

An emerging frog diversity hotspot in the northwest Kimberley of Western Australia: another new frog species from the high rainfall zone

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ABSTRACT – Surveys to remote tropical areas of the world have continued to lead to new discoveries of species, including vertebrates. A recent survey in January 2010 to the northwest Kimberley was undertaken to look for new frog species. Among the taxa discovered (including plants and land snails) was a small species of *Litoria* in the Prince Regent River Nature Reserve. *Litoria axillaris* sp. nov. is superficially similar in appearance (body shape, limbs and webbing) and in call structure to *L. tornieri*, a ground hylid which occurs in the Kimberley region and east to the Top End of the Northern Territory. The new species differs, however, in being smaller (22.0–25.0 v. 28.5–33.0 mm total length), in possessing extensions of the lateral stripe posterior to the tympanum on the lower lateral surface and anteriorly to the tip of the snout, in having dorsolateral streaks, the upper lip pigmented, the chin only weakly pigmented on the edge of the jaw, and having thighs with poorly-defined markings. *Litoria axillaris* sp. nov. shares with *L. tornieri* similar advertisement calls, including intermittent and repetitive calls; however, pulse rates of calls of the new species are less than half of those in *L. tornieri*. Further, habitat use also differs noticeably, with *L. axillaris* sp. nov. being found on top of sandstone platforms in highly dissected terrain while *L. tornieri* occurs in grasslands in tropical savannah. The new species is the fifth to be discovered and described as a result of wet season surveys targeting frogs in the Kimberley region since 2005. Its discovery highlights the high vertebrate endemism of the high rainfall zone of the northwest Kimberley and underscores the importance of protecting this biodiversity through the establishment of more extensive reserves and their proper management.

KEYWORDS: Anura, World Heritage listing, frog call.

INTRODUCTION

With more than 40 species documented to date, the Kimberley region of Western Australia is considered to be a centre of frog endemism within Australia (How and Cowan 2006; Slatyer et al. 2007; Powney et al. 2009). The high rainfall zone of the north-western Kimberley has a particularly rich frog fauna including eight endemic species (Tyler and Doughty 2009). Since 2007 four new species of frogs that occur in the northwest Kimberley have been described, three of which are endemic to the region (Doughty and Anstis 2007; Doughty and Roberts 2008; Doughty et al. 2009; Anstis et al. 2010). All four species are associated with sandstone outcrops, similar to *Litoria cavernicola* Tyler and Davies, 1979 and *Notaden weigeli* Shea and Johnston, 1988 which are also only known from the northwest Kimberley.

In January 2010 a biological survey targeting frogs, land snails and plants was carried out in the Prince Regent River Nature Reserve (Figure 1) during the monsoonal summer rainy season. Over 30 new species were discovered in less than two weeks (V. Kessner, M. and R. Barrett, pers. comm.), including a frog heard calling from the top of a sandstone platform near a large sinkhole during an expedition north of the river. Three males were collected, two of which were also recorded. The calls and appearance of the individuals resembled *Litoria tornieri* (Neiden, 1923) which occurs in the Kimberley and extends across the Top End of the Northern Territory. However, the specimens were smaller, possessed longitudinal streaks on the dorsum and the lateral stripe continued to the lower flanks. No further specimens were encountered during the rest of the field trip. Comparison of the specimens and their

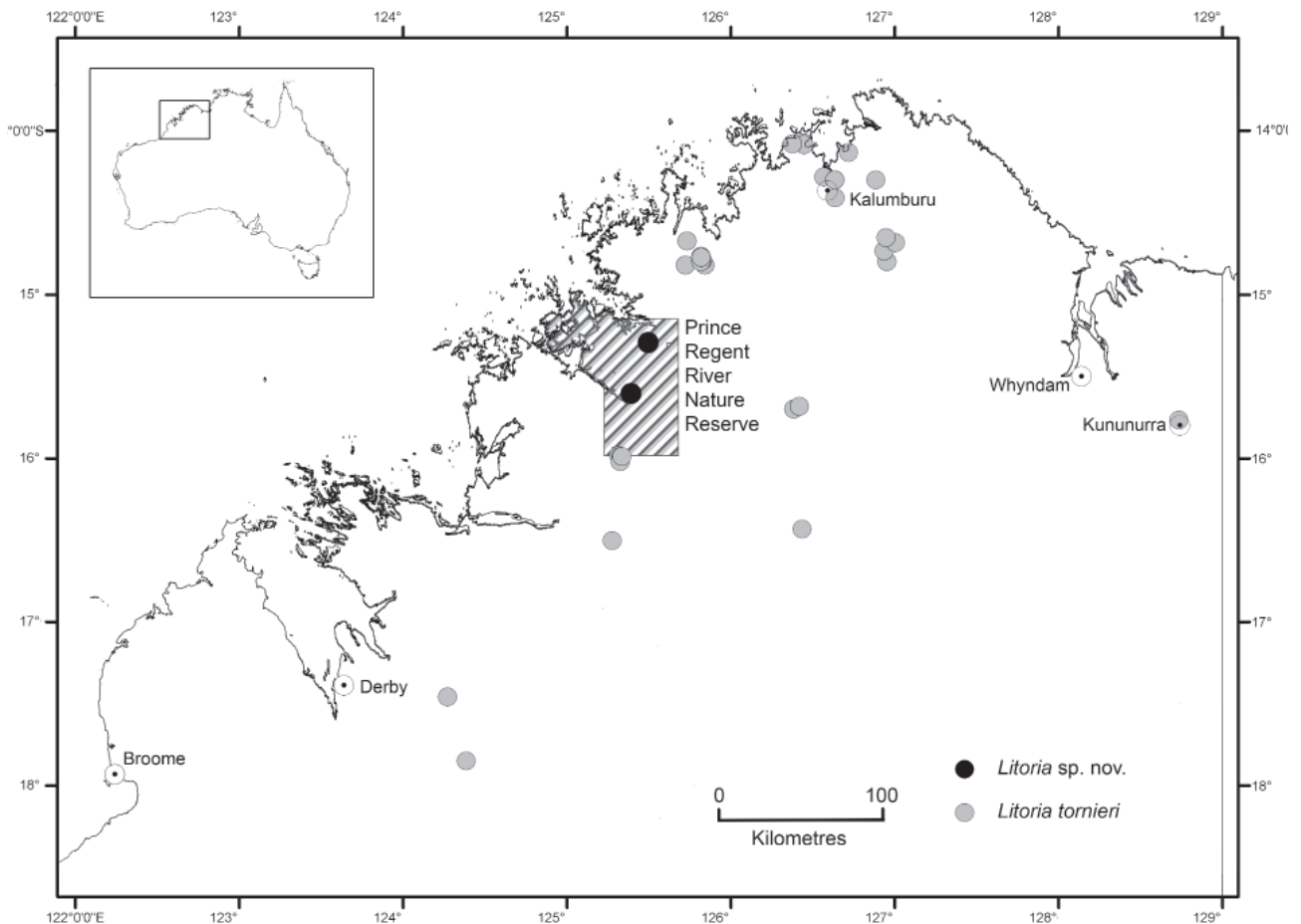


FIGURE 1 Distribution map of *Litoria* sp. nov. and *L. tornieri* from the Kimberley region, Western Australia.

calls with recently collected *L. tornieri* from the Prince Regent River Nature Reserve and the Mitchell Plateau confirmed the specimens were not *L. tornieri*, but rather an undescribed species. Another specimen was collected several months later from the same area, providing four individuals for the description presented here.

METHODS

All four specimens of the new species are males, and they were compared to 10 recently-collected *L. tornieri* males from the Kimberley (see Appendix for specimen details). All specimens are from the collections of the Western Australian Museum (WAM; prefix henceforth excluded from registration numbers). Liver samples of all specimens are stored at -70°C at WAM. Characters and their abbreviations are presented in Table 1. Small sample sizes precluded statistical analyses of quantitative data, therefore means, *SD* and ranges are presented and the results discussed qualitatively.

Digital recordings of calls were made with a Marantz PMD 660 digital recorder with an AKG D880^M microphone. Calls were analysed with Adobe Audition 2.0 and Raven Lite 1.0. Calls of the new

species were compared to *L. tornieri*, both of which utter 'intermittent' and 'repetitive' calls. For the new species there were two individuals with 'intermittent calls' recorded and one of these individuals also gave a 'repetitive call' (see below); for *L. tornieri*, there were two individuals with the repetitive call recorded, and one of these males also gave an intermittent call. The more complex 'intermittent' call is a halting, irregular call comprised of a 'burst' of 1–7 (typically 3–6) tightly-grouped notes per bout and the simpler 'repetitive' call is a single note repeated frequently at a constant rate. Notes had two dominant frequency peaks which were estimated from visual frequency displays. The following variables were scored for intermittent calls: bursts per minute, pulses per note and peak frequencies. For the repetitive calls, notes per minute, pulses per note and peak frequencies were scored.

Statistics of quantitative characters for the new species are presented below in the taxonomy section, and more detailed discussion of the comparisons with *L. tornieri* are presented at the end of the 'comparisons with other species' section. The generic taxonomy of Cogger (2000) is followed here, which excludes *Cyclorana* and *Nyctimystes*.

TABLE 1 Morphological measurements of *Litoria axillaris* sp. nov. and *L. tornieri* from the Kimberley region, Western Australia. All specimens are male. Mean±SD (range in brackets). Abbreviations: SUL – snout-urostyle length; TL – tibia length; HW – head width; IO – interorbital span; IN – internarial span; EN – eye-naris distance.

Character	<i>L. axillaris</i> sp. nov. N = 4	<i>L. tornieri</i> N = 10
SUL	24.5±1.7 (22.0–25.5)	31.2±1.7 (28.5–33.0)
TL	13.0±0.9 (11.9–13.8)	17.1±1.0 (15.7–18.4)
TL/SUL	0.53±0.02 (0.51–0.54)	0.55±0.02 (0.52–0.58)
HW	8.3±0.6 (7.7–9.1)	10.4±0.6 (9.2–11.1)
IO	4.5±0.3 (4.1–4.8)	5.2±0.3 (4.8–5.6)
IN	2.8±0.1 (2.6–2.8)	3.2±0.1 (3.0–3.3)
EN	2.3±0.1 (2.2–2.3)	2.7±0.1 (2.5–2.8)
EN/IN	0.83±0.04 (0.79–0.89)	0.84±0.05 (0.78–0.93)

TAXONOMY

Litoria Tschudi, 1838

TYPE SPECIES

Litoria freycineti Tschudi, 1838, by monotypy.

DIAGNOSIS

A large genus of hylid frogs with diverse morphologies but with the following general characteristics: head and body generally elongate, pupil horizontal, tympanum usually distinct, upper jaw toothed, fingers webbed or unwebbed, toes webbed, fingers and toes usually with dilated terminal discs (minimal in *L. dahlii*, *L. inermis*, *L. nasuta*, *L. pallida*, *L. tornieri* and *L. axillaris* sp. nov.).

Litoria axillaris sp. nov.

Kimberley Rocket Frog

Figures 2–4

Holotype

Australia: Western Australia: R171472, a calling male collected north of the Prince Regent River, Kimberley region (15°17'37"S, 125°29'46"E) on 19 January 2010 by P. Doughty and M. Pepper.

Paratypes

Australia: Western Australia: R169971, a male collected 9.3 km ENE King's Cascade on the Prince Regent River, Kimberley region (15°36'15"S, 125°23'26"E) on 30 March 2010 by M.D. Barrett and R.L. Barrett; R171471 and R171473 – as for holotype.



FIGURE 2 Photographs in life: left) *Litoria axillaris* sp. nov. (WAM R169971); right) *L. tornieri* (M. Anstis).

DIAGNOSIS

A small (to 25.5 mm SUL), slender hylid ground frog with triangular head, pointed snout (EN/IN – 0.83), protruding eyes and elongate limbs (TL/SUL – 0.53). Distinguished from other *Litoria* by a combination of the following characters: discs on tips of digits only slightly expanded, toes half webbed, pale brownish-grey background colouration, stripe on tibia unbroken, lateral stripe on side of head continues posteriorly to tympanum then (after hiatus above arm) along lower lateral surfaces, lateral stripe extends anteriorly to tip of snout, hiatus of pigment before the eye, two longitudinal dorsolateral streaks, and thighs with diffuse stripes. There are two kinds of advertisement call: an intermittent call comprised of 1–7 notes per burst (4–5 pulses/note; peak frequencies 2300 and 4600 Hz) repeated 46 times per minute, and a repetitive call comprised of a single note repeated 222 times per minute (12–14 pulses/note; 2200 and 4400 Hz).

DESCRIPTION OF HOLOTYPE

Body size small (25.0 mm SUL); head triangular with pointed snout, tip of snout in lateral view with oblique tip that projects slightly over lower jaw, EN/IN – 0.83; nares below canthus rostralis, small, vertically elongate, directed posteriorly; canthus rostralis curving slightly inwards with rounded edge; eyes large and protruding; small gland below corner of mouth, ca 1/3 size of tympanum; tympanum circular with distinct annulus; vomerine teeth: two short ridges anterior to choanae, each with three sharpened downward projections; tongue oval, free edge blunt and un-notched.

Limbs slender; arms moderately long, forearm with skin fold along posterior edge; fingers slender, unwebbed but with slight fringing and terminating in weakly expanded tips (only marginally wider than finger); two large palmar tubercles at base of wrist, tubercles under fingers round and moderately large;

first and second fingers with 1 tubercle; third and fourth with 2 tubercles; nuptial pad on inner side of first finger oval-shaped and comprised of rugose tissue; relative finger lengths 3>4>1>2. Legs long (TL/SUL – 0.51), tarsus with skin fold along posterior edge; toes long and slender, webbed to second tubercle from tip on fourth toe and last tubercle on third and fifth toes, continuing to tip as fringe; inner metatarsal tubercle small, flattened and oriented parallel to foot, outer metatarsal tubercle reduced to small bump; tubercles below toes small, round and directed slightly distally: first and second toes with 1 tubercle; third and fifth with 2 tubercles and fourth with 3 tubercles; relative toe lengths: 4>5>3>2>1.

Skin on dorsum and limbs relatively smooth, but with irregularities and furrows evident; ventrum, lower sides and back of thighs rugose; coccyx slightly protruding, cloaca positioned below coccyx and directed posteriorly.

Colouration

In life, greyish-brown dorsally, sides and forelimbs grey, upper surfaces of legs greyish-brown; eyes (pupil and lower iris) dark but dorsal portion of iris reddish-orange with upper edge of pupil edged with gold. Two dark dorsolateral streaks with poorly-defined edges begin near arms and terminate near the coccyx. A dark lateral stripe begins at tip of snout, with conspicuous crescent-shaped hiatus of colour before eye; stripe continues past eye over tympanum (ventral edge unpigmented) with another hiatus above arm; stripe continues further along sides in axillary region, angling ventrally and posteriorly and terminating diffusely along ventral edge of sides. Upper labial surface with a continuous dark edge, less dark than lateral stripe; region between lateral and labial stripes pale greyish-white. Arms with dark blotches on posterior edge, scattered blotches at insertion of arm anteriorly; groin suffused with a yellowy wash, continuing anteriorly to terminus of lateral streak on sides; coccyx edged with black, with dark markings along boundary of torso-leg



FIGURE 3 Holotype of *Litoria axillaris* sp. nov. (WAM R171472) in dorsal, ventral and lateral views.

attachment. Anterior and posterior surfaces of thigh with broad but poorly-defined stripe; outer edge of tibia with continuous dark stripe, clearly defined dorsally, less so ventrally; inner edge of tibia also with continuous stripe, but less defined; tarsus dark. Ventral surfaces pale yellowy-white; chin with dark mottling only near edge of jaw.

In preservative, the colouration becomes a dark grey (Figure 3). The dorsolateral streaks and yellowy wash in the groin are lost.

Measurements of holotype (mm)

SUL – 25.0, TL – 12.7, HW – 8.4, IO – 4.5, IN – 2.8, EN – 2.2.

VARIATION

Table 1 presents the ranges of the characters measured for the four known specimens. Colouration was similar to the holotype, with most of the differences being in the extent of the mottling on the upper lip and the conspicuousness of the dorsolateral streaks. Pigmentation on the chin also varied from almost none

(R171471, R171473) to mottling along the edge of the jaw (R169971, as per the holotype).

ADVERTISEMENT CALL

Figure 4 shows both types of call of *L. axillaris* sp. nov. The intermittent call comprised rapid bursts of 1–7 notes, with the bursts given at irregular intervals. Notes of the intermittent calls had 4–5 pulses per note and dominant frequencies of 2300 and 4600 Hz (both ca ± 200 Hz). The repetitive call was given by the male 222 times/minute, and repetitive calls of the recorded and other unrecorded males (pers. obs.) could be sustained for over a minute. The single note that was repeated had 12–14 pulses and dominant frequency peaks of 2200 and 4400 Hz (both also with ± 200 Hz). Given only two intermittent calls and one repetitive call were available, more calls are required to accurately assess variation.

DISTRIBUTION

This species is known only from two localities north of the Prince Regent River: the northernmost records are inland from Prince Fredrick Harbour near the Roe River,

TABLE 2 Summary of call characteristics of *Litoria axillaris* sp. nov. and *L. tornieri*. * Frequency peaks were ca 400 Hz wide. Sample sizes (N) represent individuals recorded.

Character	<i>L. axillaris</i> sp. nov.	<i>L. tornieri</i>
Intermittent call:	N = 2	N = 1
Bursts/min	46	42
Pulses/note	4–5	10–12
Frequency peaks (Hz)*	2300, 4600	1950, 3500
Repetitive call:	N = 1	N = 2
Notes/min	222	154
Pulses/note	12–14	28–33
Frequency peaks (Hz)*	2200, 4400	1950, 3500

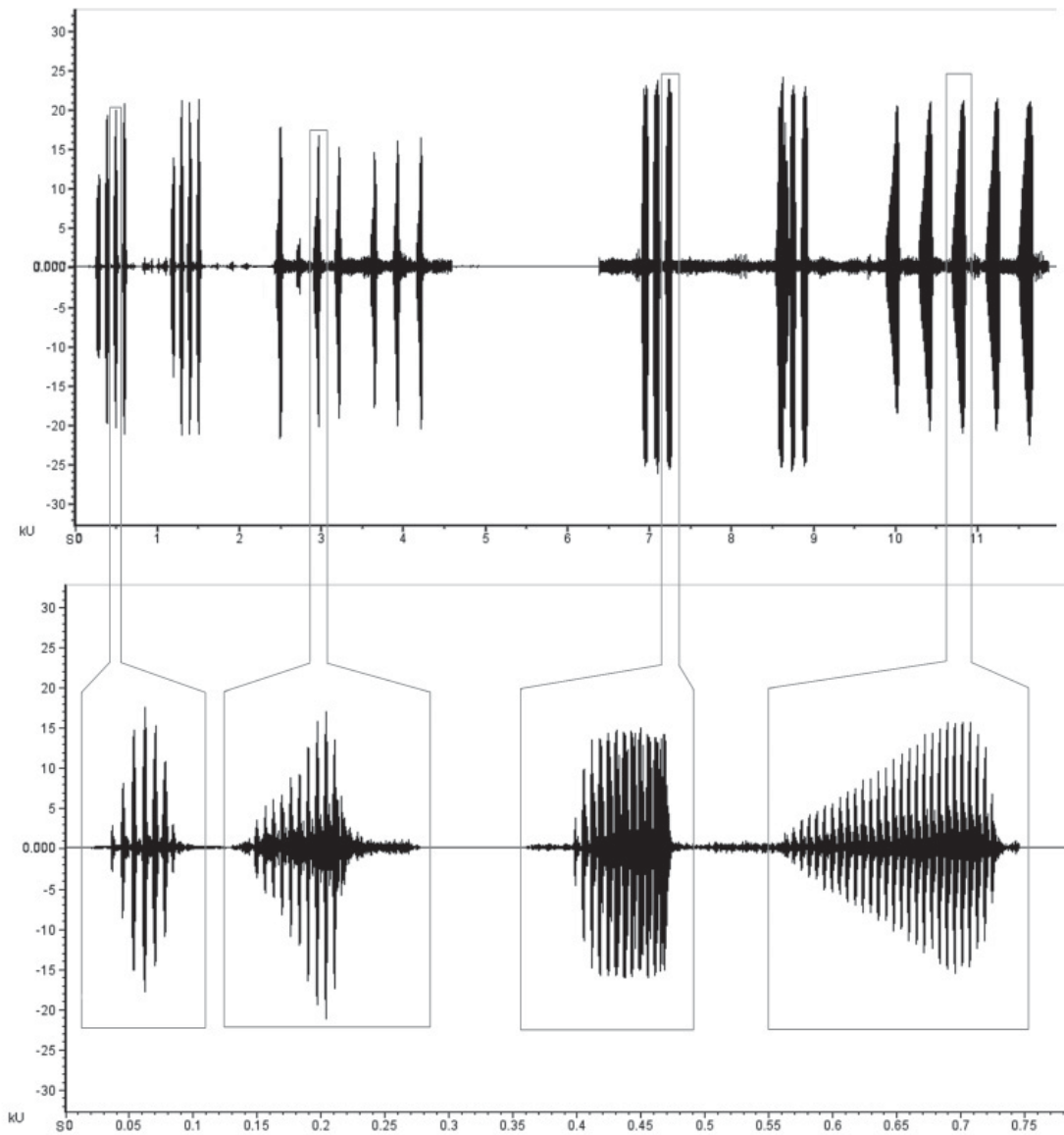


FIGURE 4 Calls of *Litoria axillaris* sp. nov. (left) and *L. tornieri* (right) for comparison. Upper figures shows the spectrogram of calls; lower figure shows pulses within a single note. Within each species, the leftmost call is the intermittent call (showing two separate bursts of notes) and the call on the right is the repetitive call. See Table 2 and text for details.

and the southern record is from near King's Cascade on the Prince Regent River. Both locations are within the boundaries of the Prince Regent River Nature Reserve in the Kimberley region of Western Australia (Figure 1).

HABITAT

All individuals were encountered on top of sandstone platforms in highly dissected mountainous terrain. Males collected from the northern site were calling from Spinifex (*Triodia*) clumps that grew between sandstone sheets at the edge of a sinkhole. The male collected near King's Cascade was 'among low lying grasses and herbs on shallow sand lens surrounded by low rocky hills at summit of broad sandstone hill' (M. and R. Barrett, pers. comm.). The known habitat suggests that this species breeds in shallow pools or rivulets on sheeting sandstone on plateaux, rather than creeks and swamps lower in the landscape as for *L. tornieri*.

ETYMOLOGY

The Latin word *axillaris* refers to the area of the body where the lateral stripe continues in this species, compared to termination of the stripe on the sides in *L. tornieri*. Used as a noun in apposition.

COMPARISON WITH OTHER SPECIES

There are over 40 species of frogs in the Kimberley region, but *L. axillaris* sp. nov. is distinguishable from all other species by many characters. Its small size (25 mm SUL) excludes many of the larger-bodied species such as *Cyclorana*, *Limnodynastes*, *Notaden* and *Platyplectrum*. The gracile build with triangular head separates *L. axillaris* from *Uperoleia* species, and the large eyes and non-flattened body shape separate them from *Crinia* species. Within *Litoria*, *L. axillaris* is smaller than the large tree frogs, and it is larger than *L. microbelos* and also lacks widely expanded terminal discs. Its brownish colouration excludes it from green species, such as *L. bicolor*.

Species that may also be active on the same rock platforms as *L. axillaris* are the rock hylids *L. coplandi*, *L. staccato* and *L. aurifera*. However, these latter species (plus *L. rubella* and *L. watjulumensis*) possess widely expanded terminal discs that are much wider than the finger; in *L. axillaris* the expanded discs are only slightly wider than the finger. In addition, all species except *L. staccato* have fully webbed toes.

Other ground hylids (commonly known as 'rocket frogs') are the species most likely to be confused with *L. axillaris*. However, all species except *L. tornieri* (discussed below) and *L. watjulumensis* (discussed above) lack a continuous dark line along the length of the outer tibia. In addition, *L. nasuta* has an extremely long head and limbs and has longitudinal skin folds on the dorsum, and *L. inermis* and *L. pallida* lack the expanded discs on digits, the dorsolateral streaks and the lateral stripe is poorly defined.

The most similar-looking and sounding species to *L. axillaris* is *L. tornieri*. Both possess similar proportions

(along with the other rocket frogs) (Table 1), slightly expanded finger and toe pads, an unbroken dark line on the outer tibia, a lateral stripe that runs from the snout to the side (including a hiatus of colour before the eye) and markings on the thighs. They differ, however, in that *L. axillaris* is smaller, colouration is greyish-brown (v. pale to brick red), the lateral stripe continues past the arm and on to the sides (v. one or two small blotches posterior to the tympanum), the upper lip is pigmented, dorsolateral streaks are present, markings on thighs are diffuse (v. mottled) and the chin is at most edged with black (v. extensively pigmented). Habitat preferences differ between the two species as well, with *L. axillaris* being associated with rugged sandstone outcrops and *L. tornieri* with flooded grasslands or creeks in tropical savannah. Call differences are presented in Table 2. Although sharing similar call rates, pulses per note of *L. axillaris* were less than half of those of *L. tornieri*. Frequency peaks also differed, with *L. axillaris* possessing higher frequencies for both intermittent and repetitive calls, as would be expected for the smaller body size (Hoskin et al. 2009).

REMARKS

As *L. axillaris* is only known from two locations and four specimens, a conservative listing of its status should be 'data deficient'. Although there are some threatening processes in the Australian monsoonal tropics (Bowman et al. 2010), the area where they occur is relatively secure at present because access is extremely limited owing to the rugged terrain and high rainfall in the wet season which makes land access extremely difficult. Nevertheless, feral species such as cattle, Cane Toads and weeds, and altered burning regimes may affect ecosystem functioning and therefore have an impact on all native fauna.

As has been noted in recent descriptions of Kimberley frogs (e.g. Doughty et al. 2009; Anstis et al. 2010), the high rainfall area of the northwest Kimberley has a large number of endemic species compared to the rest of the Kimberley, which is more subdued topographically and receives less annual rainfall. Moreover, Slatyer et al. (2007) identified the northwest Kimberley as a region of high frog endemism within Australia, and their analysis was conducted prior to the description of five new species from the region. This trend will only increase, as more descriptions of northwest Kimberley frog species are currently in preparation.

A clear pattern to emerge from the recent surveys and discovery of frog species from the northwest Kimberley is that biodiversity knowledge is far from complete. On the January 2010 expedition, specialists looking for land snail and plant species discovered at least 10 species from each group in about 10 days (V. Kessner, M. and R. Barrett, pers. comm.). Recent surveys of the Kimberley islands have also found new species of lizards, snails and plants (R. Palmer, pers. comm.), some of which are present on the poorly-surveyed mainland as well. It is likely that the combination of high rainfall and rugged

topography in the northwest Kimberley resulted in a relatively stable refuge where speciation could occur and/or where relictual species avoided extinction (see also Couper and Hoskin 2008).

Given the exceptionally high known biological diversity of the northwest Kimberley, the high level of endemism and the continuing pace of species discovery across many animal and plant groups, it is clear the region requires maximum protection in the form of increased reserves, higher level of protection of those reserves (including World Heritage listing) and proper management to preserve biodiversity, and the processes responsible for generating and sustaining it.

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APPENDIX

Comparative material examined: *Litoria tornieri*. All locations are from Western Australia (WAM prefixes omitted).

R167725, R167773, R167775, R167776, R167826, R167828 (Mitchell Plateau), R167829 (Mitchell Falls), R168050, R168086, R168164 (Prince Regent River Nature Reserve).