

# Two new species of the genus *Cophixalus* from the Raja Ampat Islands west of New Guinea (Amphibia, Anura, Microhylidae)

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<http://zoobank.org/D0A2D523-7D80-493A-A120-5E3C8B588A28>

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## Abstract

Received 4 June 2015  
Accepted 3 September 2015  
Published 1 October 2015

Academic editor:  
Peter Bartsch

## Key Words

Asterophryinae  
bioacoustics  
*Cophixalus*  
morphology  
new species

Based on morphological and bioacoustic traits, two new species of the microhylid genus *Cophixalus* Boettger, 1892 are described from the Raja Ampat Islands off the western tip of New Guinea. Both are small (SUL < 23 mm), slender, scansorial species that are morphologically most similar to *Cophixalus tetzlaffi* Günther and *C. monosyllabus* Günther, two congeners also known only from far western New Guinea. Their description brings the total number of *Cophixalus* known from New Guinea and surrounding islands to 46, and the total number from western New Guinea (Papua and West Papua Provinces including the Raja Ampat Islands) to 10. One *Cophixalus* specimen from Salawati Island is considered a hermaphrodite because it has a well-developed vocal sac and vocal slits, but also has an ovary containing eggs in an advanced developmental stage. This frog uttered advertisement calls that did not differ from calls of conspecific males. The first evidence of the genus *Cophixalus* from Misool Island is also documented.

## Introduction

The frog genus *Cophixalus* comprises 63 recognised species (Frost 2014). Of these, 19 occur in north-eastern Australia, 35 are known only from Papua New Guinea (many of them described in recent years; for example from Kraus and Allison (2009) and Kraus (2012)), five are known only from western New Guinea (Papua and West Papua Provinces of Indonesia), three are recorded from both Papua New Guinea and Indonesian New Guinea, and one species seems to be endemic to the island of Halmahera about 300 km off the western tip of New Guinea. Although *Cophixalus montanus* (Boettger) from Halmahera has been known since 1895, five of the species known from the western part of New Guinea (on Yapen Island, on the Wandammen Peninsula, and on the

Bomberai Peninsula) were described only recently (Günther 2003, 2006, 2010, Kraus 2012) and many additional *Cophixalus* species probably await discovery in western New Guinea. Here we describe two new *Cophixalus* species from the Raja Ampat Islands off the western tip of New Guinea.

## Material and methods

Frogs were generally located at night by tracking their advertisement calls, and selected specimens were photographed in life prior to preservation. Tissue probes from liver were taken from some specimens and stored in about 96% ethanol to enable DNA sequencing. All specimens were fixed in 10% formalin and transferred to 75% ethanol for permanent storage.

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:

SUL – snout-urostyle length: from tip of snout to distal tip of urostyle-bone. SUL is subject to lower measurement error than the traditionally used snout-vent length (SVL) (R. Günther, pers. obs.) so we have used it here. However both measurements are very similar, SUL being at most 0.5–1.0 mm shorter – if at all – than SVL in small frogs. We therefore directly compare SUL measurements reported here with SVL measurements of congeners presented in the literature. TL – tibia length: external distance between knee and ankle; TaL – length of tarsus: external distance, tarsal and ankle joints held at a right angle; T4L – length of fourth toe: from tip of toe to proximal end of inner metatarsal tubercle; T1D – transverse diameter of disc of first toe; T4D – transverse diameter of disc of fourth toe; F3L – length of third finger from tip to proximal margin of palmar tubercles; F3D – transverse diameter of disc of third finger; F1D – transverse diameter of disc of first finger; T1L – length of first toe: distal of inner metatarsal tubercle; MTL – length of inner metatarsal tubercle; HL – head length: from tip of snout to posterior margin of tympanum; HW – head width, taken in the widest point; SL – snout length: from an imaginary line that connects the centres of eyes to tip of snout; END – distance from anterior corner of orbital opening to centre of naris; IND – internarial distance between centres of external nares; ED – eye diameter: from anterior to posterior corner of orbital opening; TyD – horizontal diameter of tympanum.

Advertisement calls were recorded with a Sony™ WM D6C Professional Walkman tape recorder and a Sennheiser ME66 shotgun microphone and analysed with Avisoft-SAS Lab Pro software. All specimens are stored in the collection of the Museum Zoologicum Bogoriense (MZB) in Cibinong (Bogor), Indonesia and bear registration numbers of that institution.

All statistical calculations were done with the program Statgraphics Centurion Version 15.2.14 (Statpoint Technologies, Inc., Warrenton, Virginia, USA). All p-values in the running text and in the tables are calculated by the non-parametric Mann-Whitney (Wilcoxon) Test for comparison of medians. All mean values are arithmetic means. Box-whisker plots are used to illustrate comparative mensural data.

Voucher specimens, including types, of the genus *Cophixalus* that were studied for comparative purposes are listed in the papers by Richards et al. (1992), Günther (2003, 2006, 2010), Richards and Oliver (2007, 2010), Günther and Richards (2011), and Günther et al. (2014). Additional comparative information was taken from original species descriptions and recompiled treatises (Zweifel 1956a, 1956b, 1962, Tyler 1963, Menzies 2006, Kraus and Allison 2006, 2009, Kraus 2012).

## Results

### *Cophixalus rajampatensis* sp. n.

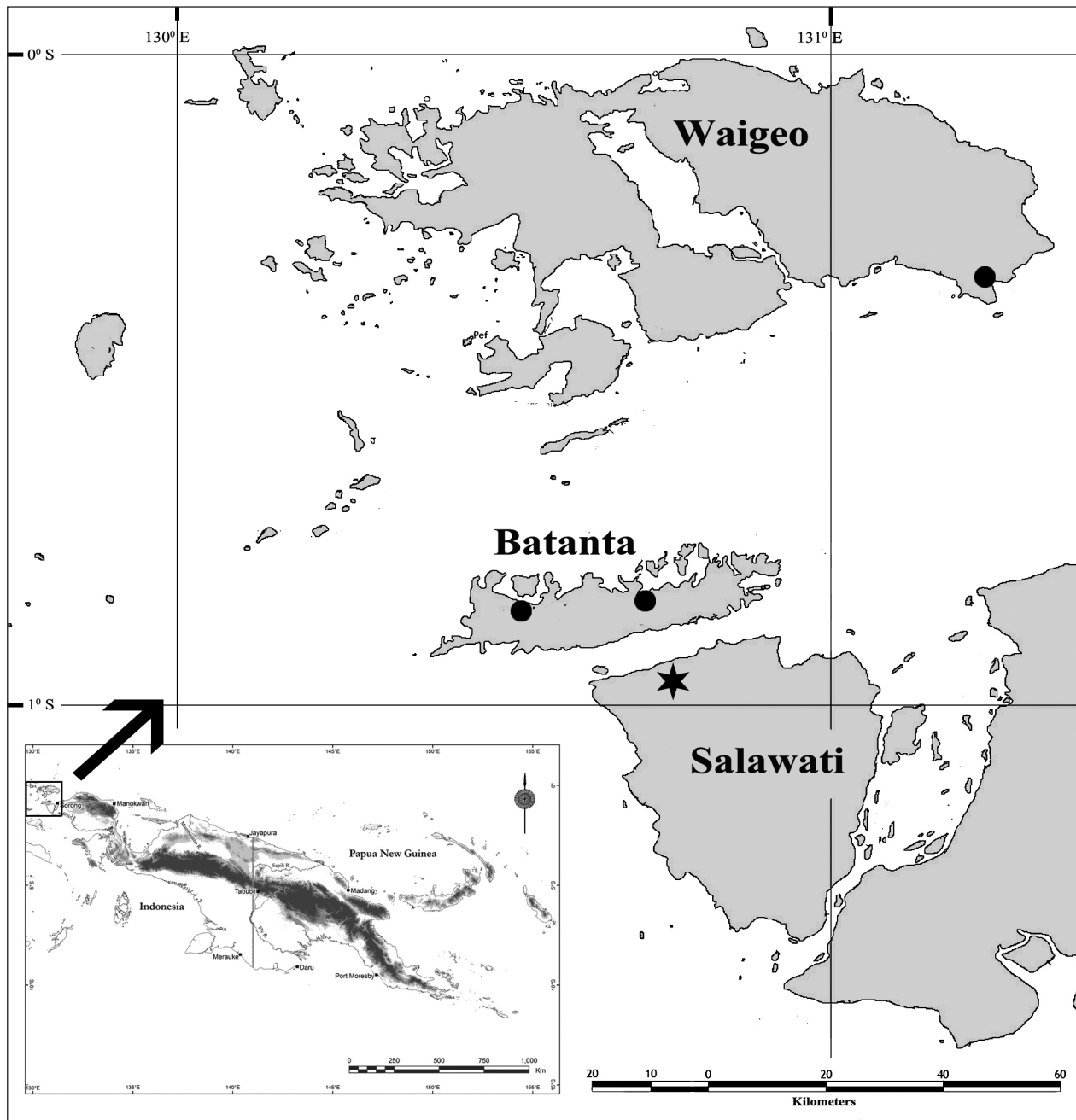
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**Holotype.** MZB Amph.12094 (field number, FN: SJR 7638); adult male collected at unnamed camp near Urbinasopen Village, Waigeo Island, Raja Ampat Islands, West Papua Province, Indonesia (00°20.231'S, 131°15.528'E) (Fig. 1) on 12/06/2005 by S. Richards, B. Tjaturadi and K. Krey.

**Paratypes.** MZB Amph.12097 (FN: SJR 7615), MZB Amph.12169 (FN: 7617), same data as holotype; MZB Amph.12098 (FN: SJR 7575), MZB Amph.12095 (FN: 7592) collected at Warinkabom Camp, Batanta Island, Raja Ampat Islands, West Papua Province, Indonesia (00°50.196'S, 133°43.318'E on 7 and 9/06/2005 respectively by S. Richards, B. Tjaturadi and K. Krey; MZB Amph.12092 (FN: SJR 7551), MZB Amph.12096 (FN: SJR 7559), MZB Amph.12163 (FN: 7516) collected at Waire Camp, Batanta Island, Raja Ampat Islands, West Papua Province, Indonesia (00°50.384'S, 130°31.534'E on 6-7/06/2005 by S. Richards, B. Tjaturadi and K. Krey. All seven paratypes are adult males.

**Diagnosis.** With an SUL of 17.6–19.5 mm in eight adult males, the new species is one of the smaller species of *Cophixalus*. Body slender, dorsum smooth except for occasional scattered tubercles and partly interrupted dorsolateral skin folds; legs moderately long (TL/SUL 0.48–0.52), third toe clearly longer than fifth. Toe and finger discs distinct, those of fingers slightly larger than, or equal in size to, those of toes (T4D/F3D 0.8–1.0), except that of first finger which is scarcely wider than penultimate phalanx. Call a short train of peeps or whistles, each with a mean duration of 178 milliseconds (ms). Number of notes (= peeps) per call 2–5 (mean 3.42), repeated at a rate of 3.3–4.6 notes/s (mean 3.96) and dominant frequency 3.7 kHz.

**Description of the holotype** (Fig. 2a–d). For measurements see Table 1. Head much broader than long (HL/HW 0.78), canthus rostralis rounded; loreal region flat; snout protruding in profile and nearly rounded in dorsal view; nostrils directed laterally; horizontal eye diameter greater than eye-naris distance; tympanic annulus scarcely visible, tympanum less than half eye diameter (TyD/ED 0.38), supratympanic fold short; internarial distance greater than distance between eye and naris (END/IND 0.75); tongue large, broadened posteriorly with a small notch, posterior and lateral margins free; prepharyngeal fold not serrated; long vocal slits on both sides of the tongue. Legs moderately long, no webbing between fingers or toes; disk of third finger wider than disk of fourth toe (T4D/F3D 0.89), disks of fingers II, III and IV about the same width as those of toes II, III and IV, first finger much smaller than other fingers, its disk only scarcely



**Figure 1.** Distribution of *Cophixalus rajampatensis* sp. n. (circles) and *Cophixalus salawatiensis* sp. n. (stars) in the Raja Ampat Islands off western New Guinea.

wider than the penultimate phalanx; relative length of fingers  $3 > 4 = 2 > 1$ ; third toe clearly longer than the fifth, disk of first toe slightly smaller than disk of fifth toe, disks of remaining toes clearly wider than those of first and fifth toe; all finger and toe disks with terminal grooves; relative length of toes  $4 > 3 > 5 > 2 > 1$ , subarticular, metatarsal and metacarpal tubercles not or only scarcely developed. Some tubercles on flanks, posterior back and dorsal shanks and irregular and partly interrupted dorsolateral skin folds from near eye to inguinal region. All remaining dorsal, lateral, and ventral surfaces smooth, except a gular fold between insertion of the fore limbs that indicates posterior margin of the vocal sac.

In preservative dorsal surfaces of head, body and extremities mid-brown, most tubercles with dark base and light tip, dorsolateral folds are accompanied by dark brown stripes. A fine light middorsal line from snout to anal opening. Body sides blotchy; a conspicuous whitish fleck extends from posterior of eye through tympanum to arm insertion. Ventral surfaces of extremities off-white with dense irregularly shaped brown spots; belly off-white with a few brown spots anteriorly, throat and chest intensely brown; region around anal opening blackish. In life dorsal surfaces bronze-brown with a few dark brown flecks laterally; tubercles pink. Conspicuous is an off-white stripe from tip of snout along canthus rostralis

**Table 1.** Body measurements and body ratios of the type series of *Cophixalus rajampatensis* sp. n. MZB 12094 is the holotype, all types are adult males, all measurements in mm. Inv.-No = Registration number; MZB = Museum Zoologicum Bogoriense; SD = Standard deviation; explanation of measurements in “Material and methods”.

Inv.-No	MZB 12092	MZB 12094	MZB 12095	MZB 12096	MZB 12097	MZB 12098	MZB 12163	MZB 12169	Mean $\pm$ SD
SUL	18.5	18.6	17.6	17.8	19.5	17.9	18.3	18.1	18.3 $\pm$ 0.56
TL	9.6	9.3	8.8	8.9	9.4	9.0	9.2	9.3	
TaL	5.9	6.0	5.3	5.7	5.8	5.9	5.9	5.8	
L4T	8.7	8.5	7.9	8.5	8.6	8.7	8.4	8.6	
T4D	0.8	0.8	0.8	0.8	0.9	0.8	0.7	0.8	
L3F	4.5	4.3	3.8	4.2	4.1	4.2	4.3	4.6	
F3D	1.0	0.9	0.8	0.9	0.9	0.8	0.8	0.9	
F1D	0.3	0.25	0.25	0.3	0.2	0.25	0.2	0.3	
T1D	0.4	0.4	0.4	0.4	0.35	0.35	0.3	0.4	
HL	5.7	5.3	5.1	5.2	5.5	5.1	5.6	5.8	
HW	6.9	6.8	6.5	6.4	6.7	6.2	6.6	6.5	
SL	2.8	2.8	2.5	2.4	2.7	2.5	2.6	2.7	
END	1.7	1.5	1.5	1.3	1.4	1.5	1.6	1.5	
IND	2.0	2.0	1.8	1.7	2.1	2.0	1.9	2.0	
ED	2.2	2.4	1.9	2.1	2.3	2.1	2.0	2.2	
TyD	1.1	0.9	0.7	0.8	1.0	0.9	0.9	0.9	
L1T	1.4	1.3	1.5	1.2	1.2	1.2	1.3	1.4	
LMT	0.9	0.8	0.7	0.8	0.7	0.7	0.9	0.9	
TL/SUL	0.52	0.50	0.50	0.50	0.48	0.50	0.50	0.51	0.50 $\pm$ 0.01
TaL/SUL	0.32	0.32	0.30	0.32	0.307	0.33	0.32	0.32	0.32 $\pm$ 0.01
L4T/SUL	0.47	0.46	0.45	0.48	0.44	0.49	0.46	0.48	0.47 $\pm$ 0.02
L3F/SUL	0.24	0.23	0.22	0.24	0.21	0.23	0.23	0.25	0.23 $\pm$ 0.012
F3D/SUL	0.054	0.048	0.045	0.051	0.046	0.045	0.044	0.050	0.048 $\pm$ 0.004
T4D/SUL	0.043	0.043	0.045	0.045	0.046	0.045	0.038	0.044	0.044 $\pm$ 0.003
T4D/F3D	0.80	0.89	1.00	0.89	1.00	1.00	0.88	0.89	0.92 $\pm$ 0.074
F1D/SUL	0.016	0.013	0.014	0.017	0.010	0.014	0.011	0.017	0.014 $\pm$ 0.002
T1D/SUL	0.022	0.022	0.023	0.022	0.018	0.020	0.016	0.022	0.021 $\pm$ 0.002
T1D/F1D	1.33	1.60	1.60	1.33	1.75	1.40	1.50	1.33	1.48 $\pm$ 0.16
LMT/L1T	0.64	0.62	0.47	0.67	0.58	0.58	0.69	0.64	0.61 $\pm$ 0.069
HL/SUL	0.31	0.27	0.29	0.29	0.28	0.28	0.31	0.32	0.29 $\pm$ 0.018
HW/SUL	0.37	0.37	0.37	0.36	0.34	0.35	0.36	0.36	0.36 $\pm$ 0.011
HL/HW	0.83	0.78	0.78	0.81	0.82	0.82	0.85	0.89	0.83 $\pm$ 0.036
SL/SUL	0.151	0.150	0.142	0.135	0.138	0.140	0.142	0.149	0.143 $\pm$ 0.006
END/IND	0.85	0.75	0.83	0.76	0.67	0.75	0.84	0.75	0.78 $\pm$ 0.061
ED/SUL	0.119	0.129	0.108	0.118	0.118	0.117	0.109	0.122	0.118 $\pm$ 0.007
TyD/ED	0.50	0.38	0.37	0.38	0.43	0.43	0.45	0.41	0.41 $\pm$ 0.062

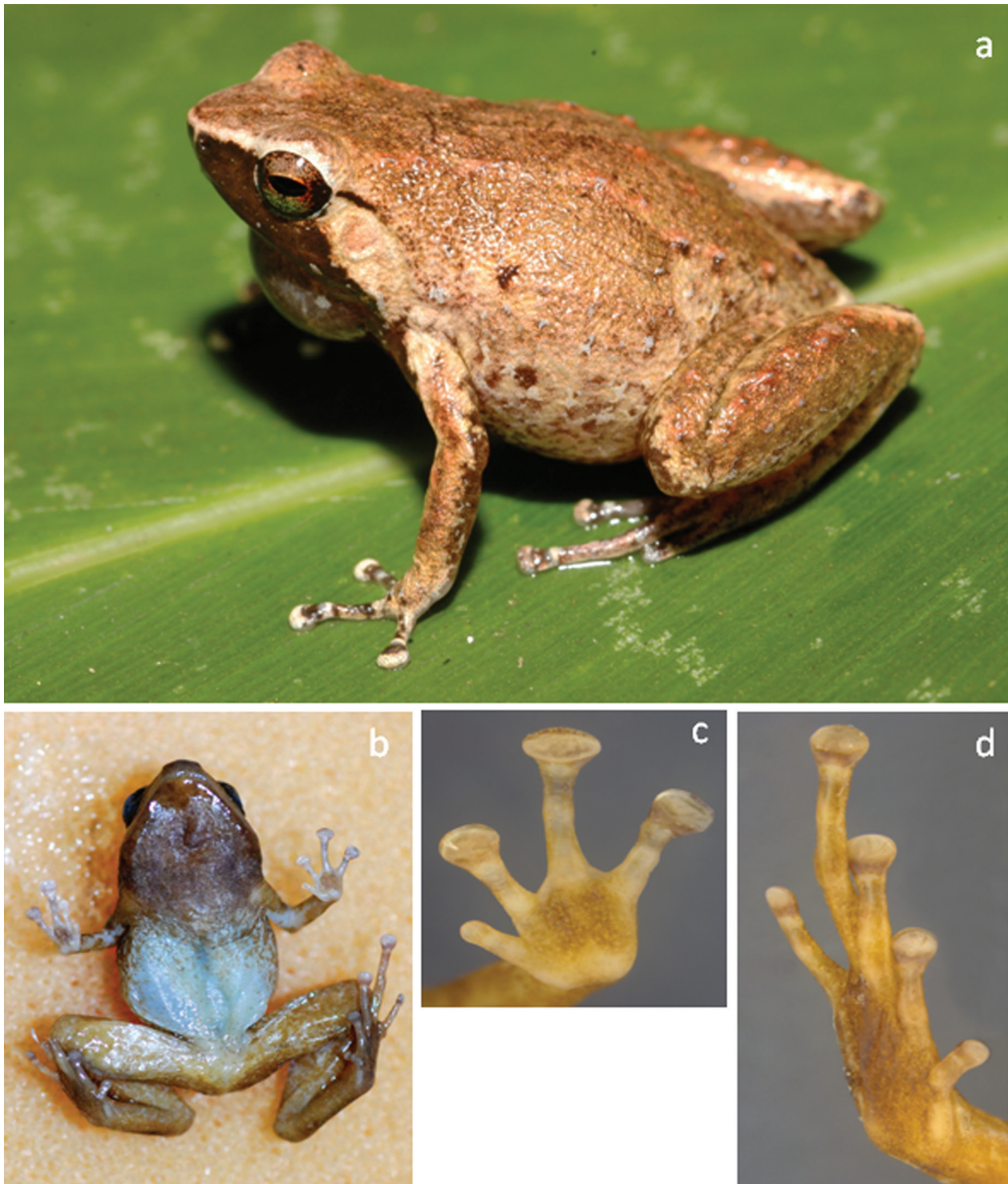
and margin of upper eyelid and reaching to posterior eye margin (this off-white stripe has nearly disappeared in fixative), and a dark brown “face-mask” covering loreal and gular region up to insertion of upper arm. Iris silvery with orange parts anteriorly and posteriorly and many irregular dark brown spots.

**Variation in the type series.** Mensural variation for the type series is shown in Table 1. Basic colour and colour pattern elements of all preserved paratypes are fairly uniform and closely resemble the holotype. Characteristic for most paratypes is a lighter brown dorsum which is bordered by irregular blackish dorsolateral lines and dark brown upper flanks. Three paratypes exhibit a dark mid-dorsal line; none have a light mid-dorsal line like the holotype. Abdomen from unspotted to various degrees of spotted; throat and chest uniform dark brown or heavily

spotted; loreal, subocular and gular region middle to dark brown in fixative and blackish in life. All specimens with a large off-white postocular fleck which is bordered antero-dorsally by a smaller dark spot and ventrally by the posterior “face-mask”. Six specimens have a small blackish spot above insertion of fore leg. The conspicuous pale canthal stripe that was present in all living specimens is very inconspicuous in the fixed ones.

**Vocalisation.** Most calling activity occurred at night after rain. Calls of three males (MZB 12095, 12096 and 12163) recorded at temperatures of approximately 26 °C were analysed. Calls each contained 2–5 (mean 3.4, SD 0.7) finely pulsed notes which sound like peeps or whistles (Fig. 3), and 4–6 calls were uttered in succession (a call series) with variable intervals between individual calls (4–20 s) and between call series (20 s to some

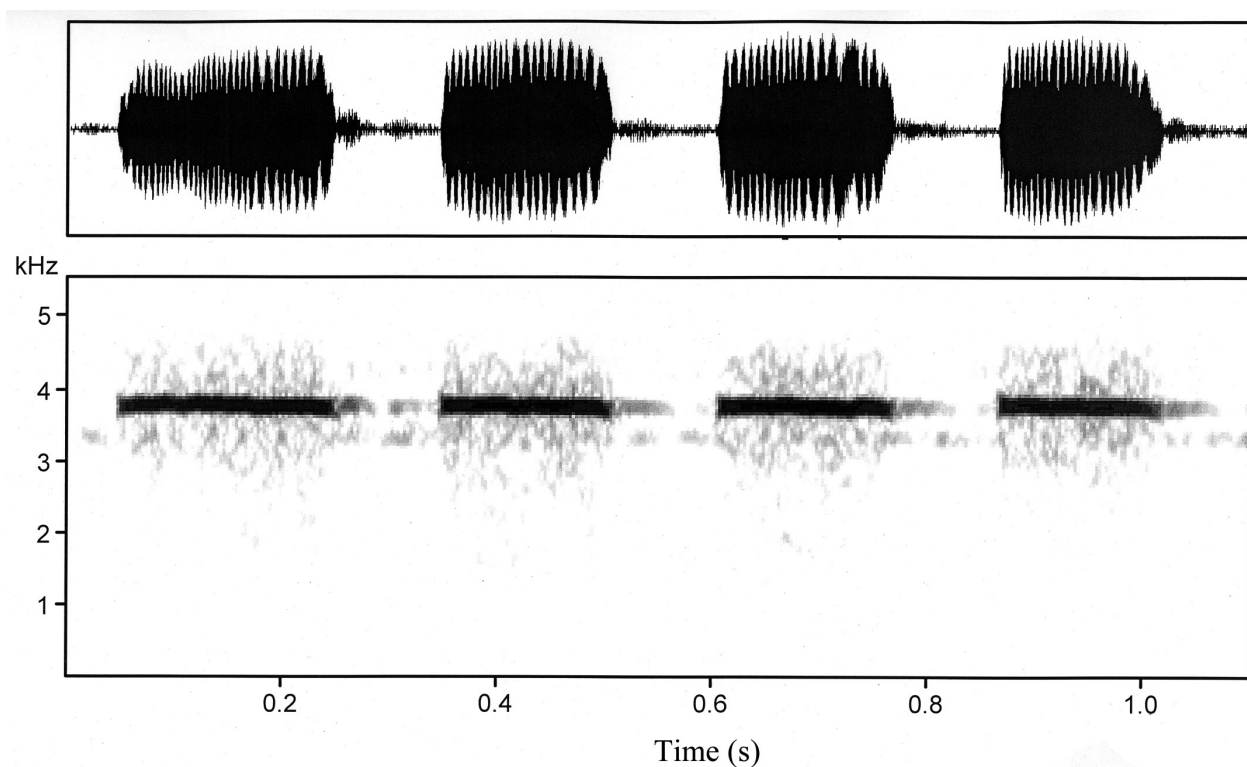




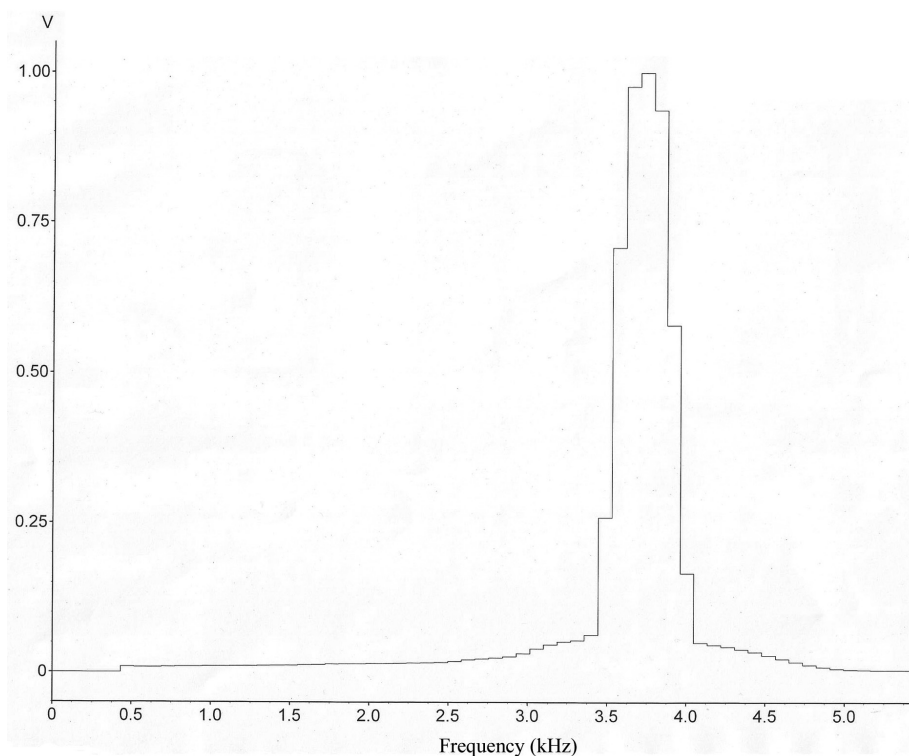
**Figure 2.** Holotype of *Cophixalus rajampatensis* sp. n. (a) dorsolateral view in life, (b) ventral view after preservation, (c) palmar view of left hand after preservation, (d) plantar view of right foot after preservation.

minutes). The shortest time between two successive calls within a series was 3.5 s. The call length was 0.40–1.54 s, mean 0.88 s, SD 0.22,  $n=52$ . Mean of means of note length was 178 ms, SD 10.4, range of means 158–202 ms,  $n=52$ ; total range of note length 142–238 ms. Mean of means of internote length 115 ms, SD 34.9, range of means 68–172 ms,  $n=52$ ; total range of internote intervals

63–179 ms. Mean note repetition rate was 3.96 notes/s, SD 0.37, range 3.3–4.6 notes/s,  $n=52$ . Frequencies are concentrated mainly between 3.4 and 4.0 kHz, with a dominant frequency of 3.7 kHz (Fig. 4). Most notes start explosively with nearly maximum amplitude, and volume may remain constant during the entire note but may also undulate, with the greatest volume mostly in the middle



**Figure 3.** Wave form (above) and spectrogram (below) of an advertisement call of *Cophixalus rajampatensis* sp. n. consisting of four notes.



**Figure 4.** Power spectrum of an advertisement call of *Cophixalus rajampatensis* sp. n.

of the note. The end of the note has a less steep amplitude slope than the beginning. The first note of a call is nearly always the longest.

**Distribution and ecological remarks.** *Cophixalus ampatensis* sp. n. is currently known from two localities on Batanta Island and one locality on Waigeo Island, both



in the Raja Ampat Island group off western New Guinea (Fig. 1). It was found to be common in moderately to heavily logged lowland rainforest where males called from the surfaces of leaves in low foliage ~30 cm – 1 m above the ground after heavy rain at night. Intensive searches on nearby Salawati Island failed to detect this species there despite similar climatic conditions and high activity of other frogs on that island. A number of other faunal lineages show evidence of a disjunction between Salawati and Batanta (e.g. Oliver et al. 2008), reflecting the different geological histories of these islands within the Raja Ampat Island Group. Batanta shares much of its biogeographic history with Waigeo, and the deep Sagewin strait that separates them from Salawati appears to be a major barrier for at least some taxa. Together these observations suggest that *C. rajampatensis* sp. n. probably does not occur on Salawati, and may be endemic to Batanta and Waigeo Islands.

**Etymology.** The latinized specific epithet *rajampatensis* refers to the fact that the species occurs on the Raja Ampat Islands off the western tip of New Guinea.

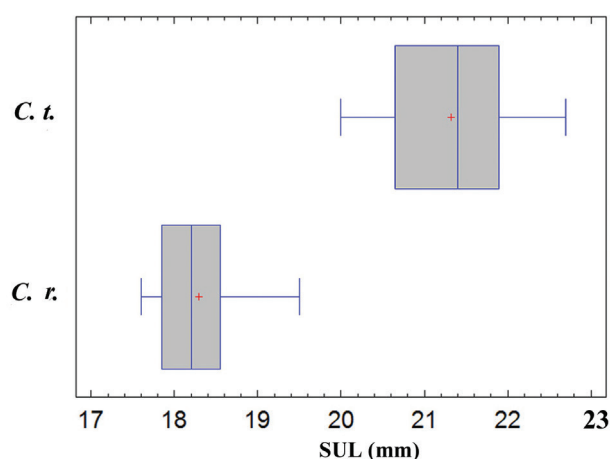
**Comparison with other species.** *Cophixalus* species described from New Guinea and adjacent islands that can be immediately distinguished from *C. rajampatensis* (with males 17.6–19.5 mm) by their smaller adult size are (sizes presented below are for adult males unless otherwise indicated): *amabilis* Kraus (13.6–14.3 mm), *ateles* (Boulenger) (12–14 mm), *desticans* Kraus & Allison (13.1–16.2 mm), *humicola* Günther (14.5–16.2), *iowaorum* Kraus & Allison (13.2–16.0 mm), *kethuk* Kraus & Allison (12.4–13.5 mm), *linnaeus* Kraus & Allison (13.4–14.7 mm), *misimae* Richards & Oliver (15.5–16.1 mm), *phaeobalis* Kraus & Allison (15.3 mm), *timidus* Kraus & Allison (13.5–17.5 mm), *tomaiodactylus* Kraus & Allison (13.2–16.1 mm), *tridactylus* Günther (14.3–16.2), and *viridis* Günther, Richards & Dahl (15.8–16.2 mm). With an SVL of 15.7 mm the only known specimen of *Cophixalus pictus* Kraus is smaller than *C. rajampatensis* but its description was based on a rather poorly preserved (and presumed immature) male from the Bomberai Peninsula of West Papua Province (Kraus 2012) and, if immature, this distinction could disappear once adult material has been documented. However the new species also differs from *C. pictus* in a number of features that are unlikely to reflect the immature status of the holotype and only known specimen, including having (vs. lacking) a distinct supratympanic fold, in having longer legs (TL/SUL 0.48–0.52 vs. TL/SVL 0.47) and in having a very different ratio of internarial distance to eye-to-naris distance (END/IND 0.67–0.85 vs. 1.08 in *C. pictus*) (Kraus 2012). A further 15 species can be readily distinguished by their much larger size: *balbus* Günther (26–28 mm), *biroi* (Méhely) (to 27 mm; Zweifel 1979), *caverniphilus* Kraus & Allison (25.5–36.7 mm), *cheesmanae* Parker (to 31 mm; Zweifel 1979), *clapporum* Kraus (23.2–27.5 mm), *cryptotympanum* Zweifel (to 30 mm (both sexes)

at the type locality; to 40 mm elsewhere: Zweifel 1956, 1962, Menzies 2006), *cupricarens* Kraus & Allison (23.4–28.7 mm), *kaindiensis* Zweifel (to 28 mm; Zweifel 1979), *montanus* (to 26 mm (sex not stated; Parker 1934), *nubicola* Zweifel (22.4–24.3 mm), *parkeri* Loveridge (to 30 mm), *riparius* Zweifel (to 45 mm) and *verrucosus* (Boulenger) (to 25 mm).

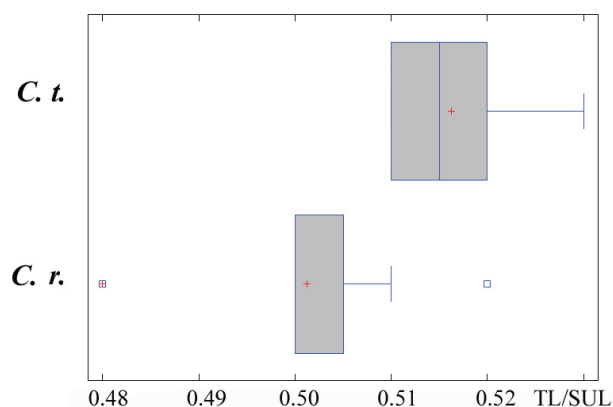
From the species with overlapping body sizes: *C. albolineatus* Kraus (16.8–20.5 mm), *C. interruptus* Kraus & Allison (16.6–18.7 mm), *C. melanops* Kraus & Allison (16.4–18.9 mm), *C. tagulensis* Zweifel (to 18 mm), *C. tenuidactylus* Günther & Richards (18.4–20.3 mm) and *C. verecundus* Zweifel & Parker (15–17 mm) the new species can be immediately distinguished by having finger discs of the same size or larger than toe discs (vs. smaller than the toe discs). *Cophixalus variabilis* Kraus & Allison (13.6–18.6 mm) has a tuberculate (vs. smooth) dorsum with extensive colour variation including longitudinal stripes in about 50% of specimens (lacking in *rajampatensis*). *Cophixalus bewaniensis* Kraus & Allison (15–17 mm) and *C. shellyi* Zweifel (~17 mm) have strongly reduced first fingers and *C. sphagnicola* Zweifel & Allison (15.8–18.5 mm), in contrast to *C. rajampatensis* sp. n., completely lacks discs on fingers and toes. *Cophixalus pipilans* Zweifel (16.1–18.5 mm) has longer legs (TL/SVL >0.53 vs. TL/SUL 0.48–0.52) and calls with 20–33 (vs. 2–5) peeping notes. *Cophixalus daymani* Zweifel (to 21.7 mm [females]) is distinguished by very short hind legs (TL/SUL less than 0.38 vs. 0.48–0.52) and occurring higher than 2200 m a.s.l. *Cophixalus nexipus* Kraus (18.9–22.7 mm) differs by having basal webbing on toes and advertisement calls consisting of a single, long note lasting more than one second (vs. 2–5 short, finely pulsed peeps). *Cophixalus wempi* Richards & Oliver (15.5–16.1 mm) has (vs. lacks) a distinct spiniform tubercle above the eyelid and has advertisement calls with 28–33 (vs. 2–5) peeping notes.

On the basis of external morphology *C. tetzlaffi* and *C. monosyllabus* exhibit most similarities to *C. rajampatensis* sp. n. and are compared in more detail. With an SUL of 20.0–22.7 mm, mean 21.3 mm, SD 0.92, *n*=8, *C. tetzlaffi* is larger than *C. rajampatensis* sp. n. with an SUL of 17.6–19.5 mm, mean 18.3, SD 0.60, *n*=8 (Fig. 5). Relative tibia length of *C. tetzlaffi* is significantly greater than that of *C. rajampatensis* sp. n. (TL/SUL 0.51–0.53 vs. 0.48–0.52; *p*=0.008, Fig. 6), although the values overlap. There are also significant differences between these species (no overlap in the values) in their advertisement calls; note length of *C. tetzlaffi* (347–518 ms) is longer than that of *C. rajampatensis* sp. n. (142–238 ms); inter-note interval in the former is longer (186–299 ms) than in the latter (63–179 ms); and note repetition rate in the former is slower 1.5–1.8 notes/s than in the latter 3.3–4.6 notes/s.

Ten male specimens of *C. monosyllabus* have a larger snout-urostyle length than eight males of *C. rajampatensis* sp. n. and there is no overlap: 20.6–24.3 mm, mean 22.9 mm (SD 1.04) vs. 17.6–19.5 mm, mean 18.3 mm



**Figure 5.** Box-Whisker-Plot of snout-urostyle length in mm (SUL) of eight males of *Cophixalus tetzlaffi* (*C.t.*) and eight males of *C. rajampatensis* sp. n. (*C. r.*). The horizontal blue line represents the range, the vertical blue line represents the median, the box represents the interquartile (50% of the values) and the red cross indicates the arithmetic mean.



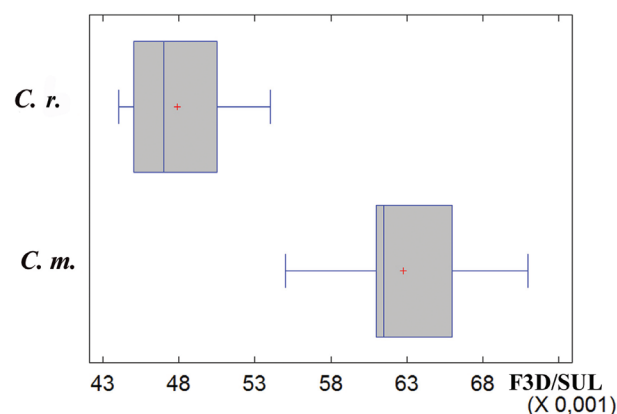
**Figure 6.** Box-Whisker-Plot of the ratio TL/SUL of eight males of *Cophixalus tetzlaffi* (*C.t.*) and eight males of *C. rajampatensis* sp. n. (*C. r.*). Small squares are so-called outliers.

(SD 0.56) and also differ significantly in the following body ratios (*monosyllabus* vs. *rajampatensis*): F3D/SUL (0.055–0.067 vs. 0.044–0.054; Fig. 7), F3L/SUL (0.26–0.28 vs. 0.21–0.25), F1D/SUL (0.017–0.031 vs. 0.010–0.017), HW/SUL (0.37–0.42 vs. 0.34–0.37; Fig. 8) and END/IND 0.84–0.96 vs. 0.67–0.85,  $p=0.001$ ). Moreover, *C. monosyllabus* and *C. rajampatensis* sp. n. differ in their advertisement calls. Calls of the former consist of single notes while calls of the latter always contain 2–5 notes, mean 3.4 notes, SD 0.7.

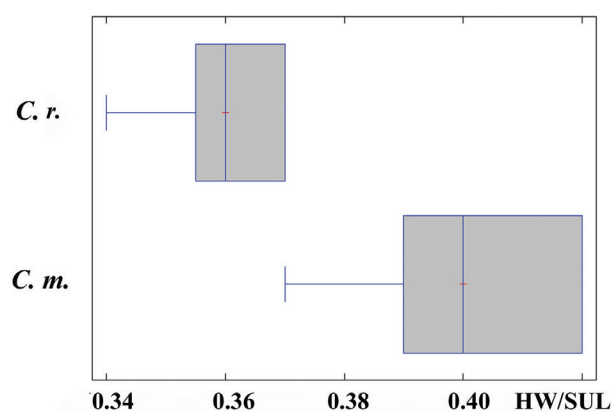
#### *Cophixalus salawatiensis* sp. n.

<http://zoobank.org/66A11935-9819-4272-B3E1-CA2E04159C61>

**Holotype.** MZB Amph.12165 (FN: SJR 7797); adult male collected at Weybya camp, Salawati Island, Raja Ampat Islands, West Papua Province, Indonesia (00°57.383'S,



**Figure 7.** Box-Whisker-Plot of the ratio F3D/SUL of ten males of *Cophixalus monosyllabus* (*C.m.*) and eight males of *C. rajampatensis* sp. n. (*C. r.*).



**Figure 8.** Box-Whisker-Plot of the ratio HW/SUL of ten males of *Cophixalus monosyllabus* (*C.m.*) and eight males of *C. rajampatensis* sp. n. (*C. r.*).

130°47.060'E on 27/06/2005 by S. Richards, B. Tjaturadi and K. Krey.

**Paratypes.** MZB Amph.12157 (FN: SJR 7731), MZB Amph.12159 (FN: 7756), MZB Amph.12161 (FN: SJR 7755), MZB Amph.12162 (FN: SJR 7730), MZB Amph.12166 (FN: SJR 7757), MZB Amph.12167 (FN: 7772), MZB Amph.12168 (FN: 7760), MZB Amph.12170 (FN: SJR 7795), and MZB Amph.12171 (FN: SJR 7796), same data as for holotype, collected between 24–27/06/2005. All specimens are adult males and MZB Amph.12166 is considered a hermaphrodite (see below).

**Diagnosis.** *Cophixalus salawatiensis* sp. n. can be distinguished from all congeners by a combination of the following characters: Body small (SUL of 10 males 19.6–22.5 mm), slender, dorsum smooth except for scattered tubercles, head laterally with a distinct dark 'face mask' (grey in life); legs moderately long (TL/SUL 0.49–0.53), third toe clearly longer than fifth, no webbing between digits. Toe and finger discs distinct, those of fingers





**Figure 9.** Holotype of *Cophixalus salawatiensis* sp. n. (a) dorsolateral view in life, (b) ventral view after preservation, (c) palmar view of left hand after preservation, (d) plantar view of right foot after preservation.

**Table 2.** Body measurements and body ratios of the type series of *Cophixalus salawatiensis* sp. n. MZB 12165 is the holotype, all types are adult males, MZB 12166 is a hermaphrodite; all measurements in mm. For explanation of abbreviations see Table 1.

Inv.-No.	MZB 12157	MZB 12159	MZB 12161	MZB 12162	MZB 12165	MZB 12166	MZB 12167	MZB 12168	MZB 12170	MZB 12170	Mean $\pm$ SD
SUL	20.8	21.5	22.5	21.2	20.2	21.7	19.6	20.1	20.3	19.8	20.8 $\pm$ 0.94
TL	10.2	10.9	11.3	10.6	10.4	10.8	10.0	10.6	10.5	10.1	
TaL	6.5	6.4	7.0	6.7	6.1	6.8	6.4	6.7	6.7	6.4	
L4T	10.3	10.1	10.8	10.2	9.7	10.4	9.6	9.8	9.5	9.6	
T4D	1.0	1.1	1.1	0.9	1.1	1.0	1.0	0.9	1.0	1.0	
L3F	5.1	4.9	5.3	4.9	4.7	5.2	4.6	5.1	5.2	4.5	
F3D	1.2	1.1	1.2	1.1	1.1	1.2	1.1	1.1	1.0	1.0	
F1D	0.4	0.5	0.6	0.5	0.4	0.4	0.5	0.4	0.4	0.4	
T1D	0.5	0.5	0.6	0.6	0.5	0.5	0.6	0.6	0.5	0.5	
HL	7.0	6.9	6.4	6.3	6.1	6.5	6.2	5.9	6.3	5.8	
HW	8.1	8.2	8.5	8.0	7.7	8.0	8.0	7.5	8.0	7.6	
SL	3.2	3.1	3.0	2.9	3.1	3.0	3.0	3.1	2.9	2.7	
END	1.8	1.8	1.9	1.7	1.7	1.7	1.7	1.6	1.8	1.8	
IND	2.1	2.3	2.2	2.1	1.8	1.9	2.1	2.1	2.1	2.0	
ED	2.6	2.6	2.7	2.6	2.5	2.4	2.5	2.4	2.4	2.3	
TyD	0.7	1.0	0.9	0.8	0.7	0.9	0.7	1.0	0.8	0.7	
L1T		1.7	1.7	1.8	1.7	1.5	1.5	1.6	1.6	1.5	
LMT		0.9	0.8	0.8	0.7	1.0	0.9	0.8	0.9	1.1	
TL/SUL	0.49	0.51	0.50	0.50	0.51	0.50	0.51	0.53	0.52	0.51	0.51 $\pm$ 0.01
TaL/SUL	0.31	0.30	0.31	0.33	0.30	0.31	0.33	0.33	0.33	0.32	0.32 $\pm$ 0.01
L4T/SUL	0.50	0.47	0.48	0.48	0.48	0.48	0.49	0.49	0.47	0.48	0.48 $\pm$ 0.009
L3F/SUL	0.25	0.23	0.24	0.23	0.23	0.24	0.23	0.25	0.26	0.23	0.24 $\pm$ 0.01
F3D/SUL	0.058	0.051	0.053	0.052	0.054	0.055	0.056	0.055	0.049	0.050	0.053 $\pm$ 0.003
T4D/SUL	0.048	0.051	0.049	0.042	0.054	0.046	0.051	0.045	0.049	0.050	0.049 $\pm$ 0.003
T4D/F3D	0.83	1.00	0.92	0.82	1.00	0.83	0.91	0.82	1.00	1.00	0.91 $\pm$ 0.08
F1D/SUL	0.019	0.023	0.027	0.024	0.020	0.018	0.026	0.020	0.020	0.020	0.022 $\pm$ 0.003
T1D/SUL	0.024	0.023	0.027	0.028	0.025	0.023	0.031	0.030	0.025	0.025	0.026 $\pm$ 0.003
T1D/F1D	1.25	1.00	1.00	1.20	1.25	1.25	1.20	1.50	1.25	1.25	1.22 $\pm$ 0.14
LMT/L1T		0.53	0.47	0.44	0.41	0.67	0.60	0.50	0.56	0.73	0.55 $\pm$ 0.11
HL/SUL	0.34	0.32	0.28	0.30	0.30	0.30	0.32	0.29	0.31	0.29	0.31 $\pm$ 0.02
HW/SUL	0.39	0.38	0.38	0.38	0.38	0.37	0.41	0.37	0.39	0.38	0.38 $\pm$ 0.01
HL/HW	0.86	0.84	0.75	0.79	0.79	0.81	0.78	0.79	0.79	0.76	0.80 $\pm$ 0.03
SL/SUL	0.154	0.144	0.133	0.137	0.153	0.138	0.153	0.154	0.142	0.136	0.144 $\pm$ 0.008
END/IND	0.86	0.78	0.86	0.81	0.94	0.89	0.81	0.76	0.86	0.90	0.85 $\pm$ 0.06
ED/SUL	0.125	0.121	0.120	0.123	0.124	0.111	0.128	0.119	0.118	0.116	0.121 $\pm$ 0.005
TyD/ED	0.27	0.38	0.33	0.31	0.28	0.41	0.28	0.42	0.33	0.30	0.33 $\pm$ 0.05

slightly larger than, or equal in size to, those of toes (T4D/F3D 0.82–1.0). Call a train of 6–8 notes that sound like peeps or whistles; calls last for approximately 0.5 s, notes are less than 50 ms and produced at a rate of 13.5–15.6/s.

**Description of the holotype** (Figs 9a–d): For measurements see Table 2. Head wider than long (HL/HW 0.79), canthus rostralis straight and rounded; loreal region flat; snout protruding in profile and acuminate in dorsal view; nostrils directed laterally and near end of snout; horizontal eye diameter greater than eye-naris distance; tympanum scarcely visible, about one third of eye diameter (TyD/ED 0.28), supratympanic fold weakly expressed and S-shaped; internarial distance only slightly greater than distance between eye and naris (END/IND 0.94); tongue medium-sized, a little broadened posteriorly and lacking notch, with posterior and lateral margins free; prepharyngeal ridge not serrated; long vocal slits on

both sides of the tongue. Legs moderately long (TL/SUL 0.51), no webbing between fingers or toes; disks of fingers II, III and IV about same width as disks of toes II, III and IV, disks of finger I as well as of toe I and V much smaller than that of other fingers and toes, relative length of fingers 3>4>2>1; third toe clearly longer than the fifth, all finger and toe disks with terminal grooves; relative length of toes 4>3>5>2>1, no clearly expressed subarticular tubercles on fingers and toes and no distinct palmar or plantar tubercles. Some low, pale-tipped tubercles on flanks, dorsally on shanks, and in two weakly-defined rows on posterior surfaces of back. All remaining dorsal, lateral, and ventral surfaces smooth, except a gular fold between insertion of the fore limbs that indicates the posterior margin of the vocal sac.

In preservative dorsal surfaces of head, body and limbs light grey-brown, flanks lighter than dorsum; most tubercles with dark base and light tip; irregular dark brown

flecks on limbs and flanks. A longish dark-brown postocular spot followed by a small dark-brown spot above arm insertion. A broad off-white fleck extends from posterior of eye through tympanum up to arm insertion. This fleck is bordered antero-dorsally by the dark postocular spot and ventrally by the posterior part of the dark brown “face-mask”. The face-mask continues below the eyes, runs along the loreal region and reaches to the snout tip. Ventral surfaces of limbs and abdomen off-white with irregularly shaped brown spots that are often reticulated, throat and chest dark brown with a few off-white speckles; region around anal opening blackish.

In life dorsum grey-orange, central dorsum more intensely coloured than flanks, conspicuous is a big orange spot on foreleg and a whitish canthal stripe that continues on upper eyelid. Dorsal surface of head with a mixture of grey and orange spots, face-mask greyish. The small dark and the big off-white postocular flecks less intensely marked than in fixative. Dorsal and lateral tubercles more strongly expressed than in preservative, a dorsolateral row of inconspicuous tubercles present.

**Variation in the type series** (in preservative): Mensural variation for the type series is shown in Table 2. Basic colour and colour pattern elements of all paratypes are fairly uniform and resemble the holotype. Ground colour of dorsal surfaces light grey to light brown. Dorsolateral glandular ridges weakly developed and often interrupted - they extend in some specimens from eye to lumbar region, in others they are shorter and confined to middle and posterior back. Dorsolateral prior glandular ridges in most specimens indicated by rows of dark brown spots that vary from rare to numerous and can form shorter or longer stripes. Characteristic for most paratypes is a dark brown postocular spot as well as a spot of the same colour above insertion of fore arm. Tympanal region in all specimens off-white and clearly demarcated from the dark postocular spot and the dark “face-mask”. Dark brown lateral colour of head merges into that of dark gular region. Lateral surfaces of body usually more strongly pigmented towards dorsal regions. One specimen (MZB Amph.12166) shows heavily spotted dorsal and lateral surfaces. Throat and chest in all specimens covered by a dense net of dark brown flecks, abdomen off-white with few small brownish flecks and ventral surfaces of limbs a little more mottled than abdomen. No specimen with either dark or light mid-dorsal line.

MZB Amph.12166 is considered a hermaphrodite because it has a well-developed vocal sac and two vocal slits in the floor of the mouth, but also has an ovary containing eggs in an advanced developmental stage (Fig. 10). This frog also uttered advertisement calls that were recorded and that did not differ from calls of conspecific males.

**Vocalisation.** Calling occurred at night, predominantly after heavy rain. The advertisement call of *Cophixalus salawatiensis* sp. n. consists of a short series of 6–8 peeps or whistles (Fig. 11) with fairly long and irregular intervals between the calls. Shortest inter-call interval 7 s

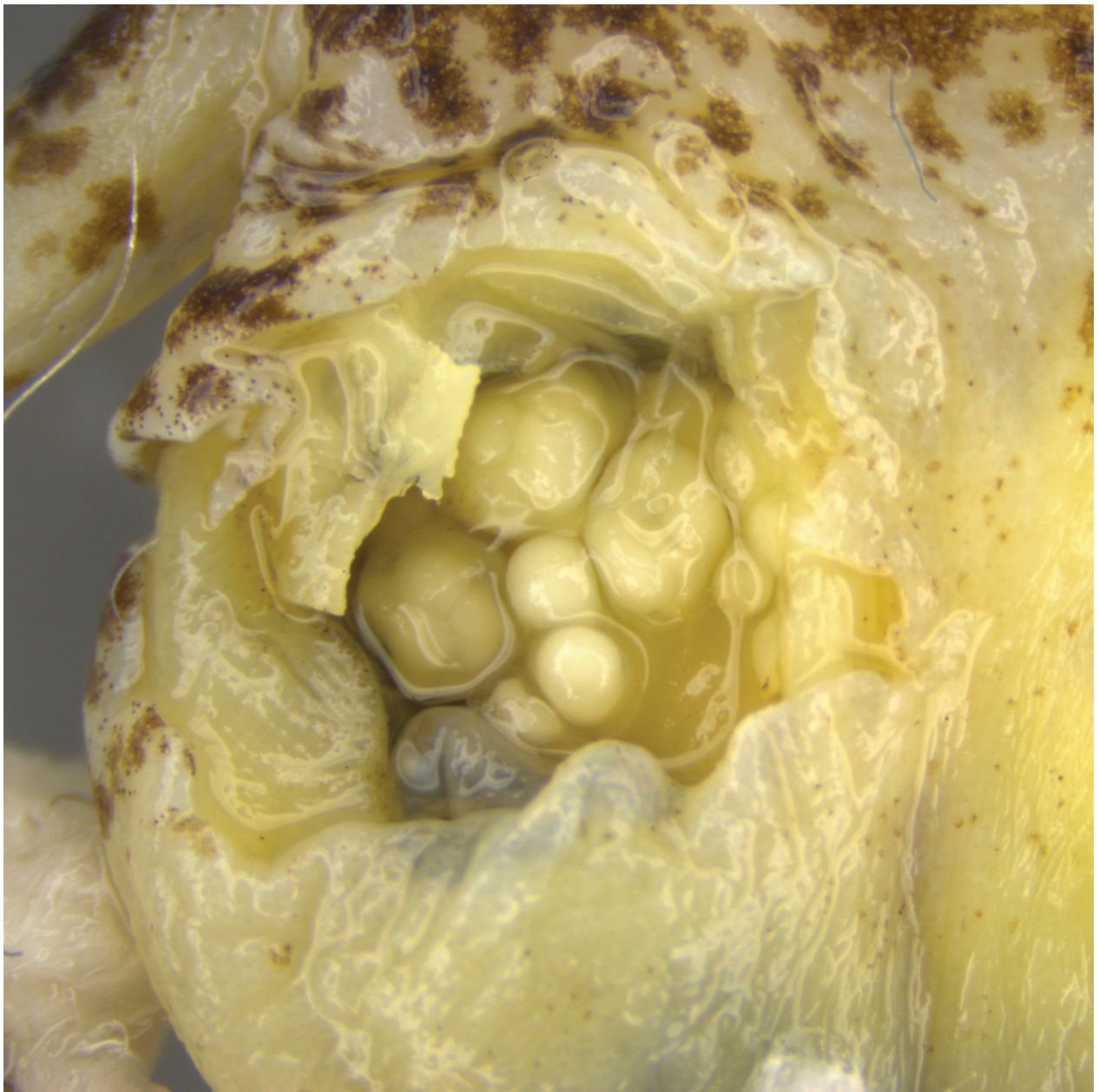
and longest 58 s. Thirty-nine calls of three males, (MZB Amph.12166–168), all recorded at 24 °C, were analysed. Mean duration of these calls was 0.53 s, SD 0.16, range 0.42–0.55 s. Mean number of notes/call 7.2, SD 0.77, range 6–8. Mean of means of note length 43.6 ms, SD 1.39, range 41–46 ms, total range of note length 32–50 ms. Mean of means of internote interval length 31.2 ms, SD 2.0, range of means 26–33 ms, total range 21–41 ms. Mean repetition rate 14.3 notes/s, SD 0.51, range 13.5–15.6 notes/s. First note of almost all calls the shortest, and last interval the longest of all inter-note intervals. All notes are composed of many dense pulses. Their amplitude rises rapidly up to maximal level, remains stable on this level over most of the note and then drops gradually to the end of the note. Frequencies scatter from 2.5 to 3.25 kHz with dominant frequency at 2.9 kHz (Fig. 12). Harmonics are very weakly expressed and there is no modulation of frequencies (Fig. 11 below).

**Distribution and ecological remarks.** *Cophixalus salawatiensis* sp. n. is currently known only from one location on Salawati Island in the Raja Ampat Island group off western New Guinea (Fig. 1). It was common in moderately logged lowland rainforest where males called from the surfaces of leaves in low foliage ~30 cm – 1.5 m above the ground after heavy rain at night. Intensive searches on nearby Batanta and Waigeo islands failed to detect this species there despite similar climatic conditions and strong activity of other frogs. This suggests that *C. salawatiensis* sp. n. probably does not occur there. A recently collected *Cophixalus* specimen (NME A2216/15 in the “Naturkundemuseum Erfurt, Germany”) represents the first evidence of the genus *Cophixalus* from Misool Island. The specimen, a male, was collected by D. Telnov on 20 March 2009 from inside a rotten log where it guarded (at least) five rather well developed eggs in a “primeval moist lowland forest, district Misool Utara, Aduwey, valley of River Ifeyo, 01°58'41''S and 129°55'18''E”. It measures 21.2 mm SUL and is morphologically most similar to *C. salawatiensis* but without knowledge of its advertisement calls we refrain from confirming the species’ presence there. However it is biogeographically interesting to confirm that the genus *Cophixalus* also occurs on Misool. It is not known whether *C. salawatiensis* occurs on the nearby New Guinea mainland.

**Etymology.** The latinized specific epithet *salawatiensis* means that the new species occurs on Salawati Island off the western tip of New Guinea.

**Comparison with other species** (see species comparison section for *C. rajampatensis* for specific size ranges of all congeners discussed below). *Cophixalus amabilis*, *ateles*, *bewaniensis*, *desticans*, *humicola*, *interruptus*, *iovaorum*, *kethuk*, *linnaeus*, *melanops*, *misimae*, *phaeobalis pictus*, *pipilans*, *tagulensis*, *timidus*, *tomaiodactylus*, *tridactylus*, *variabilis*, *verecundus*, *viridis* and *wempi* all have adult

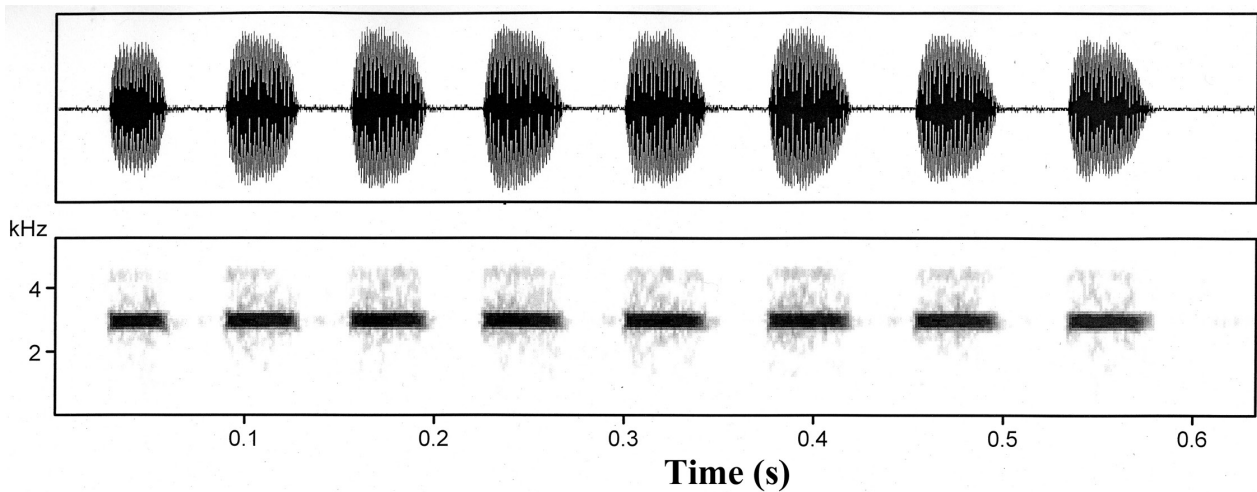




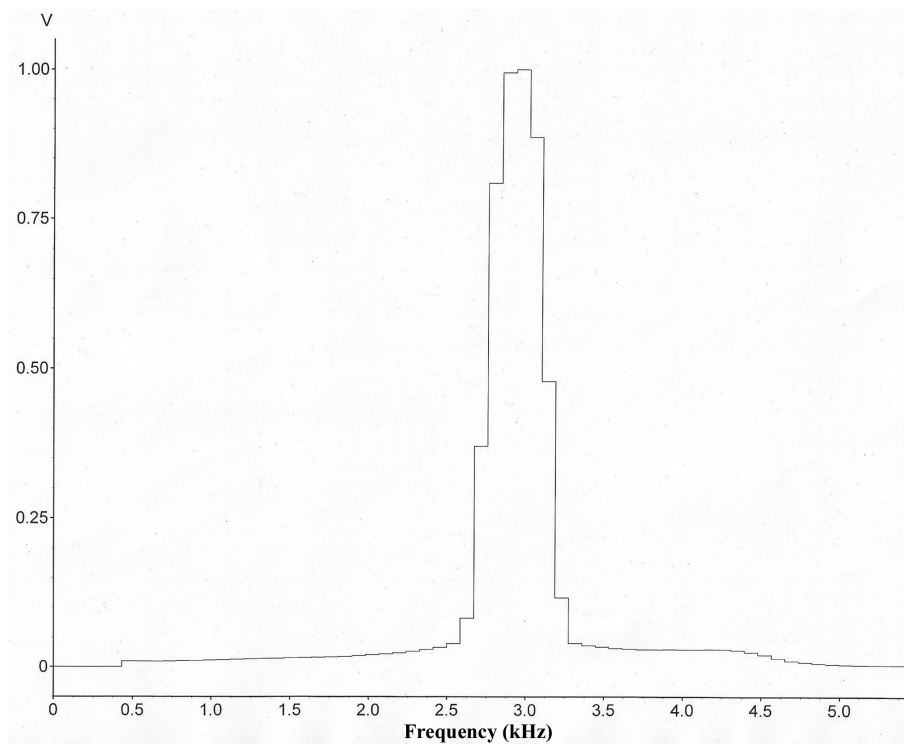
**Figure 10.** Ventral view of the opened up abdomen of *Cophixalus salawatiensis* sp. n., MZB Amph.12166, showing eggs of different developmental stages in a specimen with vocal slits that was recorded calling.

male SUL's of less than 19 mm and so can be immediately distinguished from *C. salawatiensis* (SUL 19.6–22.5 mm). With an SVL of 15.7 mm the only known specimen of *Cophixalus pictus* Kraus is smaller than *C. salawatiensis* but its description was based on a rather poorly preserved (and presumed immature) male from the Bomberai Peninsula of West Papua Province (Kraus 2012) and, if immature, this distinction could disappear once adult material has been documented. However *C. salawatiensis* also differs from *C. pictus* in a number of features that are unlikely to reflect the immature status of the holotype and only known specimen, including having (vs. lacking) a distinct supratympanic fold, in having longer legs (TL/SUL 0.49–0.53 vs. TL/SVL 0.47) and in having a very dif-

ferent ratio of internarial distance to eye-to-naris distance (END/IND 0.76–0.94 vs. 1.08 in *C. pictus*) (Kraus 2012). *Cophixalus balbus*, *biroi*, *caverniphilus*, *cheesmanae*, *clapporum*, *cryptotympanum*, *cupricarenus*, *kaindiensis*, *montanus*, *nubicola*, *parkeri*, *riparius* and *verrucosus*) all have minimum adult male body sizes > 23 mm and so can also be distinguished from *C. salawatiensis* sp. n. (SUL 19.6–22.5 mm). From the species of about the same size *C. albolineatus* has finger discs smaller than toe discs, while in the new species finger discs are of the same size or larger than toe discs. *Cophixalus shellyi* has a short, strongly reduced first finger (vs. normal length with moderately large disc in *salawatiensis*) and *C. sphagnicola* and *C. tenuidactylus*, in contrast to *C. salawatiensis*,



**Figure 11.** Wave form (above) and spectrogram (below) of an advertisement call of *Cophixalus salawatiensis* sp. n. consisting of eight notes.



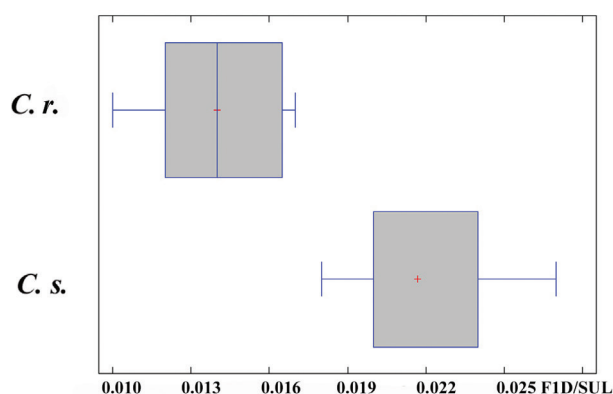
**Figure 12.** Power spectrum of an advertisement call of *Cophixalus salawatiensis* sp. n.

completely lack discs on fingers and toes. *C. daymani* and *C. nubicola* are distinguished by their very short hind legs (TL/SUL less than 0.48 vs. more than 0.49 in *C. salawatiensis* sp. n.). *Cophixalus nexipus* differs by having basal webbing on toes and advertisement calls consisting of a single, long note lasting more than one second (vs. 6–8 notes). *Cophixalus pulchellus* Kraus & Allison has a dorsum boldly blotched with black on a light grey background (vs. uniform in *C. salawatiensis*).

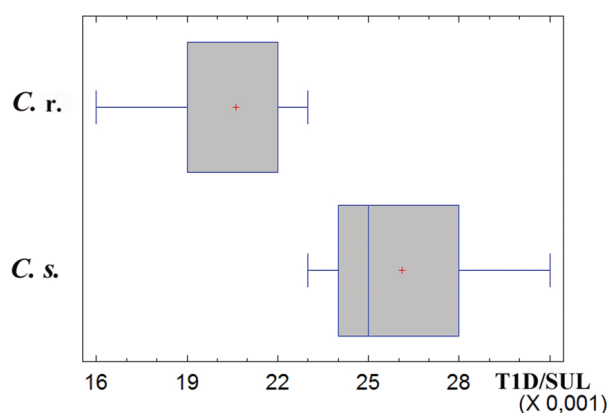
In external morphology, *C. tetzlaffi*, *C. monosyllabus* and the above described *C. rajampatensis* exhibit most similarities to *C. salawatiensis* sp. n.

*Cophixalus tetzlaffi* has clearly smaller discs on finger one and toe one than *C. salawatiensis* sp. n. – the ratio F1D/SUL in 8 specimens of *C. tetzlaffi* is 0.016, SD 0.0016, range 0.014–0.018; mean of the same ratio in 10 specimens of *C. salawatiensis* sp. n. is 0.022, SD 0.0031, range 0.018–0.027; mean of the ratio T1D/SUL in *C. tetzlaffi* is 0.020, SD 0.0019, range 0.018–0.023 and in *C. salawatiensis* sp. n. 0.026, SD 0.0028, range 0.023–0.031. These species also have different advertisement calls – calls of *C. tetzlaffi* consist of 3–4 notes with note lengths of more than 300 ms, those of *C. salawatiensis* sp. n. consist of 6–8 notes with a note length of less than 50 ms.

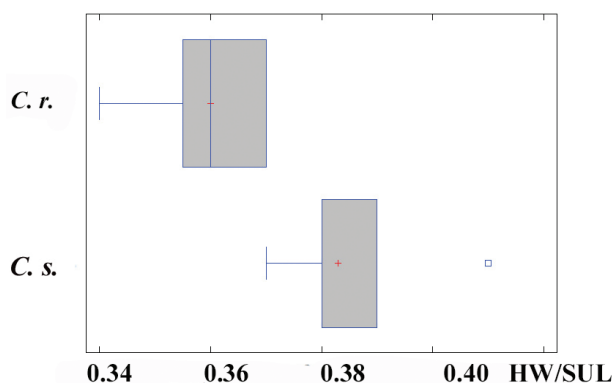




**Figure 13.** Box-Whisker-Plot of the ratio F1D/SUL of eight males of *Cophixalus rajampatensis* sp. n. (*C. r.*) and ten males of *C. salawatiensis* sp. n. (*C. s.*).



**Figure 14.** Box-Whisker-Plot of the ratio T1D/SUL of eight males of *Cophixalus rajampatensis* sp. n. (*C. r.*) and ten males of *C. salawatiensis* sp. n. (*C. s.*).



**Figure 15.** Box-Whisker-Plot of the ratio HW/SUL of eight males of *Cophixalus rajampatensis* sp. n. (*C. r.*) and ten males of *C. salawatiensis* sp. n. (*C. s.*).

*Cophixalus monosyllabus* is morphologically very similar to *C. salawatiensis* sp. n. and, although the species differ significantly in body size [mean SUL of the former ( $n=10$  adult males) 22.9 mm, SD 1.04, range 20.6–24.3 mm and of the latter ( $n=10$  adult males) 20.8 mm, SD

0.94, range 19.6–22.5 mm ( $p=0.001$  for comparisons of medians)], there is substantial overlap in SUL. The species also differ significantly in size of disc of third finger - mean ratio F3D/SUL in *C. monosyllabus* 0.063, SD 0.004, range 0.055–0.071 and in *C. salawatiensis* sp. n. 0.053, SD 0.003, range 0.049–0.058 ( $p=0.0004$  for comparison of medians) but again there is some overlap. However these species have consistently and strikingly different advertisement calls – in *C. monosyllabus* these consist of single notes with a duration of more than 140 ms vs. 6–8 notes with note duration not longer than 50 ms in *C. salawatiensis* sp. n. and we consider these differences sufficient to warrant their recognition as distinct species.

*C. rajampatensis* ( $n=8$ ) and *C. salawatiensis* sp. n. ( $n=10$ ) have non-overlapping body sizes (17.6–19.5 vs. 19.6–22.5 mm) and further differ in the following body ratios: F1D/SUL 0.010–0.017 (mean 0.014) in the former vs. 0.018–0.027 (mean 0.022) in the latter, (Fig. 13); T1D/SUL 0.016–0.023 (mean 0.021) vs. 0.023–0.031 (mean 0.26),  $p=0.0005$  (Fig. 14); HW/SUL 0.34–0.37 (mean 0.36) vs. 0.37–0.41 (mean 0.38),  $p=0.0009$  (Fig. 15), and T1D/F1D 1.33–1.75 (mean 1.48) vs. 1.00–1.50 (mean 1.22),  $p=0.002$ .

*Cophixalus rajampatensis* and *C. salawatiensis* sp. n. also differ in their advertisement calls; calls of the former consist of 2–5 notes per call, note length 142–238 ms, 3.3–4.6 notes/s vs. 6–8 notes per call, note length 32–50 ms, 13.5–15.6 notes/s in the latter.

## Acknowledgements

Field work in the Raja Ampat Islands was supported by Conservation International and the South Australian Museum. We are extremely grateful to Yance deFretes, Muhamad Farid and Jatna Supriatna of Conservation International, and to Herlina Kafiari, Rizana Kurniati, Elias Kore, Sofia Roni, Arthur Tipawael and Adelina Werimon for assistance in the field. We are also extremely grateful to the Indonesian Institute of Sciences (LIPI) for their support and approval of specimens export and to the Forestry Department, especially Balai KSDA Papua 2, Sorong and Directorate Jenderal PHKA. We thank Mark Hutchinson and Carolyn Kovach for assistance at the South Australian Museum, Ulrich Scheidt (Naturkundemuseum Erfurt) for lending frogs from Misool, Paul Oliver and James Menzies for constructive comments on the manuscript and Lukas Kirschey (Museum für Naturkunde Berlin) for producing Figures 2c, 2d, 9c, 9d and 10.

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