (Boulenger, 1914)] (Tyler 1968, Menzies & Zweifel 1974, Richards 2001); it further differs from members of the *L. arfakiana* group (*Litoria arfakiana, L. oenicolen* and *L. wollastoni*) by its strongly curved canthus rostralis (straight in members of the *L. arfakiana* group; Menzies & Zweifel 1974). *Litoria angiana* (Boulenger, 1915) is a much larger species (males 40.1-65.9 mm) (Tyler 1968), while males of *Litoria brongersmai* (Loveridge, 1945), *L. dorsivena* (Tyler, 1968), *L. modica*, *L. rara* Günther & Richards, 2005, *L. rivicola* Günther & Richards, 2005, *L. pratti* (Boulenger, 1911), and *L. scabra* Günther & Richards, 2005 are much smaller (< 33 mm SVL; Tyler 1968, Günther & Richards 2005).

On the basis of superficial similarities in colouration and/or call structure the new taxon is most similar to *L. macki* and *L. spinifera*. It can be easily distinguished from both of these taxa by possessing extensive webbing between fingers 2-3-4, its smaller size (Table 1) and the absence of prominent conical tubercles on the body, especially above the orbit. It can be further distinguished from *L. macki* by possessing relatively smaller discs on the fingers (Table 1); and from *L. spinifera* in lacking the row of very spiniform tubercles along the posterior edge of the tarsus and tibia. The advertisement call of *L. spinifera* is a single note, quite unlike the series of notes produced by *L. spartacus* sp. n. The call of *L. spartacus* sp. n. is similar to that of *L. macki*; it is described and compared with *L. macki* below.

Description of holotype: Adult male (with vocal slits and calling when collected) with the following measurements: SVL 37.3; EN 2.8; HW 12.9; EYE 4.7; TL 23.0; IN 4.6; HL 13.1; TYM 1.9; 3FP 1.1; 3FD 1.8; 4TD 2.1; 4TP 1.1. Body moderately slender, limbs long (TL/SV 0.618), head wider than body in dorsal profile, distinct from neck (HW/SVL 0.345). Snout rounded in dorsal and lateral profiles, upper jaw protruding marginally over lower jaw. Canthus rostralis strongly curved, loreal region slightly concave, nares oriented antero-laterally, much closer to tip of snout than to eyes. Eyes large (EYE/SVL 0.126) and prominent, clearly protruding in

Fig. 3. Male *Litoria spartacus* sp. n. from Benaria River (paratype SAMA R61238) photographed in life at night. Note prominent conical tubercles on hind legs. Photo: S. Richards.

Fig. 4. Gravid female *Litoria spartacus* sp. n. from Moro torrent (paratype SAMA R60293) photographed in life during the day, note darker colouration. Photo: S. Richards.

both lateral and dorsal view, pupil horizontal. Tympanum clearly visible, small (TYM/SVL 0.053), less than half diameter of eye (TYM/EYE 0.404), annulus distinct and bordered dorsally by supratympanic fold that runs from posterior corner of eye and terminates above axilla. Dorsal skin finely granular with numerous scattered small tubercles, concentrated dorsally; ventrally skin smooth on throat, granular on abdomen; vomerine teeth in two clumps medial to choanae; tongue anteriorly ovoid.

Fingers long, relative lengths 3>4>2>1; webbing between fingers 1-2 in thin vestigial strip, webbing between fingers 2-3-4 extending approximately to penultimate subarticular tubercle; thin dermal flanges extending to disc on finger 3. Discs prominent and expanded on all fingers, (3FP/3FD = 0.611) with circum-marginal grooves. Distinct brown nuptial rugosities laterally on inner edge of first finger; single low, indistinct rounded subarticular tubercles on all digits; metacarpal tubercles indistinct, marginally bifid. Six rounded white tubercles of varying sizes on postero-ventral edge of fore arms.

Toes long; relative lengths 4-3-5-2-1; webbing vestigial between 1-2, extending to discs on toes 3, 5, 2, and to penultimate subarticular tubercle on both sides of toe 4; indistinct dermal flanges extending to disc on toe 4. Discs prominent (4TP/4TD = 0.524) with circum-marginal grooves; subarticular tubercles low, indistinct and rounded, inner metatarsal tubercle oval; outer metatarsal tubercle much smaller and rounded. Numerous small but distinct spiniform tubercles along lateral edge of tibia and tarsus; numerous small rounded tubercles on posterior edge of femur and around vent.

In preservative dorsal ground colour dark blue-green, with prominent irregular brown patches on the dorsum, around the nares, below the eye, and in the tympanic region. Small patches of white in rictal regions, ventro-laterally and around vent. Ventral surface pale yellow with scattered small round patches of very light brown on throat. Dorsally upper arms and legs with extensive blue-green blotching on dark brown background; lower legs, arms and digits covered with brown and green maculations of varying density on a pale yellow background; ventrally limbs largely pale yellow with extensive pale brown maculations, particularly towards lateral edges.

Fig. 5. Distinctive orange-yellow inner thighs of *Litoria spartacus* sp. n. Photo: S. RICHARDS.

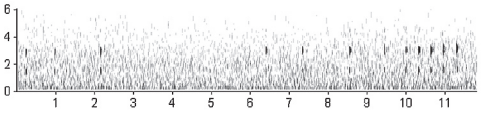

Fig. 6. Audiospectrogram of advertisement call of male *Litoria spartacus* sp. n. from Benaria River (paratype SAMA R61238) recorded at an air temperature of 21.5 °C.

Variation: Nine of the ten paratypes are adult males (SVL 35.62-37.51 mm). Measurements are summarised in Table 1. All specimens exhibit a similar dorsal pattern of brown with blue-green blotches. Relative proportions of these colours vary: SAMA R60291 and R60295 are predominately brown dorsally with green blotches, while the paratype from Benaria River (SAMA R61238) is predominately green dorsally with no large unobscured areas of dark brown. The amount of brown mottling on the ventral surfaces also varies. Most paratypes have more extensive mottling than the holotype, particularly around the anterior edge of the throat, but also on the limbs, and in two specimens (SAMA R60295-96) on the abdomen. All specimens have spiniform tubercles along both sides of the tibia and the posterior edge of the tarsus.

Fig. 7. Moro torrent, type locality of *Litoria spartacus* sp. n. in the Kikori Integrated Conservation and Development Project area. Photo: S. RICHARDS.

The female specimen (SAMA R60293) is considerably larger than the males and has the following measurements (in mm); SVL 51.1; EN 4.2; HW 17.3; EYE 5.2; TL 31.2; IN 6.2; HL 16.3; TYM 2.1; 3FD 3; 3FP 2; 4TD 3.4; 4TP 1.9. All ratios are within the range calculated for males, with the exception of 4TP/4TD (0.524), suggesting that females may have slightly wider toe discs. The colouration of the female is similar to the males, with the exception that there is considerably more green colouration on the digits. The female is noticeably more robust in overall appearance than the males (head not wider than body), in part probably refecting her gravid condition.

Colour in life: The following description is based on photographs of three individuals in life. A comparison of photographs taken at night and during the day suggests that in common with many other frogs, the overall colouration becomes considerably paler at night. In all specimens the dorsum has a yellowish green background that is overlaid by extensive light to dark brown blotching. This blotching is extensive on the body, but more broken and more sparse on the head. Faint whitish markings are present below the eye and tympanum in some specimens. Lateral surfaces are variably yellowish-green, or yellowish-green and brown, sometimes

Frog #	Call length (s)	Number of notes	Dominant Frequency	Notes/s	Note length
SAMA R61238	5.34	10	2880	1.88	0.023 (0.004) 0.018-0.031
SAMA R61238	11.15	12	2950	1.07	0.027 (0.005) 0.017-0.034
SAMA R61238	18.16	14	3016	0.72	0.034 (0.007) 0.025-0.049
N/A	10.29	14	2829	1.36	0.061 (0.03) 0.018-0.115

Tab. 2. Call features of *Litoria spartacus* sp. n. Note length is given as mean (SD) range.

with white spotting. The ventral surfaces are a dirty off white mixed with very light grey patches, sometimes with brown speckling concentrated laterally. Dorsal surfaces of the arms and legs show the same basic combination of colours as dorsum. The hidden surface of the thighs and tarsus is egg-yolk yellow to orange (Fig. 5). The iris is yellowish white with numerous thin brown reticulations.

Advertisement call: The advertisement call of *Litoria spartacus* is a series of 10-14 bell-like, un-pulsed notes lasting about 5-20 seconds. Major characteristics of the call are presented in Table 2. The frequency range is narrow giving a rather musical quality to the notes, a feature typical of many torrent-dwelling species (e.g. Richards 2001). A conspicuous feature of the call is that inter-note interval decreases dramatically during the call. In the call illustrated in Figure 6, mean inter-note interval between the first five notes is 0.848 s (SD 0.113; range 0.737-0.972) and between the final five notes is just 0.319 s (SD 0.076; range 0.274-0.455). This call pattern is similar to, but calls are much shorter than, *Litoria macki* (Richards 2001). The calls of *L. macki* contain 14-44 notes and last up to 50 s (Richards 2001)

Etymology: 'spartacus' noun in apposition, a name suggested by the Bain family of Adelaide, generous supporters of research at the South Australian Museum.

Distribution: *Litoria spartacus* is currently known from Moro and Benaria River, Southern Highlands Province, Papua New Guinea. Both sites are within the Kikori Integrated Conservation and Development Project area.

Natural History: Males of *Litoria spartacus* were found in riparian rainforest where they called from 3-10 m high in branches overhanging torrential streams (Fig. 7). This calling position was very difficult to access and many additional frogs were heard but not collected. The single female is gravid and contains approximately 75-120 large (2.5 mm diameter), mature unpigmented eggs and small numbers of small, immature eggs. This suggests that in this species a second egg clutch is produced at the same time as an existing clutch matures and is ready for laying.

Acknowledgements

We are extremely grateful to the WWF-Kikori Project for their financial and logistical support of SJR's research in the Kikori ICDP area between 1999 and 2004. In particular Daniel Wemp, Max Kuduk, Tanya Leary, Ted Mamu, Amos Ona and Olo Gebia have provided excellent facilities and logistical support during a series of biodiversity surveys in the region. Rose Singadan and Paulus Kei (University of PNG) provided support in Port Moresby and Barbara Roy of the PNG Department of Environment and Conservation (DEC) approved several export permits. For approval of our work in Southern Highlands Province (SHP) we are most grateful to DEC and the SHP Provincial Government. Francis Crome and the PNG Gas project were most supportive during the 2005 survey that collected the Benaria River specimen. Jim Robins of the National Research Institute helped

with SJR's research visas. Funding for laboratory equipment was provided in part by the Mark Mitchell Research Foundation, and additional support was provided by the Violet Scott Estate and the South Australian Museum Board. The curators of the following museums kindly provided access to specimens in their care; Barry Clarke (Natural History Museum, London), Marinus Hoogmoed and Pim Arntzen (RMNH), and Giuliano Doria (MSNG). This project was further supported by a significant and generous donation from the Bain family of Adelaide, and a grant from Conservation International, to both of whom we owe a great debt of gratitude. Both SJR and PMO would particularly like to thank Mark Hutchinson and Carolyn Kovach for their continuing assistance at the South Australian Museum.

References

Günther, R. (2006): Derived reproductive modes in New Guinean anuran amphibians and description of a new species with paternal care in the genus *Callulops* (Microhylidae). – J. Zool., **268:** 153-170.

Günther, R. & S.J. Richards (2005): Three new mountain stream dwelling *Litoria* (Amphibia: Anura: Hylidae) from Western New Guinea. – Russ. J. of Herp., **12**: 195-212.

Heads, M. (2001): Birds of paradise, biogeography and ecology in New Guinea: a review. – J. Biogeog., **28**: 893-925.

Heads, M. (2002): Birds of paradise, vicarience biogeography and terrane tectonics in New Guinea. – J. Biogeog., **29**: 261-283.

Menzies, J.I. & R.G. Zweifel (1974): Systematics of *Litoria arfakiana* of New Guinea and sibling species (Salienta, Hylidae). – Am. Mus. Nov., **2558:** 1-16.

Pigram, C.J. & H.L. Davies (1987): Terranes and the accretion history of the New Guinea orogen. – BMR J. Aust. Geol. Geophys., **10**: 193-211.

Richards, S.J. (2001): A new species of torrent-dwelling frog (Anura: *Litoria*) from the mountains of Indonesian New Guinea (West Papua). – Mem. Qld. Mus., **46**: 733-739.

Richards, S.J. (2002): Rokrok: an illustrated field guide to frogs of the Kikori Integrated Conservation and Development Project area of Papua New Guinea. – Port Moresby (WWF).

Tyler, M.J. (1968): Papuan hylid frogs of the genus *Hyla*. – Zool. Verhandl., **96**: 1-203.

Tyler, M.J., M. Davies. & K. Aplin (1986): A new stream-dwelling species of *Litoria* (Anura: Hylidae) from New Guinea. – Trans. R. Soc. S. Austral., **110**: 63-67.

Appendix 1.
Specimens examined

Litoria arfakiana: MSNG 29723A, Hatam, Arfak Mountains, Papua Province, Indonesia (lectotype). *Litoria dorsivena*: SAMA R7902-R7911, Telefomin, Sanduan Province, PNG, (type series). *Litoria macki*: MZB Amp.3870 Wapoga Alpha Mineral Exploration Camp, Papua, Indonesia (holotype); MZB 3871-2, QM J75810, SAMA R55363 same locality as holotype; SAMA R55364 Lagoria Landing site 21 9LS-21), Papua, Indonesia (all paratypes). *Litoria micromembrana*: SAMA R4150, Mount Podamp, PNG (holotype); SAMA R61629, SAMA R61637-40, UPNG 10031, Finimterre, Hindenburg Range, Western Province, PNG; SAMA R61599-01, UPNG 10029, UPNG 10032, SAMA R61602, Abalgamut, SAMA R61603, Kikiapa, both localities on the Huon Peninsula, PNG. *Litoria modica*: SAMA R8108, Oruge, PNG, (paratype); SAMA R61616-19, UPNG 10030, Mount Akrik, Star Mountains, Western Province, PNG; SAMA R61609-12, UPNG 10035-36, Mount Binnie Summit, Western Province, PNG; SAMA R61604-07, UPNG 10033, Mount Sisa, Southern Highlands Province, PNG; SAMA R61608, UPNG 10030, Mount Stolle, Sanduan Province, PNG. *Litoria napaea*: AMNH 49575 Idenburg River, Snow Mountains, Papua Province, (paratype); SAMA R61620-28, MZB 11833-42 Wapoga LS21, Papua Province, Indonesia. *Litoria oenicolen*: AMNH 87922 Baiyer River, Western Highlands Province, Papua New Guinea (holotype). *Litoria pratti*: BM 1947.2.23.54 (female), 1947.2.23.55, 1947.2.23.56 Wendessi, Papua Province, Indonesia; BM 1947.2.23.57, BM 1947.2.23.58 Arfak Mountains, Papua Province, Indonesia, (both cotypes). *Litoria rivicola*: ZMB 60327, ZMB 60328 30 km SE of Nabire, Papua Province, Indonesia (paratypes). *Litoria scabra*: MZB 11335, headwaters of the Wapoga River, Papua Province, Indonesia (holotype); MZB 11336-40, SAMA R60706-60709, ZMB 67357-67359, same locality as holotype (paratypes). *Litoria spinifera*: SAMA R6295-6301 Oruge, Western Highlands Province, PNG, (paratypes); SAMA R9167, Camp 1, Pio River, PNG; SAMA R9108A-D, Elmagale, Southern Highlands Province, PNG;

SAMA R55357-62, UPNG 9963-4 Crater Mountain Wildlife Management area, 55-75 km S of Kundiawa, Eastern Highlands Province, PNG.

Litoria wollastoni: BM 1947.2.23.59 Octakwa River, Papua Province, Indonesia (holotype).

Manuscript received: 11 May 2006

Authors' addresses: STEPHEN RICHARDS, Vertebrates Department, South Australian Museum, North Terrace, Adelaide, S.A. 5000, Australia, E-Mail: richards.steve@saugov.sa.gov.au; PAUL OLIVER, Vertebrates Department, South Australian Museum, North Terrace, Adelaide, S.A. 5000, Australia, E-Mail: paul.oliver@student.adelaide.edu.au.