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Another new *Cyrtodactylus* (Squamata: Gekkonidae) from Guwahati, Assam, India

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Abstract

We describe a new species of *Cyrtodactylus* from Guwahati city in the state of Assam, India and provide additional data on the recently described *Cyrtodactylus guwahatiensis*. *Cyrtodactylus urbanus* **sp. nov.** falls in the newly defined *khasiensis* group within the Indo-Burma clade of *Cyrtodactylus* and is the poorly supported sister taxon to *Cyrtodactylus khasiensis*. The new species differs from other members of the *khasiensis* group in mitochondrial sequence data (12.5–17.1 % uncorrected pairwise ND2 sequence divergence) as well as aspects of morphology including the number and arrangement of precloacal pores in males, the number of mid-ventral scales and paravertebral tubercles, and colour pattern. This is the second *Cyrtodactylus* endemic to the Guwahati region, the fourth from Assam and the twelfth from Northeast India.

Key words: Biodiversity, Northeast India, ND2, urban biodiversity, systematics

Introduction

Cyrtodactylus Gray is the most speciose gekkonid genus with 286 described species, second only to *Anolis* Daudin within the Squamata (Uetz *et al.* 2019). The genus is distributed from the Himalayas in Pakistan, India, Nepal and Tibet through South and Southeast Asia to northern Australia, Papua New Guinea and the Solomon Islands (Davis *et al.* 2019). Global phylogenies reveal a west to east pattern of diversification with four broad geographically structured clades—Tibetan Plateau/Trans-Himalayas, Western Himalayas, Indo-Burma and Southeast Asia (which includes the peninsular Indian and Sri Lankan endemic subgenus *Geckoella* Gray; Wood *et al.* 2012; Agarwal *et al.* 2014; Agarwal & Karanth 2015).

Species diversity within *Cyrtodactylus* is not evenly distributed across the clades. The Tibetan Plateau is currently only represented by *Cyrtodactylus tibetanus* (Boulenger) and potentially one or two additional species, the Western Himalayan clade by five species, Indo-Burma by at least 26 species, and the Southeast Asian clade is the most diverse with over 200 species, including those extending into the Pacific region as well as the subgenus *Geckoella* (Wood *et al.* 2012; Bauer *et al.* 2013; Agarwal *et al.* 2014, 2018a,b,c; Uetz *et al.* 2019). Much of the species discovery within *Cyrtodactylus* has been since the turn of the present century, with more than 50% of the species described since 2010. While most of these discoveries have been from insular and mainland Southeast Asia, exploration in Indo-Burma has led to the discovery of a host of new species from the region (Bauer 2002, 2003; Mahony 2009; Grismer *et al.* 2018a, b, c; Agarwal *et al.* 2018b, c). Myanmar alone accounts for 37 species of which 31 were described in five papers, including 22 in 2018 (Bauer 2002, 2003; Grismer *et al.* 2018a, b, c). In contrast, only five species were known from adjacent regions of Northeast India (including the state of West Bengal), eastern Nepal and Bangladesh until 2018, following which eight species were described and an additional species raised from

synonymy (Agarwal et al. 2018b, c) for a total of 14 species for the region: *C. ayeyarwadyensis* Bauer, *C. bhupa-thyi* Agarwal, Mahony, Giri, Chaitanya & Bauer, *C. gubernatoris* Annandale, *C. guwahatiensis* Agarwal, Mahony, Giri, Chaitanya & Bauer, *C. himalayicus* Annandale, *C. jaintiaensis* Agarwal, Mahony, Giri, Chaitanya & Bauer, *C. kazirangaensis* Agarwal, Mahony, Giri, Chaitanya & Bauer, *C. kazirangaensis* Agarwal, Mahony, Giri, Chaitanya & Bauer, *C. khasiensis* Jerdon, *C. markuscombaii* (Darevsky Helfeberger, Orlov & Shah), *C. martinstolli* (Darevsky Helfeberger, Orlov & Shah), *C. martinstolli* (Darevsky Helfeberger, Orlov & Shah), *C. magalandensis* Agarwal, Mahony, Giri, Chaitanya & Bauer, *C. septentrionalis* Agarwal, Mahony, Giri, Chaitanya & Bauer, *C. septentrionalis* Agarwal, Mahony, Giri, Chaitanya & Bauer, *C. tripuraensis* Agarwal, Mahony, Giri, Chaitanya & Bauer.

The recent spate of new species discoveries from northeast India and Myanmar clearly indicates the diversity of the region is severely underestimated, largely due to poor sampling. Fieldwork in and around Guwahati, the largest city in Assam, India resulted in the discovery of additional specimens of the poorly known *C. guwahatiensis* from near its type locality as well as another *Cyrtodactylus* from additional localities. In this paper we define the *Cyrtodactylus khasiensis* group, present additional data on morphology of the recently described *C. guwahatiensis*, and describe the second species of *Cyrtodactylus* from in and around the city of Guwahati, Assam, *Cyrtodactylus urbanus* **sp. nov.**

Materials and methods

Morphology. Fourteen specimens were collected from Guwahati in the state of Assam, India. Specimens were fixed in formaldehyde solution, preserved in 70% ethanol and deposited in the National Zoological Collection, maintained by the North Eastern Regional Centre, Zoological Survey of India, Shillong (VR/ERS/ZSI/683- VR/ERS/ZSI/696). Measurements were made using a Mitutoyo[™] dial caliper to the nearest 0.1 mm. The following measurements were recorded (following Agarwal et al. 2018b): SVL, snout to vent length; TRL, trunk length; BW, body width; TL, tail length; TW, tail width; HL, head length; HW, head width; HH, head height; FL, forearm length; CL, crus length; OD, eye diameter; NE, nostril to eye distance; SE, snout tip to eye distance; EE, eye to ear distance; EL, ear length; IN, internarial distance; IO, interorbital distance; RL, greatest rostral length; RW, greatest rostral width; PcP, precloacal pores; PcFP, precloacofemoral pores; MVSR, mid-ventral scale rows (counted between ventrolateral folds); PVT, para vertebral tubercles (PVT, counted from the most anterior tubercle on the occiput to mid-sacrum); DTR, dorsal tubercle rows (counted transversely across the body); SL, supralabials; IL, infralabials. Digits and toes were measured from the point of insertion and numbered from inner (I) to outer (V). Two separate series for subdigital lamellae were counted on the first and fourth digits on right manus and pes: a basal series that includes scales of a width at least twice the diameter of palmar scales up to and including a single large scale at the digital inflection, and an apical series including lamellae distal to the digital inflection and not including the ventral claw sheath. To get an idea about the diet preference of the new species, we did stomach-flushing for all the specimens in the type series following Legler & Sullivan (1979).

Molecular data. We created an alignment for the Indo-Burma clade of *Cyrtodactylus* using published ND2 sequences from Agarwal *et al.* (2014, 2018c) and Grismer *et al.* (2018a, b, c), using members of the Western Himalayan clade to root trees (Table 1). We generated partial ND2 sequences (up to 1029 nucleotides) for three individuals of the new species (Table 1) using the primers MetF1 and H5934 (Macey *et al.* 1997) for amplification and the former for sequencing, which was carried out by Medauxin Bangalore. We built a Maximum Likelihood (ML) tree using RAxML HPC 7.4.2 (Stamatakis 2006) applying the GTR + G model of sequence evolution with 10 independent ML runs and support assessed with 1000 rapid bootstraps, executed through the raxmlGUI 1.3 (Silvestro & Michalak 2012). Uncorrected % pairwise sequence divergence was calculated in MEGA 5.2.2 (Tamura *et al.* 2011).

Abbreviations for museum collection used are Bombay Natural History Society, Mumbai, India (BNHS); California Academy of Sciences, San Francisco, USA (CAS); Centre for Ecological Sciences, Bangalore, India (CES); La Sierra University Herpetological Collection, La Sierra University, Riverside, California, USA (LSUHC); Smithsonian National Museum of Natural History, Washington D.C., USA (USNM); Brigham Young University, Provo, Utah, USA (BYU) and National Zoological Collection, maintained by the North Eastern Regional Centre, *Zoological Survey of India*, Shillong, India (VR/ERS/ZSI).

Results

The new *Cyrtodactylus* from Guwahati is sister to *C. khasiensis* with moderate bootstrap support, the two nested within the well supported *C. khasiensis* group (lowland clade of Agarwal *et al.* 2014; Fig. 1). The new species is 14.1 % divergent from its closest relative *C. khasiensis* and 12.5–17.1 % divergent from other members of the clade in uncorrected pairwise ND2 sequence divergence (Table 2). We provide a definition for the *C. khasiensis* group, an expanded diagnosis for *C. guwahatiensis* and describe *Cyrtodactylus urbanus* **sp. nov.**

Species	Musuem No.	Locality	GenBank
			Accession
			Numbers
Cyrtodactylus annandalei	CAS 215722	Myanmar, Sagaing Divisioin, Alaungdaw Kathapa National Park	JX440524
Cyrtodactylus aunglini	LSUHC 13948	Myanmar, Mandalay Region, Pyin Oo Lwin District, Kyauk Nagar Cave,	MH764589
Cyrtodactylus ayeyarwadyensis	CAS 222812	Myanmar, Ayeyarwady Division, Mwe Hauk Village	GU550715
Cyrtodactylus bhupathyi	CES09/1235	India, West Bengal, Kalimpong District, Nr. Lower	KM255204
	BNHS 2255	Mongpong	
Cyrtodactylus brevidactylus	CAS 214105	Myanmar, Mandalay Division, Popa Mountain Park	GU550714
Cyrtodactylus cf fasciolatus	CES09/1257	India, Himachal Pradesh, Sirmaur District, Nr. Nahan	KM255185
Cyrtodactylus cf. lawderanus	CES09/1276	India, Himachal Pradesh, Mandi District, Aut	KM255190
Cyrtodactylus cf. lawderanus	CES09/1264	India, Himachal Pradesh, Shimla District, Nr. Jutogh	KM255178
Cyrtodactylus chamba	CES09/1291	India, Himachal Pradesh, Chamba District, Nr.	KM255191
	BNHS 2331	Chamba	
Cyrtodactylus chrysopylos	CAS 226141	Myanmar, Shan State, Ywa Ngan Township	JX440531
Cyrtodactylus fasciolatus	CES09/1337	India, Himachal Pradesh, Shimla District, Nr. Subathu	KM255184
Cyrtodactylus feae	USNM 559805	Myanmar, Mandalay Division, Popa Mountain Park	JX440536
Cyrtodactylus gansi	CAS 222412	Myanmar, Chin State, Min Dat Township	JX440537
Cyrtodactylus gubernatoris	CES09/1197 BNHS 2207	India, Sikkim, East District, Singtam	KM255181
Cyrtodactylus guwahatiensis	CES09/1127 BNHS 2146	India, Assam, Guwahati District, Guwahati	KM255194
Cyrtodactylus himalayanus	CES09/1307	India, Jammu and Kashmir, Kishtwar District, Kisht- war-Atholi Rd.	KM255186
Cyrtodactylus jaintiaensis	CES09/1228 BNHS 2248	India, Meghalaya, Jaintia Hills District, Nr. Jowai	KM255195
Cyrtodactylus kazirangaensis	CES09/1128 BNHS 2148	India, Assam, Golaghat District, Kohora	KM255170
Cyrtodactylus khasiensis	CES09/1229 BNHS 2249	India, Meghalaya, East Khasi Hills District, Cherra- punjee Resort	KM255188
Cyrtodactylus lawderanus	CES09/1343	India, Uttarakhand, Almora District, Almora	KM255189
Cyrtodactylus meersi	LSUHC 13455	Myin Mo Shwe Taung Pagoda, Bago Region Taik- kyi Township, Yangon (north) District, Myanmar	MH624104
Cyrtodactylus montanus	CES09/1211 BNHS 2231	India, Tripura, North District, Phuldungsei	KM255200
Cyrtodactylus myaleiktaung	LSUHC13965	Myanmar, Mandalay Region, Mandalay District, Mya Leik Taung	MH764598
Cyrtodactylus myintkyawthurai	CAS 245200	Central Bago Yoma, between Pallan Gyi Forest Camp and summit, Bago Region Myamnar (18.92108°N, 95.814027°E, 268 m)	MH624107

TABLE 1. List of Cyrtodactylus ND2 sequences used in this study. Museum abbreviations are as defined in Methods.

.....continued on the next page

TABLE 1. (Continued)			
Species	Musuem No.	Locality	GenBank
			Accession
			Numbers
Cyrtodactylus nagalandensis	CES09/1233	India, Nagaland, Kohima District, Khonoma	MH971164
	BNHS 2253		
Cyrtodactylus peguensis	LSUHC 13454	Myanmar, Bago Region, Myin Mo Shwe Taung	MH756190
		Pagoda	
Cyrtodactylus pyinyaungensis	BYU 52234	Myanmar, Mandalay Region, 5.3 km north of Pyiny-	MF872307
		aung Village	
Cyrtodactylus russelli	CAS 226137	Myanmar, Sagaing Division, Htamanthi Wildlife	JX440555
	05000/1105	Sanctuary	
Cyrtodactylus septentrionalis	CES09/1137	India, Assam, Bongaigaon District, Nr. Abhayapuri	MH971164
	BNHS 1989		13/440550
Cyrtodactylus slowinskii	CAS 210205	Myanmar, Sagaing Division, Alaungdaw Katnapa	JX440559
Contro da otroluz on	CES00/1465	National Park	VM255106
Cyrioduciyius sp.	CES09/1403	Lake	KW1233190
Curtodactulus sp	CES09/13/19	Lake India Arunachal Pradesh Changlang District Miao	KM255179
Cyrtodaetylus sp.	CES09/1349	India, Arunachal Pradesh, Changlang District, Miao	KM255102
Cyriodaetylus sp.	CES09/1459	India, Anunachal Prodach, Wast Kamana District, Mido	KW1255192
Cyriodaciyius sp.	CES09/1404	India, Afunachai Pradesh, west Kameng District,	KIVI233190
<i>Cyrtodactylus</i> sp	CES09/1455	India Mizoram Nr Aizawl	KM255197
Cvrtodactylus sp	L SUHC	Myanmar Magway Region Min Bu Townshin Shwe	MH624118
Cyrrodderyrus sp.	226139	Settaw Wildlife Sanctuary	111102 1110
Cvrtodactvlus tripuraensis	CES09/1225	India, Tripura, North District, Gumti	KM255202
	BNHS 2245	,	
Cyrtodactylus tripuraensis	CES09/1210	India, Tripura, North District, Rowa Wildlife Sanctu-	KM255202
	BNHS 2230	ary	
Cyrtodactylus urbanus sp. nov.	VR/ERS/	India, Assam, Kamrup (M) district, Guwahati, Basishta	MN911174
	ZSI/688	Temple	
Cyrtodactylus urbanus sp. nov.	VR/ERS/	India, Assam, Kamrup (M) district, Guwahati, Basishta	MN911175
	ZSI/689	Temple	
Cyrtodactylus urbanus sp. nov.	Unvouchered	India, Assam, Kamrup (M) district, Guwahati, Basishta	MN911176
		Temple	

TABLE 2. Pairwise uncorrected ND2 sequence divergence (%) between members of the *khasiensis* group. Bold represents intraspecific diversity in *Cyrtodactylus urbanus* **sp. nov.**

		1	2	3	4	5	6
1	Cyrtodactylus urbanus sp. nov.	0.4					
2	Cyrtodactylus ayeyarwadyensis	13.1					
3	Cyrtodactylus guwahatiensis	15.0	15.3				
4	Cyrtodactylus kazirangaensis	17.1	16.7	19.7			
5	Cyrtodactylus khasiensis	14.1	15.3	16.9	18.4		
6	Cyrtodactylus septentrionalis	13.2	14.4	11.3	18.6	15.7	
7	Cyrtodactylus tripuraensis	12.5	9.3	14.9	17.0	15.1	14.1

Systematics

Cyrtodactylus khasiensis group

Definition. The Cyrtodactylus khasiensis group (= lowland clade within the South of Brahmaputra clade of Agar-

wal *et al.* 2014; Agarwal *et al.* 2018c) is a genetically distinct, monophyletic clade with seven known species, *C. ayeyarwadyensis, C. guwahatiensis, C. kazirangaensis, C. khasiensis, C. septentrionalis, C. tripuraensis* and *C. urbanus* **sp. nov.** (description below). The *khasiensis* group is defined by the following morphological characters: maximum SVL of 65–81 mm; 8–12 supralabials; 8–11 infralabials; 19–24 rows of longitudinal tubercles; 30–43 ventral scales; 9–37 enlarged, usually contiguous, pore-bearing precloacal scales in males; no enlarged plate-like subcaudal scales. Members of the *Cyrtodactylus khasiensis* group are distributed in lowland habitats (up to 900 m elevation) largely south of the Brahmaputra River, with one species distributed north of the Brahmaputra and one in lowland Myanmar (Fig. 2).



FIGURE 1. Maximum Likelihood phylogeny of Indo-Burmese *Cyrtodactylus*; numbers at nodes represent bootstrap support (values <60 not shown).



FIGURE 2. Elevational map of northeast India showing the distribution of members of the *khasiensis* clade: 1, *C. septentrionalis*; 2, *C. guwahatiensis* and *C. urbanus* **sp. nov.**; 3, *C. kazirangaensis*; 4, *C. khasiensis*; 5, *C. tripuraensis* (from three localities); 6, *C. ayeyarwadyensis*.

Cyrtodactylus guwahatiensis Agarwal, Mahony, Giri, Chaitanya & Bauer 2018

Figs. 3–4, Table 3

Holotype. Adult male (BNHS 2146), collected from Hengrabari Road, Guwahati, Assam State, India (26.16193° N, 91.78298° E) by Ishan Agarwal, 11 June 2009.

Voucher no.	VR/ERS/	VR/ERS/	VR/ERS/	VR/ERS/	VR/ERS/	VR/ERS/	VR/ERS/
	ZSI/690	ZSI/694	ZSI/693	ZSI/696	ZSI/691	ZSI/692	ZSI/695
Locality	Hengrabari	Gitanagar	Gitanagar	Gitanagar	Hengrabari	Hengrabari	Gitanagar
Sex	М	М	М	М	М	F	F
SVL	68.1	69.6	66.4	61.9	67.4	70.5	69.8
TRL	31.6	31	28.3	26.6	23.7	31.6	28.8
BW	11	12.5	10.7	10.8	13.1	11.9	12.6
TL	55.6+	58.5	68	54.5	83.6	80.2	76.6
TW	6.5	7.9	6.8	6.7	6.1	6.8	5.7
HL	17.9	18.2	18.1	17.2	17.8	18.5	19.5
HW	12.5	13.4	12.3	11.7	12.4	12.9	14.2
HD	8.2	8	7.5	6.6	7.4	8.7	8.1
FL	8.9	8.6	8.9	8.8	8.9	9.8	9.8
CL	10.0	11.5	11.8	10.8	11.2	11.4	12.6
OD	3.6	4.2	3.5	3.5	3	3.5	3.9
NE	5.5	5.4	5.2	6.6	5.5	5.2	5.9
SE	7.1	7.6	7.9	7.8	7.2	7.8	7.5
EE	5.7	5.8	5.7	4.9	5	5.3	5
EL	1.2	1.9	1.9	2.1	1.4	1.2	2.3
IN	2.1	2.1	2.3	1.8	1.7	2.1	2.2
IO	4.3	2	1.9	2.1	1.3	2.9	2.7
F1	3.8	2.5	2.3	3.6	3.7	2.8	3.2
F2	4.3	4.6	4.2	4.5	5	4.4	4.3
F3	4.5	4.7	5.0	5.2	5.7	4.8	5.7
F4	5.3	6.2	5.4	6.1	6.2	6.1	6.1
F5	5.1	3.6	4.0	4.1	5.1	4.2	4.9
T1	3.1	3.4	2.5	2.8	3.6	2.5	3.2
T2	4.4	4.0	3.8	4.2	5.8	4.4	4.0
Т3	5.2	6.3	5.8	5.5	7.1	5.6	6.6
Τ4	6.9	7.5	6.8	6.6	7.6	6.8	7.0
Т5	5.1	7.0	5.2	5.3	5.2	5.6	6.1
RL	1.7	2.7	2.5	2.1	2.3	2.4	2.3
RW	2.4	3.8	3.5	2.9	3	2.6	3.2
PcP	39	35		36	39		
MVSR	30	35	34	33	34	30	33
PVT	36	37	36	38	38	38	35
DTR	21	22	22	23	22	23	22
SL(R/L)	10,11	10,9	10,10	11,11	10,9	8,8	10,9
IL(R/L	8,8	10,9	9,8	9,9	10,9	8,8	9,8
Lam Manus (4th)	17	17	18	17	18	17	15
Lam Pes (4th)	20	19	18	19	21	19	19

TABLE 3. Morphometric and meristic data for *Cyrtodactylus guwahatiensis* from Guwahati, Assam, India. + indicates incomplete tail



FIGURE 3. A: Dorsal view, B: ventral view and C: details of dorsal pholidosis of adult male (VR/ERS/ZSI/690) of *Cyrtodactylus guwahatiensis*.

Referred Material. Adult males (VR/ERS/ZSI/690, VR/ERS/ZSI/691, VR/ERS/ZSI/693, VR/ERS/ZSI/694 and VR/ERS/ZSI/696) and females (VR/ERS/ZSI/692 and VR/ERS/ZSI/695), all collected from Geetanagar, Guwahati (26.16873° N, 91.79417° E) by Sanath Bohra, 24 June 2018.

Diagnosis. *Cyrtodactylus guwahatiensis* **sp. nov.** can be distinguished from all congeners by its moderate body size (SVL to 70.5 mm); 8–11 supralabials; 8–10 infralabials; 21–24 longitudinal rows of bluntly conical, feebly keeled dorsal tubercles; tubercles extending till third segment of tail; 35–38 paravertebral tubercles; 30–35 mid-ventral scales; no precloacal groove; 26–39 precloacofemoral pores in a contiguous series (interrupted by 11 unpored scales in only the holotype); a row of enlarged scales above and below precloacal pore-bearing scales, slightly larger than pore-bearing scales; 13–16 total subdigital lamellae beneath toe IV of pes; subcaudal scalation of original tail without enlarged plates; dorsal pattern of 8–10 transverse rows of two or three pale buff blotches outlined by thick dark reticulations. Tail with alternating dark and lighter bands.



FIGURE 4. A: *Cyrtodactylus guwahatiensis* (VR/ERS/ZSI/696) showing continuous precloaco-femoral pores and B: *Cyrtodactylus urbanus* **sp. nov.** (VR/ERS/ZSI/683) showing only precloacal pores

Distribution and Natural History. This species is only known from a disturbed forest and residential areas of Guwahati, Assam; based on voucher specimens from Hengrabari and Geetanagar and photographic records from Assam State Zoo and Kharguli hills. The species has been observed on loose soil, secondary plantations and trees surrounded by rocks. One individual was spotted inside a dry well. Gravid females were observed between month of April and August. Their diet consists of small arthropods including cockroaches, spiders and beetles.

Cyrtodactylus urbanus sp. nov.

Figs. 5–9, Table 4

Holotype. VR/ERS/ZSI/683, adult male, SVL 71.9 mm. Basistha, Guwahati, Assam State, India (26.106301°N, 91.787199° E), 106 m elevation above sea level, collected on 13 June 2018, by Jayaditya Purkayastha.

Paratypes. Adult females (VR/ERS/ZSI/684, SVL 74.3 mm; VR/ERS/ZSI/688, SVL 75.6 mm and VR/ERS/ZSI/689, SVL 73.2 mm), Adult males (VR/ERS/ZSI/685, SVL 65.4 mm; VR/ERS/ZSI/686, SVL 68.6 mm; VR/ERS/ZSI/687, SVL 70.3 mm); same collection details as holotype.

Diagnosis and comparison with regional congeners. *Cyrtodactylus urbanus* **sp. nov.** can be distinguished from regional congeners by its moderate body size (SVL to 74.0 mm); 9–11 supralabials; 8–10 infralabials; 21–24 longitudinal rows of bluntly conical, feebly keeled dorsal tubercles; tubercles extending beyond base of tail; 38–45 paravertebral tubercles; 30–34 mid-ventral scales; no precloacal groove; 9–12 precloacal pores in a contiguous series, no femoral pores or pits; a row of enlarged scales above and below precloacal pore-bearing scales, slightly larger than pore-bearing scales;. There are 5–6 basal lamellae, 1–4 broken lamellae and 8–10 distal lamellae under 4th finger and 6–7 basal lamellae, 2–3 broken lamellae and 10–12 distal lamellae under 4th toe. Subcaudal scalation of original tail without enlarged plates. Dorsal pattern of 6–7 longitudinal rows of two indistinct transverse pale buff blotches outlined by light edges, light mid-dorsal line. Tail with alternating dark and lighter bands. Iris in life silver-grey with brown reticulations.

Cyrtodactylus urbanus **sp. nov.** can be differentiated from other members of the *C. khasiensis* group by the following characters (see Table 5): 9–12 precloacal pores in males (*versus* 10–28 precloacofemoral pores in *C. ayeyarwadyensis*; 26–39 precloacofemoral pores which may be interrupted by up to 11 unpored scales in *C. guwahatiensis*; 29–37 precloacofemoral pores in *C. tripuraensis*) and 30–34 MVSR (*versus* 37–43 in *C. kazirangaensis*). The new species may be distinguished from *C. septentrionalis* by a slightly lower precloacal pore count in males (9–12 *versus* 13–14), more subdigital lamellae beneath toe IV of the pes (19–21 *versus* 15–20) and fewer scales across the belly (30–34 *versus* 35–38). Furthermore, *Cyrtodactylus urbanus* **sp. nov.** differs from *C. ayeyarwady-ensis* in having a prominent mid-dorsal stripe (absent in *C. ayeyarwadyensis*) and fewer transverse blotches on the dorsum (6–8 *versus* 9–11) *Cyrtodactylus urbanus* **sp. nov.** is very similar to *C. khasiensis*, from which it differs in mean counts across a number of characters as follows: *Cyrtodactylus urbanus* **sp. nov**. has fewer paravertebral tubercles (38–40 *versus* 42–53 in *C. khasiensis*); fewer mid-ventral scale rows (30–34 *versus* 34–42); and fewer apical subdigital lamellae (8–10 *versus* 13–15). The tail pattern in the original tail of the new species has approximately 14 dark bands, the first six similar to spots on the dorsum.

Etymology. The specific epithet is an adjective meaning of or belonging to a city and reflects the urban habitat of the species, through which we also wish to highlight the importance of urban biodiversity. We propose Urban bent-toed gecko as common name for the gecko.

Description of holotype. Adult male, SVL 71.9 mm, with both hemipenes everted. Head just more than onefifth of SVL (HL/SVL 0.23), wider than long (HW/HL 0.68), somewhat depressed (HD/HL 0.52), distinct from neck; loreal region somewhat inflated, interorbital area flat, canthus rostralis not prominent; snout slightly less than half of the head length (SE/HL 0.46), twice as long as orbit diameter (OD/SE 0.53); scales on forehead, canthus rostralis and snout homogeneous. Scales from posterior margin of eyes to nape smaller than those of forehead, roughly hexagonal, juxtaposed and weakly pointed; scales on interorbital and occipital regions heterogeneous, without distinct tubercles. Eye one quarter of head length (OD/HL 0.25); pupil vertical with crenulate margins; supraciliaries small, spiny, decreasing in size towards posterior end of orbit, those on the anterior end of orbit largest; ear opening oval, obliquely oriented, one-tenth of the head length (EL/HL 0.10); eye to ear distance about half eye diameter (OD/SE 0.54). Rostral wider than deep (RL/RW 0.60), partially divided dorsally by weakly developed rostral groove; single much enlarged supranasal on either side, separated by two small internasal, about the same size as enlarged scales on snout; rostral in contact with first supralabials, nasals, supranasals and an internasal; nostrils semicircular, laterally oriented, posterior half covered by nasal pad, each in broad contact with rostral and surrounded by supranasal, first supralabial, and three postnasals; two rows of scales separate orbit from supralabials; mental wider (2.1 mm) than long (1.5 mm), triangular; two well developed postmentals on either side, inner pair more than twice the size (2.6 mm) of and separating outer pair (1.0 mm), in moderate contact (1.2 mm) behind mental; inner postmentals bordered by mental, infralabial I, outer postmental and six gular scales; outer postmental bordered by inner postmental, infralabial I and II, and four gular scales on either side; supralabials (to midorbital position) 10 (right) -9 (left),



FIGURE 5. A: Dorsal view, B: ventral view and C: details of dorsal pholidosis of *Cyrtodactylus urbanus* **sp. nov.** (male holo-type, VR/ERS/ZSI/683) in life.

bordered by a row of large, flat, somewhat elongate scales; infralabials 9, infralabials I to III bordered ventrally by a row of enlarged scales, largest anteriorly.

Body moderately slender, trunk slightly less than half of SVL (TRL/SVL 0.43) with weakly developed ventrolateral folds that are not denticulate; dorsal scales heterogeneous, mostly rounded granules, intermixed with irregularly arranged, enlarged tubercles (2–4 times size of granules), bluntly conical and feebly keeled throughout, becoming more conical and slightly smaller towards flank, largest on the sacral region, ventrolateral folds with single row of scattered enlarged, smooth tubercles; tubercles extend from occipital region beyond the tail base; tubercles on nape smaller than those of dorsum; tail flat, weakly pointed and feebly keeled; 22 rows of dorsal tubercles; 45 paravertebral tubercles; ventral scales much larger than dorsals, smooth, cycloid, imbricate to subimbricate; slightly smaller in size under thighs, no enlarged scales between precloacal pores and vent; scales across the belly 31; gular region with small granular scales throughout except a few rows bordering mental, postmentals and infralabials larger, flat and juxtaposed. Nine distinct precloacal pores in a continuous series, precloacal grooves absent, hemipenal bulge distinct.



FIGURE 6. Head of *Cyrtodactylus urbanus* **sp. nov.** (male holotype, VR/ERS/ZSI/683), A: dorsal view B: lateral view and C: ventral view.

Forearm (FL/SVL 0.15) and tibia (CL/SVL 0.17) short; digits relatively short, strongly inflected at each joint, all bearing robust, recurved claws; subdigital lamellae widened beneath basal phalanx; basal lamellae 4-5-6-6-4 (right manus) and 4-5-5-7-5 (right pes); distal lamellae (intervening rows of nonlamellar granules between basal and distal lamellae series in parentheses): 6(1)-8(2)-10(3)-9(4)-9(2) (right manus) and 7(2)-9(2)-10(2)-11(2)-10(2) (right meanus) and 1 < II < V < III < III < IV (right manus) and I < II < V < III < VI (right pes); scales on the palm and sole smooth, weakly raised, subimbricate; scales on forelimb heterogeneous, comprising flat, subimbricate scales on upper arm, those on forearm heterogeneous, ventral portion covered heterogenous imbricate scales; scales on hindlimbs heterogeneous, dorsal part of thigh and shank with larger scales, intermixed with scattered, enlarged, conical, feebly keeled tubercles; anterior portion of thighs and ventral aspect of hindlimbs with much enlarged, smooth, imbricate scales. Tail original, complete, rounded in cross-section, slender, tapering; Two rows of enlarged, flat, weakly pointed, smooth, tubercles positioned paravertebrally on tail base only, remaining dorsal caudal scales smooth, imbricate with midventral series of paired scales; no enlarged plates.

Colouration in life (Fig. 5). Dorsal ground colouration dark brown. Head has dark brown ground colour with faint yellow patches behind the nasal scales as well as in the supraciliary region. Nape has few cream coloured spots on brown ground colour. The dorsal part of trunk region shows alternating dark and light pattern, a mid-dorsal cream coloured line divides the trunk and extends posteriorly to the level of the cloaca. The dorsal markings are "w" shaped. The same markings continue onto the tail extending to the tail tip, reducing, however, to simple transverse bars on the distal portion of the tail. The caudal region has 14 dark bands alternating with lighter ones. The thigh and hind limbs show indistinct cream coloured blotches or crossbars alternating with dark brown ground colour. Similar pattern observed in the forelimb.



FIGURE 7. Fully everted hemipenis of *Cyrtodactylus urbanus* **sp. nov.** (male holotype, VR/ERS/ZSI/683), A: sulcal view and B: asulcal view.

Hemipenis. The hemipenis of the holotype of *C. urbanus* **sp. nov.** is bilobed, elongated and muscular, but the lobes are not clearly distinguishable or demarcated. The apex seems bulbous and almost round in shape with no ornamentation on the sulcal surface. The length of the lobe of the hemipenis is almost $1/4^{th}$ of its total length (hemepenis length= 5.2 mm, lobe length=2.1 mm). The sulcus spermaticus is clearly bifurcated, goes around the lobe head before entering it. The sulcus spermaticus is deeply grooved. The asulcal surface has mildly rough, granules present on the lobe head. The pedicel is unadorned on both sulcal and asulcal surfaces.

Distribution and Natural History. This species is only known from degraded moist deciduous forests in and around Guwahati, Assam; based on voucher specimens from the type locality, Basistha, and photographic vouchers from Deeporbeel, Garbhanga Reserve Forest, Gotanagar and Rani Reserve Forest. The type series was collected from around the Basistha Temple in Guwahati (Fig. 9) on 13 June 2018 between 1900h and 2100h. The animals were seen to be active between the months of March and November. Being a nocturnal species, they are most active two to five hours after dark and are mostly seen inside rock crevices and small rocky caves which are associated with running hill streams. Gravid females were observed from mid-April to early August. The diet of this species primarily consists of spiders, crickets and other small arthropods. In one instance we also found semi-digested ecdysed skin of *Cyrtodactylus* in the stomach.



FIGURE 8. Type series of Cyrtodactylus urbanus sp. nov. Individuals are labeled by VR/ERS/ZSI specimen number.

	rolotype ralatypes						
Voucher no.	VR/ERS/	VR/ERS/	VR/ERS/	VR/ERS/	VR/ERS/	VR/ERS/	VR/ERS/
	ZSI/683	ZSI/686	ZSI/685	ZSI/687	ZSI/684	ZSI/688	ZSI/689
Sex	М	М	М	М	F	F	F
SVL	71.9	68.6	65.4	70.3	74.3	75.6	73.3
TRL	30.9	32.3	28.6	32.0	33.9	31.2	31.2
BW	13.1	11.7	12.2	11.0	14.6	15.4	15.8
TL	85.0	71.9	85.6	89.8	76.9	80.7	81.6
TW	7.2	6.1	6.8	6.4	7.7	7.2	6.9
HL	19.5	18.6	18.6	18.2	21	19.6	20
HW	13.2	12.9	13	13.5	14.4	14.2	14.1
HD	8.6	7.5	7.0	7.7	8.2	8.2	7.9
FL	10.9	10.3	9.8	10.7	10.7	11.0	10.1
CL	12.3	12.4	12.9	13.5	13.4	13.4	13.4
OD	4.1	3.6	3.4	3.4	3.4	3.7	4.1
NE	5.5	6.5	5.9	5.9	7.2	6.3	6.5
SE	7.6	7.7	7.4	7.8	8.3	8.7	8.3
EE	5.2	5.6	5.2	6.0	6	6.2	5.5
EL	1.6	1.8	1.8	1.3	1.6	1.9	1.2
IN	2.8	1.9	2.7	2.6	2	3	2.2
IO	3.4	2	1.5	3.6	2	2.6	2.6
F1	4.4	3.4	3.9	4.5	3.9	4	3.9
F2	6.3	4.3	5.6	5.6	5.7	4.9	4.9
F3	6.4	4.6	6.1	6.8	7	6.2	6.3
F4	7.8	6.6	6.6	7.5	7.4	7	6.6
F5	5.2	5.3	5.2	6.8	5.9	6.1	5.6
T1	3.8	2.5	3.5	4.4	3.3	3.6	3.8
T2	5.7	5.1	6.4	7.2	6.5	5.9	6.1
Т3	8	7.3	7.7	8.5	8.2	7.4	7.8
T4	8.1	8	9.7	9.2	9.1	8.3	8
Т5	6.5	6.5	7.5	8.3	7.3	7.4	7.9
RL	1.9	1.9	1.7	1.6	1.5	1.7	1.7
RW	3.1	2.6	2.8	2.9	2.7	2.7	2.9
РсР	9	11	12	11	-	-	-
MVSR	31	34	30	31	34	34	34
PVT	38	38	40	40	38	37	40
DTR	22	23	23	23	24	22	23
SL(R/L)	10/9	9/9	8/9	10/10	11/9	10/11	11/11
IL (R/L	9/9	9/8	8/8	8/8	10/10	10/9	10/10
Lam Manus (4th)	19	18	17	19	16	18	17
Lam Pes (4th)	21	20	20	20	20	19	21

 TABLE 4. Morphometric and meristic data for *Cyrtodactylus urbanus* sp. nov. from Basishta, Guwahati, Assam, India.

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Discussion

Northeast India overlaps with the Himalaya and Indo-Burma Biodiversity Hotspots and is rich in biodiversity with numerous endemic species of herpetofauna (e.g. Kamei *et al.* 2012; Datta-Roy *et al.* 2013; Mahony *et al.* 2017; Agarwal *et al.* 2018b,c; Purkayastha & David 2019). Notwithstanding these endemics, which include many new descriptions within the last decade, this vast, hilly region remains poorly studied in terms of herpetofauna. The de-

scription of *Cyrtodactylus urbanus* from Guwahati makes it the second gecko, after *C. guwahatiensis*, known only from in and around Guwahati as well as the fourth *Cyrtodactylus* endemic to Assam and the 12th from northeast India (Agarwal 2018b, c). These findings point towards the importance of studying urban biodiversity of the region.

Guwahati serves as the gateway and economic hub of Northeast India, but the city still retains eighteen hills, eight reserve forests, two wildlife sanctuaries, a Ramsar site and above all, the mighty river Brahmaputra flows along the length of the city. A recent study revealed the presence of 26 species of amphibians, 57 species of reptiles, 214 species of birds, and 36 species of mammals in greater Guwahati (Purkayastha 2018). The hills within the city provide an altitudinal gradient and a rocky environment with hill streams flowing within them, which provide a habitat conducive for *Cyrtodactylus* spp. to thrive. Unfortunately, due to gravel mining, we are fast losing large tracts in the hills, with the type localities of both endemic *Cyrtodactylus* species at the urban fringes of Guwahati bearing the brunt of this habitat destruction.



FIGURE 9. Habitat of Cyrtodactylus urbanus sp. nov., Basistha, Guwahati, Assam

Both *Cyrtodactylus guwahatiensis* and *C. urbanus* **sp. nov.** are only known from Guwahati city, but they have not been encountered at the same locality and are not sister taxa. *Cyrtodactylus guwahatiensis* is only known from the Hengrabari Reserve Forest and its adjoining areas (Assam State Zoo, Geetanagar, Japorigog), whereas *C. urbanus* **sp. nov.** is more widely distributed within and around the city (Garbhanga Reserve Forest, Rani Reserve Forest and their fringes, Basistha, Deeporbeel, Gotanagar). *Cyrtodactylus guwahatiensis* is the strongly supported sister of *C. septentrionalis*, both species are known from localities <15 km from the Brahmaputra and ~40–110 m above sea level. *Cyrtodactylus urbanus* **sp. nov.** is, on the other hand, the poorly supported sister of *C. khasiensis* that is distributed on the northern edge of the Shillong Plateau. More sampling across this landscape is needed to understand species diversity and the distribution of species and clades. One will have to wait and see how many more species remain to be discovered in mountainous Northeast India and if the diversity will parallel that of the relatively better studied Myanmar.

	PcP/ PcFP	MVSR	PVT	DTR	Transverse series of	Mid-dorsal stripe
					blotches on the dorsum	
C. ayeyarwadyensis	10-28 (PcP)	32-37	50	22-24	9–11	absent
C. guwahatiensis	26-39 (PcFP)	30-35	30-35	21-24	8-10	absent
C. kazirangaensis	10-11 (PcP)	37–43	36–38	22-23	6–7	present
C. khasiensis	10-12 (PcP)	34–42	42-53	19–23	9	indistinct
C. septentrionalis	14 (PcP)	35–38	38–42	23-24	6–9	indistinct
C. tripuraensis	29-37 (PcFP)	35–43	44–54	19–21	8-10	absent
C. urbanus sp. nov.	9-12(PcP)	30–34	37–40	22–24	6–8	present

TABLE 5. Diagnostic characters for members of the Cyrtodactylus khasiensis complex. Abbreviations as in methods.

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APPENDIX 1. Specimens examined

- *Cyrtodactylus ayeyarwadyensis*: Holotype (male) CAS 226154; paratypes (males) CAS 216506, CAS 226149–226150, CAS 226153; paratypes (females) CAS 226147, CAS 226152, CAS 226156, USNM JBS8637.
- *Cyrtodactylus guwahatiensis*: Holotype (male) BNHS 2146; referred material (males) (VR/ERS/ZSI/690, VR/ERS/ZSI/691, VR/ERS/ZSI/693, VR/ERS/ZSI/694 and VR/ERS/ZSI/696); (females) (VR/ERS/ZSI/692 and VR/ERS/ZSI/695).*Cyrtodactylus kazirangaensis*: Holotype (male), BNHS 2149; paratypes (males), BNHS 2147 & BNHS 2148
- *Cyrtodactylus khasiensis*: Holotype (male), BMNH 1906.8.10.4; paralectotype ZSI K6199; referred material (males), BNHS 2249–2252

Cyrtodactylus septentrionalis: Holotype (female), BNHS 1990; paratype (male), BNHS 1989

Cyrtodactylus tripuraensis: Holotype (male) BNHS 2244; paratypes (males) BNHS 2236–2238, BNHS 2242–2243, BNHS 2245; paratypes (females) BNHS 2230, BNHS 2239–2241.