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New species of Mongrel Frogs (Pyxicephalidae: *Nothophryne*) for northern Mozambique inselbergs

Werner Conradie ^{a,b}, Gabriela B. Bittencourt-Silva ^c, Harith M. Farooq ^{d,e,f},
Simon P. Loader ^g, Michele Menegon ^h and Krystal A. Tolley ^{i,j}

^aPort Elizabeth Museum (Bayworld), Marine Drive, Humewood 6013, South Africa; ^bSchool of Natural Resource Management, George Campus, Nelson Mandela University, George 6530, South Africa; ^cDepartment of Environmental Sciences, University of Basel, Basel 4056, Switzerland; ^dFaculty of Natural Sciences, Lúrio University, Pemba, 958, Mozambique; ^eDepartment of Biology and CESAM, University of Aveiro, Aveiro, Portugal; ^fDepartment of Biological and Environmental Sciences and Gothenburg Global Biodiversity Centre, University of Gothenburg, Box 461, 405 30 Gothenburg, Sweden; ^gDepartment of Life Sciences, Natural History Museum, London SW5 5BD, United Kingdom; ^hTropical Biodiversity Section, Museo delle Scienze, Viale del Lavoro e della Scienza, 3, 38122 Trento, Italy; ⁱSouth African National Biodiversity Institute, Kirstenbosch Research Centre, Private Bag X7 Newlands 7700, Cape Town, South Africa; ^jCentre for Ecological Genomics and Wildlife Conservation, Department of Zoology, University of Johannesburg, Auckland Park 2000, Johannesburg, South Africa

ABSTRACT

Nothophryne Poynton, 1963 is a monotypic genus of frog, with the nominal species *N. broadleyi* found only on Mount Mulanje, in southern Malawi. Recent surveys in northern Mozambique, however, have uncovered at least four new species associated with four inselbergs (Mount Inago, Mount Namuli, Mount Ribáuè and Taratibu Hills). Previous phylogenetic analyses using mitochondrial genes suggest that each mountain isolate has an endemic species of *Nothophryne*. Herein we provide a rediagnosis of the genus and comparative diagnoses of four new species based on new material.

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KEYWORDS

Africa; amphibian; inselbergs; Pyxicephalidae; species; taxonomy

Introduction

Northern Mozambique is regarded as one of the most poorly studied areas in southern Africa particularly in terms of herpetofauna (Poynton & Broadley 1985; Tolley *et al.* 2016). In recent years, biological surveys of some of the many inselbergs have been conducted (e.g. Branch *et al.* 2005; Timberlake *et al.* 2007, 2009, 2012; Portik *et al.* 2013a; Bayliss *et al.* 2014; Farooq & Conradie 2015; Farooq *et al.* 2015; Conradie *et al.* 2016). These field studies have produced new records of range-restricted reptiles and amphibians and the discovery of new species (Branch & Bayliss 2009; Branch & Tolley 2010; Portik *et al.* 2013b; Branch *et al.* 2014). Given that species level phylogenies often reveal additional lineages, it has become clear that many taxonomic groups associated with these sky islands likely contain cryptic taxa (e.g. Branch & Tolley 2010; Branch *et al.* 2014).

The mongrel frog *Nothophryne broadleyi* Poynton (1963) was described from Mount Mulanje in southern Malawi as a monotypic genus. The species is named after the late

Zimbabwean herpetologist Don Broadley who was the first to collect this frog. Later, during an expedition to northern Mozambique lead by Don Broadley, two individuals of *Nothophryne* were collected from Mount Ribáuè (Blake 1965). Poynton (1966) assigned this material to the nominal species, *N. broadleyi*, although he noted a slight difference in hindlimb length and the presence of slightly expanded fingertips. He regarded these differences to be to minor and therefore not supporting its distinctiveness as a new species.

Nothophryne are relatively small frogs from the family Pyxicephalidae that are found on rocky outcrops associated with mossy patches and water rivulets from seepages. Their fingertips are swollen, which facilitate adherence on slippery rock surfaces (Poynton 1963, 1966). Eggs are laid on wet moss and the semi-terrestrial larvae are found in the thin water film over the rock surface. The landscape in northern Mozambique consists of numerous smaller granite inselbergs, as well as other larger mountains (e.g. Mount Namuli, Mount Inago and Mount Ribáuè), which was believed to be excellent habitat for *Nothophryne*.

In 2014 and 2017 we had the opportunity to visit Mount Ribáuè in the footsteps of Don Broadley, where we collected a series of *Nothophryne* specimens. We also collected additional material from other localities (Mount Namuli and Mount Inago, and Taratibu Hills) in northern Mozambique. Bittencourt-Silva *et al.* (2016) identified at least four cryptic lineages of *Nothophryne* from the above-mentioned mountains using the Bayesian mixed Yule-Coalescent model (bGMYC) for species delimitation and uncorrected pairwise distances between 16S ribosomal DNA sequences. Given those results, we use morphological and acoustic data to revisit the taxonomic status of the Mount Ribáuè population, as well as the additional populations on Mount Inago, Mount Namuli, and Taratibu Hills in northern Mozambique. Furthermore, we provide uncorrected pairwise distances (p-distances) between sequences of one nuclear and one mitochondrial genes of *Nothophryne*.

Materials and Methods

Sampling

Specimens referable to the genus *Nothophryne* were collected from northern Mozambique (Fig. 1; Bittencourt-Silva *et al.* 2016) between 2009 and 2017. The material was formalin-fixed for 48 hours and transferred to 70% ethanol for long-term storage in the herpetological collections of the Port Elizabeth Museum in South Africa (PEM), Natural History Museum in the United Kingdom (NHM UK), and the Museu de História Natural de Maputo in Mozambique.

Morphological Measurements

Specimens were measured to the nearest 0.1 mm using digital callipers under a Nikon SMZ1270 dissecting microscope for the following 16 morphological characters as defined by Watters *et al.* (2016): Snout–urostyle length (SUL, direct line distance from from the tip of the snout to the posterior end of the urostyle), Head width (HW, at the widest point; angle at the jaws), Head length (HL, from the posterior of the jaws to the tip of the snout), Interorbital distance (IOD, the shortest distance between the anterior corners of the orbits), Eye diameter (ED, horizontally from the anterior to posterior corner of the eye), Eye–nostril distance (EN, from anterior corner of the eye to the posterior

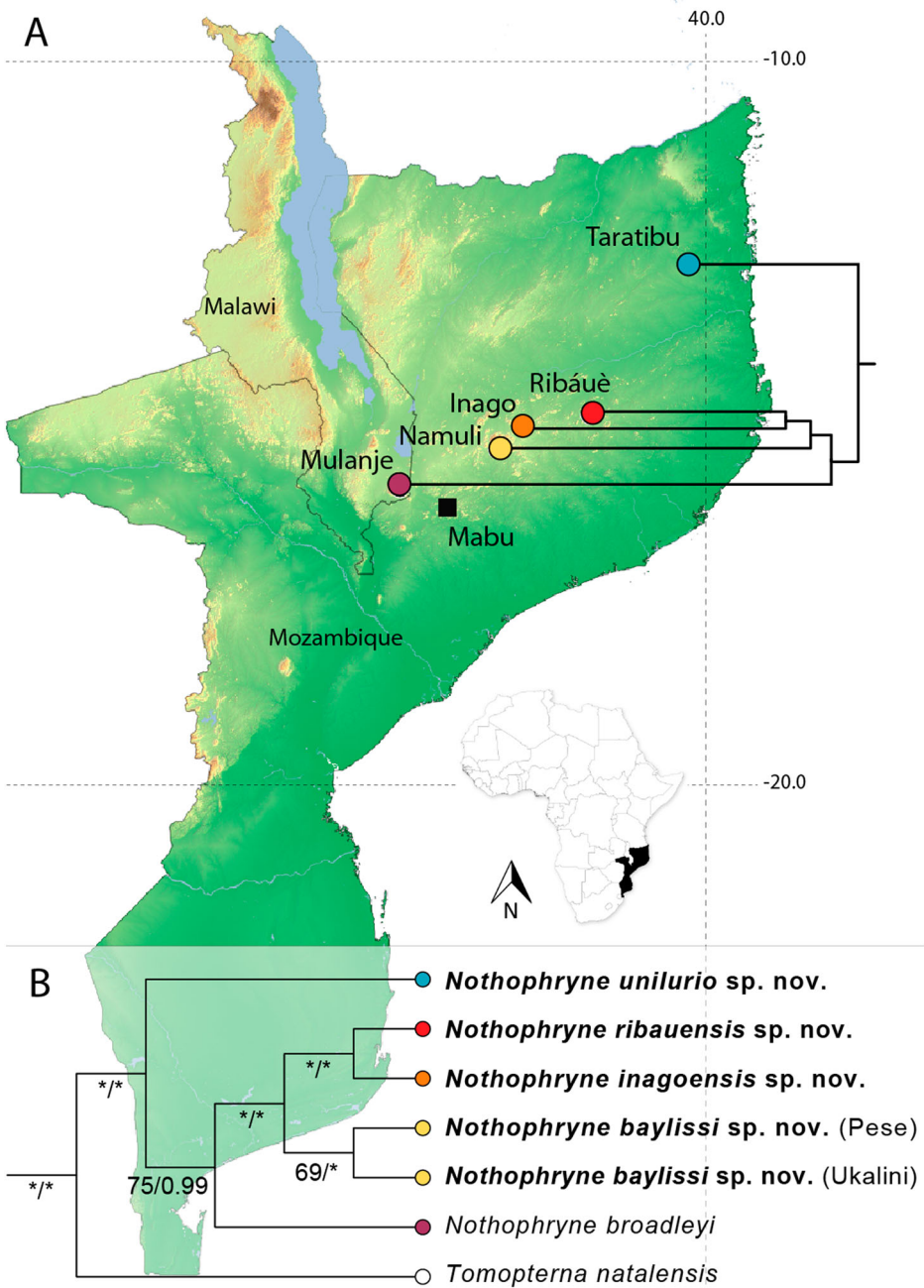


Figure 1. Distribution and phylogenetic relationships of *Nothophryne*. (A) Type localities of *Nothophryne* species. (B) Tree topology (adapted from Bittencourt-Silva et al. 2016) showing branch support values corresponding to ML non parametric bootstraps (left) and BI posterior probabilities (right). Maximum support values (>70% bootstrap, >0.95pp) are represented by asterisks.

margin of the nostril), Internarial distance (IND, shortest distance between the inner margins of the nostrils), Snout length (SL, distance from the tip of the snout to the anterior corner of the eye), Tympanum diameter (TD, greatest horizontal width of the tympanum),

Tibia length (TL, distance from the outer surface of the flexed knee to the heel/tibiotarsal inflection), Foot length (FL, from the base of the inner metatarsal tubercle to the tip of Toe IV), Thigh length (THL, distance from the vent to the knee), Hand length (HAL, from the base of the outer palmar tubercle to the tip of Finger IV), Forearm length (FLL, from the flexed elbow to the base of the outer palmar tubercle), Upper eyelid width (UEW, greatest width of the upper eyelid margins, measured perpendicular to the anterior-posterior axis), and Finger IV disk width (Fin4DW, the widest horizontal diameter of Finger IV). All measurements were taken on the right side of the body for consistency. Sample sizes of four of the five populations were inadequate to carry out quantitative analyses on the morphological data (ranging from 2–8 individuals). This was further confounded by the presence of juveniles and adults, as well as both sexes in the dataset. We therefore limit our morphological examination to a qualitative assessment.

Advertisement Calls

Advertisement calls were recorded in the field using an NAGRA ARES-ML recorder with a Sony F-V4 T Microphone, and analysed using Sound Ruler Acoustic Analysis (Version 0.9.6.0) using default settings (Gridi-Papp 2007). One male from Mount Mulanje (9 separate calls), Mount Namuli (30 separate calls), and Mount Ribáuè (10 separate calls) were recorded. No call data was available from individuals from Mount Inago and Taratibu Hills. The low number of calls did not allow for detail statistical analyses. Each species call is described in more detailed in the systematic accounts. The following standard measurements were taken: call duration, call interval, number of notes per call, pulse rate, and frequency.

Molecular Analysis

Partial sequences of one mitochondrial fragment (16S) rRNA and one nuclear gene, recombination activating gene 1 (RAG1), of *Nothophryne* (which were derived from Bittencourt-Silva *et al.* 2016) and other ranids (for comparison) were downloaded from Genbank and aligned in Geneious v.7 (Kearse *et al.* 2012). Uncorrected pairwise distances (p-distance) were calculated in PAUP* (Swofford 2001). GenBank accession numbers for all sequences and uncorrected pairwise distances are presented in the supplementary material Table 1 to 3.

Results

Although our sample sizes are limited, the genus *Nothophryne* appears to be morphologically conservative. Our qualitative examination of the morphological features point only to minor morphological differences in the presence of the median lingual process and a defined tympanum (Fig. 2; discussed below). Regardless, the high genetic divergence (see Supplementary Tables 1 to 2), call differences and allopatric distributions provide evidence that the *Nothophryne* populations from each of the localities surveyed (Mount Namuli, Mount Inago, Mount Ribáuè and Taratibu Hills) represent a distinct species. We therefore provide species descriptions for four new species from these localities and a refined description of the nominal form from Mount Mulanje. All material is referable to *Nothophryne* based on the following characteristics (Poynton 1963): body depressed,

toes unwebbed, no tarsal fold or tubercle, subarticular tubercles weakly developed, fingertips slightly expanded into discs, vocal sac expanded through small slits in the base of the mouth, presence of a median lingual process on the dorsal surface of the tongue; skin rough with elevated tubercles. The pairwise distances show high interspecific differentiation among 16S and RAG1 sequences of *Nothophryne* species (Supplementary Tables 1 to 2). Lower interspecific p-distance observed was between the geographically close species, *N. inagoensis* sp. nov. and *N. ribauensis* sp. nov. (16S: 4%, RAG1: 2%) compared to geographically distant species. Regardless, the values are still comparable with other species level differences within the Pyxicephalidae (Supplementary Tables 1 to 2).

***Nothophryne broadleyi* Poynton, 1963**

Mongrel Frog; Broadley's Mountain Frog (Figs 3A–D)

Synonym—*Nothophryne broadleyi* – Poynton 1963, p. 326; Poynton 1964, p. 212; Stewart 1967, p. 102; Stevens 1974, p. 8; Poynton & Broadley 1985, p. 173; Poynton & Broadley 1991, p. 262; Broadley 2001, p. 34; Channing 2001, p. 301; Mercurio 2011, p. 286.

Material examined—PEM A10714 (adult male), SAIAB 96460.1-3 (three adult males), BMNH 165-817 (adult female paratype), BMNH 1973-373 (adult female), BMNH 1973-375 and 276 (two adult males). All material listed here is from Mount Mulanje, southern Malawi.

Redefined Diagnosis—*Nothophryne broadleyi* can be distinguished from other *Nothophryne* by the following: presence of a long narrow median lingual process (approximately 1.0 mm) on the dorsal surface of the tongue (*N. baylissi* sp. nov. – up to 0.5 mm long; *N. inagoensis* sp. nov. – less than 0.2 mm long; *N. ribauensis* sp. nov. – marginally elevated tubercle; *N. unilurio* sp. nov. – absent) (Fig. 2A), tympanum clearly visible (obscured or barely visible in *N. baylissi* sp. nov.), and slower higher pitched call with evenly spaced notes (compared to faster and more complicated call structures in *N. baylissi* sp. nov. and *N. ribauensis* sp. nov.). The sequences of *Nothophryne broadleyi* differ from the other species of *Nothophryne* by 5–7% (16S p-distance) and 3–5% (RAG1 p-distance). *Nothophryne broadleyi* is allopatric with respect to all other *Nothophryne* species.

Description of adult male (PEM A10714)—Small to medium size frog, SUL 17.8 mm. Body is slender, dorsolateral flattened, widest at armpits. Head broad (HW/SUL 0.40), rounded from above in profile, head length is moderate to short (HL/SUL 0.32). Canthus rostralis rounded, straight from eye to nostril, loreal region slightly sloped outwards towards nostrils. Nostrils small, rounded, directed laterally, teardrop shaped angled downwards and backwards to eye, positioned slightly closer to the eye than the snout (EN/SL 0.48). Internarial distance is larger than distance between eye and nostril (IND/EN 1.46). Eyes directed anterolaterally, the eyes protrude, and not visible from below, moderate in size (ED/HW 0.31; ED/HL 0.39), nearly equal to interorbital distance (ED/IOD 1.2). Distance between anterior corners of eyes is equal to the internarial distance (IOD/IND 0.54). The angle of the jaw slopes slightly upwards posteriorly from snout to just behind eye level. Tympanum clearly visible, with no clear glandular ridge above tympanum from eye to base of forearm. Jaws without maxillary and premaxillary teeth, lower jaw with small anterior vomerine odontophore with central projection; choanae small,

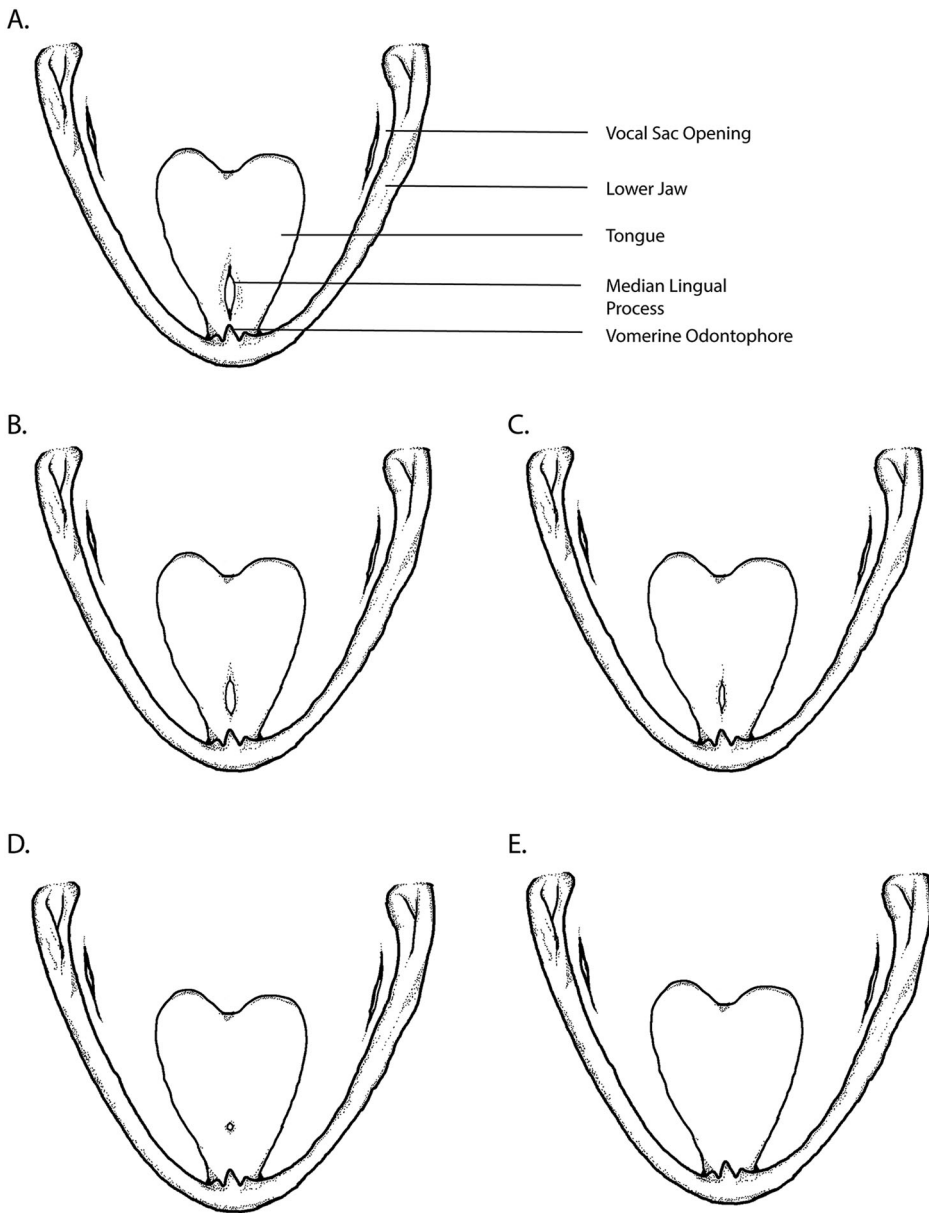


Figure 2. Schematic representation of median lingual process e on the dorsal surface of the tongue of *Nothophryne* spp. (A) *N. broadleyi* PEM A1074 (B) *N. baylissi* sp. nov. NHM UK 2018.02284, (C) *N. inagoensis* sp. nov. PEM A12159, (D) *N. ribauensis* sp. nov. PEM A11372, (E) *N. unilurio* sp. nov. PEM A12114.

round, located at anterior margins of the roof of the mouth; tongue long (2.9 mm), same width proximally to distally (~2.2 mm), slightly bifurcated distally, 75% attached to lower jaw, narrow median lingual process present on the dorsal surface of the tongue.

The dorsal surfaces of the head, trunk and limbs are rough, with glands and skin folds present; the rictal gland is smooth slightly elevated from angle of jaw to form a continuous

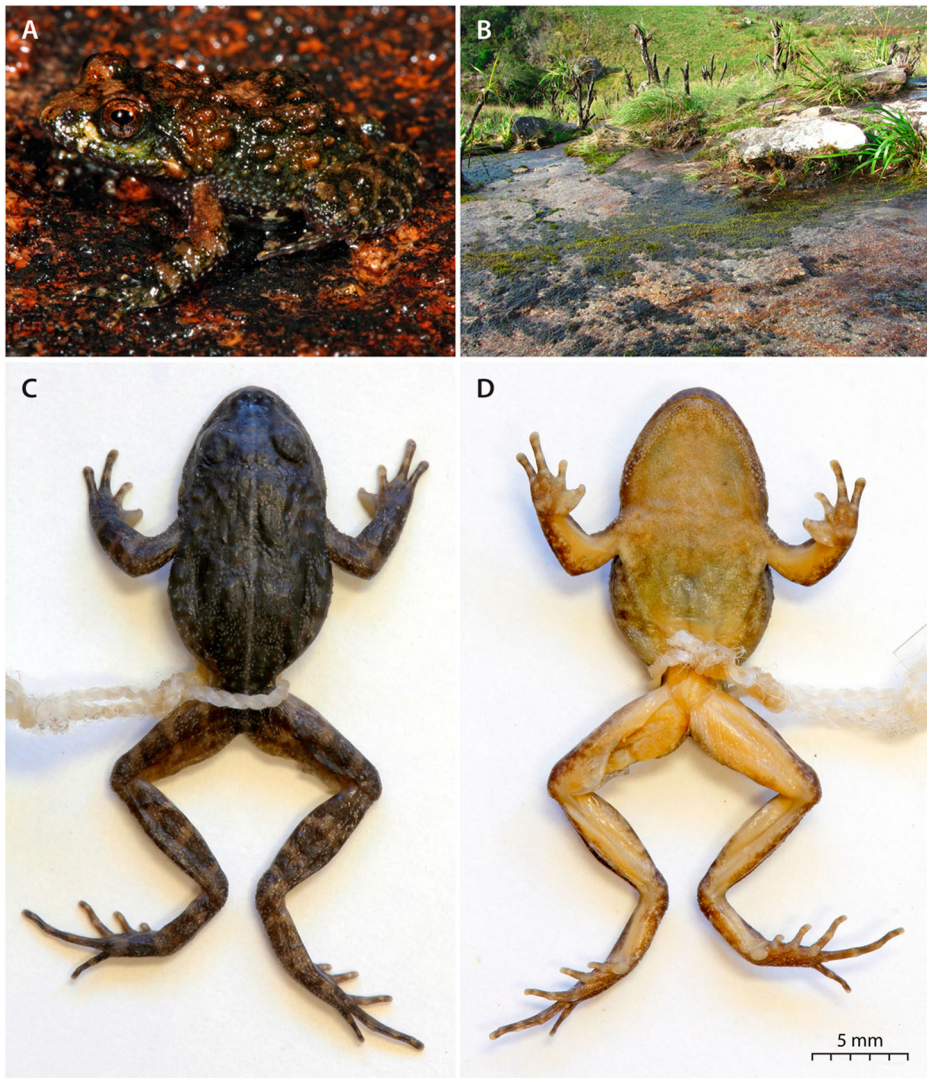


Figure 3. *Nothophryne broadleyi* from Mount Mulanje. (A) Adult male, (B) habitat, (C) dorsal view of male PEM A10714, (D) ventral view of male PEM A10714.

posteriorly directed ridge just above arm insertion, with numerous white tipped asperities. Supratympanic fold inconspicuous; throat with enlarged anterior scattered asperities (forming six randomly scattered deep rows), scattered asperities (forming 2–3 randomly scattered deep rows) along the lateral margins of jaw to just behind jaw angle. No gular pouch or flap present, a small slit on the inside of the mouth at the angle of the jaw gives access to the vocal sac. Ventrally smooth, upper jaw protruding over lower jaw, with very light mottled appearance, vocal sac dark anteriorly, getting mottled to about arm insertion (Fig. 3D).

Forelimbs stubby, hand small (HAL/SUL 0.23), fingertips bluntly rounded and slightly swollen. Relative finger lengths $I < II < IV < III$; subarticular tubercles distinct, rounded, with one on each finger, no proximal subarticular present. No webbing between fingers. Thenar tubercle small, rounded, partially obscured by nuptial pad that reaches

the distal phalanx of the first finger; two palmar tubercles small, rounded, and smooth; inner and outer metacarpal tubercle absent. One very small mid-supernumerary palmar tubercle present on the palm.

Hind limbs moderately long (TL/SUL 0.51; FL/SUL 0.45), feet nearly equal in length of tibia (TL/FL 1.1); thighs are moderately developed, with rough elevated glands on the inner posterior faces; relative toe lengths are I < II < III < V < IV. The toe tips are slightly expanded; sub-articular tubercles: one on Toes I to III, two on Toes IV and V. No webbing between toes. Inner metatarsal tubercle conical and prominent, outer metatarsal tubercle absent.

Colour in life (Fig. 3A)—The dorsum green with darker raised glands covered with small white tipped asperities, dorsal lighter yellow to white vertebral line present, light yellow to white interorbital band present, bordered behind by a darker bar. Venter is clear with slight black mottling and blotches. Nuptial pads prominent, but lighter than rest of fingers. Arms and legs are strongly cross-banded.

Colour in preservative—The dorsum dark brown with small white tipped asperities on the darker raised glands, dorsal lighter vertebral line present. Venter immaculate white with bold black pigmentation, throat finely and evenly black pigmentation up to anterior chest region in line with forearms. The inner thighs and anterior abdomen free of pigmented, forearms slightly pigmented.

Variation—All males examined showed similar body proportions to the male described above (Table 2; Supplementary Table 4). The males range in SUL from 16.6–19.2 mm. All males examined had a light vertebral line, also reported in most specimens (male and females) examined previously (Poynton & Broadley 1985). SAIAB 96460.1 and 96460.3 have fewer asperities on dorsum, warts and are mostly confined to the outer edges of the throat. SAIAB 96460.1 has three larger mid palmer tubercles than other males examined. Males up to 20 mm and females up to 27.5 mm (Poynton & Broadley 1985). In males, the throat has a more blotched patterning compared to evenly pigmented females.

Advertisement call—The following call description is based on a single male that was calling from a concealed position amongst moss, located on an exposed rock surface with a film of water running from a seepage (Fig. 4A). The call sounds like a stretched out “trrrr”, which is repeated up to nine times in less than 45 seconds or at a rate of 12 calls per minute with the dominant frequency at 3 469 Hz and the fundamental frequency

Table 1. Specimen information and GenBank accession numbers for the *Nothophryne* sequences referred to in the present study (from Bittencourt-Silva *et al.* 2016). Mozambique (MZ); Malawi (MW); Mount (Mt). Collections: (PEM) Port Elizabeth Museum; (SAIAB) South African Institute of Biodiversity.

Species	Voucher	Locality	Latitude	Longitude	16S	RAG1
1. <i>N. inagoensis</i> sp. nov.	PEM A11658	Mt Inago, MZ	−15.04500	37.39611	KU761276	KU761284
1. <i>N. baylissi</i> sp. nov.	PEM A(AC770)	Mt Namuli, MZ	−15.36154	37.07211	KU761277	KU761285
1. <i>N. baylissi</i> sp. nov.	PEM A(AC776)	Mt Namuli, MZ	−15.36154	37.07211	KU761278	KU761286
1. <i>N. baylissi</i> sp. nov.	NHM UK 2018.02284	Mt Namuli, MZ	−15.36154	37.07211	KU761281	KU761289
1. <i>N. baylissi</i> sp. nov.	PEM A11343	Mt Namuli (Pese), MZ	−15.38742	37.03165	KU761280	KU761288
1. <i>N. unilurio</i> sp. nov.	PEM A12114	Taratibu, MZ	−12.82178	39.68658	KU761279	KU761287
1. <i>N. ribauensis</i> sp. nov.	PEM A11369	Mt Ribáuè, MZ	−14.91186	38.31623	KU761282	KU761290
1. <i>N. broadleyi</i>	SAIAB 96460.1	Mt Mulanje, MW	−15.89231	35.6149	KU761283	KU761291

Table 2. Morphological measurements (mm) of the type series of four *Nothophryne* species (no additional material used to compile this table). Male (M), female (F), and juvenile (J) Values indicate average and standard deviation (in parenthesis). Refer to the Material and Methods section for explanation of abbreviations. *tymp. obscure (only three individuals per class present).

Species	<i>N. broadleyi</i>		<i>N. baylissi</i> sp. nov.			<i>N. inagoensis</i> sp. nov.	<i>N. ribauensis</i> sp. nov.			<i>N. unilurio</i> sp. nov.
	M (n = 4)	F (n = 2)	M (n = 16)	F (n = 6)	J (n = 6)	J (n = 18)	M (n = 2)	F (n = 2)	J (n = 6)	M (n = 2)
SUL	17.8 (0.8)	21.6 (3.0)	18.0 (0.6)	23.3 (2.0)	15.8 (2.3)	13.8 (0.9)	18.6 (0.8)	22.7 (1.5)	16.1 (1.0)	18.0 (1.0)
HW	7.2 (0.5)	8.7 (0.2)	7.7 (0.5)	9.3 (0.8)	6.3 (0.5)	5.3 (0.4)	7.2 (0.5)	9.0 (0.3)	6.0 (0.6)	7.7 (0.6)
HL	5.6 (0.5)	6.8 (0.3)	6.2 (0.2)	7.3 (0.5)	5.1 (0.5)	5.0 (0.5)	6.0 (0.5)	7.3 (0.1)	5.5 (0.3)	6.2 (0.3)
IOD	1.6 (0.2)	2.0 (0.2)	1.5 (0.2)	1.8 (0.2)	1.4 (0.3)	1.4 (0.1)	1.3 (0.2)	2.1 (0.1)	1.6 (0.2)	1.5 (0.2)
ED	2.2 (0.3)	2.6 (0.3)	2.4 (0.2)	2.6 (0.2)	2.0 (0.3)	1.9 (0.2)	2.7 (0.3)	2.7 (0.1)	2.0 (0.1)	2.4 (0.1)
EN	1.2 (0.1)	1.5 (0.1)	1.6 (0.1)	1.8 (0.2)	1.3 (0.1)	1.3 (0.2)	1.4 (0.1)	1.7 (0.1)	1.4 (0.1)	1.6 (0.1)
IND	1.9 (0.1)	2.2 (0)	1.9 (0.2)	2.2 (0.2)	1.7 (0.2)	1.5 (0.2)	2.0 (0.1)	2.3 (0.2)	1.8 (0.2)	1.9 (0.2)
SL	2.7 (0.3)	3.2 (0.1)	3.0 (0.3)	3.6 (0.4)	2.5 (0.2)	2.3 (0.2)	2.8 (0.3)	3.0 (0.3)	2.6 (0.2)	3.0 (0.2)
TD	0.8 (0.3)	0.8 (0)	0.8 (0.1)*	0.9 (0.1)*	0.7 (0.1)*	0.5 (0.1)	1.2 (0.3)	1.1 (0.1)	0.7 (0.1)	0.8 (0.1)
TL	9.0 (1.2)	11.0 (0.6)	9.1 (0.4)	11.4 (0.6)	7.8 (0.9)	7.2 (0.9)	10.0 (1.2)	12.2 (0.2)	8.8 (1.1)	9.1 (1.1)
FL	8.6 (1.2)	11.2 (0.8)	8.9 (0.4)	11.3 (0.8)	7.1 (0.8)	6.7 (1.1)	8.6 (1.2)	11.8 (0.2)	8.5 (0.9)	8.9 (0.9)
THL	8.2 (0.8)	10.0 (1.3)	9.5 (0.3)	11.7 (0.7)	8.1 (1.0)	6.7 (1.6)	10.3 (0.8)	11.9 (0.3)	8.8 (0.9)	9.5 (0.9)
HAL	4.4 (0.7)	5.5 (0.3)	4.3 (0.3)	5.5 (0.6)	3.8 (0.3)	3.6 (0.3)	4.5 (0.7)	5.5 (0.3)	4.3 (0.5)	4.3 (0.5)
FLL	3.7 (0.5)	4.5 (0.1)	3.8 (0.2)	4.5 (0.4)	3.3 (0.4)	2.7 (0.3)	4.0 (0.5)	5.3 (0.3)	3.2 (0.3)	3.8 (0.3)
UEW	1.6 (0.1)	1.8 (0.4)	1.7 (0.1)	2.1 (0.2)	1.3 (0.1)	1.2 (0.2)	2.0 (0.1)	2.1 (0.1)	1.5 (0.2)	1.7 (0.2)
Fin4DW	0.5 (0.1)	0.6 (0.1)	0.4 (0.1)	0.5 (0.1)	0.3 (0.0)	0.4 (0.1)	0.5 (0.1)	0.5 (0.1)	0.5 (0.1)	0.4 (0.1)

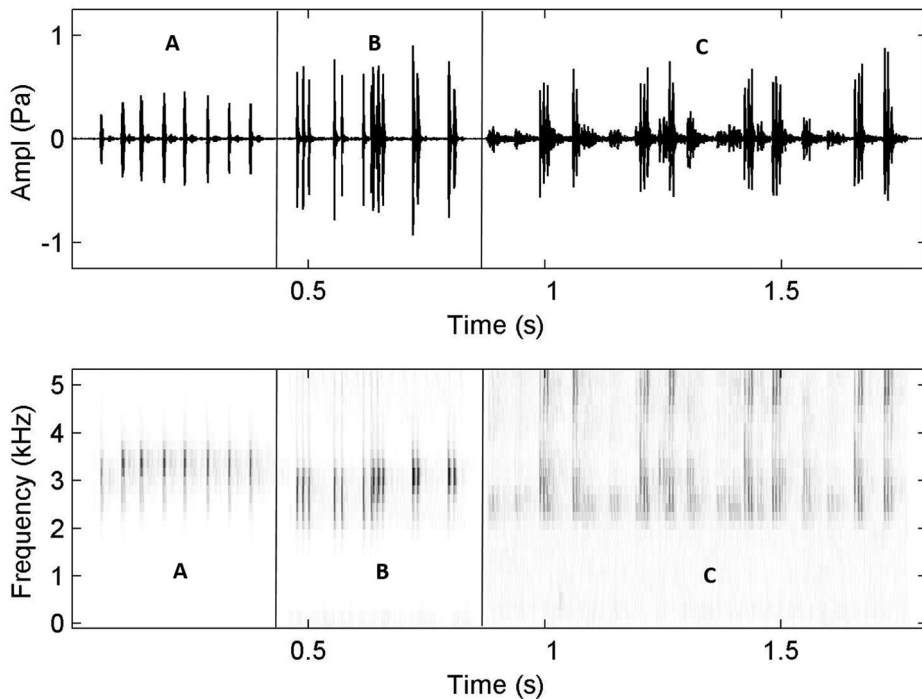


Figure 4. Advertisement call of three species of *Nothophryne*. Top: oscillogram; Bottom: frequency graph of a single call. (A) *N. broadleyi* from Mount Mulanje, (B) *N. baylissi* sp. nov. from Mount Namuli, (C) *N. ribauensis* sp. nov. from Mount Ribáuè.

at 1 734 Hz. The call duration is 0.3 ± 0.1 seconds (s) and is separated from the next call by 5.3 ± 1.4 s ($n = 9$). Each call comprises out of three to eight evenly spaced notes. Separate note duration is 5.7 ± 1.3 milliseconds (ms), with 40.0 ± 7.5 ms interval between successive notes. The only previous description of *Nothophryne broadleyi* call is described as a “weak chirp” (Poynton & Broadley 1985; Channing 2001).

Natural History—Collected under rocks on the summit of Mount Mulanje (2 715 m above sea level – asl) (Poynton 1963) and under moss (Cunningham pers. comm. 2010) (Fig. 3B). Males call hidden underneath moss growing on the surface of the rock near seepages. Eggs are laid in wet moss near seepages. Egg diameter about 1.5 mm, with a clutch size up to 30 eggs. Tadpoles disperse by moving across wet rock (Poynton & Broadley 1985).

Distribution—Currently only known from the Mount Mulanje isolate in southern Malawi (Poynton & Broadley 1985; Mercurio 2011). Poynton & Broadley (1985) suggest that there might be a second species present on the lower slopes on Mount Mulanje.

Nothophryne baylissi sp. nov.

urn:lsid:zoobank.org:act:61F1B19E-8D7F-4628-A1C6-820F1EBA114F
 Namuli Mongrel Frog; Namuli Mountain Frog (Figs 4A–D, 6A–C)

Synonym—*Nothophryne broadleyi* – Timberlake et al. 2009; Conradie et al. 2016 (part)

Holotype—NHM UK 2018.02284 (was PEM A11320) adult male, collected from eastern slopes of Ukalini Forest at the base of the two Namuli granite domes (15.3615° S, 37.07211° E, 1 591 m asl), Mozambique by W. Conradie on 27 November 2014.

Paratype males (18)—a) PEM A11322, 11324, 11326-7, 11329, 11331, 11333, 11334-7, 11340. Same collection details as the holotype. b) PEM A11342, 11344-7. Collected from Namuli massif on the lower slopes of the granite dome, Mount Pese (15.38642° S, 37.03352° E, 1 110 m asl), Mozambique by G.B. Bittencourt-Silva and H.M. Engelbrecht on 28 November 2014. All specimens were adult males.

Paratype females (7)—a) NHM UK 2018.02285 (was PEM A11321), PEM A11323, 13328, 11330, 11339. Same collection details as holotype. b) PEM A11343. Collected from Namuli massif on the lower slopes of the granite dome, Mount Pese (15.38642° S, 37.03352° E, 1 110 m asl) by G.B. Bittencourt-Silva and H.M. Engelbrecht on 28 November 2014. All specimens are adult females.

Additional juvenile material (3)—PEM A11325, 11332, and 11338. Same collection details as holotype.

Diagnosis—*Nothophryne baylissi* sp. nov. can be distinguished from other *Nothophryne* by the following: presence of a narrow median lingual process (approximately 0.5 mm) on the dorsal surface of the tongue (from *N. broadleyi* – up to 1.0 mm long; *N. inagoensis* sp. nov. – less than 0.2 mm long; *N. ribauensis* sp. nov. – marginally elevated tubercle; *N. unilurio* sp. nov. – absent) (Fig. 2B), tympanum obscured or barely visible (clearly visible in *N. broadleyi*, *N. ribauensis* sp. nov., *N. unilurio* sp. nov.), and medium paced call with clusters of notes (compared to higher pitched and evenly spaced call of *N. broadleyi*, and more complicated call structures of *N. ribauensis* sp. nov.). The sequences of *Nothophryne baylissi* sp. nov. differ from the other species of *Nothophryne* by 5–7% (16S p-distance) and 3–5% (RAG1 p-distance). *Nothophryne baylissi* sp. nov. is allopatric with all other *Nothophryne* species.

Etymology—We name this species in honour of Dr Julian Bayliss who was the first to document this unique species of frog from the slopes of Mount Namuli, during the Kew Gardens-Darwin Initiative expedition to these inselbergs (Timberlake *et al.* 2009).

Description of the Holotype—Small to medium size frog, SUL 17.9 mm. Body is slender, dorsolateral flattened, widest at armpits. Head broad (HW/SUL 0.39), rounded from above in profile, head length is moderate to short (HL/SUL 0.34). Canthus rostralis rounded, straight from eye to nostril, loreal region slightly sloped outwards towards nostrils. Nostrils small, rounded, directed laterally, teardrop shaped angled downwards and backwards to eye, positioned midway between the eye and the snout (EN/SL 0.50). Internarial distance is smaller than distance between eye and nostril (IND/EN 0.80). Eyes directed anterolaterally, the eyes protrude, and slightly visible from below, moderate in size (ED/HW 0.32; ED/HL 0.37), nearly equal to interorbital distance (ED/IOD 1.29). Distance between anterior corners of eyes is much greater to the internostril distance (IOD/IND 1.42). The angle of the jaw slopes slightly upwards posteriorly from snout to just behind eye level. Tympanum obscure, with no clear glandular ridge above tympanum from eye to base of forearm. Jaws without maxillary and premaxillary teeth, lower jaw with small, anterior vomerine

odontophore with central projection; choanae small, round, located at anterior margins of the roof of the mouth; tongue long (3.2 mm), same width proximally to distally (~1.5 mm), slightly bifurcated distally, 25% attached to lower jaw, median narrow small median lingual process present on the dorsal surface of the tongue.

The dorsal surfaces of the head, trunk and limbs are rough, with glands and skin folds present, chevron elevated shape on back; the rectal gland is smooth slightly elevated from angle of jaw to form a continuous posteriorly ridge just before arm insertion. Supratympanic fold inconspicuous. No gular pouch or flap present, a small slit on the inside of the mouth at the angle of the jaw gives access to the vocal sac. Ventrally smooth, upper jaw protruding over lower jaw, with very light mottled appearance, vocal sac dark with some lighter mottling (Fig. 5D).

The forelimbs are stubby, hands small (HAL/SUL 0.24), fingertips bluntly rounded and slightly swollen. Relative finger lengths $I < II < IV < III$; subarticular tubercles distinct, rounded, with one on each finger, no proximal subarticular present. No webbing between fingers. Thenar tubercle small, rounded, partially obscured by nuptial pad that reaches the distal phalanx of the first finger; two palmar tubercles small, rounded, and smooth; inner metacarpal tubercle absent; outer metacarpal tubercle present, smaller than mid-palmar metacarpal tubercle. One very small mid-supernumerary palmar tubercle present on the palm at base of Finger III.

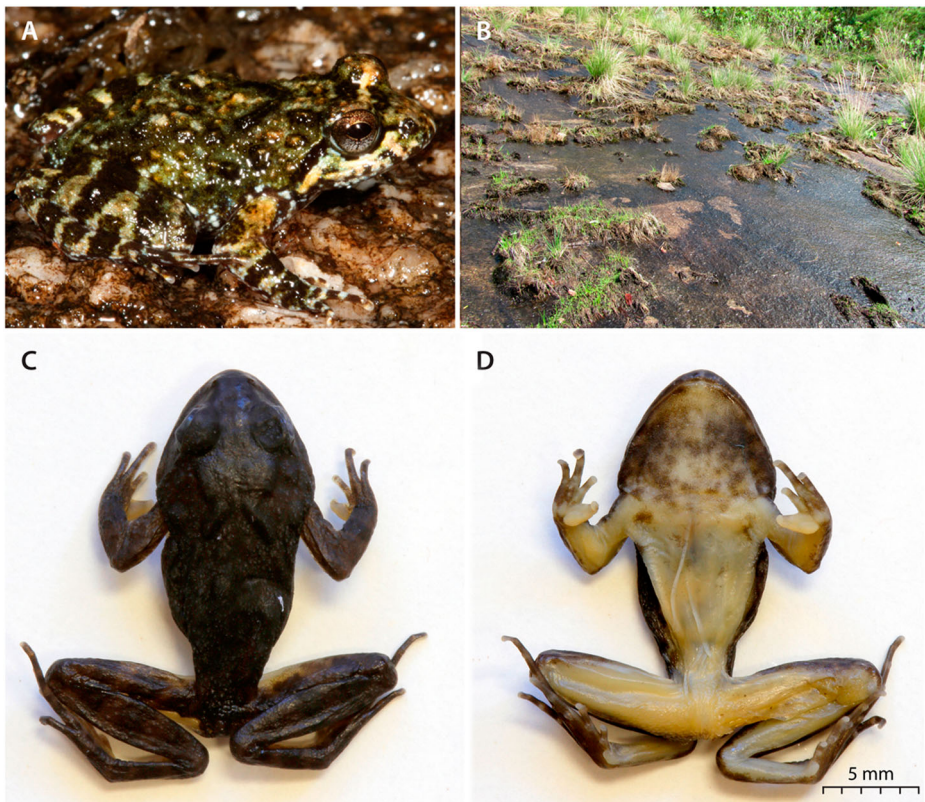


Figure 5. *Nothophryne baylissi* sp. nov. from Mount Namuli. (A) Adult male, (B) habitat, (C) dorsal view of holotype male NHM UK 2018.02284, (D) ventral view of holotype male NHM UK 2018.02284.

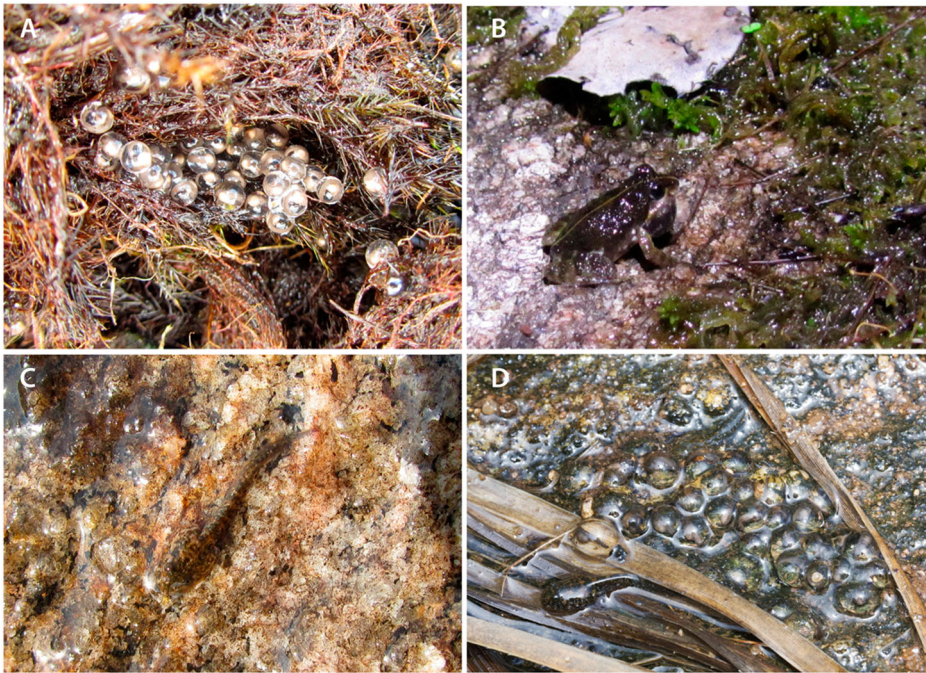


Figure 6. (A) Eggs of *N. baylissi* sp. nov. laid in moist moss, (B) adult male calling in open, (C) tadpole on rock surface with water film from Mt. Namuli, (D) tadpole and eggs of *N. unilurio* sp. nov. from Taratibu.

Hind limbs moderately long (TL/SUL 0.51; FL/SUL 0.49), feet nearly equal in length of tibia (TL/FL 1.0); thighs are moderately developed, with rough elevated glands on the inner posterior ventral surface; relative toe lengths are I < II < III < V < IV. The toe tips are slightly expanded; subarticular tubercles: one on Toes I to III, two on Toes IV and V. No webbing between toes. Inner metatarsal tubercle conical and prominent, outer metatarsal tubercle absent.

Colour in life (Fig. 5A)—The dorsum green with darker raised glands covered with small white tipped asperities, dorsal lighter yellow to white vertebral line present, light yellow to white interorbital band present, bordered behind by a darker bar. Venter is clear with slight black mottling and blotches. Nuptial pads prominent, but lighter than rest of fingers. Arms and legs are strongly cross-banded.

Colour in preservative—The dorsum very dark with small white tipped asperities on the raised glands, lighter interorbital bar present. Venter immaculate white with some black blotches anterior, throat finely and unevenly black pigmentation up to anterior chest region in line with forearms. The inner thighs and anterior abdomen free of pigmented, forearms slightly pigmented. Palms and soles of feet dark.

Male variation—All males examined showed similar body proportions to the male described above (Table 2; Supplementary Table 4). The males range in SUL from 13.3–19.5 mm. All, except PEM A11307, 11331 and 11326, have vertebral line. PEM A11326 and 11322 light dorsum with paired darker blotches. All males have narrow small

median lingual process present on the dorsal surface of the tongue. The tympanum is only visible in three (PEM A11322, 11345, 11346) out of 18 paratype males.

Female variation—The females range in SUL from 20.7–25.9 mm (Table 2; Supplementary Table 4). White vertebral line present in PEM A11323 and 11330. White mid-dorsal patch present in PEM A11325. Light inter orbital bar and snout present in PEM A11339 and NHM UK 2018.02285. The tympanum is only visible in three (PEM A11323, 11328, 11328) out of seven paratype females.

Advertisement call—The following call description is based on a single male recorded on the eastern slopes of Mount Namuli on 27 November 2014 at approximately 20:00 (Fig. 4B). The call consist out of two high pitched “creak”, which is repeated up to six times in less than 2 s or at a rate of 20 calls per minute with the dominant frequency at 2 096–3 094 Hz and the fundamental frequency at 1 453–1 547 Hz. The call duration is 0.13 ± 0.07 s and is separated from the next call by 0.38 ± 0.31 s ($n = 30$). Each call comprises out of 5–13 notes, arranged in either clusters of 2–6 notes ($n = 5$) or evenly spaced ($n = 14$). Separate note duration is 4.4 ± 1.9 ms, with 12.5 ± 18.1 ms interval between successive notes.

Natural History—Males call exposed from positions near seeping water on the rock face (Figs 5B, 6B). Eggs are laid in moist moss growing over rock surface (Fig. 5A). Tadpoles live on films of water flowing over rock surface (Fig. 6C).

Distribution—Currently only known from Mount Namuli in central Mozambique.

Nothophryne inagoensis sp. nov.

urn:lsid:zoobank.org:act:7433A790-7227-4992-875C-9BB353754306

Inago Mogrel Frog; Inago Mountain Frog (Figs 7A–D)

Holotype—PEM A12159, juvenile, collected from a granite dome located on the southern side of Mount Inago (15.04500° S, 37.39611° E, 1 267 m asl), Mozambique by W. Conradie, K.A. Tolley and G.B. Bittencourt-Silva on 18 April 2017.

Paratypes (15)—PEM 12160-70, NHML NHM UK 2018.02289-90, all juveniles. Same collection details as holotype.

Additional material (2)—PEM A11657-7, two metamorphs, collected from the northern slopes of Mount Inago (15.15567° S, 37.42836° E, 1 230 m asl), Mozambique by J. Bayliss on 15 May 2009.

Diagnosis—*Nothophryne inagoensis* sp. nov. can be distinguished from other *Nothophryne* by the following: presence of a very short narrow median lingual process (approximately 0.2 mm) on the dorsal surface of the tongue (*N. broadleyi* – up to 1.0 mm long; *N. baylissi* sp. nov. – up to 0.5 mm long; *N. ribauensis* sp. nov. – marginally elevated tubercle; *N. unilurio* sp. nov. – absent) (Fig. 2C), tympanum visible (differs only form *N. baylissi* sp. nov. which is obscured or barely visible). The sequences of *Nothophryne inagoensis* sp. nov. differ from the other species of *Nothophryne* by 4–6% (16S p-distance) and 2–5% (RAG1 p-distance). *Nothophryne inagoensis* sp. nov. is allopatric from all other *Nothophryne* species.

Etymology—The new species is named after Mount Inago, where this species is endemic.

Description of holotype—Small to medium size frog, SUL 15.2 mm. Body is slender, dorso-lateral flattened, widest at armpits. Head broad (HW/SUL 0.38), rounded from above in profile, head length is moderate to short (HL/SUL 0.34). Canthus rostralis rounded, straight from eye to nostril, loreal region slightly sloped outwards towards nostrils. Nostrils small, rounded, directed laterally, teardrop shaped angled downwards and backwards to eye, positioned slightly closer to the snout than the eye (EN/SL 0.50). Internarial distance is larger than distance between eye and nostril (IND/EN 1.39). Eyes directed anterolaterally, the eyes protrude, and visible from below, moderate to large in size (ED/HW 0.37; ED/HL 0.41), just more than one and a half times the interorbital distance (ED/IOD 1.62). Distance between anterior corners of eyes is smaller than the internostril distance (IOD/IND 0.72). The angle of the jaw slopes slightly upwards posteriorly from snout to just behind eye level. Tympanum clearly visible, with a light glandular ridge above tympanum from eye to base of forearm. Jaws without maxillary and premaxillary teeth, lower jaw with small anterior vomerine odontophore with central projection; choanae small, round, located at anterior margins of the roof of the mouth; tongue very long (4.8 mm), same width proximally to distally (~2.5 mm), bifurcated distally, first 25% attached to lower jaw, very small narrow median lingual process present on the dorsal surface of the tongue.

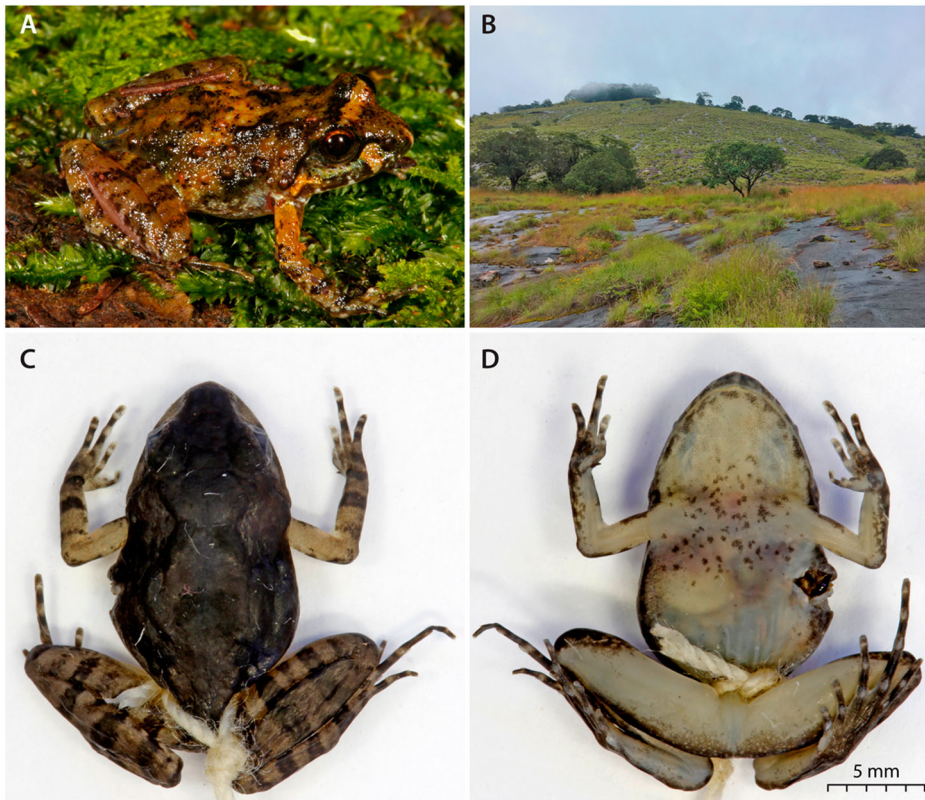


Figure 7. *Nothophryne inagoensis* sp. nov. from Mount Inago. (A) Juvenile, (B) habitat, (C) dorsal view of holotype PEM A12159, (D) ventral view of holotype PEM A12159.

The dorsal surfaces of the head, trunk and limbs are smooth, with slightly raised glands and skin folds present; the rectal gland is smooth slightly elevated from angle of jaw to form a continuous posteriorly ridge just before arm insertion, with some white tipped spikes. Supratympanic fold conspicuous; throat with no enlarged anterior scattered spikes. No gular pouch or flap present, a small slit on the inside of the mouth at the angle of the jaw gives access to the vocal sac. Ventrally smooth, upper jaw protruding over lower jaw, with very light mottled appearance, vocal sac dark with no mottled appearance anteriorly, getting mottled to about arm insertion (Fig. 7D).

The forelimb is stubby, hand small (HAL/SUL 0.26), finger tips bluntly rounded and slightly swollen. Relative finger lengths $I < II < IV < III$; subarticular tubercles distinct, rounded, with one on each finger, no proximal subarticular present. No webbing between fingers. Thenar tubercle small, rounded, that reaches the distal phalanx of the first finger; inner metacarpal tubercle absent, outer metacarpal tubercle inconspicuous, central metacarpal tubercle present. One very small palmar tubercle present on the palm at the base of Finger III.

Hind limbs moderately long (TL/SUL 0.54; FL/SUL 0.51), foot nearly equal in length of tibia (TL/FL 1.1); thighs are moderately developed, with rough elevated glands on the inner posterior faces; relative toe lengths are $I < II < III < V < IV$. The toe tips are slightly expanded; subarticular tubercles: one on Toes I to III, two on Toes IV and V. No webbing between toes. Inner metatarsal tubercle conical and prominent, outer metatarsal tubercle absent.

Colour in life (Fig. 7A)—The dorsum brown with darker raised glands, no lighter vertebral line present, a lighter triangular snout patch present. Venter is clear with very slight black pigmentation present anteriorly of the snout forming larger blotches to the forearm midline. Arms and legs are strongly cross-banded, with upper arms clear of bands.

Colour in preservative—The dorsum dark brown with small darker raised glands, no dorsal lighter vertebral line present. Venter immaculate white with no bold black pigmentation, throat finely black pigmentation up to anterior chest region just below line with forearms. From just above the forearms midline is larger darker blotches randomly scattered to just below the forearms midline. Sole of feet and hands are dark pigmented, with tubercles being lighter in colouration. The inner thighs and anterior abdomen free of pigmented, forearms slightly pigmented. Palm and sole of feet darkened.

Variation—All the material examined conforms morphologically to the holotype (Table 2; Supplementary Table 4). All paratypes conform to the overall coloration described for the holotype: except all the paratypes have a interorbital bar lighter coloured than the lighter triangular snout patch, PEM A 12161 and 12172 have a light mid dorsal line, and all have a different degree of darker pigmentation over the throat up to the forearm midline.

Advertisement call—Currently unknown. At the time of the collection no breeding activity was observed.

Natural History—Juveniles were collected hiding under moss growing over the rock face where water seeps occurs (Fig. 7B).

Distribution—Currently only known from Mount Inago in central Mozambique.

***Nothophryne ribauensis* sp. nov.**

urn:lsid:zoobank.org:act:5BCE8B9A-96A3-4872-A54F-1C8CBAA76CD1

Ribáuè Mongrel Frog; Ribáuè Mountain Frog (Figs 8A–D)

Synonym—*Nothophryne broadleyi* – Blake 1965, p. 38, Poynton 1966, p. 23, Poynton & Broadley 1985, p. 173 (in part); Poynton & Broadley 1991, p. 262 (in part); Broadley 2001, p. 34 (in part); Channing 2001, p. 301 (in part); Mercurio 2011, p. 286 (in part); Conradie *et al.* 2016 (part).

Holotype—PEM A11372, adult male, collected from the eastern slopes of Mount M'pàluwé, part of the Ribáuè massif (14.91186° S, 38.31623° E, 632 m asl), Mozambique by W. Conradie and H.M. Engelbrecht on 3 December 2014.

Paratype male—PEM A11371, adult male. Same collection details as holotype.

Paratypes female (2)—PEM A11369-7, gravid adult females. Same collection details as holotype.

Additional material (6)—PEM A12174, 12176-78, NHML NHM UK 2018.02287-8 all juveniles, collected from the exposed granite slopes of Mount Ribáuè (15.15567° S, 37.42836° E, 1 230 m asl) by W. Conradie, S.P. Loader, K.A. Tolley and G.B. Bittencourt-Silva on 12–14 April 2017.

Diagnosis—*Nothophryne ribauensis* sp. nov. can be distinguished from other *Nothophryne* by the following: presence of an elevated median lingual process (approximately 0.1 mm) on the dorsal surface of the tongue (*N. broadleyi* – up to 1.0 mm long; *N. baylissi* sp. nov. – up to 0.5 mm long; *N. inagoensis* sp. nov. – up to 0.2 mm long; *N. unilurio* sp. nov. –absent) (Fig. 2D), tympanum clearly visible (differs only from *N. baylissi* sp. nov. which is obscured or barely visible), and very fast paced call with a very complicated call structure (compared to the more evenly spaced or clustered calls of *N. broadleyi* and *N. ribauensis* sp. nov.). The sequences of *Nothophryne ribauensis* sp. nov. differ from the other species of *Nothophryne* by 4–6% (16S p-distance) and 2–5% (RAG1 p-distance). *Nothophryne ribauensis* sp. nov. is allopatric with all other *Nothophryne* species.

Etymology—The new species is named after Mount Ribáuè, from which it is currently only known from both Mount Ribáuè and Mount M'pàluwé section of the massif.

Description of holotype—Small to medium size frog, SUL 18.1 mm. Body is slender, dorso-lateral flattened, widest at armpits. Head broad (HW/SUL 0.39), rounded from above in profile, head length is moderate to short (HL/SUL 0.33). Canthus rostralis rounded, straight from eye to nostril, loreal region slightly sloped outwards towards nostrils. Nostrils small, rounded, directed laterally, teardrop shaped angled downwards and backwards to eye, positioned slightly closer to the snout than the eye (EN/SL 0.54). Internarial distance is larger than distance between eye and nostril (IND/EN 1.36). Eyes directed anterolaterally, the eyes protrude, and visible from below, moderate to large in size (ED/HW 0.38; ED/HL 0.46), nearly twice the interorbital distance (ED/IOD 1.92). Distance between anterior corners of eyes is smaller than the internostril distance (IOD/IND 0.73). The angle of the

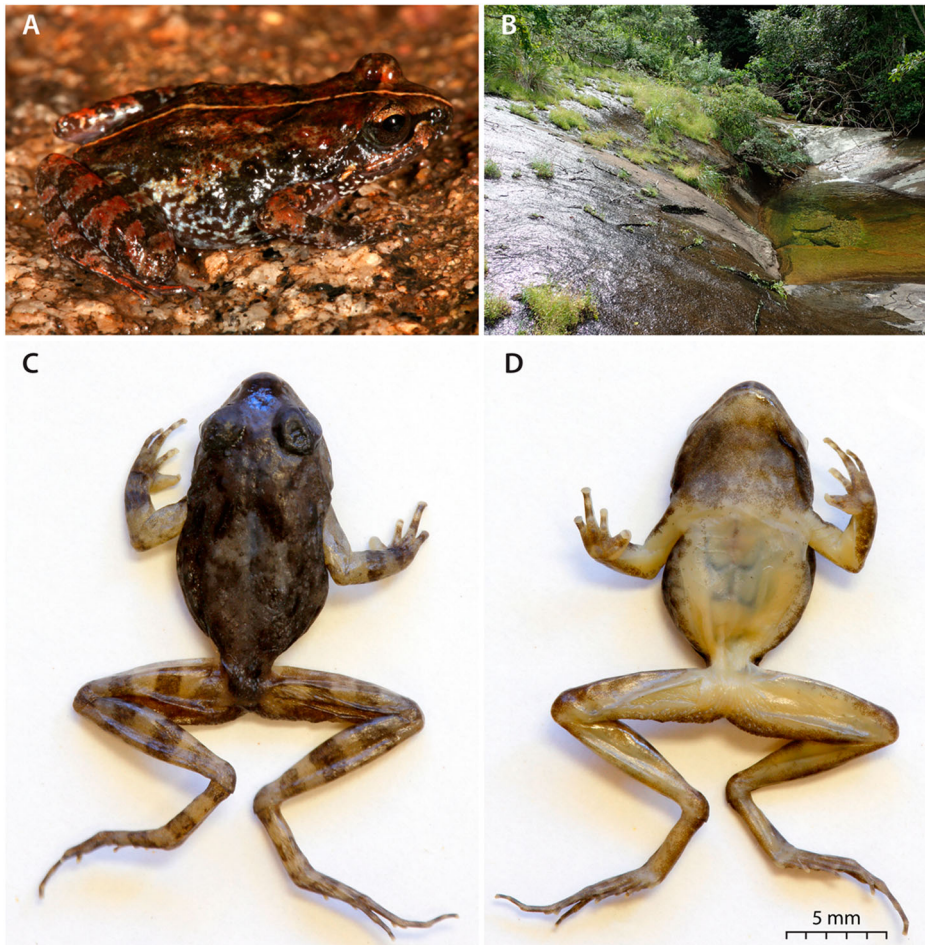


Figure 8. *Nothophryne ribauensis* sp. nov. from Mount Ribáuè. (A) Adult, (B) habitat, (C) dorsal view of holotype PEM A11372, (D) ventral view of holotype PEM A11372.

jaw slopes slightly upwards posteriorly from snout to just behind eye level. Tympanum clearly visible, with a light glandular ridge above tympanum from eye to base of forearm. Jaws without maxillary and premaxillary teeth, lower jaw with small anterior vomerine odontophore with central projection; choanae small, round, located at anterior margins of the roof of the mouth; tongue very long (4.3 mm), same width proximally to distally (~2.2 mm), bifurcated distally, first 25% attached to lower jaw, no narrow median lingual process present on the dorsal surface of the tongue.

The dorsal surfaces of the head, trunk and limbs are smooth, with slightly raised glands and skin folds present; the rectal gland is smooth slightly elevated from angle of jaw to form a continuous posteriorly ridge just before arm insertion, with some white tipped asperities. Supratympanic fold conspicuous; throat with no enlarged anterior scattered asperities. No gular pouch or flap present, a small slit on the inside of the mouth at the angle of the jaw gives access to the vocal sac. Ventrally smooth, upper jaw protruding over lower jaw, with very light mottled appearance, vocal sac dark with no mottled appearance anteriorly, getting mottled to about arm insertion (Fig. 8D).

The forelimbs are stubby, hands small (HAL/SUL 0.25), fingertips bluntly rounded and slightly swollen. Relative finger lengths $I < II < IV < III$; subarticular tubercles distinct, rounded, with one on each finger, no proximal subarticular present. No webbing between fingers. Thenar tubercle small, rounded, partially obscured by nuptial pad that reaches the distal phalanx of the first finger; inner metacarpal tubercle absent, outer metacarpal tubercle inconspicuous, central metacarpal tubercle present. One very small palmar tubercle present on the palm at the base of Finger III.

Hind limbs moderately long (TL/SUL 0.56; FL/SUL 0.54), feet nearly equal in length of tibia (TL/FL 1.0); thighs are moderately developed, with rough elevated glands on the inner posterior faces; relative toe lengths are $I < II < III < V < IV$. The toe tips are slightly expanded; subarticular tubercles: one on Toes I to III, two on Toes IV and V. No webbing between toes. Inner metatarsal tubercle conical and prominent, outer metatarsal tubercle absent.

Colour in life (Fig. 8A)—The dorsum brown with darker raised glands covered with small white tipped asperities, no lighter vertebral line present, a light yellow to white triangle on snout, lighter mid-dorsal chevron patch present. Venter is clear with slight black mottling and blotches. Nuptial pads prominent, but lighter than rest of fingers. Arms and legs are strongly cross-banded.

Colour in preservative—The dorsum dark brown with small white tipped asperities on the darker raised glands, dorsal lighter vertebral line absent, mid-dorsal light patch present. Venter immaculate white with no bold black pigmentation, throat finely and evenly black pigmentation up to anterior chest region above line with forearms. The inner thighs and anterior abdomen free of pigmented, forearms slightly pigmented. Palm and sole of feet darkened.

Variation—Additional paratype male conform to the holotype description in all regards and showed similar body proportions described above (Table 2; Supplementary Table 4). All specimens examined, except for paratype female (PEM A11370), showed no light vertebral line with mid-dorsum lighter patch. Paratype females conform to holotype, except: dorsum smoother with no elevated glands or skin folds, throat slightly mottled, longer thinner fingers, tips more swollen. Thenar tubercle much larger, rounded, palmar tubercles obvious, rounded, with on the palm, one at base of each finger, except Finger III with two, more prominent than in the males. Central metacarpal tubercle much larger than outer metacarpal tubercle, which is elevated.

Advertisement call—The following call description is based on a single male recorded on the eastern slopes of the Ribáuè massif, specifically Mount M'pàluwé (part of the massif) on 3 December 2014 at approximately 20:00 (Fig. 4C). Adult males were calling exposed from a seepage area over exposed rock surface. The call consist out of long "chuckle", which is repeated up to up to five times in less than 10 s or at a rate of 128 calls per minute with the dominant frequency at 2 842 Hz and the fundamental frequency at 1 335 Hz. The call duration is 0.56 ± 0.40 s and is separated from the next call by 2.45 ± 2.02 s ($n = 11$). The call structure is very complicated with up to 15 pulsed groups of notes.

Natural History—Males call exposed from seepages over rock face (Fig. 8B).

Distribution—Currently only known from Mount Ribáuè in central Mozambique.

***Nothophryne unilurio* sp. nov.**

urn:lsid:zoobank.org:act:C0667E79-6887-463F-A2FB-8FD33E89BC8A

Quirimbas Mongrel Frog; Quirimbas Mountain Frog (Figs 9A–D, 6D)

Holotype—PEM A12114, adult male, collected from Taratibu Hills (12.82178° S, 39.68658° E, 475 m asl), Mozambique by H. M. Farooq on 20 December 2014.

Paratype—PEM A12115, adult male. Same collection details as holotype.

Diagnosis—*Nothophryne unilurio* sp. nov. can be distinguished from other *Nothophryne* by the following: absence of a median lingual process on the dorsal surface of the tongue (*N. broadleyi* – up to 1.0 mm long; *N. baylissi* sp. nov. – up to 0.5 mm long; *N. inagoensis* sp. nov. – up to 0.2 mm long; *N. ribauensis* sp. nov. – a marginally elevated tubercle) (Fig. 2E), tympanum clearly visible (obscured in *N. baylissi* sp. nov. The sequences of *Nothophryne unilurio* sp. nov. differ from the other species of *Nothophryne* by 6–7% (16S p-distance) and 4–5% (RAG1 p-distance). This species is allopatric with all other *Nothophryne* species.

Etymology—Named after Lúrio University, Pemba, Mozambique where Harith Farooq is Director of the Natural Sciences Faculty. The composition comprise out of *uni* for University and *lurio* for Lúrio.

Description of holotype—Small to medium size frog, SUL 17.3 mm. Body is slender, dorso-lateral flattened, widest at armpits. Head broad (HW/SUL 0.40), rounded from above in profile, head length is moderate to short (HL/SUL 0.31). Canthus rostralis rounded, straight from eye to nostril, loreal region slightly sloped outwards towards nostrils. Nostrils small, rounded, directed laterally, teardrop shaped angled downwards and backwards to eye, positioned midway between snout and the eye (EN/SL 0.52). Internarial distance is larger than distance between eye and nostril (IND/EN 1.5). Eyes directed anterolaterally, the eyes protrude, and not visible from below, moderate in size (ED/HW 0.33; ED/HL 0.43), larger than the interorbital distance (ED/IOD 1.28). Distance between anterior corners of eyes is equal to the internostril distance (IOD/IND 1.0). The angle of the jaw slopes slightly upwards posteriorly from snout to just behind eye level. Tympanum clearly visible, with inconspicuous glandular ridge above tympanum from eye to base of forearm. Jaws without maxillary and premaxillary teeth, lower jaw with small anterior vomerine odontophore with central projection; choanae small, round, located at anterior margins of the roof of the mouth; tongue very long (4.2 mm), narrower proximally than distally (~1.7 mm), well bifurcated distally, first 50% attached to lower jaw, no narrow median lingual process present on the dorsal surface of the tongue.

The dorsal surfaces of the head, trunk and limbs are smooth, no raised glands and skin folds present; the rictal gland is smooth, but slightly elevated from angle of jaw to form a continued posteriorly ridge just before arm insertion, dorsum scattered with some white tipped asperities. Supratympanic fold inconspicuous; throat with no enlarge anterior or lateral scattered asperities. No gular pouch or flap present, a small slit on the inside of the mouth at the angle of the jaw gives access to the vocal sac. Ventrally smooth, upper

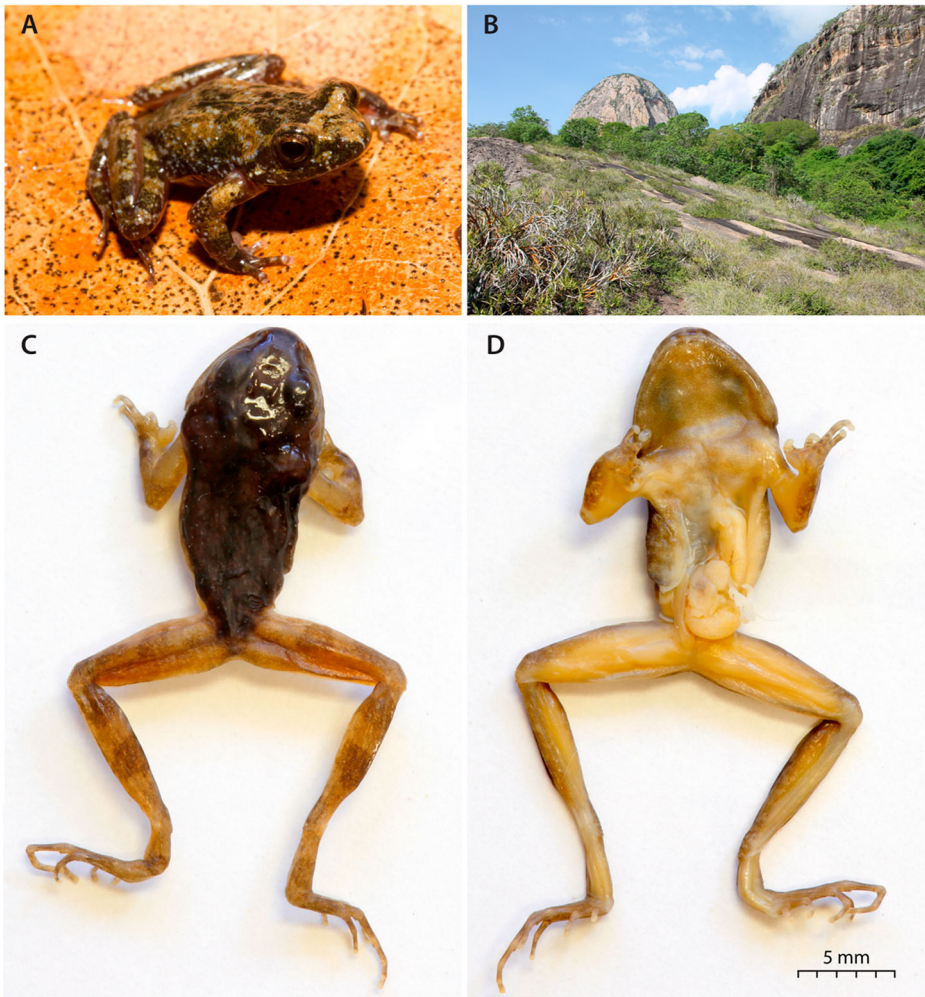


Figure 9. *Nothophryne unilurio* sp. nov. from Taratibu Hills. (A) Sub-adult, (B) habitat, (C) dorsal view of holotype PEM A12114, (D) ventral view of holotype PEM A12114.

jaw protruding over lower jaw, with very light mottled appearance, vocal sac dark with no white mottled appearance anteriorly, getting more mottled to about arm insertion (Fig. 9D).

The forelimbs are stubby, hands small (HAL/SUL 0.20), fingertips bluntly rounded and slightly swollen. Relative finger lengths $I < II < IV < III$; subarticular tubercles distinct, rounded, with one on each finger, no proximal subarticular present. No webbing between fingers. Thenar tubercle small, rounded, partially obscured by nuptial pad that reaches the distal phalanx of the first finger; inner metacarpal tubercle absent, outer metacarpal tubercle inconspicuous, central metacarpal tubercle present. Small palmar tubercles present on the palm at the base of Fingers II, III and IV.

Hind limbs moderately long (TL/SUL 0.57; FL/SUL 0.51), feet nearly equal in length of tibia (TL/FL 1.1); thighs are moderately developed, with rough elevated glands on the inner posterior faces; relative toe lengths are $I < II < III < V < IV$. The toe tips are slightly expanded; subarticular tubercles: one on Toes I to III, two on Toes IV and V. No webbing

between toes. Inner metatarsal tubercle conical and prominent, outer metatarsal tubercle absent.

Colour in life (Fig. 9A)—The dorsum light brown with dark greenish raised glands covered with small white tipped asperities, scattered white spots, no lighter vertebral line present, a light triangle on snout. Venter is clear with slight black mottling and blotches. Nuptial pads prominent, but lighter than rest of fingers. Arms and legs are strongly cross-banded.

Colour in preservative—The dorsum brown with small white tipped asperities, light interorbital bar, dorsal lighter vertebral line absent, mid-dorsal light patch present, arms and legs lighter than dorsum. Venter immaculate white with no bold black pigmentation, throat finely and evenly black pigmentation up to anterior chest region above line with forearms. The inner thighs and anterior abdomen free of pigmented, forearms slightly pigmented. Palms of hand and soles of feet darkened pigmented than limbs.

Variation—Paratype male showed similar body proportions to the holotype described above (Table 2; Supplementary Table 4). It further conforms to the holotype description, except for that the throat lighter pigmented with more prominent lighter blotching, tongue much shorted (~2.1 mm), and palmar tubercles more prominent (two at the base of each finger compared to one in holotype).

Advertisement call—Unknown.

Natural History—Males call hidden from under rocks and moss near streams which is found on exposed rock surface. Freshly laid eggs and tadpoles were seen on a tiny film of water flowing over rock surface (Fig. 6C).

Distribution—Currently only known from low lying inselbergs in north eastern Cabo Delgado Province of Mozambique. The type locality is situated at the Taratibu's Conservancy Area, near the Base camp, in the Quirimbas National Park.

Discussion

The type series of *Nothophryne broadleyi* is based on a series of females, and the diagnosis is established on osteological features and external morphological features (Poynton 1963). Subsequently, additional information was given by Poynton & Broadley (1985), which included the description of males of *N. broadleyi*. Here, we provide a detailed description of the male of *N. broadleyi* from Mount Mulanje, and comparative diagnoses of four new species from Mozambique based on new material.

When Poynton (1963) diagnosed the new genus he recorded a narrow median lingual process on the dorsal surface of the tongue. This feature is used in the key to identify the species from *Cacosternum* (Poynton & Broadley 1985). Furthermore, this feature is also missing from other closely related species in the family, i.e. *Tomopterna* (sister genus), *Anhydromphryne*, *Arthroleptella*, and *Natalobatrachus*. Here we adjust the genus diagnosis to include the presence or absence of this median lingual process, which is only present in species from Mount Mulanje, Mount Namuli and Mount Inago, reduced to a marginally elevated tubercle in Mount Ribáuè, and absent from the more eastern species found on at

Taratibu Hills. Grant *et al.* (1997) described the structure of the median lingual process in more detail and that the presence and absence could be influenced by the age of the animal. They further assign *Nothophryne* median lingual process to Group C2 and described it as being non retractable, elongated, and being longitudinally reclining in pointed processes pits. Although the species from Mount Inago and Taratibu Hills are based on sub-adult material, currently this character can be used to distinguish between the western and eastern species. If and how median lingual process change ontogenetically is required to fully understand the diagnostic utility of this character in the future.

The 16S rRNA gene is often used as standard DNA barcoding marker for amphibians (e.g. Vences *et al.* 2005). For *Nothophryne*, the minimum observed p-distance between putative species for 16S sequences was 4%. This difference is consistent with interspecific p-distances observed in other groups of frogs (e.g. Vences *et al.* 2005, Supplementary Tables 1 and 2). The high differentiation observed among RAG1 sequences, which is a conserved nuclear gene, is also consistent with results observed in other species of anurans (e.g. Ndriantsoa *et al.* 2013, Supplementary Table 2). Overall, the molecular data analysed here corroborates the species distinctiveness in the genus *Nothophryne*.

With the description of four new species we have expanded the species diversity of the genus *Nothophryne* to five. Given the paucity of biological surveys and the high number of inselbergs in Mozambique we predict the genus might contain more species and new surveys are clearly required. The current level of anthropogenic impact on the inselbergs of Mozambique (Timberlake *et al.* 2007, Timberlake *et al.* 2009, Bayliss *et al.* 2010, Timberlake *et al.* 2012, Bayliss *et al.* 2014) means both described species and those that potentially await description are of high conservation concern. All species have narrow distributional ranges, restricted entirely to single mountain areas, and therefore require concerted conservation effort to protect their native habitat.

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We dedicate this paper to Donald G. Broadley (1932–2016). Don, by which most of us knew him, discovered the monotypic genus *Nothophryne* from Dzole Peak, Mount Mulanje on 24 December 1962, which led to Poynton (1966) naming the monotypic species in his honour. Don led the fourth expedition to Mozambique (Blake 1965; Poynton 1966), where this species was then documented from the Mount Ribáuè inselberg, which then represented the only known population of *Nothophryne* outside Malawi and the first record for Mozambique. Our South African National Biodiversity Institute (SANBI) 2014 expedition was funded by National Geographic Society-Committee for Research and Exploration (NGS-CRE) and SANBI. Our 2017 expedition was funded by NGS-CRE and the Critical Ecosystem Partnership Fund-Eastern Afromontane Biodiversity Hotspot Small Grant Mechanism through BirdLife International (grants to KAT). Mike Scott (Khangela Safaris) provided field logistics and assistance. The Natural History Museum of Maputo provided collecting and export permits for Mozambique material, with permission from the provinces of Zambézia and Nampula (Provincial Directorate of Land, Environment and Rural Development). We are grateful for field assistance, support and companionship from Hanlie Engelbrecht, Dave Langerman, Hermengildo Matimele and Erica Tovela.

Supplemental Material

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ORCID

Werner Conradie  <http://orcid.org/0000-0003-0805-9683>
 Gabriela B. Bittencourt-Silva  <http://orcid.org/0000-0002-7391-8408>
 Harith M. Farooq  <http://orcid.org/0000-0001-9031-2785>
 Simon P. Loader  <http://orcid.org/0000-0003-4162-0575>
 Michele Menegon  <http://orcid.org/0000-0002-2366-1771>
 Krystal A. Tolley  <http://orcid.org/0000-0002-7778-1963>

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