

Two new frog species from the Foja Mountains in north-western New Guinea (Amphibia, Anura, Microhylidae)

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Accepted January 18, 2018.

Published online at www.senckenberg.de/vertebrate-zoology on May 28, 2018.

Editor in charge: Raffael Ernst

Abstract

Two new microhylid frogs in the genera *Choerophryne* and *Oreophryne* are described from the Foja Mountains in Papua Province of Indonesia. Both are small species (males 15.9–18.5 mm snout-urostyle length [SUL] and 21.3–22.9 mm SUL respectively) that call from elevated positions on foliage in primary lower montane rainforest. The new *Choerophryne* species can be distinguished from all congeners by, among other characters, a unique advertisement call consisting of an unpulsed (or very finely pulsed) peeping note lasting 0.29–0.37 seconds. The new *Oreophryne* species belongs to a group that has a cartilaginous connection between the procoracoid and scapula and rattling advertisement calls. Its advertisement call is a loud rattle lasting 1.2–1.5 s with a note repetition rate of 11.3–11.7 notes per second.

Kurzfassung

Es werden zwei neue Engmaulfrösche der Gattungen *Choerophryne* und *Oreophryne* aus den Foja-Bergen in der Papua Provinz von Indonesien beschrieben. Es handelt sich in beiden Fällen um kleine Arten (Männchen 15,9–18,5 mm Kopf-Rumpf-Länge bzw. 21,3–22,9 mm Länge), die von erhöhten Sitzwarten auf Blättern von Bäumen und Büschen im primären Bergregenwald rufen. Die neue *Choerophryne*-Art kann von allen anderen Arten der Gattung durch ihren einzigartigen Paarungsruf, der aus einem ungepulsten oder sehr fein gepulsten Piepen von 0,29–0,37 Sekunden Dauer besteht, unterschieden werden. Die neue *Oreophryne*-Art gehört zu einer Gruppe mit knorpeliger Verbindung zwischen Procoracoid und Scapula und scheppernden Paarungsrufen. Ihre Rufe bestehen aus einem 1,2–1,5 Sekunden dauernden lauten Scheppern mit einer Wiederholungsrate von 11,3–11,7 Silben pro Sekunde.

Key words

New Guinea, Papua Province, Indonesia, taxonomy, new frogs.

Introduction

The Foja Mountains are an isolated mountain range located in northern Papua Province, Indonesian New Guinea. The biodiversity of the the Fojas remained poorly documented (Diamond 1982) until November 2005 when a Rapid Assessment Program biological survey by Conservation International and the Indonesian Institute of Sciences (LIPI) revealed numerous undescribed taxa there, including a new species of bird (Beehler *et al.* 2007). Amongst the new taxa discovered during that survey and

the preliminary reconnaissance conducted during planning activities for it, were a number of frog species, three of which (*Litoria gasconi*, *Callulops fojaensis* and *Pseudocallulops foja*) have since been described (RICHARDS *et al.* 2009; OLIVER *et al.* 2012; GÜNTHER *et al.* 2016). Here we describe and illustrate two additional new species of frogs collected during the 2005 Foja Mountains expedition, each of which is currently known only from this isolated mountain range.

Material and methods

Most frogs were collected at night after they were located by their advertisement calls. Representative specimens were photographed in life, and specimens were euthanised in an aqueous chlorobutanol solution and subsequently fixed in 5 % formalin. Liver samples were taken from some specimens before fixation, and stored in 95 % ethanol to enable later DNA sequencing. All specimens were transferred to 70 % ethanol within two days of fixation. The following measurements were taken with a digital calliper (> 10 mm) or with a binocular dissecting microscope fitted with an ocular micrometer (< 10 mm) to the nearest 0.1 mm from preserved specimens only:

- SUL** snout-urostyle length from tip of snout to posterior tip of urostyle bone; SUL is generally slightly shorter than snout-vent length (SVL). As the measurement error is higher in the latter, we prefer to use the former. Both measurements are sufficiently similar (unpublished data) that, where relevant, we compare our SUL measurements with SVLs presented for members of the genus in some papers;
- TL** tibia length: external distance between knee and tibio-tarsal articulation;
- TaL** length of tarsus: external distance between tibio-tarsal and tarsal-metatarsal joints held at right angles;
- T4L** length of 4th toe: from tip of toe to proximal end of inner metatarsal tubercle;
- T4D** transversal diameter of disc of 4th toe;
- T1D** transversal diameter of disc of first toe;
- F3L** length of 3rd finger;
- F3D** transversal diameter of disc of 3rd finger;
- F1D** transversal diameter of disc of first finger;
- HL** head length: from tip of snout to posterior margin of tympanum;
- HW** head width: taken in the region of the tympana;
- SL** snout length, from an imaginary line connecting the centres of the eyes to tip of the snout;
- EST** distance from anterior corner of orbital opening to tip of snout;
- END** distance from anterior corner of orbital opening to centre of naris;
- IND** internarial distance between centres of nares;
- ED** eye diameter: from anterior to posterior corner of orbital opening;
- TyD** horizontal diameter of tympanum.

Advertisement calls were recorded under natural conditions with a Sony TCM 5000EV tape recorder and a Sennheiser ME66 Microphone with K6 power module, and analysed with Avisoft-SAS Lab Pro software. Air temperatures adjacent to calling males were recorded using a rapid-reading digital thermometer. We measured temporal and spectral parameters of calls using the definitions of COCROFT & RYAN (1995) and these are presented as “mean ± SD (range)”.

Material of species of *Choerophryne* KAMPEN, 1914 examined for this study, including species previously included in *Albericus* BURTON & ZWEIFEL, 1995, is listed in GÜNTHER & RICHARDS (2011) and in IANELLA *et al.* (2014, 2015). Additional comparisons with other “short-nosed” *Choerophryne* relied on the papers by KRAUS & ALLISON (2005a, 2005b, 2009) and KRAUS (2010). Comparative material from the genus *Oreophryne* BOETTGER, 1895 is listed in GÜNTHER *et al.* (2012) and GÜNTHER (2015). Moreover, we referred to most of the original species descriptions and recompiled treatises to make our comparisons.

Abbreviations of collections:

- AMNH** American Museum of Natural History, New York, USA;
- MZB** Museum Zoologicum Bogoriense, Cibinong, Java, Indonesia;
- ZMA** Zoologisch Museum, Universiteit van Amsterdam; now Naturalis Biodiversity Center, Leiden, Netherlands.

Choerophryne pipiens sp. nov.

Holotype. MZB Amph.11976 (Field number: FN SJR 9834), adult male, “Bog Camp”, Foja Mountains, Papua Province, Indonesia (2°34.36’S, 138°43.03’E, ~1600 m above sea level [a.s.l.]), collected by S. RICHARDS and B. TJATURADI on 22 November 2005.

Paratypes. MZB Amph.11971 (FN SJR 9848), MZB Amph.11975 (FN SJR 9845), MZB Amph.11979 (FN SJR 9843), MZB Amph.11986 (FN SJR 9847); MZB Amph.12003 (FN SJR 9917), MZB Amph.12044–45 (FN SJR 9844 and 9849), collection data same as for holotype except MZB Amph.12003 collected on 1 December 2005 and all remaining paratypes collected 23 November 2005.

Diagnosis. Included within *Choerophryne* on the basis of loss of procoracoids, clavicles, and omosternum; fusion of urostyle and sacrum; and having fifth toe longer than third. A species of the genus *Choerophryne* lacking an elongated snout. Snout-urostyle length in males (n=7) 15.9–18.5 mm (mean 17.2±0.92 mm), SUL of the single female 18.4 mm. No webs between fingers or toes; fifth toe longer than third; finger discs wider than toe discs (ratio T4D/F3D 0.62–0.90); shanks short (TL/SUL 0.38–0.43). Eyes medium sized (ED/SUL 0.112–0.127), eye-naris distance equal to or greater than internarial distance (END/IND 1.00–1.38); snout tip acuminate. In preservative dorsum smooth with a few tubercles on flanks and posterior to eyes, in life dorsally with many tubercles. Region around ear off-white; an indistinct off-white stripe from posterior edge of eye along flanks to inguinal region; mid-dorsum varies from off-white or light brown to dark brown; discs of fingers and toes predominantly light yellowish and only inconspicuously speckled with darker pigment. Most diagnostic is the advertisement call, an unpulsed (or very finely

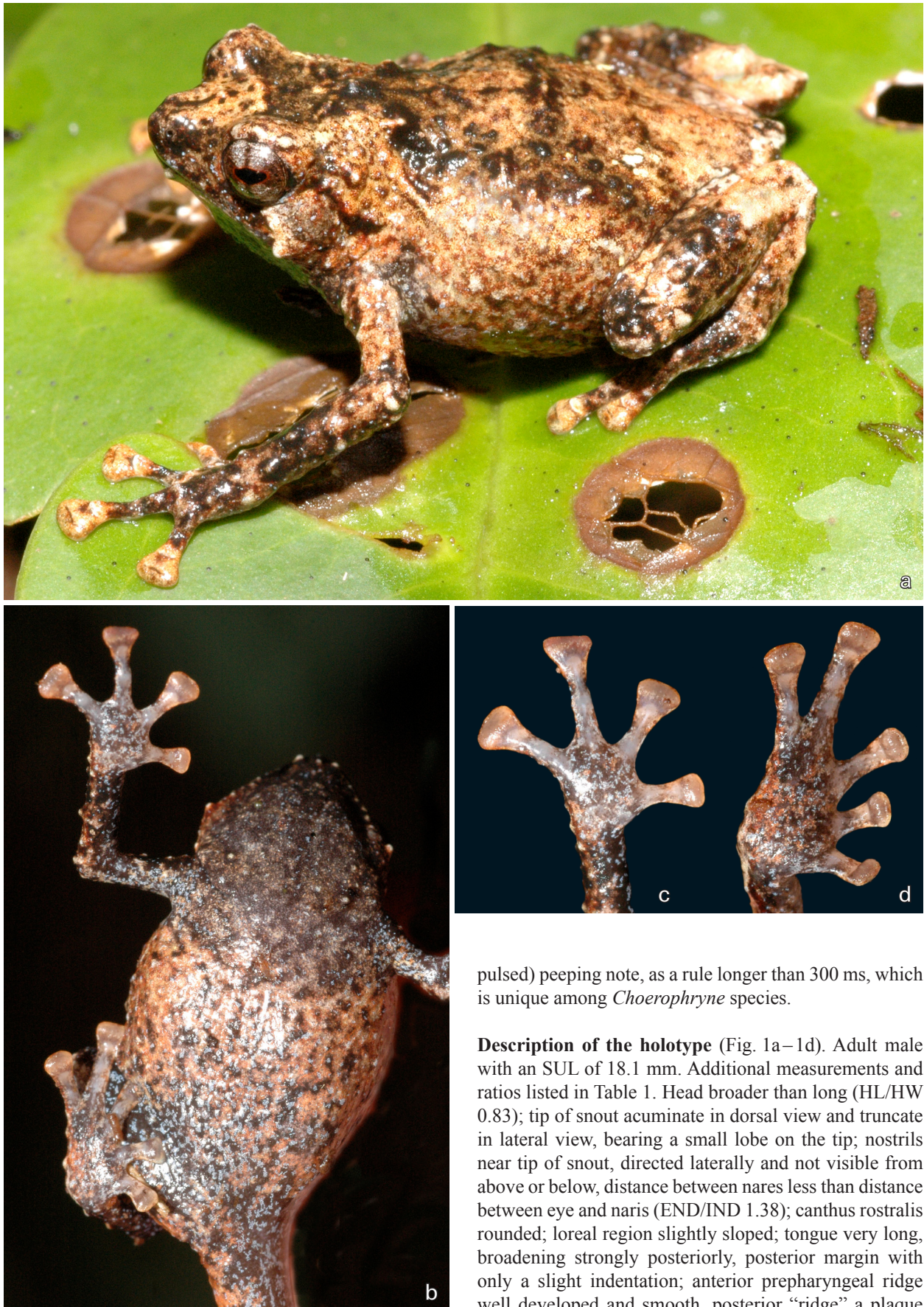


Fig. 1a–d. Holotype of *Choerophryne pipiens* sp. nov. in life, (a) dorsolateral view, (b) ventral view, (c) palmar view of right hand, (d) plantar view of right foot.

pulsed) peeping note, as a rule longer than 300 ms, which is unique among *Choerophryne* species.

Description of the holotype (Fig. 1a–1d). Adult male with an SUL of 18.1 mm. Additional measurements and ratios listed in Table 1. Head broader than long (HL/HW 0.83); tip of snout acuminate in dorsal view and truncate in lateral view, bearing a small lobe on the tip; nostrils near tip of snout, directed laterally and not visible from above or below, distance between nares less than distance between eye and naris (END/IND 1.38); canthus rostralis rounded; loreal region slightly sloped; tongue very long, broadening strongly posteriorly, posterior margin with only a slight indentation; anterior prepharyngeal ridge well developed and smooth, posterior “ridge” a plaque with many longitudinal furrows; moderately long vocal slits on both sides of mouth floor near corner of mouth; tympanum medium-sized (about one-half of eye diam-



Fig. 2. Preserved types of *Choerophryne pipiens* sp. nov. in dorsal view.

eter), no supratympanic fold in preservative. Fingers unwebbed with broad, grooved terminal discs, their relative lengths $3 > 4 > 2 > 1$ (Fig. 1c); disc of third finger more than twice width of penultimate phalanx, no prominent metacarpal or subarticular tubercles. Shanks rather short (TL/SUL 0.41). All toes with wide, grooved terminal discs, those of fourth toe narrower than those of third finger; no webs between toes, no metatarsal tubercles, no prominent subarticular tubercles; relative lengths of toes $4 > 5 > 3 > 2 > 1$ (Fig. 1d). All dorsal and ventral surfaces in life densely covered with conspicuous smaller and larger tubercles, in preservative many tubercles disappeared, others became poorly visible; only one tubercle in the shoulder region and another one posterior to the eye are more expressed in preservative than in life.

Colour in life. Ground colour of dorsal and lateral surfaces light yellowish-brown, with dark brown flecks on sides of head, on forelegs and hind legs, as an indistinct “X” in the neck region and as a crossband mid-dorsally; tips of fingers and toes predominantly yellowish, dorsal and ventral part of iris silvery, its anterior and posterior part red-orange (Fig. 1a). Ground colour of abdomen reddish covered by a mixture of irregular light grey and dark grey-brown spots; throat, chest and ventral surfaces of legs covered by a mixture of different tones of grey. Ventral surfaces of finger tips and toe tips yellowish. A prominent white capped tubercle on anterior and posterior lower jaw (Fig. 1b).

Colour in preservative. Ground colour of dorsal and lateral surfaces light grey-brownish with irregularly shaped dark brown and blackish flecks and spots mainly on head

and dorsum. Conspicuous are an indistinct “X”-shaped fleck in the shoulder-nape region, a crossband on mid-dorsum and in the middle of shanks and forearms. Also conspicuous are whitish heels and whitish finger and toe tips. Abdomen light grey with irregular brown spots partly connected with each other, these brown spots becoming very dense anteriorly covering ground colour on throat and most of ground colour of ventral surfaces of legs. Conspicuous are unpigmented ventral surfaces of fingers and toes and sparsely pigmented palm and sole.

Morphological variation of the types in preservative.

Measurements and body ratios of the type specimens are presented in Table 1. SUL of seven adult males ranges from 15.9 to 18.5 mm (mean 17.2 ± 0.92 mm); one adult female has an SUL of 18.4 mm. Their dorsal surfaces are shown in Fig. 2. Most specimens have an acute snout tip while in several the snout tip is narrowly rounded, and most have a broad dark brown longitudinal mid-dorsal stripe from eyes to posterior back; its lateral margins are as a rule darker than its centre and it forms an X-like figure between shoulders and eyes. This dark stripe is dorsolaterally confined by an irregular yellowish longitudinal stripe. One specimen (MZB Amph.12003) has dark flanks and another (MZB Amph.11975) has a completely whitish dorsum, except a brown “X” between shoulders and eyes (Fig. 3). A whitish postocular fleck that includes the tympanum is present in all specimens. Four specimens exhibit a fairly distinct whitish lumbar spot, in three specimens this spot is rather indistinct, in one it is not present and in another specimen (MZB Amph. 11971) it is interspersed with tiny white spots. Discs of fingers and toes in all specimens are conspicuously pale. As in



Fig. 3. Unusual coloured specimen of *Choerophryne pipiens* sp. nov. (MZB Amph.11975) with snout and most of the dorsum whitish in life.

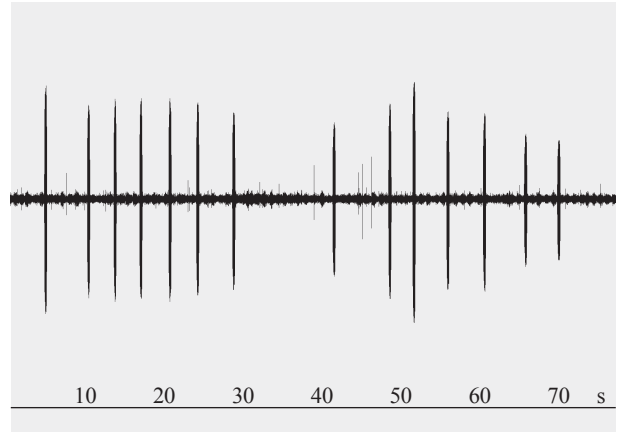


Fig. 4. Long-term oscillogram of a call series of 14 calls, from *Choerophryne pipiens* sp. nov.

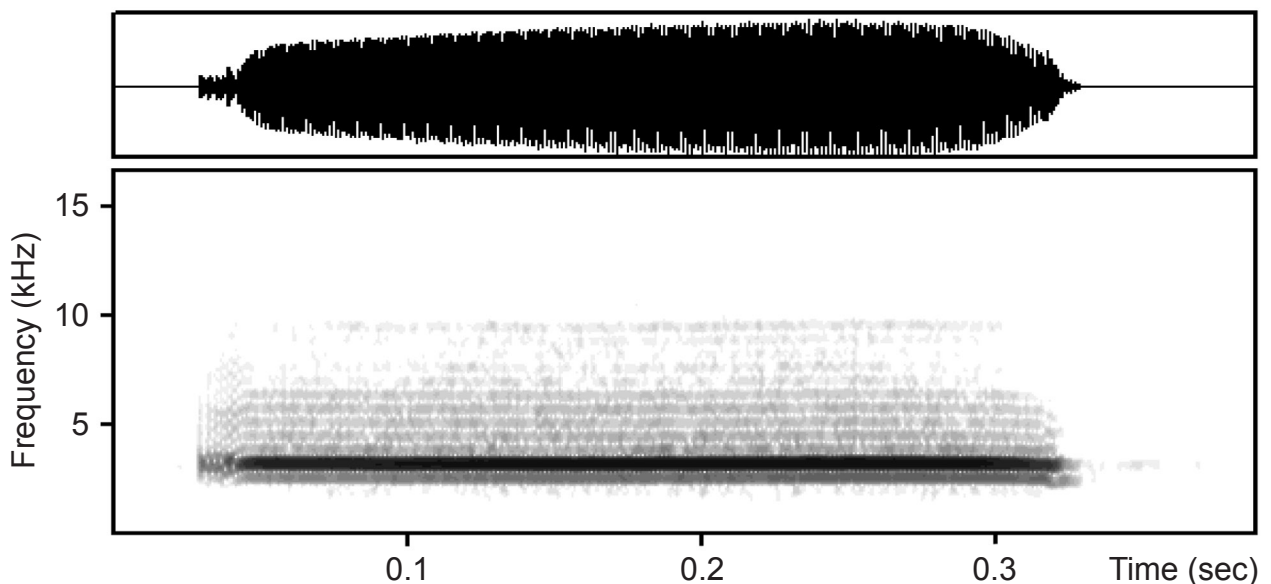
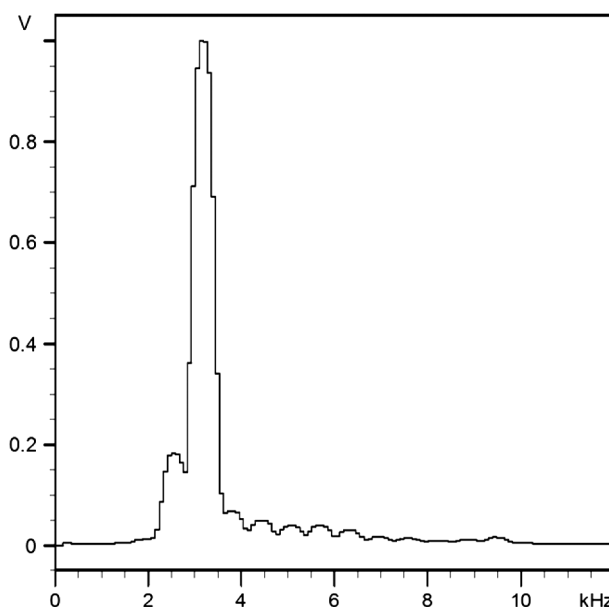


Fig. 5. Oscillogram (top) and spectrogram (lower) of an advertisement call from *Choerophryne pipiens* sp. nov. consisting of one finely pulsed note.



many other short nosed members of the genus *Choerophryne*, the region around the tibio-tarsal articulation or at least on distal shanks is striking yellowish-white. Ventral surfaces from completely dark reddish-brown (MZB Amph.12003), through more or less mottled, to uniform yellowish with only a few brownish spots on chin and ventral legs.

Distribution and ecological notes. This species was found perched on leaves in extremely wet, mossy lower-montane forest where males called at heights between ~1.0 and 2.5 m above the ground on both wet and dry nights. An adult female (MZB Amph.11971) contained just four apparently mature eggs of about 2 mm diameter, two in each ovary. This species is known only from

Fig. 6. Amplitude spectrum of an advertisement call from *Choerophryne pipiens* sp. nov.

Table 1. Body measurements and body ratios of the type series of *Choerophryne pipiens* sp. nov. MZB Amph.11976 is the holotype, MZB Amph.11971 is an adult female, all others are adult males. All measurements are in mm; Reg.No.= registration number, SD = standard deviation. All other abbreviations are explained in “Materials and methods”.

Reg.No.	MZB 11971	MZB 11975	MZB 11976	MZB 11979	MZB 11986	MZB 12003	MZB 12044	MZB 12045	Mean±SD
SUL	18.4	16.5	18.1	15.9	17.6	16.8	18.5	17.0	
TL	7.2	7.0	7.5	6.8	7.2	7.1	7.0	7.1	
TaL	5.1	5.0	5.2	4.5	5.1	4.8	5.0	4.9	
T4L	6.1	5.7	6.2	5.6	6.0	5.7	5.9	6.0	
T4D	1.2	0.9	0.9	0.7	1.0	1.0	1.2	0.8	
T1D	0.9	0.8	0.9	0.8	0.7	1.0	0.8	1.0	
F3D	1.4	0.9	1.2	1.1	1.3	1.2	1.4	1.3	
F1D	0.9	0.7	0.9	0.6	0.7	0.7	0.8	0.8	
HL	5.8	5.5	5.7	4.9	5.6	5.7	6.1	5.3	
HW	6.9	6.6	6.9	6.4	6.5	6.5	7.0	6.2	
END	1.7	1.6	1.8	1.4	1.5	1.5	1.5	1.6	
IND	1.3	1.3	1.3	1.2	1.5	1.4	1.5	1.4	
SL	3.1	2.6	3.2	2.7	2.6	2.6	2.9	2.7	
EST	2.4	2.3	2.4	2.0	1.9	2.0	2.2	2.1	
ED	2.3	2.1	2.2	2.0	2.1	2.0	2.1	1.9	
TyD	1.3	1.1	1.2	1.0	1.1	1.1	1.2	1.0	
TL/SUL	0.39	0.42	0.41	0.43	0.41	0.42	0.38	0.42	0.41±0.017
TaL/SUL	0.28	0.30	0.29	0.28	0.29	0.29	0.27	0.29	0.29±0.009
T4L/SUL	0.33	0.35	0.34	0.35	0.34	0.34	0.32	0.35	0.34±0.01
T4D/SUL	0.065	0.055	0.050	0.044	0.057	0.059	0.065	0.047	0.055±0.008
F3D/SUL	0.076	0.061	0.066	0.069	0.074	0.071	0.076	0.076	0.071±0.006
T4D/F3D	0.86	0.90	0.75	0.64	0.77	0.83	0.86	0.62	0.78±0.10
T1D/F1D	1.00	1.14	1.00	1.33	1.00	1.43	1.00	1.25	1.14±0.17
HL/SUL	0.32	0.33	0.31	0.31	0.32	0.34	0.3	0.31	0.32±0.011
HW/SUL	0.38	0.40	0.38	0.40	0.37	0.39	0.38	0.36	0.38±0.014
HL/HW	0.84	0.83	0.83	0.77	0.86	0.88	0.87	0.85	0.84±0.034
END/SUL	0.092	0.097	0.099	0.088	0.085	0.089	0.081	0.094	0.091±0.006
IND/SUL	0.071	0.079	0.072	0.075	0.085	0.083	0.081	0.082	0.079±0.005
END/IND	1.31	1.23	1.38	1.17	1.00	1.07	1.00	1.14	1.16±0.14
ED/SUL	0.125	0.127	0.122	0.126	0.119	0.119	0.114	0.112	0.121±0.006
TyD/SUL	0.071	0.067	0.066	0.063	0.063	0.065	0.065	0.059	0.065±0.003
TyD/ED	0.57	0.52	0.55	0.40	0.52	0.55	0.57	0.53	0.53±0.055
SL/SUL	0.168	0.158	0.177	0.170	0.148	0.155	0.157	0.159	0.162±0.009
EST/SUL	0.130	0.139	0.133	0.126	0.108	0.119	0.119	0.124	0.125±0.009

the type locality near the summit of the Foja Mountains in Papua Province, Indonesian New Guinea (Figs. 9 and 10).

Vocalisation. The advertisement call of the new species, recorded at an air temperature of 17°C, consists of a long “peeping” note that is uttered singly or in shorter or longer series and time between single calls or between call series varies considerably (Fig. 4). We recorded calls from three males, two of them bearing field numbers SJR 9835 and 9860 and deposited in the Museum Zoologicum Bogoriense but not available for inclusion in the type series. One male produced three calls at long intervals, the second produced 22 calls at variable intervals, and the third produced 19 calls also at variable intervals. We arbitrarily consider calls to be part of the same ‘series’ if intercall intervals are < 7 s. Length of calls (in ms) from the first male (n=3) was 296±10.1 (285–305), and the two intervals between calls were 37 and 20 s.

Length of calls produced by the second male (n=22) was 357±11.5 (333–374) and of 16 intercall intervals shorter than 7 s was 4.4±1.5 (2.9–6.9) s, while intervals between call series (separated by intervals > 7 s) were 9 s, 12 s, 13 s, 20 s and 38 s. Mean length of calls produced by the third male (n=19) was 303±7.4 (290–317) ms; length of 13 intercall intervals shorter than 7 s was 4.3±0.6 (3.0–5.2) s; intervals greater than 7 s were 15 s, 36 s, 37 s, 38 s and 68 s. Oscillograms of the calls have a spindle-like appearance (Fig. 5, top). In optimal recordings about 600 pulses/s are discernible. Because pulses in many recordings are so fine that they are not discernible, calls could also be considered unpulsed. A finely pulsed (or unpulsed) structure predominates during the greatest part of the call; only at its beginning and its end are some pulses longer and therefore better discernible. Calls are finely tuned with many harmonic bands but are not frequency modulated (Fig. 5, lower). Lowermost visible harmonic band is at 2.6 kHz, dominant frequency centres

around 3.25 kHz (Fig. 6), and there follow five better expressed and five less expressed harmonics. The number of harmonics may vary from specimen to specimen.

Etymology. The specific epithet *pipiens* is a Latin present participle of the verb “pipiare” and means whistling or peeping. It refers to the conspicuous peeping calls of the males.

Comparisons with other species. As MENZIES (1999) pointed out in his comprehensive study on the (then) genus *Albericus*, many species are difficult to distinguish morphologically but are clearly distinguished by their advertisement calls. The following species have peeping, whistling or squeaking calls and shall be explicitly delimited from the new species. Species with clicking calls are not considered further.

Choerophryne darlingtoni (LOVERIDGE, 1948) is larger than *Ch. pipiens* sp. nov. (18–26 mm vs. 15.9–18.5 mm SVL) and its calls last 160–320 ms at 15–18°C and have 180–260 pulses/s (MENZIES, 1999) vs. about 600 pulses/s in the new species. *Choerophryne exclamitans* (KRAUS & ALLISON, 2005) has a hidden tympanum in males, vs. visible in *Ch. pipiens* sp. nov. and it utters 3–48 peeping notes per call, with an average note repetition rate of 4.7 notes/s and note duration of about 20 ms (KRAUS & ALLISON 2005b). *Choerophryne siegfriedi* (MENZIES, 1999) is larger than *Ch. pipiens* sp. nov. (18.2–21.3 mm vs. 15.9–18.5 mm) and its call notes last 160–210 ms at 16°C, while those of *Ch. pipiens* sp. nov. last 285–374 ms. *Choerophryne swanhildae* (MENZIES, 1999) is smaller (13.6–15.4 mm), has longer shanks (TL/SVL 0.43–0.48 vs. 0.38–0.43), narrower finger discs (F3D/SVL 0.055–0.061 vs. 0.061–0.076 in *Ch. pipiens* sp. nov.) and advertisement call notes less than 100 ms long at 15–16.5°C. *Choerophryne tubercula* is smaller than the new species (15.0–15.1 mm vs. 15.9–18.5 mm), shows more and stronger tubercles on dorsal and lateral surfaces and its call resembles a harsh “ank” with about 160 pulses/s (RICHARDS *et al.* 1992). The call of *Ch. variegata* is unknown but it has longer hind legs than *Ch. pipiens* sp. nov. (TL/SVL 0.47 vs. 0.38–0.43), shorter head (HL/SVL 0.27 vs. 0.31–0.34) and larger eyes (ED/SVL 0.133 vs. 0.112–0.127).

The new species is morphologically and bioacoustically most similar to *Ch. brunhildae* (MENZIES, 1999) and *Ch. murrita* (KRAUS & ALLISON, 2009). Our analyses of 22 calls from the holotype and two paratypes of *Ch. brunhildae* recorded at 18.8–23°C revealed a call length of 541 ± 49.6 (404–615) ms and a pulse repetition rate of 224 ± 32.6 (175–274) pulses/s; these values differ significantly from those of the new species. *Ch. brunhildae* utters squeaking calls, not peeping ones like *Ch. pipiens* sp. nov. The calls of *Ch. brunhildae* are clearly pulsed and harmonics appear in spectrograms as short vertical stripes and not as long horizontal stripes as in *Ch. pipiens*. The course of a note is also characterized by a strong rise and a strong descent of the amplitude in *Ch. brunhildae* vs. a slow rise and slow descent in *Ch. pipiens* sp. nov. *Choerophryne brunhildae*

has a smaller tympanum than *Ch. pipiens* sp. nov. (TyD/SVL 0.051–0.057 vs. 0.059–0.071), all other body ratios are more or less overlapping.

There is broad overlap with *Ch. murrita* in most morphological traits, but snout shape and some bioacoustic traits clearly differ. When seen from above, the snout of *Ch. murrita* is bluntly rounded, while the snout of most *Ch. pipiens* sp. nov. is distinctly acute (Fig. 2). Call notes are finely pulsed in *Ch. pipiens* sp. nov. but unpulsed in *Ch. murrita* (KRAUS & ALLISON 2009). Duration of 56 notes from two *Ch. murrita* varies from 112 to 213 ms vs. 290–374 ms in 44 notes from three *Ch. pipiens* sp. nov.

Oreophryne albitympanum sp. nov.

Holotype. MZB Amph.11996 (Field number: FN SJR 9833), adult male, “Bog Camp”, Foja Mountains, Papua Province, Indonesia (2°34.36’S, 138°43.03’E, ~1600 m a.s.l.), collected by S. RICHARDS and B. TJATURADI on 22 November 2005.

Paratypes. MZB Amph.11985 (FN SJR 9846), MZB Amph. 11989–90 (FN SJR 9853 and 9920), MZB 11990 (FN SJR 9920), MZB Amph.11991 (FN SJR 9861), MZB Amph.11993 (FN SJR 9863), MZB Amph.12006 (FN SJR 9921), MZB Amph.12012–13 (FN SJR 9857 and 9873), collection data same as for holotype except MZB Amph.11985 and Amph.11989 collected on 23 November 2005, MZB Amph.11991, Amph.11993 and Amph.12012 collected on 24 November 2005, MZB Amph.12013 collected on 25 November 2005 and MZB Amph.11990 and Amph.12006 collected on 2 December 2005.

Diagnosis. A species of the genus *Oreophryne* based on the presence of eleutherognathine maxillae, procoracoids and clavicles that do not extend to the scapulae. Snout-urostyle length in males (n=7) of 21.3–22.9 mm and in females (n=2) 24.9–26.1 mm. Cartilaginous connection between procoracoid and scapula; no webs between fingers, basal webs between toes 3 and 4 as well as between 4 and 5; fifth toe longer than third; finger discs clearly wider than toe discs (ratio T4D/F3D 0.64–0.91); further body ratios are TL/SUL 0.40–0.46, HL/HW 0.82–0.90, ED/SUL 0.129–0.147, TyD/ED 0.32–0.44, and END/IND 0.78–0.95. In preservative, a conspicuous whitish postocular fleck including most of the tympanum; most specimens with a whitish mid-dorsal line. Dorsal surfaces in preservative yellowish with irregular lighter and darker brown mottling, ventral surfaces also yellowish with dense or scarce brown dotting. Advertisement call a loud rattle of 1.2–1.5 s with a note repetition rate of 11.3–11.7 notes per second (s). Note length 32–45 milliseconds (ms) and internote length 37–69 ms. Dominant frequency at 4.2 kHz.

Description of the holotype (Fig. 7). Adult male with an SUL of 21.8 mm. Additional measurements and ratios are listed in Table 2. Head broader than long (HL/HW 0.88), tip of snout rounded in dorsal view, truncate and hardly protruding in lateral view; nostrils directed laterally and visible from above, distance between nares larger than distance between eye and naris (END/IND 0.86); canthus rostralis clearly defined and slightly con-

cave in dorsal view; loreal region slightly skewed and slightly concave; pupil horizontally oval; tongue long, wide and with posterior indentation, only its most anterior region adhered to mouth floor; middle part of anterior prepharyngeal ridge smooth and well expressed, its lateral parts scarcely visible; posterior prepharyngeal ridge clearly denticulate; long vocal slits on both sides of mouth floor near corner of the mouth; tympanum small (TyD/ED 0.34), its annulus partly covered by skin; short and nearly horizontally directed supratympanic fold. Forelegs and hind legs moderately long; fingers unwebbed and with broad and grooved terminal discs (disc of third finger 2.5 times width of penultimate phalanx), their relative lengths $3 > 2 \sim 4 > 1$ (Fig. 7c); no prominent metacarpal or subarticular tubercles. All toes with wide and grooved terminal discs, discs of toes less than twice as wide as penultimate phalanges; basal webs between toes 3, 4 and 5, no webs between toes 1, 2 and 3; subarticular tubercles on toes scarcely developed, inner metatarsal tubercle elongate and better developed; relative lengths of toes $4 > 5 > 3 > 2 > 1$ (Fig. 7d). Few distinct tubercles sparsely scattered on all dorsal surfaces of body and extremities; a conspicuous glandular fold starting as a prominent supratympanic tubercle and extending, after an emargination on the anterior dorsum, to a whitish lumbar spot; all lower surfaces smooth.

Colour in life. Ground colour of dorsal and lateral surfaces lighter or darker yellowish with reddish dots and streaks and irregular brown spots (compare Fig. 7a). Iris silvery with dark grey-brown venation and orange inner margin; mid-dorsal line off-white and reaching from snout tip to end of urostyle; ventral surfaces off-white with light-yellowish flecks and numerous brownish dots (Fig. 7b), ventral sides of hands and feet also with dense brown punctuations and light flecks (Fig. 7c and 7d).

Colour in preservative. Ground colour of flanks off-white, of dorsum yellowish and of dorsal limbs light brown; the dorsolateral glandular ridges are bordered inferiorly by irregularly shaped brown spots and superiorly by a nearly unspotted yellowish area; due to the emarginated course of these ridges, this yellowish area shows the form of an hourglass; this hourglass mark is confined anteriorly by a triangular brown spot; an interocular light yellowish bar is confined posteriorly by a more solid brown stripe and anteriorly by a more diffuse brown stripe; both stripes as well as the triangle spot in the nape region are medially interrupted by the yellowish mid-dorsal line; dorsal hind legs are almost unspotted, dorsum of forearm exhibits a conspicuous brown spot distally. Conspicuous are also a crescent-shaped dark brown supratympanic spot, whitish ear region, spotted head sides and whitish lumbar spots. Ventral surfaces uniformly straw yellow to the naked eye but with numerous dark brown dots when enlarged.

Morphological variation of the types in preservative. For body measurements and ratios of all types see Ta-

ble 2. Snout-urostyle length in males ($n=7$) from 21.3–22.9 mm and in females ($n=2$) from 24.9–26.1 mm. Ground colour of dorsal surfaces may be off-white, yellowish or light brownish, only one specimen (MZB Amph.12013) is completely dark brown on dorsum. Characteristic for almost all specimens is a short straight or gently curved postocular glandular ridge that is inferiorly demarcated by a dark brown fleck,)(–shaped dorso-lateral glandular ridges (that are more or less interrupted in most specimens and extend maximally from eye to the lumbar region); a prominent tubercle between tympanum and insertion of forelimb; a whitish interocular bar that may include parts of the upper eye lid; more or less demarcated whitish lumbar spots; a narrow or wide light mid-dorsal line from snout tip to end of body; a whitish area from eye through tympanum to the above mentioned tubercle; a dark brown fleck or band on distal forearm; ventral surfaces evenly stippled with brown dots or covered by brown flecks or a brownish network.

In life MZB Amph.11990 (Fig. 8) shows a paler dorsal colouration than the holotype without a reddish component, has a wider mid-dorsal line extending to hind legs, and a less expressed “)(” mark on anterior dorsum (more distinct in preservative).

Distribution and ecological notes. *Oreophryne albitympanum* sp. nov. was found in moss-covered trees in extremely wet, lower-montane forest where males called at heights of between ~2.0 and 4.0 m above the ground on both wet and dry nights. This species is known only from the type locality near the summit of the Foja Mountains in Papua Province, Indonesian New Guinea (Figs. 9 and 10).

Vocalisation. Five calls from one male (MZB Amph. 11990) were analysed. The advertisement call of the new species is a loud rattle lasting 1.4 ± 0.12 (1.2–1.5) s. Each call contains 16 ± 1.2 (14–17) strongly pulsed notes (Fig. 11). Note length ($n=80$) was 38.2 ± 3.3 (32–45) ms. Internote length ($n=75$) was 51.6 ± 5.7 (37–69) ms. Note repetition rate ($n=5$) was 11.4 ± 0.16 (11.3–11.7) notes/s. Individual notes ($n=80$) consist of 7.2 ± 0.50 (6–8) pulses. Pulse repetition rate ($n=80$) was 189.6 ± 14.7 (159–219) pulses/s. There is an increase in note and internote duration during the course of the call; first note and first internote interval are as a rule the shortest, and last note and last interval are the longest of the call. Notes start at maximum amplitude with the first pulse somewhat apart from its successors (Fig. 11, top). Frequencies scatter mainly in a range of 2–6 kHz (Fig. 12), dominant frequency has its peak at 4.2 kHz. Air temperature during recording was 17°C.

Etymology. The specific epithet *albitympanum* is a compound of the Latin adjective *albus*, -a, -um meaning white and the Latin substantive *tympanum* meaning eardrum. It refers to the whitish fleck posterior to the eye, that also includes most of the tympanum, that is exhibited by most specimens. This whitish fleck is more pronounced in



Fig. 7a–d. Holotype of *Oreophryne albitympanum* sp. nov. in life, (a) dorsolateral view, (b) ventral view, (c) palmar view of right hand, (d) plantar view of left foot.

preserved specimens than in living ones. The epithet is treated as an invariable noun in apposition.

Comparison with other species. About 30 *Oreophryne* species have a cartilaginous connection between procoracoid and scapula. Among this group of *Oreophryne* are species having a peeping call and those with a rattling call. We compare *Oreophryne albitympanum* sp. nov. to all *Oreophryne* of similar size, with a rattling advertisement call and a cartilaginous procoracoid-scapula connection; and to those species for which these characters are unknown.

Five species sharing these characters, *Oreophryne alticola* ZWEIFEL, COGGER & RICHARDS, 2005; *O. brevirostris* ZWEIFEL, COGGER & RICHARDS, 2005; *O. geminus* ZWEIFEL, COGGER & RICHARDS, 2005; *O. habbemensis* ZWEIFEL, COGGER & RICHARDS, 2005 and *O. terrestris* ZWEIFEL, COGGER & RICHARDS, 2005 are terrestrial forms living in alpine grasslands (vs. arboreal and living in

Table 2. Body measurements and body ratios of the type series of *Oreophryne albitympanum* sp. nov. MZB Amph.11996 is the holotype, MZB Amph.12012 and MZB Amph.12013 are adult females, all others are adult males. All measurements are in mm; Reg.No. = registration number, SD = standard deviation. All other abbreviations are explained in “Materials and methods”.

Reg.No.	MZB 11985	MZB 11989	MZB 11990	MZB 11991	MZB 11993	MZB 11996	MZB 12006	MZB 12012	MZB 12013	Mean $\pm$ SD
SUL	22.2	21.3	22.2	21.5	22.0	21.8	22.9	26.1	24.9	
TL	9.3	9.8	9.3	9.2	9.6	9.5	9.1	10.8	10.0	
TaL	6.8	6.6	6.6	6.7	6.9	6.6	6.6	7.4	6.9	
T4L	9.5	9.4	9.3	9.7	10.0	9.5	9.0	11.0	10.5	
T4D	0.9	1.0	1.2	1.0	1.0	1.0	1.0	1.3	1.2	
T1D	0.9	0.8	1.0	0.7	0.8	0.7	0.9	1.1	0.9	
F3D	1.2	1.2	1.4	1.2	1.1	1.3	1.1	1.8	1.5	
F1D	0.9	0.7	1.0	1.0	0.8	0.7	0.8	1.3	1.0	
HL	7.5	7.3	7.2	7.7	8.0	7.5	7.5	8.2	7.6	
HW	8.5	8.8	8.4	9.1	8.9	8.5	8.9	10.0	9.4	
END	2.0	1.8	1.9	1.8	1.9	1.9	1.8	2.4	1.9	
IND	2.3	2.2	2.0	2.2	2.2	2.2	2.3	2.6	2.2	
SL	3.7	3.7	3.7	3.9	3.8	3.9	3.5	4.2	3.6	
EST	2.8	3.0	2.8	3.0	3.1	2.9	2.7	3.6	2.9	
ED	3.1	3.1	3.0	3.0	3.2	3.2	3.0	3.4	3.2	
TyD	1.1	1.0	1.0	1.2	1.1	1.1	1.1	1.3	1.4	
TL/SUL	0.42	0.46	0.42	0.43	0.44	0.44	0.40	0.41	0.40	0.42 $\pm$ 0.021
TaL/SUL	0.31	0.31	0.30	0.31	0.31	0.30	0.29	0.28	0.28	0.30 $\pm$ 0.013
T4L/SUL	0.43	0.44	0.42	0.45	0.45	0.44	0.39	0.42	0.42	0.43 $\pm$ 0.019
T4D/SUL	0.041	0.047	0.054	0.047	0.045	0.041	0.044	0.050	0.048	0.046 $\pm$ 0.004
F3D/SUL	0.054	0.056	0.063	0.056	0.050	0.064	0.048	0.073	0.060	0.058 $\pm$ 0.008
T4D/F3D	0.75	0.83	0.86	0.83	0.91	0.77	0.91	0.72	0.80	0.82 $\pm$ 0.067
T1D/F1D	0.75	1.14	1.00	0.70	1.00	1.00	1.13	0.85	0.90	0.94 $\pm$ 0.15
HL/SUL	0.34	0.34	0.32	0.36	0.36	0.34	0.33	0.31	0.31	0.33 $\pm$ 0.02
HW/SUL	0.38	0.41	0.38	0.42	0.40	0.39	0.39	0.38	0.38	0.39 $\pm$ 0.015
HL/HW	0.88	0.83	0.86	0.85	0.90	0.88	0.84	0.82	0.81	0.85 $\pm$ 0.030
END/SUL	0.090	0.085	0.085	0.084	0.086	0.087	0.079	0.092	0.076	0.085 $\pm$ 0.005
IND/SUL	0.104	0.103	0.090	0.102	0.100	0.101	0.100	0.100	0.088	0.099 $\pm$ 0.006
END/IND	0.87	0.82	0.95	0.82	0.86	0.86	0.78	0.92	0.86	0.86 $\pm$ 0.052
ED/SUL	0.140	0.146	0.135	0.140	0.145	0.147	0.131	0.130	0.129	0.138 $\pm$ 0.007
TyD/SUL	0.050	0.047	0.045	0.056	0.050	0.050	0.048	0.050	0.056	0.050 $\pm$ 0.004
TyD/ED	0.35	0.32	0.30	0.40	0.34	0.34	0.37	0.38	0.44	0.36 $\pm$ 0.043
SL/SUL	0.167	0.174	0.167	0.181	0.173	0.179	0.153	0.161	0.145	0.167 $\pm$ 0.01
EST/SUL	0.126	0.141	0.126	0.140	0.141	0.133	0.118	0.138	0.116	0.131 $\pm$ 0.009

forest) and differ further in the following characters: *O. alticola* has shorter limbs (TL/SUL 0.33–0.38 vs. 0.40–0.46), a shorter eye to naris distance (END/SUL 0.064–0.065 vs. 0.076–0.090), smaller finger and toe discs (F3D/SUL 0.031–0.040 vs. 0.048–0.073 and T4D/SUL 0.026–0.033 vs. 0.041–0.054), and a call consisting of a series of 4–7 notes with 2–23 pulses/note (vs. 14–17 notes with 6–8 pulses/note); *O. brevirostris* has shorter limbs (TL/SUL 0.29–0.38 vs. 0.40–0.46), a shorter eye to naris distance (END/SUL 0.059–0.074 vs. 0.076–0.090) and smaller finger and toe discs (F3D/SUL 0.028–0.040 vs. 0.048–0.073 and T4D/SUL 0.025–0.036 vs. 0.041–0.054); *O. geminus* has shorter limbs (TL/SUL 0.32–0.39 vs. 0.40–0.46) and smaller finger and toe discs (F3D/SUL 0.030–0.041 vs. 0.048–0.073 and T4D/SUL 0.025–0.039 vs. 0.041–0.054), and a call consisting of a series of 20–28 notes with 9–21 pulses/note (vs. 14–17 notes with 6–8 pulses/note); *O. habbemensis* has shorter limbs (TL/SUL 0.33–



Fig. 8. Paratype (MZB Amph.11990) of *Oreophryne albitympanum* sp. nov. in life.

0.38 vs. 0.40–0.46) and smaller toe discs (T4D/SUL 0.034–0.038 vs. 0.041–0.054); *O. terrestris* has smaller finger and toe discs (F3D/SUL 0.031–0.042 vs. 0.048–

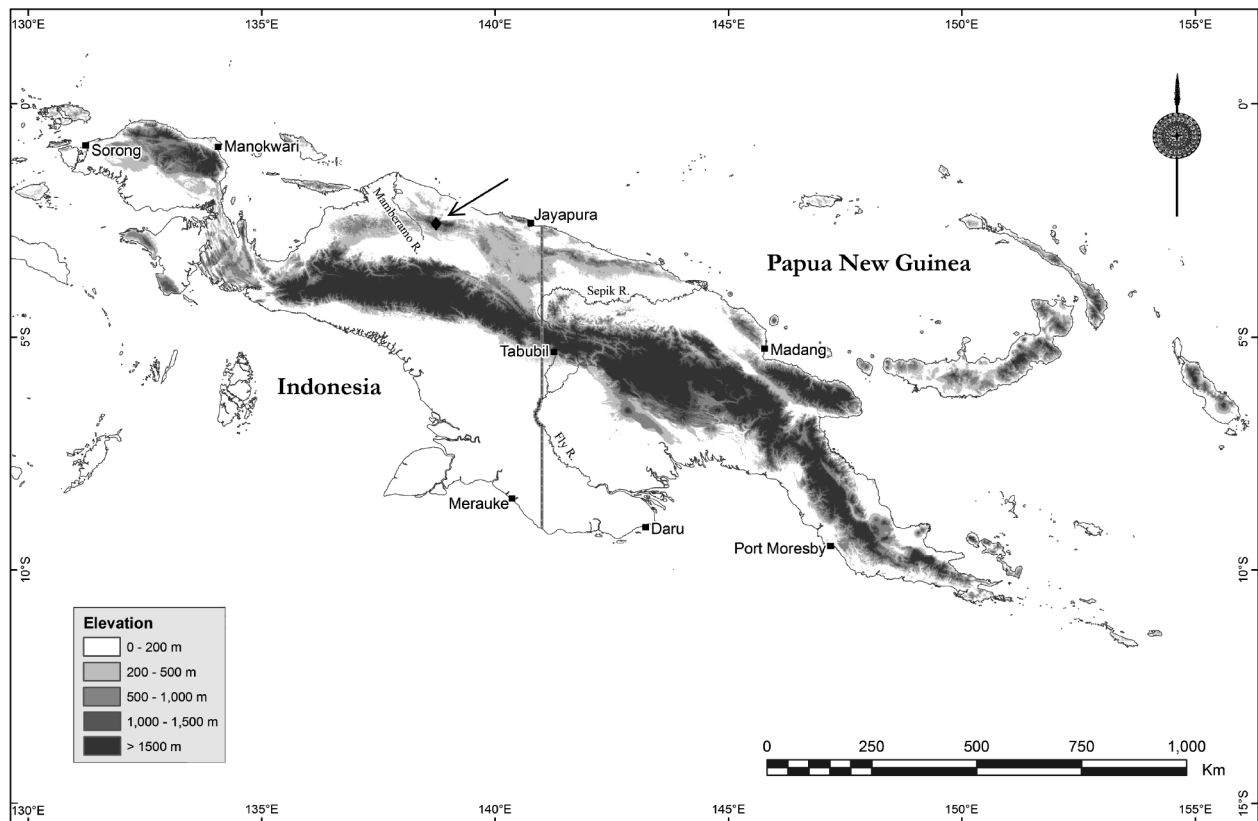


Fig. 9. Map of New Guinea showing the type locality (arrow) of *Oreophryne albitympanum* sp. nov. and *Choerophryne pipiens* sp. nov. in the Foja Mountains, northern Papua Province of Indonesia.



Fig. 10. Wet mossy rainforest near the summit of the Foja Mountains, habitat for *Choerophryne pipiens* and *Oreophryne albitympanum*.

0.073 and T4D/SUL 0.024–0.042 vs. 0.041–0.054) and a call consisting of a series of 12–16 notes with 2–7 pulses/note (vs. 14–17 notes with 6–8 pulses/note). *Oreophryne brevicrus* ZWEIFEL, 1956 is also an alpine species but may not be strictly terrestrial (e.g. ZWEIFEL, COGGER & RICHARDS, 2005). It differs from the new species in lacking web between the toes (vs. distinct basal web between toes 3 and 4, and toes 4 and 5), and having a call consisting of 18–23 notes with 4–11 pulses/note (vs. 14–17 notes with 6–8 pulses/note) and having a much lower dominant frequency of 1.6–2.2 kHz (vs. 4.2 kHz). *Oreophryne anamiattoi* KRAUS & ALLISON, 2009 is larger (SVL of males 23.4–26.7 mm vs. 21.3–22.9 mm); has smaller eyes (ED/SUL 0.110–0.130 vs. 0.129–0.147); no webbing between toes, stronger pigmented face mask and venter, longer calls (1.8–2.3 s vs. 1.2–1.5 s) and lower note repetition rate (8.6–9.6 notes/s vs. 11.3–11.7 notes/s). *Oreophryne clamata* GÜNTHER, 2003 is both morphologically and bioacoustically similar to *O. albitympanum* sp. nov. It is smaller (SUL of five males 18.5–20.4 mm vs. 21.3–22.9 mm in seven males of the new species; Fig. 13) and differs also in the ratios TL/SUL (0.46–0.50 vs. 0.40–0.46; Fig. 14), HL/SUL (0.70–0.82 vs. 0.83–0.90; Fig. 15) and T4D/F3D (0.62–0.67 vs. 0.69–0.91; Fig. 16). Moreover advertisement calls of both species differ in note duration: 15–34 ms in *O. clamata* vs. 32–45 ms in *O. albitympanum* sp. nov., and note repetition rate in the former is 16.3–18.4 notes/s vs. 11.3–11.7 notes/s in the latter.

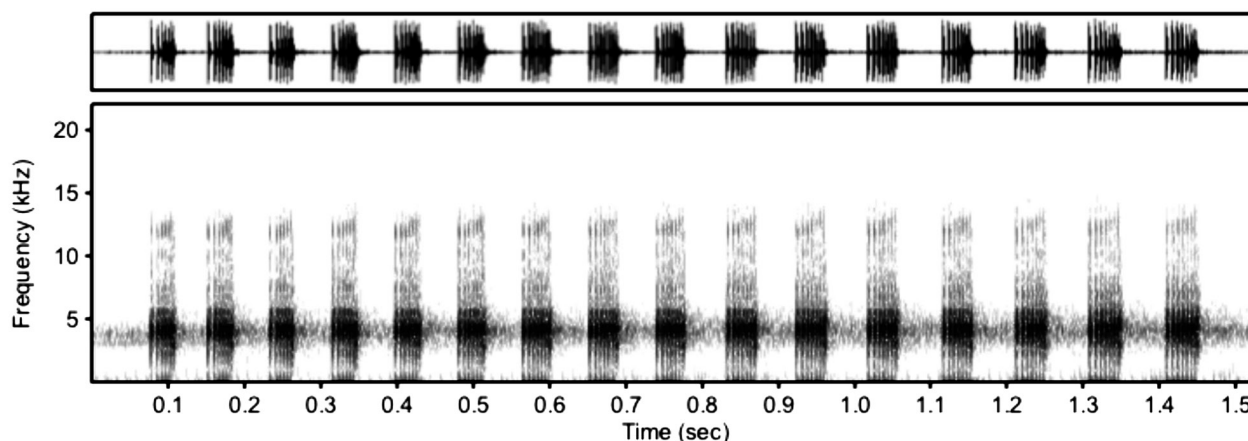


Fig. 11. Oscillogram (top) and spectrogram (lower) of an advertisement call from *Oreophryne albitympanum* sp. nov. (MZB Amph.11990; Fig. 8) consisting of 16 strongly pulsed notes.

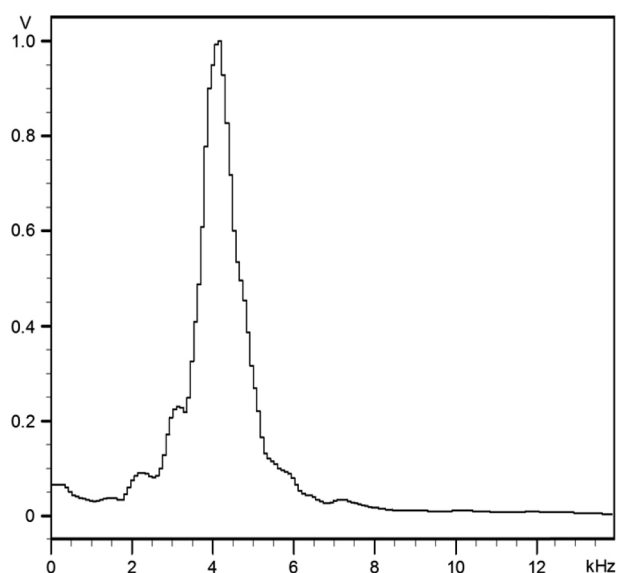


Fig. 12. Amplitude spectrum of an advertisement call from *Oreophryne albitympanum* sp. nov.

Two male syntypes of *O. crucifer* (KAMPEN, 1913) are larger than the males of *O. albitympanum* sp. nov. with SUL of 23.6 mm and 24.4 mm, and have the fifth toe shorter than the third, vs. vice versa in the new species. Syntype ZMA 5819 differs moreover clearly in the ratio END/IND (1.25 vs. 0.78–0.95). RICHARDS *et al.* (2015) described the call of *O. crucifer* as “a loud and harsh rattle of about 30 notes that last 1.5–2 seconds”. This means *O. crucifer* also has a clearly higher note repetition rate than the new species. Specimens of *O. curator* GÜNTHER, RICHARDS & DAHL, 2014 show a much greater variability in dorsal colouration than the new species. With a duration of more than 2.5 s its calls are longer than those of *O. albitympanum* sp. nov. (1.2–1.5 s); note length 26–28 ms vs. 32–45 ms in *O. albitympanum* sp. nov.; and note repetition rate 12.3–13.4 notes/s vs. 11.3–11.7 notes/s. Three males of *O. flava* PARKER, 1934 (deposited in the AMNH) with SUL of 19.8–20.7 are slightly smaller than seven males of *O. albitympanum* sp. nov. (21.3–22.9). Ratio

T4D/SUL in six specimens of *O. flava* (three males and three females) is 0.039–0.042 and in *O. albitympanum* sp. nov. 0.041–0.054; ratio T4D/F3D is 0.61–0.67 in *O. flava* and 0.072–0.091 in *O. albitympanum* sp. nov. and ratio HL/HW is 0.89–0.94 in *O. flava* and 0.82–0.90 in *O. albitympanum* sp. nov. Males of *O. gagneorum* KRAUS, 2013 and *O. parkoporum* KRAUS, 2013 are less than 20 mm long and so are clearly smaller than the new species. With a body length up to 45 mm, *O. idenburgensis* ZWEIFEL, 1956 is a clearly larger species than the new one. The (female) holotype of *O. kampeni* PARKER, 1934 with an SUL of 23.0 mm has stronger developed webs between toes than *O. albitympanum* sp. nov.; fifth toe shorter than third (vice versa in the new species) and a ratio T4D/F3D 0.067 vs. 0.072–0.091. *Oreophryne minuta* RICHARDS & ISKANDAR, 2000 has a much smaller body size (males up to 11.5 mm SVL) and no discs on fingers and toes. *Oreophryne moluccensis* (PETERS & DORIA, 1878) has toes one-third webbed vs. basal webs between toes 3 and 4 and 4 and 5 in the new species. *Oreophryne oviprotector* GÜNTHER, RICHARDS, BICKFORD & JOHNSTON, 2012 differs by the ratios END/IND (0.95–1.20 vs. 0.78–0.95 in the new species) and TL/SUL (0.46–0.51 vs. 0.40–0.46). Further, its advertisement calls are shorter (0.83–0.96 s vs. 1.2–1.5 s), note and internote length are also shorter (9–14 ms and 22–31 ms vs. 32–45 and 37–69 ms) and note repetition rate is much faster (26.0–27.7 notes/s vs. 11.3–11.7 notes/s). *Oreophryne waira* GÜNTHER, 2003 is smaller (SUL of males 17.8–18.9 mm vs. 21.3–22.9 mm) than the new species and has a different ratio END/IND (0.94–1.05 vs. 0.79–0.95) and TyD/ED (0.21–0.28 vs. 0.32–0.44). Moreover, its call is considerably shorter (0.34–0.62 s vs. 1.2–1.5 s) and note repetition rate is higher (about 14 notes/s at temperatures of 19–21 °C) than in the new species. *Oreophryne wolterstorffi* (WERNER, 1901) has more extensive webs between toes, web between toe 4 and 5 reaches up to penultimate subarticular tubercle of toe 5, vs. basal webs only between toes 3 and 4 and 4 and 5 in *O. albitympanum* sp. nov. and web between toe 4 and 5 does not reach to penultimate subarticular tubercle of toe 5.

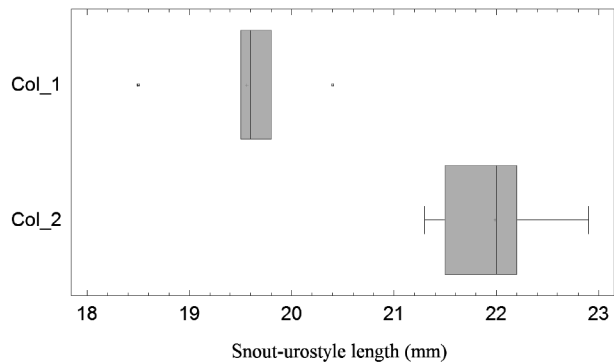


Fig. 13. Box-Whisker-Plot of snout-urostyle length (SUL) in five males of *Oreophryne clamata* (Col_1) and seven males of *O. albitympanum* sp. nov. (Col_2).

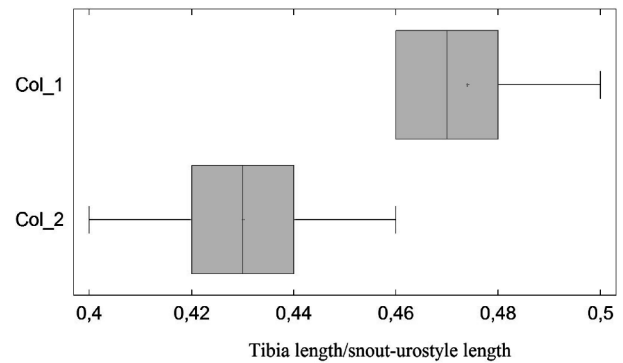


Fig. 14. Box-Whisker-Plot of ratio Tibia length/snout-urostyle length (TL/SUL) in five *Oreophryne clamata* (Col_1) and nine *O. albitympanum* sp. nov. (Col_2).

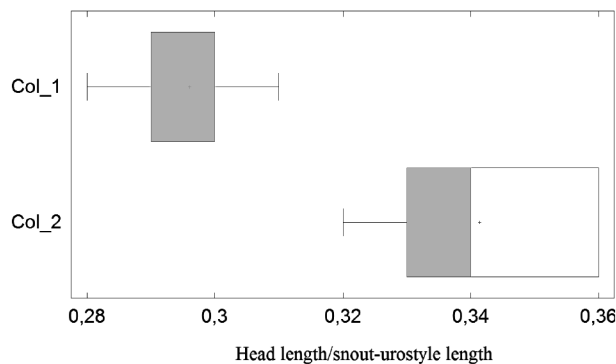


Fig. 15. Box-Whisker-Plot of ratio Head length/snout-urostyle length (HL/SUL) in five *Oreophryne clamata* (Col_1) and nine *O. albitympanum* sp. nov. (Col_2).

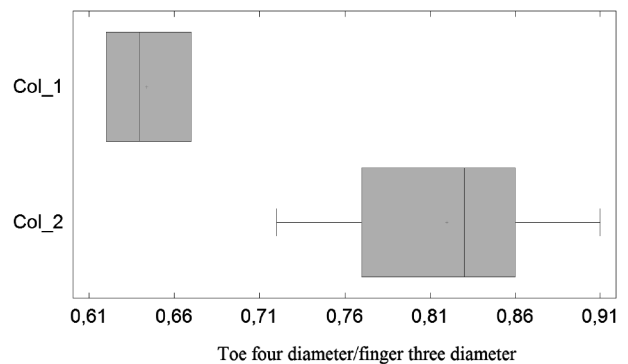


Fig. 16. Box-Whisker-Plot of ratio Diameter of disc of toe four/ diameter of disc of finger three (T4D/F3D) in five *Oreophryne clamata* (Col_1) and nine *O. albitympanum* sp. nov. (Col_2).

Discussion

The descriptions of these two frog species brings to five the number of frogs described on the basis of collections made during the 2004–2005 Foja Mountains RAP expeditions. Two of these, *Litoria gasconi* and *Pseudocallurops foja*, occur at low- to mid-altitudes (RICHARDS *et al.* 2009; GÜNTHER *et al.* 2016) whereas three (*Callurops fojaensis*, *Choerophryne pipiens* sp. nov. and *Oreophryne albitympanum* sp. nov.) are known only from near the summit of the range (>1,500 m, OLIVER *et al.* 2012; this study).

Choerophryne pipiens was included in a phylogenetic assessment of the genus (as *Choerophryne* sp. A4) by OLIVER *et al.* (2017), who demonstrated that it belongs to a clade inferred to have diversified primarily in montane habitats of New Guinea's central cordillera and that subsequently independently colonised the North Coast Ranges. The two species most morphologically and bioacoustically similar to *C. pipiens*, *C. brunhildae* from the isolated Adelbert and Torricelli Ranges in northern Papua New Guinea (MENZIES 1999; KRAUS 2013) and *C. murrita* from montane habitats in the central cordillera (KRAUS & ALLISON 2009) were not included in that study and a bet-

ter understanding of these species' relationships to congeners must await a more comprehensive phylogenetic assessment.

KRAUS (2013) described two new *Oreophryne* species from the isolated Adelbert and Torricelli mountains in northern Papua New Guinea that have a cartilaginous connection between the procoracoid and scapula. He noted that *O. cameroni* and *O. parkopanorum* are the only members of the genus occurring in the mainland North Coast Ranges (excluding the geologically independent 'Birds-head Region') to exhibit this feature. The discovery of *O. albitympanum* sp. nov. in the Foja Mountains, a range isolated by extensive and presumably unsuitable lowland habitats from the Adelbert and Torricelli Ranges, suggests that more species exhibiting this character may occur on other isolated ranges in the region. KRAUS (2013) also noted that all *Oreophryne* species known to date from these ranges have one of two call types; a series of unpulsed peeping notes or a pulsed rattle; in contrast a range of other call types are exhibited by members of the genus in the central cordillera and in other areas of the mainland. The call of *O. albitympanum*, a simple 'rattle', conforms to this pattern of limited call types in the North Coast Ranges, reflecting the relatively recent origin and limited colonisation of these accreted island arcs.

Acknowledgements

We thank the Indonesian Institute of Sciences (LIPI) for permission to undertake research in Papua Province, Indonesia and for providing export permits. Work in the Foja Mountains in 2005 was part of a Conservation International Rapid Assessment Program (RAP) biodiversity survey. BRUCE BEEHLER, NEVILLE KEMP, Dr YATNA SUPRIATNA, and Dr YANCE DE FRETES of Conservation International provided support and assistance during the survey and the community of Kwerba generously hosted our field studies. SANCOYO LANANG facilitated our work in Indonesia, and Ibu MUMPUNI, HELLEN KURNIATI and IRFAN SETIK from the Museum Zoologicum Bogoriense allowed examination of specimens in their care, approved export permits, registered specimens and provided various other assistances. MARK HUTCHINSON and CAROLYN KOVACH provided access to specimens at the South Australian Museum and LISA CAPON kindly produced Figure 9. Additional funding for this project was provided by grants from the MARK MITCHELL Foundation, the Australian Pacific Science Foundation, the WINIFRED VIOLET SCOTT Trust and the South Australian Museum Board. We are grateful to JAMES MENZIES (Adelaide) who provided call recordings of *Choerophryne brunhildae* and FRED KRAUS (Ann Arbor) for another relevant call recording.

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Choerophryne pipiens — urn:lsid:zoobank.org:act:A3C4800F-5F3F-4613-9046-60E7289C0554;

Oreophryne albitympanum — urn:lsid:zoobank.org:act:60F710F0-DF61-4BAE-89A7-76AF0DEFA22B.

The electronic edition of this work was published in a journal with an ISSN, and has been archived and is available from the following digital repository: www.senckenberg.de/vertebrate-zoology.