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# A new frog species (Microhylidae: *Cophixalus*) from boulder-pile habitat of Cape Melville, north-east Australia

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## Abstract

In Australia, microhylid frogs are found almost exclusively in the tropical north-east, but in this region diversity is high. Sixteen species occur in the Wet Tropics region and a further six species are found further north on Cape York Peninsula. Most Australian microhylid species belong to the genus *Cophixalus* (18 species). The majority of these have highly localized distributions, with two-thirds being found on single mountain ranges. While most *Cophixalus* are small (10–29 mm snout to vent length) rainforest species, four differ dramatically in morphology and ecology, being large (30–53 mm) species that inhabit isolated areas of jumbled boulder-pile habitat. Here I describe a new species of *Cophixalus* from boulder-pile habitat in the Melville Range on Cape Melville, north-east Cape York Peninsula. *Cophixalus petrophilus* **sp. nov.** is highly distinct from all congeners in morphology, colour pattern and mating call. This species is restricted to deeply piled granite boulder habitat that is largely devoid of vegetation. As for the other four boulder-pile *Cophixalus*, *C. petrophilus* **sp. nov.** is large and shows other similar morphological adaptations to this unique habitat (e.g., long limbs, large finger discs). However, it is notable in that it is the smallest of the boulder-pile species (26–32 mm) and it has particularly large eyes. I speculate that the latter trait is an adaptation to dimly lit conditions deep within the boulder-field. *Cophixalus petrophilus* **sp. nov.** was only found in exposed boulder habitat, whereas the co-occurring boulder species, *C. zweifeli*, was found using forested areas on and adjacent to the boulder-fields at night. Cape Melville is the only boulder-field with two co-occurring boulder *Cophixalus* and it appears that there is habitat partitioning between them. *Cophixalus petrophilus* **sp. nov.** has a highly localised distribution but appears common within this and is probably secure.

**Key words:** *Cophixalus zweifeli*, *Cophixalus saxatilis*, boulder, granite, Cape York

## Introduction

The family Microhylidae is represented in Australia by two genera: *Cophixalus* Boettger, 1892 (18 species) and *Austrochaperina* Fry, 1912 (5 species) (Zweifel 1985, 2000; Hoskin 2004, 2012). These frogs are almost exclusively restricted to the tropical north-east, with 22 species occurring in the Wet Tropics and Cape York regions of north-east Queensland. Just one species occurs outside this area, *Austrochaperina adelphe* (Zweifel 1985), which is restricted to the far north of the Northern Territory. The Wet Tropics is the center of microhylid diversity in Australia, with 16 species. In this region microhylid frogs comprise >50% of rainforest frog diversity (Hoskin & Hero 2008). Most of these species are found in upland rainforests and many are highly localized to single mountain ranges (Hoskin 2004, 2012). Six microhylid species are found further north on Cape York Peninsula: two are rainforest species of McIlwraith Range, three are restricted to isolated boulder-field mountains, and one is widespread across a variety of habitats (Zweifel 1985, 2000; Hoskin 2004; Hoskin & Aland 2011). This latter species (*A. gracilipes* Fry, 1912) is unusual in occurring in open forest habitats and is the only microhylid species shared between Australia and New Guinea, occurring in savannas and rainforests of northern Cape York and southern New Guinea (Zweifel 1985).

Most Australian microhylid species are restricted to rainforest. These rainforest species occupy the lower levels of the forest, living amongst leaf-litter, logs, rocks and low vegetation, and are of small body size (snout to vent length, SVL 10–29 mm) (Zweifel 1985; Hoskin 2004, 2008, Hoskin 2012). Four species (*C. saxatilis* Zweifel

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& Parker, 1977, *C. zweifeli* Davies & McDonald, 1998, *C. kulakula* Hoskin & Aland, 2011, *C. pakayakulangun* Hoskin & Aland, 2011) differ conspicuously in ecology and morphology, as they occur in boulder-pile habitat and are larger (SVL 30–47 mm). These boulder-piles are generally devoid of vegetation, being composed of huge granite boulders (about the size of cars and houses) piled up to hundreds of meters deep. Rainforest vegetation grows in gullies and other areas where soil is present, and figs, umbrella trees and other vegetation cling to the rocks in more sheltered, moister areas. The boulder mountains are generally surrounded by dry vegetation that is subject to regular burning. The deep boulder-fields remain cool and moist below the surface layers and are sheltered from fire, and thus act as lithorefugia to rainforest lineages (Couper & Hoskin 2008).

The four boulder *Cophixalus* are each found in separate, isolated boulder-fields: *C. saxatilis* at Black Mountain (Black Trevethan Range) on the northern periphery of the Wet Tropics rainforests (Zweifel & Parker 1977), *C. zweifeli* 175 km to the north in the Melville Range (Cape Melville) (Davies & McDonald 1998), *C. kulakula* 220 km further north in the Mt Tozer region (Hoskin & Aland 2011), and *C. pakayakulangun* 30 km north in the Stanley Hills region (Hoskin & Aland 2011). The boulder species live deep down in the boulders during the dry season and emerge during the summer wet (monsoon) season to call and feed on the surface rocks and surrounding vegetation. All Australian microhylid frogs are terrestrial breeders with direct development (Zweifel 1985; Hoskin 2004). This breeding mode has enabled the boulder frogs to breed in boulder-piles, habitats in which there is often no standing water. Eggs are laid in moist crevices between or beneath rocks (Hoskin 2004; Hoskin & Aland 2011) and all development takes place within the egg.

The boulder-fields of Cape York are remote and generally inaccessible by road in the wet season when boulder frogs are active. Targeted wet season surveys led to the discovery of two new boulder species in the Iron Range region in 2009–2010 (Hoskin & Aland 2011). Here I describe a new species of *Cophixalus* discovered during targeted herpetofauna surveys of Cape Melville, north-east Queensland in early 2013. Two other new species were also discovered during these surveys, a *Saproscincus* skink (Hoskin, in press) and a *Saltuarius* gecko (Hoskin & Couper, 2013). Cape Melville is dominated by a mountain range of granite boulder-fields, with patches of rainforest in gullies and on an elevated plateau. This mountain range is highly isolated from other elevated rainforest areas of north-east Queensland and is already recognized for having three endemic, rock-associated vertebrates. The new *Cophixalus* species is described herein.

## Methods

**Morphometrics.** Specimens examined are listed as the type series of *C. petrophilus* **sp. nov.** (N = 5) and in the Appendix for *C. zweifeli* (N = 7) and *C. saxatilis* (N = 9). Specimens are held in the Queensland Museum (QMJ codes). The following characters were measured: snout to vent length (SVL), from snout to urostyle; hindlimb length (HLL), from knee to heel (i.e. tibiofibula length); forearm length (FLL), from elbow to 'heel' of the palm (i.e. radioulna length); head width (HW), measured at the tympana (i.e. at widest point of the head); head length (HL), from anterior edge of tympanum to snout; head depth (HD), vertical measurement of head from top of head between eyes to under the jaw (measured parallel to the sagittal plane); eye diameter (ED), measured across horizontal axis; eye to naris distance (EN), measured between closest points; inter-nare distance (IN), measured between closest points; tympanum width (TYMP), measured across horizontal axis; third finger disc width (3DW); third finger length (3FL), from split with second finger to tip of disc; fourth toe disc width (4DW); fourth toe length (4TL), from split with third toe to tip of disc. All measurements of preserved specimens were taken using Mitutoyo electronic callipers and rounded to the nearest 0.1 mm. Field measurements of SVL and weight (WT) were taken using Mitutoyo vernier callipers and a spring-loaded Pesola, respectively.

**Call recording and analysis.** Recordings of *C. petrophilus* **sp. nov.** and *C. zweifeli* were made in the field using an Edirol R09 recorder and a Sennheiser (K6 ME-66) directional microphone. One *C. petrophilus* **sp. nov.** (QMJ92560) was recorded, at an air temperature of 25°C. Two *C. zweifeli* (QMJ92555, QMJ92557) were recorded, at an air temperature of 28°C. Recordings of two *C. saxatilis* were obtained from Keith McDonald. No temperatures were available for these calls. The software Raven Pro Version 1.3 was used to measure call traits. Spectrograms were produced using the Hann window function with a window size of 256 samples and a 3 dB bandwidth of 248 Hz. The following call traits were measured: call rate, the time between consecutive calls; call duration, the length of a single call from the beginning of the first note or pulse to the end of the last note or pulse;

number of notes or pulses; note or pulse rate (number of notes or pulses divided by call duration); dominant frequency (the frequency at which the call is of greatest intensity. The calls of *C. petrophilus* **sp. nov.** and *C. saxatilis* are very different in structure to those of *C. zweifeli*. The calls of the former two species are a tapping sound with no obvious pulses within each note, whereas the call of *C. zweifeli* is a single yelp composed of hundreds of fine pulses. Therefore, notes were measured in *C. petrophilus* **sp. nov.** and *C. saxatilis*, whereas pulses were measured in *C. zweifeli*. Four calls were randomly chosen for each male to give the average call characteristics of that individual.

**Genetics.** All genetic techniques follow those outlined in Hoskin (2004). One individual (QMJ92560) of *C. petrophilus* **sp. nov.** was sequenced for portions of the mitochondrial 16S rRNA and 12S rRNA genes (963 base pairs in total). The sequences were aligned against sequences from all Australian species of *Cophixalus* (except *C. peninsularis* Zweifel, 1985) and *Austrochaperina* (Hoskin, unpub. data). Genetic divergences stated are uncorrected pairwise patristic distances, calculated in Geneious version 6.1.6. Sequences have been deposited in GenBank (12S = KF573629, 16S = KF573630).

## Systematics

Morphological diagnosis of Australo-Papuan microhylid genera is based on characters of internal morphology (Zweifel 1985, 2000). This was not conducted here due to the limited number of specimens. In terms of external morphology, the new species shows a clear similarity to the larger *Cophixalus* species (*vs* all other Australian frogs) in having long, slender fingers with large, truncated finger pads. The new species is clearly assignable to *Cophixalus* based on genetic data (Hoskin, unpub. data).

***Cophixalus petrophilus* sp. nov.**
Blotched Boulder-frog
Figs 1, 2A, 2B, 3

**Material examined. Holotype:** QMJ92560, male, Melville Range (14°18'54" S, 144°29'54" E; elevation 120 m a.s.l.), Cape Melville, north-east Queensland, C. J. Hoskin, 10 February 2013. **Paratypes:** QMJ92568 (female), QMJ92569 (male), QMJ92573 (female), QMJ92574 (male), Melville Ra. (14°16'44" S, 144°29'22" E; elevation 470 m a.s.l.), north-east Queensland, C. J. Hoskin, 20 March 2013.

**Diagnosis.** *Cophixalus petrophilus* **sp. nov.** can be distinguished from all congeners by the following characters: medium body size (SVL 26.4–31.8 mm), blotched dorsal pattern of males and females, and large eyes (ED/SVL = 0.11–0.14). The mating call is also distinct from all *Cophixalus*, being a medium paced, low-pitched rattle.

**Etymology.** From the Latin, petrophilus refers to 'rock-loving', in recognition of the restriction of this species to boulder-field habitat. The species epithet is treated as a noun in apposition.

**Measurements of holotype (mm):** SVL 28.3; HLL 14.1; FLL 7.4; HW 10.0; HL 6.9; HD 3.4; ED 3.7; EN 1.9; IN 1.9; TYMP 2.2; 3DW 1.5; 3FL 4.3; 4DW 1.0; 4TL 6.7.

**Description of type series.** Data presented as range followed by mean in brackets. **Adult measurements (mm):** SVL 26.4–31.8 (29.2); HLL 13.3–15.4 (14.4); FLL 6.8–8.7 (7.5); HW 9.8–11.8 (10.8); HL 6.9–8.6 (7.7); HD 3.4–4.8 (4.1); ED 3.2–4.2 (3.7); EN 1.9–2.7 (2.3); IN 1.7–2.3 (2.0); TYMP 1.7–2.2 (1.9); 3DW 1.4–1.9 (1.6); 3FL 4.1–5.1 (4.6); 4DW 0.8–1.2 (1.0); 4TL 6.3–7.7 (6.9). **Adult proportions:** Table 1. **Comparison of sexes:** Females are larger than males (female SVL 31.2–31.8 mm, male SVL 26.4–28.3 mm) but no major differences in proportions were detected between the sexes (Table 1). ***Head:*** Narrower than body, triangular in dorsal view; snout truncated at the nares, blunt to projecting in profile; canthus rostralis rounded to angular, loreal region steep; nares much closer to tip of snout than to eye, nares anterolateral on tip of snout; eyes large; eye diameter greater than eye to naris distance; internarial distance about equal to distance from eye to naris; tympanum large (approximately half diameter of eye), indistinct to moderately distinct beneath overlying skin, bordered dorsally by supra-tympanic fold. ***Body:*** Oval. ***Limbs:*** Hindlimbs and forearms relatively long; fingers and toes unwebbed; relative finger length 3>4>2>1; fingers 2, 3 and 4 long and slender with large, truncated discs; first finger short (about one-third to

half length of second) with small and rounded disc; broad, low, rounded outer palmar tubercles; subarticular tubercles low, moderately prominent; relative length of toes 4>3>2>5>1 (2 and 5 about equal length), toes long and slender, toe 4 very long; toe discs moderately truncated, discs smaller on toes 1 and 5; low, rounded inner metatarsal tubercle, no outer metatarsal tubercle; subarticular tubercles low and rounded, moderately prominent; discs on fingers larger than discs on toes. ***Skin:*** Dorsal surfaces smooth, with scattered fine tubercles; ventral surface smooth; indistinct supra-tympanic fold. ***Colour pattern in preservative*** (Fig. 3): All dorsal surfaces cream or creamy brown with darker brown blotches. Blotching includes a prominent W-shaped mark on the shoulders, a dark bar across the top of the head between the eyes, and irregular blotching over the lower back and limbs. Dark band around wrists; tops of hands white; top of finger pads grey. Pale lumbar ocelli visible; particularly prominent on the darker males. Greyish triangle on top of snout; eyelids light to dark grey. Dorsal blotching fades out on flanks. Ventral surfaces uniformly pale (white or cream) except for grey shading on undersides of hands and feet. Dark band from nare to above tympanum, broken by eye; in some specimens, rather than a dark band, much of the loreal region is dark. Tympanum pale with light brown center. Iris dark but heavily flecked with silver. Groin and posterior thigh finely mottled and smudged brown and grey; the orange seen in life in the groin, posterior thigh and on the 'calf' appears as white or soft orange areas in preserved specimens.

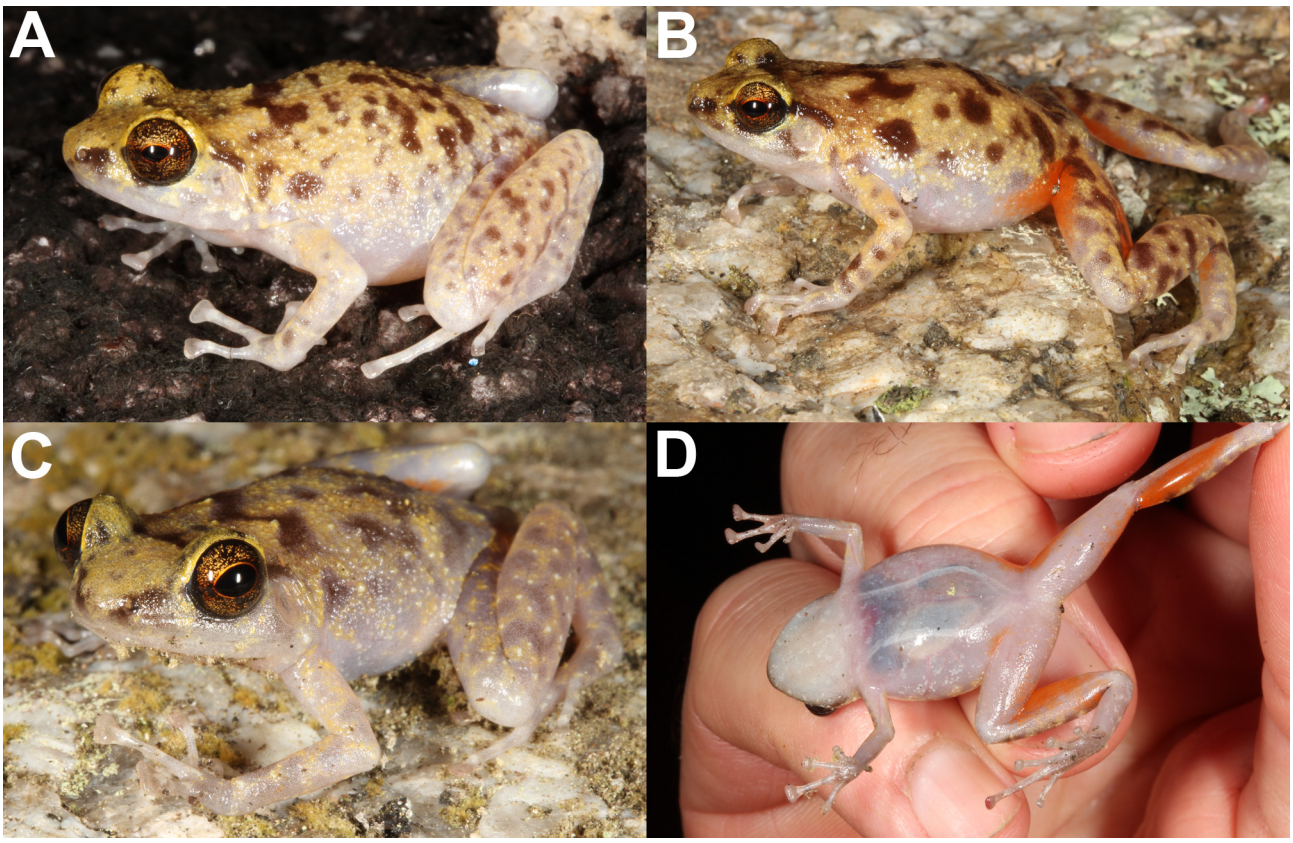


**FIGURE 1.** *Cophixalus petrophilus* **sp. nov.** in life: (A) male, holotype; (B) male; (C) female; (D) male, ventral.

**Measurements of live individuals.** The holotype was measured in the field: SVL 27.1 mm, WT 1.85 g.

**Colour pattern in life** (Figs 1, 2A, 2B). Dorsal surfaces of males creamy yellow with dark brown blotching; colours and markings paler in females. Dorsal markings include a prominent dark W-shaped mark on the shoulders, a dark bar across the top of the head between the eyes, irregular dark blotching over the back, dark or grey blotching or mottling on the upper flanks and limbs, and indistinct yellow lumbar ocelli. Top of hands, feet and digits white or pale grey; top of pads grey. Yellow triangle on top of snout and eyelids. Dark band from nare, through eye, and over tympanum. Tympanum pale. Dark horizontal line through iris, similar depth and colour to pupil, bordered above and below by red; upper and lower iris black but heavily flecked with gold. Dorsal blotching and yellow background colour fades out mid-flank to unmarked grey or white lower flank. Ventral surfaces uniformly white or pinkish grey; throat white; internal organs (heart, liver, gut) opaquely visible; two longitudinal white bands visible in males, from near forearm insertion to near hindlimb insertion; undersides of hands and feet

grey (Fig. 1D). Groin and hidden parts of hindlimbs (posterior thigh, 'calf', top of feet) orange; slightly paler in females.

**TABLE 1.** Morphological and call comparison between *C. petrophilus* **sp. nov.**, *C. zweifeli* and *C. saxatilis*. Morphology data is presented as SVL (mm), then traits as a proportion of SVL or another trait. Traits are: SVL: snout to vent length, HLL: hindlimb (tibiofibula) length, FLL: forelimb (radioulna) length, 3DW: third finger disc width, 4DW: fourth toe disc width, HW: head width, HL: head length, ED: eye diameter, TYMP: tympanum diameter, EN: eye to nare distance, IN: inter-nare distance. Specimens measured are the type series of *C. petrophilus* **sp. nov.** and the specimens listed in the Appendix for *C. zweifeli* and *C. saxatilis*. Call traits are defined in the Methods.

| | | *C. petrophilus* **sp. nov.** | | *C. zweifeli* | | *C. saxatilis* | |
|---|---|---|---|---|---|---|---|
| Trait | Sex | mean | range | mean | Range | mean | range |
| SVL (mm) | M | 27.6 | 26.4–28.3 | 37.1 | 36.3–37.9 | 32.7 | 30.0–35.0 |
| SVL (mm) | F | 31.5 | 31.2–31.8 | 45.0 | 41.5–48.9 | 42.2 | 39.9–45.1 |
| HLL/SVL | M | 0.50 | 0.50–0.50 | 0.46 | 0.45–0.47 | 0.49 | 0.46–0.51 |
| HLL/SVL | F | 0.49 | 0.49–0.49 | 0.47 | 0.46–0.49 | 0.46 | 0.45–0.48 |
| FLL/SVL | M | 0.26 | 0.25–0.26 | 0.25 | 0.25–0.25 | 0.28 | 0.26–0.30 |
| FLL/SVL | F | 0.26 | 0.24–0.28 | 0.26 | 0.25–0.27 | 0.26 | 0.24–0.27 |
| 3DW/SVL | M | 0.053 | 0.052–0.054 | 0.050 | 0.050–0.050 | 0.050 | 0.047–0.053 |
| 3DW/SVL | F | 0.055 | 0.050–0.060 | 0.056 | 0.053–0.059 | 0.062 | 0.057–0.067 |
| 3DW/4DW | M | 1.67 | 1.50–1.85 | 1.83 | 1.61–2.05 | 1.44 | 1.24–1.59 |
| 3DW/4DW | F | 1.67 | 1.29–2.04 | 1.40 | 1.33–1.46 | 1.39 | 1.26–1.62 |
| HW/SVL | M | 0.37 | 0.35–0.38 | 0.34 | 0.34–0.34 | 0.37 | 0.35–0.39 |
| HW/SVL | F | 0.37 | 0.37–0.38 | 0.34 | 0.31–0.37 | 0.38 | 0.36–0.40 |
| HL/SVL | M | 0.26 | 0.24–0.28 | 0.22 | 0.22–0.23 | 0.26 | 0.25–0.26 |
| HL/SVL | F | 0.27 | 0.26–0.27 | 0.23 | 0.23–0.23 | 0.25 | 0.24–0.26 |
| HW/HL | M | 0.37 | 0.35–0.38 | 0.34 | 0.34–0.34 | 0.37 | 0.35–0.39 |
| HW/HL | F | 0.37 | 0.37–0.38 | 0.34 | 0.31–0.37 | 0.38 | 0.36–0.40 |
| ED/SVL | M | 0.13 | 0.13–0.14 | 0.09 | 0.09–0.10 | 0.11 | 0.10–0.11 |
| ED/SVL | F | 0.12 | 0.11–0.13 | 0.09 | 0.09–0.09 | 0.09 | 0.08–0.10 |
| ED/TYMP | M | 1.91 | 1.71–2.15 | 1.35 | 1.30–1.40 | 1.99 | 1.86–2.11 |
| ED/TYMP | F | 1.93 | 1.93–1.93 | 1.31 | 1.16–1.46 | 1.75 | 1.31–2.20 |
| TYMP/SVL | M | 0.068 | 0.063–0.076 | 0.069 | 0.068–0.070 | 0.054 | 0.049–0.059 |
| TYMP/SVL | F | 0.062 | 0.055–0.069 | 0.068 | 0.061–0.074 | 0.054 | 0.046–0.062 |
| ED/EN | M | 1.72 | 1.50–1.92 | 1.23 | 1.20–1.26 | 1.40 | 1.21–1.52 |
| ED/EN | F | 1.47 | 1.25–1.68 | 1.21 | 1.05–1.37 | 1.16 | 0.99–1.33 |
| EN/HL | M | 0.29 | 0.28–0.31 | 0.34 | 0.32–0.35 | 0.30 | 0.29–0.33 |
| EN/HL | F | 0.31 | 0.30–0.31 | 0.32 | 0.29–0.36 | 0.33 | 0.30–0.36 |
| EN/IN | M | 1.10 | 1.00–1.25 | 1.01 | 0.99–1.03 | 1.02 | 0.92–1.09 |
| EN/IN | F | 1.18 | 1.09–1.28 | 1.18 | 1.08–1.28 | 1.01 | 0.92–1.11 |
| Call rate (s) | M | 3.5 | 3.3–3.9 | 3.1 | 2.5–3.4 | 4.1 | 3.6–5.2 |
| Call duration (s) | M | 1.00 | 0.92–1.07 | 0.27 | 0.25–0.29 | 3.19 | 2.40–3.94 |
| No. notes | M | 12 | 11–13 | | | 29 | 18–39 |
| No. pulses | M | | | 220 | 198–244 | | |
| Notes/s | M | 12.0 | 11.7–12.2 | | | 8.8 | 7.5–10.0 |
| Pulses/s | M | | | 821 | 785–904 | | |
| Dom. Freq. (Hz) | M | 1296 | 1270–1316 | 2449 | 2426–2464 | 1602 | 1367–1845 |


**FIGURE 2.** Comparison of: (A) *C. petrophilus* **sp. nov.**, male; (B) *C. petrophilus* **sp. nov.**, female; (C) *C. saxatilis*, male; (D) *C. saxatilis*, female; (E) *C. zweifeli*, male; (F) *C. zweifeli*, female.

**Call.** Calls were only obtained for a single individual (holotype, QMJ92560). The mating call of *C. petrophilus* **sp. nov.** is a fairly short, medium-paced, low-pitched rattle of the following characteristics (mean followed by range in brackets): duration 1.00 s (0.92–1.07), notes per call 12 (11–13), note rate 12.0 notes/s (11.7–12.2), dominant frequency 1.30 kHz (1.27–1.32) (Table 1). Calls are uttered at an interval of approximately 3.5 seconds (3.3–3.9). Air temperature at the time of recording was approximately 25ºC. Figure 4A displays a single representative call.

**Comparison.** Assigned to *Cophixalus* based on external morphology and genetics (see first paragraph of 'Systematics'). Distinguished from all congeners by medium body size (male SVL: 26.4–28.3 mm, female SVL 31.2–31.8 mm), large and truncated finger pads, blotched colour pattern of males and females, large eyes (ED/SVL = 0.11–0.14), and low-pitched rattling call. Most closely resembles the other boulder species due to larger size,

long fingers, and large, obviously truncated finger pads. The new species differs from these four species as follows. *Cophixalus petrophilus* **sp. nov.** is distinguished from *C. kulakula* by its smaller size (SVL 26.4–31.8 mm *vs* 39.8–48.0 mm) and blotched dorsal pattern. Distinguished from *C. pakayakulangun* by smaller size (SVL 26.4–31.8 mm *vs* 42.2–52.9 mm), orange groins, and blotched dorsal pattern of males and females. *Cophixalus petrophilus* **sp. nov.** is distinguished from *C. saxatilis* by its smaller size (male SVL 26.4–28.3 mm *vs* 30.0–35.0 mm; female SVL 31.2–31.8 mm *vs* 39.9–45.1 mm), larger eyes (ED/SVL 0.11–0.14 *vs* 0.08–0.11), and larger tympanum, particularly in males (TYMP/SVL 0.063–0.076 *vs* 0.049–0.059) (Table 1; Fig. 2). Additionally, *C. petrophilus* **sp. nov.** males are more heavily blotched than male *C. saxatilis*, and *C. petrophilus* **sp. nov.** females are blotched dark on creamy yellow whereas *C. saxatilis* females are fairly immaculate and bright yellow (Fig. 2). Further, the call of *C. petrophilus* **sp. nov.** is a fairly short, medium-paced rattle, whereas that of *C. saxatilis* is a slow tap (Table 1; Fig. 4). *Cophixalus petrophilus* **sp. nov.** co-occurs with *C. zweifeli* but is readily distinguished from that species by its smaller size (SVL 26.4–31.8 mm *vs* 36.3–48.9 mm), longer hindlimbs (HLL/SVL 0.49–0.50 *vs* 0.45–0.49), wider head (HW/SVL 0.35–0.38 *vs* 0.31–0.37), longer head (HL/SVL 0.24–0.28 *vs* 0.22–0.23), and larger eyes (ED/SVL 0.11–0.14 *vs* 0.09–0.10) (Table 1; Fig. 2). Additionally, *C. petrophilus* **sp. nov.** has a blotched dorsal surface whereas the dorsal surface of *C. zweifeli* is immaculate (Fig. 2). The calls of *C. petrophilus* **sp. nov.** and *C. zweifeli* are very different, with that of the former being a low-pitched rattle and that of the latter being a high-pitched 'yelp' (Table 1; Fig. 4). *Cophixalus petrophilus* **sp. nov.** is readily distinguished from all Australian frogs (except the larger *Cophixalus* species) by having long slender fingers with large, truncated finger pads.

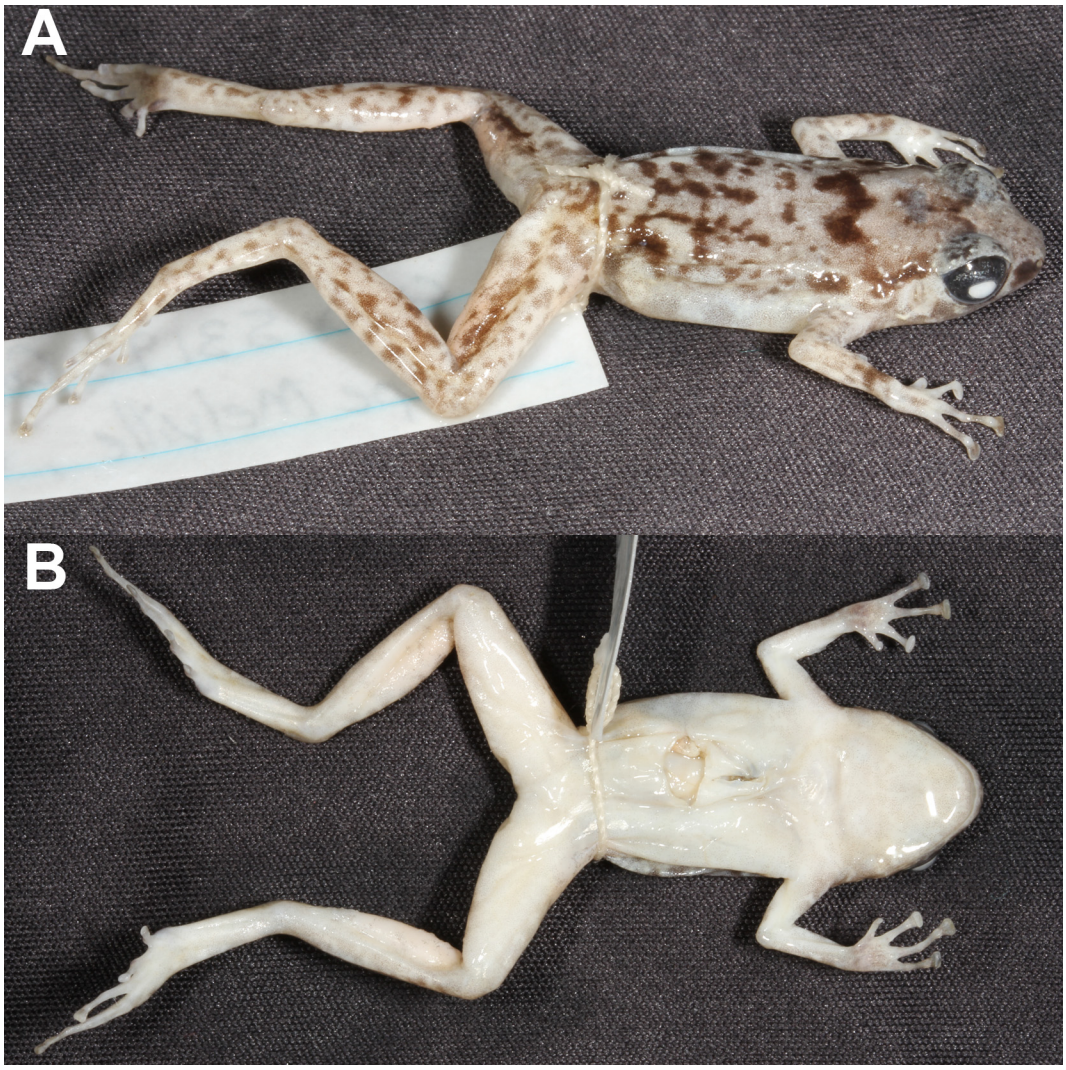


**FIGURE 3.** Holotype of *C. petrophilus* **sp. nov.** (QMJ92560): (A) dorsolateral, (B) ventral.

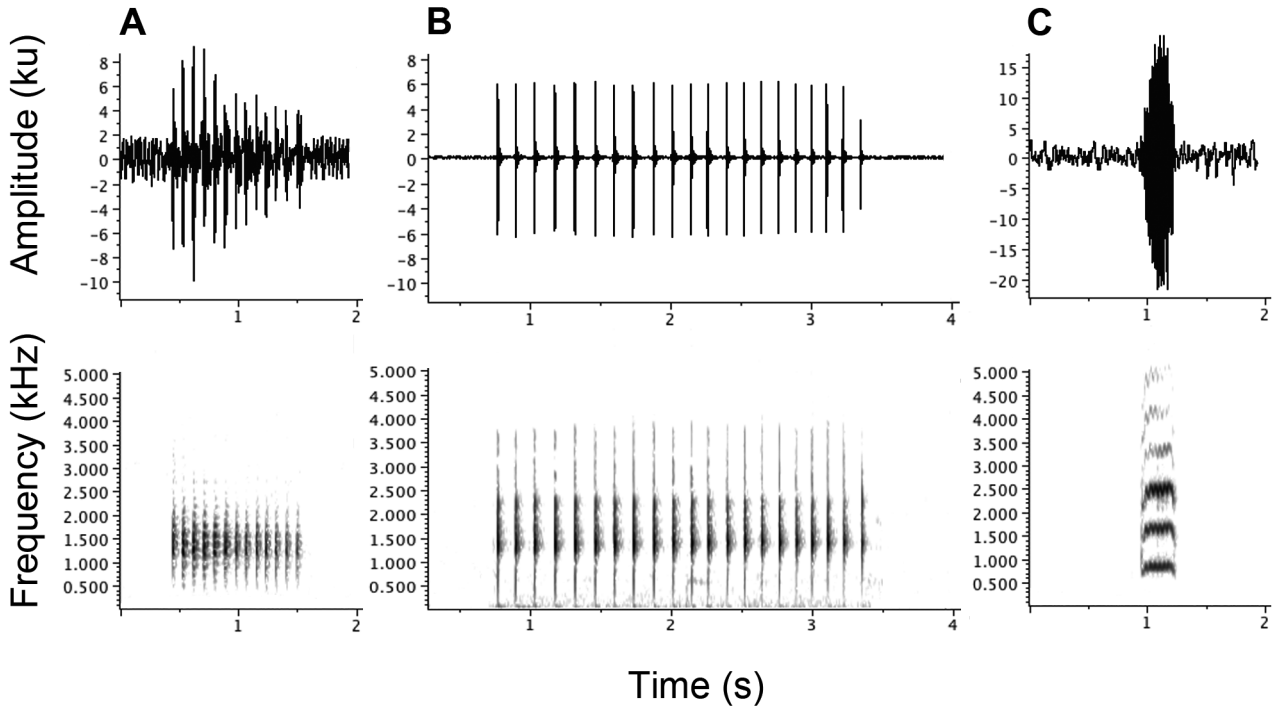


**FIGURE 4.** A single call of: (A) *C. petrophilus* **sp. nov.**, (B) *C. saxatilis*, (C) *C. zweifeli*. Top row shows waveform, displaying amplitude (*y*-axis) against time (*x*-axis, seconds). Bottom row shows spectrogram, displaying call frequency (*y*-axis) and intensity (degree of shading) against time (*x*-axis, seconds).

**Genetics.** There is substantial sequence divergence (for 963 bp 12S and 16S rRNA) between *C. petrophilus* **sp. nov.** and all other Australian *Cophixalus* (8.1–13.6%) (Hoskin, unpub. data). Phylogenetic analyses suggest that *C. petrophilus* **sp. nov.** is most closely related to *C. zweifeli* and *C. infacetus*, with sequence divergence between *C. petrophilus* **sp. nov.** and these two species being 8.1% and 8.2%, respectively (Hoskin, unpub. data).

**Distribution.** Known only from granite boulder-fields of the Melville Range, Cape Melville, north-east Australia (Fig. 5). *Cophixalus petrophilus* **sp. nov.** has been found at two sites, one at 120 m elevation at the southern end of Melville Range (14°18'54" S, 144°29'54" E) and the other at 470 m elevation in the central uplands of the range (14°16'44" S, 144°29'22" E). These sites are approximately 4 km straight-line distance apart. Cape Melville is dominated by extensive boulder-fields (Fig. 6A), and the species is probably widely distributed through these.

**Habitat and habits.** *Cophixalus petrophilus* **sp. nov.** inhabits deeply piled granite boulder habitat that is largely devoid of vegetation (Fig. 6A). At both sites the species was found at night sitting on surface boulders of very deeply piled boulder-field. Exploration below the surface at these sites revealed a deep labyrinth of boulders with no sign of soil or surface water to the depths that could be safely explored. Humidity was very high within the boulder-fields, the rock crevices were moist in places, and water flowed over the rock surfaces during rain and deep into the boulder-field. Indeed during heavy rain, and for a short period after, a loud sound of flowing water could be heard coming from the boulder-fields. Conditions were fairly dry during the survey of the lowland site in February 2013 and only a single individual (the holotype) was found when he called following a brief shower at 5 am. No individuals were found during the preceding night despite extensive searches of the boulder-field and surrounding rainforest. In contrast, conditions were moister during the survey of the upland site in March 2013 and four individuals (two males and two females) were found in a relatively small area of boulder-field (the rock patch in the top left of Figure 6B). No males were heard calling at this site and the frogs were found at night sitting on surface rocks or moving towards the surface from the depths of the boulder-field. The lack of calling activity at this time of the year conforms to the general pattern in Australian *Cophixalus* frogs of calling through the first two-thirds of the wet season (approximately Sept.–Feb.) but not in the latter part of the wet season (Hoskin & Aland 2011).

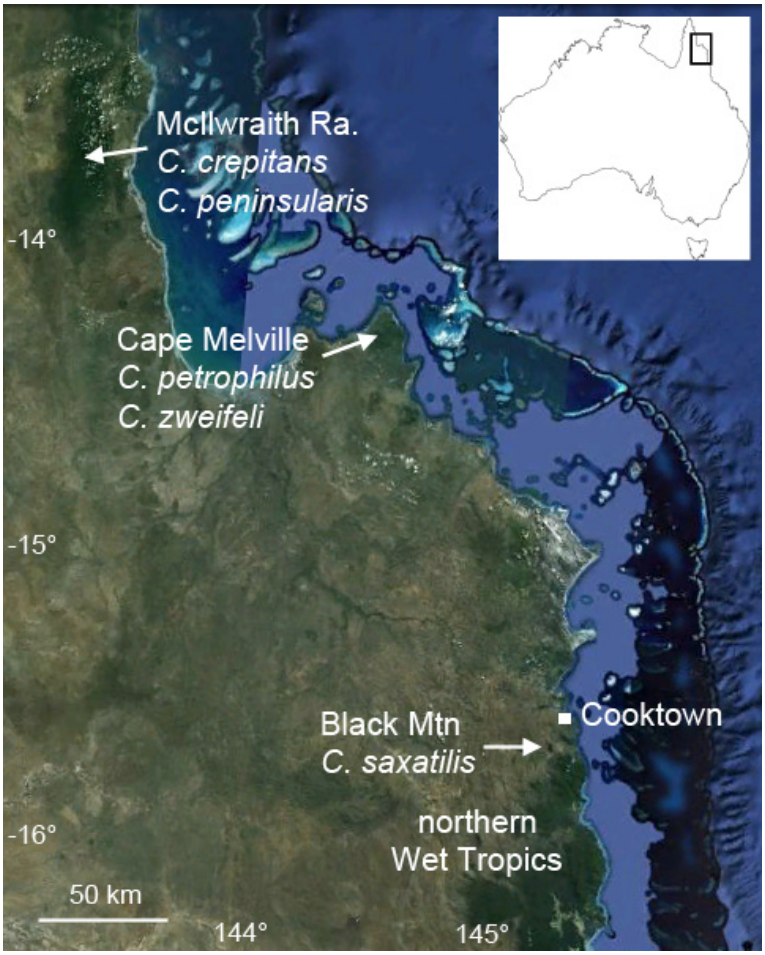


**FIGURE 5.** Map of north-east Queensland, showing the locality of Cape Melville, McIlwraith Range and Black Mountain, and the *Cophixalus* present in each of these areas. The map also shows the northern Wet Tropics, a region containing numerous rainforest *Cophixalus* species. The inset shows Australia. Background image is from Google Earth (2013).

The holotype was calling from a rock crevice about two boulder 'layers' below the surface. The crevice was moist and mossy compared to the surrounding rock surfaces. The male was wedged in the crevice, facing out, calling at regular intervals. *Cophixalus petrophilus* **sp. nov.** is likely a terrestrial breeder like all other Australian microhylid frogs (Hoskin 2004; Hoskin & Aland 2011), and it is likely that the male was calling from the nest site. In a similar species, *C. saxatilis*, in which males also call from exposed boulder-fields, an egg clutch has been found in a rock crevice attended by a male (Hoskin 2004). No other breeding information is known for *C. petrophilus* **sp. nov.**. Other frogs found in the vicinity of both sites were *C. zweifeli* and *Litoria andiirrmalin* McDonald, 1997, although neither of these species was found in micro-sympatry with *C. petrophilus* **sp. nov.**. While all *C. petrophilus* **sp. nov.** were found in exposed boulder-field largely devoid of vegetation, the other two species were found nearby in boulder-field abutting rainforest or boulder habitat under a rainforest canopy. Other vertebrates found at the *C. petrophilus* **sp. nov.** sites were the gecko *Gehyra dubia* (Macleay 1877) at night at both sites, and, during the day, the skink *Cryptoblepharus fuhni* Covacevich & Ingram 1978 at the lowland site and an undescribed *Saproscincus* skink (Hoskin, in press) at the upland site.

## Discussion

This brings the number of Australian *Cophixalus* to 19 species and the number of Australian microhylid frogs to 24. Six vertebrates are now known to be endemic to Cape Melville: three frogs, *Litoria andiirrmalin*, *Cophixalus zweifeli* and *Cophixalus petrophilus* **sp. nov.**; two skinks, *Cryptoblepharus fuhni* and an undescribed *Saproscincus* (Hoskin, in press); and the gecko *Saltuarius eximius* (Hoskin & Couper, 2013). This tally of endemic vertebrates is

extremely high for a single mountain range in Australia, especially when calculated relative to area. All these species except *C. fuhni* are divergent members of rainforest-associated clades of north Queensland (Hoskin, in prep.), which is interesting given that the area of current rainforest at Cape Melville is relatively small. Rainforest area is likely to have been even smaller during cool, dry global conditions associated with glacial maxima (as seen for the Wet Tropics rainforest, e.g. Mortiz *et al.* 2009; Hoskin *et al.* 2011). Persistence of these lineages at Cape Melville can probably be attributed in large part to adaptation to deep rock habitats, which provide cool, moist conditions and can buffer organisms from short and long-term hot and/or dry climatic conditions (Couper & Hoskin 2008). Deeply layered rock environments are also protected from fire. All the endemic vertebrates at Cape Melville are associated with rocky habitats.

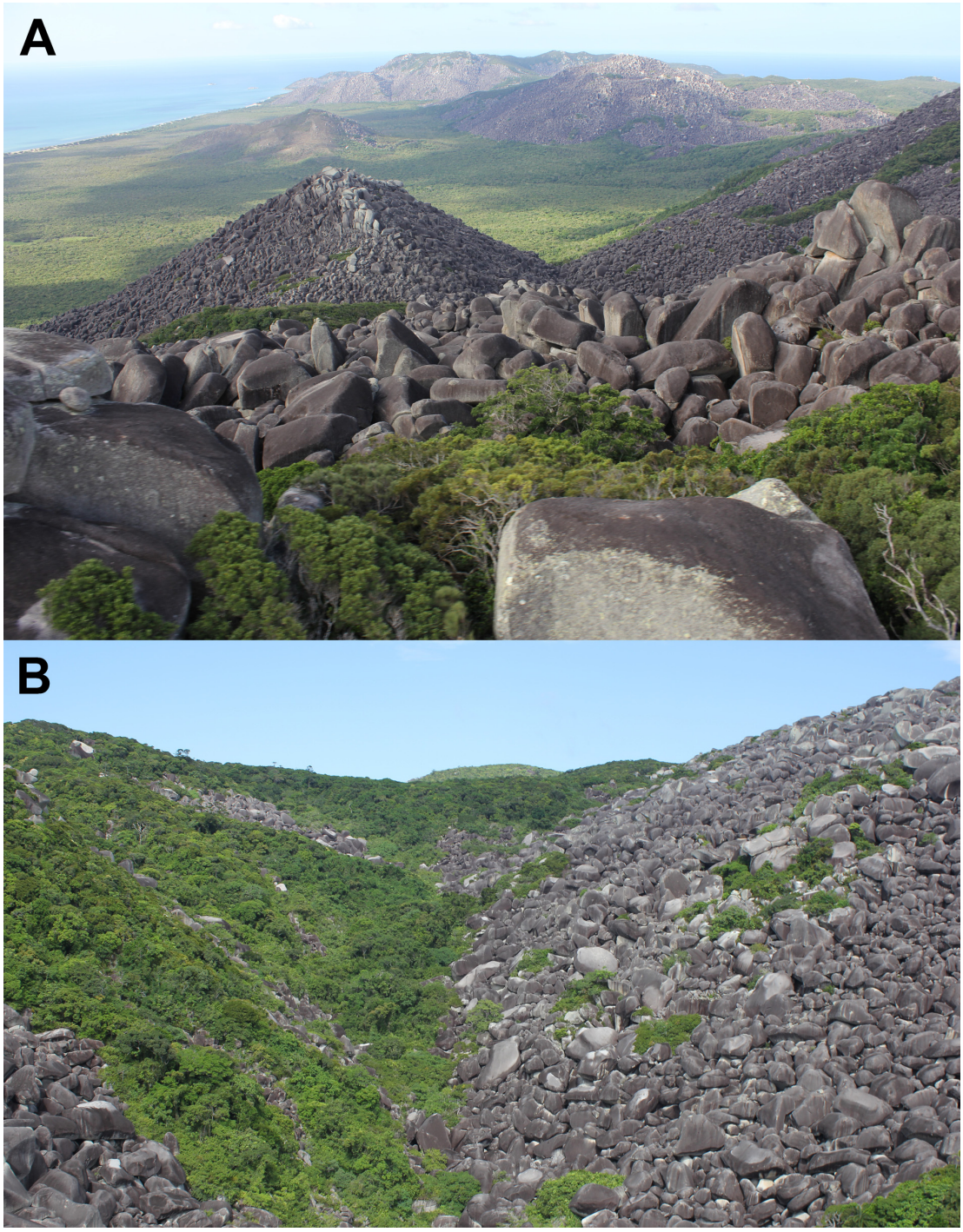


**FIGURE 6.** Habitat of *C. petrophilus* **sp. nov.**, Melville Range. The Melville Range is largely composed of massive boulder-piles devoid of vegetation (6A). Rainforest occurs on some slopes and gullies (6B) and more extensively on the elevated plateau (the edge of which can be seen on the ridgeline here).

*Cophixalus petrophilus* **sp. nov.** is the fifth boulder *Cophixalus* described, and has similar morphological adaptations to boulder-pile habitat (i.e., large size, long limbs, large finger discs) (Hoskin *et al.*, in prep.). The boulder *Cophixalus* described prior to this species are all distinctly large (average SVLs: *C. saxatilis*, male 33 mm, female 42 mm; *C. zweifeli*, male 37 mm, female 45 mm; *C. kulakula*, 43 male mm, female 44 mm; *C. pakayakulangun*, male 44 mm, female 51 mm) compared to all rainforest species (average SVLs range from 13–23 mm). *Cophixalus petrophilus* **sp. nov.** (average SVLs: male 28 mm, female 32 mm) is larger than all rainforest species but the smallest of the boulder species. Another interesting difference is that *C. petrophilus* **sp. nov.** has distinctly large eyes compared to the other boulder species. *Cophixalus petrophilus* **sp. nov.** was only found in exposed boulder-pile and not in adjacent vegetated areas, despite considerable searching. Being restricted to the exposed boulder-fields, *C. petrophilus* **sp. nov.** likely spends much time through the year in the dimly lit depths of the boulder-field, and this may explain its relatively large eyes. The blotched colouration of males and females is highly camouflaged against the granite rocks, suggesting they spend the majority of their time on this surface. *Cophixalus petrophilus* **sp. nov.** is most similar in appearance to male *C. saxatilis* of Black Mountain (smaller size, blotched colouration) (Table 1; Fig. 2). Male *C. saxatilis* also live primarily in exposed boulder-field, whereas female *C. saxatilis* are more commonly encountered around the vegetated margins of the boulder-field.

Cape Melville is the only boulder-field with two boulder *Cophixalus*, *C. petrophilus* **sp. nov.** and *C. zweifeli*, and observations in the field suggest habitat partitioning. While *C. petrophilus* **sp. nov.** was only found in exposed boulder-pile and not in adjacent vegetated areas, the opposite was true for *Cophixalus zweifeli*, which was found primarily in boulder-field amongst and adjacent to rainforest. In the evening, female *C. zweifeli* were observed emerging from deep boulder-pile adjacent to areas with rainforest cover, and at night females were found foraging on rocks and low vegetation in rainforest growing amongst or immediately adjacent to the boulder-field. Only two male *C. zweifeli* were found and these were both calling from boulders on a soil slope adjacent to the boulder-field. Another two males were heard calling from the same area. No males were heard calling from the exposed boulder-field. Given that *Cophixalus* males call from near their nest site (Zweifel 1985; Hoskin 2004; Felton *et al.* 2006; Hoskin & Aland 2011), this suggests that eggs are laid in areas where boulders are set amongst soil under rainforest; as has been observed in the boulder species *Cophixalus kulakula* (Hoskin & Aland 2011). In contrast, the only *C. petrophilus* **sp. nov.** heard calling was doing so from a rock crevice in the exposed boulder-field, and it is highly likely that eggs would be laid in this setting; as seen in *C. saxatilis* (Hoskin 2004). It would therefore appear that habitat partitioning at Cape Melville can be broadly summarized as *C. petrophilus* **sp. nov.** in the exposed boulder-fields and *C. zweifeli* in boulder habitats amongst and adjacent to rainforest. Habitat partitioning is further supported by the fact that *C. petrophilus* **sp. nov.** and *C. zweifeli* differ in most aspects of morphology (Table 1; Comparison section).

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**APPENDIX.** Additional material examined.

***Cophixalus saxatilis:*** QMJ27150, male, Black Mtn, Black Trevethan Range, 20 km south of Cooktown (15°41' S, 145°14' E); QMJ48798, female, Black Gap, Black Mountain NP (15°39'20" S, 145°13'12" E); QMJ48799, female, Black Gap, Black Mountain NP (15°39'20" S, 145°13'12" E); QMJ48800, male, Black Gap, Black Mountain NP (15°39'20" S, 145°13'12" E); QMJ57834, female, Black Gap, Black Mountain NP (15°40'20" S, 145°16'12" E); QMJ61099, male, Black Mtn, via Cooktown (15°42' S, 145°15' E); QMJ68248, female, Black Mountain NP (15°39'30" S, 145°13'30" E); QMJ68249, female, Black Mountain NP (15°39'30" S, 145°13'30" E); QMJ92595, male, Black Gap, Black Mountain (15°39'02" S, 145°13'15" E).
***Cophixalus zweifeli:*** SAMA (South Australian Museum) R51080, female, Cape Melville NP (14°15'25" S, 144°27'40" E); QMJ64888, female, Cape Melville NP (14°15'25" S, 144°27'40" E); QMJ64889, female, Cape Melville NP (14°15'30" S, 144°27'40" E); QMJ92555, male, Cape Melville NP (14°18'55" S, 144°29'50" E); QMJ92557, male, Cape Melville NP (14°18'55" S, 144°29'56" E); QMJ92558, female, Cape Melville NP (14°18'55" S, 144°29'56" E); QMJ92559, male, Cape Melville NP (14°18'55" S, 144°29'50" E).