

**CYRTODACTYLUS MAJULAH, A NEW SPECIES OF BENT-TOED GECKO
(REPTILIA: SQUAMATA: GEKKONIDAE) FROM SINGAPORE
AND THE RIAU ARCHIPELAGO**

L. Lee Grismer

Department of Biology, La Sierra University, 4500 Riverwalk Parkway, Riverside, California 92515, USA
Email: lgrismer@lasierra.edu

Perry L. Wood, Jr.

Department of Biology, Brigham Young University, 150 East Bulldog Boulevard, Provo, Utah 84602 USA
Email: pwood@byu.edu

Kelvin K. P. Lim

Raffles Museum of Biodiversity Research, Department of Biological Sciences, National University of Singapore
6 Science Drive 2, Singapore 117600
Email: kelvinlim@nus.edu.sg

ABSTRACT. — *Cyrtodactylus majulah* is a new species of bent-toed gecko from Singapore and Pulau Bintan in the Riau Archipelago of Indonesia that had been masquerading under the nomen *C. quadrivirgatus*. It is differentiated from *C. quadrivirgatus* and all its congeners in Sundaland by having the following suite of unique morphological and colour pattern characteristics: a maximum SVL of 68.0 mm; eight or nine supralabials; seven or eight infralabials; strongly tuberculated body and limbs; 39–46 paravertebral tubercles; 43–53 ventral scales; no abrupt contact of large and small postfemoral scales; no enlarged femoral scales; 20–23 subdigital lamellae on the fourth toe; no femoral pores; no deep precloacal groove; enlarged, precloacal scales; 7–11 precloacal pores; no enlarged, median subcaudals; tubercles on the anterior portion of the tail; no reticulated pattern on the head; a blotched dorsal pattern; and lacking paired, dark, semi-lunar shaped blotches on the upper nape. This nocturnal, arboreal, forest and swamp dwelling species frequents tree trunks, leaves and low bushes and is the basal member of a monophyletic group that contains *C. pantiensis* and *C. payacola* from Peninsular Malaysia.

KEY WORDS. — Gekkonidae, *Cyrtodactylus majulah*, Singapore, new species

INTRODUCTION

Authors of recently described species of the Asian gekkonid genus *Cyrtodactylus* have all commented on the unprecedented rate at which the contents of this genus is increasing (152 species at the present count; see <http://www.reptile-database.org>; Shea et al., 2012) and that the abatement of this rate is nowhere in sight (i.e., David et al., 2011; Iskandar et al., 2011; Ngo, 2011; Oliver et al., 2011; Schneider et al., 2011; Shea et al., 2012). Although the majority of the new *Cyrtodactylus* described within the last few years have come from mainland Indochina (see <http://www.reptile-database.org>), principally Vietnam, several new species have emerged from Sundaland (Oliver et al., 2009; Chan & Norhayati, 2010; Grismer et al., 2010; Iskandar et al., 2011), the Philippines (Welton et al., 2009, 2010a, 2010b); Wallacea, Australia, and New Guinea (Oliver et al., 2011; Shea et al.,

2012). Notably absent among the regions of discovery has been the island nation of Singapore. Despite Singapore's rich herpetological history (see Grismer, 2011a: 81–87 for a review), its herpetofauna has always been considered a subset of that of Peninsular Malaysia, implying that it had no endemic herpetofaunal taxa.

We report here a distinctive species of *Cyrtodactylus* from the Central Catchment Nature Reserve of Singapore (Fig. 1) that was first reported as *Cyrtodactylus marmoratus* (Sworder, 1925; Smith, 1930). In his original description of *C. quadrivirgatus*, Taylor (1962) noted its presence throughout the Malay Peninsula south of the Isthmus of Kra, and that the absence of femoral pores precluded its close relationship to *C. marmoratus*, much less their conspecificity. However, this was curiously overlooked by Grandison (1972) in her report of *C. marmoratus* from Gunung Benom, Pahang.

Dring (1979) noted that all *C. marmoratus* from the Malay Peninsula, including Singapore, should be transferred to *C. quadrivirgatus*. Although this taxonomic recommendation was followed by all subsequent authors (Denzer & Manthey, 1991; Lim & Lim, 1992; Chan-ard et al., 1999; Manthey & Grossman, 1997; Cox et al., 1998; Baker & Lim, 2008; Das, 2010; Grismer 2011a, 2011b), Grismer (2011a) noted the unique colour pattern of the Singapore population and its close resemblance to other swamp dwelling congeners from Peninsular Malaysia and questioned its assignment to *C. quadrivirgatus*. Genetic evidence reported herein from this population indicate it is not even closely related to *C. quadrivirgatus*, but is in fact part of a clade of freshwater swamp dwelling *Cyrtodactylus* species from Peninsular Malaysia that consists of *C. semenanjungensis* Grismer & Leong, 2005; *C. pantiensis* Grismer, Chan, Grismer, Wood & Belabut, 2008; and *C. payacola* Johnson, Quah, Shahrul, Muin, Wood, Grismer, Greer, Chan, Norhayati, Bauer & Grismer, 2012. Specimens from Singapore, as well as a specimen from Pulau Bintan in the Riau Archipelago of Indonesia, also bear a unique suite of morphological and colour pattern characteristics that are not found in any other species of *Cyrtodactylus* in Sundaland, and as such, they are described herein as new.

MATERIAL AND METHODS

Morphological analysis. — Colour notes were taken using digital images of living specimens prior to preservation. The following measurements on the type series were taken with Mitutoyo dial calipers to the nearest 0.1 mm under a Nikon SMZ 1500 dissecting microscope on the left side of the body where appropriate: snout-vent length (SVL), taken from the tip of snout to the vent; tail length (TL), taken from the vent to the tip of the tail, original or regenerated; tail width (TW), taken at the base of the tail immediately posterior to the postcloacal swelling; forearm length (FL), taken on the dorsal surface from the posterior margin of the elbow

while flexed 90° to the inflection of the dorsiflexed wrist; tibia length (TBL), taken on the ventral surface from the posterior surface of the knee while flexed 90° to the base of the heel; axilla to groin length (AG), taken from the posterior margin of the forelimb at its insertion point on the body to the anterior margin of the hind limb at its insertion point on the body; head length (HL), the distance from the posterior margin of the retroarticular process of the lower jaw to the tip of the snout; head width (HW), measured at the angle of the jaws; head depth (HD), the maximum height of head from the occiput to the throat; eye diameter (ED), the greatest horizontal diameter of the eyeball; eye to ear distance (EE), measured from the anterior edge of the ear opening to the posterior edge of the eye ball; eye to snout distance (ES), measured from anteriormost margin of the eyeball to the tip of snout; eye to nostril distance (EN), measured from the anterior margin of the eye ball to the posterior margin of the external nares; interorbital distance (IO), measured between the anterior edges of the orbit; ear length (EL), the greatest horizontal distance of the ear opening; and internarial distance (IN), measured between the nares across the rostrum.

Additional character states evaluated on the type series and comparative material (Appendix) were numbers of supralabial and infralabial scales counted from the largest scale immediately posterior to the dorsal inflection of the posterior portion of the upper jaw to the rostral and mental scales, respectively; the presence or absence of tubercles on the anterior margin of the forearm; the number of paravertebral tubercles between limb insertions counted in a straight line immediately left of the vertebral column starting at the midpoint between the forelimb insertions and ending at the midpoint between the hind limb insertions; the number of longitudinal rows of body tubercles counted transversely across the center of the dorsum from one ventrolateral fold to the other; the number of longitudinal rows of ventral scales counted transversely across the center of the abdomen from one ventrolateral fold to the other; the number of subdigital lamellae beneath the fourth toe counted from the base of the first phalanx to the claw; the total number of precloacal and femoral pores (i.e., the contiguous rows of femoral and precloacal scales bearing pores are combined as a single meristic); the presence or absence of a precloacal depression or groove; the degree and arrangement of body and tail tuberculation; the relative size and morphology of the subcaudal scales; the presence or absence of a white network of lines forming a reticulum on the top of the head; colour pattern on body and nape (i.e., striped, banded, or blotched); degree of striping on the flanks and their degree of contact with a postorbital stripe; and the presence or absence of wide, dark bands on an original tail.

Some of the information on character states and their distribution in other species was obtained from Chan & Norhayati (2010), Das & Lim (2000), De Rooij (1915), Dring (1979), Grismer (2008), Grismer et al. (2008); Hikida (1990), Inger & King (1961), Manthey & Grossman (1997), Rösler & Glaw (2008), Smith (1930), and Taylor (1963). Additional specimens examined are listed in the appendix. Institutional abbreviations follow Sabaj-Pérez (2010), with the exception

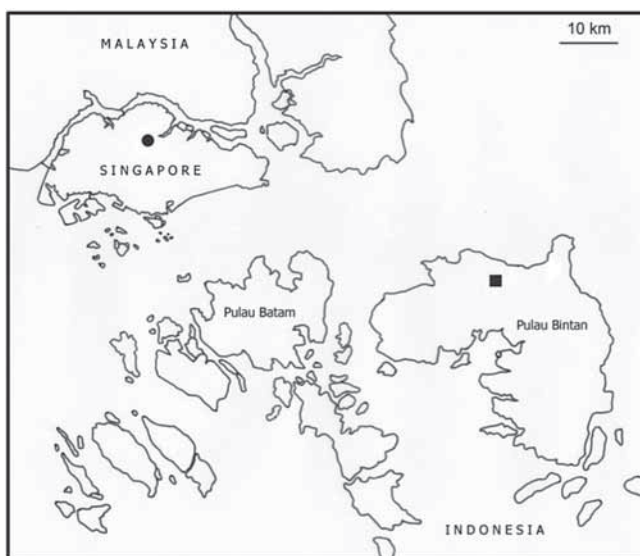


Fig. 1. Location of *Cyrtodactylus majulah* in Singapore and Pulau Bintan, Indonesia.

Table 1. Voucher numbers, species and locality information for the individuals used in this study.

Voucher	Species	Locality
LSUHC 8933	<i>Cyrtodactylus batucolus</i>	West Malaysia, Melaka, Pulau Besar
LSUHC 8934	<i>C. batucolus</i>	West Malaysia, Melaka, Pulau Besar
LSUHC 6471	<i>C. elok</i>	West Malaysia, Pahang, Fraser's Hill, the Gap
FMNH 255454	<i>C. interdigitalis</i>	Lao PDR, Khammouan Province, Nakai District
FMNH 265812	<i>C. intermedius</i>	Thailand, Sa Kaeo, Muang Sa Kaeo
LSUHC 9513	<i>C. intermedius</i>	Thailand, Chantaburi Province
LSUHC 9514	<i>C. intermedius</i>	Thailand, Chantaburi Province
ZRC 2.6951	<i>C. majulah</i>	Nee Soon Swamp, Singapore
ZRC 2.6952	<i>C. majulah</i>	Nee Soon Swamp, Singapore
LSUHC 8906	<i>C. pantiensis</i>	West Malaysia, Johor, Gunung Panti, Bunker Trail
LSUHC 8905	<i>C. pantiensis</i>	West Malaysia, Johor, Gunung Panti, Bunker Trail
LSUHC 10070	<i>C. payacola</i>	West Malaysia, Penang, Bukit Panchor
LSUHC 10071	<i>C. payacola</i>	West Malaysia, Penang, Bukit Panchor
LSUHC 9982	<i>C. payacola</i>	West Malaysia, Penang, Bukit Panchor
LSUHC 4018	<i>C. quadrivirgatus</i>	West Malaysia, Selangor, Kepong, FRIM
LSUHC 6503	<i>C. quadrivirgatus</i>	West Malaysia, Selangor, Templer's Park
LSUHC 9870	<i>C. quadrivirgatus</i>	West Malaysia, Perak, Bukit Larut
LSUHC 8859	<i>C. quadrivirgatus</i>	West Malaysia, Perak, Bukit Larut
LSUHC 5633	<i>C. quadrivirgatus</i>	West Malaysia, Perak, Temengor, PITC Logging Camp
LSUHC 9058	<i>C. quadrivirgatus</i>	West Malaysia, Terengganu, Pulau Perhentian Besar
LSUHC 5017	<i>C. quadrivirgatus</i>	West Malaysia, Pahang, Sungai Lembing Logging Camp
LSUHC 10072	<i>C. quadrivirgatus</i>	West Malaysia, Penang, Bukit Panchor
LSUHC 10073	<i>C. quadrivirgatus</i>	West Malaysia, Penang, Bukit Panchor
LSUHC 5640	<i>C. quadrivirgatus</i>	West Malaysia, Perak, Temengor, PITC Logging Camp
LSUHC 6863	<i>C. quadrivirgatus</i>	West Malaysia, Kedah, Pulau Langkawi, Gunung Raya
LSUHC 6737	<i>C. quadrivirgatus</i>	West Malaysia, Penang, Pulau Pinang, Empangan Air Hitam
LSUHC 7733	<i>C. quadrivirgatus</i>	Malaysia, Johor, Endau-Rompin, Peta, Sungai Semawak
LSUHC 6461	<i>C. quadrivirgatus</i>	West Malaysia, Pahang, Fraser's Hill
LSUHC 6607	<i>C. quadrivirgatus</i>	West Malaysia, Pahang, Genting Highlands
LSUHC 9191	<i>C. quadrivirgatus</i>	West Malaysia, Perak, Pulau Pangkor
LSUHC 5022	<i>C. quadrivirgatus</i>	West Malaysia, Pahang, Pulau Tioman, Sungai Mentawak
LSUHC 9620	<i>C. quadrivirgatus</i>	West Malaysia, Kedah, Sungai Sedim
LSUHC 8971	<i>C. quadrivirgatus</i>	West Malaysia, Johor, Gunung Ledan
LSUHC 8127	<i>C. quadrivirgatus</i>	West Malaysia, Johor, Selai, Lubuk Tapah
LSUHC 4980	<i>C. quadrivirgatus</i>	West Malaysia, Pahang, Sungai Lembing Logging Camp
LSUHC 4823	<i>C. quadrivirgatus</i>	West Malaysia, Selangor, Kepong, FRIM
LSUHC 6349	<i>C. seribuatebrisis</i>	West Malaysia, Johor, Pulau Nangka Kecil
FMNH 265806	<i>C. sp.</i>	Thailand, Loei, Phu Rua
LSUHC 7685	<i>C. sworderi</i>	Malaysia, Johor, Endau-Rompin, Peta, Sungai Kawal
LSUHC 8900	<i>C. semenanjungensis</i>	West Malaysia, Johor, Gunung Panti, Bunker Trail

of ZRC for USDZ, following conventional usage. DWNP refers to the Department of Wildlife and National Parks collection, Krau, Pahang, Malaysia; LSUHC refers to the La Sierra University Herpetological Collection, La Sierra University, Riverside, California, USA; and LSUDPC refers to the La Sierra University Digital Photo Collection.

Phylogenetic analysis. — We obtained sequence data from a 1505 bp fragment of the mitochondrial NADH dehydrogenase subunit 2 (ND2) including the flanking tRNA's (tRNA^{met}, tRNA^{trp}, tRNA^{aala}, tRNA^{asn}, tRNA^{acys}, tRNA^{tyr}) gene from 31 ingroup samples and 10 outgroup taxa based on Bauer et al. (in prep; Table 1). Total genomic DNA was isolated from liver or skeletal muscle stored in 95% ethanol

using the Qiagen DNeasyTM tissue kit (Valencia, CA, USA). ND2 was amplified using a double-stranded Polymerase Chain Reaction (PCR) under the following conditions: 2.5 µl genomic DNA, 2.5 µl light strand primer 2.5 µl heavy strand primer, 2.5 µl dinucleotide pairs, 2.5 µl 5× buffer, MgCl 10× buffer, 0.18 µl Taq polymerase, and 9.82 µl H₂O. PCR reactions were executed on an Eppendorf Mastercycler gradient thermocycler under the following conditions: initial denaturation at 95°C for 2 min, followed by a second denaturation at 95°C for 35 s, annealing at 50–55°C for 35 s, followed by a cycle extension at 72°C for 35 s, for 31 cycles (Greenbaum et al., 2007). PCR products were purified using AMPure magnetic bead solution (Agencourt Bioscience, Beverly, MA, USA). Purified PCR products were

Table 2. Primers used for amplification and sequencing of ND2 for this study.

Primer name	Primer reference		Sequence
L4437b	(Macey et al., 1997)	External	5'-AAGCAGTTGGGCCCATACC-3'
CyrtintF1	(Siler et al., 2010)	Internal	5'-TAGCCYTCTCYTCYATYGCCC-3'
CyrtintR1	(Siler et al., 2010)	Internal	5'-ATTGTKAGDGTGRCYAGGSTKGG-3'
L5002	(Macey et al., 1997)	External	5'-AACCAAACCCAACTACGAAAAAT-3'

Table 3. Best-fit models of evolution selected by Model test v3.7 (Posada & Crandall, 1988) using the Akaike Information Criteria (AIC) and models applied for Bayesian analyses.

Gene	Model selected	Model applied
ND2		
1 st pos	GTR+ Γ	GTR+ Γ
2 nd pos	GTR+I+ Γ	GTR+I+ Γ
3 rd pos	GTR+ Γ	GTR+ Γ
tRNAs	HKY+ Γ	HKY+ Γ

then sequenced through the Davis Sequencing, Inc. facility (Davis, CA). Primers used for amplification and sequencing are presented in Table 2.

For the phylogenetic analyses we applied a pluralistic approach using the character based method of Maximum Parsimony (MP) and two model-based methods, Maximum Likelihood (ML) and Bayesian Inference (BI). The Akaike Information Criterion (AIC) as implemented in ModelTest v3.7 (Posada & Crandall, 1998), was used to calculate the best-fit model of evolution for each codon position (Table 3). Maximum Parsimony (MP) criteria and bootstrap estimates for nodal support was employed in PAUP* v4.0 (Swofford, 2002). One thousand bootstrap replicates for each heuristic search was run with 10 random additional sequence replicates using tree bisection and reconnection (TBR) branch swapping. The 1000 bootstrap replicates were summarised as a 50% majority rule consensus tree. Maximum Likelihood analysis was performed using RAxML HPC v7.2.3 (Stamatakis et al., 2008), 1000 bootstrap pseudoreplicates via the rapid hill-climbing algorithm (Stamatakis et al., 2008). The Bayesian analysis was carried out in MrBayes v3.1 (Huelsenbeck & Ronquist, 2001; Ronquist & Huelsenbeck, 2003) using default priors. Two simultaneous runs were performed with eight chains per run, seven hot and one cold following default priors. The analysis was run for 10,000,000 generations and sampled every 1000 generations from the Markov Chain Monte Carlo (MCMC). The analysis was halted after the average standard deviation split frequency was below 0.01. The programme Are We There Yet? (AWTY) (Nylander et al., 2008) was employed to plot the log likelihood scores against the number of generations to assess convergence and to determine the appropriate number of burnin trees. We conservatively discarded the first 25% of the trees as burnin. A consensus tree was then computed from the two parallel runs using TreeAnnotator v1.6.1 (Drummond, 2007). Nodes that had posterior probabilities above 0.95 were considered significantly supported.

RESULTS

The molecular phylogeny indicates that the Singapore population is not part of the *Cyrtodactylus quadrivirgatus* species group, but a member of a swamp-dwelling clade of species that includes *C. semenanjungensis* and the sister species *C. payacola* and *C. pantiensis* to which it is most closely related (Figs. 2, 3). The morphological analysis unequivocally separates the Singapore and Pulau Bintan populations from *C. quadrivirgatus* and all other Sundaland species (Table 4) and as such, is described below as:

Cyrtodactylus majulah, new species (Figs. 3–5)

Gymnodactylus marmoratus (not of Kuhl) – Sworder, 1925: 63; Smith, 1930: 12

Cyrtodactylus quadrivirgatus (not of Taylor) – Lim & Lim, 1992: 121; Baker & Lim, 2008: 80

Cyrtodactylus quadrivirgatus (in part) – Dring, 1979: 228; Denzer & Manthey, 1991: 314; Chan-ard et al., 1999: 24; Manthey & Grossman, 1997: 227; Teo & Rajathurai, 1997: 390; Cox et al., 1998: 89; Das, 2010: 214; Grismer, 2011a: 426; Grismer, 2011b: 118

Holotype. — Adult male, 67.9 mm SVL (ZRC 2.6950); Singapore: Central Catchment Nature Reserve, Nee Soon Swamp-forest (1°22'48.99"N, 103°49'05.39"E; 51 m); coll: L. Grismer, E. Quah, K. O. Chan, A. Figueroa & A. Devan-Song, 22 Jun.2011.

Paratypes. — Adult male: 68.0 mm SVL (ZRC 2.6951); adult male: 62.7 mm SVL (ZRC 2.6952); adult male: 67.2 mm SVL (LSUHC 10458); adult male: 67.2 mm SVL (ZRC 2.6953); collection data as per holotype.

Non-types. — Singapore. 1 ex.: 50.9 mm SVL (ZRC 2.1133); Botanic Gardens; coll: F. N. Chasen, Feb.1924. 1 female: 59.0 mm SVL (ZRC 2.2552); Nee Soon Swamp-forest; coll: K. Lim & P. K. L. Ng, 31 Dec.1989. 1 ex.: 41 mm SVL (ZRC 2.3190); Nee Soon Swamp-forest; coll: K. Lim, 14 Nov.1990. 1 juvenile: 28.9 mm SVL (ZRC 2.3205); Nee Soon Swamp-forest; coll: P. K. L. Ng, 23 Nov.1990. 1 male: 68.0 mm SVL (ZRC 2.3261); Nee Soon Swamp-forest; coll: P. K. L. Ng, 1 Jan.1991. 2 ex.: 61.6–40.3 mm SVL (ZRC 2.3283–3284); forest at Upper Peirce Reservoir Park; coll: R. C. H. Teo, 24 Oct.1991. 1 female: 63 mm SVL (ZRC 2.4576); Nee Soon Swamp-forest; coll: T. M. Leong, 27 Feb.1999. 1 female: 66.5 mm SVL (ZRC 2.4862); forest at Upper Seletar Reservoir Park; coll: T. M. Leong & C. P. Lim, 5 Jan.2001. 1 ex.: 60 mm SVL (ZRC 2.5643); forest at Upper Seletar Reservoir Park; coll: T. M. Leong, 15 Mar.2003. 1 male: 68.5 mm SVL (ZRC 2.6796); Nee Soon Swamp-forest; coll: T. M. Leong, T. O'Dempsey & S. H. Yeo, 2 Jan.2009. Indonesia. 1 ex. (ZRC 2.6555), 58 mm SVL; Riau Archipelago, Pulau Bintan, northern coastal forest; coll: T. M. Leong & R. Subaraj, 18 Oct.2007.

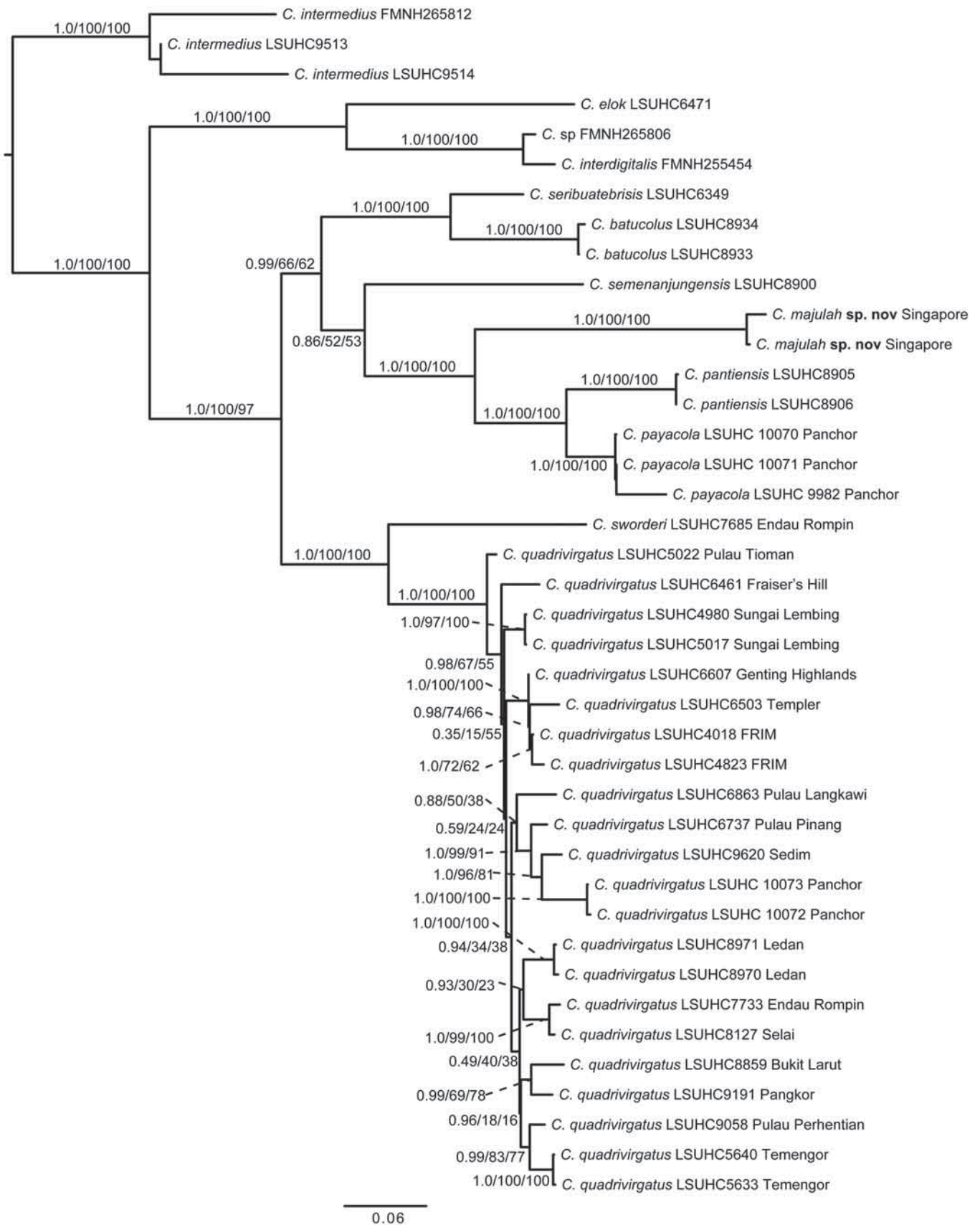


Fig. 2. Bayesian Inference tree (-ln L 13794.01) tree based on 1505 bp of ND2 showing the relationships between populations of *Cyrtodactylus quadrivirgatus* and the placement of *C. majulah* in the clade of swamp dwelling species. The tree is a Maximum Likelihood topology with Bayesian posterior probabilities (BPP) and ML and MP bootstrap support values, respectively (BPP/ML/MP), at the nodes.

Diagnosis. — *Cyrtodactylus majulah* new species is differentiated from its Sundaland congeners by having the unique combination of a maximum SVL of 68.0 mm; eight or nine supralabials; seven or eight infralabials; strongly tuberculated body and limbs; 39–46 paravertebral tubercles; 43–53 ventral scales; no abrupt contact of large and small postfemoral scales; no enlarged femoral scales; 20–23 subdigital lamellae; no femoral pores; no deep preloacal groove; enlarged preloacal scales; 7–11 preloacal pores; no enlarged median subcaudals; tubercles on the anterior portion of the tail; no reticulated pattern on head; having a blotched dorsal pattern; and lacking the paired, dark, semi-lunar shaped blotches on the upper nape prominently outlined in white. These and other characters are scored across all Sundaland species (Table 4).

Description of holotype. — Adult male SVL 67.9 mm; head moderate in length (HL/SVL 0.27) and wide (HW/HL 0.64), flat (HD/HL 0.42), distinct from neck, and triangular in dorsal profile; lores weakly inflated, prefrontal region deeply concave, canthus rostralis rounded; snout elongate (ES/HL 0.44), rounded in dorsal profile; eye large (ED/HL 0.22); ear opening elliptical, obliquely oriented, moderate in size (EL/HL 0.09); eye to ear distance greater than diameter of eye; rostral square, partially divided dorsally by three small postrostral scales, bordered posteriorly by left and right supranasals, laterally by first supralabials; external nares bordered anteriorly by rostral, dorsally by a large, anterior supranasal and smaller posterior supranasal, posteriorly by

two postnasals and ventrally by first supralabial; eight (R,L) rectangular supralabials extending to just beyond upturn of labial margins tapering abruptly below midpoint of eye, first supralabial largest; eight (R,L) infralabials tapering smoothly posteriorly to beyond orbit; scales of rostrum and lores raised, slightly larger than granular scales on top of head and occiput; scales of occiput intermixed with slightly enlarged tubercles; dorsal superciliaries not elongate or keeled; mental triangular, bordered laterally by first infralabials and posteriorly by large left and right trapazoidal postmentals which contact medially for 50% of their length posterior to mental; one row of slightly enlarged, elongate sublabials extending posteriorly to 6th infralabial; gular scales small, granular, grading posteriorly into slightly larger, flatter, throat scales which grade into larger, flat, smooth, imbricate, pectoral and ventral scales.

Body relatively short (AG/SVL 0.45) with poorly defined ventrolateral folds; large postaxillary skin growth on right side; dorsal scales small, granular interspersed with moderately sized, conical, semi-regularly arranged, keeled tubercles; tubercles extend from occiput onto base of tail but no farther; tubercles on occiput and nape relatively small, those on body largest; approximately 22 longitudinal rows of tubercles at midbody between ventrolateral, body folds; 46 paravertebral tubercles on body; 43 flat, imbricate, ventral scales between ventrolateral, body folds, ventral scales larger than dorsal scales; preloacal scales large; no deep preloacal groove or depression.



Fig. 3. a) *Cyrtodactylus semenanjungensis* LSUDPC 4450 from Gunung Panti Forest Reserve, Johor, Malaysia. b) *C. majulah* LSUDPC 6307 from the Nee Soon Swamp, Singapore. c) *C. pantiensis* LSUDPC 4477 from Gunung Panti Forest Reserve, Johor, Malaysia. d) *C. payacola* LSUDPC 6267 from Bukit Panchor, Penang, Malaysia.

Table 4. Diagnostic character states of Sunda Region *Cyrtodactylus*.

	<i>majalah</i> new species	<i>quensis</i>	<i>balensis</i>	<i>bateolis</i>	<i>batik</i>	<i>brevipalmatus</i>	<i>camericolus</i>	<i>consobrinus</i>	<i>duro</i>	<i>elak</i>	<i>funosus</i>	<i>ingeri</i>	<i>jarakensis</i>	<i>legrismeri</i>	<i>macrotuberculatus</i>	<i>malyanus</i>	<i>marmoratus</i>	<i>senhauensis</i>	<i>masui</i>	<i>pantensis</i>	<i>peguensis</i>	<i>pubiscus</i>	<i>pucellus</i>	<i>quadrivirgatus</i>	<i>semenanjungensis</i>	<i>strassmanni</i>	<i>yoshi</i>	<i>lateralis</i>
SVL	62-68	92-95	72-86	75.2	108-113	64-73	64-81	97-121	79.3	56-68	71-75	65-76	67	81-92	100-120	70-73	76	75	105	77.1	85	59-74	115	51-71	59-69	95.5	75-96	85
tuberculation moderate to strong	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes
tubercles on forelimbs	yes	no	yes	yes	no	yes	no	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes
tubercles on hind limbs	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
tubercles on head and/or occiput	yes	no	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
tubercles on anterior portion of tail	yes	no	no	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	—
ventral scales	43-51	45-51	40-45	38-42	48-57	35-45	51-58	58-65	59	44	35-40	40-43	61	27-35	19-22	58-62	40-50	28-39	51	40-46	29-38	43-55	33-35	34-42	48-53	63	50-58	60-64
enlarged median subcaudals	no	yes	yes	no	yes	no	no	yes	no	no	no	yes	no	yes	yes	yes	no	no	no	no	yes	yes	no	no	no	no	no	no
proximal subdigital lamellae broad	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	/	no	yes
subdigital lamellae broad	20-23	18-23	21-23	17-19	12-15	16-19	22-26	23-28	22	18 or 19	20-22	23-27	24	18-20	21-23	21-23	23-24	19-22	22	19-23	16-18	17-22	19-20	19-20	17-21	20-23	25-30	21-22
lamellae on 4 th toe	no	no	yes	yes	no	yes	no	no	no	no	no	no	no	yes	yes	no	yes	yes	yes	yes	—	no	yes	no	yes	yes	no	—
contact of posterior thigh scales abrupt	no	no	yes	yes	no	yes	no	yes	no	no	yes	no	no	yes	yes	yes	yes	yes	no	no	no	yes	yes	yes	no	no	no	—
enlarged femoral scales	no	no	yes	yes	no	yes	no	yes	no	no	yes	no	no	yes	yes	yes	yes	yes	no	no	no	yes	yes	yes	no	no	no	—
femoral pores deep	0	no	6-9	0	0	6-7	0	1-6	0	0	42-52	0	0	0	/	0	3-10	yes	no	no	no	yes	no	no	no	no	no	0
preclitoral groove	no	yes	no	no	no	no	yes	no	yes	no	no	no	no	no	yes	no	yes	no	no	no	no	yes	yes	no	yes	no	no	no

Table 4. Cont'd.

enlarged precloacal scales	precloacal pores	precloacal and femoral pores/scales continuous	reticulate pattern on head	body banded, blotched, or striped	
yes	7-11	no	no	blotched	<i>majulah</i> new species
yes	7	0	yes	blotched	<i>awensis</i>
yes	9-10	no	yes	blotched	<i>balensis</i>
yes	0	43-46	no	blotched	<i>batulus</i>
yes	0	0	no	blotched	<i>batik</i>
yes	9-10	no	no	blotched	<i>brevipalmatus</i>
yes	4	no	yes	blotched	<i>cavernicolus</i>
yes	9-10	no	yes	blotched	<i>conobrinus</i>
no	12	0	no	banded	<i>durio</i>
yes	8	no	no	blotched	<i>elok</i>
yes	42-52	yes	no	blotched	<i>fumosus</i>
yes	8	no	yes	blotched	<i>ingeri</i>
yes	11	no	no	blotched	<i>javakensis</i>
yes	4	no	yes	blotched	<i>legrismeri</i>
yes	/	yes	no	blotched	<i>macrothoracatus</i>
yes	8-10	no	yes	blotched	<i>malyanus</i>
yes	12-16	no	no	blotched	<i>marmoratus</i>
yes	yes	42-45	no	blotched	<i>seribawensis</i>
no	7	no	yes	blotched	<i>natsumi</i>
yes	8-9	no	no	blotched	<i>panthensis</i>
yes	7-9	no	yes	banded	<i>pegensis</i>
yes	7-9	no	no	blotched	<i>pinisulcus</i>
yes	yes	14-18	no	banded	<i>putchellus</i>
yes	0-4	no	no	striped	<i>puadivivatus</i>
yes	no	no	no	banded	<i>semenanjungensis</i>
yes	10	no	no	striped	<i>siremanani</i>
yes	8-12	no	no	blotched	<i>yoshii</i>
—	13	no	no	blotched	<i>lateralis</i>

Forelimbs moderate in stature, relatively short (FL/SVL 0.13); granular scales of forearm slightly larger than those on body, interspersed with slightly larger tubercles; palmar scales rounded, slightly raised; digits well-developed, inflected at basal, interphalangeal joints; subdigital lamellae transversely expanded proximal to joint inflections, more granular distal to inflection; digits slightly more narrow distal to inflections; claws well-developed, claw base sheathed by a dorsal and ventral scale; hind limbs more robust than forelimbs, moderate in length (TBL/SVL 0.17), covered dorsally by granular scales interspersed with large, conical tubercles and anteriorly by flat, slightly larger scales; ventral scales of thigh flat, imbricate, larger than dorsals; ventral tibial scales flat, imbricate; no rows of enlarged, flat, imbricate, femoral scales; small postfemoral scales do not form an abrupt union with large ventral scales of posteroventral margin of thigh; plantar scales low, flat; digits well-developed, inflected at basal, interphalangeal joints; subdigital lamellae transversely expanded proximal inflections, more granular distal to inflections, digits more narrow distal to inflections; 21 subdigital lamellae on right 4th toe, 22 on left; claws well-developed, base of claw sheathed by a dorsal and ventral scale.

Tail moderate, 88.1 mm in length, original, 6.5 mm in width at base, tapering to a point; dorsal scales of base of tail granular becoming flatter posteriorly; no median row of transversely enlarged subcaudal scales; subcaudal scales larger than dorsal caudal scales; one pair of paravertebral and dorsolateral tubercle rows on either side of midline on first one-fifth of tail; paravertebral tubercle rows not widely separated; caudal tubercles decrease in size posteriorly, extending approximately one-fifth length of tail; one enlarged, postcloacal tubercle at base of tail on hemipenial swelling; all postcloacal scales flat; partially everted hemipenes bilobed.

Colouration in life (Fig. 4). — Dorsal ground colour of head, neck, trunk, limbs, and tail brown; straw-yellow mottling on head and rostrum extending from postorbital region onto nape as a poorly defined stripe; mottling coalesces on dorsum to isolate brown ground colour in four longitudinal rows of large, elongate blotches that extend to base of tail; mottling transitions into six yellowish caudal bands not encircling the tail and separating five wider dark brown bands; posterior



Fig. 4. Holotype of *Cyrtodactylus majulah* (ZRC 2.6950, male) from Central Catchment Nature Reserve, Nee Soon Swamp-forest, Singapore.

30% of tail is uniformly dark brown; gular region, ventral surface of belly and limbs beige; each ventral scale bearing one or two small black spots; palmar and plantar regions grey; subcaudal region dark brown with irregularly shaped beige blotches; iris dark red.

Variation. — The general colouration and pattern of the paratypes closely match that of the holotype (Fig. 5). ZRC 2.6952 tends to have a more transversely banded pattern as opposed to a longitudinally spotted pattern. ZRC 2.6953 has a regenerated tail that is uniformly light brown bearing a dense, darker stippling pattern. The posterior two-thirds of the tail of ZRC 2.6951 is missing. The light caudal bands of ZRC 2.6952 extend to the end of the tail whereas in the holotype (ZRC 2.6950) and LSUHC 10458, the bands extend only two-thirds of the length of the tail. The light mottling on the snout is slightly more distinct in ZRC 2.6555. Meristic differences are shown in Table 5.

Distribution. — *Cyrtodactylus majulah* new species is known from Singapore Island, only from the forested areas of the Central Catchment Nature Reserve, and on Pulau Bintan in the Riau Archipelago of Indonesia. Both islands are located off the southern end of the Malay Peninsula (Fig. 1). '*Cyrtodactylus quadrivirgatus*' reported from other parts of Singapore such as Bukit Timah Nature Reserve and Pulau Tekong (Teo & Rajathurai, 1997; Baker & Lim, 2008), apparently are not conspecific with *C. majulah*, and their identity will be re-evaluated elsewhere.

Natural history. — The type series was obtained in the Nee Soon Swamp Forest (Corner, 1978), in the north-eastern part of the Central Catchment Nature Reserve that covers the central area of Singapore Island. All five specimens were found on the trunks of small trees in the vicinity of leafy cover 1.5–2 m above the ground. Four other specimens were seen in the same vicinity under the same conditions. One was seen 0.75 m above the ground on the surface of an exposed leaf. The habitat in which the type series was collected is a lowland equatorial rainforest criss-crossed by small streams (Fig. 6). All specimens were found in dense vegetation in the vicinity of water courses. *Cyrtodactylus majulah* new species is not restricted to swamp-forest habitat, for it has



Fig. 5. Type series of *Cyrtodactylus majulah* (all males). From left to right: ZRC 2.6950 (holotype), ZRC 2.6951 (paratype), ZRC 2.6952 (paratype), LSUHC 10458 (paratype), and ZRC 2.6953 (paratype).

also been observed (KKPL, pers. obs.) in other parts of the Central Catchment Nature Reserve in drier old secondary lowland forest. A specimen (ZRC 2.1133) was obtained from the Botanic Gardens in 1924, but it seems to be extinct at that locality. ZRC 2.4576 is a gravid female carrying two eggs and was collected 27 Feb. 1999 indicating that breeding occurs at least around this time of year.

Etymology. — In the Malay language (Bahasa Melayu), *majulah* means to go forward, to progress. This is in allusion to the present rapid advancement of research in the taxonomy of *Cyrtodactylus*, in which many species have recently been formally named, and more are waiting to be described.

Comparisons. — *Cyrtodactylus majulah* is distinguished from all its congeners on Sundaland except *C. brevipalmatus* (Smith), *C. cavernicolus* Inger & King, *C. elok* Dring, *C. ingeri* Hikada, *C. pubisulcus* Inger, *C. quadrivirgatus* Taylor, and *C. semenanjungensis* Grismer & Leong, by having a maximum SVL of less than 70 mm. It differs from *C. batucolus* Grismer, Chan, Grismer, Wood & Belabut; *C. fumosus* (Müller); *C. leegrimeri* Chan & Norhayati; *C. macrotuberculatus* Grismer & Norhayati; *C. peguensis* (Boulenger); *C. pulchellus* Gray; *C. quadrivirgatus*; and *C. seribuatensis* Youmans & Grismer, in having more than 42 ventral scales. From *C. cavernicolus*; *C. consobrinus* (Peters); *C. durio* Grismer, Anuar, Quah, Muin, Chan, Grismer & Norhayati; *C. jarakensis* Grismer, Chan, Grismer, Wood & Belabut; *C. lateralis* (Werner); *C. malayanus* (de Rooij); and



Fig. 6. Microhabitat of *Cyrtodactylus majulah* in the Nee Soon Swamp, Singapore.

Table 5. Meristic data for the type series of *Cyrtodactylus majulah* new species.

	ZRC 2.6555 paratype	ZRC 2.6950 holotype	ZRC 2.6951 paratype	ZRC 2.6957 paratype	ZRC 10458 paratype	ZRC 2.6953 paratype
supralabials	9	8	8	9	9	9
infralabials	7	8	8	8	7	8
paravertebral tubercles	42	46	42	43	39	45
ventral scales	48	43	47	50	51	53
4 th toe subdigital lamellae	23	21	20	21	21	20
preloacal pores	8	8	7	9	9	11
sex	male	male	male	male	male	male
SVL	58.1	67.9	68.0	62.7	67.2	67.2
TL	—	88.1	27b	87.2	87.3	70.2
TW	5.2	6.5	5.5	5.4	6.6	6.2
FL	8.9	9.1	10.3	8.5	9.1	9.1
TBL	9.9	11.6	11.5	10.1	10.9	11.2
AG	24.6	30.3	31.5	26.5	31.5	30.3
HL	15.6	18.0	17.9	16.2	18.4	17.4
HW	9.5	11.6	11.7	10.6	11.1	11.4
HD	6.5	7.5	7.1	6.1	7.0	6.7
ED	3.7	4.0	4.5	3.4	4.7	4.1
EE	4.2	5.3	5.2	4.3	4.6	4.9
ES	7.0	8.0	7.4	6.8	7.4	7.6
EN	5.1	5.8	5.4	5.3	5.5	5.7
IO	2.9	3.9	3.3	3.5	3.8	3.3
EL	0.9	1.7	1.5	1.2	1.7	1.2
IN	1.8	1.9'	1.8	1.8	1.8	1.8

C. stresemanni Rösler & Glaw; it differs in having fewer than 52 ventral scales. From *C. batucolus*; *C. batik* Iskandar, Rachmansah & Umilaela; *C. brevipalmatus* (Smith); *C. elok*; *C. peguensis*; and *C. yoshi* Hikada; it differs in having more than 19 subdigital lamellae on the fourth toe. It differs from *C. jarakensis* and *C. yoshii* in having fewer than 24 subdigital lamellae on the fourth toe. *Cyrtodactylus majulah* differs from all Sundaland *Cyrtodactylus* except *C. aurensis* Grismer, *C. baluensis* (Mocquard), *C. batik*, *C. consobrinus*, *C. ingeri*, *C. leegrimeri*, *C. macrotuberculatus*, *C. malayanus*, *C. peguensis*, and *C. pulchellus* in not having enlarged subcaudal scales. It is further separated from *C. aurensis*, *C. cavernicolus*, *C. durio*, *C. macrotuberculatus*, *C. marmoratus*, *C. pubisulcus*, *C. pulchellus*, and *C. stresemanni* in not having a deep preloacal groove. *Cyrtodactylus majulah* has 7–11 preloacal pores which separates it from *C. batucolus*, *C. batik*, *C. semenanjungensis*, and *C. seribuatensis* Youmans & Grismer, which lack preloacal pores; and from *C. lateralis*, *C. marmoratus*, and *C. durio* which have more than 11.

Cyrtodactylus majulah new species had long been referred to as *C. quadrivirgatus* (Lim & Lim, 1992; Teo & Rajathurai, 1997; Baker & Lim, 2008). Grismer (2011a) noted a significant departure in colour pattern between the Singapore population and that of *C. quadrivirgatus* from southern Peninsular Malaysia at Endau-Rompin, Johor and indicated that the conspecificity of these populations was under examination. *Cyrtodactylus majulah* new species differs from *C. quadrivirgatus* in having a dorsal pattern composed of large, semi-paired, paravertebral spots as opposed to stripes

and broken bands; more ventral scales (43–51 vs. 34–42); lacking, as opposed to having enlarged femoral scales (Fig. 7); and having 7–11 preloacal pores as opposed to 0–4 preloacal pores. *Cyrtodactylus majulah* new species is most similar to *C. pantiensis* from the nearby Gunung Pantii Forest Reserve, Johor in southern Peninsular Malaysia but differs in having eight or nine supralabials as opposed to 10 or 11; having seven or eight infralabials as opposed to 9–11; 39–46 paravertebral tubercles as opposed to 35–37; having a maximum SVL of 68.0 mm as opposed to 77.2 mm; and lacking the paired, dark, semi-lunar shaped blotches on the upper nape prominently outlined in white that are diagnostic of *C. pantiensis*. There is also a sequence divergence of 17.8–18.1% between these two taxa.

DISCUSSION

The results of this study add to a growing body of data on the hidden lizard diversity in Peninsular Malaysia and Singapore (Grismer, 2011a). This is especially true for common, widely distributed species, which upon close examination, often prove to be complexes of multiple species (Grismer et al., 2008, 2010). *Cyrtodactylus quadrivirgatus* is proving to be just such a species. Johnson et al. (2012) noted that the swamp-dwelling species *C. payacola* from western Peninsular Malaysia was previously considered part of *C. quadrivirgatus*, as was the Singapore population. This should be an indicator that other wide ranging common species could also be species complexes and if we are to truly understand and effectively

and efficiently manage the biodiversity of Peninsular Malaysia and Singapore, then a closer inspection of many of these species should be undertaken. Such inspection need not await a detailed molecular analysis as such, as the tens of newly described species from the Malay Peninsula have already been reliably distinguished by morphological analyses (see Grismer, 2011a; Grismer et al., 2010).

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Comparative material. — *Cyrtodactylus aurens* Grismer – Peninsular Malaysia, Johor, Pulau Aur: LSUHC 3937, 7013,



Fig. 7. Cloacal region of *Cyrtodactylus quadrivirgatus* (LSUHC 8185) from Endau-Rompin, Johor, Malaysia, showing the large femoral scales (upper); and *C. majulah* (ZRC 2.6951) from the Central Catchment Nature Reserve, Nee Soon Swamp-forest, Singapore, showing the absence of enlarged femoral scales (lower).

7022–23, 7285–86, 7300, 8040. *Cyrtodactylus baluensis* (Mocquard) – Malaysian Borneo, Sabah, Kinabalu: ZRC 2.5744, 2.5747; Malaysian Borneo, Sabah: ZRC 2.1116–21; Brunei Darussalam, Temburong, Kuala Belalong: ZRC 2.4729. *Cyrtodactylus batucolus* Grismer et al. – Peninsular Malaysia, Melaka, Pulau Besar, Pantai Putera: LSUHC 8933, 8935–36, 8939, 8941–43 (type series).

Cyrtodactylus brevipalmatus (Smith) – Thailand (no data): LSUHC 1899.

Cyrtodactylus cavernicolus Inger & King – Malaysian Borneo, Sarawak, Niah Cave: LSUHC 4055–56, ZRC 2.5327, 2.5775. *Cyrtodactylus consobrinus* (Smith) – Peninsular Malaysia, Selangor, Kepong, Forest Research Institute Malaysia: LSUHC 4019, 4389, 4820–21; Peninsular Malaysia, Pahang, Sungai Lembing logging camp: LSUHC 4912, 4941–12; Malaysian Borneo, Sarawak, near Niah Cave: LSUHC 4062. *Cyrtodactylus elok* Dring – Peninsular Malaysia, Pahang, Raub, Lakum Forest Reserve: ZRC 2.5649, 2.5668. *Cyrtodactylus fumosus* (Müller) – Indonesia, north Sulawesi, Lembeh Island: FMNH 14249–50. *Cyrtodactylus ingeri* Hikida – Malaysian Borneo, Sabah, Turtle Island: LSUHC 6167–76; Malaysian Borneo, Sabah, Poring: ZRC 2.5957.

Cyrtodactylus jarakensis Grismer et al. – Peninsular Malaysia, Perak, Pulau Jarak: LSUHC 9111 (holotype). *Cyrtodactylus malayanus* (de Rooij) – Malaysian Borneo, Sarawak, Kapit District, Nanga Tekalit Camp along Mengiong River: FMNH 149154, 149231. *Cyrtodactylus marmoratus* (Kuhl) – Indonesia, west Java: ZRC 2.1134.

Cyrtodactylus matsuii Hikida – Malaysian Borneo, Sabah, Crocker Range: ZRC 2.5761.

Cyrtodactylus oldhami (Theobald) – Thailand, Phuket, Kathu: ZRC 2.5213, 2.5226, 2.5230. *Cyrtodactylus pantiensis* Grismer et al. – Peninsular Malaysia, Johor, Gunung Panti Forest Reserve: LSUHC 8904–07 (type series). *Cyrtodactylus pubisulcus* Inger – Malaysian Borneo, Sarawak, near Niah Cave: LSUHC 4069. *Cyrtodactylus pulchellus* Gray – Peninsular Malaysia, Pahang, Genting Highlands: LSUHC 6637; Peninsular Malaysia, Perak, Bukit Larut: ZRC 2.5656–60, 2.5666; Peninsular Malaysia, Pulau Pinang, Ampangan Air Hitam: LSUHC 6668, 6725–29, 6785, 6829; Peninsular Malaysia, Perlis, Gua Kelam: LSUHC 8806–10; Peninsular Malaysia, Perlis, Kuala Perlis: LSUHC 8815–16. *Cyrtodactylus quadrivirgatus* Taylor – Peninsular Malaysia, Selangor, Kepong, Forest Research Institute Malaysia: LSUHC 4018, 4823; Peninsular Malaysia, Perak, Bukit Larut: ZRC 2.4865–66; Peninsular Malaysia, Pahang, Pulau Tioman: LSUHC 4813, 5022, 5101, 5173, 5517, 5562, 5582, 6136, 6146; Peninsular Malaysia, Pahang, Sungai Lembing logging camp: LSUHC 4980, 5017; Peninsular Malaysia, Perak, Temengor, PITC logging camp: LSUHC 5633–34, 5640; Peninsular Malaysia, Pahang, Pekan: LSUHC 6069, 6986, 6106. *Cyrtodactylus saddleiri* Wells & Wellington – Australia, Indian Ocean, Christmas Island: ZRC 2.1158, 2.1154–55, 2.1164–65.

Cyrtodactylus semenanjungensis Grismer & Leong – Peninsular Malaysia, Johor, Gunung Panti foothills: ZRC 2.5603, 2.5627; Peninsular Malaysia, Johor, near Jemaluang: ZRC 2.5077–78. *Cyrtodactylus seribuatensis* Youmans & Grismer – Peninsular Malaysia, Pahang,

Pulau Seribuat: LSUHC 5191–52, 5218–31, 5243, 5578; Peninsular Malaysia, Pahang, Pulau Sembilang: LSUHC 5522; Peninsular Malaysia, Johor, Pulau Sibul: LSUHC 5604, 5778–80, 5784–89; Peninsular Malaysia, Johor, Pulau Sibul Tengah: LSUHC 5812–13. *Cyrtodactylus tiomanensis* Das & Lim – Peninsular Malaysia, Pahang, Pulau Tioman: LSUHC 3771–72, 3793–94, 3847, 4581–84, 4587, 4590, 4597, 5027–30, 5044, 5411, 5479, 5512, 5519–20, 6250–51, 6268. *Cyrtodactylus yoshii* Hikida – Malaysian Borneo, Sabah, Poring: ZRC 2.4851.

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