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The genera *Fejervarya* and *Minervarya* in Myanmar: Description of a new species, new country records, and taxonomic notes (Amphibia, Anura, Dicroglossidae)

Gunther Köhler[1], Linda Mogk[1], Khin Pa Pa Khaing[1] & Ni Lar Than[2]

[1] Senckenberg Forschungsinstitut und Naturmuseum, Senckenberganlage 25, 60325 Frankfurt a. M., Germany; gkoehler@senckenberg.de — [2] East Yangon University, Thanlyin, Yangon, Myanmar; nilarthan65@gmail.com

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Abstract

We describe a new species of frog, *Fejervarya kupitzi* from Myanmar, and record three species for the first time in this country: *Fejervarya orissaensis, Minervarya chiangmaiensis*, and *M. muangkanensis*. For these four species and for *F. limnocharis* which occurs in northern and eastern Myanmar and widely across Southeast Asia, we provide species accounts summarizing their variation in external morphology with an emphasis on Myanmar populations. We describe the advertisement call of *F. orissaensis* and *M. muangkanensis*, and we describe and illustrate the tadpole of *F. orissaensis*. And we provide an identification key to the five species of *Fejervarya* and *Minervarya* currently recognized in Myanmar.

Key words

Bioacoustics; cryptic species diversity; *Fejervarya kupitzi* **sp. nov.**; *Fejervarya limnocharis*; *Fejervarya orissaensis*; *Minervarya chiangmaiensis*; *Minervarya muangkanensis*; tadpole morphology.

Introduction

Southeast Asia covers only 4% of the earth's land area but is home to 20–25% of the planet's plant and animal species and is recognized as a major global biodiversity hotspot (Myers *et al*., 2000; Mittermeier, 2004; Corlett, 2014; Bruyn *et al*., 2014). This extraordinary biodiversity is attributed to the region's geographic position at the transition between several biogeographic regions, its position in the humid tropics, its dynamic geological history, and its vivid pattern of different habitats, often fragmented and isolated and therefore promoting speciation (Woodruff, 2010).

Southeast Asia has a very dynamic geologic history. Due to sea level fluctuations of up to ± 50 m during each of the Pleistocene glacial cycles, the land area varied enormously. During the glacial peaks, when mean sea levels were 62 m below today's levels, the land area was 1.5–2.0 times larger than today (Woodruff, 2010). During the Pleistocene oscillations in land area and sea levels, the forests expanded and contracted. The uplift and the geological composition of the Himalayas has been linked to the movement of the various plates and the successive arrival of land masses (Jain *et al*., 2016). This dynamic geographic history is relevant to the diversity of fauna and flora species of today. Allopatric speciation is generally favored, when previously continuous distribution areas of a certain species are fragmented into several isolated subareas.

Many new species of amphibians and reptiles have been described from Myanmar in the last two decades, increasingly marking the area as a 'biodiversity hotspot' (e.g., Grismer *et al*., 2018; Sheridan & Stuart, 2018). However, our knowledge about the diversity, ecology and conservation of frogs is still fragmentary and thus much more research, both in the field and in the lab, is

needed. Many species still await discovery and formal description and for the majority of currently recognized frog species, we do not know much more than their name. Early collections by Leonard Fea followed by collections by French and British herpetologists set the groundwork for our understanding of the biodiversity within Myanmar. However, little research using modern methods have been undertaken to study the anurans of this country.

In the case of supposedly wide-ranging species, it has yet to be evaluated whether these really are a single species occurring in a large geographic area or if these actually represent a complex of several – morphologically similar (cryptic) – species. The frogs now grouped into two genera, *Fejervarya* and *Minervarya* (see Sanchez *et al*., 2018) is such a case that is in need of taxonomic revisions. According to Frost (2019), only a single species of *Fejervarya*, *F. limnocharis*, definitely occurs in Myanmar. He lists three additional species, one of which (*F. multistriata*) is suggested to be a synonym of *F. limnocharis*, whereas the other two species are stated to possibly occur in Myanmar.

The present study aims to elucidate the diversity and taxonomy of *Fejervarya* and *Minervarya* in Myanmar based on specimens collected during our own field work and supplemented by relevant specimens housed in various institutions.

Materials and methods

Specimens examined for this study were either personally collected or borrowed from museums (see Appendix 1 for specimens examined). In evaluating species boundaries within the populations of the studied frogs, we follow the unified species concept (deQueiroz, 2007). As lines of evidence for species delimitation, we apply a phenotypic criterion (external morphology) and a criterion for reproductive isolation (genetic distinctness of the mitochondrial 16S and 12S genes, as well as bioacoustic data). Prior to preservation of collected specimens in the field, we took color photographs of each individual in life.

Before preservation, tadpoles and their mouthparts were photographed using a small glass tank and a digital SLR camera (Canon EOS 7D) with a Canon ME 65 mm magnifier lens. Photographs of the lateral view (left side of specimen to show spiracle) were done with untreated or anaesthetized specimens, photographs of mouth parts were taken from freshly killed specimens with their mouth parts fixated in an open position with a drop of full-strength formalin. Collected tadpoles were anaesthetized and euthanized using an aqueous solution of T61 (Intervet Deutschland GmbH, Unterschleißheim, Germany). All tadpoles were fixed and preserved in 4% formalin. We collected tissue samples (tip of tail or one hind leg in advanced tadpole stages) and preserved these in 98% non-denaturated ethanol for DNA extraction prior to treatment with formalin. We euthanized the frogs with a pericardial injection of T61. We cut tissue samples from the hand or tongue of selected individuals of frogs before they came into contact with formalin. The tissue samples were deposited in the collection of the Senckenberg Forschungsinstitut und Naturmuseum, Frankfurt, Germany (SMF).

Specimens were then preserved by injecting a solution of 5 mL absolute (i.e., 36%) formalin in 1 L of 96% ethanol into the body cavity and thighs, and stored in 70% ethanol. The collected specimens have been deposited in the collection of East Yangon University (EYU), Thanlyin, Myanmar, and at SMF. Abbreviations for museum collections are CAS (California Academy of Sciences, San Francisco), MNHN (Muséum National d'Histoire Naturelle, Paris), and SMF. Coordinates and elevation were recorded using Garmin GPS receivers with built-in altimeters. All coordinates are in decimal degrees, WGS 1984 datum. The capitalized colors and color codes (the latter in parentheses) are those of (Köhler, 2012) in the color descriptions. Abbreviations used are EYD (eye diameter); FL (foot length); HL (head length); HW (head width); IND (internasal diameter); IOD (interorbital diameter); NED (nostril – eye distance); HNL (hand length); LKRF (labial keradont row formula); SHL (shank length); SL (snout length); SVL (snout – vent length); TED (tympanum – eye distance); THL (thigh length); TYD (longitudinal tympanum diameter). Webbing formulae follow (Savage & Heyer, 1997). Terminology of snout shape follows (Heyer *et al*., 1990). Comparative morphological data for some species (i.e., *Fejervarya iskandari* Veith, Kosuch, Ohler & Dubois 2001, *F. kawamurai* Djong, Matsui, Kuramoto, Nishioka & Sumida 2011, *F. sakishimensis* Matsui, Toda & Ota, 2007, *F. triora* Stuart, Chuaynkern, Chan-ard & Inger 2006) were taken from or complemented with data from the respective original descriptions of these taxa.

Species identification of collected tadpoles was verified by matching 16S barcodes with respective barcodes of adult frogs via a Maximum-Likelihood analysis. The barcodes of adult frogs were generated from specimens secured by us at the same sites where the tadpoles were collected.

We recorded anuran vocalizations using a digital audio recorder (Olympus LS-12) with a Sennheiser ME 66 shotgun microphone capsule and a Sennheiser K6 powering module. The microphone was positioned between 0.5 and 1.5 m from the calling frog. Files were recorded as uncompressed 24-bit WAV files at a sampling frequency of 96 kHz. The spectral and temporal parameters were analyzed and the power spectra were calculated in RAVEN PRO 1.4. (Blackman DFT window; 2048 samples; 3 dB filter bandwidth of 158 Hz; grid spacing of 21.5 Hz; overlap 90%). Temporal measurements of calls such as repetition rates, duration of notes, and number of pulses, were measured on the waveforms. Terminology in call descriptions follows (Köhler *et al*., 2017).

We extracted DNA following the protocol of Ivanova *et al*. (2006). To eliminate potential PCR-inhibiting contaminants, the tissue samples were incubated overnight at 4°C in 100 µL 1x PBS buffer before overnight digestion with the vertebrate lysis buffer at 56°C. After extraction,

the DNA was eluted in 50 µL TE buffer. A fragment of the mitochondrial 16S rRNA gene was amplified in an Eppendorf Mastercycler® pro using the following protocol: initial denaturation for 1 min at 94°C; followed by 5 cycles with denaturation for 15 s at 94°C, hybridization for 45 s at 45°C and elongation for 1:30 min at 72°C; followed by 30 cycles 15 s at 94°C, 45 s at 48°C and 1 min at 72°C; final elongation for 7 min at 72°C. The reaction mix for each sample contained 1 µL DNA template, 14 µL water, 4 µL 2.5 mM dNTPs (Invitrogen), 2.5 µL PCR-buffer, 1 µL 25 mM $MgCl_2$, 0.5 µL (containing 5 units) Taq Polymerase (PeqLab), and 1 µL of each primer (forward: L2510, 5'–CGCCTGTTTATCAAAAACAT–3'; reverse: H3056, 5'–CCGGTCTGAACTCAGATCACGT–3').

For generating the 12S sequences we used a slightly different protocol: initial denaturation for 2 min at 94°C; followed by 35 cycles with denaturation for 35 s at 94°C, hybridization for 45 s at 58°C and elongation for 1 min at 72°C; final elongation for 10 min at 72°C. The reaction mix for each sample contained 1.5 µL DNA template, 10.5 µL water, 4 µL 2.5 mM dNTPs (Invitrogen), 2.5 µL PCR-buffer, 1 µL 25 mM $MgCl_2$, 0.5 µL (containing 5 units) Taq Polymerase (PeqLab), and 2,5 µL of each primer (forward FS01, AACGCTAAGATGAA CCCTAAAAAGTTCT; reverse: R16M1, GGGTATCTAA TCCCAGTTTG). Both primers are from Eurofins MWG Operon.

We aligned the sequences with MUSCLE (Edgar, 2004) using the default settings in Geneious 6.1.2 (Drummond *et al*., 2010). Using MEGA 7 (Kumar *et al*., 2016), we computed uncorrected pairwise genetic distances, determined GTR + G as the best-fitting substitution model, and conducted a Maximum Likelihood (ML) analysis with 10,000 bootstrap replicates and gaps as a fifth character (i.e., using all sites). In evaluating the uncorrected *p*-distances calculated for our samples, we follow other recently published barcoding studies on dicroglossid frogs (Howlader, 2011; Kotaki *et al*., 2010; Howlader *et al*., 2016).

According to the respective requirements of the different software applications, the formats of the sequences were converted using the online server ALTER (Glez-Peña *et al*., 2010). The best substitution model for each gene (analyzed separately) of our dataset was identified using PartitionFinder2 (Lanfear *et al*., 2017), with linked branch lengths (supported by most of the phylogenetic programs) via PhyML 3.0 analysis (Guindon *et al*., 2010). Model selection was detected using the corrected (for finite sample size) Akaike Information Criterion (AICc) (Burnham & Anderson, 2004). Given the correlation between gamma (+G) and invariant sites (+I) parameters, models that include both +G and +I are often inadequate (Sullivan *et al*., 1999; Mayrose *et al*., 2005; Yang, 2006). Thus, we did not use models that included both parameters together. In all analyses, we used *Hoplobatrachus tigerinus* (GenBank accession numbers AB488902, AB488879), *Occidozyga lima* (AB488903, AB488880), and *Sphaerotheca dob*sonii (AB277305, AB277290) as outgroups. We generated 58 new 16S sequences and 50 new 12S sequences of frogs of the genera *Fejervarya* and *Minervarya* (see Appendix 2). All of the following analyses were conducted for each gene individually, and the two genes concatenated. Sequences were concatenated in Geneious 6.1.2 (Drummond *et al*., 2010). We performed Bayesian Inference analysis (BI) with MrBayes 3.2 (Huelsenbeck & Ronquist, 2001; Ronquist & Huelsenbeck, 2003). BI analyses were performed setting 5 runs with 8 chains discarding the first 25% as the burn-in period and an initial set of 1,000,000 generations for MCMC with a sampling frequency of 500 generations, adding 500,000 generations until chains reached convergence. We considered convergence when the standard deviation of split frequencies was 0.015 or less. Additionally, convergence was diagnosed by PRSF (Potential Scale Reduction Factor) which should approach 1.0 as runs converge (Gelman & Rubin, 1992). We used the IQTree webserver (Trifinopoulos *et al*., 2016) to run a Maximum Likelihood (ML) analysis using 10,000 ultrafast Bootstrap approximation (UFBoot) replicates with 10,000 maximum iterations and minimum correlation coefficient of 0.99 (Minh *et al*., 2013) plus 10,000 replicates of Shimodaira-Hasegawa approximate likelihood ratio (SH-aLRT), which proved to be accurate with a high statistical power (Guindon *et al*., 2010). We used FigTree 1.3.1 for tree viewing (http://tree.bio.ed.ac.uk/software/figtree/). We estimated evolutionary genetic divergence, computing uncorrected pairwise distances with Mega 7 (Kumar *et al*., 2016) to assess the degree of intra and interspecific differences, using a Bootstrap estimation method of 10,000 replications. We designed a species tree based on the two mtDNA gene sequences concatenated, using *BEAST (Drummond *et al*., 2012) in BEAST 2.4.7 (Ogilvie *et al*., 2017) under 1,000,000 generations for the mcmc model, visualized in DensiTree 2.2.6 (Bouckaert & Heled, 2014). We performed an initial species delimitation analysis by visualizing barcode gaps in the pairwise distribution of each mtDNA gene separately (excluding the outgroup), using the automatic barcode gap discovery (ABGD) approach (Puillandre *et al*., 2012) through its webserver (http://wwwabi.snv.jussieu.fr/public/ abgd/abgdweb.html), setting the use of Simple Distance, default values for Prior Intraspecific divergence, except for relative gap width (1.5) which does not work for some genes (as also noted by Kekkonen *et al*., 2015). Because high values in relative gap width tend to overly split species (Yang *et al*., 2016), we used an intermediate value of 1.0.

Results and Conclusions

The final alignments of 16S and 12S were of 700 and 666 nucleotide positions, respectively, for 346 samples (genera *Fejervarya* and *Minervarya*) plus the three outgroups (Appendix 2). Partition schemes were recorded as GTR+G for both genes. The trees obtained through BI, ML, *Beast, and ABGD showed a high degree of con-

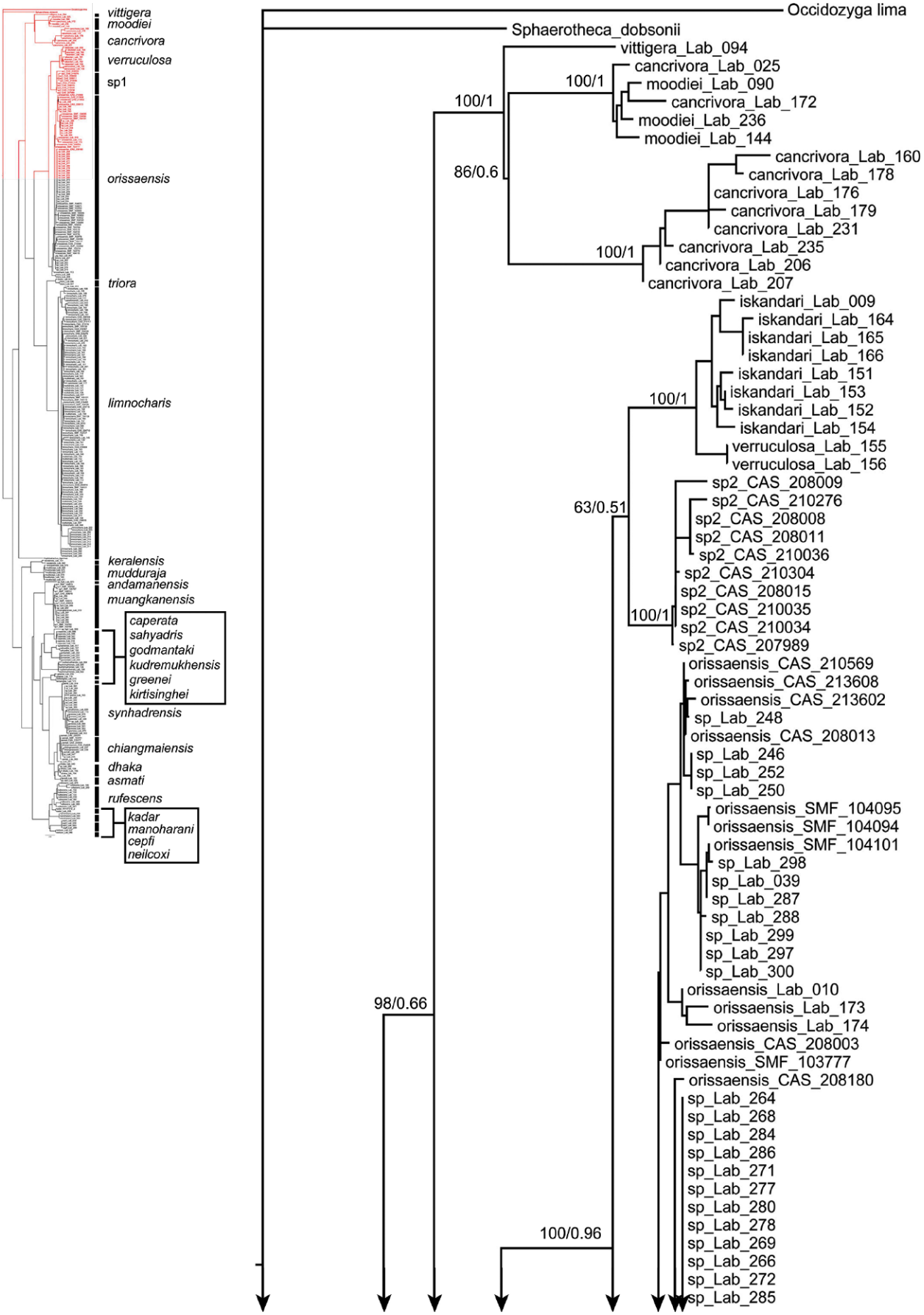
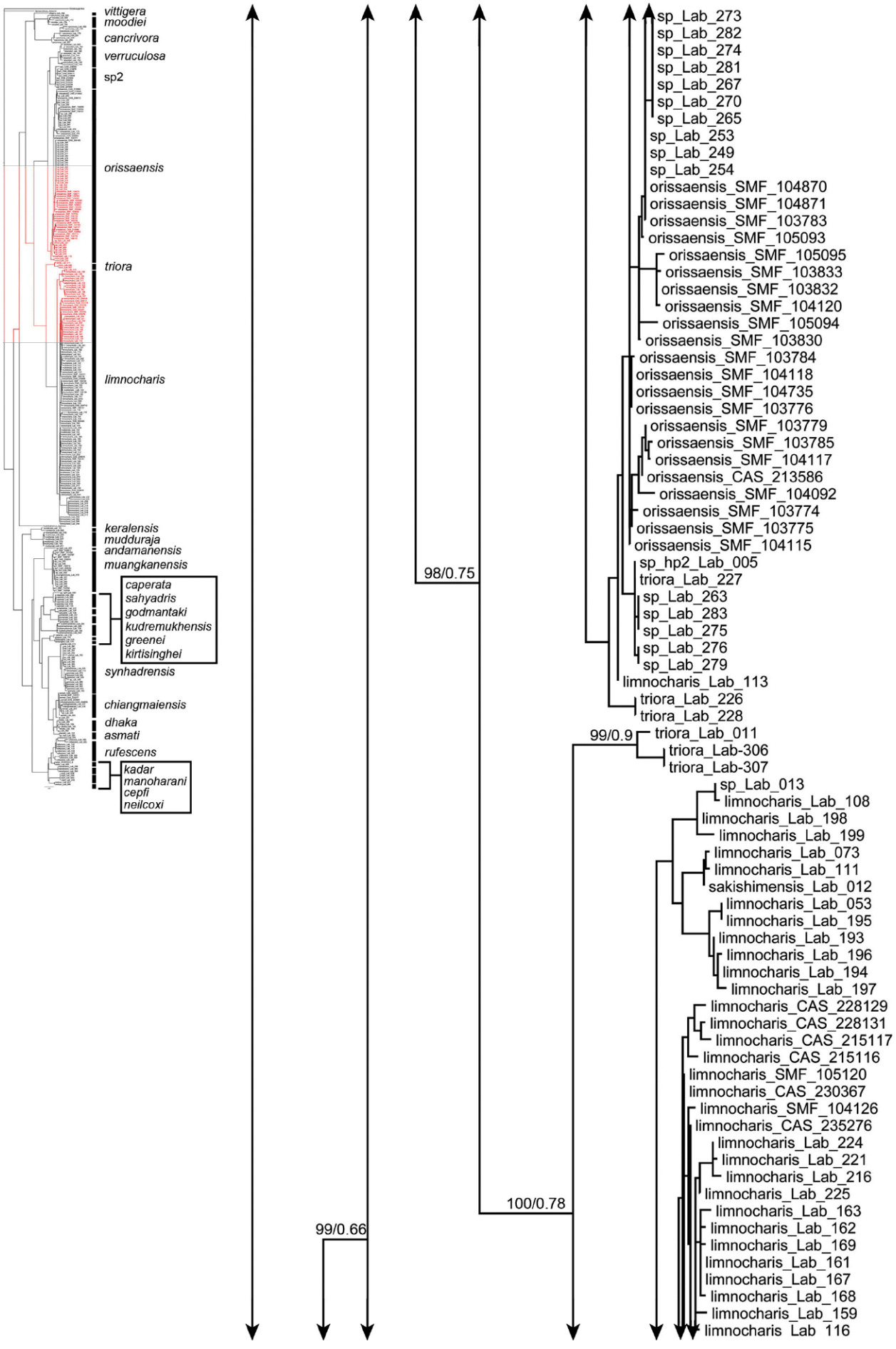


Fig. 1 (pages 186–190)**.** Phylogenetic tree of specimens of frogs of the genera *Fejervarya* and *Fejervarya*, from a maximum-likelihood analysis of DNA sequences of two mitochondrial genes: 16S and 12S. The numbers at nodes are bootstrap values (left) and Bayesian posterior probabilities (right).


vittigera
moodiei
cancrivora
verruculosa
sp2
orissaensis
triora
limnocharis
keralensis
mudduraja
andamanensis
muangkanensis
caperata
sahyadris
godmantaki
kudremukhensis
greenei
kirtisinghei
synhadrensis
chiangmaiensis
dhaka
asmati
rufescens
kadar
manoharani
cepfi
neilcoxi
98/0.75
99/0.66
100/0.78
99/0.9
sp_Lab_273
sp_Lab_282
sp_Lab_274
sp_Lab_281
sp_Lab_267
sp_Lab_270
sp_Lab_265
sp_Lab_253
sp_Lab_249
sp_Lab_254
orissaensis_SMF_104870
orissaensis_SMF_104871
orissaensis_SMF_103783
orissaensis_SMF_105093
orissaensis_SMF_105095
orissaensis_SMF_103833
orissaensis_SMF_103832
orissaensis_SMF_104120
orissaensis_SMF_105094
orissaensis_SMF_103830
orissaensis_SMF_103784
orissaensis_SMF_104118
orissaensis_SMF_104735
orissaensis_SMF_103776
orissaensis_SMF_103779
orissaensis_SMF_103785
orissaensis_SMF_104117
orissaensis_CAS_213586
orissaensis_SMF_104092
orissaensis_SMF_103774
orissaensis_SMF_103775
orissaensis_SMF_104115
sp_hp2_Lab_005
triora_Lab_227
sp_Lab_263
sp_Lab_283
sp_Lab_275
sp_Lab_276
sp_Lab_279
limnocharis_Lab_113
triora_Lab_226
triora_Lab_228
triora_Lab_011
triora_Lab-306
triora_Lab-307
sp_Lab_013
limnocharis_Lab_108
limnocharis_Lab_198
limnocharis_Lab_199
limnocharis_Lab_073
limnocharis_Lab_111
sakishimensis_Lab_012
limnocharis_Lab_053
limnocharis_Lab_195
limnocharis_Lab_193
limnocharis_Lab_196
limnocharis_Lab_194
limnocharis_Lab_197
limnocharis_CAS_228129
limnocharis_CAS_228131
limnocharis_CAS_215117
limnocharis_CAS_215116
limnocharis_SMF_105120
limnocharis_CAS_230367
limnocharis_SMF_104126
limnocharis_CAS_235276
limnocharis_Lab_224
limnocharis_Lab_221
limnocharis_Lab_216
limnocharis_Lab_225
limnocharis_Lab_163
limnocharis_Lab_162
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limnocharis_Lab_161
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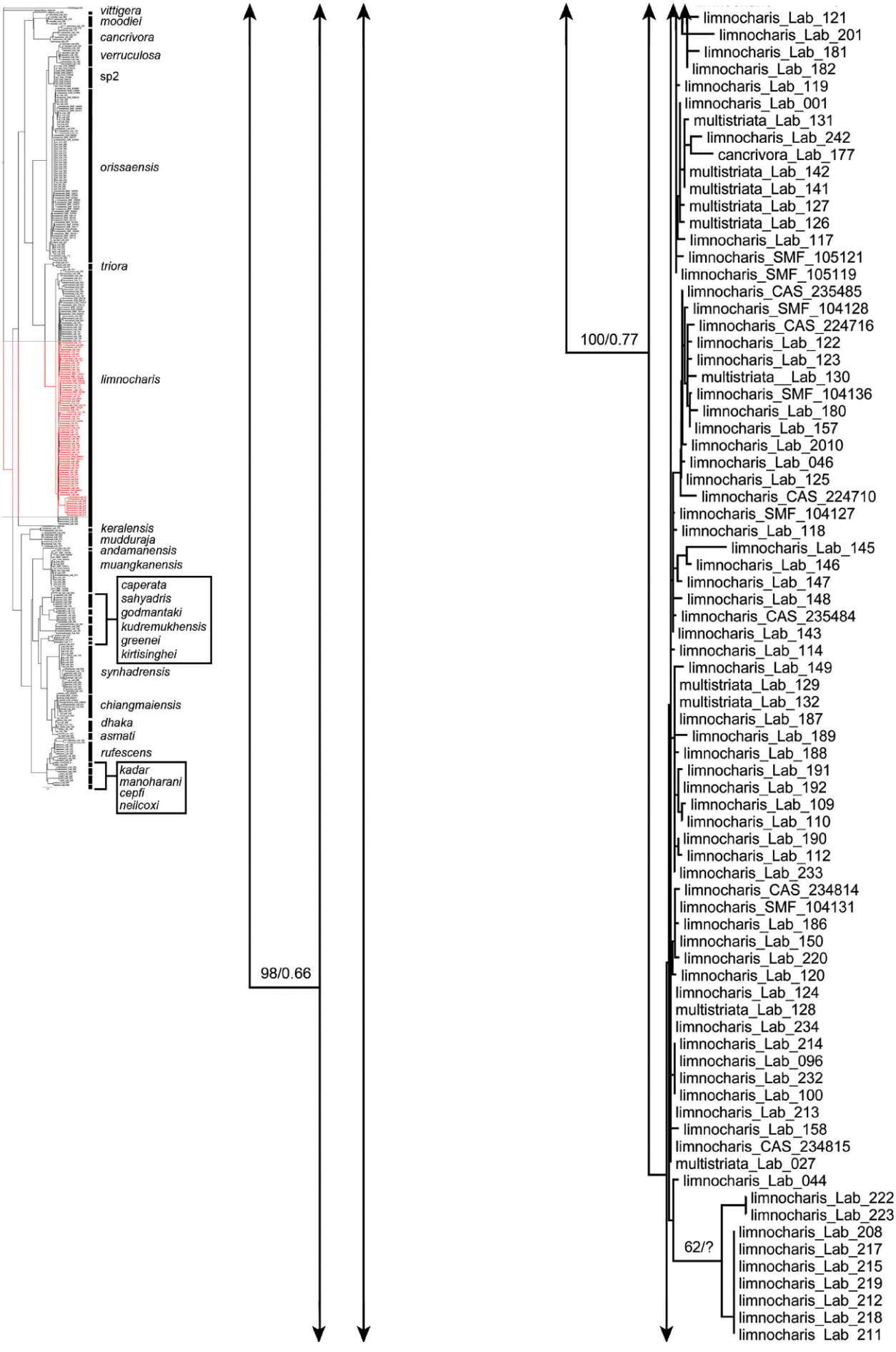
limnocharis_Lab_159
limnocharis_Lab_116


vittigera
moodiei
cancrivora
verruculosa
sp2
orissaensis
triora
limnocharis
keralensis
mudduraja
andamanensis
muangkanensis
caperata
sahyadris
godmantaki
kudremukhensis
greenei
kirtisinghei
synhadrensis
chiangmaiensis
dhaka
asmati
rufescens
kadar
manoharani
cepfi
neilcoxi
98/0.66
100/0.77
limnocharis_Lab_121
limnocharis_Lab_201
limnocharis_Lab_181
limnocharis_Lab_182
limnocharis_Lab_119
limnocharis_Lab_001
multistriata_Lab_131
limnocharis_Lab_242
cancrivora_Lab_177
multistriata_Lab_142
multistriata_Lab_141
multistriata_Lab_127
multistriata_Lab_126
limnocharis_Lab_117
limnocharis_SMF_105121
limnocharis_SMF_105119
limnocharis_CAS_235485
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limnocharis_CAS_224716
limnocharis_Lab_122
limnocharis_Lab_123
multistriata__Lab_130
limnocharis_SMF_104136
limnocharis_Lab_180
limnocharis_Lab_157
limnocharis_Lab_2010
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limnocharis_Lab_125
limnocharis_CAS_224710
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limnocharis_Lab_118
limnocharis_Lab_145
limnocharis_Lab_146
limnocharis_Lab_147
limnocharis_Lab_148
limnocharis_CAS_235484
limnocharis_Lab_143
limnocharis_Lab_114
limnocharis_Lab_149
multistriata_Lab_129
multistriata_Lab_132
limnocharis_Lab_187
limnocharis_Lab_189
limnocharis_Lab_188
limnocharis_Lab_191
limnocharis_Lab_192
limnocharis_Lab_109
limnocharis_Lab_110
limnocharis_Lab_190
limnocharis_Lab_112
limnocharis_Lab_233
limnocharis_CAS_234814
limnocharis_SMF_104131
limnocharis_Lab_186
limnocharis_Lab_150
limnocharis_Lab_220
limnocharis_Lab_120
limnocharis_Lab_124
multistriata_Lab_128
limnocharis_Lab_234
limnocharis_Lab_214
limnocharis_Lab_096
limnocharis_Lab_232
limnocharis_Lab_100
limnocharis_Lab_213
limnocharis_Lab_158
limnocharis_CAS_234815
multistriata_Lab_027
limnocharis_Lab_044
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limnocharis_Lab_223
limnocharis_Lab_208
limnocharis_Lab_217
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limnocharis_Lab_211
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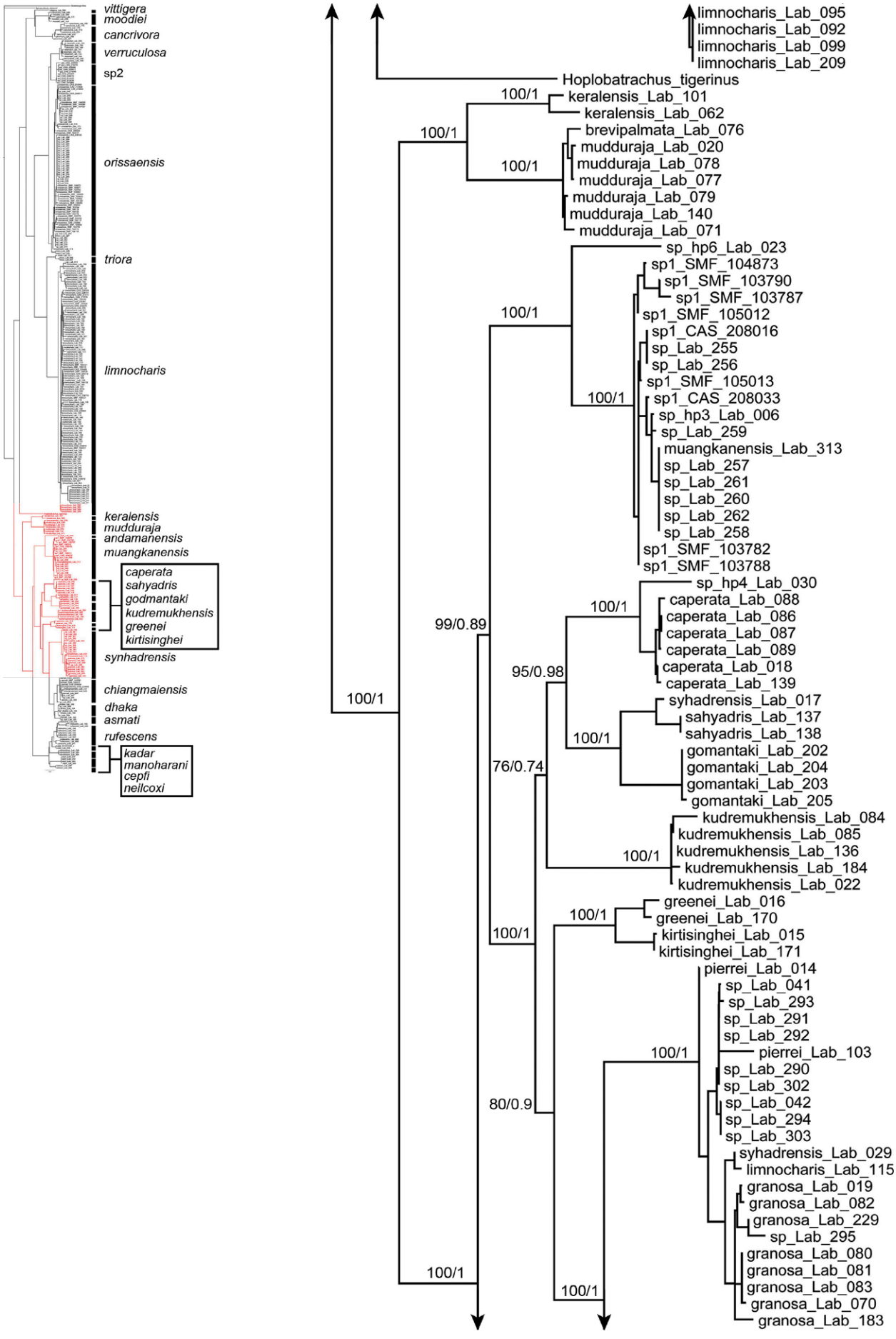
vittigera
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caperata
sahyadris
godmantaki
kudremukhensis
greenei
kirtisinghei
synhadrensis
chiangmaiensis
dhaka
asmati
rufescens
kadar
manoharani
cepfi
neilcoxi
limnocharis_Lab_095
limnocharis_Lab_092
limnocharis_Lab_099
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Hoplobatrachus_tigerinus
keralensis_Lab_101
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brevipalmata_Lab_076
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sp_Lab_262
sp_Lab_258
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sp_hp4_Lab_030
caperata_Lab_088
caperata_Lab_086
caperata_Lab_087
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caperata_Lab_018
caperata_Lab_139
syhadrensis_Lab_017
sahyadris_Lab_137
sahyadris_Lab_138
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gomantaki_Lab_204
gomantaki_Lab_203
gomantaki_Lab_205
kudremukhensis_Lab_084
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kudremukhensis_Lab_136
kudremukhensis_Lab_184
kudremukhensis_Lab_022
greenei_Lab_016
greenei_Lab_170
kirtisinghei_Lab_015
kirtisinghei_Lab_171
pierrei_Lab_014
sp_Lab_041
sp_Lab_293
sp_Lab_291
sp_Lab_292
pierrei_Lab_103
sp_Lab_290
sp_Lab_302
sp_Lab_042
sp_Lab_294
sp_Lab_303
syhadrensis_Lab_029
limnocharis_Lab_115
granosa_Lab_019
granosa_Lab_082
granosa_Lab_229
sp_Lab_295
granosa_Lab_080
granosa_Lab_081
granosa_Lab_083
granosa_Lab_070
granosa_Lab_183
100/1
100/1
100/1
100/1
100/1
100/1
99/0.89
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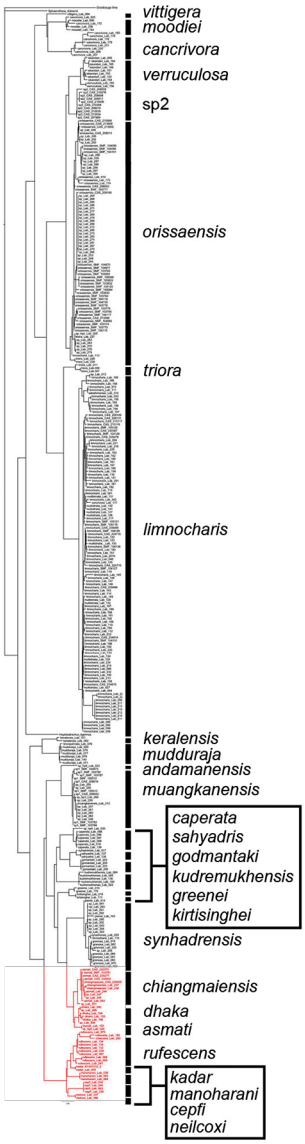
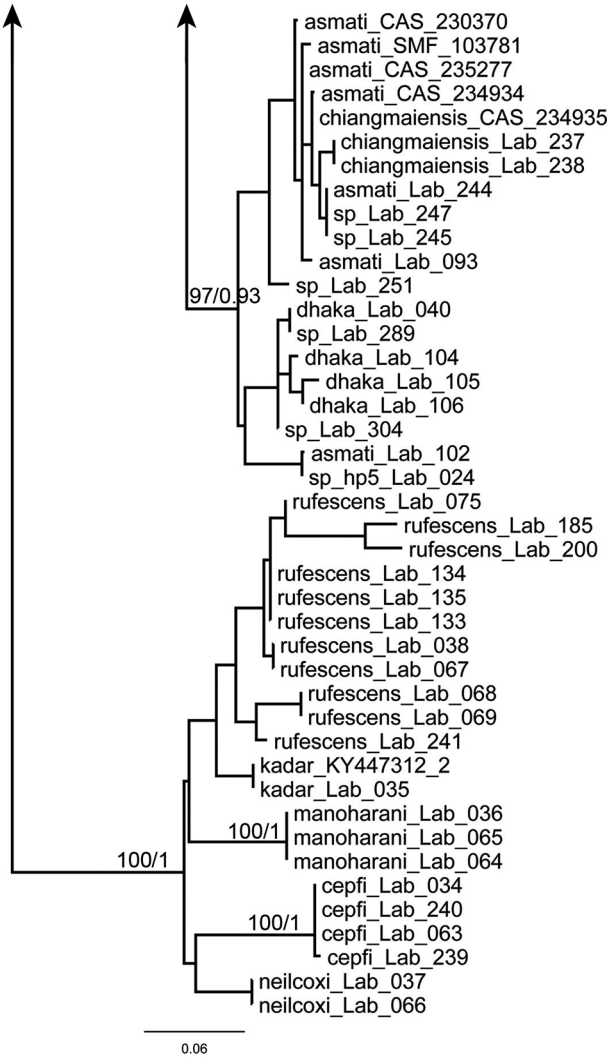
100/1





gruence at well-supported nodes, with some differences in branch arrangement at poorly supported nodes (Figs. 1 and 2). The analysis of genetic divergence with ABGD resulted in 32 groups (excluding outgroups).

Our final trees of the single markers and also of the concatenated alignment all recover the deep split between what are now recognized as two genera, *Fejervarya* and *Minervarya* (Figs. 1 and 2). Our samples from Myanmar (i.e., sequences of CAS and SMF specimens of *Fejervarya* and *Minervarya* from this country) are found in five clades that are distributed across the tree, none of which are sister species to another. Three of these clades are in the *Fejervarya* clade whereas two are in the *Minervarya* clade. In the latter clade many of the currently recognized species are recovered as monophyletic (i.e., *M. carperata*, *M. gomantaki*, *M. greenei*, *M. kirtisinghei*, and *M. sahyadris*). However, some of the nominal taxa appear either as non-monophyletic or are not recovered as distinct clades at all. Scattered all across our tree are specimens that were originally labeled "*limnocharis*" in Genbank. Some of these are clearly misidentifications, but the majority reflects the past habit to assign any specimen of *Fejervarya* that seemed difficult to identify to the latter species, mostly as a matter of convenience.

In the *Minervarya* clade, *keralensis* and *mudduraja* form sister clades that together form a clade basal to the remaining species of this genus in our analyses. Among the *mudduraja* clade is a single sequence labeled "*Fejervarya* cf. *brevipalmata*", which is clearly conspecific with the remaining specimens in this clade and therefore very likely misidentified.

Specimens labeled *granosa*, *pierrei*, and *syhadrensis* form a clade without much internal structure that would support the distinctness of these samples. Also the ABGD analysis include all of these specimens in a single group. We refrain from drawing taxonomic conclusions from the non-distinctness of *granosa*, *pierrei*, and *syhadrensis* in our analyses as we did not study the onomatophores. This clade contains sequences of the type series of *granosa*, but it can not be ruled out that the GenBank sequences labeled *pierrei* and *syhadrensis* are based on misidentified *granosa*. A single specimen of *syhadrensis*

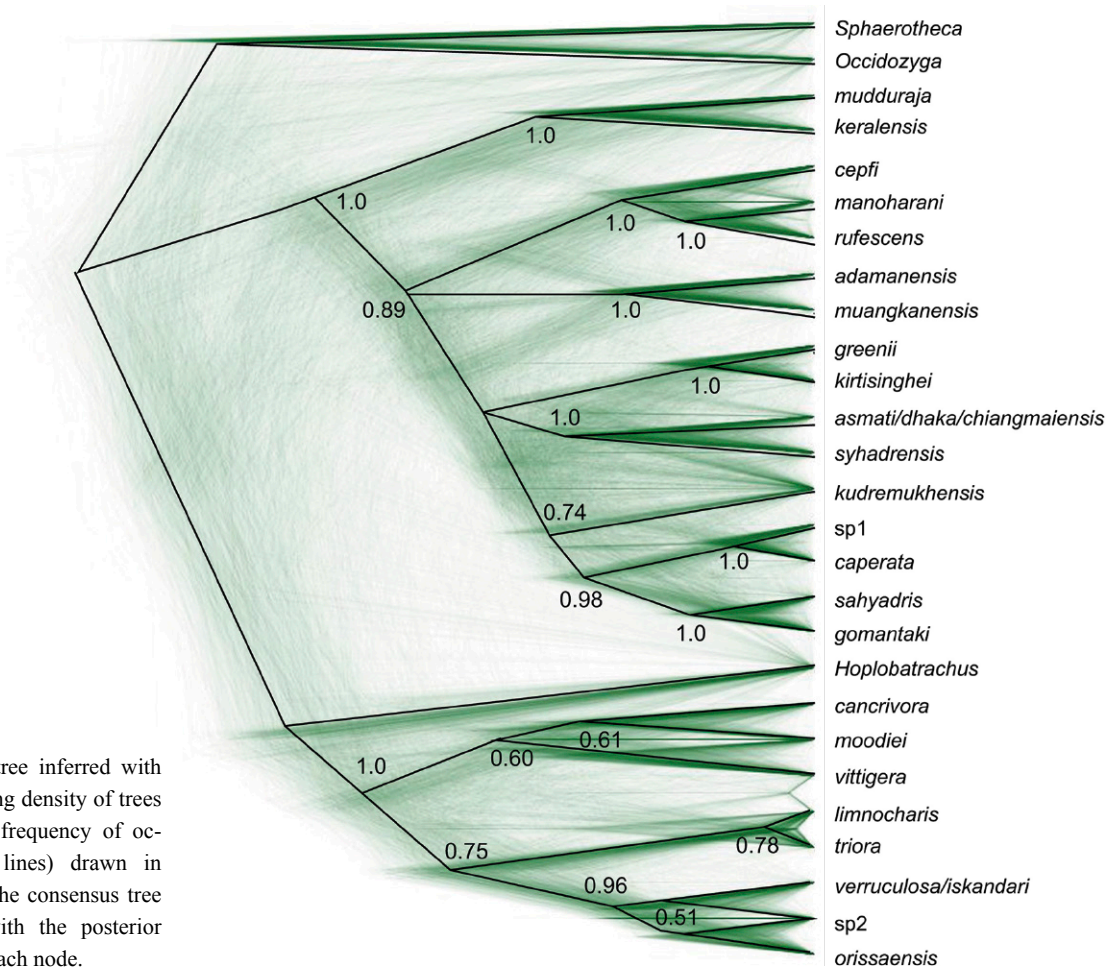


Fig. 2. Species tree inferred with *BEAST showing density of trees proportional to frequency of occurrence (thin lines) drawn in DensiTree and the consensus tree (black lines) with the posterior probability for each node.

(our Lab_017) clusters with two individuals of *sahyadris* (Lab_137, Lab_138) at a distant position in the tree. A detailed study of geographic variation using molecular markers, bioacoustics, and morphology is needed to clarify the taxonomic status of these species.

Also somewhat complicated is the taxonomic interpretation of a clade that contains specimens identified as belonging to the nominal taxa *asmati*, *chiangmaiensis* and *dhaka* as well as specimens referred to as "*Fejervarya* sp. A" by Mulcahy *et al*. (2018). In this clade are sequences of the holotype and one paratype of *M. chiangmaiensis* (i.e., Lab_237, Lab_238), and of the type series of *M. dhaka* (i.e., Lab_104–106). Furthermore, it contains the sequence of a specimen identified as *M. asmati* by its original describer (our Lab_102; see Howlader *et al*., 2016). These three nominal taxa are recovered as clades and are recognized as separate groups in our ABGD analysis. A single sequence (i.e., Lab_251) is placed on its own outside of these three clades but is grouped with *chiangmaiensis* in our ABGD analysis. Furthermore, the mean genetic distances between the three subclusters in *asmati–chiangmaiensis–dhaka* clade range from 2.4 to 3.4% in the 16S gene and 4.0 to 5.8% in the 12S gene. These data led us to tentatively recognize these three taxa as valid species and assign the Myanmar samples of this clade to *M. chiangmaiensis* based on their genetic similarity. This represents the first country record of this species for Myanmar. Below we present a short account for this species, summarizing its morphological variation in Myanmar.

The cluster containing specimens named *cepfi*, *kadar*, *manoharani*, and *rufescens*, recovers these taxa as distinct and monophyletic. This is also supported by our ABGD analysis.

A sample from Andaman Islands (i.e., Lab_023) which probably should be assigned to *M. andamanensis*, is recovered as sister to a clade that contains specimens from Myanmar and western Thailand. This latter clade was referred to as "*Fejervarya* hp3" by previous authors (Mulcahy *et al*., 2018; Kotaki *et al*., 2010; Sanchez *et al*., 2018). This clade contains a 16S sequence of the holotype of *Fejervarya muangkanensis* and thus is referred to this name by us. This represents the first country record of this species for Myanmar. Below we present a short account for this species, summarizing its morphological variation in Myanmar, as well as describing its advertisement call.

In our *Fejervarya* clade, the nominal species *cancrivora*, *moodiei*, and *vittigera* form a clade that is basal to the remaining species of this genus in our analyses. Sister to a clade containing samples of *cancrivora* is a clade that contains samples originally named *moodiei* and *cancrivora*, with a geographic origin (according to GenBank) of Bangladesh, Indonesia, and Malaysia, re-

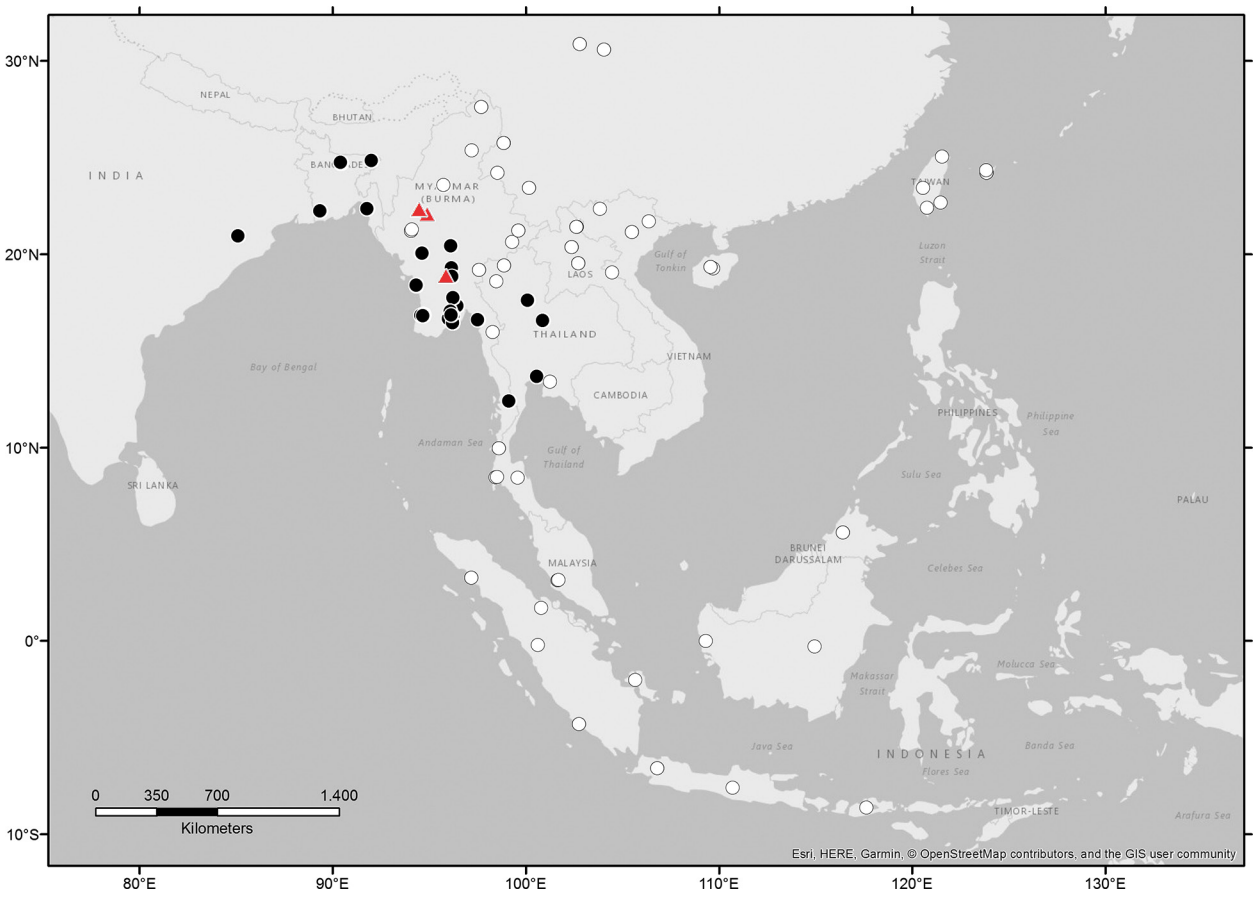


Fig. 3. Map indicating collecting localities of the *Fejervarya* species occurring in Myanmar. Each symbol can represent one or more adjacent localities. Black circles: *F. orissaensis*; white circles: *F. limnocharis*; red triangles: *F. kupitzi*.

spectively. Originally described from the Philippines, *F. moodiei* is now assumed to occur from eastern India through Bangladesh, Myanmar, tropical China, and Thailand north of the Isthmus of Kra as well as on the Philippines (KURNIAWAN *et al.*, 2010; KURNIAWAN *et al.*, 2011).

GenBank sequences originally labeled *Fejervary triora* appear at two places in our phylogenetic trees. One of these clusters contains a sequence of a topotypic paratype of *F. triora* (FMNH 266160) as well as an additional topotypic specimen (FMNH 266337) from the type description (DQ860094–95, our Lab_311–312; STUART *et al.*, 2006). Thus, these sequences most likely represent the „true“ *Fejervary triora*. The second cluster of sequences labeled „*Fejervary triora*“ in Genbank (i.e., Lab_226–228, from Thung Salaeng Luang National Park, Phetchabun, Thailand) are included in a large clade that contains also specimens identified as *F. orissaensis* from the general area of the type locality of the latter species. This clade also contains numerous specimens from localities scattered widely across Myanmar and also some from Bangladesh and western Thailand (Fig. 3). We refer to this clade as *F. orissaensis*, thereby formally recording this species for the first time for Myanmar, Bangladesh, and Thailand. Formerly, in these countries, this species was referred to as “*Fejervarya* sp. hp2” (KOTAKI *et al.*, 2010; MULCAHY *et al.*, 2018; SANCHEZ *et al.*, 2018). Below we present a short account for this species, summarizing its morphological variation in Myanmar, as well as describing its tadpole and advertisement call.

In our trees two clades are phylogenetically close to the *orissaensis* clade, one of which contains Genbank sequences originally labeled *iskandari* and *verruculosa*, the other clade (labeled “sp2” in our tree) containing specimens from Myanmar, not associated with any described nominal species. The distinctness of the latter clade is supported by the results of our morphologic analyses, and we provide a formal description of this new species below.

The *iskandari–verruculosa* clade contains a sequence of the holotype of *F. iskandari* (MNHN 1997.4916; our Lab_166) as well as of two additional specimens from the original description of this taxon (Lab_164–165). The Genbank sequences labeled *F. verruculosa* (Lab_155–156) were generated from frogs collected on Flores, Indonesia (KURNIAWAN *et al.*, 2014). Our ABGD analysis splits the samples into an *iskandari* and a *verruculosa* clade. A recent study provided evidence that *F. iskandari* also occurs on the Lesser Sunda Islands (KURNIAWAN *et al.*, 2014). In the latter study, the two “cf. *verruculosa*” samples also showed up in a single clade together with *iskandari*. More work is needed in order to clarify the taxonomy of the *Fejervarya* populations on the Sunda Archipelago.

Finally, there is a large clade containing *Fejervarya* samples from a huge geographic area (here referred to as

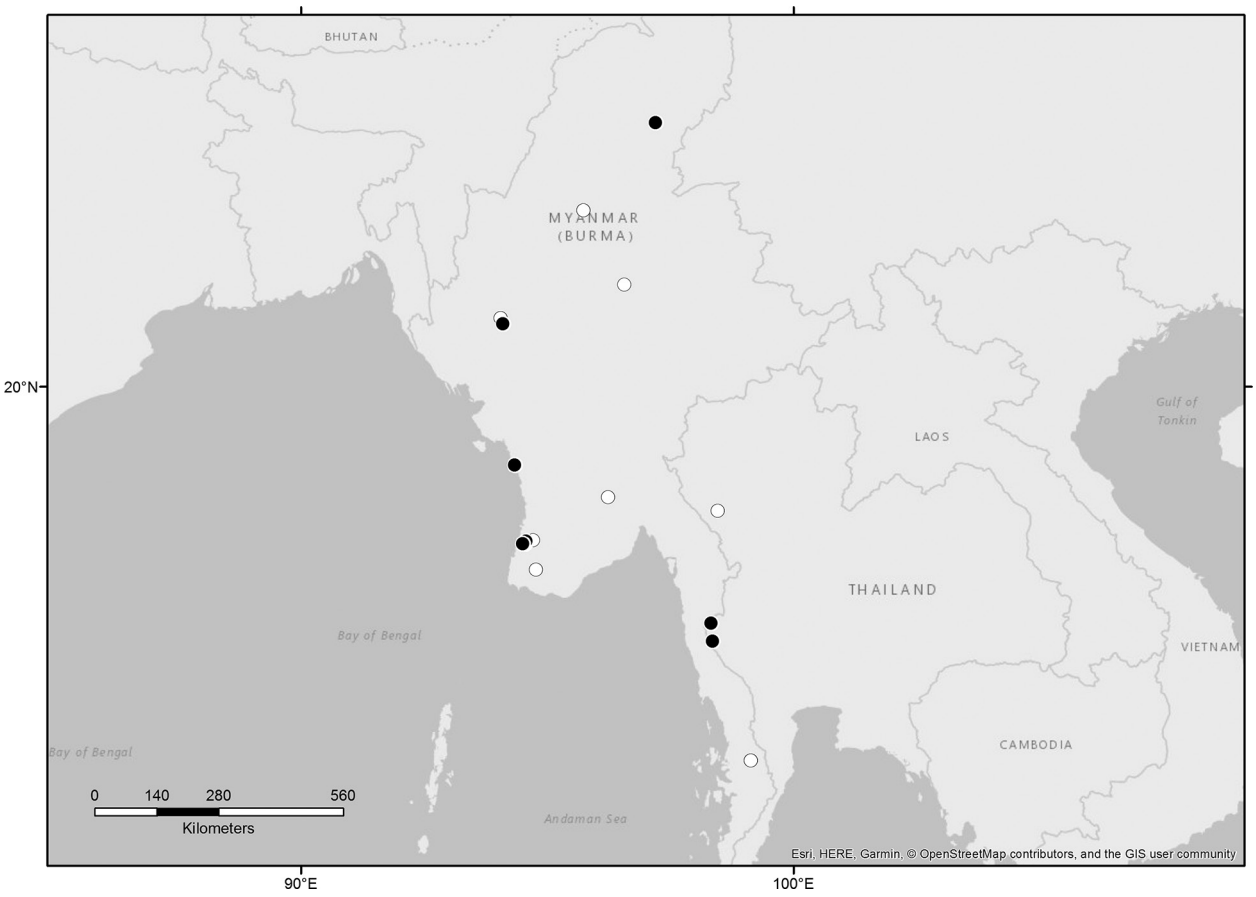


Fig. 4. Map indicating collecting localities of the *Fejervarya* species occurring in Myanmar. Each symbol can represent one or more adjacent localities. Black circles: *M. muangkanensis*; white circles: *M. chiangmaiensis*.

the *limnocharis* clade), from northern and eastern Myanmar, across Thailand, Loas, Cambodia, Vietnam, southern China, through Malaysia, the Philippines, to the Sunda Archipelago and reaching Japan in the east (Fig. 3). Most of the GenBank samples contained in this clade were originally labeled *limnocharis* or *multistriata*, respectively. The latter name was mostly used for samples from southern China. Furthermore, this clade includes samples originally named *sakishimensis* from Iriomote Island, Japan. Except for the samples from the eastern portion of this geographic range (i.e., Taiwan and Japan, up to 3.3% mean genetic distance from Southeast Asian subclusters), all sequences in this clade show very little genetic divergence with mean interclade genetic variation of 0.4 to 2.2%. These mt DNA data indicate that the specimens identified as *multistriata* are not distinct from *limnocharis*. Obviously, the taxonomic status of the *Fejervarya* populations of tropical China and on Taiwan and Japan need further study for clarification.

In summary, our samples from Myanmar are assigned to five species of which three represent first country records (i.e., *F. orissaensis*, *M. chiangmaiensis*, and *M. muangkanensis*), one undescribed species, as well as the wide-spread species *F. limnocharis* (Figs. 3 and 4). In external morphology these five species are somewhat conservative and not easily identified based on morphology alone. However, they do differ in some morphometric characters (see Fig. 5) as well as in the amount of toe webbing and in some details of coloration (see respective diagnosis sections below). We provide accounts for these five species below, with an emphasis on their Myanmar populations.

Fejervarya kupitzi sp. nov.

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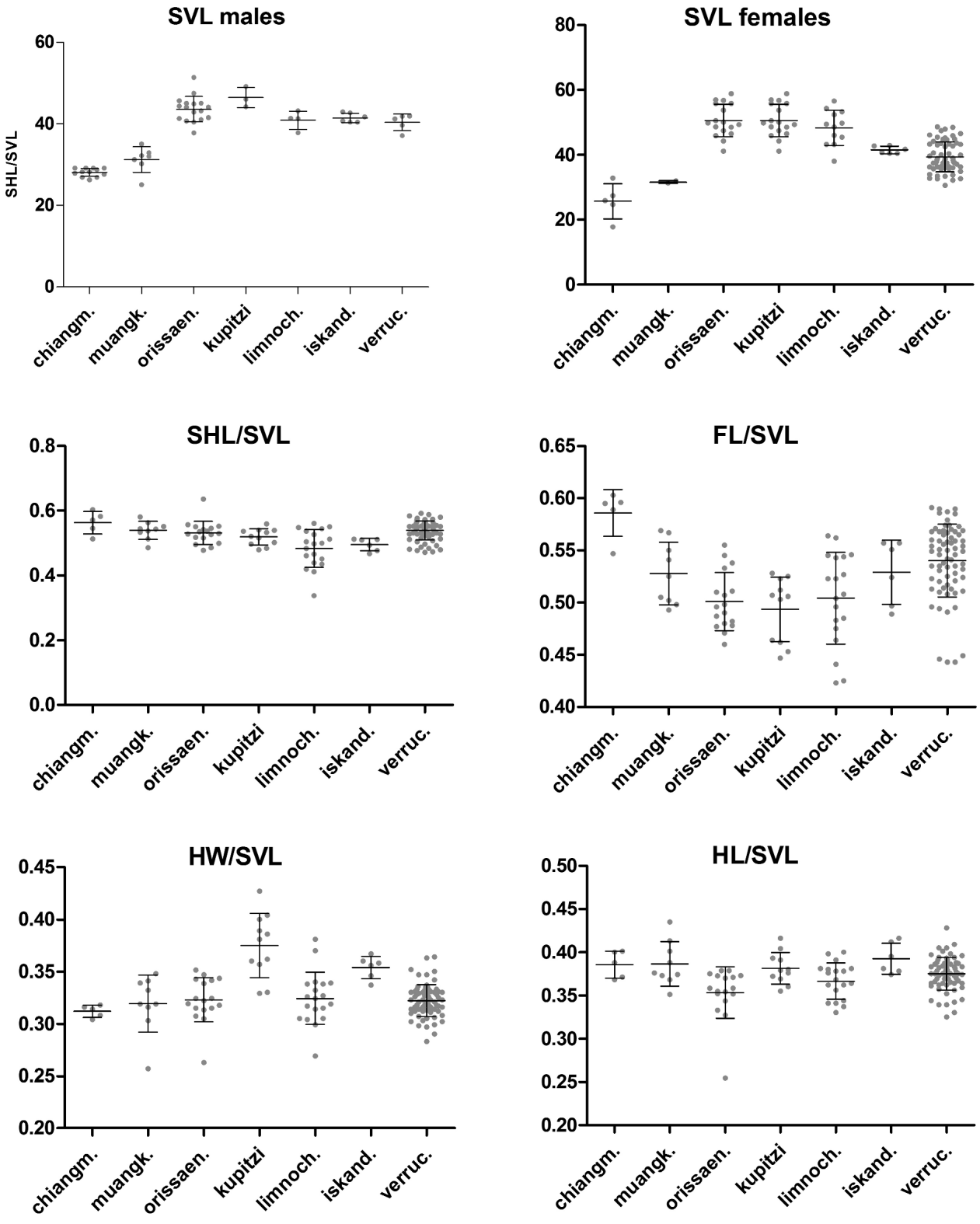
Figs. 6–7

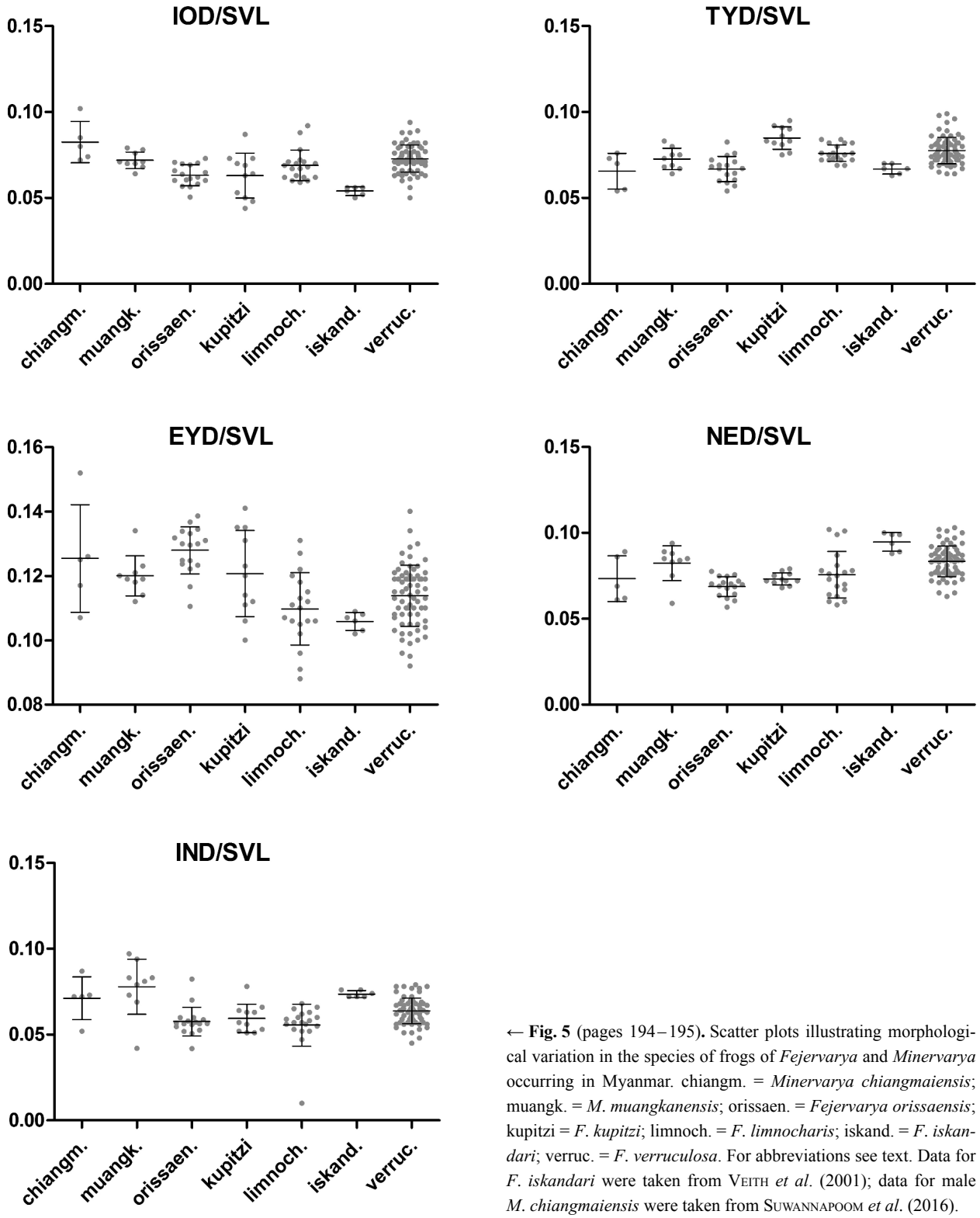
Holotype. CAS 210034, an adult male from Alaungdaw Kathapa National Park, along road between Thabakesay, Log Cabin Camp, and Payawa Sakhan, Elephant Camp (22.317863°N, 94.479012°E, WGS84), 375 m, Sagaing Division, Myanmar, collected 6 July 1999 by Joseph B. Slowinski, K. D. Wiseman, J. M. Lovette, and Jens V. Vindum.

Paratypes. CAS 210036, SMF 105717, same collecting data as holotype; CAS 208011, Alaungdaw Kathapa National Park (22.315139°N, 94.48375°E), 450 m, Sagaing Division, Myanmar, collected 28 February 1998 by J. B. Slowinski, C. L. Spencer and J. V. Vindum; CAS 208015, Alaungdaw Kathapa National Park (22.303333°N, 94.435361°E), 520 m, Sagaing Division, Myanmar, collected 27 February 1998 by J. B. Slowinski, C. L. Spencer and J. V. Vindum; CAS 210276–77, Alaungdaw Kathapa National Park, left bank of Pwedon Chaung across from Payawa Sakhan, Elephant Camp (22.32233°N, 94.48647°E), 340 m, Sagaing Divi-



sion, Myanmar, collected 13 July 1999 by J. B. Slowinski, K. D. Wiseman, J. M. Lovette and Jens V. Vindum; CAS 210304, Alaungdaw Kathapa National Park, Paya Chaung (22.318056°N, 94.485306°E), 350 m, Sagaing Division, Myanmar, collected 15 July 1999 by K. D. Wiseman, J. M. Lovette, and J. V. Vindum; CAS 208009, SMF 105718, Alaungdaw Kathapa National Park, Paya Chaung Creek (22.31908°N, 94.48647°E), 395 m, Sagaing Division, Myanmar, collected 25 February 1998 by J. B. Slowinski, C. L. Spencer and J. V. Vindum; CAS 207989, Bago Yoma (18.88328°N, 95.87914°E), 405 m, Bago Division, Myanmar, collected 13 November 1997 by J. B. Slowinski. CAS 208008 and SMF 105718 are adult males, CAS 207989, 208011, 208015, 210036, 210304, 210276–77, SMF 105717 are adult females.

Diagnosis. A species of the genus *Fejervarya* (sensu SANCHEZ *et al.*, 2018) that differs from all congeners by the following combination of characters (1) SVL 44.2–49.2 mm in males, 51.2–63.6 mm in females; (2) head about as long as wide, ratio HL/HW



← **Fig. 5** (pages 194–195)**.** Scatter plots illustrating morphological variation in the species of frogs of *Fejervarya* and *Minervarya* occurring in Myanmar. chiangm. = *Minervarya chiangmaiensis*; muangk. = *M. muangkanensis*; orissaen. = *Fejervarya orissaensis*; kupitzi = *F. kupitzi*; limnoch. = *F. limnocharis*; iskand. = *F. iskandari*; verruc. = *F. verruculosa*. For abbreviations see text. Data for *F. iskandari* were taken from Veith *et al*. (2001); data for male *M. chiangmaiensis* were taken from Suwannapoom *et al*. (2016).

0.92–1.15, mean 1.02; ratio HW/SVL 0.33–0.43, mean 0.38; (3) a large tympanum, discernible, ratio TYD/SVL 0.075–0.095, mean 0.085; (4) relatively short hind legs and feet (ratio SHL/SVL 0.49–0.58, mean 0.52; ratio FL/SVL 0.45–0.53, mean 0.49); (5) relative finger length III>I>II=IV; (6) poorly developed toe webbing; webbing formula I 1.1–2.1 II 1.1–2.6 III 1.8–3.1 IV 3.5–1.5 V to I 0.8–2 II 1–2.1 III 1–3 IV 3–1 V; (7) pale vertebral line absent; (8) tubercles on dorsal and lateral head and body, and body flanks.

Fejervarya kupitzi differs from its congeners as follows: From *F. cancrivora* and *F. moodiei* by having an outer metatarsal tubercle (absent in *F. cancrivora* and *F. moodiei*), by its smaller size (SVL 44.2–49.2 mm in males, 51.2–63.6 mm in females of *F. kupitzi* versus 58.6–77.2 mm in males, 76.4–99.1 mm in females of

F. cancrivora, and 44.5–74.9 mm in males, 46.1–88.1 mm in females of *F. moodiei*), and by having a head that is about as long as wide (versus head width less than head length in *F. cancrivora* and *F. moodiei*); from *F. iskandari* by its larger size (SVL 44.2–49.2 mm in males, 51.2–63.6 mm in females of *F. kupitzi* versus 40.4–42.7 mm in adults of *F. iskandari*), a larger tympanum (ratio TYD/SVL 0.075–0.095, mean 0.085, in *F. kupitzi* versus 0.062–0.086, mean 0.072, in *F. iskandari*), by having a shorter inner tarsal ridge (along distal one-third of tarsus in *F. kupitzi* versus distal half of tarsus in *F. iskandari*), and by having a head that is about as long as wide (versus head width less than head length); from *F. limnocharis* and *F. orissaensis* by having a broader head (ratio HW/SVL 0.33–0.43, mean 0.38, in *F. kupitzi* versus 0.27–0.38, mean 0.32, in *F. limnocharis*, 0.26–0.37, mean 0.32, in *F. orissaensis*), a larger tympanum (ratio TYD/SVL 0.074–0.095, mean 0.085, in *F. kupitzi* versus 0.069–0.084, mean 0.076, in *F. limnocharis*, 0.054–0.085, mean 0.69, in *F. orissaensis*), and by lacking a pale medial dorsal stripe (often present in *F. limnocharis* and *F. orissaensis*); from *F. triora* by lacking a broad supratympanic fold obscuring dorsoposterior margin of tympanum (versus such a fold present in *F. triora*) and by having a head that is about as long as wide (versus head broader than long); from *F. kawamurai* and *F. sakishimensis* by its larger tympanum (ratio TYD/SVL 0.075–0.095, mean 0.085, in *F. kupitzi* versus 0.059–0.085, mean 0.069, in *F. kawamurai*, 0.063–0.99, mean 0.074, in *F. sakishimensis*); it further differs from *F. kawamurai* by its larger size (SVL 44.2–49.2 mm in males, 51.2–63.6 mm in females of *F. kupitzi* versus 30.7–41.8 mm in males, 36.8–48.7 mm in females of *F. kawamurai*), and by having longer legs (ratio SHL/SVL 0.48–0.56, mean 0.52, in *F. kupitzi* versus 0.37–0.49, mean 0.43, in *F. kawamurai*); from *F. vittigera* by having a free flap of skin along outer edge of fifth toe and metatarsal (versus absent in *F. vittigera*). *Fejervarya kupitzi* differs from the two species of *Minervarya* that are known to occur in Myanmar (i.e., *M. chiangmaiensis* and *M. muangkanensis*) by its larger size (SVL 44.2–49.2 mm in males, 51.2–63.6 mm in females of *F. kupitzi* versus <36 mm in adults of *M. chiangmaiensis* and *M. muangkanensis*) and by having a distinct, glandular supratympanic fold from posterior edge of upper eyelid along upper margin of tympanum and then obliquely down to shoulder, obscuring dorsoposterior margin of tympanum (versus only a short and indistinct ridge above tympanum, not connected to posterior margin of eye and not bending down to shoulder).

Description of the holotype (Fig. 6). Adult male, as indicated by butterfly-shaped dark blotch on throat; SVL 49.2 mm; habitus robust; head broad, about as wide as long, ratio HL/HW 1.08; snout rounded in dorsal view, projecting beyond lower jaw, rounded to obtuse in profile; nostril dorsolateral, closer to tip of snout than eye; canthus rounded, slightly constricted behind nostrils; lores concave and oblique; ratio EYD/SVL 0.12; IOD less than width of upper eyelid; pineal body visible; distinct tympanum, dorsoposterior margin obscured by supratympanic fold, slightly depressed relative to skin of temporal region, tympanic rim weakly elevated relative to tympanum; ratio TYD/EYD 0.72; vomerine teeth on two oblique ridges, about equal in distance to each other as to choanae, with two teeth on each ridge; median protuberance at tip of mandible; tongue notched; tips of all four fingers rounded, not expanded into discs; relative finger lengths III>I>II=IV; no webbing; distinct subarticular tubercles, palmar tubercle distinct, bifid; thenar tubercle large, about twice the size of palmar tubercle; tips of toes rounded, not expanded into discs; relative toe lengths IV>III>V>II>I; webbing formula I 1–2 II 1–2.5 III 1.5–3 IV 3.1–1.1 V; movable flap of skin on postaxial side of Toe V from level of outer metatarsal tubercle to distal subarticular tubercle; weak fold on distal one-third of tarsus; elongate, oval inner metatarsal tubercle; small round outer metatarsal tubercle present; skin on top of head shagreen; skin on dorsum and flank granular with a few low short ridges; skin on side of head granular; skin on venter smooth; skin on upper surface of forelimbs smooth, that of hind limbs granular; skin on anterior and posterior surface of thigh smooth; distinct, glandular supratympanic fold from posterior edge of upper eyelid along upper margin of tympanum and then obliquely down to shoulder; no dorsolateral fold; large rictal gland present. Measurements (mm) of holotype: SVL 49.2; HL 20.5; HW 19.0; SL 8.4; EYD 5.9; IOD 3.6; TYD 4.3; TED 1.4; SHL 24.7; THL 24.9; HNL 11.2; FL 24.9; NED 3.9.

Coloration after about ten years preservation in 70% ethanol was recorded as follows: Dorsal ground color Burnt Umber (48) with suffusions of Verona Brown (37); hind limbs Burnt Umber (48) with Raw Umber (280) cross bars; parts of hands Cream Color (12); chin Tawny Olive (17) with Fuscous (283) suffusions (283); ventral surface of body Tawny Olive (17) with Raw Umber (23) stipples on lateral portions of venter; a Dusky Brown (285) butterfly-shaped marking present in throat region; ventral surfaces of limbs Tawny Olive (17); palmar surfaces Cream Color (12) with suffusions of Clay Color (18) on proximal phalanges; plantar surfaces Raw Umber (23); posterior surface of thigh Burnt Umber (48) with Cream Color (12) mottling.

Variation. The paratypes agree well with the holotype in general appearance, morphometrics and coloration (see Table 1; Fig. 7). Variation was evident in the gular coloration of the females (Fig. 8).

Etymology. In recognition of the contributions by David and Elke Kupitz to the research and conservation of biodiversity through the nonprofit BIOPAT initiative, the specific name of this newly discovered species of frog is dedicated to Mr. Richard Kupitz. Therefore, this frog is scientifically named *Fejervarya kupitzi*.

Natural history notes. The type locality is located in a protected area, Alaungdaw Kathapa National Park, a rath-

Table 1. Selected measurements and proportions of the species of *Fejervarya* and *Minervarya* known to occur in Myanmar. Range is followed by mean value and standard deviation in parentheses. For abbreviations see text.

		F. kupitzi ♂ 3 | ♀ 8	***F. limnocharis*** ♂ 7 | ♀ 12	***F. orissaensis*** ♂ 17 | ♀ 18	***M. chiangmaiensis*** ♂ 0 | ♀ 5	***M. muangkanensis*** ♂ 7 | ♀ 2
SVL	males	44.21–49.16 (46.48±2.50)	37.82–46.17 (42.64±2.75)	37.75–51.36 (43.58±3.12)		25.08–35.10 (31.24±3.11)
	females	51.20–63.57 (57.13±4.22)	37.99–56.57 (48.33±5.40)	41.13–59.95 (51.10±7.66)	27.38–32.81 (30.10±3.84)	31.30–31.88 (31.59±0.41)
SHL / SVL	males	0.502–0.521 (0.513±0.010)	0.338–0.537 (0.445±0.063)	0.478–0.636 (0.531±0.036)		0.513–0.563 (0.541±0.015)
	females	0.480–0.560 (0.521±0.030)	0.412–0.561 (0.501±0.044)	0.468–0.559 (0.518±0.036)	0.582–0.603 (0.592±0.014)	0.486–0.581 (0.534±0.067)
FL / SVL	males	0.506–0.525 (0.513±0.011)	0.423–0.523 (0.470±0.040)	0.460–0.555 (0.501±0.028)		0.493–0.567 (0.525±0.029)
	females	0.447–0.528 (0.486±0.033)	0.464–0.564 (0.524±0.033)	0.445–0.513 (0.485±0.029)	0.589–0.603 (0.596±0.010)	0.505–0.569 (0.539±0.045)
HL / SVL	males	0.369–0.416 (0.386±0.026)	0.330–0.380 (0.358±0.016)	0.327–0.379 (0.358±0.016)		0.368–0.435 (0.393±0.024)
	females	0.355–0.404 (0.380±0.016)	0.337–0.400 (0.372±0.022)	0.328–0.491 (0.366±0.067)	0.388–0.401 (0.394±0.009)	0.351–0.374 (0.363±0.016)
HW / SVL	males	0.360–0.386 (0.370±0.015)	0.305–0.381 (0.341±0.027)	0.261–0.351 (0.323±0.021)		0.303–0.348 (0.325±0.016)
	females	0.329–0.427 (0.377±0.036)	0.269–0.338 (0.314±0.019)	0.271–0.370 (0.319±0.039)	0.308–0.318 (0.313±0.007)	0.257–0.339 (0.298±0.058)
HL / HW	males	1.024–1.076 (1.043±0.029)	0.949–1.244 (1.054±0.096)	0.993–1.244 (1.113±0.063)		1.121–1.434 (1.212±0.116)
	females	0.915–1.151 (1.012±0.071)	1.109–1.306 (1.185±0.065)	1.945–1.495 (1.154±0.219)	1.220–1.302 (1.261±0.058)	1.104–1.366 (1.235±0.185)
IOD / SVL	males	0.044–0.073 (0.060±0.015)	0.062–0.088 (0.070±0.009)	0.051–0.073 (0.063±0.006)		0.068–0.079 (0.073±0.004)
	females	0.048–0.087 (0.064±0.013)	0.059–0.092 (0.068±0.009)	0.056–0.080 (0.066±0.009)	0.074–0.080 (0.077±0.004)	0.064–0.070 (0.067±0.004)
IND / SVL	males	0.051–0.063 (0.057±0.006)	0.053–0.068 (0.585±0.005)	0.042–0.082 (0.058±0.008)		0.069–0.097 (0.081±0.009)
	females	0.051–0.078 (0.060±0.009)	0.010–0.066 (0.054±0.015)	0.001–0.064 (0.053±0.027)	0.072–0.073 (0.072±0.001)	0.042–0.094 (0.068±0.037)
TYD / SVL	males	0.075–0.090 (0.084±0.008)	0.069–0.084 (0.076±0.006)	0.054–0.083 (0.067±0.007)		0.067–0.083 (0.074±0.006)
	females	0.076–0.095 (0.085±0.007)	0.069–0.084 (0.076±0.005)	0.054–0.085 (0.071±0.012)	0.073–0.076 (0.075±0.002)	0.064–0.069 (0.066±0.004)
EYD / SVL	males	0.120–0.135 (0.130±0.009)	0.095–0.122 (0.111±0.009)	0.111–0.139 (0.128±0.007)		0.114–0.134 (0.121±0.006)
	females	0.100–0.141 (0.117±0.014)	0.088–0.131 (0.109±0.013)	0.094–0.139 (0.114±0.018)	0.117–0.125 (0.121±0.006)	0.112–0.118 (0.115±0.005)
NED / SVL	males	0.073–0.078 (0.076±0.003)	0.059–0.081 (0.069±0.009)	0.057–0.078 (0.069±0.006)		0.075–0.094 (0.086±0.006)
	females	0.068–0.079 (0.072±0.003)	0.060–0.102 (0.080±0.015)	0.046–0.086 (0.070±0.016)	0.062–0.086 (0.074±0.017)	0.059–0.083 (0.071±0.018)
TYD / EYD	males	0.551–0.718 (0.645±0.085)	0.605–0.862 (0.690±0.094)	0.411–0.670 (0.523±0.063)		0.564–0.676 (0.613±0.034)
	females	0.618–0.857 (0.734±0.102)	0.583–0.934 (0.708±0.145)	0.424–0.777 (0.633±0.144)	0.583–0.651 (0.617±0.048)	0.541–0.418 (0.579±0.055)

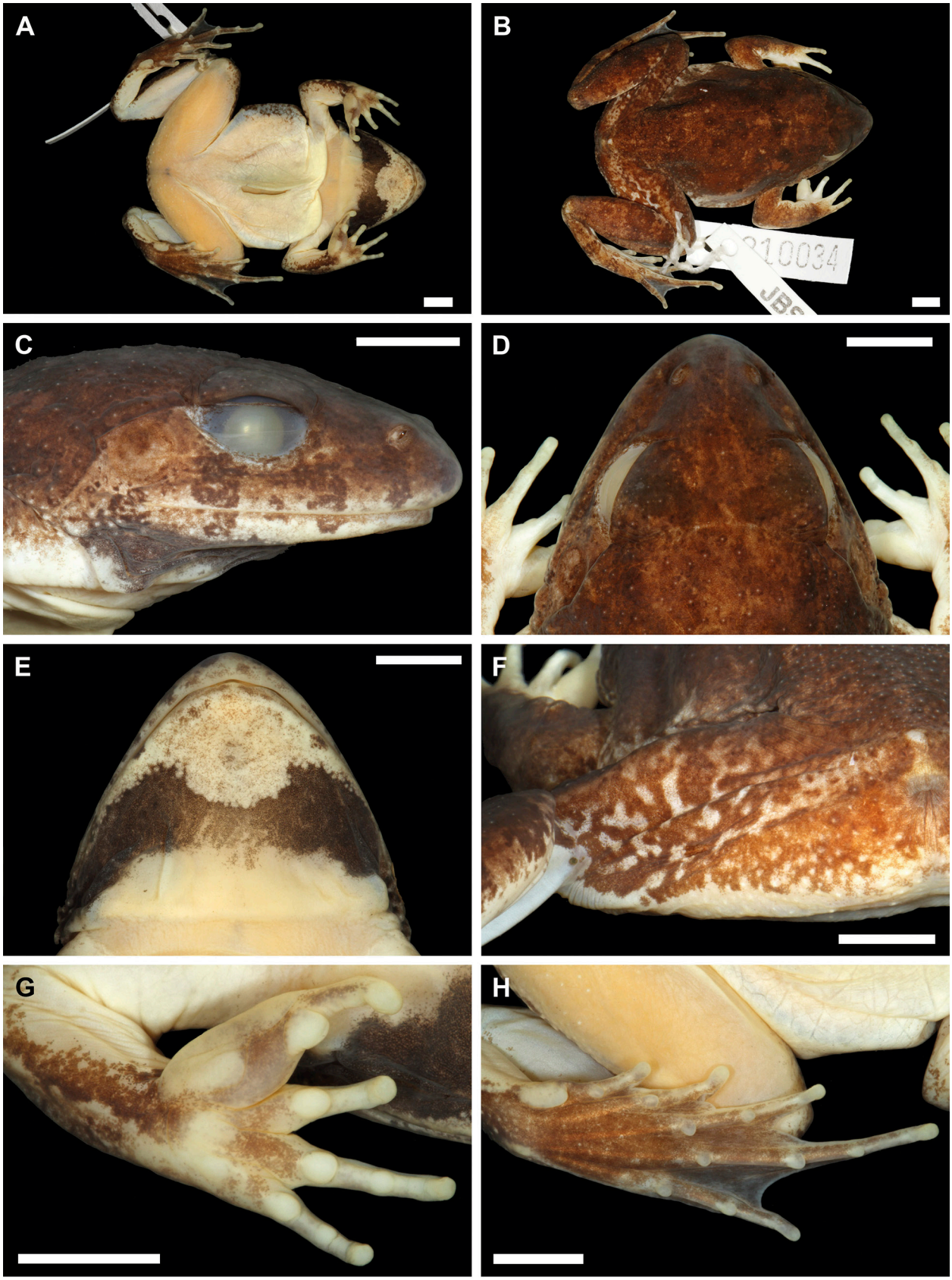


Fig. 6. Holotype of *Fejervarya kupitzi* (CAS 210034). Scale bars equal 5.0 mm. Photos by G.K.

er hilly region with elevations above sea level fluctuating from roughly 230 to 710 m. According to the CAS catalogue, several of the paratypes were collected along the edge of a stream. For CAS 210304, the air temperature at the time of collecting was recorded as 26.5°C and the relative humidity as 87%.

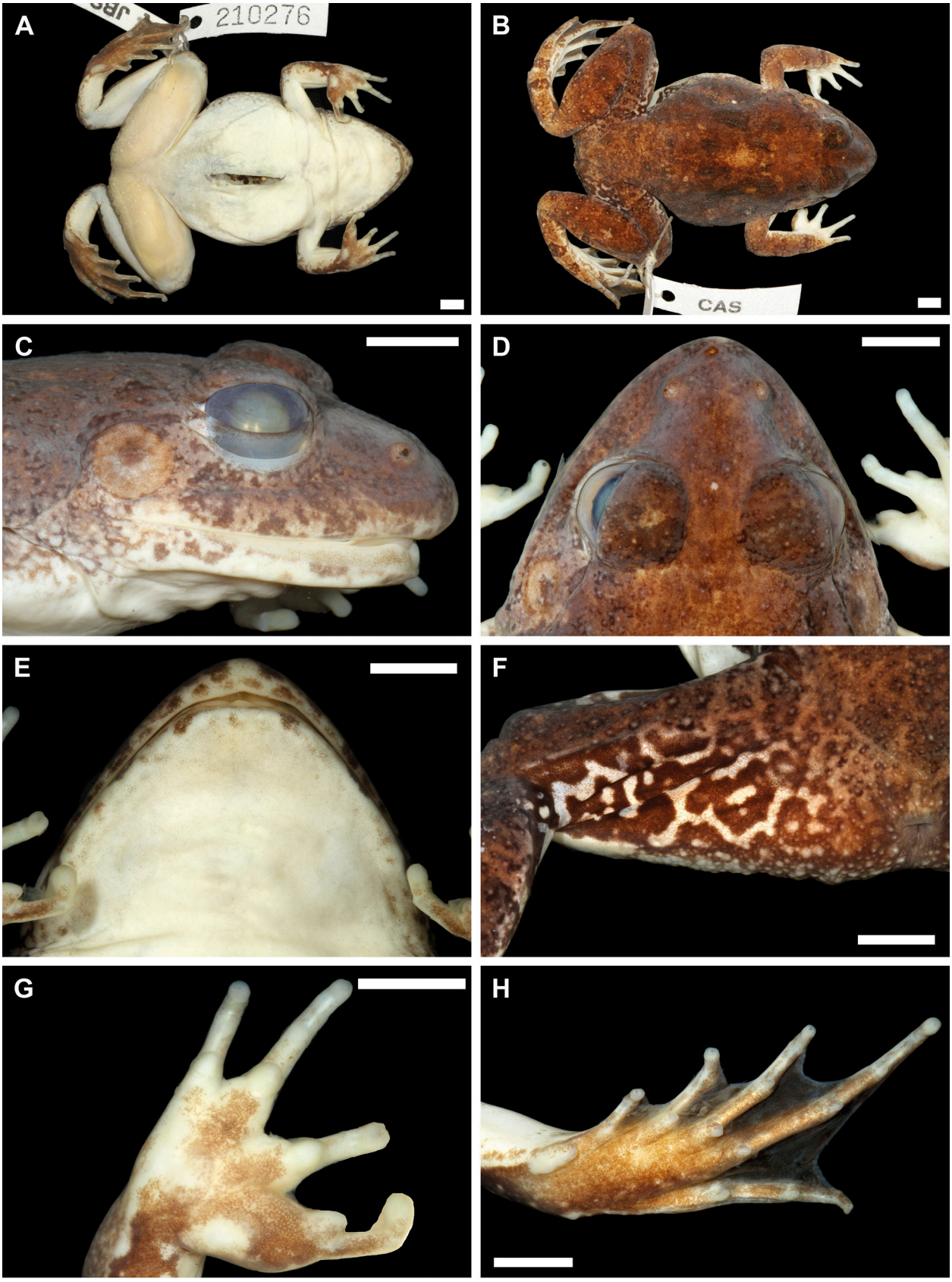


Fig. 7. Female paratype of *Fejervarya kupitzi* (CAS 210276). Scale bars equal 5.0 mm. Photos by G.K.

Geographic Distribution and Conservation. As currently known, *Fejervarya kupitzi* is known from Alaungdaw Kathapa National Park in western-central Myanmar and a single locality in the Bago Yoma range in south-central Myanmar at elevations between 340 and 520 m asl (Fig. 3). All known specimens of this species came

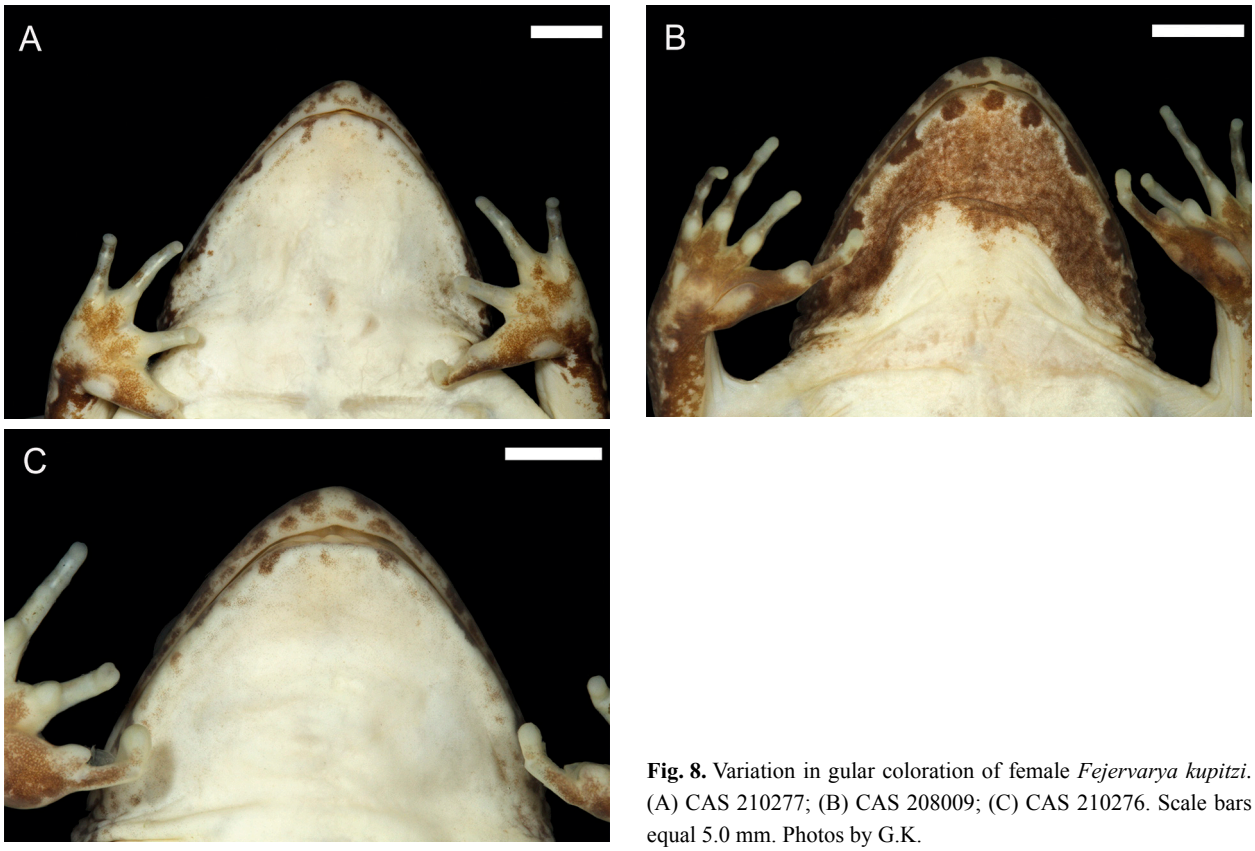


Fig. 8. Variation in gular coloration of female *Fejervarya kupitzi*. (A) CAS 210277; (B) CAS 208009; (C) CAS 210276. Scale bars equal 5.0 mm. Photos by G.K.

from forested, hilly areas. A specimen of *Fejervarya* that was collected on the grounds surrounding the headquarters of Alaungdaw Kathapa National Park Headquarters (which is outside of the park), about 50 km (airline) ESE of the type locality of *F. kupitzi*, and at 110 m asl, was identified as *F. orissaensis* based on its 16S and 12S DNA sequences. Thus, it is likely that *F. kupitzi* is restricted to forested, hilly regions and probably does not has a wide geographic distribution, although of course larger than known currently. Given the little we know about this species, we classify *F. kupitzi* as Data Deficient based on the IUCN Red List Categories and Criteria (IUCN 2012).

Fejervarya orissaensis (Dutta, 1997)

Limnonectes orissaensis Dutta 1997:2. Holotype: KU 197186; type locality: "near a temporary rain water pool at Sainik School area, Bhubaneswar, Khurda District, Orissa, India."
Fejervarya Bangladesh large type: Islam *et al*., 2008
Fejervarya sp. large type: Hasan *et al*., 2012
Fejervarya sp. 'hp2': Kotaki *et al*., 2010; Mulcahy *et al*., 2018; Sanchez *et al*., 2018
Fejervarya cf. *limnocharis*: Köhler *et al*., 2018

Diagnosis. A species of the genus *Fejervarya* (sensu Sanchez *et al*., 2018) that differs from all congeners by the following combination of characters (1) SVL 37.8–51.4 mm in males, 41.1–60.0 mm in females; (2) head usually longer than wide, ratio HL/HW 0.95–1.50, mean 1.13; ratio HW/SVL 0.26–0.37, mean 0.32; (3) a moderate-sized tympanum, discernible, ratio TYD/SVL 0.054–0.085, mean 0.069; (4) relatively short hind legs and feet (ratio SHL/SVL 0.47–0.64, mean 0.52; ratio FL/SVL 0.45–0.55, mean 0.49); (5) relative finger length III>I>II=IV; (6) poorly developed toe webbing; webbing formula I 1.5–2.1 II 1–2.8 III 3–4 IV 4–3 V to I 1–2 II 1–2.1 III 1.5–2 IV 2.1–1 V; (7) pale vertebral line present or absent; (8) tubercles on dorsal and lateral head and body, and body flanks, short longitudinal ridges often present on dorsum.

Fejervarya orissaensis differs from its congeners as follows: From *F. cancrivora* and *F. moodiei* by having an outer metatarsal tubercle (absent in *F. cancrivora* and *F. moodiei*), by its smaller size (SVL 37.8–51.4 mm in males, 41.1–60.0 in females of *F. orissaensis* versus 58.6–77.2 mm in males, 76.4–99.1 mm in females of *F. cancrivora*, and 44.5–74.9 mm in males, 46.1–88.1 mm in females of *F. moodiei*); from *F. iskandari* by its larger size (SVL 37.8–51.4 mm in males, 41.1–60.0 mm in females of *F. orissaensis* versus 40.4–42.7 mm in adults of *F. iskandari*) and by having a shorter inner tarsal ridge (along distal one-third of tarsus in *F. orissaensis* versus distal half of tarsus in *F. iskandari*); from *F. limnocharis* by having longer legs (ratio SHL/SVL 0.47–0.64, mean 0.52, in *F. orissaensis* versus 0.34–0.56, mean 0.48, in *F. limnocharis*), by being slightly larger (SVL 37.8–51.4 mm in males, 41.1–60.0 mm in females of *F. orissaensis* versus 34.7–46.2 mm in males, 38.0–56.6 mm in females of *F. limnocharis*), and by having slightly more toe webbing (i.e., on medial side of Toe II the two distal phalanges are free of webbing in *F. orissaensis*

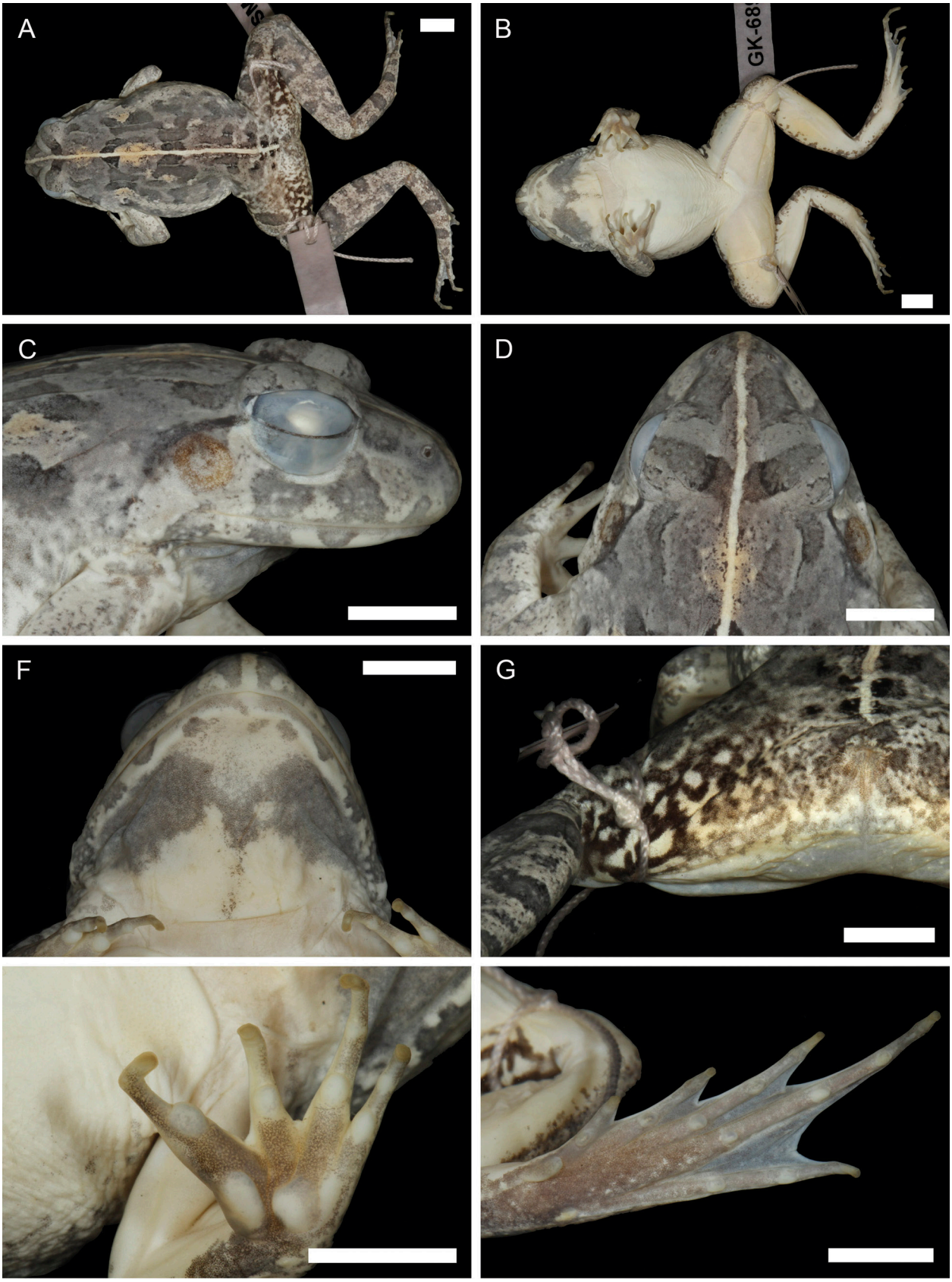


Fig. 9. Adult male of *Fejervarya orissaensis* (SMF 104113). Scale bars equal 5.0 mm. Photos by G.K.

versus also a portion of Phalanx III is free of webbing in *F. limnocharis*); from *F. triora* by having a head that is longer than wide (versus head about as long as wide in *F. triora*); from *F. kawamurai* by its larger size (SVL 37.8–51.4 mm in males, 41.1–60.0 mm in females of *F. orissaensis* versus 30.7–41.8 mm in males, 36.8–48.7 mm in

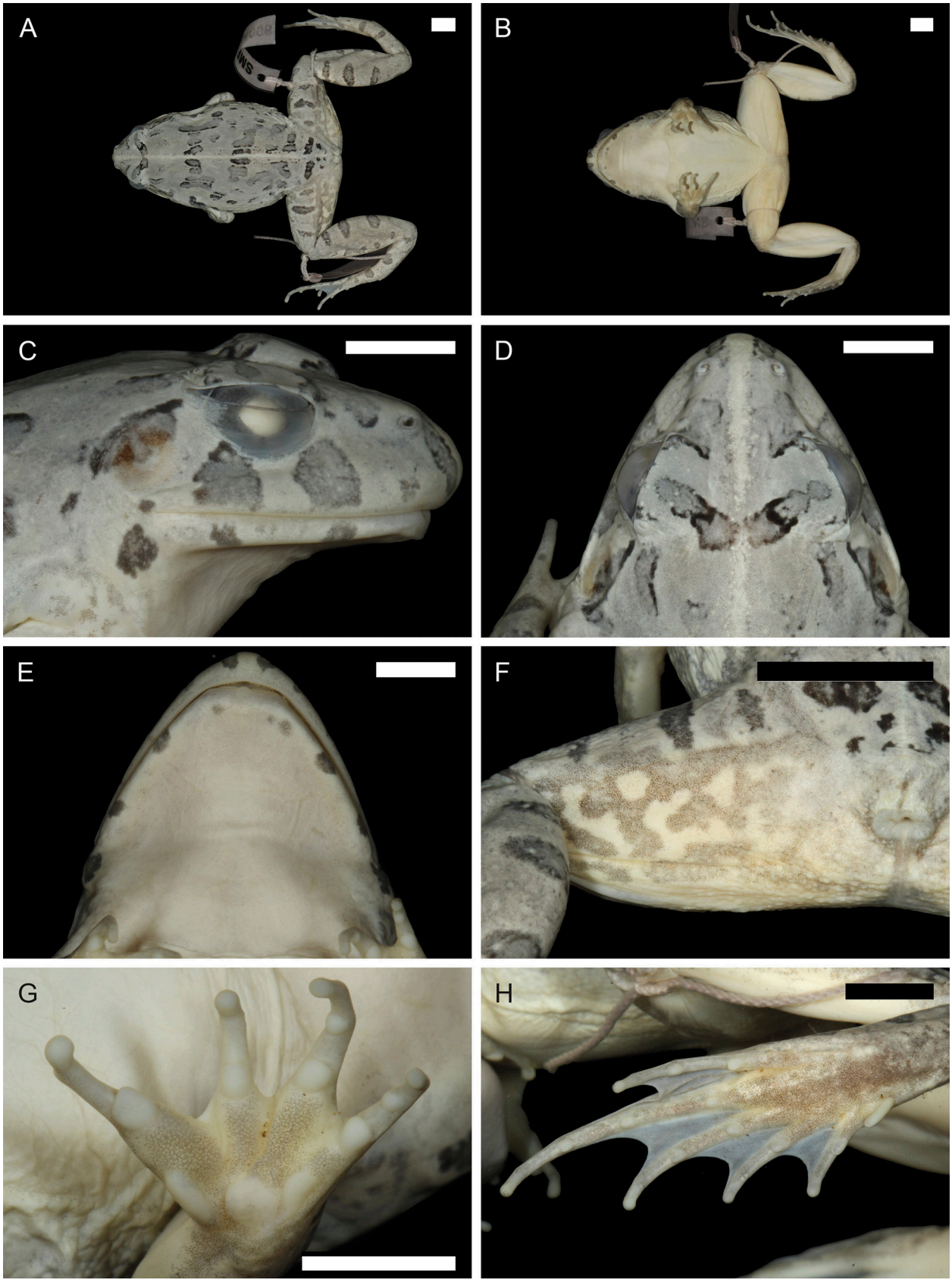


Fig. 10. Adult female of *Fejervarya orissaensis* (SMF 104096). Scale bars equal 5.0 mm. Photos by G.K.

females of *F. kawamurai*) and by having longer legs (ratio SHL/SVL 0.47–0.64, mean 0.52, in *F. orissaensis* versus 0.37–0.49, mean 0.43, in *F. kawamurai*); from *F. sakishimensis* by having longer feet (ratio FL/SVL 0.45–0.55, mean 0.49, in *F. orissaensis* versus 0.50–0.61, mean 0.54, in *F. sakishimensis*); from *F. vittigera* by having a free flap

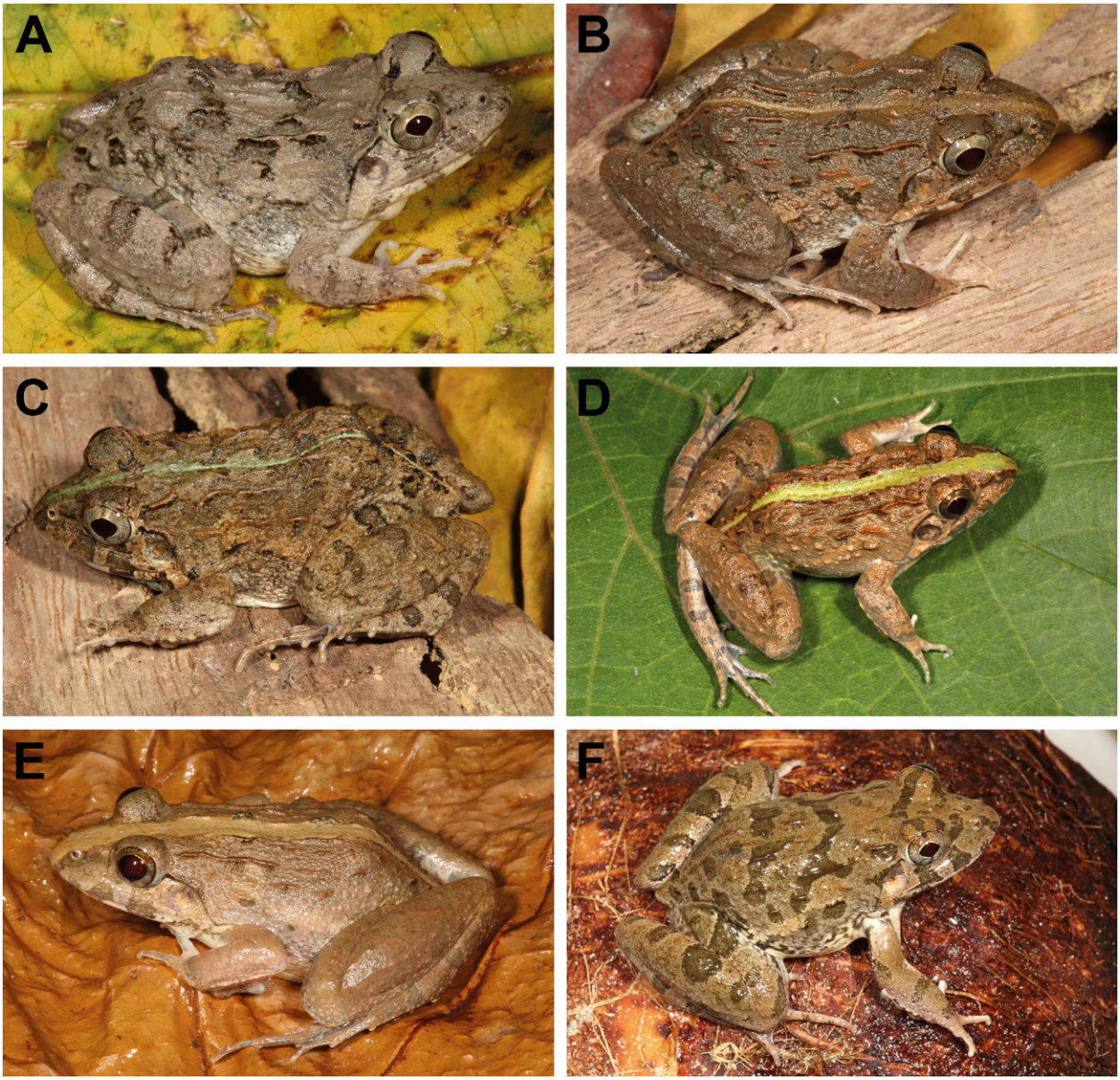


Fig. 11. *Fejervarya orissaensis* in life. (A) SMF 104093; (B) SMF 104097; (C) SMF 104098; (D) SMF 103777; (E) SMF 103775; (F) SMF 104121. (A,E) are adult females, (B–D,F) are adult males. Photos by G.K.

of skin along outer edge of fifth toe and metatarsal (versus absent in *F. vittigera*). *Fejervarya orissaensis* differs from the two species of *Minervarya* that are known to occur in Myanmar (i.e., *M. chiangmaiensis* and *M. muangkanensis*) by its larger size (SVL 37.8–51.4 mm in males, 41.1–60.0 mm in females of *F. orissaensis* versus < 36 mm in adults of *M. chiangmaiensis* and *M. muangkanensis*) and by having a distinct, glandular supratympanic fold from posterior edge of upper eyelid along upper margin of tympanum and then obliquely down to shoulder (versus only a short and indistinct ridge above tympanum, not connected to posterior margin of eye and not bending down to shoulder).

Description (Figs. 9–11). Habitus robust; head usually longer than wide, as wide as long in some individuals; snout subelliptical in dorsal view, projecting beyond lower jaw, obtuse in profile; nostril dorsolateral, closer to tip of snout than eye; canthus rounded, slightly constricted behind nostrils; lores concave and oblique; IOD less than or subequal the width of upper eyelid; pineal body visible; distinct tympanum, slightly depressed relative to skin of temporal region, tympanic rim weakly elevated relative to tympanum; vomerine teeth on two oblique ridges, about equal in distance to each other as to choanae; median protuberance at tip of mandible; tongue notched; tips of all four fingers rounded, not expanded into discs; relative finger lengths III > I > II = IV; no webbing; distinct subarticular tubercles, palmar tubercle distinct, bifid or even separated as two distinct tubercles; thenar tubercle large, about twice the size of palmar tubercle; tips of toes rounded, not expanded into discs; relative toe lengths IV > III > V > II > I; webbing formula I 1.5–2.1 II 1–2.8 III 3–4 IV 4–3 V to I 1–2 II 1–2.1 III 1.5–2 IV 2.1–1

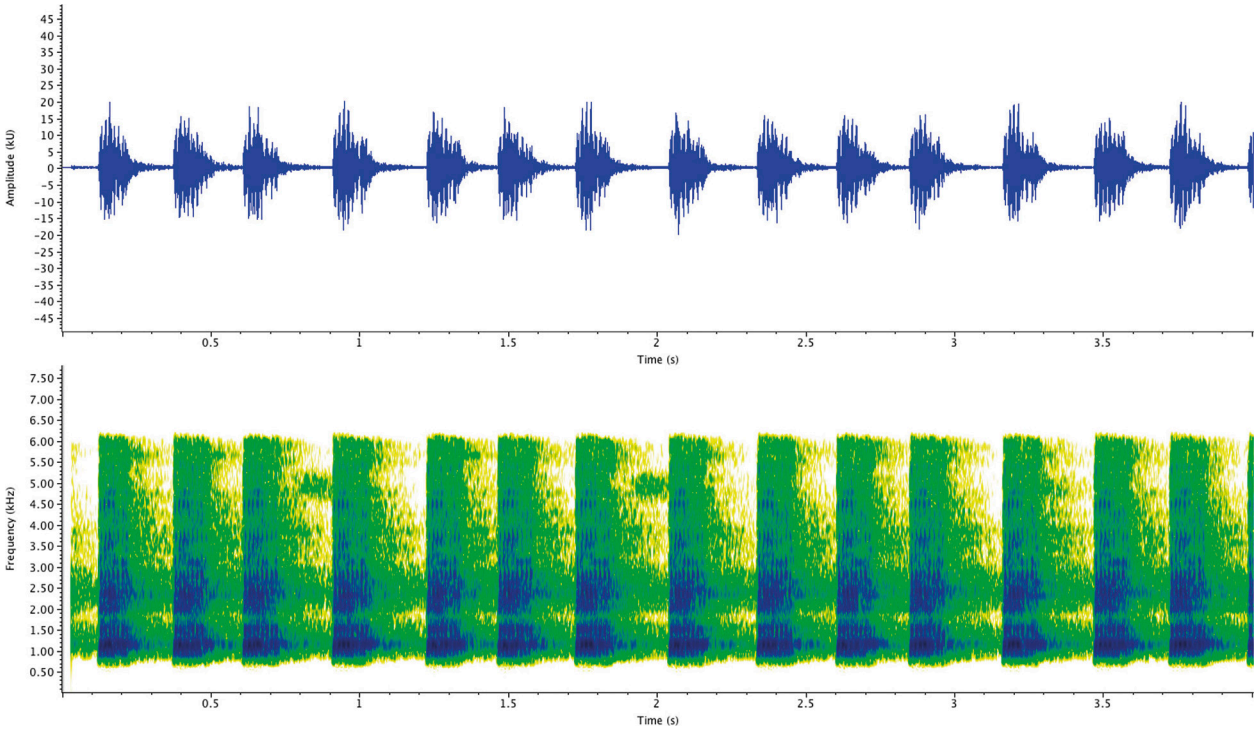


Fig. 12. Advertisement call of a male of *Fejervarya orissaensis* (SMF 104871).

V; movable flap of skin on postaxial side of Toe V from level of outer metatarsal tubercle to distal subarticular tubercle; weak fold on distal one-third of tarsus; elongate, oval inner metatarsal tubercle; small round outer metatarsal tubercle present; skin on top of head shagreen; skin on dorsum and flank usually granular with varying density of tubercles and often also with short longitudinal ridges; skin on side of head granular; skin on venter smooth; skin on upper surface of forelimbs smooth, that of hind limbs granular; skin on anterior and posterior surface of thigh smooth; distinct, glandular supratympanic fold from posterior edge of upper eyelid along upper margin of tympanum and then obliquely down to shoulder, obscuring dorsoposterior margin of tympanum; no dorsolateral fold. For variation in selected morphometric characters see Table 1.

Advertisement call. The call of a male *Fejervarya orissaensis* (SMF 104871) was recorded after it was placed in a glass aquarium (60 cm × 80 cm × 40 cm) on 5 June 2018 with an ambient temperature of 22°C. The call consisted of a series of slightly pulsed notes. Each of these notes lasted 0.145 ± 0.007 s and was composed of 7–8 pulses/call (average 7.6 ± 0.50). The note interval was 0.12 ± 0.030 s, the dominant frequency was 1128 ± 22.7 Hz, and the first harmonic was about 2517 ± 148.8 Hz (Fig. 12).

Tadpole morphology. The following description is based on two tadpoles (SMF 104902, 105094) at Gosner stage 36 (Fig. 13): Total length 24.1 mm; body and tail musculature grayish brown with dark brown blotches; tail fins transparent with grayish brown blotches and suffusions; body ovoid in dorsal view; snout round in dorsal

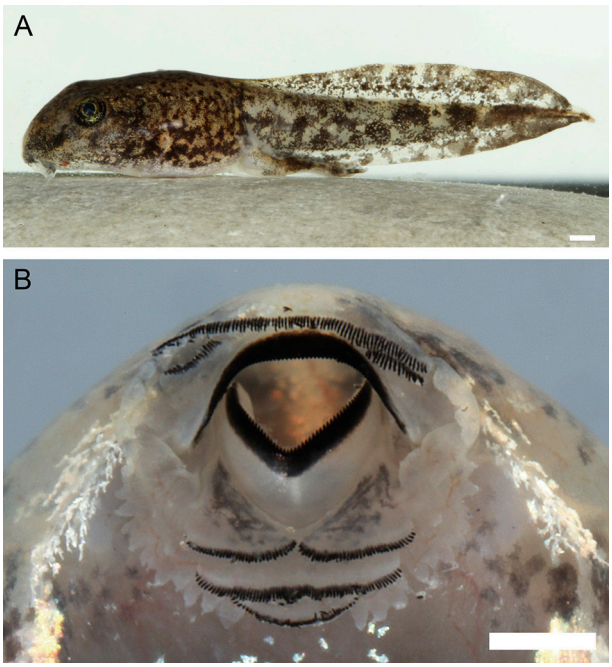


Fig. 13. Tadpole of *Fejervarya orissaensis*. (A) Lateral view of SMF 104902; (B) oral disc of SMF 105094. Scale bars equal 1.0 mm. Photos by G.K.

view and blunt in lateral view; Oral disc not emarginated, situated and directed anteroventrally; oral disc with a large gap of papillae anterior and a small gap posterior but with one lateral row of triangular papillae and some isolated conical submarginals; jaw sheaths serrated, upper one saddle-shaped, lower one V-shaped; LKRF 2/3; anterior keratodont rows slightly longer than posterior

rows and A-2 with wide median gap (gap wider than each row fragment); P1 and P2 rows nearly of same length, P3 shorter than P1 and P2, P1 with a narrow median gap; eyes directed dorsolaterally; nostrils positioned dorsal and directed dorsolateral, ovoid to reniform, elevated on the inner fringe, forming a triangular operculum; spiracle sinistral, directed posterodorsally, opening positioned in lower one-third of lateral body; cloacal tube situated medially, longer than wide and attached to ventral fin; the attached side of tube is somewhat longer than the free side with a dextral orientated opening; dorsal and ventral fins rise at base of tail, reach their maximum height at midlength of tail and decrease again towards tip of tail. Tip of tail pointed.

Geographic Distribution and Conservation. As currently known, *Fejervarya orissaensis* is distributed from the state of Orissa in eastern India across Bangladesh and southeastern Myanmar into western Thailand (Fig. 3). The specimens we have examined were collected at elevations between near sea level and 105 m asl. This species seems to be quite adaptable in regard of the tolerated habitats and even seems to prefer disturbed habitat. We collected *F. orissaensis* along the edges of streams, lakes and ponds, in wet grass, adjacent to rice fields and along trails. Like all species of this genus, it is nocturnal and terrestrial and preys upon a large variety of invertebrates. Given its large geographic distribution and its usual abundance wherever this species occurs, we consider the conservation status of *F. orissaensis* as Least Concern based on the IUCN Red List Categories and Criteria (IUCN 2012).

Fejervarya limnocharis (Gravenhorst, 1829)

Rana limnocharis Gravenhorst, 1829: 42. Neotype RMNH 4287; type locality: not stated explicitly, but from context indicted as Java, Indonesia (Dubois & Ohler, 2000).

Diagnosis. A species of the genus *Fejervarya* (sensu Sanchez *et al*., 2018) that differs from all congeners by the following combination of characters (1) SVL 34.7–46.2 mm in males, 38.0–56.6 mm; (2) head usually longer than wide, ratio HL/HW 0.95–1.14, mean 1.13; ratio HW/SVL 0.27–0.38, mean 0.32; (3) a moderate-sized tympanum, discernible, ratio TYD/SVL 0.069–0.084, mean 0.076; (4) relatively short hind legs and feet (ratio SHL/SVL 0.34–0.56, mean 0.48; ratio FL/SVL 0.42–0.56, mean 0.50); (5) relative finger length III>I>II=IV; (6) poorly developed toe webbing; webbing formula I 1.7–2.5 II 1.4–2.8 III 2.1–3.3 IV 3.6–2 V to I 1–2 II 1–2.5 III 1.5–3 IV 3.1–1 V; (7) pale vertebral line present or absent; (8) tubercles on dorsal and lateral head and body, and body flanks, short longitudinal ridges often present on dorsum.

Fejervarya limnocharis differs from its congeners as follows: From *F. cancrivora* and *F. moodiei* by having an outer metatarsal tubercle (absent in *F. cancrivora* and *F. moodiei*), by its smaller size (SVL 34.7–46.2 mm in males, 38.0–56.6 mm in females of *F. limnocharis* versus 58.6–77.2 mm in males, 76.4–99.1 mm in females of *F. cancrivora*, and 44.5–74.9 mm in males, 46.1–88.1 mm in females of *F. moodiei*); from *F. iskandari* by its larger size (SVL 34.7–46.2 mm in males, 38.0–56.6 mm in females of *F. limnocharis* versus 40.4–42.7 mm in adults of *F. iskandari*) and by having a shorter inner tarsal ridge (along distal one-third of tarsus in *F. limnocharis* versus distal half of tarsus in *F. iskandari*); from *F. orissaensis* by having shorter legs (ratio SHL/SVL 0.34–0.56, mean 0.48, in *F. limnocharis* versus 0.47–0.64, mean 0.52, in *F. orissaensis*), by being slightly smaller (SVL 34.7–46.2 mm in males, 38.0–56.6 mm of *F. limnocharis* versus 37.8–51.4 mm in males, 41.1–60.0 mm in females of *F. orissaensis*) and by having slightly less toe webbing (i.e., on medial side of Toe II a portion of Phalanx III is free of webbing in *F. limnocharis* versus only the two distal phalanges are free of webbing in *F. orissaensis*); from *F. triora* by lacking a broad supratympanic fold obscuring dorsoposterior margin of tympanum (versus such a fold obscuring dorsoposterior margin of tympanum present in *F. triora*) and by having a head that is about as long as wide (versus head usually longer than wide in *F. limnocharis*); from *F. kawamurai* by its larger size (34.7–46.2 mm in males, 38.0–56.6 mm of *F. limnocharis* versus 30.7–41.8 mm in males, 36.8–48.7 mm in females of *F. kawamurai*) and by having longer legs (ratio SHL/SVL 00.34–0.56, mean 0.48, in *F. limnocharis* versus 0.37–0.49, mean 0.43, in *F. kawamurai*); from *F. vittigera* by having a free flap of skin along outer edge of fifth toe and metatarsal (versus absent in *F. vittigera*). *Fejervarya limnocharis* differs from the two species of *Minervarya* that are known to occur in Myanmar (i.e., *M. chiangmaiensis* and *M. muangkanensis*) by its larger size (SVL 34.7–46.2 mm in males, 38.0–56.6 mm of *F. limnocharis* versus <36 mm in adults of *M. chiangmaiensis* and *M. muangkanensis*) and by having a distinct, glandular supratympanic fold from posterior edge of upper eyelid along upper margin of tympanum and then obliquely down to shoulder (versus only a short and indistinct ridge above tympanum, not connected to posterior margin of eye and not bending down to shoulder).

Description (Fig. 14). Habitus robust; head usually longer than wide, as wide as long in some individuals; snout subelliptical in dorsal view, projecting beyond lower jaw, obtuse in profile; nostril dorsolateral, closer to tip of snout than eye; canthus rounded, slightly constricted behind nostrils; lores concave and oblique; IOD less than or subequal the width of upper eyelid; pineal body visible; distinct tympanum, lightly depressed relative to skin of temporal region, tympanic rim weakly elevated relative to tympanum; vomerine teeth on two oblique ridges, about equal in distance to each other as to choanae; median protuberance at tip of mandible; tongue notched; tips of all four fingers rounded, not expanded into discs; relative finger lengths III>I>II=IV; no webbing; distinct subarticular tubercles, palmar tubercle distinct, bifid or even separated as two distinct tubercles; thenar tubercle

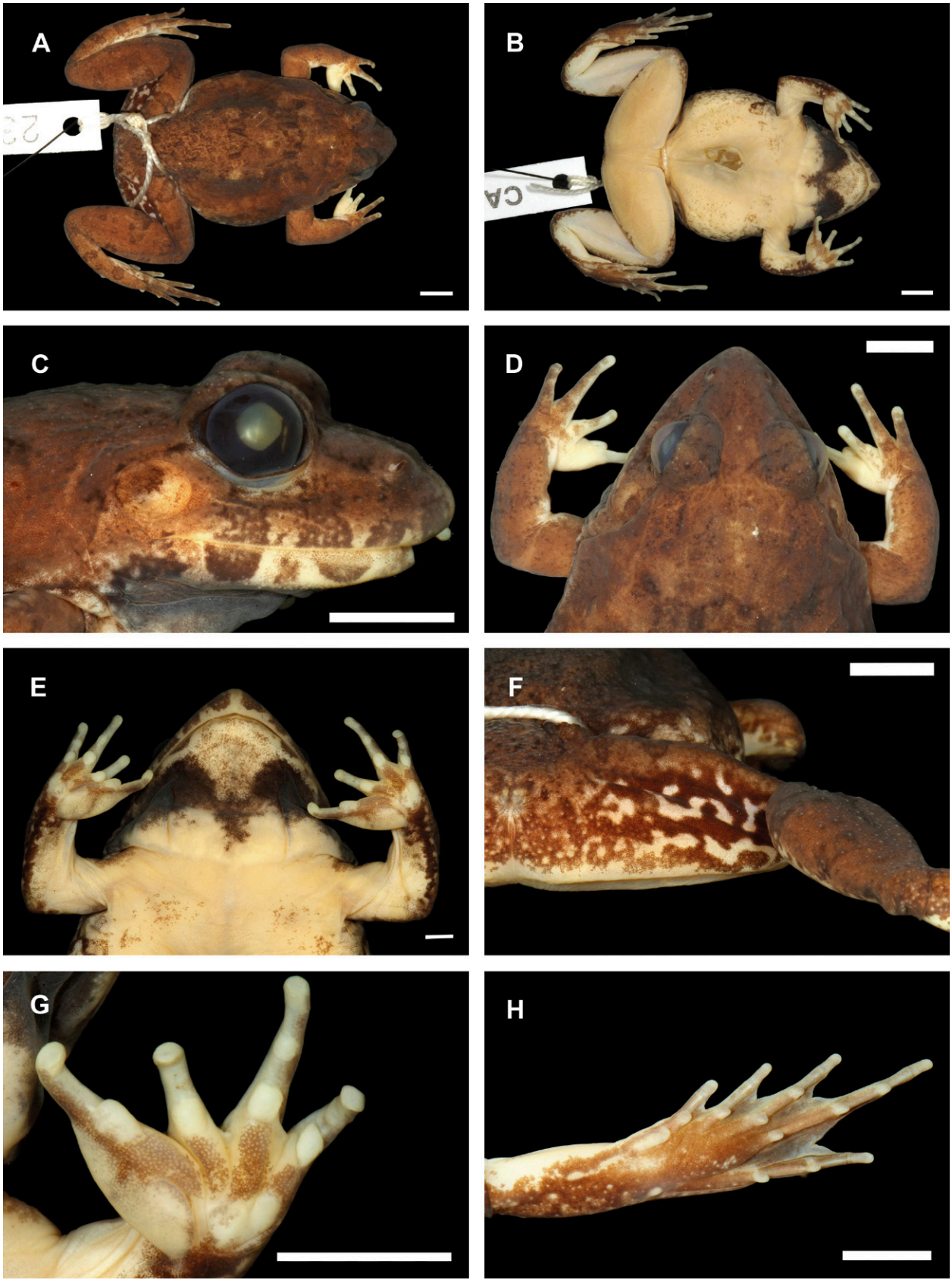


Fig. 14. Adult male of *Fejervarya limnocharis* (CAS 234814). Scale bars equal 5.0 mm. Photos by G.K.

large, about twice the size of palmar tubercle; tips of toes rounded, not expanded into discs; relative toe lengths IV > III > V > II > I; webbing formula I 1.7–2.5 II 1.4–2.8 III 2.1–3.3 IV 3.6–2 V to I 1–2 II 1–2.5 III 1.5–3 IV 3.1 –1 V; movable flap of skin on postaxial side of Toe V from level of outer metatarsal tubercle to distal subarticu-

lar tubercle; weak fold on distal one-third of tarsus; elongate, oval inner metatarsal tubercle; small round outer metatarsal tubercle present; skin on top of head shagreen; skin on dorsum and flank usually granular with varying density of tubercles and often also with short longitudinal ridges; skin on side of head granular; skin on venter smooth; skin on upper surface of forelimbs smooth, that of hind limbs granular; skin on anterior and posterior surface of thigh smooth; distinct, glandular supratympanic fold from posterior edge of upper eyelid along upper margin of tympanum and then obliquely down to shoulder; no dorsolateral fold. For variation in selected morphometric characters see Table 1.

Natural history notes. Ziegler (2002) provided a summary of the natural history of this species (as *Limnonectes limnocharis*) and also described its advertisement call. The tadpole of this species was illustrated and described under various generic allocations (e.g., Maeda & Matsui, 1990; Qi & Dongwuzhi, 1991; Ziegler, 2002; Fei *et al*., 2010).

Geographic Distribution and Conservation. As currently known, *Fejervarya limnocharis* is distributed from northern and eastern Myanmar, across Thailand, Loas, Cambodia, Vietnam, southern China, through Malaysia, the Philippines, to the Sunda Archipelago. This species seems to be quite adaptable in regard of the tolerated habitats and even seems to prefer disturbed habitat. It has been collected along the edges of streams, lakes and ponds, in wet grass, adjacent to as well as within rice fields. Given its large geographic distribution and its usual abundance wherever this species occurs, we consider the conservation status of *F. limnocharis* as Least Concern based on the IUCN Red List Categories and Criteria (IUCN 2012).

Minervarya chiangmaiensis (Suwannapoom, Yuan, Poyarkov, Yan, Kamtaeja, Murphy, and Che, 2016)

Fejervarya chiangmaiensis Suwannapoom, Yuan, Poyarkov, Yan, Kamtaeja, Murphy, and Che, 2016: 330. Holotype: KIZ024057; type locality: "Ban Monjong, Omkoi District, Chiang Mai Province, Thailand (N17°28′16.93″, E98°27′28.26″, 460 m a.s.l.)."

Diagnosis. A species of the genus *Minervarya* (sensu Sanchez *et al*., 2018) that differs from all congeners by the following combination of characters [our data from five females are presented first, then data in brackets, if available, for 12 males from Suwannapoom *et al*., 2016] (1) SVL 24.7–32.8 mm [26.3–29.1 mm]; (2) head longer than wide, ratio HL/HW 1.18–1.30, mean 1.24 [1.06–1.18, mean 1.11]; ratio HW/SVL 0.30–0.32, mean 0.31 [0.35–0.38, mean 0.37]; (3) a moderate-sized tympanum, discernible, ratio TYD/SVL 0.054–0.076, mean 0.066; (4) relatively short hind legs and feet (ratio SHL/SVL 0.51–0.60, mean 0.56 [0.44–0.56, mean 0.56]; ratio FL/SVL 0.55–0.60, mean 0.59 [0.51–0.56, mean 0.54]); (5) relative finger length III>I>II=IV; (6) poorly developed toe webbing; webbing formula I 1.5–2.5 II 1.5–3 III 2–3.1 IV 3.5–2 V to I 1–2 II 1–2.5 III 1.5–3 IV 2.5–1 V; (7) pale vertebral line present or absent; (8) tubercles on dorsal and lateral head and body, and body flanks, short longitudinal ridges often present on dorsum.

For a comparison of *Minervarya chiangmaiensis* with its congeners see Suwannapoom et al. (2016). From the other species of *Fejervarya* and *Minervarya* currently recognized from Myanmar it differs as follows: From *Fejervarya kupitzi*, *F. limnocharis*, and *F. orissaensis* it differs by its smaller size (SVL 24.7–32.8 mm in males, 26.3–29.1 mm in females of *M. chiangmaiensis* versus >35 mm in adults of the three species of *Fejervarya*) and by having a only a short, indistinct glandular supratympanic fold above tympanum, not connected to posterior margin of eye and not bending down to shoulder (versus supratympanic fold distinct and running from posterior edge of upper eyelid along upper margin of tympanum and then obliquely down to shoulder in the three species of *Fejervarya*); from *M. muangkanensis* by having longer feet (ratio FL/SVL 0.55–0.60, mean 0.59, in *M. chiangmaiensis* versus 0.49–0.57, mean 0.53, in *M. muangkanensis*) and by having a weak inner metatarsal fold, on distal one-half of tarsus (versus ill-defined inner metatarsal fold, on distal one-fourth of tarsus *M. muangkanensis*).

Description (Fig. 15–16). Habitus robust; head longer than wide; snout subovoid in dorsal view, projecting beyond lower jaw, rounded in profile; nostril dorsolateral, closer to tip of snout than eye; canthus rounded, slightly constricted behind nostrils; lores concave and oblique; IOD less than or subequal the width of upper eyelid; pineal body visible; tympanic rim weakly elevated relative to tympanum; vomerine teeth on two oblique ridges, about equal in distance to each other as to choanae; median protuberance at tip of mandible; tongue notched; tips of all four fingers rounded, not expanded into discs; relative finger lengths III>I>II=IV; no webbing; distinct subarticular tubercles, palmar tubercle distinct, bifid or even separated as two distinct tubercles; thenar tubercle large, about twice the size of palmar tubercle; tips of toes rounded, not expanded into discs; relative toe lengths IV>III>V>II>I; webbing formula I 1.5–2.5 II 1.5–3 III 2–3.1 IV 3.5–2 V to I 1–2 II 1–2.5 III 1.5–3 IV 2.5–V; movable flap of skin on postaxial side of Toe V from level of outer metatarsal tubercle to distal subarticular tubercle; inner metatarsal fold weak, on distal one-half of tarsus; elongate, oval inner metatarsal tubercle; small round outer metatarsal tubercle present; skin on top of head shagreen; skin on dorsum and flank usually granular with varying density of tubercles and often also with short longitudinal ridges; skin on side of head granular; skin on venter smooth; skin on upper surface of forelimbs smooth, except for a few low tubercles on upper arm, that of hind limbs granular; skin on anterior and posterior surface of thigh smooth; a short, indistinct glandular supratympanic fold above tympanum, not con-

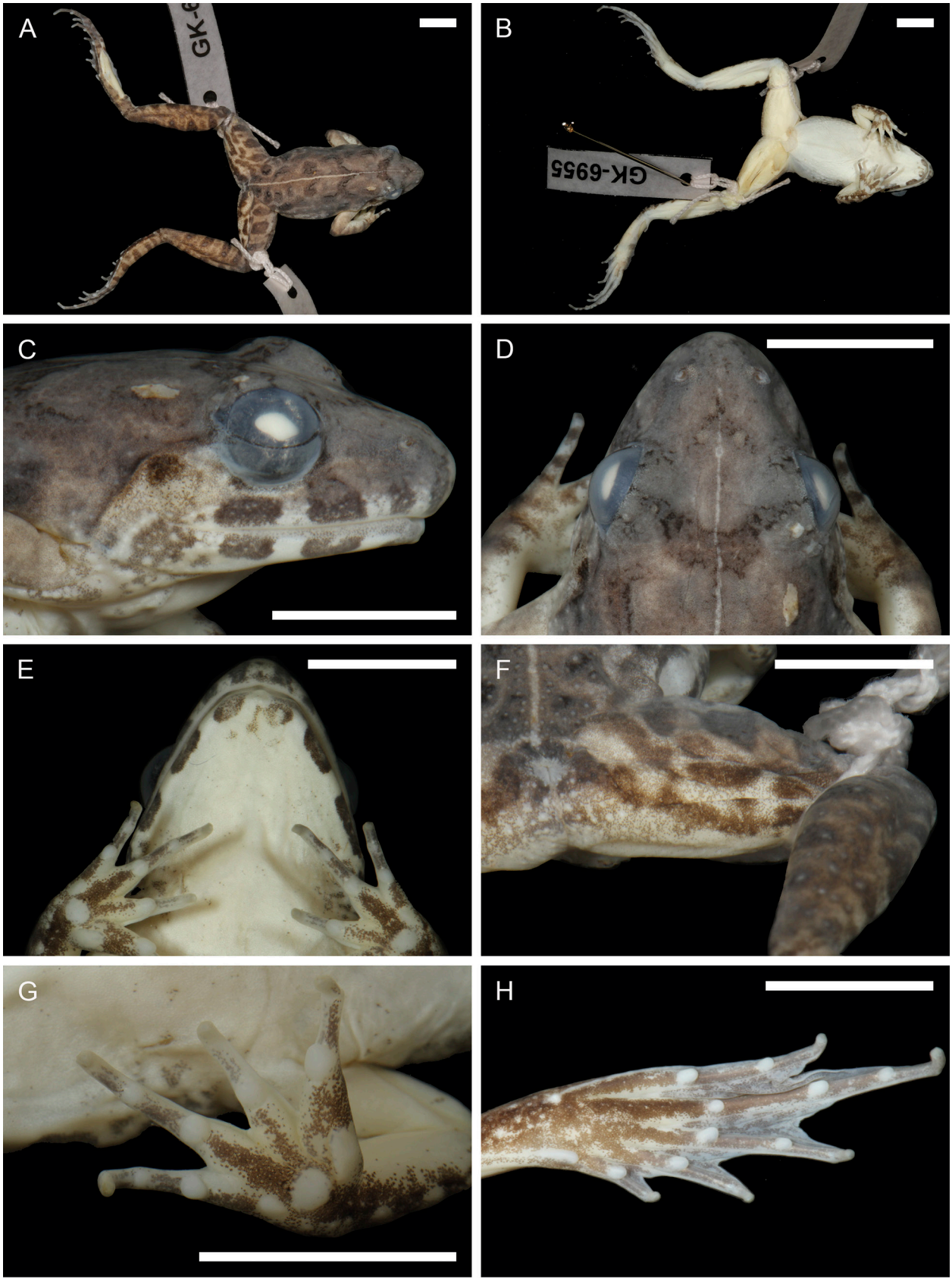


Fig. 15. Adult female of *Fejervarya chiangmaiensis* (SMF 103781). Scale bars equal 5.0 mm. Photos by G.K.

nected to posterior margin of eye and not bending down to shoulder; no dorsolateral fold. For variation in selected morphometric characters see Table 1.

Natural history notes. SUWANNAPOOM et al. (2016) provided a summary of the natural history of this species and also described its advertisement call.

Fig. 16. Adult female of *Fejervarya chiangmaiensis* (SMF 103781) in life. Photo by G.K.

Geographic Distribution and Conservation. As currently known, *Minervarya chiangmaiensis* is distributed disjunctly in Myanmar and western Thailand (Fig. 4) at elevations between near sea level and 1420 m asl. Given the little we know about this species, we classify *M. chiangmaiensis* as Data Deficient based on the IUCN Red List Categories and Criteria (IUCN 2012).

Minervarya muangkanensis (Suwannapoom, Yuan, Jiang, Yan, Gao, and Che, 2017)

Fejervarya muangkanensis Suwannapoom, Yuan, Jiang, Yan, Gao, and Che, 2017: 245. Holotype: KIZ 024627; type locality: "Ban Tha Khanun, Thong Pha Phum, Kanchanaburi Province, Thailand (N15°11'52.73", E98°19'29.71"; 712 m a.s.l.)."

Fejervarya sp. 'hp3': Kotaki *et al*., 2010; Mulcahy *et al*., 2018; Sanchez *et al*., 2018

Diagnosis. A species of the genus *Fejervarya* (sensu Sanchez *et al*., 2018) that differs from all congeners by the following combination of characters: (1) SVL 25.1–35.1 mm in males, 31.3–40.9 mm in females; (2) head longer than wide, ratio HL/HW 1.10–1.43, mean 1.22; ratio HW/SVL 0.26–0.35, mean 0.32; (3) a moderate-sized tympanum, discernible, ratio TYD/SVL 0.064–0.083, mean 0.073; (4) relatively short hind legs and feet (ratio SHL/SVL 0.49–0.58, mean 0.54; ratio FL/SVL 0.49–0.57, mean 0.53); (5) relative finger length III>0I>II=IV; (6) poorly developed toe webbing; webbing formula I 2–2.5 II 1.5–3 III 2–3.1 IV 3.8–1.1 V to I 1–2 II 1–2.3 III 1–2.6 IV 2.6–0.5 V; (7) pale vertebral line present or absent; (8) tubercles on dorsal and lateral head and body, and body flanks, short longitudinal ridges often present on dorsum.

For a comparison of *Minervarya muangkanensis* with its congeners see Suwannapoom *et al*. (2017). From the other species of *Fejervarya* and *Minervarya* currently recognized from Myanmar it differs as follows: From *Fejervarya kupitzi*, *F. limnocharis*, and *F. orissaensis* it differs by its smaller size (SVL 25.1–35.1 mm in males, 31.3–40.9 mm in females of *M. muangkanensis* versus >35 mm in adults of the three species of *Fejervarya*) and by having a only a short, indistinct glandular supratympanic fold above tympanum, not connected to posterior margin of eye and not bending down to shoulder (versus supratympanic fold distinct and running from posterior edge of upper eyelid along upper margin of tympanum and then obliquely down to shoulder in the three species of *Fejervarya*); from *M. chiangmaiensis* by having shorter feet (ratio FL/SVL 0.49–0.57, mean 0.53, in *M. muangkanensis* versus 0.55–0.60, mean 0.59, in *M. chiangmaiensis*) and by having an ill-defined inner metatarsal fold, on distal one-fourth of tarsus (versus inner metatarsal fold weak, on distal one-half of tarsus in *M. chiangmaiensis*).

Description (Figs. 17–18). Habitus robust; head longer than wide; snout subovoid to rounded in dorsal view, projecting beyond lower jaw, rounded in profile; nostril dorsolateral, closer to tip of snout than eye; canthus

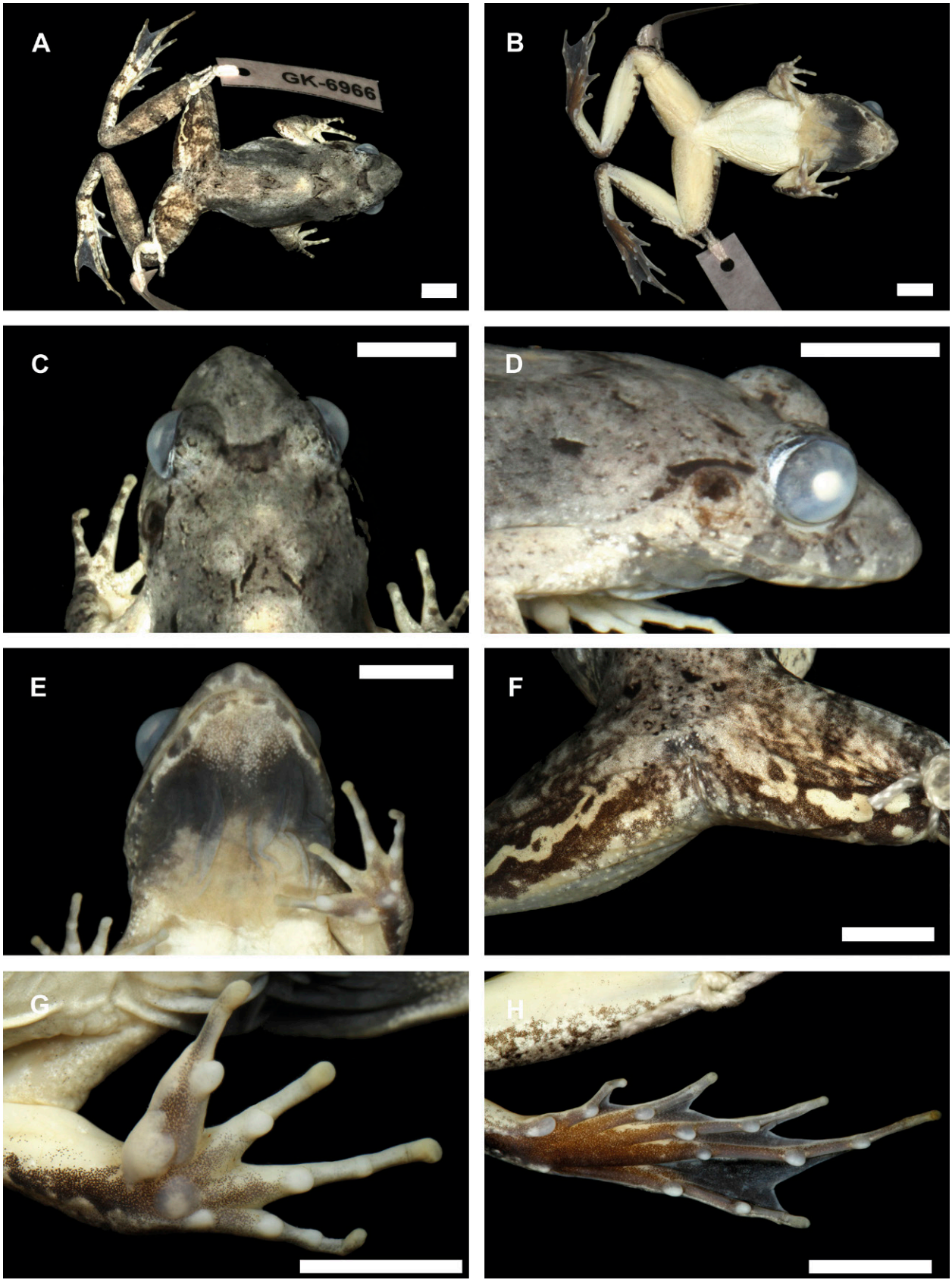


Fig. 17. Adult male of *Fejervarya muangkanensis* (SMF 103782). Scale bars equal 5.0 mm. Photos by G.K.

rounded, slightly constricted behind nostrils; lores concave and oblique; IOD less than or subequal the width of upper eyelid; pineal body visible; tympanic rim weakly elevated relative to tympanum; vomerine teeth on two oblique ridges, about equal in distance to each other as to choanae; median protuberance at tip of mandible;

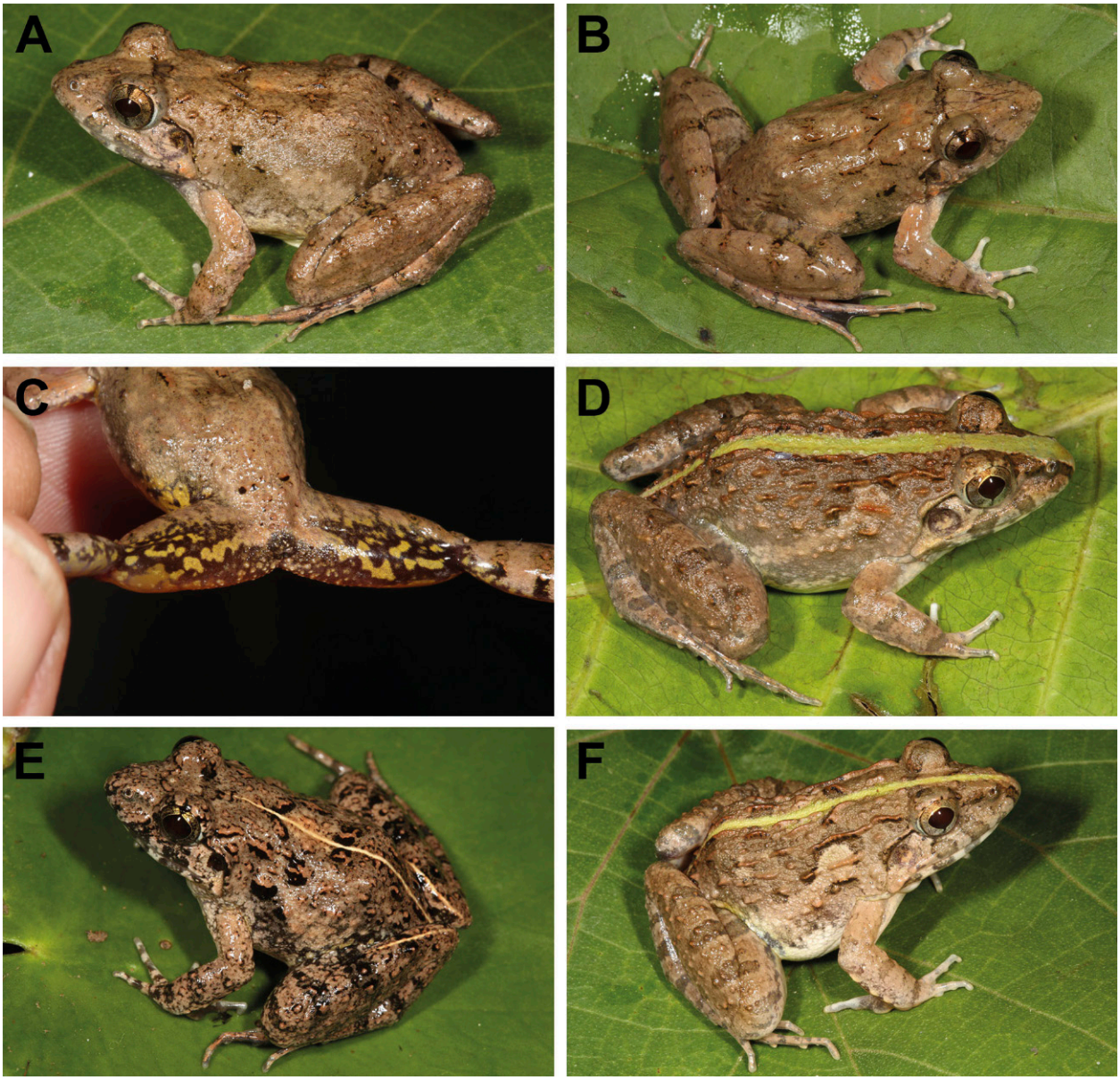


Fig. 18. *Fejervarya muangkanensis* in life. (A) SMF 103782; (B) SMF 103787; (C) SMF 103787; (D) SMF 105012; (E) SMF 104873; (F) SMF 103793. (E) is an adult female, (A–D, F) are adult males. Photos by G.K.

tongue notched; tips of all four fingers rounded, not expanded into discs; relative finger lengths III>I>II=IV; no webbing; distinct subarticular tubercles, palmar tubercle distinct, bifid or even separated as two distinct tubercles; thenar tubercle large, about twice the size of palmar tubercle; tips of toes rounded, not expanded into discs; relative toe lengths IV>III>V>II>I; webbing formula I 2–2.5 II 1.5–3 III 2–3.1 IV 3.8–1.1 V to I 1–2 II 1–2.3 III 1–2.6 IV 2.6–0.5 V; movable flap of skin on postaxial side of Toe V from level of outer metatarsal tubercle to distal subarticular tubercle; inner metatarsal fold ill-defined, on distal one-fourth of tarsus; elongate, oval inner metatarsal tubercle; small round outer metatarsal tubercle present; skin on top of head shagreen; skin on dorsum and flank usually granular with varying density of tubercles and often also with short longitudinal ridges; skin on side of head granular; skin on venter smooth; skin on upper surface of forelimbs smooth, except for a few low tubercles on upper arm, that of hind limbs granular; skin on anterior and posterior surface of thigh smooth; a short, indistinct glandular supratympanic fold above tympanum, not connected to posterior margin of eye and not bending down to shoulder; no dorsolateral fold. For variation in selected morphometric characters see Table 1.

Coloration in life of an adult male (SMF 103782) was recorded as follows: Dorsal ground color Raw Sienna (32) with an indistinct Dusky Brown (285) interorbital bar and Sepia (268) blotches at dorsal ridges; lip bars Vandyke Brown (282); posterior surface of thigh (282) with Salmon Color (83) blotches fused to an irregular line on left side; ventral surface of head Pale Buff (1); a Jet Black (300) butterfly-shape gular marking, edged with Vinaceous Pink (245); venter Cream White (52) with a pair of Brick Red (326) ventrolateral lines and with suf-

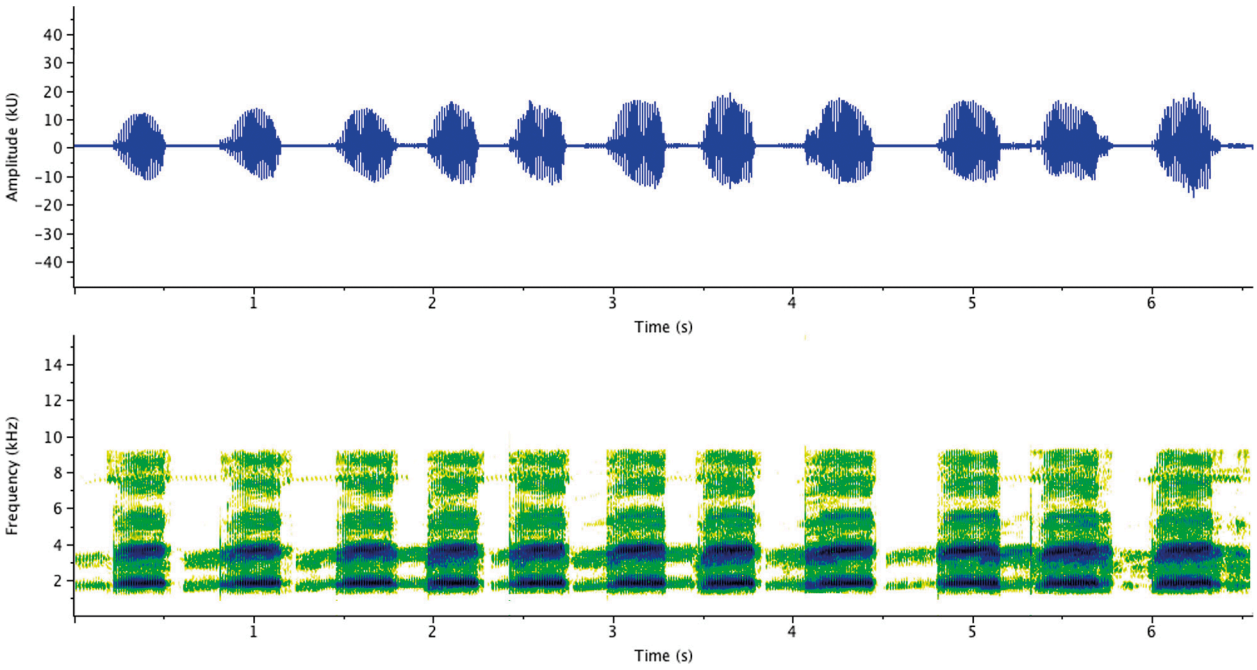


Fig. 19. Advertisement call of a male of *Fejervarya muangkanensis* (SMF 103782).

fusions of Warm Buff (4) in ventral inguinal region; ventral region of thigh Salmon Color (58); ventral surfaces of hands Vinaceous Pink (245) and ventral surfaces of feet Dark Carmine (61); iris Clay Color (18). Coloration in life of another adult male (SMF 103789) was recorded as follows: Dorsal ground color Glaucous (289) with suffusions of Pratt´s Rufous (72) on dorsum on head. For another adult male (SMF 103791), the dorsal ground color in life was recorded as Glaucous (289) with a suffusion of Drab (19) and a light bluff vertebral line. In life, all males were recorded to have had a dark area immediately posterior to the blackish butterfly-shaped marking on throat, a character mostly lost in preservative.

Advertisement call. The call of a male *Minervarya muangkanensis* (SMF 103782) was recorded in the field on 20 June 2018 (ambient temperature 23°C). The call consisted of a series of pulsed notes. Each of these notes lasted 0.330 ± 0.031 s and was composed of 19 – 25 pulses/call (average 22.1 ± 1.88). The note interval was 0.251 ± 0.072 s, the dominant frequency was 1824 ± 11.3 Hz, and the first harmonic was about 3764 ± 25.1 Hz (Fig. 19).

Natural history notes. In the area between Pathein and Nge Saung beach (Irawady, Myanmar), individuals of this species were collected at night in a patch of muddy grass area, partly covered with shallow flowing surface water. This rather open area is surrounded by bushes and low secondary forest in a hilly region. On 20 June 2018, numerous calling males were scattered across the grassy floor, often hiding in low vegetation but some calling individuals were sitting exposed without cover.

Geographic Distribution and Conservation. As currently known, *Minervarya muangkanensis* is distributed disjunctly in southern Myanmar and extreme western Thailand from 15 to 900 m asl (Fig. 4). Given the little we know about this species, we classify *M. muangkanensis* as Data Deficient based on the IUCN Red List Categories and Criteria (IUCN 2012).

Key to species of *Fejervarya* and *Minervarya* in Myanmar

1a Small species, SVL 24 – 35 mm in males, 26 – 41 mm in females; supratympanic fold indistinct, short, restricted to area above tympanum, not connected to posterior margin of eye and not bending down to shoulder; area immediately posterior to black butterfly-shaped marking dark in life in adult males (Fig. 20a) **2**

1b Larger species, SVL 37.8 – 51.4 mm in males, 41.1 – 60.0 mm in females; supratympanic fold distinct and running from posterior edge of upper eyelid along upper margin of tympanum and then obliquely down to shoulder; area immediately posterior to black butterfly-shaped marking pale in adult males (Fig. 20b) **3**

2a Inner metatarsal fold very short, on distal one-fourth of tarsus; ratio FL/SVL 0.49 – 0.57, mean 0.53; SVL 25.1 – 35.1 mm in males, 31.3 – 40.9 mm in females ***Minervarya muangkanensis***

2b Inner metatarsal fold longer, on distal one-half of tarsus; ratio FL/SVL 0.55 – 0.60, mean 0.59; SVL 26.3 – 29.1 mm in males, 24.7 – 32.8 mm in females ***Minervarya chiangmaiensis***

3a Head broad, usually at least as broad as long; snout rounded in dorsal view; SVL 44.2 – 49.2 mm in males, 51.2 – 63.6 mm in females ***Fejervarya kupitzi***

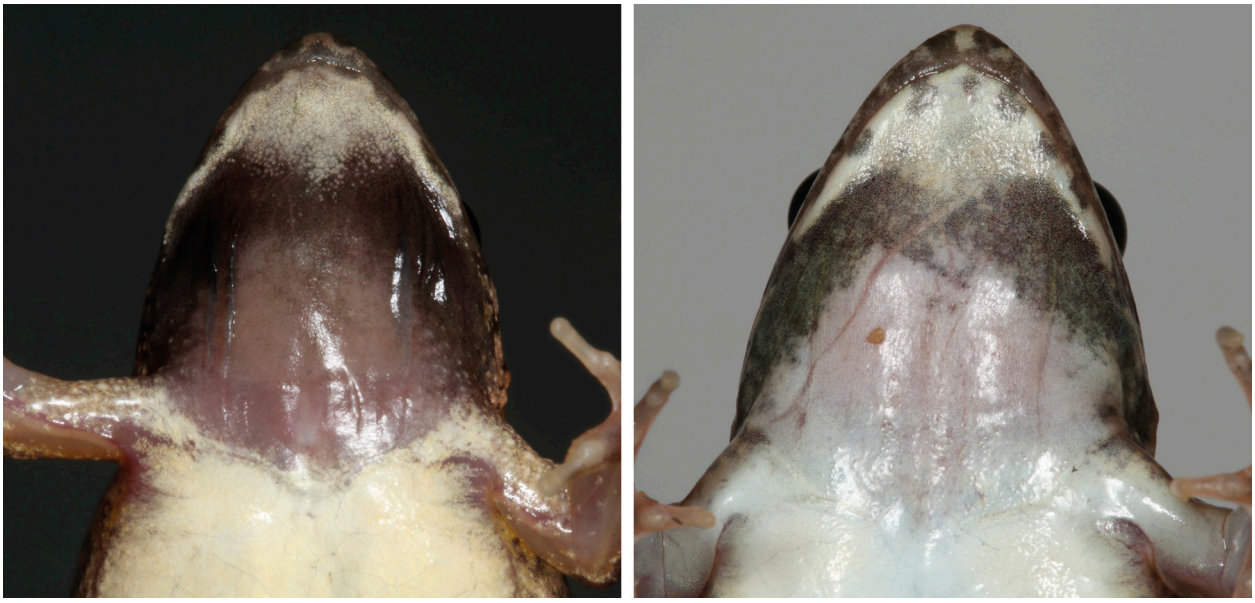


Fig. 20. Ventral view of head in (A) *Fejervarya muangkanensis* (SMF 103782); (B) *Fejervarya orissaensis* (SMF 103774). Photos by G.K.

3b Head more elongate, usually longer than broad; snout subelliptical in dorsal view; SVL variable **4**

4a Slightly less toe webbing with a portion of Phalanx III on medial side of Toe II free of webbing; shorter hind legs, ratio SHL/SVL 0.34–0.56, mean 0.48; SVL 34.7–46.2 mm in males, 38.0–56.6 mm in females; distributed in northern and eastern Myanmar ***Fejervarya limnocharis***

4b Slightly more toe webbing with only the two distal phalanges on medial side of Toe II free of webbing; longer hind legs, ratio SHL/SVL 0.47–0.64, mean 0.52; SVL 37.8–51.4 mm in males, 41.1–60.0 mm in females; distributed in western and central Myanmar ***Fejervarya orissaensis***

Discussion

During this study we encountered unexpected species diversity among the frogs of the genera *Fejervarya* and *Minervarya* of Myanmar, with five species in two genera. Whereas the two species of *Minervarya* are broadly sympatric and even have been collected syntopically (e.g., at Bago Yoma), the three species of *Fejervarya* show an allopatric or parapatric geographic distribution pattern. Most of western and central Myanmar represents the area of occurrence of *F. orissaensis*, whereas in the northern and eastern portions of the country it is replaced by *F. limnocharis*. The latter species is distributed over a vast geographic area across most of Southeast Asia with very little genetic divergence in the studied gene fragments. We interpret this pattern as evidence for a recent dispersal across this large area. Those Greater and Lesser Sunda islands as well as Borneo that lie on the Sunda Shelf, had been connected by dry land (Sundaland) when the sea levels were much lower during the last glacial maximum, 18,000 to 20,000 years ago (Bird *et al*., 2005; Raes *et al*., 2014). At that time, among other fauna and flora, terrestrial amphibians likely had continuous populations across this former land mass. On the other hand, the geographic range of *F. kupitzi* seems to be very restricted. Currently, it is only known for sure from Alaungdaw Kathapa National Park and from the Bago Yoma mountain range. Although it probably has a larger geographic distribution as currently understood, it is most likely endemic to central Myanmar.

The taxonomy of the *limnocharis*-like populations in East Asia (eastern China and Japan) need further evaluation. In our phylogenetic tree these populations are found in our *limnocharis*-clade. However, since these populations are outside of the geographic scope of the present work we do comment on their possible taxonomic status. Also, the taxonomic status of the populations we here refer to as *F. orissaensis* needs to be confirmed by further studies since there are several *Fejervarya* species of which no molecular genetic or bioacoustic data are available but for which we cannot rule out that they are conspecific with the species we here call *F. orissaensis* such as some taxa from Nepal (e.g., *Rana teraiensis* Dubois, 1984).

The genus *Minervarya* has a mostly South Asian distribution whereas *Fejervarya* includes species mostly distributed across Southeast Asia (Sanchez *et al*., 2018). Myanmar is effectively in the transition zone of both of these two zoogeographic realms. Therefore it is no surprise that this country supports populations of both genera. The *Fejervarya* species known to occur in Myanmar are those with the western-most geographic distribution of their genus, whereas the two *Minervarya* species of Myanmar occupy the easternmost areal of their genus.

In external morphology the five species of *Fejervarya* and *Minervarya* known to occur in Myanmar are very conservative, making it somewhat difficult to distinguish

them based on their respective phenotype. However, details of coloration (e.g., of the throat) and body size readily differentiate the two species of *Minervarya* from the species of *Fejervarya*. And whereas *F. kupitzi* can be diagnosed based on its broad head and relatively large tympanum, *F. limnocharis* and *F. orissaensis* are essentially cryptic in external appearance.

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Appendix 1

Specimens Examined

Fejervarya cancrivora — **Indonesia:** Bali: Sangsit: SMF 23458–60; Java: Buitenzorg: SMF 6430, 6433–34, 31265–67; Samarang: SMF 6409–10; Jawa Barat: Pulau Sanggiang: SMF 53796–97; Jawa Timur: Bawean: SMF 55320–21; Lampung: Pulau Sebesi: SMF 53798–99, 53800; Nusa Tenggara Barat: Dompoe: SMF 23474–76; Laboean Hadji, Lombok: SMF 23463–66; Mamben, Lombok: SMF 23461; Mount Rinjani, Sadjang, Lombok: SMF 6482; Narmada, Lombok: SMF 23487–89; Sadjang, Lombok: SMF 6456; Semongkat Atas: SMF 23473; Sumbawa Besar, Sunda Islands: SMF 23469–72; Sumbawa, Sunda Islands: SMF 6483–98; Swela, Lombok: SMF 23462; Udjung, Lombok: SMF 23467–68; Wawo: SMF 23477–80; Nusa Tenggara Timur: Flores, Sunda Islands: SMF 6426; Waingapoe, Soemba: SMF 23481–86; Sulawesi: Penango, Mengkoka: SMF 1847–48; Sulawesi Tenggara: Buton: SMF 6535; near Weltevreden: SMF 23456; Sumatra: Ranau: SMF 31264. **Singapur:** no further data: SMF 60914.

Fejervarya iskandari — **Indonesia:** Java: Chianjur: MNHN 1997.4916.

Fejervarya kupitzi — **Myanmar:** Bago: Bago Yoma: CAS 207989; Sagaing: Alaungdaw Kathapa National Park: CAS 208009, 208011, 208015, 210034, 210036, 210276–77, 210304, SMF 105717–18.

Fejervarya limnocharis — **China:** Hainan: Nodowha: SMF 5049; Hongkong: Hongkong: SMF 4935–36, 5050–58, 39609–10; Shanghai: Shanghai: SMF 4937–81, 39594–99, 39600–08; Yunnan: Liuku-Longling rd, ca 7 km S (by rd) of Liuku bridge: CAS 228129, 228131; Shanjiang village, just S of Liuku: CAS 215116–17. **Myanmar:** Chin: Kanpatlat Township, in Kanpatlat town: CAS 234814–15; Kanpatlat Township, Let Mon Village: CAS 235276; Kachin: Bhamo: MNHN 1893.452–53; Myitkyina Township, Pidaung Wildlife Sanctuary, near Ma-Li-Hka Village: CAS 230367; Nagmung Township, W of Hton Hlar Village: CAS 224710, 224716; Kayin: Carin Mountains: MNHN 1893.450–51; Shan: Kyaitone Township, Gy Phyu village: CAS 235484–85. **Thailand:** Krung Thep Mahanakhon (Bangkok): Bangkok: SMF 5070–71; Mae Hong Son: Pangmapha, Ban Soppong: SMF 104126–28; Pangmapha, near Ban Nam Rin: SMF 104131, 104136; ridge north of viewpoint between Pangmapha and Pai: 105119–20; Pangmapha district, at NamLang River: SMF 105121; Nakhon Sawan: 25 km west of Nakhon Sawann, Lat Yao: SMF 82922–26.

Fejervarya moodiei — **Philippines:** Masbate: Panal: SMF 74338–39; Mindoro Oriental: Calapan, Mindoro: SMF 6412–25, 9962, 16208, 16374; Palawan: Central Culion, Calamianes: SMF 6452–53; Tarusan: SMF 74401–11; Tumarbong: SMF 74412–13; Samar: Gandera: SMF 74414; Sulu: near Siasi (City), Siasi Island: SMF 74877.

Fejervarya orissaensis — **India:** Orissa: Jagatsinghpur Town area: MNHN 2003.113; Takatpur: MNHN 2003.112, 2003.1121–22. **Myanmar:** Bago: Bago Yoma: CAS 208180; Bago, near International Airport: SMF 105093–94; Elephant Camp, ca. 50 km airline NNW Taungoo: SMF 103851, 104109–25, 104735, 104870–71; Irawady: near Kan Ywa: SMF 103779, 103784; near Kyanigan: SMF 103783; near Pathein: SMF 103778; near Pathein on the road to Chaung Thar: SMF 103775–76; on road from Pathein to Kan Ywa: SMF 103785–86; on road from Pathein to Thanlyetsun: SMF 103780; Magwe: Mimbu (Sagu) Township, Shwesettaw Wildlife Sanctuary: CAS 213602, 213608; Mandalay: W of Yamethin: CAS 210569; Mawlamyine: Nwar La Pot Temple, Paung Township: SMF 103241–42, 103830; Rakhaing: Ngapali, Dam Lake: SMF 104098, 104101–07; Ngapali, Pleasant View Resort: SMF 104093–99, 104100; Sagaing: Alaungdaw Kathapa National Park Headquarters (outside park), grounds surrounding headquarters: CAS 208013 ; Yangon: Bumi Nethan Restaurant, Kawhmu Township: SMF 103774, 103777; East Yangon University: SMF 104092, 105095; Mingalardon Township, Hlawga Wildlife Park: CAS 213586; Kungyungon, near Taw Hlan village: SMF 103832–33, 104980; Yangon, Highland Lodge: CAS 208003.

Fejervarya verruculosa — **Indonesia:** Maluku Utara: Wetar, Iliwaki: SMF 6539–47.

Fejervarya vittigera — **Philippines:** Cebu Island: Cebu City: SMF 6450–51; Manila: Manila: SMF 6367–90; Quirino: Sierra Madre:

SMF 74646; Sulu: pond by Tarawakan, Tawi Tawi Island: SMF 75181–82; Zamboanga del Norte: Mutia: SMF 74706–07.

Minervarya chiangmaiensis — **Myanmar:** Chin: Kanpatlat Township, Let Mon Village: CAS 235277; Mindat Township, Hteen Chaung stream: CAS 234934–35; Ayeyarwady: near Pathein on the road to Chaung Thar: SMF 103781; Kachin: Myitkyina Township, Pidaung Wildlife Sanctuary, near Ma-Li-Hka Village: CAS 230370.

Minervarya greenii — **Sri Lanka:** Central: Nuwara Ellija: SMF 5017–21.

Minervarya muangkanensis — **Myanmar:** Ayeyarwady: near Kyanigan: SMF 103782; near Mwe Hauk Village: CAS 208016, 208033; on road from Kan Ywa to Negwesaung: SMF 103787–91, 105012–13; Rakhaing: Ngapali, Dam Lake: SMF 104873.

Minervarya nepalensis — **Nepal:** Center: Godavari: MNHN 1975. 1606.

Minervarya pierrei — **Nepal:** Eastern: Belbari: MNHN 1975. 1739–44; Birtamode: MNHN 1975.1680; Sukhani: MNHN 1975. 1711–14.

Minervarya syhadrensis — **Nepal:** Western: Patisango Khola: MNHN 1996.9048–52, 1996.9054–55. **Pakistan:** Sindh: Mirpur Sakro: SMF 64215; Sonda: SMF 47772.

Appendix 2

GenBank accession numbers of specimens included in molecular analyses

Species	voucher / Lab number	16S	12S
Fejervarya cancrivora	LAB_160	AF346810	
Fejervarya cancrivora	LAB_176	EU435281	
Fejervarya cancrivora	LAB_177	EU435283	
Fejervarya cancrivora	LAB_178	EU435302	
Fejervarya cancrivora	LAB_179	EU435303	
Fejervarya cancrivora	LAB_206	KR816724	
Fejervarya cancrivora	LAB_207	KR816727	
Fejervarya cancrivora	LAB_231	KT972728	
Fejervarya cancrivora	LAB_235	KX055955	
Fejervarya iskandari	LAB_009	AB277303	AB277287
Fejervarya iskandari	LAB_151	AB570268	
Fejervarya iskandari	LAB_152	AB570269	
Fejervarya iskandari	LAB_153	AB570270	
Fejervarya iskandari	LAB_154	AB570271	
Fejervarya iskandari	LAB_164	AJ292016	
Fejervarya iskandari	LAB_165	AJ292017	
Fejervarya iskandari	LAB_166	AJ292018	
Fejervarya kupitzi	CAS 208011	MK958580	MK958593
Fejervarya kupitzi	CAS 208015	MK958581	MK958594
Fejervarya kupitzi	CAS 210034	MK958582	MK958595
Fejervarya kupitzi	SMF 105717	MK958583	MK958596
Fejervarya kupitzi	CAS 210036	MK958584	
Fejervarya kupitzi	CAS 210304	MK958585	MK958597
Fejervarya kupitzi	CAS 207989	MK621448	MK621381
Fejervarya kupitzi	SMF 105718	MK621449	MK621382
Fejervarya kupitzi	CAS 208009	MK621450	MK621383
Fejervarya kupitzi	CAS 210276	MK621451	MK621384
Fejervarya limnocharis	CAS 230367	MK958571	MK958590
Fejervarya limnocharis	CAS 234814	MK958572	MK958591
Fejervarya limnocharis	CAS 234815	MK958573	
Fejervarya limnocharis	CAS 215116	MK621388	MK621338
Fejervarya limnocharis	CAS 215117	MK621389	MK621339
Fejervarya limnocharis	CAS 224710	MK621390	MK621340
Fejervarya limnocharis	CAS 224716	MK621391	MK621341
Fejervarya limnocharis	CAS 228129	MK621392	MK621342
Fejervarya limnocharis	CAS 228131	MK621393	MK621343

Appendix 2 continued.

Species	voucher / Lab number	16S	12S
Fejervarya limnocharis	CAS 235276	MK621394	MK621344
Fejervarya limnocharis	CAS 235484	MK621395	MK621345
Fejervarya limnocharis	CAS 235485	MK621396	MK621346
Fejervarya limnocharis	LAB_001	AB277292	AB277278
Fejervarya limnocharis	LAB_012	AB488886	AB488863
Fejervarya limnocharis	LAB_013	AB488887	AB488864
Fejervarya limnocharis	LAB_027	AB488884	AB488861
Fejervarya limnocharis	LAB_044	AB277302	AB277286
Fejervarya limnocharis	LAB_046	AB277301	
Fejervarya limnocharis	LAB_053	AB488885	
Fejervarya limnocharis	LAB_073	AB070736	AB070728
Fejervarya limnocharis	LAB_092	AF206462	AF206081
Fejervarya limnocharis	LAB_093	AF206466	AF206085
Fejervarya limnocharis	LAB_095	AY843588	AY843588
Fejervarya limnocharis	LAB_096	DQ458253	DQ458239
Fejervarya limnocharis	LAB_099	EU979847	EU979787
Fejervarya limnocharis	LAB_100	EU979848	EU979788
Fejervarya limnocharis	LAB_108	AB070732	
Fejervarya limnocharis	LAB_109	AB070733	
Fejervarya limnocharis	LAB_110	AB070734	
Fejervarya limnocharis	LAB_111	AB070735	
Fejervarya limnocharis	LAB_112	AB070737	
Fejervarya limnocharis	LAB_114	AB162445	
Fejervarya limnocharis	LAB_116	AB277293	
Fejervarya limnocharis	LAB_117	AB277294	
Fejervarya limnocharis	LAB_118	AB277295	
Fejervarya limnocharis	LAB_119	AB277296	
Fejervarya limnocharis	LAB_120	AB277297	
Fejervarya limnocharis	LAB_121	AB277298	
Fejervarya limnocharis	LAB_121	AB277298	
Fejervarya limnocharis	LAB_122	AB296097	
Fejervarya limnocharis	LAB_123	AB296098	
Fejervarya limnocharis	LAB_124	AB296099	
Fejervarya limnocharis	LAB_125	AB296100	
Fejervarya limnocharis	LAB_126	AB296101	
Fejervarya limnocharis	LAB_127	AB354237	
Fejervarya limnocharis	LAB_128	AB354238	
Fejervarya limnocharis	LAB_129	AB354239	
Fejervarya limnocharis	LAB_130	AB354240	
Fejervarya limnocharis	LAB_131	AB354241	
Fejervarya limnocharis	LAB_132	AB354242	
Fejervarya limnocharis	LAB_141	AB530611	
Fejervarya limnocharis	LAB_142	AB530612	
Fejervarya limnocharis	LAB_143	AB530625	
Fejervarya limnocharis	LAB_145	AB570262	
Fejervarya limnocharis	LAB_146	AB570263	
Fejervarya limnocharis	LAB_147	AB570264	
Fejervarya limnocharis	LAB_148	AB570265	
Fejervarya limnocharis	LAB_149	AB570266	
Fejervarya limnocharis	LAB_150	AB570267	
Fejervarya limnocharis	LAB_157	AF215416	
Fejervarya limnocharis	LAB_158	AF261262	
Fejervarya limnocharis	LAB_159	AF285212	
Fejervarya limnocharis	LAB_161	AF346811	
Fejervarya limnocharis	LAB_162	AJ292014	
Fejervarya limnocharis	LAB_163	AJ292015	

Appendix 2 continued.

Species	voucher / Lab number	16S	12S
Fejervarya limnocharis	LAB_167	AJ292019	
Fejervarya limnocharis	LAB_168	AJ292020	
Fejervarya limnocharis	LAB_169	AJ292021	
Fejervarya limnocharis	LAB_180	EU604200	
Fejervarya limnocharis	LAB_181	EU604201	
Fejervarya limnocharis	LAB_182	EU604202	
Fejervarya limnocharis	LAB_186	GU934327	
Fejervarya limnocharis	LAB_187	HQ226055	
Fejervarya limnocharis	LAB_188	HQ226056	
Fejervarya limnocharis	LAB_189	HQ226057	
Fejervarya limnocharis	LAB_190	HQ226058	
Fejervarya limnocharis	LAB_191	HQ226059	
Fejervarya limnocharis	LAB_192	HQ226060	
Fejervarya limnocharis	LAB_193	HQ226061	
Fejervarya limnocharis	LAB_194	HQ226062	
Fejervarya limnocharis	LAB_195	HQ226063	
Fejervarya limnocharis	LAB_196	HQ226064	
Fejervarya limnocharis	LAB_197	HQ226065	
Fejervarya limnocharis	LAB_198	HQ226066	
Fejervarya limnocharis	LAB_199	HQ226067	
Fejervarya limnocharis	LAB_201	JQ621940	
Fejervarya limnocharis	LAB_208	KR827738	
Fejervarya limnocharis	LAB_209	KR827739	
Fejervarya limnocharis	LAB_211	KR827741	
Fejervarya limnocharis	LAB_212	KR827742	
Fejervarya limnocharis	LAB_213	KR827743	
Fejervarya limnocharis	LAB_214	KR827744	
Fejervarya limnocharis	LAB_215	KR827745	
Fejervarya limnocharis	LAB_216	KR827746	
Fejervarya limnocharis	LAB_217	KR827747	
Fejervarya limnocharis	LAB_218	KR827748	
Fejervarya limnocharis	LAB_219	KR827749	
Fejervarya limnocharis	LAB_220	KR827750	
Fejervarya limnocharis	LAB_221	KR827751	
Fejervarya limnocharis	LAB_222	KR827752	
Fejervarya limnocharis	LAB_223	KR827753	
Fejervarya limnocharis	LAB_224	KR827754	
Fejervarya limnocharis	LAB_225	KR827755	
Fejervarya limnocharis	LAB_232	KU840566	
Fejervarya limnocharis	LAB_233	KU840567	
Fejervarya limnocharis	LAB_234	KU840568	
Fejervarya limnocharis	LAB_242	U55272	
Fejervarya limnocharis	SMF 105119	MK958574	
Fejervarya limnocharis	SMF 105120	MK958575	MK958592
Fejervarya limnocharis	SMF 105121	MK958576	
Fejervarya limnocharis	SMF 104126	MK621397	MK621347
Fejervarya limnocharis	SMF 104127	MK621398	MK621348
Fejervarya limnocharis	SMF 104128	MK621399	MK621349
Fejervarya limnocharis	SMF 104131	MK621400	MK621350
Fejervarya limnocharis	SMF 104136	MK621401	MK621351
Fejervarya moodiei	LAB_090	AB530508	AB372082
Fejervarya moodiei	LAB_144	AB543602	
Fejervarya moodiei	LAB_172	AY841754	
Fejervarya moodiei	LAB_236	KX055956	
Fejervarya orissaensis	CAS 208003	MK621411	MK621352
Fejervarya orissaensis	CAS 208180	MK621412	MK621353

Appendix 2 continued.

Species	voucher / Lab number	16S	12S
Fejervarya orissaensis	CAS 210569	MK621413	MK621354
Fejervarya orissaensis	CAS 213586	MK621414	MK621355
Fejervarya orissaensis	CAS 213602	MK621415	MK621356
Fejervarya orissaensis	CAS 213608	MK621416	MK621357
Fejervarya orissaensis	LAB_005	AB277299	AB277281
Fejervarya orissaensis	LAB_010	AB277304	AB277288
Fejervarya orissaensis	LAB_039	AB372009	AB372019
Fejervarya orissaensis	LAB_113	AB162444	
Fejervarya orissaensis	LAB_173	AY882957	
Fejervarya orissaensis	LAB_174	AY882958	
Fejervarya orissaensis	LAB_226	KR827756	
Fejervarya orissaensis	LAB_227	KR827760	
Fejervarya orissaensis	LAB_228	KR827761	
Fejervarya orissaensis	LAB_246	MG935769	
Fejervarya orissaensis	LAB_248	MG935771	
Fejervarya orissaensis	LAB_249	MG935772	
Fejervarya orissaensis	LAB_250	MG935773	
Fejervarya orissaensis	LAB_252	MG935775	
Fejervarya orissaensis	LAB_253	MG935776	
Fejervarya orissaensis	LAB_254	MG935777	
Fejervarya orissaensis	LAB_263	MG935786	
Fejervarya orissaensis	LAB_264	MG935787	
Fejervarya orissaensis	LAB_265	MG935788	
Fejervarya orissaensis	LAB_266	MG935789	
Fejervarya orissaensis	LAB_267	MG935790	
Fejervarya orissaensis	LAB_268	MG935791	
Fejervarya orissaensis	LAB_269	MG935792	
Fejervarya orissaensis	LAB_270	MG935793	
Fejervarya orissaensis	LAB_271	MG935794	
Fejervarya orissaensis	LAB_272	MG935795	
Fejervarya orissaensis	LAB_273	MG935796	
Fejervarya orissaensis	LAB_274	MG935797	
Fejervarya orissaensis	LAB_275	MG935798	
Fejervarya orissaensis	LAB_276	MG935799	
Fejervarya orissaensis	LAB_277	MG935800	
Fejervarya orissaensis	LAB_278	MG935801	
Fejervarya orissaensis	LAB_279	MG935802	
Fejervarya orissaensis	LAB_280	MG935803	
Fejervarya orissaensis	LAB_281	MG935804	
Fejervarya orissaensis	LAB_282	MG935805	
Fejervarya orissaensis	LAB_283	MG935806	
Fejervarya orissaensis	LAB_284	MG935807	
Fejervarya orissaensis	LAB_285	MG935808	
Fejervarya orissaensis	LAB_286	MG935809	
Fejervarya orissaensis	LAB_287	AB372009	
Fejervarya orissaensis	LAB_288	AB372010	
Fejervarya orissaensis	LAB_297	AB530504	
Fejervarya orissaensis	LAB_298	AB530505	
Fejervarya orissaensis	LAB_299	AB530506	
Fejervarya orissaensis	LAB_300	AB530507	
Fejervarya orissaensis	SMF 104735	MK958577	
Fejervarya orissaensis	SMF 104870	MK958578	
Fejervarya orissaensis	SMF 104871	MK958579	
Fejervarya orissaensis	SMF 103774	MK621417	MK621358
Fejervarya orissaensis	SMF 103775	MK621418	MK621359
Fejervarya orissaensis	SMF 103776	MK621419	MK621360

Appendix 2 continued.

Species	voucher / Lab number	16S	12S
Fejervarya orissaensis	SMF 103777	MK621420	MK621361
Fejervarya orissaensis	SMF 103779	MK621421	MK621362
Fejervarya orissaensis	SMF 103783	MK621422	MK621363
Fejervarya orissaensis	SMF 103784	MK621423	MK621364
Fejervarya orissaensis	SMF 103785	MK621424	MK621365
Fejervarya orissaensis	SMF 103830	MK621425	MK621366
Fejervarya orissaensis	SMF 103832	MK621426	
Fejervarya orissaensis	SMF 103833	MK621427	MK621367
Fejervarya orissaensis	SMF 104092	MK621428	MK621368
Fejervarya orissaensis	SMF 104094	MK621429	MK621369
Fejervarya orissaensis	SMF 104095	MK621430	MK621370
Fejervarya orissaensis	SMF 104101	MK621431	MK621371
Fejervarya orissaensis	SMF 104115	MK621432	
Fejervarya orissaensis	SMF 104117	MK621433	MK621372
Fejervarya orissaensis	SMF 104118	MK621434	
Fejervarya orissaensis	SMF 104120	MK621435	
Fejervarya orissaensis	SMF 105093	MK621436	
Fejervarya orissaensis	SMF 105094	MK621437	MK621373
Fejervarya orissaensis	SMF 105095	MK621438	MK621374
Fejervarya triora	LAB_011	AB488883	AB488860
Fejervarya triora	LAB_306	DQ860094	
Fejervarya triora	LAB_307	DQ860095	
Hoplobatrachus tigerinus		AB488902	AB488879
Minervarya andamanensis	LAB_030	AB488889	AB488866
Minervarya asmati	LAB_024	AB488900	AB488877
Minervarya asmati	LAB_102	KP849815	KP849820
Minervarya caperata	LAB_018	AB488894	AB488871
Minervarya caperata	LAB_086	AB355842	AB355829
Minervarya caperata	LAB_087	AB355843	AB355830
Minervarya caperata	LAB_088	AB355844	AB355831
Minervarya caperata	LAB_089	AB355845	AB355832
Minervarya caperata	LAB_139	AB530606	
Minervarya cepfi	LAB_034	KY447309	
Minervarya cepfi	LAB_063	KY447311	
Minervarya cepfi	LAB_239	KY447308	
Minervarya cepfi	LAB_240	KY447310	
Minervarya chiangmaiensis	CAS 230370	MK958567	MK958586
Minervarya chiangmaiensis	CAS 234934	MK958568	MK958587
Minervarya chiangmaiensis	CAS 235277	MK958569	MK958588
Minervarya chiangmaiensis	CAS 230370	MK621385	MK621335
Minervarya chiangmaiensis	CAS 235277	MK621386	MK621336
Minervarya chiangmaiensis	LAB_237	KX834135	
Minervarya chiangmaiensis	LAB_238	KX834136	
Minervarya chiangmaiensis	LAB_244	MG935767	
Minervarya chiangmaiensis	LAB_245	MG935768	
Minervarya chiangmaiensis	LAB_247	MG935770	
Minervarya chiangmaiensis	LAB_251	MG935774	
Minervarya chiangmaiensis	LAB_255	MG935778	
Minervarya chiangmaiensis	LAB_256	MG935779	
Minervarya chiangmaiensis	LAB_257	MG935780	
Minervarya chiangmaiensis	LAB_258	MG935781	
Minervarya chiangmaiensis	LAB_259	MG935782	
Minervarya chiangmaiensis	LAB_260	MG935783	
Minervarya chiangmaiensis	LAB_261	MG935784	
Minervarya chiangmaiensis	LAB_262	MG935785	
Minervarya chiangmaiensis	SMF 103781	MK958570	

Appendix 2 continued.

Species	voucher / Lab number	16S	12S
Minervarya chiangmaiensis	SMF 103781	MK621387	MK958589
Minervarya dhaka	LAB_040	AB372011	AB372077
Minervarya dhaka	LAB_104	KP849818	KP849822
Minervarya dhaka	LAB_105	KP849817	KP849823
Minervarya dhaka	LAB_106	KP849819	KP849824
Minervarya dhaka	LAB_289	AB372011	
Minervarya dhaka	LAB_304	AB530511	
Minervarya gomantaki	LAB_202	KR781084	
Minervarya gomantaki	LAB_203	KR781085	
Minervarya gomantaki	LAB_204	KR781086	
Minervarya gomantaki	LAB_205	KR781087	
Minervarya greenii	LAB_016	AB488891	AB488868
Minervarya greenii	LAB_170	AY014378	
Minervarya kadar	LAB_035	KY447312	
Minervarya keralensis	LAB_062	GQ478322	GQ478318
Minervarya keralensis	LAB_101	JX573181	JX573190
Minervarya kirtisinghei	LAB_015	AB488890	AB488867
Minervarya kirtisinghei	LAB_171	AY014380	
Minervarya kudremukhensis	LAB_022	AB488898	AB488875
Minervarya kudremukhensis	LAB_084	AB355840	AB355827
Minervarya kudremukhensis	LAB_085	AB355841	AB355828
Minervarya kudremukhensis	LAB_136	AB530603	
Minervarya kudremukhensis	LAB_184	GQ478323	
Minervarya manoharani	LAB_036	KY447315	
Minervarya manoharani	LAB_064	KY447316	
Minervarya manoharani	LAB_065	KY447313	
Minervarya muangkanensis	CAS 208016	MK621439	MK621375
Minervarya muangkanensis	CAS 208033	MK621440	MK621376
Minervarya muangkanensis	SMF 103782	MK621441	
Minervarya muangkanensis	SMF 103787	MK621442	
Minervarya muangkanensis	SMF 103788	MK621443	
Minervarya muangkanensis	SMF 103790	MK621444	MK621377
Minervarya muangkanensis	SMF 104873	MK621445	MK621378
Minervarya muangkanensis	SMF 105012	MK621446	MK621379
Minervarya muangkanensis	SMF 105013	MK621447	MK621380
Minervarya muangkanesis	LAB_006	AB277300	AB277284
Minervarya muangkanesis	LAB_313	MF166918	
Minervarya mudduraja	LAB_020	AB488896	AB488873
Minervarya mudduraja	LAB_071	GQ478324	
Minervarya mudduraja	LAB_076	AB167946	AB167918
Minervarya mudduraja	LAB_077	AB355833	AB355820
Minervarya mudduraja	LAB_078	AB355834	AB355821
Minervarya mudduraja	LAB_079	AB355835	AB355822
Minervarya mudduraja	LAB_140	AB530607	
Minervarya neilcoxi	LAB_037	KY447317	
Minervarya neilcoxi	LAB_066	KY447318	
Minervarya rufescens	LAB_038	KY447321	
Minervarya rufescens	LAB_067	KY447320	
Minervarya rufescens	LAB_068	KY447323	
Minervarya rufescens	LAB_069	KY447322	
Minervarya rufescens	LAB_075	AB167945	AB167917
Minervarya rufescens	LAB_133	AB488897	
Minervarya rufescens	LAB_134	AB530601	
Minervarya rufescens	LAB_135	AB530602	
Minervarya rufescens	LAB_185	GU136103	
Minervarya rufescens	LAB_200	JF832393	

Appendix 2 continued.

Species	voucher / Lab number	16S	12S
Minervarya rufescens	LAB_241	KY447319	
Minervarya sahyadris	LAB_017	AB488893	AB488870
Minervarya sahyadris	LAB_137	AB530604	
Minervarya sahyadris	LAB_138	AB530605	
Minervarya synhadrensis	LAB_014	AB488888	AB488865
Minervarya synhadrensis	LAB_019	AB488895	AB488872
Minervarya synhadrensis	LAB_029	AB488892	AB488869
Minervarya synhadrensis	LAB_041	AB372012	AB372080
Minervarya synhadrensis	LAB_042	AB372016	AB372079
Minervarya synhadrensis	LAB_070	KY820766	
Minervarya synhadrensis	LAB_080	AB355836	AB355823
Minervarya synhadrensis	LAB_081	AB355837	AB355824
Minervarya synhadrensis	LAB_082	AB355838	AB355825
Minervarya synhadrensis	LAB_083	AB355839	AB355826
Minervarya synhadrensis	LAB_103	KP849816	KP849821
Minervarya synhadrensis	LAB_115	AB162446	
Minervarya synhadrensis	LAB_183	GQ478321	
Minervarya synhadrensis	LAB_229	KR995134	
Minervarya synhadrensis	LAB_290	AB372012	
Minervarya synhadrensis	LAB_291	AB372013	
Minervarya synhadrensis	LAB_292	AB372014	
Minervarya synhadrensis	LAB_293	AB372015	
Minervarya synhadrensis	LAB_294	AB372016	
Minervarya synhadrensis	LAB_295	AB372017	
Minervarya synhadrensis	LAB_302	AB530509	
Minervarya synhadrensis	LAB_303	AB530510	
Minervarya verruculosa	LAB_155	AB606420	
Minervarya verruculosa	LAB_156	AB606421	
Occidozyga lima		AB488903	AB488880
sp1	LAB_023	AB488899	AB488876
Sphaerotheca dobsonii		AB277305	AB277290

Appendix 3

Raw morphometric data of specimens included in the present study. For abbreviations see text.

Nr.	Species	Sex	SVL	SHL	FL	HW	IOD	IND	HL	TYD	EYD	NED
CAS 208016	*chiangmaiensis*	female	32.81	19.10	19.77	10.10	2.43	2.36	13.15	2.50	3.84	2.81
CAS 208033	*chiangmaiensis*	female	27.38	16.50	16.13	8.70	2.19	1.99	10.61	2.00	3.43	1.69
SMF 103781	*chiangmaiensis*	female	24.70	14.10	14.70	7.50	2.10	2.15	9.10	1.35	3.10	2.20
CAS 234934	*chiangmaiensis*	female	17.74	9.10	9.70	5.60	1.28	1.27	7.10	1.25	2.70	1.09
CAS 234935	*chiangmaiensis*	female	25.81	14.10	15.37	8.10	2.64	1.33	9.57	1.39	2.76	1.77
CAS 207989	*kupitzi*	female	54.95	30.70	28.74	18.10	3.50	3.08	20.84	5.07	7.21	4.12
CAS 210276	*kupitzi*	female	62.39	30.20	28.25	20.60	3.30	3.17	22.16	5.70	8.78	4.28
CAS 210277	*kupitzi*	female	58.59	29.10	27.04	20.90	2.79	3.02	21.08	4.46	7.22	4.22
CAS 208015	*kupitzi*	female	51.20	27.30	25.75	20.50	3.58	3.27	20.13	4.26	5.86	4.04
CAS 210304	*kupitzi*	female	53.82	29.00	28.40	23.00	4.69	3.38	21.05	4.48	5.70	3.89
CAS 208013	*kupitzi*	female	59.95	31.00	30.18	22.20	3.90	3.63	22.17	4.21	5.64	4.32
SMF 105717	*kupitzi*	female	63.57	30.50	29.52	24.20	4.40	4.20	23.89	5.13	6.35	4.35
CAS 210036	*kupitzi*	female	56.92	30.50	25.43	23.00	4.17	4.43	22.97	5.40	6.30	4.10

Appendix 3 continued.

Nr.	Species	Sex	SVL	SHL	FL	HW	IOD	IND	HL	TYD	EYD	NED
CAS 208011	*kupitzi*	female	55.59	30.00	28.48	21.60	2.80	2.94	21.11	4.54	6.24	3.97
CAS 208009	*kupitzi*	male	44.21	22.80	23.19	16.00	1.94	2.25	16.45	3.99	5.99	3.36
SMF 105718	*kupitzi*	male	46.07	24.00	23.30	16.60	2.89	2.64	17.00	3.44	6.24	3.37
CAS 210034	*kupitzi*	male	49.16	24.70	24.92	19.00	3.59	3.12	20.45	4.25	5.92	3.85
CAS 235484	*limnocharis*	female	43.16	22.10	23.50	14.10	3.08	2.25	16.46	3.56	5.46	2.96
CAS 228131	*limnocharis*	female	54.28	26.20	25.19	18.00	3.40	3.59	20.50	4.58	5.76	4.18
CAS 215116	*limnocharis*	female	56.57	28.50	27.30	19.10	3.78	3.11	21.55	4.21	6.07	4.15
CAS 215117	*limnocharis*	female	52.37	26.20	25.38	16.60	3.78	3.24	19.70	3.79	5.53	3.65
CAS 228129	*limnocharis*	female	45.94	25.00	25.90	14.00	2.84	2.77	18.28	3.19	4.87	3.58
CAS 235485	*limnocharis*	female	49.42	26.00	26.04	16.10	2.91	0.49	19.34	3.54	5.94	3.78
CAS 224710	*limnocharis*	female	45.46	25.00	24.80	13.60	3.05	2.97	15.48	3.44	5.10	2.72
CAS 224716	*limnocharis*	female	43.17	24.20	23.54	14.00	2.60	2.40	16.30	3.29	5.64	2.74
SMF 5071	*limnocharis*	female	53.24	29.20	27.82	16.70	4.92	3.36	21.27	3.97	5.84	4.63
SMF 82922	*limnocharis*	female	49.77	20.49	25.27	15.11	3.00	2.34	16.75	3.77	5.08	5.07
SMF 82923	*limnocharis*	female	48.58	22.40	26.36	13.05	3.77	2.53	16.59	3.98	4.26	4.91
SMF 82926	*limnocharis*	female	37.99	17.70	21.36	12.10	2.62	2.21	13.75	2.77	3.45	3.76
CAS 235276	*limnocharis*	male	41.25	18.60	20.46	12.60	2.54	2.33	15.67	3.29	5.03	2.65
SMF 5070	*limnocharis*	male	41.36	22.20	20.84	14.00	3.65	2.34	15.24	3.47	4.58	3.23
SMF 82924	*limnocharis*	male	43.19	14.60	18.29	13.60	3.03	2.27	14.27	3.22	4.52	3.26
SMF 82925	*limnocharis*	male	37.82	16.61	19.77	12.81	2.67	2.57	13.48	2.73	4.36	3.07
CAS 230370	*muangkanensis*	female	31.88	15.50	16.10	8.20	2.05	1.33	11.20	2.20	3.56	1.87
SMF 104873	*muangkanensis*	female	31.30	18.20	17.80	10.60	2.20	2.95	11.70	2.00	3.70	2.60
CAS 235277	*muangkanensis*	male	25.08	13.40	14.23	7.60	1.99	1.74	10.90	1.84	3.09	1.88
SMF 103782	*muangkanensis*	male	32.00	18.00	17.30	10.90	2.25	3.10	12.40	2.40	3.85	3.00
SMF 103790	*muangkanensis*	male	32.20	17.50	16.90	10.70	2.50	2.60	12.00	2.40	3.90	2.70
SMF 103789	*muangkanensis*	male	32.90	17.90	16.40	10.50	2.25	2.40	12.10	2.20	3.90	2.90
SMF 103791	*muangkanensis*	male	30.20	16.65	16.60	10.50	2.30	2.40	12.10	2.50	4.05	2.70
SMF 103788	*muangkanensis*	male	31.20	16.00	15.65	9.85	2.20	2.60	12.90	2.50	3.70	2.65
SMF 103787	*muangkanensis*	male	35.10	18.90	17.30	11.20	2.50	2.90	13.20	2.40	4.00	3.00
CAS 208003	*orissaensis*	female	53.67	29.50	26.45	15.00	3.38	2.97	19.83	4.54	5.89	3.62
CAS 208180	*orissaensis*	female	49.84	25.30	24.79	15.00	3.47	3.17	18.65	3.84	5.34	3.63
CAS 210569	*orissaensis*	female	55.84	31.20	28.13	16.90	3.86	2.39	21.69	3.88	5.38	4.11
CAS 213586	*orissaensis*	female	55.86	29.60	28.12	18.10	4.48	3.30	21.02	4.38	5.64	4.04
CAS 213602	*orissaensis*	female	56.90	28.30	25.58	16.90	3.35	2.52	19.53	3.60	5.99	3.44
CAS 213608	*orissaensis*	female	46.42	24.40	23.64	12.60	2.81	2.06	16.35	3.51	5.30	2.51
SMF 104093	*orissaensis*	female	44.25	20.70	19.71	13.30	2.50	2.50	14.60	2.69	5.31	3.48
SMF 104094	*orissaensis*	female	50.49	26.10	24.96	17.30	3.15	3.03	18.41	3.42	5.98	3.64
SMF 104095	*orissaensis*	female	48.65	24.40	23.31	15.20	2.90	2.59	16.60	3.32	4.93	2.25
SMF 104096	*orissaensis*	female	50.02	25.40	23.46	15.90	3.10	2.76	18.60	3.71	5.28	3.71
SMF 104099	*orissaensis*	female	47.41	25.00	21.89	14.80	2.90	2.53	17.39	3.47	5.24	3.54
SMF 104100	*orissaensis*	female	45.90	24.00	23.09	15.60	3.20	2.83	16.60	3.39	5.98	3.63
SMF 104101	*orissaensis*	female	41.13	20.80	21.12	13.50	2.94	2.58	20.18	3.17	5.70	2.76
SMF 104109	*orissaensis*	female	56.79	30.05	27.05	18.50	4.05	3.24	20.61	3.07	7.24	4.14
SMF 104115	*orissaensis*	female	48.49	25.60	23.94	16.10	3.30	2.61	16.48	3.39	6.14	3.39
SMF 104117	*orissaensis*	female	58.83	31.50	26.55	20.00	4.22	2.80	21.47	4.05	6.56	5.04
SMF 104118	*orissaensis*	female	49.28	24.40	23.51	17.10	3.45	3.05	16.16	3.53	6.17	3.43
SMF 104092	*orissaensis*	male	51.36	25.40	23.62	13.50	2.60	3.08	16.80	3.55	5.99	2.92
SMF 104097	*orissaensis*	male	44.07	22.00	22.51	14.20	3.10	2.32	15.79	2.96	5.50	3.17
SMF 104098	*orissaensis*	male	43.17	21.00	20.79	13.60	2.60	2.43	15.20	2.75	5.61	2.67
SMF 104105	*orissaensis*	male	37.75	20.00	20.13	13.10	2.41	2.65	14.29	2.72	5.16	2.43
SMF 104110	*orissaensis*	male	44.92	25.00	24.93	15.20	2.91	2.53	16.66	3.71	5.54	3.49
SMF 104111	*orissaensis*	male	44.39	22.90	21.77	14.40	2.58	2.43	15.91	2.86	5.94	3.01
SMF 104112	*orissaensis*	male	45.65	24.00	23.28	14.30	2.80	2.61	16.20	2.76	6.08	3.21
SMF 104113	*orissaensis*	male	44.06	23.90	22.32	15.10	3.12	2.29	11.21	3.13	5.45	2.67
SMF 104114	*orissaensis*	male	40.40	25.70	20.05	14.20	2.80	2.26	15.30	3.07	5.29	2.87
SMF 104116	*orissaensis*	male	45.02	21.50	21.51	14.60	2.80	1.89	14.99	2.65	5.50	2.86

Appendix 3 continued.

Nr.	Species	Sex	SVL	SHL	FL	HW	IOD	IND	HL	TYD	EYD	NED
SMF 104119	*orissaensis*	male	41.33	22.10	20.14	12.60	2.50	3.40	15.50	2.77	5.56	3.13
SMF 104120	*orissaensis*	male	45.08	24.80	22.45	15.40	3.15	2.56	16.68	3.37	5.86	3.37
SMF 104121	*orissaensis*	male	47.50	26.20	25.90	14.60	2.70	2.41	16.70	2.71	5.25	3.32
SMF 104122	*orissaensis*	male	41.05	22.40	19.69	14.10	2.70	2.38	15.30	2.46	5.32	2.82
SMF 104123	*orissaensis*	male	41.54	21.50	22.33	13.20	2.50	2.44	15.50	2.83	5.76	2.92
SMF 104124	*orissaensis*	male	40.73	21.50	19.17	13.00	2.30	2.44	14.00	2.82	5.08	2.81
SMF 104125	*orissaensis*	male	42.87	23.00	20.43	13.50	3.13	2.42	15.18	2.32	5.65	3.21
SMF 23624	*verruculosa*	female	30.59	17.40	16.71	10.00	2.47	2.38	12.19	2.38	3.94	2.64
SMF 23550	*verruculosa*	female	32.16	17.60	18.62	10.60	2.29	2.48	12.49	2.69	3.48	3.20
SMF 23541	*verruculosa*	female	32.60	17.40	19.22	10.30	2.38	2.45	12.50	2.58	4.24	3.32
SMF 23578	*verruculosa*	female	32.61	18.10	17.97	11.30	2.48	2.29	12.62	2.54	4.01	2.85
SMF 23590	*verruculosa*	female	32.73	16.10	18.23	11.00	2.63	2.08	14.02	2.42	3.86	3.30
SMF 23538	*verruculosa*	female	33.36	18.50	19.57	11.10	2.67	2.39	12.88	2.59	4.23	3.45
SMF 23601	*verruculosa*	female	33.42	18.40	17.89	11.20	2.57	2.18	13.41	2.88	3.77	2.36
SMF 23567	*verruculosa*	female	33.76	18.70	19.19	11.90	2.99	2.07	13.66	3.35	4.72	2.97
SMF 23606	*verruculosa*	female	33.97	16.30	16.84	10.10	2.52	2.21	12.18	2.54	3.61	2.86
SMF 74092	*verruculosa*	female	34.87	16.50	18.71	12.21	1.74	1.77	12.70	3.36	4.69	3.27
SMF 23575	*verruculosa*	female	35.63	20.10	19.89	12.20	2.54	2.83	13.92	2.44	4.43	3.18
SMF 23595	*verruculosa*	female	35.69	19.80	19.79	11.00	2.93	2.11	12.57	2.91	4.37	3.15
SMF 23592	*verruculosa*	female	35.71	17.30	17.66	10.80	2.81	2.77	12.23	2.28	3.67	2.62
SMF 23547	*verruculosa*	female	35.94	18.50	19.73	10.70	2.53	2.33	13.32	2.61	4.29	3.06
SMF 23589	*verruculosa*	female	35.94	19.90	20.51	11.30	2.37	2.33	13.13	2.51	4.21	2.87
SMF 23572	*verruculosa*	female	36.20	18.50	18.81	11.70	2.71	2.19	14.05	3.41	4.29	3.30
SMF 23581	*verruculosa*	female	36.21	18.80	20.24	11.90	3.17	2.52	13.19	3.14	3.97	3.29
SMF 23570	*verruculosa*	female	36.25	20.00	19.26	11.70	2.32	2.29	13.84	3.54	3.93	2.75
SMF 23580	*verruculosa*	female	36.31	18.30	18.62	11.90	2.51	2.10	12.97	2.64	4.12	2.36
SMF 23607	*verruculosa*	female	36.46	19.20	19.48	12.20	2.77	2.19	13.61	2.64	4.01	2.58
SMF 23583	*verruculosa*	female	37.13	20.90	21.94	12.00	2.67	2.49	14.23	2.73	4.30	3.49
SMF 23596	*verruculosa*	female	37.44	20.60	20.26	12.10	3.06	2.42	13.57	2.62	4.67	3.16
SMF 23622	*verruculosa*	female	37.45	21.60	20.83	12.40	3.14	2.09	14.53	3.04	4.21	2.35
SMF 23579	*verruculosa*	female	37.46	19.90	19.52	11.60	2.45	2.12	12.70	2.69	4.46	3.21
SMF 23585	*verruculosa*	female	37.50	20.70	21.52	12.40	2.41	2.45	14.41	3.22	4.49	3.27
SMF 23573	*verruculosa*	female	37.53	20.50	21.11	11.70	2.90	2.39	13.79	2.53	4.39	2.93
SMF 23537	*verruculosa*	female	37.60	21.60	22.05	11.40	2.35	2.09	12.21	2.70	3.76	2.85
SMF 23582	*verruculosa*	female	37.69	21.10	20.44	12.30	2.80	2.42	14.98	3.09	4.57	3.40
SMF 23566	*verruculosa*	female	37.74	20.90	21.64	12.10	3.31	2.54	14.25	2.86	4.17	3.15
SMF 23588	*verruculosa*	female	37.74	20.30	21.11	12.50	3.02	2.53	15.45	2.59	3.75	3.19
SMF 23597	*verruculosa*	female	37.85	20.11	20.12	11.80	2.68	2.52	14.18	2.79	4.35	2.88
SMF 23591	*verruculosa*	female	38.05	18.30	20.35	11.60	2.86	2.16	15.08	3.39	4.36	3.17
SMF 55317	*verruculosa*	female	38.25	21.00	21.79	12.10	2.71	2.38	14.36	2.87	4.57	3.23
SMF 23587	*verruculosa*	female	38.27	20.20	21.71	12.70	2.91	2.63	13.87	2.74	4.21	2.97
SMF 23557	*verruculosa*	female	38.68	21.10	20.69	12.40	2.88	1.74	14.92	3.27	4.70	2.93
SMF 23568	*verruculosa*	female	38.93	21.50	22.76	12.50	3.11	2.52	14.58	2.97	4.65	3.74
SMF 23586	*verruculosa*	female	38.98	18.60	17.49	11.30	2.78	2.24	12.88	2.55	3.59	2.91
SMF 23548	*verruculosa*	female	39.54	21.60	22.49	12.40	2.48	2.83	14.91	3.02	4.71	3.86
SMF 23542	*verruculosa*	female	39.87	21.30	21.90	11.30	2.87	2.71	15.11	2.96	4.73	3.58
SMF 23599	*verruculosa*	female	39.97	20.50	20.32	13.20	2.81	2.53	14.98	3.19	4.65	3.07
SMF 55316	*verruculosa*	female	40.31	22.10	22.34	13.10	2.84	2.82	15.11	3.01	4.94	3.12
SMF 23608	*verruculosa*	female	40.55	21.40	21.28	12.90	3.83	1.93	15.07	2.81	4.12	3.21
SMF 23549	*verruculosa*	female	42.50	23.90	24.13	13.20	3.12	3.32	15.88	3.39	4.69	3.04
SMF 23604	*verruculosa*	female	42.73	22.70	23.52	13.50	3.01	2.77	14.74	3.20	5.11	3.25
SMF 23584	*verruculosa*	female	43.01	22.50	23.73	13.70	2.56	2.92	15.87	2.76	4.35	2.81
SMF 23610	*verruculosa*	female	43.22	22.80	21.34	14.20	3.12	2.53	16.22	2.99	5.18	3.79
SMF 55315	*verruculosa*	female	43.32	22.90	22.05	13.70	2.76	2.79	15.86	3.37	5.17	3.37
SMF 23564	*verruculosa*	female	43.36	24.70	22.91	13.80	3.54	2.44	16.94	3.48	4.69	3.29
SMF 55314	*verruculosa*	female	43.48	24.30	24.68	14.50	3.15	2.56	14.95	3.46	5.24	3.34

Appendix 3 continued.

Nr.	Species	Sex	SVL	SHL	FL	HW	IOD	IND	HL	TYD	EYD	NED
SMF 23611	*verruculosa*	female	43.59	25.30	25.70	14.20	2.71	2.73	17.14	3.58	5.48	3.81
SMF 23565	*verruculosa*	female	44.14	24.10	25.11	15.30	3.12	2.38	17.09	3.54	4.64	3.67
SMF 23598	*verruculosa*	female	44.64	23.80	23.08	13.70	2.71	2.53	15.13	3.34	4.61	3.24
SMF 23560	*verruculosa*	female	44.74	25.60	25.01	13.70	3.43	3.04	16.51	3.30	4.31	3.58
SMF 23558	*verruculosa*	female	44.89	26.20	24.16	14.80	2.99	2.50	16.21	3.67	4.79	3.75
SMF 23561	*verruculosa*	female	45.14	25.20	23.00	14.90	3.71	3.37	18.28	3.77	4.68	3.78
SMF 23560	*verruculosa*	female	45.45	26.72	20.14	14.50	3.45	2.69	17.09	3.49	4.99	3.85
SMF 23571	*verruculosa*	female	45.87	24.50	23.55	14.60	3.74	2.95	16.32	3.22	4.67	3.94
SMF 23612	*verruculosa*	female	46.10	25.10	24.13	14.60	2.97	2.87	17.20	3.51	5.11	3.85
SMF 23545	*verruculosa*	female	46.54	23.60	25.41	14.50	3.37	2.83	16.92	3.77	5.25	4.28
SMF 23540	*verruculosa*	female	47.46	27.10	27.22	14.90	3.55	3.65	17.56	3.64	4.98	4.17
SMF 23539	*verruculosa*	female	47.89	27.00	26.83	14.30	3.47	3.29	17.41	3.44	4.77	4.52
SMF 23614	*verruculosa*	female	48.43	26.20	24.88	15.90	3.81	2.59	19.07	3.49	5.85	4.13
SMF 23613	*verruculosa*	female	48.64	22.90	21.69	16.20	3.06	3.21	19.16	3.29	5.12	4.12
SMF 74096	*verruculosa*	female	62.37	33.10	27.66	22.70	3.48	3.49	23.84	5.26	5.93	4.88
SMF 23546	*verruculosa*	male	37.14	18.10	18.97	11.20	2.44	2.56	14.21	3.06	4.27	3.43
SMF 23551	*verruculosa*	male	39.67	19.70	19.47	12.60	2.63	2.52	15.12	2.80	4.52	3.86
SMF 23562	*verruculosa*	male	41.22	22.50	23.28	12.90	3.01	2.23	15.19	3.72	4.44	3.18
SMF 23559	*verruculosa*	male	41.89	24.80	23.66	14.10	3.10	2.12	16.22	3.60	4.98	2.99
SMF 23555	*verruculosa*	male	41.93	23.10	21.98	15.20	3.15	2.84	15.90	3.28	4.69	3.38

ZooBank Registration

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