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Supplementary morphological information for *Cornufer manus* (Kraus & Allison, 2009) and *Cornufer vogti* (Hediger, 1934), with information on colour in life

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Abstract. Manus Island is part of the Admiralty Islands, a herpetologically rich but poorly studied area. Seven species of *Cornufer* (von Tschudi, 1838) are known to occur on the island, five of which have been described. Based on material collected from Manus Island in 2014, we here describe the first female of *Cornufer manus* and the first male of *Cornufer vogti*. Additionally, we provide new information on intraspecific variation from a further eight adult males of *C. manus*, two subadults of *C. vogti*, as well as the first photographs of both species in life.

Key words: Papua New Guinea, Admiralty Islands, Manus, Ceratobatrachidae

Introduction

The Admiralty Islands are an isolated group of islands about 275 km north of mainland Papua New Guinea (Richards et al. 2007). The Admiralty Islands are part of the larger Bismarck Archipelago, which, together with the Solomon Islands and islands of Vanuatu, form the East Melanesian biodiversity hotspot that hosts many (endemic) frog species. Manus Island,

with 181,000 hectares, is the largest island of the Admiralty Islands and, much like the other islands in the Archipelago, resulted from volcanic activity in the Upper Eocene and has been isolated since then (Lindley 2006). The island is home to three genera of frogs, one of which is *Cornufer*, with the other two being *Litoria* and *Papurana* (Richards et al. 2007). *Cornufer* is a speciose genus of Ceratobatrachidae that is widely distributed in Oceania. *Cornufer* was, until

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recently, synonymised with *Platymantis*, a genus now restricted to frogs from the Philippines (Brown et al. 2015). These direct-developing frogs occupy both terrestrial and arboreal habitats, primarily in forested areas (Brown et al. 2015), and have clear morphological adaptations of the terminal discs on fingers and toes associated with their respective ecologies. Currently, 58 species are known, but estimates suggest that this is a major underrepresentation of the actual number of species (Brown et al. 2006, 2013, Kraus & Allison 2009, Frost 2021). While there is a high morphological diversity in the genus, many species share similar morphologies, explaining why many cryptic species remain to be described (Brown et al. 2015, Richards & Aplin 2015). The Bismarck Archipelago is home to 24 species of *Cornufer*, five of which are endemic to the Admiralty Archipelago (*C. admiraltiensis*, *C. custos*, *C. latro*, *C. manus* and *C. vogti*) (Hediger 1934, Richards et al. 2007, 2015, Kraus & Allison 2009). Two additional species from Manus remain undescribed (Richards & Aplin 2015).

Cornufer vogti was the first species described from the Manus region (the type locality is Rambutyo Island, 50 km southeast of Manus) and is based on one female specimen (Hediger 1934). *Cornufer manus*, on the other hand, is one of the more recently described species, being described from Manus Island in 2009 and is endemic to the island (Kraus & Allison 2009). More recent fieldwork (by J.R. Clegg, P.N. Taylor, and M.M.T. Jocque, but also Richards et al. 2007) in the region allowed for the collection of additional material of these species, but until now, no description of a male *C. vogti* or a female *C. manus* specimens exists, even though such a description would provide valuable taxonomic information. In this paper, we describe the male and two subadults of *C. vogti* and the female and multiple males of *C. manus* and provide new information on colouration in life and the first photographs of both species in life.

Material and Methods

All morphometric measurements were taken using digital callipers to the nearest 0.1 mm under a stereomicroscope. All measurements were taken three times by the same person (M.P.J. Nicolai) and averaged. Measurements, terminology and abbreviations follow the original description of *C. manus* (Kraus & Allison 2009): body length from snout-vent (SV); tibia length from heel to outer surface of flexed knee (TL); horizontal diameter of eye (EY); distance from anterior corner of eye to centre of naris (EN); internarial distance, between centres of external

nares (IN); distance from anterior corner of eye to tip of snout (SN); head width at widest point, typically at the level of the tympana (HW); head length, from tip of snout to posterior margin of tympanum (HL); horizontal tympanum diameter (TY); length of hand from proximal margin of inner metacarpal tubercle to distal margin of third finger disc (HAND III); length of foot from proximal margin of inner metatarsal tubercle to distal margin of fourth toe disc (FOOT); width of the third finger disc (WFD); width of the fourth toe disc (WTD). In addition, we followed Kok et al. (2018) and also measured interorbital distance (the shortest distance between the two eyes) (IOD); tip of snout length, measured from centre of naris to tip of snout (TSL); length of fingers 1 (HAND I), 2 (HAND II) and 4 (HAND IV), measured from the proximal edge of the palmar tubercle forearm length; from outer surface of elbow joint to proximal edge of metacarpal tubercle (FAL); thigh length, from vent opening to outer surface of flexed knee (THL); and tarsus length (TL), from outer surface of heel to proximal edge of outer metatarsal tubercle. The sex of adults was determined by the presence of mature testes in males, enlarged ova in females in addition to the presence/absence of vocal slits.

Results

Identification

Specimens were identified based on morphology (Richards et al. 2007, 2015, Kraus & Allison 2009, Richards & Aplin 2015). Diagnostic features of *C. manus* included the combined presence of expanded finger discs (excluding *C. admiraltiensis* and *C. latro*), the absence of a narrow snout (excluding *C. custos*) and small body size (excluding *C. vogti*), albeit bigger than *Cornufer* sp. nov. 1 *sensu* Richards & Aplin (2015), which is reported to be tiny, i.e. smaller than 22 mm body length (Richards & Aplin 2015). We also compared the male and female specimens of *Cornufer* sp. nov. 2 *sensu* Richards & Aplin (2015). We found congruence with Richards & Aplin (2015) that *Cornufer* sp. nov. 2 is larger, with more distinctly enlarged fingers and toe discs and is broad-headed compared to the specimens we assign to *C. manus*. Specimens were assigned to *C. vogti* based on their large size, absence of finger discs and extensive webbing between toes, thus excluding all other *Cornufer* species on the island (Hediger 1934, Menzies 2006).

Species accounts

Cornufer manus (Kraus & Allison, 2009), type locality is Manus Island.



Fig. 1. (A) dorsum, (B) venter, (C) palmar view of hand and (D) side of head, of the single known female specimen of *Cornufer manus* (RBINS 18298), (photo Michaël Nicolai).

Material examined: RBINS 18298 (Field no. PNG14-179), adult female, Yiringou Village, Manus Island, Papua New Guinea (2.0388 S, 147.2371 E), collected 9 December 2014 by Clegg, Taylor and Jocque; RBINS 18295-18297 and RBINS 18299-18303 (Field no. PNG14-108, PNG-109, PNG14-138, PNG14-180, PNG14-181, PNG14-182, PNG14-185, PNG14-199), adult males, same information, except collected on 6, 7 and 9 December 2014.

Description of female: An adult (Fig. 1.), showing clear size difference with previously described males and males present in the RBINS collections, lacking vocal slits and with enlarged ova. Head wide (HW/SV = 0.41), almost as long as wide (HL/HW = 0.97), with vertical loreal region and rounded lip; canthus rounded, straight when viewed from above; nostrils small, directed laterally, much closer to tip of snout than to eyes; internarial distance less than distance from naris to eye (EN/IN = 1.23); snout rounded in lateral view, acutely rounded when viewed from above; eyes large (EY/SV = 0.12); pupil horizontal; tympanum relatively distinct, reasonably large (TY/SV = 0.08), approximately three-quarters width of eye (TY/EY = 0.71), which is notably larger than in males (TY/EY < 0.62), with distinct annulus. Supratympanic fold short and poorly defined. Dorsal, lateral, and ventral surfaces smooth. Fingers basally webbed, relative lengths II > IV > II > I; tips flattened into wide discs (WFD/SV = 0.06) bearing terminal grooves, much wider than penultimate phalanges. Subarticular and metacarpal tubercles well-developed. All toes with basal webbing, bearing flattened discs with terminal grooves (WTD/SVL = 0.04); relative lengths IV > III > V > II > I. Toe discs smaller than finger discs (WFD/WTD T = 1.34). Subarticular tubercles well-developed; inner metatarsal tubercle large and oval; outer small

and oval; plantar surface lacking supernumerary tubercles. Hind limbs moderately long (TL/SV = 0.54).

Colour in preservative: Dorsal background colour is dark brown, heavily mottled with darker brown (Fig. 1A-D). A distinct, purple-brown interorbital line, eyelids darker. Top of limbs barred with darker brown. Loreal region is dark brown. Unlike males, the upper lip and face are brown. Sides light straw-coloured, minutely stippled with black and dark brown, stippling denser dorsally, becoming sparser ventrally. Rear of thighs is light straw-coloured, heavily blotched with dark brown. Tympanum light straw-coloured with a brown blotch on upper third. Venter light straw-coloured, heavily stippled with dark brown, blotched with dark brown in throat region, sparsely stippled posteriorly. Palmar and plantar surfaces are dark brown with minute light straw-coloured punctuations. Palmar and plantar tubercles light straw-coloured.

Measurements of female (in mm): SV = 32.3, TL = 17.5, HW = 13.2, HL = 12.9, IN = 2.7, EN = 3.4, SN = 5.9, EY = 3.8, TY = 2.7, WFD = 1.9, WTD = 1.5, IOD = 3.6, TSL = 2.8, Hand I = 5.2, HAND II = 6.1, HAND III = 9.2, HAND IV = 7.4, FAL = 8.6, THL = 15.1, TAL = 9.3, FOOT = 15.9.

Colour in life: Based on photographs of all specimens (Fig. 2). Male colour pattern was similar among specimens in that it is cryptic. Dorsal ground colour varies from hazel brown, heavily mottled with dark brown to straw-coloured yellow without blotches (e.g. RBINS 18301). Most specimens have a dark brown W-shaped pattern mid-body on the back; however, it is absent in the most unpigmented (i.e. loss of dark brown colouration) individual (RBINS

Table 1. Mensural data for male specimens of *Cornufer manus*.

Character	Mean (n = 8)	Range
SV	26.4	24.9-28.4
HW	10.0	9.5-10.7
HL	10.5	9.9-11.0
IOD	3.2	2.9-3.7
IN	2.0	1.7-2.3
EN	2.8	2.5-3.4
SN	4.8	4.1-5.3
TSL	1.5	1.3-1.8
EY	3.3	2.7-3.8
TY	2.0	1.8-2.2
HAND I	4.0	3.6-4.8
HAND II	5.2	4.8-5.5
HAND III	7.3	6.8-7.9
HAND IV	5.9	5.5-6.5
WFD	1.5	1.4-1.7
FAL	6.8	6.3-7.5
THL	12.8	11.2-14.0
TL	14.2	13.3-14.9
TAL	7.2	6.7-7.7
FL	12.6	11.7-13.6
WTD	1.0	0.7-1.2

18301). A distinct interorbital line can range from a straw-coloured, simple, thin line to an interorbital bar. Upper third of tympanum dark brown, lower two-thirds cream. Upper lip dark brown with straw-coloured marbling. Iris golden-brown. Sides light straw-coloured, minutely stippled with dark brown, stippling denser dorsally, sparser ventrally. Venter cream with dark mottling, slightly translucent. Top of limbs barred with darker brown, more pronounced in lighter individuals. Finger discs are paler than digits. Groin, thighs, and front of shanks ventrally bright orange-red. Unfortunately, no photograph in

life was taken, nor were there any notes of the female specimen.

Interspecific variation: The sole female differs from males in being slightly bigger (males 24.9-28.4 mm, female 32.3 mm). A side-by-side comparison shows that females have marginally more webbing on their hands than males. Morphometric variation among males can be found in Table 1. Colouration in preservative is highly variable. Dorsal colour varies from dark brown to light grey. Most specimens have a dorsal dark brown W which is most apparent in individuals with a lighter colour (RBINS 18302, RBINS 18299), although it seems to be absent in the most lightly pigmented individual (RBINS 18301). Most specimens have a lighter interorbital bar that varies in intensity from brown to pale tan, bordered by a darker bar having the same colour as the eyelids. Ventral colouration is variable, ranging from an almost white ground colour with only a few minute pigmented flecks in the throat region (e.g. RBINS 18300) to dark individuals with a dark brown ground colour with light blotches (e.g. RBINS 18295). In all specimens, pigmentation is pronounced in the throat region. Limbs have barring that varies in distinctness, being more distinct in bright animals and less distinct in darker specimens.

Ecology and distribution: *Cornufer manus* is a scansorial species; all animals were found at night close to fresh water (i.e. small streams and ponds) on leaves or on tree trunks between 30 cm and 150 cm above ground level. Previous work in the region (Richards & Aplin 2015) shows that the species is found at least 5 m above the ground in primary forest and heavily disturbed habitats such as village gardens. Yiringou Village is located around 20 km southwest of Lorengau, the type locality of *C. manus*. It appears that *C. manus* is present in a variety of habitats and thus occupies at least part of the island, potentially across the entire island (Fig. 3).



Fig. 2. Portraits of three male specimens of *Cornufer manus*. (A) RBINS 18296, (B) RBINS 18300, and (C) RBINS 18297, (photo Merlijn Jocque).

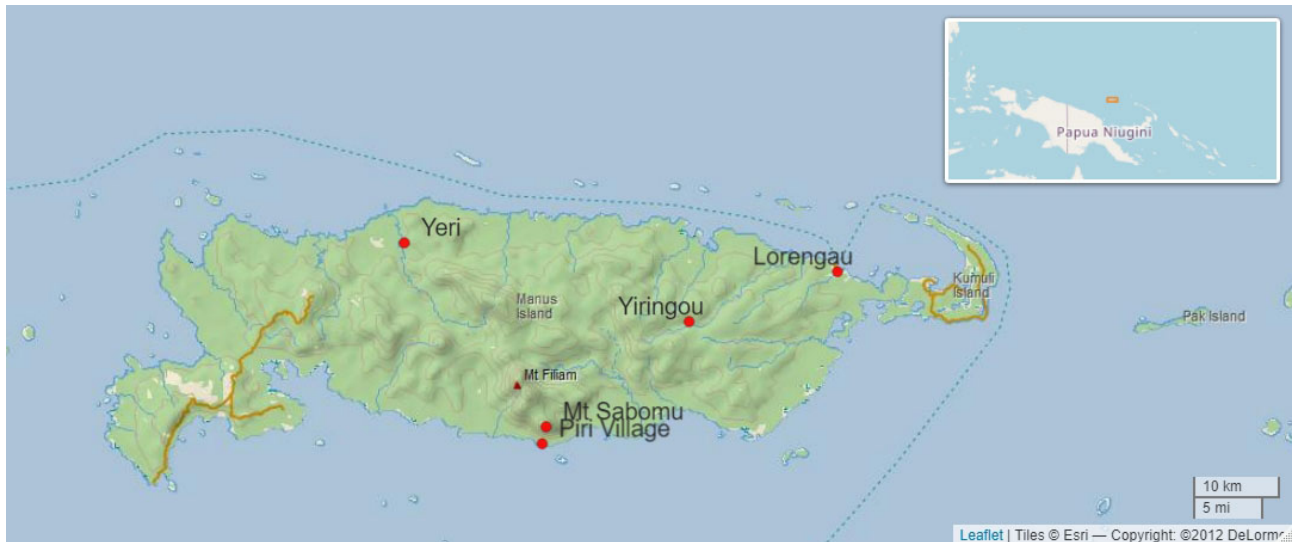


Fig. 3. Known occurrences of *Cornufer manus*. Yiringou, Mount Sabomu (Richards et al. 2015), Piri village (Richards et al. 2015), Yeri (Richards et al. 2015), Lorengau (Kraus & Allison 2009).

Cornufer vogti (Hediger, 1934), type locality is Rambutyo Island.

Material examined: RBINS 18633 (Field no. PNG14-144), adult male, Yiringou Village, Manus Island, Papua New Guinea (2.0388 S, 147.2371 E), collected 7 December 2014 by Clegg, Taylor and Jocque; RBINS 18634-18635 (Field no. PNG14-143 and PNG14-198), subadults, the same information as above, except collected on 7 and 11 December 2014.

Description of male: An adult male (Fig. 4) showing a clear size difference compared to the female holotype and having distinct vocal slits. Head wide

(HW/SV = 0.39), longer than wide (HL/HW = 1.18); canthus rounded, sloped when viewed from above; nostrils small, directed dorsolaterally, much closer to tip of snout than to eyes; internarial distance less than distance from naris to eye (EN/IN = 1.53); snout rounded when viewed from the side, pointed when viewed from above; eyes large (EY/SV = 0.13) placed dorsally; tympanum relatively distinct, small (TY/SV = 0.05), smaller than half width of eye (TY/EY = 0.39), with distinct annulus. Pupil horizontal. Supratympanic fold distinct, running until base of arm. Dorsal, lateral, and ventral surfaces smooth. Fingers lack webbing, relative lengths III > IV > II ≈ I; tips without distinct discs (WFD/SV = 0.01).

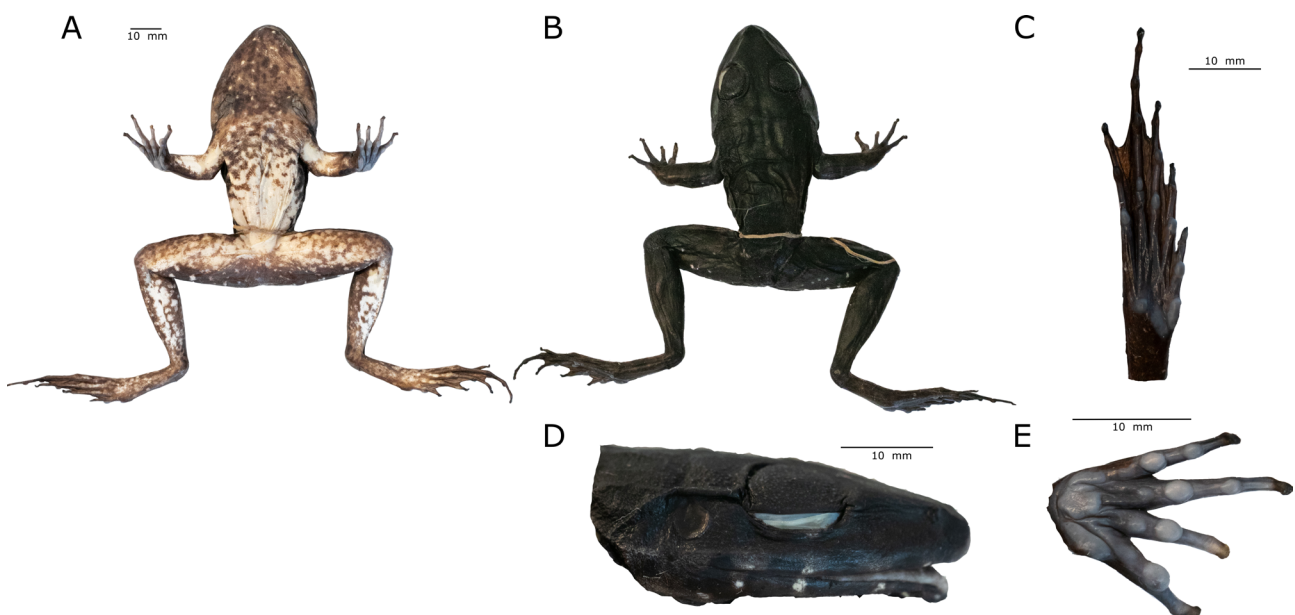


Fig. 4. (A) Venter, (B) dorsum, (C), ventral view of foot, (D) side of head, (E) palmar view of hand of the single known male specimen of *Cornufer vogti* (RBINS 18633), (photo Michaël Nicolai).

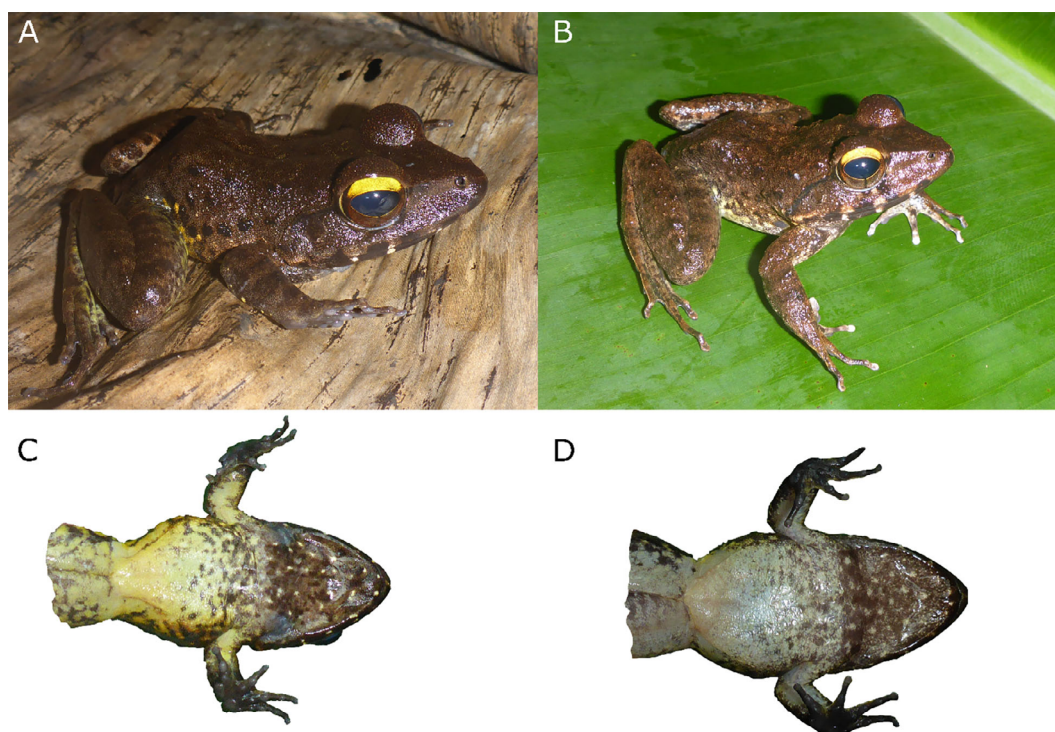


Fig. 5. Portraits of a male adult (RBINS 18633) specimen (A) and (C) and a juvenile (RBINS 18634) specimen (B) and (D) of *Cornufer vogti*. (C) and (D) show ontogenetic differences in ventral colouration, with adult male being more yellow than juvenile (photo Merlijn Jocque).

Subarticular and metacarpal tubercles well-developed. All toes with extensive webbing, having small discs (WTD T/SVL = 0.02); relative lengths IV > III > V > II > I. Toe discs larger than finger discs (WFD/WTD T = 0.91). Subarticular tubercles well-developed; inner metatarsal tubercle large, elongated and oval; outer small and oval; plantar surface lacking supernumerary tubercles. Hind limbs moderately long (TL/SV = 0.53).

Measurements of male (in mm): SV = 83.2, HW = 32.4, HL = 38.1, IN = 6.6, EN = 10.2, SN = 16.0, EY = 11.1, TY = 4.3, WFD = 1.2, WTD = 1.4, IOD = 7.1, TSL = 5.3, Hand I = 15.7, HAND II = 15.7, HAND III = 19.7, HAND IV = 17.1, FAL = 16.5, TL = 44.4, THL = 41.6, TAL = 20.3, FOOT = 42.7.

Colour in preservative: Dorsal ground colour is very dark brown in male and juvenile specimens (Fig. 4A-E). Tympanum is the same colour as dorsum, coloured centre but slightly lighter outer ring. Upper lip dark brown with faint white bars, lower lip dark brown-purple coloured with white dots. Iris milky white. Upper sides dark with small and larger white dots and blotches, lower side white. Venter white with large, dark brown blotches, becoming denser towards the throat. Throat dark brown with black and white dots. Throat slightly less dark in subadults compared to adult male. Dorsal face of limbs is the

same colour as dorsum, with posterior sides bearing white dots. Ventral sides of limbs are white with dark mottling. Webbing is the same colour as dorsum.

Colour in life: Dorsal colour of all specimens is dark brown with dark, almost black, blotches (Fig. 5). Tympanum is also dark brown. Iris bicolor, bright golden above pupil and darker yellow-brown below the pupil. Upper and lower lips alternatively dark brown and white. White patches are always smaller than dark brown patches. The regions between the two patches on the upper lip gradually fade from one colour to the other. Lower lip has more clear-cut borders with more distinct white patches. Sides are dark brown with darker brown and yellow blotches, which become larger ventrally where they merge, and the ground colour becomes yellow. Throat dark brown with distinct whitish spots. Ground colour of venter differs between the adult male and the subadults, being white in subadults and yellow in adult. Anterior part of venter blotched with darker brown in both life stages. Dorsal face of limbs barred with even darker brown. Finger discs paler than digits. Groin, thighs, and front of shanks ventrally dark brown marbled with the same colour as venter.

Interspecific variation: Based on the presence of ova in the description of the holotype (Hediger 1934), the holotype is considered a female. Only a few

Table 2. Mensural data for subadults and holotype of *Cornufer vogti*.

Character	Mean (mm) (n = 2)	Range	Holotype (mm) (Hediger, 1934)
SV	54.3	51.7-56.9	158
HW	21.8	19.7-23.8	70
HL	24.7	22.6-26.7	
IOD	5.1	4.6-5.5	20
IN	4.4	3.9-4.9	
EN	7.2	6.8-7.60	
SN	10.8	10.4-11.1	
TSL	3.5	3.2-3.9	
EY	7.5	6.6-8.5	
TY	3.1	3.1	8
HAND I	11.2	11.1-11.4	
HAND II	11.3	11.0-11.8	
HAND III	14.2	14.0-14.5	
HAND IV	11.8	11.7-11.9	
WFD	0.8	0.83	
FAL	11.7	10.5-12.8	
THL	27.3	26.1-28.5	58
TL	29.9	28.3-31.4	68
TAL	13.3	13.3-13.3	
FL	28.6	27.3-29.8	97
WTD	0.9	0.8-1.0	

measurements and ratios were mentioned making comparison limited (Table 2) (Hediger 1934). Sexual dimorphism is distinct, with the female being almost twice as large as the males. All individuals (both sexes and both life stages) share that HAND I and HAND II are approximately the same sizes. The ratio of TYM/EYE is approximately 0.4 in both male and female individual but varies in the subadults, with the smallest juvenile having a higher ratio (TYM/EYE = 0.5). Similarly, the ratio of TYM/SVL is approximately 0.05 in all specimens, being only marginally larger in the subadults (TYM/SVL = 0.06). Comparison of colour in preservative is difficult as the holotype is highly discoloured, now appearing uniformly cream-brown. Ventrally the holotype is white.

Ecology and distribution: No new ecological information was collected for this species.

Discussion

The information provided here helps to fill some gaps in the herpetological knowledge of the East Melanesian biodiversity hotspot. The paucity of

information on frogs in the region can be appreciated in how the descriptions are based on small numbers of specimens. *Cornufer vogti* was described in 1934 from a single female (based on the small size and the presence of ova), and *C. manus* was described in 2009 from two males in a 35-year-old museum collection (MCZ). Also, other *Cornufer* from the Bismarck Archipelago, and Manus specifically, were described based on few specimens and often from one sex only, e.g. *C. sulcatus* (Kraus & Allison, 2007), *C. bufonulus* (Kraus & Allison, 2007), *C. citrinospillus* (Brown et al., 2013), *C. nakanaiorum* (Brown et al., 2006), *C. mamusiorum* (Foufopoulos et al., 2004), *C. macrosceles* (Zweifel, 1975) and *C. mimicus* (Brown & Tyler, 1968).

Documenting more morphological features helps to understand the frog diversity on the island better and hopefully sets a better base for monitoring in the future. Live photographs from many frog species in Manus are lacking but are, together with detailed morphological descriptions, critical first steps towards a reliable identification in the field and further data collection on the distribution



and the ecology of these species. The documented morphological variation presented here illustrates the value of a detailed description of both sexes and, if possible, of multiple life stages. For example, while juvenile *C. vogti* have a white belly, it is yellow in adult males. Such information is not available for females, even though ontogenetic colour change (that is potentially sexually dichromatic) might be an important life-history trait related to communication and sexual selection (Bell & Zamudio 2012).

Filling the gaps in species knowledge substantiating the morphological variation and ecology is sometimes underestimated but is an important part of deepening our understanding of amphibians species. The broader documentation of missing information such as colour in life, bioacoustics, ecological information and, if necessary, more in-depth descriptions of males and females should be stimulated, especially in hard-to-reach and understudied regions.

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Author Contributions

Specimen collection (M.M.T. Jocque, J.R. Clegg, P.N. Taylor), morphological data collection (M.P.J. Nicolai, S. Porchetta), manuscript writing (M.P.J. Nicolai, S. Porchetta, M.M.T. Jocque), revision of the manuscript (all authors).

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