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**A NEW SPECIES OF THE MINIATURIZED FROG GENUS
PAEDOPHRYNE (ANURA: MICROHYLIDAE)
FROM PAPUA NEW GUINEA**

Fred Kraus¹

ABSTRACT – I describe a new species of *Paedophryne* from low-elevation foothill rainforest on Normanby Island off southeastern Papua New Guinea. This new species is the largest member of the genus so far discovered, with body length of the sole adult male 11.1 mm, and with adult females ranging from 10.6–11.6 mm. As well, it differs from other species in the genus in having smooth dorsal skin, a disc on the second toe, relatively larger first digits, and in a number of body proportions and details of color pattern. As for other species in the genus, it is an inhabitant of rainforest leaf litter restricted to a portion of the East Papuan Composite Terrane, an agglomeration of terranes that were assembled offshore of New Guinea and sutured to it during the early Miocene.

Key words: D'Entrecasteaux Islands; East Papuan Composite Terrane, Milne Bay Province; Normanby Island

INTRODUCTION

The most miniaturized lineage of tetrapods is *Paedophryne*, a Papuan genus of microhylid frog only recently described (Kraus, 2010) and now known from six species (Kraus, 2011; Rittmeyer et al., 2012). Adults of these species vary from 7.0–11.3 mm snout-vent length, with females being slightly larger than males, as is typical for Papuan microhylids. All species are inhabitants of the interstices within leaf litter and have a unique combination of morphological characters. The first digits are vestigial and the finger tips are flattened, making these species immediately recognizable externally. Furthermore, they have a long, strap-like tongue, seven presacral vertebrae, prepollex and prehallux each reduced to a single element, a hypertrophied *M. submentalis*, the *M. depressor mandibulae* overlying posterior margin of tympanum, and the *M. adductor mandibularis anterior longus* small and inserting only on lateral portions of

¹Department of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, MI 48109, USA.

frontoparietals (Kraus, 2010). Given their unusual microhabitat, the frogs are most easily found at night by scanning the surface of the litter or by turning the top layers of litter to find hidden animals. Males may call day or night, a feature that seems to vary inter-specifically so far as I can determine from my experience.

During recent fieldwork on an island off southeastern Papua New Guinea I discovered another species of *Paedophryne*, which is the largest member of the genus discovered to date and the second insular species. I describe the new species here.

MATERIALS AND METHODS

Specimens were collected under relevant national permits and institutional animal-use guidelines, fixed in 10% formalin, and stored in 65% ethanol. I made all measurements with an optical micrometer to the nearest 0.1 mm, except for toe disc width, measured to the nearest 0.03 mm. Measurements, terminology, and abbreviations follow Zweifel (1985) and Kraus and Allison (2006): body length from snout to 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 center of naris (EN); internarial distance, between centers 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); hand length, from proximal edge of palm to tip of 3rd finger (HandL); foot length, from proximal edge of sole to tip of 4th toe (FootL); width of the third finger disc (3rdF); and width of the fourth toe disc (4thT). I determined sex by presence of vocal slits (males) or examination of gonads (females, and males for which the vocal slits were not clearly discernible). I identified frogs to genus based on diminutive size; presence of eleutherognathine maxillae and a long, strap-like tongue; and the miniaturized phalangeal pattern that reduces their first fingers and first toes to mere nubs. The last is unique among Papuan frogs and immediately diagnostic.

Type specimens are deposited in the University of Michigan Museum of Zoology (UMMZ). Locality coordinates for the new species use GPS datum AUS 66 and were taken from a hand-held Garmin GPS unit.

Paedophryne titan Kraus, sp. nov.

Figs. 1, 2

Holotype.—UMMZ 242417 (field tag FK 16912), specimen in alcohol, adult female, collected by F. Kraus, J. Rivera, E. Henry, and local villagers at Domaruwa, slope S of Awaiara Bay, 10.0579° S, 151.0703° E, 556 m elevation, Normanby Island, Milne Bay Province, Papua New Guinea, 18 September 2013.

Paratypes (n = 4).—UMMZ 242416, same data as holotype; UMMZ 242414, slope S of Awaiara Bay, 10.0574° S, 151.0709° E, 549 m elevation, 14 September 2013, collected by F. Kraus; UMMZ 242415, same data as UMMZ 242414, except collected 16 September 2013; UMMZ 242418, slope S of Awaiara Bay, 10.0589° S, 151.0717° E, 500 m elevation, 19 September 2013, collected by F. Kraus, J. Rivera, E. Henry, and local villagers.



Figure 1. (A) Dorsum, (B) Ventrum, (C) side of head, (D) palmar view of left hand, and (E) plantar view of left foot of holotype of *Paedophryne titan* (UMMZ 242417). Scale bars = 3 mm (A–B), 2 mm (C, E), and 1 mm (D).

Referred specimen.—FK 16913, an entire-specimen tissue sample saved in the tissue collection at UMMZ. Same data as UMMZ 242414, except collected 17 September 2013.

Diagnosis.—A large member of the genus (male SV = 11.1, female SV = 10.6–11.6 mm) having smooth dorsal skin; relatively long legs (TL/SV = 0.48–0.51); long and narrow snout (EN/SV = 0.065–0.075, IN/SV = 0.095–0.113, EN/IN = 0.63–0.73, SN/SV = 0.11–0.14, EN/SN = 0.55–0.62); small tympana (TY/SV = 0.036–0.047); long head (HL/SV = 0.29–0.32); relatively large discs present on third and fourth toes (3rdF/SV = 0.024–0.030, 4thT/SV = 0.047–0.054, 3rdF/4thT = 0.48–0.59); disc present on the second toe; and brown, gray-brown, or red-brown dorsum blotched, mottled, or flecked with black or dark brown.

Comparisons with other species.—*Paedophryne titan* differs from (1) *P. amauensis* in its larger size (male SV = 11.1 mm vs. 7.0–8.0 mm in *P. amauensis*), longer snout (SN/SV = 0.11–0.14 vs. 0.09–0.12 in *P. amauensis*; EN/SN = 0.55–0.62 vs. 0.63–0.85 in *P. amauensis*), longer head (HL/SV = 0.29–0.32 vs. 0.27–0.29 in *P. amauensis*; HL/HW = 0.84–1.00 vs. 0.69–0.82 in *P. amauensis*), and broader toe discs (4thT/SV = 0.047–0.054 vs 0.036–0.050 in *P. amauensis*; 3rdF/4thT = 0.48–0.59 vs. 0.63–0.83 in *P. amauensis*); (2) *P. swiftorum* in its larger size (male SV = 11.1 mm vs. 8.2–8.8 mm in *P. swiftorum*), smaller eye (EY/SV = 0.13–0.15 vs. 0.15–0.17 in *P. swiftorum*; EY/SN = 1.00–1.27 vs. 1.18–1.40 in *P. swiftorum*), broader

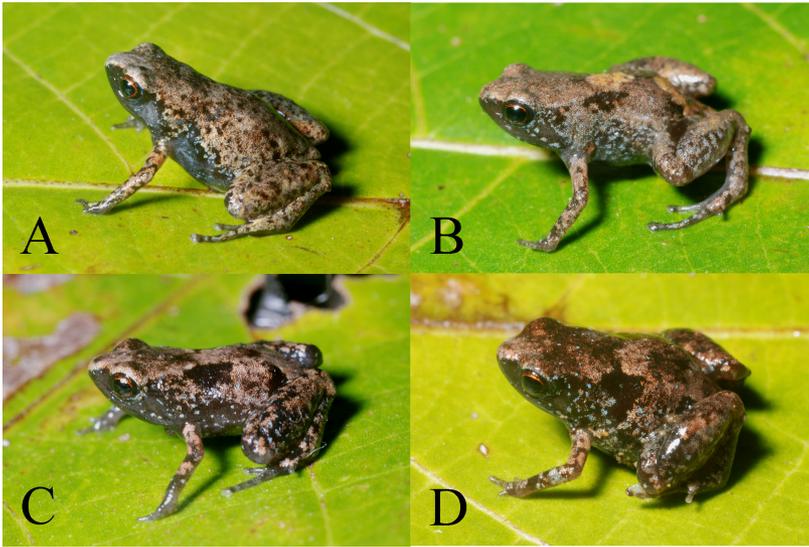


Figure 2. Portraits in life of (A) holotype UMMZ 242417, (B) paratype UMMZ 242414, (C) paratype UMMZ 242415, and (D) paratype UMMZ 242416 of *Paedophryne titan*.

discs (3rdF/SV = 0.024–0.030 vs. 0.022–0.024 in *P. swiftorum*; 4thT/SV = 0.047–0.054 vs. 0.042–0.048 in *P. swiftorum*), and narrower snout (EN/IN = 0.63–0.74 vs. 0.56–0.67 in *P. swiftorum*); (3) *P. dekoti* in its larger size (female SV = 10.6–11.6 mm vs. 8.5–9.0 mm in *P. dekoti*), longer leg (TL/SV = 0.48–0.51 vs. 0.45–0.46 in *P. dekoti*), narrower snout (EN/SN = 0.55–0.62 vs. 0.50–0.55 in *P. dekoti*), smaller tympanum (TY/SV = 0.036–0.047 vs. 0.044–0.059 in *P. dekoti*), longer first digits (compare Fig. 1D, E vs. figure 1D, E of Kraus, 2011), presence of a disc on the second toe (absent in *P. dekoti*), and dorsum flecked or spotted with dark brown (dorsum uniformly brown or with a few tan blotches in *P. dekoti*); (4) *P. verrucosa* in its larger size (male SV = 11.1 mm vs. 8.1–8.9 mm in *P. verrucosa*; female SV = 10.6–11.6 mm vs. 8.8–9.3 mm in *P. verrucosa*), smooth dorsal skin (vs. pustulose in *P. verrucosa*), longer leg (TL/SV = 0.48–0.51 vs. 0.37–0.42 in *P. verrucosa*), narrower snout (IN/SV = 0.095–0.113 vs. 0.108–0.123 in *P. verrucosa*), smaller tympanum (TY/SV = 0.036–0.047 vs. 0.043–0.062 in *P. verrucosa*), disc present on 3rd finger (vs. absent in *P. verrucosa*), and lateral surfaces darker than dorsum (vs. same color); (5) *P. kathismaphlox* in its smooth dorsal skin (vs. rugose or slightly pustulose in *P. kathismaphlox*), longer leg (TL/SV = 0.48–0.51 vs. 0.35–0.39 in *P. kathismaphlox*), broader snout (EN/IN = 0.63–0.74 vs. 0.78–0.80 in *P. kathismaphlox*), smaller tympanum (TY/SV = 0.036–0.047 vs. 0.050–0.073 in *P. kathismaphlox*), larger eye (EY/SN = 1.00–1.27 vs. 0.92–1.00 in *P. kathismaphlox*), broader toe discs (4thT/SV = 0.047–0.054 vs. 0.032–0.037 in *P. kathismaphlox*; 3rdF/4thT = 0.48–0.59 vs. 0.66–0.86 in *P. kathismaphlox*), and absence of an orange patch under anus (vs. present in *P. kathismaphlox*); and (6) *P. oyatabu* in its longer leg (TL/SV = 0.48–0.51 vs. 0.40 in *P. oyatabu*), longer snout (EN/SV = 0.065–0.075 vs. 0.062 in *P. oyatabu*; EN/SN = 0.55–0.62 vs. 0.50 in *P. oyatabu*), smaller tympanum (TY/SV = 0.036–0.047 vs. 0.062 in *P. oyatabu*), broader toe discs (4thT/SV = 0.047–0.054 vs. 0.031 in *P. oyatabu*; 3rdF/4thT = 0.48–0.59 vs. 0.80 in *P. oyatabu*), and variegated mid-dorsum (vs. with dark chevrons in *P. oyatabu*).

Description of holotype.—An adult female with an incision on right side of body; liver removed and stored separately for DNA analysis. Head moderately wide ($HW/SV = 0.36$, Fig. 1A), with steeply oblique loreal region; canthus rostralis rounded, slightly convex when viewed from above; nostrils directed anterolaterally, closer to tip of snout than to eyes; internarial distance much larger than distance from naris to eye ($EN/IN = 0.73$, $IN/SV = 0.095$, $EN/SV = 0.069$); snout rounded when viewed from the side or from above (Fig. 1A, C); eyes moderately large ($EY/SV = 0.13$; $EY/SN = 1.07$, Fig. 1C), pupil horizontal; eyelid approximately two-thirds width of interorbital distance; tympanum indistinct and small ($TY/SV = 0.047$), visible only when skin dries slightly, hidden posterodorsally. Dorsal skin smooth; supratympanic fold absent. Fingers unwebbed, flattened; F1 vestigial but distinct and projecting beyond hand; relative lengths $3 > 2 > 4 > 1$ (Fig. 1D); discs absent. Subarticular and metacarpal tubercles absent. Toes unwebbed; T2, T3, and T4 with flattened discs, the last two with terminal grooves; discs of T3 and T4 clearly wider than penultimate phalanx. Fifth toe with round tips and no disc; T1 vestigial but distinct and projecting beyond foot; relative lengths of toes $4 > 3 > 2 = 5 > 1$ (Fig. 1E). Subarticular and metatarsal tubercles absent. Plantar and palmar surfaces smooth. Hind legs rather long ($TL/SV = 0.48$, Fig. 1A). Tongue elongate, straplike, anterior third attached to floor of mouth.

In preservative, dorsum appears to the naked eye brown heavily flecked with darker brown (Fig. 1A), with the brown ground color resulting from a dense stippling of brown punctations on a pale straw-yellow substrate; brown flecks larger laterally. Limbs similar to dorsum but flecks larger. Brown color absent from large dorsal section of right shank and foot. Face with denser brown stippling and, hence, appearing darker (Fig. 1C). Tympanic area with less brown stippling and, hence, appearing slightly paler. Venter very pale whitish, heavily flecked with brown, denser on chin and throat, sparser on abdomen (Fig. 1B). Palmar and plantar surfaces brown, with unpigmented patches on central metacarpal regions and on inner metatarsal region of right foot (Fig. 1D, E). Iris black.

Measurements (in mm).— $SV = 11.6$, $TL = 5.6$, $HW = 4.2$, $HL = 3.8$, $IN = 1.1$, $EN = 0.8$, $SN = 1.4$, $EY = 1.5$, $TY = 0.6$, $3rd\ F = 0.30$, $4th\ T = 0.59$.

Variation.—Two paratypes are female, one is male, and one is juvenile. There is little mensural difference between the holotype and paratypes (Table 1), and no clear sexual or ontogenetic differences except that the juvenile has a relatively larger eye, and the male may possibly have a relatively narrower head and longer foot.

Dorsal flecking is more concentrated into large dorsolateral blotches in the paratypes compared to the holotype, and two of these also have large, pale mid-dorsal blotches. The four paratypes have scattered tiny gray-white flecks laterally, which are not apparent in the holotype. Venters of the paratypes are more densely flecked/stippled with brown, such that the pale areas usually appear as spots on a brown ground. UMMZ 242418 has larger dark-brown lateral spots than the remaining specimens. None of the paratypes has the tympanic region differentiated from adjacent areas in color.

Color in life.—Field notes for UMMZ 242414 state: "Dorsum dark tan with pale orange-tan mid-dorsal blotch and pale, orange-tan chevron above ilium, each flanked laterally by a dark-brown blotch, with another behind each eye. Sides dark tan with dark-brown flecks and smaller, more numerous pale blue-gray flecks. Face dark brown with few pale blue-gray flecks. Iris red orange. Chin to chest black, abdomen and under legs dark

Table 1. Mensural data for the type series of *Paedophryne titan*.

Character	UMMZ 242414 paratype	UMMZ 242415 paratype	UMMZ 242416 paratype	UMMZ 242417 holotype	UMMZ 242418 paratype
Sex	Male	Juvenile	Female	Female	Female
SV	11.1	9.0	10.6	11.6	11.6
TL	5.5	4.6	5.5	5.6	5.6
EN	0.8	0.7	0.8	0.8	0.8
IN	1.1	1.0	1.2	1.1	1.2
SN	1.4	1.1	1.5	1.4	1.3
TY	0.4	0.5	0.5	0.6	0.6
EY	1.5	1.3	1.5	1.5	1.7
HW	3.8	3.1	4.2	4.2	4.0
HL	3.2	2.9	3.4	3.8	3.7
HandL	2.0	1.5	1.7	2.1	1.9
FootL	4.9	3.5	4.4	4.8	4.8
3rdF	0.33	0.25	0.28	0.3	0.31
4thT	0.56	0.45	0.5	0.59	0.63
TL/SV	0.50	0.51	0.51	0.48	0.48
EN/SV	0.072	0.078	0.075	0.069	0.065
IN/SV	0.099	0.106	0.113	0.095	0.103
SN/SV	0.13	0.12	0.14	0.12	0.11
TY/SV	0.036	0.05	0.042	0.047	0.047
EY/SV	0.13	0.15	0.14	0.13	0.14
HW/SV	0.34	0.34	0.39	0.36	0.34
HL/SV	0.29	0.32	0.32	0.32	0.31
HandL/SV	0.18	0.17	0.16	0.18	0.16
FootL/SV	0.44	0.39	0.42	0.41	0.41
3rdF/SV	0.03	0.028	0.026	0.026	0.027
4thT/SV	0.05	0.05	0.047	0.051	0.054
EN/IN	0.73	0.74	0.67	0.73	0.63
3rdF/4thT	0.59	0.56	0.56	0.51	0.49
HL/HW	0.84	0.95	0.82	0.90	0.91

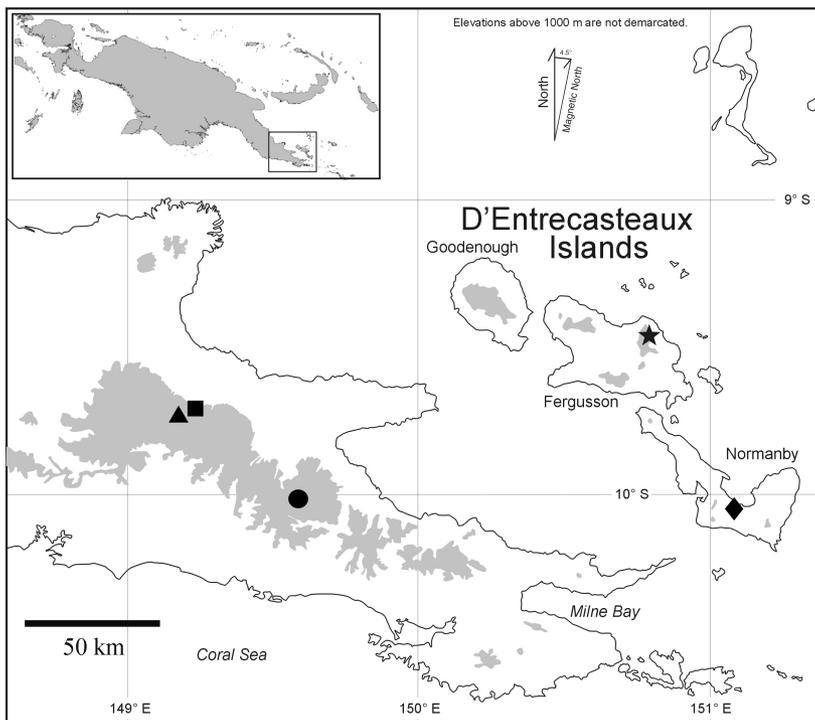


Figure 3. Map of southeastern Papua New Guinea, showing type locality for *Paedophryne titan* (diamond) in comparison to its geographically proximate congeners *P. dekot* (square), *P. kathismaphlox* (circle), *P. oyatabu* (star), and *P. verrucosa* (triangle).

gray with many pale-gray flecks. Rear legs dark tan with one central black bar/blotch on each thigh." UMMZ 242415 was brown dorsally with two black dorsolateral blotches on each side and a black dorsal blotch centered among these; sides and entire venter dark charcoal gray, almost black, with numerous tiny blue-gray flecks. Size of dark dorsal blotching, presence of orange-tan dorsal blotches, and extent of lateral blue-gray flecking varies among these two animals, an additional paratype, and the holotype (Fig. 2).

Etymology.—The species name refers to the progeny of Uranus and Gaea, who were symbolic of large size and brute strength; it recognizes that this species is the largest known member of this miniaturized genus.

Range.—Known only from 500–550 m elevation at the type locality on the eastern side of Normanby Island, Milne Bay Province, Papua New Guinea (Fig. 3, diamond). No doubt it ranges widely across this island but it remains to be determined whether it occurs on the other D'Entrecasteaux islands.

Ecological notes.—Like the other members of the genus, *Paedophryne titan* inhabits the interstices of leaf litter on the forest floor of primary rainforest. Habitat of this species is primary foothill rainforest in an area with rather gentle slopes (by New Guinean standards). During my visit, conditions were dry, and the few specimens discovered were located after considerable effort under the deepest piles of leaf litter in a forest in which such litter was generally sparse and shallow.

DISCUSSION

In color pattern and overall appearance, *Paedophryne titan* appears most similar to *P. dekot*, known only from mid-elevation foothill forest on the Mt. Suckling-Mt. Dayman massif, 200 km to the west-northwest, on mainland New Guinea (Fig. 3). In particular, the smooth dorsal skin, medium-brown dorsum that is typically adorned with a pair of dark-brown dorsolateral blotches on each side, and the dark-brown sides flecked with pale blue make the two species appear virtually identical to the naked eye. But, upon close inspection, *P. titan* differs from *P. dekot* in a number of morphometric features and presence of a disc on the second toe. The distributions of the two species suggest that the ancestor of both had a broader distribution across Milne Bay Province. The D'Entrecasteaux Islands are active metamorphic core complexes in a region of crustal extension resulting from the spreading of the Woodlark Basin (Taylor et al., 1995; Miller et al., 2012), and they appear to have formed beginning ca. 4 MYA (Baldwin et al., 1993). The diverse frog faunas on these islands (32 species in 14 genera) include virtually all of the genera that occur on the adjacent mainland. This suggests that the islands were formerly connected to the mainland because successful transmarine dispersal of so many amphibian taxa seems highly unlikely. Hence, I hypothesize that the islands became isolated from the mainland with ongoing dismemberment of the Milne Bay region caused by continued opening of the Woodlark Basin subsequent to initial emergence of the core complexes. And this event is what presumably allowed for differentiation of the ancestral species into *P. titan* and *P. dekot* today.

It remains uncertain whether *Paedophryne titan* will prove restricted to Normanby Island or will occur as well at lower elevations on the other D'Entrecasteaux islands, all of which are joined by a basin <100 m deep that connected these islands together during the Pleistocene (Goodliffe et al., 2000; Lambeck and Chappell, 2001; <http://sahultime.monash.edu.au/explore.html>). A different species of *Paedophryne* (*P. oyatabu*, Fig. 3, star) is already known from adjacent Ferguson Island, but that species occurs at a much higher elevation (1400 m). Given the fact that different *Paedophryne* species are known to ecologically replace each other at ~1000–1200 m elevation on Mt. Suckling (Kraus, 2011), it seems unlikely that the high-elevation *P. oyatabu* would occur across the lowlands of Ferguson Island as well, and I anticipate that a different species will be found to occupy those regions. Whether such a species would prove conspecific with *P. titan*, however, remains to be seen, although other low-elevation frog species are shared across these islands (cf., Kraus and Allison, 2004, 2007).

Many species of Papuan frogs have very restricted distributional ranges, and relatively few are widespread across New Guinea. As a result, many frogs are regional endemics, often being confined to single geological terranes or terrane systems. The tiny size of *Paedophryne* species may make them even poorer dispersers and, hence, more prone to narrow-range endemism than is already seen for Papuan frogs generally, a pattern seen in small frogs elsewhere (Wollenberg et al., 2011). Each *Paedophryne* species is currently known only from its type locality, and it remains unknown how widely distributed each may be. This limited knowledge is because all these species have been discovered only recently, the frogs are difficult to find (or even notice without prior experience with them), and the logistical difficulty of accessing field sites continues to limit the ability to conduct geographically

dense biological surveys in New Guinea and surrounding islands. Evidence at present, though, indicates that a diversity of *Paedophryne* species is widely distributed across the southeastern peninsula of New Guinea and adjacent islands and that even closely adjacent regions contain different species (Fig. 3). This portion of New Guinea and adjacent islands comprises the East Papuan Composite Terrane (EPCT, Pigram and Davies, 1987; Pigram and Symonds, 1991), formed by offshore agglomeration of separate terranes and their later docking with the remainder of New Guinea in the early Miocene (ca. 20 MYA). The apparent limitation of *Paedophryne* to the EPCT suggests its likely evolution on that system prior to that docking event, which, if true, would indicate the lineage to be an old one. That ancient origin, the presumably limited dispersal ability of these frogs, and the fact that most of the EPCT remains unsurveyed for reptiles and amphibians make it reasonable to expect that many additional species remain undiscovered in this genus.

KEY TO SPECIES OF *PAEDOPHRYNE*

- 1 a) Dorsal skin rugose or pustulose 2
 b) Dorsal skin smooth 3
- 2 a) Plantar surfaces warty; 5th toe < 2nd toe; dorsum and sides same color ...
 *P. verrucosa*
 b) Plantar surfaces smooth; 5th toe \approx 2nd toe; dorsum paler than sides
 *P. kathismaphlox*
- 3 a) Adult body size larger (SV = 10.6–11.6 mm) 4
 b) Adult body size smaller (SV = 7.0–9.0 mm) 5
- 4 a) Leg long (TL/SV = 0.48–0.51); tympanum small (TY/SV = 0.036–0.047);
 toe discs broad (4thT/SV = 0.047–0.054, 3rdF/4thT = 0.48–0.59); mid-
 dorsum variegated *P. titan*
 b) Leg short (TL/SV = 0.40), tympanum large (TY/SV = 0.062); toe discs
 narrow (4thT/SV = 0.031, 3rdF/4thT = 0.80); mid-dorsum with dark
 chevrons *P. oyatabu*
- 5 a) Adult body size smaller (SV = 7.0–8.0 mm); head short (HL/SV = 0.27–
 0.29); naris relatively closer to tip of snout (EN/SN = 0.63–0.85); finger
 discs broader (3rdF/SV = 0.025–0.033) *P. amauensis*
 b) Adult body size larger (SV = 8.2–9.0 mm); head longer (HL/SV = 0.32–
 0.35); naris relatively farther from tip of snout (EN/SN = 0.45–0.60);
 finger discs narrower (3rdF/SV = 0.022–0.026) 6
- 6 a) Eye smaller (EY/SN = 1.00–1.18); head relatively narrower (HL/HW =
 0.84–0.88) *P. dekot*
 b) Eye larger (EY/SN = 1.18–1.40); head relatively longer (HL/HW = 0.88–
 0.97) *P. swiftorum**

* Insufficient data are provided in the original description of this species to further distinguish it from *P. dekot*, although call data may do so. *P. swiftorum* has a call consisting of paired unpulsed notes; what I believe to have been the call (unrecorded) of *P. dekot* consisted of single pulsed notes, sounding similar to that of *P. verrucosa* (Kraus, 2011).

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