

A new species of reed snake, genus *Calamaria* (Colubridae: Calamariinae), from Mindoro Island, Philippines

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Abstract

We describe a new species of reed snake of the genus *Calamaria* Boie 1827, from Mindoro Island, Philippines. The new species differs from all other species of *Calamaria* by having the following combination of characters: a high number of subcaudal scale pairs (> 40 in males, > 30 females) and ventrals + subcaudals (> 205 in males, > 210 in females); mental scale not contacting chin shields; dorsal surface of head, body, and tail uniformly dark brown; and ventral surface of body (extending to include part or all of first longitudinal row of dorsals) uniformly pale (yellow or white in life). The new species is likely most closely related to *Calamaria schlegeli* Duméril, Bibron, and Duméril 1854, which also has a high number of subcaudal scales compared to other *Calamaria* species. The new species is the second *Calamaria* species known from Mindoro Island and the eighth known from the Philippines, and its presumed distant relationship from other Philippine *Calamaria* suggests an additional colonization of the Philippines by this genus from continental Asia.

Keywords: biodiversity, biogeography, *Calamaria alcalai* new species, Serpentes, Squamata, systematics

Introduction

The colubrid subfamily Calamariinae (Reed Snakes) includes seven genera and ~90 species of small, fossorial snakes that are collectively distributed across Southeast Asia and southern China (Stuebing et al., 2014; Leviton et al., 2018; Uetz et al., 2020). Five of the seven genera are geographically restricted to small areas of Peninsular Malaysia or to single Wallacean islands, namely *Calamorphabdium* (Bacan Island; two species), *Rabdion* (Sulawesi; two species), *Collorhabdium* and *Macrocalamus* (Peninsular Malaysia; one and eight species, respectively), and *Etheridgeum* (Sumatra; monotypic), whereas the genera *Calamaria* and *Pseudorabdion* are more diverse and distributed across multiple landmasses (David and Vogel, 1996;

de Lang and Vogel, 2005; Stuebing et al., 2014; de Lang, 2017; Quah et al., 2020). *Calamaria* (64 species) is distributed throughout Southeast Asia and southern China, and *Pseudorabdion* (15 species) is known from Borneo, Peninsular Malaysia, Sumatra, Sulawesi, and the Philippines (Uetz et al., 2020). In the Philippines, Reed Snakes are known from all Pleistocene Aggregate Island Complexes (PAICs) as well as the Babuyan and Romblon Island groups (Fig. 1; Oliveros et al., 2011; Siler et al., 2012b; Leviton et al., 2018).

The Philippine Reed Snakes include seven species of *Calamaria* and seven species of *Pseudorabdion*, all of which are small, fossorial or semifossorial and have a specialized diet of earthworms (Gaulke, 2011; Leviton et al., 2018; Weinell et al., 2019). Similarities in overall morphology, size, microhabitats, and multiple scalation and skeletal characters distinguish these two genera (Leviton and Brown, 1959; Inger and Marx, 1965; Gaulke, 2011). In particular, *Calamaria* can be distinguished from *Pseudorabdion* by having 13 longitudinal rows of dorsal body scales (vs. 15 in *Pseudorabdion*), internasal scales fused with prefrontal scales (vs. internasals distinct from prefrontals), and the tail is usually shorter (Leviton and Brown, 1959; Inger and Marx, 1965). Since Inger and Marx's (1965) and Leviton and Brown's (1959) comprehensive reviews of *Calamaria* and *Pseudorabdion*, respectively, 16 new species have been

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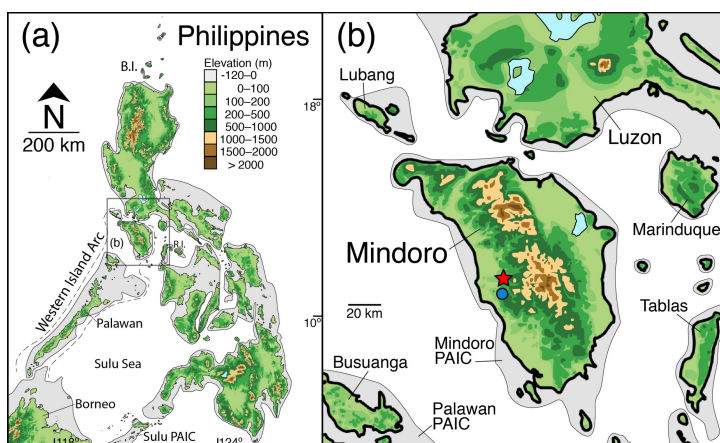


Figure 1. Map of the Philippines (a), and Mindoro Island (b) with elevation indicated by incremental shading (see key); red star = type locality of *Calamaria alcalai*, new species; blue circle = additional locality; both within the Municipality of Sablayan. Gray shading indicates areas ~ 120 m below sea level that are presumed to have been exposed land during Pleistocene glacial maxima, and represent the hypothesized limits of Pleistocene Aggregate Island Complexes (PAICs), including the distinct Mindoro PAIC, which encompasses small islands to the south; light blue color indicates large, present day lakes. In (a), B.I. = Babuyan Island Group, R.I. = Romblon Island Group.

described for these genera, although only one of these (*P. talonuran* R.M. Brown, Leviton & Sison; Brown et al., 1999) is from the Philippines (Inger and Leviton, 1961; Grismer et al., 2004; Ziegler and Quyet, 2005; Howard and Gillespie, 2007; Koch et al., 2009; Orlov, 2009; Nguyen et al., 2009; Ziegler et al., 2009, 2019; Doria and Petri, 2010; Orlov et al., 2010; Yang and Zheng, 2018; Poyarkov et al., 2019).

Here we describe a new species of *Calamaria* from Mindoro Island, Philippines, based on its distinctive phenotype. Based upon our analysis of data collected from examination of specimens of the new species and other allied Philippine snakes, our results support a potentially close relationship between the new species and the widespread Sundaland species *C. schlegeli* A.M.C. Duméril, Bibron & A.H.A. Duméril. The discovery of a new *Calamaria* from Mindoro, one apparently distantly related to other Philippine *Calamaria* (and initially misidentified as an unknown species of *Pseudorabdion*), highlights the importance of critically examining samples (determining species identity) of allegedly widely-distributed species collected during broad, comprehensive, regional biodiversity surveys (Brown et al. 2013). This discovery also suggests an additional *Calamaria* colonization of the Philippines from continental Asia.

Materials and Methods

External morphology and color pattern

We examined three specimens of the new species as well as specimens of other Philippine *Calamaria* species. Meristic characters included counts of: ventral scales (following the convention recommended by Dowling, [1951a]), subcaudal scales (not including the terminal scute), supralabial scales, infralabial scales, postocular scales, supraocular scales, paraparietal scales (Inger and Marx, 1965), scales surrounding paraparietal, pairs of chin shields, medial gular scales (between chin shields and first ventral scale), lateral gular scales (oblique rows between infralabials and first ventral scale), and longitudinal rows of dorsal body scales.

We assessed the following patterns of scalation: loreal (present or absent); preocular scale (present or absent); subcaudal scales (divided or undivided); precloacal scale (divided or undivided); nasal scale (completely divided, incompletely divided, or undivided); infralabial-mental (first infralabials medially in contact or not in contact and separated by mental scale); infralabial-chin shield (number of infralabial pairs in contact with anterior chin shields); internasal-prefrontal (internasals and prefrontals fused or not fused to each other); parietal scales (pair of parietals absent or present); anterior chin shield (pair medially in contact or not); posterior chin shield (pair medially in contact or not); type of dorsal and ventral body scales (smooth or keeled); apical pits (present or absent on dorsal scales); arrangement of longitudinal dorsal body scale rows (in horizontal or oblique rows); vertebral body scales (enlarged or not relative to other dorsal body scales); vertebrocaudal scales (enlarged or not relative to other dorsocaudal scales); reduction of dorsal body scale rows (present or absent); and dorsocaudal scale row reduction formula (Dowling, 1951b). We also recorded which supralabial scales contact each of the following scales: nasal, prefrontal, preocular, orbit, postocular, parietal, and paraparietal scales.

Measurements were taken as absolute or relative, and included: snout-vent length (SVL) and tail length (vent to tip of tail), obtained from ventral-view photographs of specimens on grid-paper using ImageJ v2.0.0 (Rueden et al., 2017); head length, head width, head height, snout length (anterior corner of eye to tip of snout), frontal scale width, supraocular scale width, and eye diameter were measured to the nearest 0.1 mm using calipers. From these measurements, we calculated the following: total length (SVL + tail length); frontal ratio (ratio of frontal scale width to supraocular scale width [Inger and Marx, 1965]), and relative tail length (tail length divided by total length). We used Köhler's (2012) color catalog to describe in-life color pattern.

Table 1. Locality and GenBank accession numbers for individuals included in phylogenetic analyses. Species, voucher specimen, locality, and GenBank accession numbers for individuals included in phylogenetic analyses. Novel DNA sequences generated for this study are shown in bold. Abbreviations: ADM = Alexander D. McKelvy; CMNH = Cincinnati Museum of Natural History; FMNH = Field Museum of Natural History; FTB = Frank T. Burbrink field tag series; KU = University of Kansas Biodiversity Institute; LSUHC = La Sierra University Herpetological Collections; PNM = Philippine National Museum; RMB = Rafe M. Brown field tag (specimen deposited in Museum Zoologicum Bogoriense, Indonesia); ROM = Royal Ontario Museum; SYS = Biological Museum of Sun Yat-sen University, Guangzhou, China; TNHC = Texas Natural History Collections, University of Texas at Austin; USMHC = Universiti Sains Malaysia Herpetological Collection, Malaysia.

Species	Specimen voucher	Locality	Cyt b	CMOS
<i>Calamaria alcalai</i> , new species	PNM 9873 (formerly KU 305555)	Sitio Palbong, Barangay Batong Buhay, Municipality of Sablayan, Occidental Mindoro Province, Philippines	MT819383	MT819429
<i>Calamaria andersoni</i>	SYS r001699	Yingjiang, Yunnan, China	MH445955	—
<i>Calamaria gervaisii</i>	KU 324661	Puguis community forest, Barangay Puguis, Municipality of La Trinidad, Benguet Province, Philippines	MT819384	MT819430
<i>Calamaria gervaisii</i>	KU 334485	Municipality of Narvacan, Ilocos Sur Province, Philippines	MT819385	MT819431
<i>Calamaria lumbricoidea</i>	KU 315159	Pasonanca Natural Park, Barangay Baluno, Municipality of Pasonanca, Zamboanga City, Philippines	MT819388	MT819434
<i>Calamaria lumbricoidea</i>	KU 334479	Mt. Lumot, Gingoog City, Misamis Oriental Province, Philippines	MT819389	MT819435
<i>Calamaria lumbricoidea</i>	USMHC 1560	Penang, Malaysia	MN338526	—
<i>Calamaria muelleri</i>	RMB 1283	Gowa, South Sulawesi, Indonesia	MT819391	—
<i>Calamaria muelleri</i>	TNHC 58955	Gowa, South Sulawesi, Indonesia	MT819390	MT819436
<i>Calamaria palavanensis</i>	KU 309445	Barangay Irawan, Municipality of Puerto Princessa, Palawan Province, Philippines	MT819386	MT819432
<i>Calamaria palavanensis</i>	KU 311411	Mt. Mantalingahan, Municipality of Rizal, Palawan Province, Philippines	MT819387	MT819433
<i>Calamaria pavimentata</i>	ROM 35605	Nguyễn Bình, Cao Bang, Vietnam	AF471081	AF471103
<i>Calamaria schlegeli</i>	LSUHC 10278	Taiping, Perak, Malaysia	MN338525	—
<i>Calamaria septentrionalis</i>	FTB 2839	unknown locality	KR814699	KR814675
<i>Calamaria yunnanensis</i>	ROM 41547	Simao, Yunnan, China	KX694891	KX694805
<i>Calamaria cf. yunnanensis</i>	FMNH 258666	Phongsaly, Laos	MN338524	—
<i>Collorhabdium williamsoni</i>	LSUHC 11704	Cameron Highlands, Pahang, Malaysia	MN338523	—
<i>Pseudorabdion longiceps</i>	ADM 0004	unknown locality	KX660529	KX660400
<i>Pseudorabdion longiceps</i>	USMHC 1707	unknown locality	MN338498	—
<i>Pseudorabdion cf. oxycephalum</i>	CMNH 5802	San Luis, Aurora, Philippines	AF471073	DQ112083

For comparisons, we examined specimens of Philippine snake species represented in the University of Kansas Biodiversity Institute herpetological collections (KU). For snake species not represented in this collection (and, in general, poorly represented in U.S. collections), we relied on published species accounts (Taylor, 1922; Inger and Marx, 1965; Wallach, 1988; Brown et al., 1999; David and Pauwels, 2004; Grismer et al., 2004; Ziegler and Quyet, 2005; Howard and Gillespie, 2007; Koch et al., 2009; Orlov, 2009; Nguyen et al., 2009; Ziegler et al., 2009; Orlov et al., 2010; Amarasinghe et al., 2015; Yang and Zheng, 2018).

Tissues, DNA data, and phylogenetic analyses

We obtained ethanol-preserved liver or muscle tissue samples from individuals that we collected or that were collected by colleagues (C.D. Siler, E.L. Rico, L.J. Welton, J. Fernandez, S.L. Travers, W. Bulalacao, B. Gurubat, R. Reyes, J. Zafe, D. Roldan-Pina) during multiple field expeditions in the Philippines (between 2006 and 2013) and Sulawesi, Indonesia (1998) and deposited in the University of Kansas Biodiversity Institute. To extract and purify genomic DNA, we lysed tissues with Proteinase K and then used a Maxwell® Rapid Sample Concentrator Instrument with the Maxwell® 16 Tissue DNA Purification Kit (Promega Corporation). Polymerase chain reaction (PCR) was used to amplify ~1,350 base pairs (bp) of the mitochondrial gene Cytochrome-b (Cyt b) and ~580 bp of the nuclear, protein-coding gene oocyte maturation factor mos (CMOS). To amplify and sequence Cyt b and CMOS, we used primers from Burbrink et al. (2000) and Lawson et al. (2005), respectively, and PCR with 34 cycles and annealing temperature 49°C (\pm 1–3°C). Amplified products were visualized using gel electrophoresis on 1.5% agarose gels. Purification of PCR product, cycle sequencing, cycle sequencing cleanups, and nucleotide sequence determination were conducted with standard GeneWiz protocols®.

We collected new DNA sequence data from nine individuals and five species, including one individual of the new Mindoro *Calamaria* and two individuals each of *C. gervaisii* A.M.C. Duméril, Bibron & A.H.A. Duméril, *C. lumbricoidea* F. Boie, *C. muelleri* Boulenger and *C. palawanensis* Inger & Marx. In addition to our new sequence data, we obtained sequences from GenBank for 11 individuals (9 species, 3 genera) from *Calamaria*, *Pseudorabdion*, and *Collorhabdium* (Table 1). *Pseudorabdion* and *Collorhabdium* are the closest relatives of *Calamaria* (Quah et al., 2020), and therefore we included them as outgroups in our phylogenetic analysis.

To *de novo* assemble and edit sequences we used Geneious®v6.1, and we used the MUSCLE plugin in Geneious

to align sequences (Edgar, 2004; Kearse et al., 2012). To calculate the number of variable and informative sites in our DNA alignment, and uncorrected genetic distances between individuals, we used R v3.5.2 (R Core Team, 2018) and packages ape v5.3 (Paradis and Schliep, 2018) and Biostrings v2.50.2 (Pagès et al., 2019).

We used IQ-TREE v1.6.11 (Nguyen et al., 2014) implemented on the web server W-IQ-TREE (Trifinopoulos et al., 2016) to infer a multi-locus maximum likelihood (ML) tree that includes representative species from *Calamaria* and their close relatives, and to identify the close relatives of the new Mindoro species. We treated each codon position of each locus as a separate partition, and we used the automatic model-selection feature (Chernomor et al., 2016) to identify and assign the best-fit substitution model for each partition during tree inference. We performed 1,000 ultrafast bootstraps to assess heuristic support for inferred clades, and we considered ultrafast bootstrap support values (UFboot) \geq 95 to strongly support the monophyly of a group (Minh et al., 2013).

Results and Discussion

The new species differs from all other species genetically and by its distinctive combination of meristic, mensural, and color pattern characters (see Systematics section; Tables 2–4). New DNA data and phylogenetic results are summarized in Table 1 and Fig. 2. Notably, the new species has a relatively longer tail and more subcaudals compared to all other Philippine species of *Calamaria* (Table 3), which likely explains why the new species was initially misidentified as a species of *Pseudorabdion*, inasmuch as tail length tends to be shorter in *Calamaria* species compared to *Pseudorabdion* species (Gaulke, 2011; Weinell et al., 2019). Among species of *Calamaria*, the new species is most similar to *Calamaria schlegeli*, which also has a relatively long tail and high number of subcaudals, and the color pattern of *C. schlegeli* has been reported as remarkably similar to that of the new species (see Inger and Marx, 1965; de Lang and Vogel, 2005; Stuebing et al., 2014; de Lang, 2017). Our inferred phylogeny also supports a close relationship between the new species and *C. schlegeli* (Fig. 2), although their high percent genetic distance (16.9% at Cyt b) suggests that these two lineages have been isolated for a considerable amount of time—supporting our treatment of the Mindoro lineage as a species distinct from *C. schlegeli*.

The inferred sister relationship between the new species and *C. schlegeli* is surprising considering their disjunct geographic distributions and suggests that the new species represents a hitherto unknown colonization of the Philippines. The new species is known only from Mindoro Island,

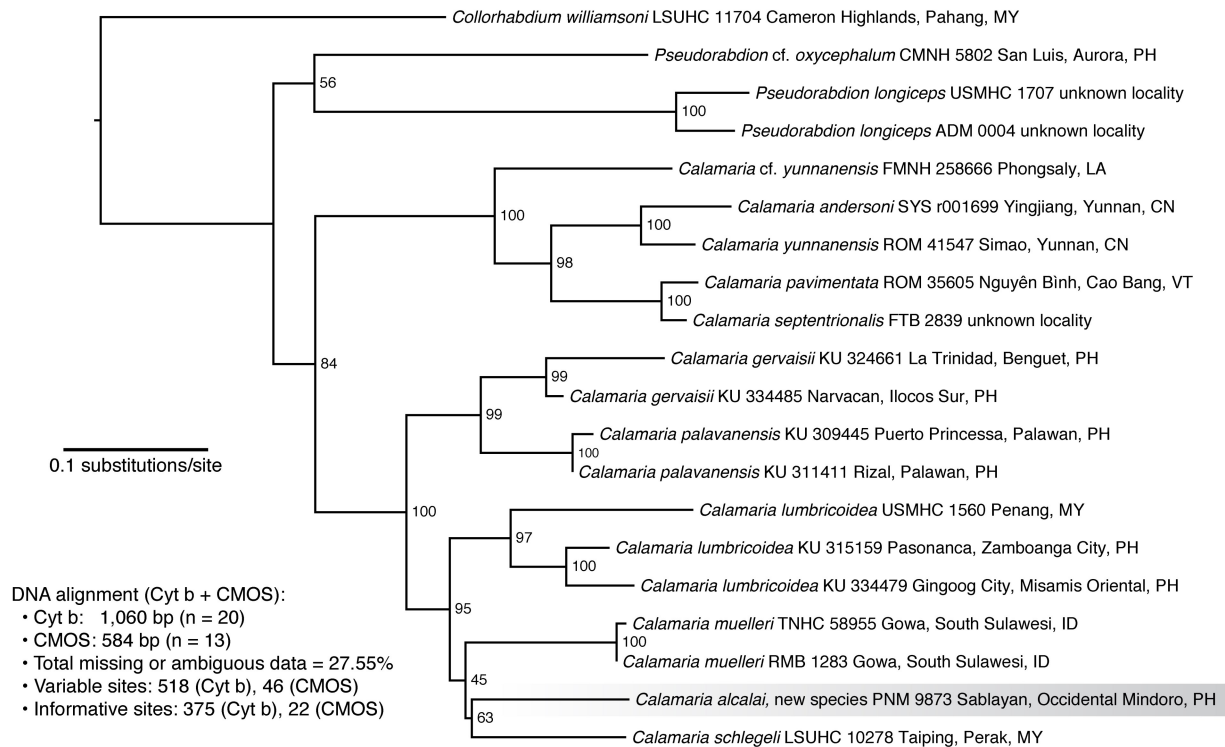


Figure 2. Maximum likelihood phylogenetic tree (Cyt b and CMOS genes) showing the position of the new species within *Calamaria*.

Philippines, whereas *C. schlegeli* is a widespread species found throughout Borneo, Sumatra, Java, Bali, Peninsular Malaysia and Thailand, and Singapore (Inger and Marx, 1965)—suggesting the likely presence of a related, undiscovered lineage on the intervening island of Palawan (and/or other islands of the Palawan PAIC).

Earlier biogeographic studies have variously supported two alternative hypotheses for colonization of the Philippine Western Island Arc, which includes the Mindoro and Palawan PAICs (Fig. 1; Brown et al., 2013). The two hypotheses include the Dual-Umbilicus Hypothesis (DUH; Brown and Guttman, 2002) and the Palawan-Arc Hypothesis (PAH; Siler et al., 2012a; Brown et al., 2016), both of which predict a close relationship between Mindoro and Palawan PAIC sister lineages, but differ in their predictions about the degree of divergence between Western Island Arc versus continental Asian lineages (Brown et al., 2013). In particular, the DUH predicts relatively recent divergence (sometime after the formation of the Sulu Sea ~20 million years ago) between Western Island Arc and continental Asian lineages, and the presence of close relatives of Philippine species on the landmasses of the Sunda Shelf (Brown et al., 2013; Brown and Siler, 2014). In contrast, the PAH predicts relatively ancient divergence between Western Island Arc and Indochinese

lineages, as a consequence of vicariance during the separation of the Palawan Microcontinent from mainland Laurasia ~35–45 million years ago, and possibly the absence of a close relative of Philippine species on landmasses of the Sunda Shelf (Blackburn et al., 2010; Siler et al., 2012a; Brown et al. 2016). To be consistent with either the DUH or PAH, extinction from Palawan must be tentatively invoked, because none of the currently known species of *Calamaria* from Palawan (i.e., *C. virgulata* F. Boie and *C. palavanensis*) appear to be closely related to the new species. We regard such an inference as tentative due to the persistent caveat that Palawan Island remains incompletely surveyed for herpetofauna due to logistical obstacles to conducting collections-based research there (Supsup et al., 2020). Additionally, the presence of a Sundaland species of *Calamaria* (i.e., *C. schlegeli*) that is closely related to the new species (Fig. 2) favors the DUH over the PAH. Alternatively, over water dispersal from Borneo to Mindoro (bypassing Palawan) is also consistent with the geographic distributions, inferred sister relationship, and phenotypic similarity of the new species and *C. schlegeli*. Future biogeographic studies of *Calamaria* should include time-calibrated phylogenetic analyses to estimate the relative plausibility of these alternative colonization hypotheses; a complete biogeographic interpretation of these relationships will

require extensive sampling across Sunda Shelf islands and from Palawan, and incorporation of these Sundaic and anticipated Palawan lineages into molecular phylogenetic studies and biogeographical inferences (Esselstyn et al., 2010; Brown et al., 2012, 2016; Siler et al., 2012a; Jose et al., 2020; Supsup et al., 2020; Supsup and Carestia, 2020).

Systematics

Calamaria alcalai, new species

urn:lsid:zoobank.org:act:872C149F-2F4B-4EA6-A4DB-D50D534BB39B

Alcala's Reed Snake

Figs. 3–4



Figure 4. In life photograph of *Calamaria alcalai*, new species (male paratype), KU 335918, Municipality of Sablayan, Occidental Mindoro Province, Philippines. Photo © Scott Travers.

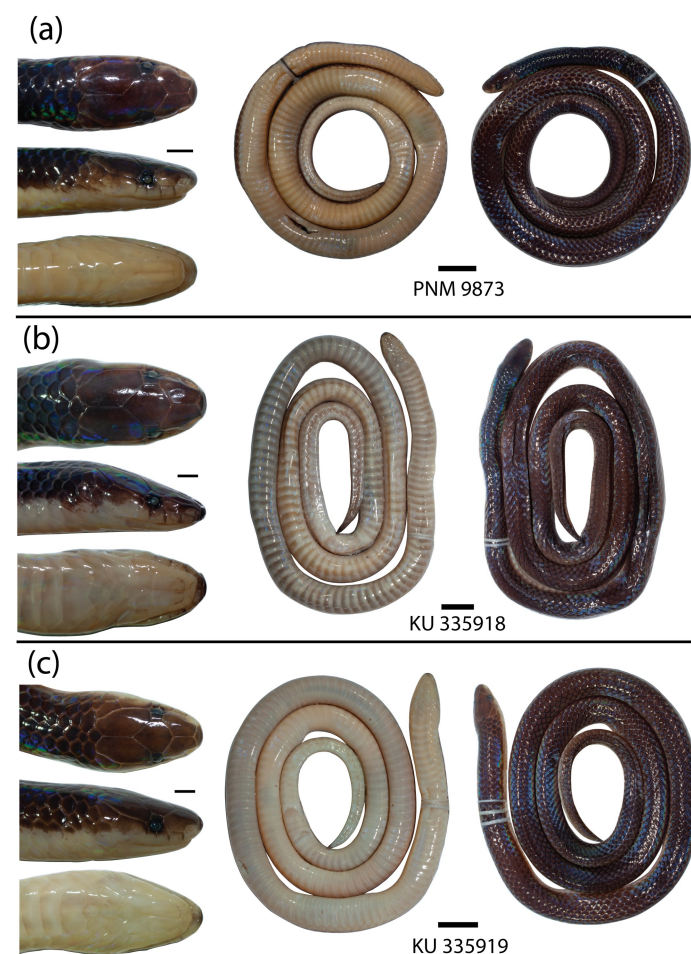


Figure 3. Type specimens of *Calamaria alcalai*, new species: (a) holotype, PNM 9873, adult male; (b–c) paratypes: KU 335918, adult male, and KU 335919 adult female, respectively. Left column: dorsal, lateral, and ventral views of the head (thin black scale bar = 2 mm); middle and right columns: ventral and dorsal views of entire specimens, respectively (scale bars = 10 mm).

Holotype

PNM 9873 (formerly KU 305555; field number ELR 645), adult male (Fig. 3a), from Sitio Palbong (local name “Malate”), Barangay Batong Buhay, Municipality of Sablayan, Occidental Mindoro Province, Philippines (approximately 12.865° N, 120.902° E, elevation 130 m above sea level); collected by Edmund B. Leo Rico on September 17, 2006.

Paratypes (2)

KU 335918 (field number RMB 17682), adult male (Figs. 3b, 4), from Sitio Aruyan, Barangay Malisbong, Municipality of Sablayan, Occidental Mindoro Province, Philippines (12.788° N, 120.916° E, elevation 230 m above sea level), collected by Wilson Bulalacao, B. Gurubat, R. Reyes, Diego Roldan-Pina, Scott Travers, and J. Zafe at approximately 2400H on July 7, 2013; KU 335919 (field number RMB 17719), adult female (Fig. 3c), same locality and collectors as first paratype but obtained between 1900–2100H on November 11, 2013.

Diagnosis

The new species differs from all other southeast Asian species by having the following combination of characters: prefrontal scales large, bordering rostral scale; internasal scales absent; 13 longitudinal rows of dorsal scales throughout length of body; subcaudal scales > 30 pairs (females), > 40 pairs (males); mental scale not in contact with chin shields; preocular scale present; prefrontal scale not in contact with eye. Color pattern in life: dorsal surface of head, body, and tail maroon or light maroon; ventral surface of head and anterior of body yellow; ventral surface of posterior of body and tail pale cream; boundary between dorsal and ventral body coloration on first

longitudinal row of dorsal scales light yellow to cream. Color pattern in ethanol: dorsal surface of head, body, and tail uniformly dark brown; ventral surface of head, body, and tail pale yellow or cream.

Description of holotype

Adult male; body cylindrical; tip of tail sharp; snout–vent length 310 mm; tail length 64 mm; total length 374 mm; relative tail length 17.1%; head length 11.5 mm; head width 5.2 mm; head height 4.4 mm; snout length 3.7 mm; frontal scale width 2.9 mm; supraocular scale width 0.5 mm; frontal ratio 5.8; eye diameter 1.1 mm; all scales of head, body, and tail smooth, iridescent; apical pits absent from dorsal scales; dorsal body scales arranged in 13 horizontal (rather than oblique) longitudinal rows throughout length of body; vertebral scales not enlarged relative to other dorsal scales; 168 ventral scales; precloacal scale undivided; subcaudal scales paired (divided), in 43 rows. Dorsocaudal scale reduction formula:

$$11 \frac{3+4(3)}{5+6(2)} 9 \frac{3+4(12)}{3+4(4)} 8 \frac{3+4(17)}{3+4(17)} 6 \frac{2+3(37)}{3+4(32)} 4 \frac{1+2(42)}{3+4(32)} 3(43)$$

Vertebrocaudal scales not enlarged relative to other dorsocaudal scale rows.

Rostral scale wider than tall; internasal scales absent; pair of prefrontal scales present, situated posterior to rostral and anterior to frontal scale, in contact with each other medially; pair of parietal scales present, posterior to frontal scale, in contact with each other medially; five supralabials present: third and fourth in contact with eye; nasal scale undivided, small, barely larger than nostril, positioned laterally on head, in contact with first supralabial; loreal scale absent; lateral margin of prefrontal scale in contact with nasal, first three supralabials, preocular and supraocular, not in contact with eye; small preocular present, in contact with supraocular, prefrontal, and third supralabial; small postocular present, in contact with supraocular, parietal, and fourth and fifth supralabials; anterior temporals absent; lateral margin of parietal in contact with fifth supralabial and one paraparietal scale; paraparietal surrounded by five scales, including fifth supralabial, parietal, and three dorsal scales.

Mental scale separated from chin shields; two pairs of chin shields (one anterior pair, one posterior pair), both pairs in contact with each other medially; anterior chin shields slightly longer than posterior chin shields; infralabials five: first pair in contact with each other medially, first three in contact with anterior chin shield, third and fourth in contact with posterior chin shield; medial gular scales numbering three between chin shields and first ventral scale; lateral gulars in four rows between infralabials and first ventral.

Color pattern following preservation in formalin, and subsequent transfer to ethanol (unrecorded in life): dorsal ground color of head, body, and tail uniformly dark brown; ventral surface of head and body uniformly white; ventral surface of tail mostly white, except light brown longitudinal line present medially (where each pair of subcaudals meet). Supralabial scales white on lower half, dark brown on upper half. Transition between ventral and dorsal color pattern sharply stratified, anteriorly passing through supralabials, second dorsal scale row, and, posteriorly, through the first dorsal scale row, and first dorsocaudal scale row.

Variation

Scale counts and measurements that vary among the holotype and paratypes are shown in Table 2. Paratypes also differ from the holotype in the following ways: KU 335918: prefrontal in contact with first two supralabials (vs. first three supralabials); preocular in contact with second and third supralabials (vs. third supralabial); dorsocaudal scale row reduction formula:

$$11 \frac{2+3(1)}{3+4(3)} 10 \frac{4+5(3)}{3+4(3)} 8 \frac{3+4(15)}{3+4(15)} 6 \frac{2+3(31)}{2+3(33)} 4 \frac{1+2(41)}{1+2(41)} 2(42)$$

Color pattern in life (unknown for the holotype): dorsal surface of head and anterior of body maroon (color 39; Köhler, 2012); dorsal surface of posterior of body and tail light maroon ferruginous (color 35); ventral surface of head and anterior of body warm buff (color 4); ventral surface of posterior of body and tail pale pinkish buff (color 3). KU 335919: nasal in contact with first and second supralabials (vs. first supralabial); prefrontal in contact with second and third supralabials (vs. first three supralabials); lateral gular scale rows between first ventral scale and infralabials: three (right side) or four (left side); dorsocaudal scale row reduction formula:

$$10 \frac{5+6(2)}{4+5(2)} 8 \frac{3+4(7)}{3+4(7)} 6 \frac{2+3(22)}{2+3(25)} 4 \frac{1+2(35)}{1+2(35)} 2(35)$$

Comparisons

This new species may be confused with juveniles of the genera *Calliophis*, *Hemibungarus*, *Oxyrhabdium*, *Myersophis*, and *Naja*, adults and juveniles of the genera *Pseudorabdion*, *Calamorphabidium*, *Rabdion*, *Collorhabdium*, *Etheridgeum*, *Macrocalamus*, other species of *Calamaria*, as well as adults and juveniles of the *Levitonius* (Weinell et al., 2020). *Calamaria alcalai* can be distinguished from all species outside of the genus *Calamaria* by having the internasals and prefrontals fused (versus distinct). Additionally, *C. alcalai* can be distinguished

Table 2. Meristic and mensural characters that vary among the holotype and two paratypes of *Calamaria alcalai*, new species. Measurements are in mm.

	PNM 9873	KU 335918	KU 335919
Sex	male	male	female
Snout–vent length	310	426	344
Tail length	64	89	55
Total length	374	515	399
Relative tail length	17.1%	17.3%	13.8%
Snout length	3.7	4.2	4.3
Frontal scale width	2.9	3.6	2.9
Supraocular scale width	0.5	0.5	0.6
Frontal ratio	5.8	7.2	4.83
Eye diameter	1.1	1.2	1.3
Head height	4.4	4.9	4.8
Head width	5.2	6.6	6.7
Head length	11.5	13.9	11.8
Number of ventrals	168	167	178
Number of subcaudal pairs	43	42	35
Number of ventrals + subcaudal pairs	211	209	213

from species of *Hemibungarus* by having the supralabials broadly in contact with the prefrontal and parietal (versus not in contact), and by having 13 longitudinal rows of dorsal scales (vs. 15); from species of *Oxyrhabdium* and *Myersophis* by having the loreal and anterior temporal scales absent (vs. present), and by having 13 longitudinal rows of dorsal scales (vs. 15); from species of *Naja* by having the supralabials broadly in contact with the prefrontal and parietal (versus not in contact), and by having 13 longitudinal rows of dorsal scales throughout the length of the body (vs. 21–23 rows behind the head, reducing to 13–15 rows before the vent); from species of *Calliophis* by having the supralabials broadly in contact with the prefrontal and parietal (versus not in contact); from *Levitonius mirus* by having subcaudals paired (vs. unpaired) and other characters (Weinell et al., 2020); and from species of *Calamorphabidium*, *Collorhabdium*, *Etheridgeum*, *Macrocalamus*, *Pseudorabdion*, and *Rabdion* by having 13 longitudinal rows of dorsal scales (vs. 15; Inger and Marx,

1965; Wallach, 1988; David and Pauwels, 2004; Amarasinghe et al., 2015). The new species is known only from the Philippine island of Mindoro, whereas *Calamorphabidium*, *Rabdion*, *Collorhabdium*, *Etheridgeum*, and *Macrocalamus* are not known from the Philippines; *Calliophis*, *Myersophis*, *Pseudorabdion*, and *Levitonius mirus* occur in the Philippines, but have not yet been recorded on the island of Mindoro (Leviton et al., 2018; Weinell et al., 2020).

The new species may be confused with other *Calamaria* species, most of which are small (< 300 mm maximum total length), have thirteen longitudinal rows of dorsal scales throughout the length of the body, subcaudals paired, internasals and prefrontals fused to each other, loreal absent, and anterior temporal absent (Inger and Marx, 1965; Feldman et al., 2016). The new species can be distinguished from all other *Calamaria* except *C. schlegeli* by having subcaudals > 40 (vs. < 35) in males and > 30 (vs. < 30) in females (Inger and Marx, 1965; Grismer et al., 2004; Ziegler and Quyet, 2005; Howard and Gillespie, 2007; Koch et al., 2009; Orlov, 2009; Nguyen et al., 2009; Ziegler et al., 2009; Orlov et al., 2010; Yang and Zheng, 2018).

The high number of subcaudals in the new species suggests a close relationship to *C. schlegeli*; both species also have the unusual condition of the mental not in contact with the anterior chin shields. *Calamaria schlegeli* contains two subspecies, *C. schlegeli schlegeli* Duméril, Bibron, and Duméril (from the Thai-Malay Peninsula, Sumatra, Borneo, and several other associated small landmasses) and *C. s. cuvieri* Jan (from Java and Bali islands), which usually differ in the color pattern of the head, in the number of subcaudal pairs distal to the location where dorsocaudals reduce to four rows, and in the fraction of individuals having the preocular present (Inger and Marx, 1965).

The new species differs from *C. s. cuvieri* by having subcaudals > 40 in males (vs. < 40) and > 30 in females (vs. < 30), preocular present (vs. usually absent), and prefrontal not in contact with eye (vs. usually in contact with eye; Inger and Marx, 1965); and from *C. s. schlegeli* by having ventrals > 165 in males (vs. < 155) and > 175 in females (vs. < 170); ventrals + subcaudals > 205 in males (vs. < 185) and > 210 in females (vs. < 200). Although Inger and Marx (1965) found that the number of subcaudals in *C. s. schlegeli* ranges from 27–44 in males (n = 26) and 19–35 in females (n = 29), only the males from northern Borneo (subcaudals 44; n = 2) and males and females from Singapore (subcaudals 37–42 or 31–35, respectively; n = 5 each) were observed to have as many or more subcaudals compared to the three individuals known of the new species.

Only seven other species of *Calamaria* are known from the Philippines, including *C. bitorques* W. Peters, *C. gervaisii*, *C. joloensis* Taylor, *C. lumbricoidea*, *C. suluensis* Taylor, *C.*

Table 3. Comparison of characters distinguishing *Calamaria alcalai*, new species from the other Philippine species of *Calamaria*. Data are from Inger and Marx (1965), except for the new species. Number of ventral scales (V), number of subcaudal scales (SC), and relative tail length (RTL; as percentage of total length) are reported for males and females; nuchal bands = one or more pale or dark crossbands on the dorsal surface of the body posterior to the head; dorsal stripes = pale, longitudinal stripes (possibly faint or broken) on dorsal surface of body; ventral bands = black bands on the ventral surface of the body ≥ 2 scale rows wide; M/ACS = mental scale in contact with anterior chin shields; FR = frontal ratio (frontal scale width divided by supraocular scale width). For the two species that also occur outside of the Philippines (i.e., *C. virgulata* and *C. lumbricoidea*), data only reflect variation known to occur in the Philippines. See Leviton et al. (2018) for detailed information on the geographic distributions of the Philippine species of *Calamaria*.

	<i>C. alcalai</i> , new species	<i>C. bitorques</i>	<i>C. gervaisii</i>	<i>C. joloensis</i>	<i>C. lumbricoidea</i>	<i>C. palavanensis</i>	<i>C. suluensis</i>	<i>C. virgulata</i>
Nuchal bands	absent	present	present or absent	absent	present or absent	absent	absent	present or absent
Dorsal stripes	absent	present or absent	present or absent	absent	present	present	present	present or absent
Ventral bands	absent	absent	absent	absent	present (sometimes nearly all black)	absent	absent	absent
M/ACS	absent	present	present	present	present	absent	present	absent
FR	4.83–7.2	1.5–2	1.3–2.5	3	1.5–2.5	1.5–2	1.75–2.15	1.75–3.5
V (males)	167–168	150–157	132–164	119	144–196	174–181	129–138	177–227
V (females)	178	157–197	142–190	—	137–229	171–187	142–168	184–247
SC (males)	42–43	17–20	15–21	13	17–27	23–25	18–20	16–21
SC (females)	35	12–17	10–18	—	13–21	16–20	14–26	8–14
RTL (%; males)	17.1–17.3	6.6–8.7	6.3–9.6	6.9	6.3–11.4	8.1–9.3	7.9–10.4	5.2–8.1
RTL (%; females)	13.8	3.9–8.6	4.1–7.0	—	3.9–8.3	5.5–6.7	6.4–10.9	2.9–4.9

Table 4. Comparison of meristic, mensural, and color pattern characters of *Calamaria alcalai*, new species, *C. schlegeli*, and geographically isolated subpopulations of *C. schlegeli*. Abbreviations: PF/E = prefrontal scale in contact with eye; SCs.DCR4 = number of subcaudals distal to position where dorsocaudals reduce to four scales; V = number of ventral scales; SC = number of subcaudals; VSC = V + SC. Data for *C. schlegeli* are from Inger and Marx (1965), except for ranges of VSC, which were estimated from V and SC data of males and females of each population using: $VSC_{min} = V_{min} + SC_{min}$ and $VSC_{max} = V_{max} + SC_{max}$; actual VSC ranges may be narrower than our estimates. *Inger and Marx (1965) report maximum number of subcaudals for female *C. schlegeli* as 37 (pg. 155 of that study), whereas the highest number shown in their table summarizing geographic variation is 35.

	<i>C. alcalai</i> , new species	<i>C. schlegeli</i>	<i>C. schlegeli</i> <i>schlegeli</i>	<i>C. schlegeli</i> <i>schlegeli</i>	<i>C. schlegeli</i> <i>schlegeli</i>	<i>C. schlegeli</i> <i>schlegeli</i>	<i>C. schlegeli</i> <i>schlegeli</i>	<i>C. schlegeli</i> <i>cuvieri</i>
Geographic population	—	—	Malay Peninsula	Singapore	Sumatra & Bangka	Belitung	Borneo	Java & Bali
Head color uniformly dark	present	present or absent	present or absent	absent	absent	absent	absent or present	present
Preocular	present	present or absent	present	present	present or absent	present	present or absent	present (rarely) or absent
PF/Eye	present	present or absent	present or absent	absent	present or absent	present or absent	present or absent	present or absent
SCs.DCR4	7–11	3–25	14–25	12–22	11–21	17–25	7–21	3–16
V (males)	167–168	129–161	140–151	132–137	130–143	134–136	134–140	140–161
V (females)	178	136–180	149–167	150–153	142–161	152	169	162–180
SC (males)	42–43	25–44	29–32	37–42	27–34	34–37	28–44	27–36
SC (females)	35	19–35 [37*]	24–28	31–35	19–32	30	28	23–28
VSC (males)	209–211	157–197	169–183	169–179	157–177	168–173	162–184	168–197
VSC (females)	213	161–208	173–195	181–188	161–193	182	197	185–208
RTL (%; males)	17.1–17.3	11.1–21.3	12.7–14.6	15.7–18.8	12.0–16.6	14.7–15.3	13.7–21.3	11.1–15.3
RTL (%; females)	13.8	7.3–14.4	9.4–11.2	12.6–14.4	8.6–12.9	12.1	9.9	7.3–10.9

palavanensis, and *C. virgulata* (Leviton et al., 2018; Weinell et al., 2019). In addition to having a greater number of subcaudals, the new species is distinguished from all Philippine *Calamaria* by having a longer relative tail length (males > 15% vs. < 12%; females > 12% vs. < 11%); from *C. bitorques* by having pale nuchal bands absent (vs. present), mental not in contact with anterior chin shields (vs. in contact), frontal ratio > 4.5 (vs. 1.5–2); from *C. joloensis* by having more ventrals (males 167–168 vs. 119; unknown for females of *C. joloensis*), mental not in contact with the anterior chin shields (vs. in contact), frontal ratio > 4.5 (vs. ~ 3); from *C. lumbricoidea* by having pale longitudinal dorsal stripes absent (vs. present), black banding on ventrals absent (vs. present), mental not in contact with the anterior chin shields (vs. in contact), frontal ratio > 4.5 (vs. 1.5–2.5); from *C. palavanensis* by having frontal ratio > 4.5 (vs. < 2); from *C. suluensis* by having more ventrals (males 167–168 vs. < 140; females 178 vs. < 170), mental not in contact with the anterior chin shields (vs. in contact), frontal ratio > 4.5 (vs. 1.75–2.15); from *C. virgulata* by having the frontal ratio > 4.5 (vs. < 4).

The only other species known from Mindoro Island is *C. gervaisii* (Leviton et al., 2018). Taylor (1922) and Marx and Inger (1955) recognized two additional *Calamaria* from Mindoro, *C. mindorensis* Boulenger and *C. tropica* Taylor, but Inger and Marx (1965) did not consider these taxa to be distinct from *C. gervaisii*. This placement of *C. mindorensis* and *C. tropica* within the synonymy of *C. gervaisii* is supported by their shared condition of having < 23 subcaudals and the mental in contact with the anterior chin shields, whereas *C. alcalai* has more subcaudals (males > 40, females > 30) and the mental not in contact with the anterior chin shields. See Table 3 for a comparison of the characters distinguishing *Calamaria alcalai*, new species from other Philippine *Calamaria*.

Natural History

PNM 9873 (KU 305555) was collected in primary dipterocarp forest. Both KU 335918 and KU 335919 were collected at night, suggesting that this species may be nocturnal. Nothing else is known about the natural history of the new species, but other *Calamaria* are exclusively worm-eaters (Inger and Marx, 1965). The relatively long tail of the new species suggests that it may not be as fossorial as other species of *Calamaria* (Greene, 1997).

Distribution

The new species is currently only known from two nearby forested sites in the Municipality of Sablayan, Occidental Mindoro Province, central-western Mindoro Island, Philippines (Fig. 1). Given the fact that so few of Mindoro's forested areas

have been properly surveyed for their herpetofaunas, little if anything can be concluded from the new species' known geographic area of occurrence. A few sites on northern Mindoro Island have been the focus of scattered, nonsystematic, and uncomprehensive herpetological survey efforts and the southern half of the island remains virtually unexplored for amphibians and reptiles. We anticipate that the new species will remain a Mindoro endemic, but if proper faunal inventory efforts on Mindoro are ever forthcoming, it will be interesting to determine if the new species' distribution extends to the eastern half of the island, beyond the central mountain range that bisects this island from north to south.

Etymology

The species epithet *alcalai* is a patronym in the genitive singular, honoring Dr. Angel C. Alcala, for his numerous contributions on the systematics, biogeography, and ecology of amphibians and reptiles of the Philippines—and, in general, for his influential promotion of conservation and sustainable management of the archipelago's terrestrial and marine biodiversity.

Key to the identification of Philippine species of *Calamaria*

- 1a. Mental scale not in contact with anterior chin shields 2
- 1b. Mental scale in contact with anterior chin shields 4
- 2a. Number of pairs of subcaudal scales < 30 (males), < 25 (females) 3
- 2b. Number of pairs of subcaudal scales > 40 (males), > 30 (females) *Calamaria alcalai*
- 3a. Number of pairs of subcaudal scales ≤ 21 (males), ≤ 14 (females) *Calamaria virgulata* (Philippine populations)
- 3b. Number of pairs of subcaudal scales 23–25 (males), 16–20 (females) *Calamaria palavanensis*
- 4a. Ventral surface of body with black bands present (each band ≥ 2 scales wide) or absent and nearly completely black 5
- 4b. Ventral surface of body mostly pale and black bands absent 5
- 5a. Dorsal surface behind head has 2–6 dark, black-edged crossbands *Calamaria bitorques*
- 5b. Dorsal surface behind head lacks dark, black-edged crossbands 6
- 6a. Diameter of eye less than eye–mouth distance 6
- 6b. Diameter of eye equal to or greater than eye–mouth distance 7
- 7a. Each dorsal body scale with a light network; a continuous light stripe on first row of dorsal body scales present 7

..... *Calamaria suluensis*
 7b. Each dorsal body scale above first row yellowish with a dark network; a dark-edged, interrupted, light stripe on first row of dorsal body scales usually present *Calamaria gervaisii*

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