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Annotated checklist of the snakes of Bengaluru Urban District, Karnataka, India with notes on their natural history, distribution, and population trends over the last 150 years

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Abstract

Systematic and thorough studies of snake populations across large areas are rare in the tropics. Bengaluru city in southern India has not had a thorough checklist of snakes in over a century, during which time land-use changes, taxonomic revisions, and fluctuating reptile populations have left the current status of snakes of this region unclear. We combine data from snake rescues, visual encounter surveys, and other reliable records to generate a contemporary checklist of 33 snake species (15 of which are novel) present within the Bengaluru Urban District with comments on their apparent habitat preferences. We also provide evidence and insight on six additional species that have not been recorded but potentially occur within the limits of the district. Compared with the earlier checklist, all but 4 species (*Naja naja*, *Ptyas mucosa*, *Daboia russelii*, and *Fowlea piscator*) have shown considerable decline within city limits. Additionally, all of India's "Big Four" medically significant venomous snake species (*Naja naja*, *Bungarus caeruleus*, *Daboia russelii*, and *Echis carinatus*) are found within the district. *Naja naja* and *Daboia russelii* appear to be well-adjusted to urbanization with serious ramifications for human-wildlife conflict and healthcare in the future as the majority of Indian snakebite deaths can be attributed to these two species. The population trajectory of *Daboia russelii* is of particular interest as it was classified as "not common" in the previous checklist, but it is presently one of the most abundant snake species in the area. Our study provides a new baseline that can be used to monitor ophidian population trends going forward.

Key words: Habitat change, Indian snakes, inventory, Ophidiofauna, population trends, Serpentes, Southern India, Squamata, tropics

Introduction

India has roughly 270 snake species, 9% of the world's 3000 odd species of snakes (Uetz et al., 2020). Cataloguing the diversity of snakes and other wildlife within discrete geographic regions is incredibly important to understand local species richness and the distributions of species in the environment. These types of inventories can be carried out at various spatial scales: at the national level (Smith and Taylor, 1945); state level (Patel and Vyas, 2019); the province/district level (Van Pham et al., 2020); or even at an incredibly localized level (Prasad et al., 2018). The city of Bengaluru, also known as the "Silicon Valley of India",

is the capital of Karnataka and is located on the Deccan Plateau in South India. The first and only checklist of the snakes of Bengaluru is over a century old (Nicholson, 1874) and listed only 18 species across 17 genera and 5 families, classifying each species as 'very common', 'moderately common', or 'not common'. While this checklist is a valuable baseline for comparison, there have been numerous taxonomic reappraisals and landscape-level changes associated with the rapid urbanization, agricultural intensification, and geographical expansion of Bengaluru city over the last 150 years. As a result, Nicholson's classification is no longer reflective of species presence and abundance in the present day. Furthermore, the 1874 checklist is incomplete and missing many key species, perhaps an artifact of sampling protocols. Nicholson did not clearly define the boundaries of his study site, but we can infer that it is likely centered around today's central business district and neighboring areas. Herein, we provide an up-to-date species checklist of the snakes known from Bengaluru Urban District with their conservation status, level of protection, and abundance (number of encounters) in each habitat type.

Study Area

Bengaluru Urban District (12.970214°N 77.56029°E; Fig. 1) encapsulates an area of 2196 km^2 and has elevations between 830–962 meters (District Administration, 2021). The climate is moderate, ranging from an average annual low of 18.6 °C to an average annual high of 29 °C, and the district receives a mean 969.8 mm of rainfall annually (World Meteorological Organization, 2010). Ramachandra et al. (2014) estimated decadal population growth at approximately 47% based on the 2001 and 2011 censuses and a growth in geographical area from 69 km^2 in 1949 to 741 km^2 in 2006. The region constitutes an ecotone between the tropical dry deciduous forests (*Terminalia-Anogeissus latifolia-Tectona* series) and the tropical thorn forests (Champion and Seth, 1968; Olson et al., 2001; Vattakaven et al., 2016).

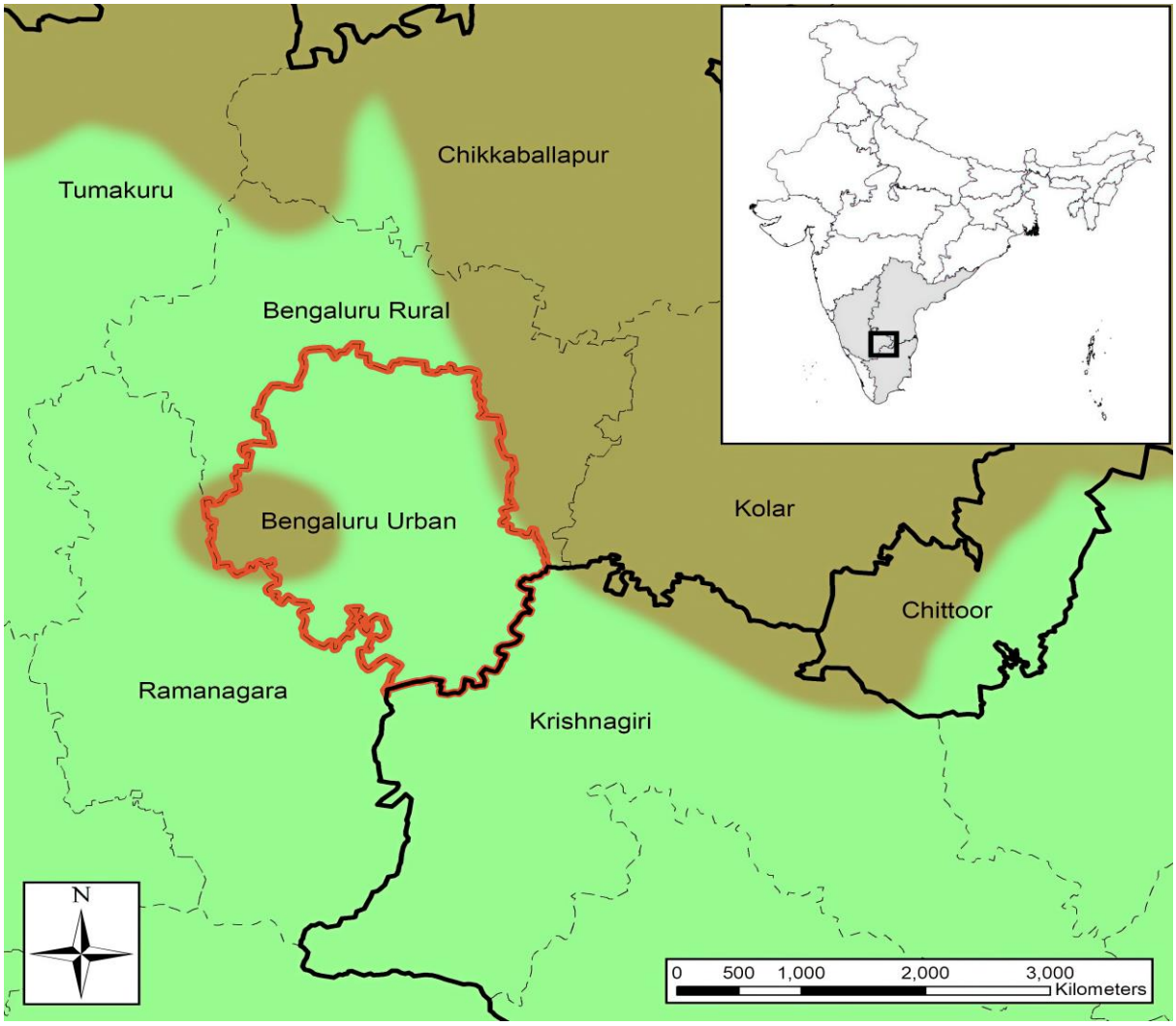

Figure 1: Map of Bengaluru Urban and surrounding districts showing tropical thorn forest (brown) and tropical dry deciduous forest (green) based on Champion and Seth (1968).

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Native vegetation is constituted by *Albizia amara*, *Albizia julibrissin*, *Albizia lebbeck* (Lebbeck), *Albizia odoratissima*, *Anogeissus latifolia* (Indian Sumac), *Azadirachta indica* (Neem), *Capparis zeylanica*, *Dalbergia latifolia* (Bombay Rosewood), *D. sissoo* (Indian Rosewood), *Ficus religiosa*, *F. benghalensis*, *F. racemosa*, *Millettia pinnata* (Honge), *Senegalia catechu* (Catechu), *Senegalia chundra*, *Tectona grandis* (Teak), *Terminalia arjuna* (Arjun), *Terminalia bellirica* (Bibhitaki), *Vachellia luecophloea*, *V. farnesiana* (Huisache), *V. nilotica* (Babul), *Ziziphus mauritiana* (Ber) and *Z. oenopolia*, to name a few. These species can still be readily found on the periphery of the city. However, diversity and overall sizes of trees within the city is rapidly declining due to urban expansion, with the most common species within the city (i.e., *Albizia saman*, *Bauhinia variegata*, *Dalbergia sisoo*, and *Delonix regia*) being ornamental in purpose and oftentimes introduced exotics (Nagendra and Gopal, 2010). This holds true even in urban parks and urban commons within the city, with a gradual reduction in overall canopy cover (Nagendra and Gopal, 2011). Open and abandoned plots in the city tend to be dominated by *Lantana*, *Ricinus*, and a few other species of little ecosystem and conservation value.

Material and Methods

To construct the checklist herein, we conducted year-round field surveys between 2014 and 2020, attended 500+ snake rescue calls, and also compiled observations from other snake rescuers, photographers, and professional herpetologists. Each observation consisted of a photographed specimen with the accompanying GPS location, observation date, and time, which we recorded using HerpMapper (2020). Habitat types were classified as "developed", "agricultural", or "natural" based on the level of urbanization and land alteration. Areas where roads and buildings occupied the majority of the land were considered "developed". Lands primarily consisting of crop fields were considered "agricultural" and those which had been largely unaltered were considered "natural". Specimens were identified using field guides e.g., Whitaker and Captain (2004) and Ramachandran and Raju (2020)—as well as pertinent literature on recent taxonomic changes.

The species names, authorities, number of records from each habitat type, taxa names and abundances as listed by Nicholson (1874), IUCN 2021 status, Wildlife Protection Act (1972) listing, and CITES listing were also recorded. The International Union for Conservation of Nature's Red List of Threatened Species (IUCN, 2021) categorizes the global extinction risk of species into the following classifications: Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Extinct in the Wild (EW), and Extinct (EX). The Indian Wildlife Protection Act (WPA, 1972) categorizes species into five schedules, with Schedule I having the highest protection status and Schedule V having the least. The Convention on International Trade in Endangered Species (CITES, 2021) regulates the trade in imperiled species and categorizes them into three appendices, with Appendix I having the most protection and Appendix III having the least. The map of the study area (Fig. 1) was created using ArcMap 10.8.1 (ESRI, 2011) and modified to depict the ecoregions of Champion and Seth (1968).

Results

A total of 33 snake species spanning 9 families and 25 genera were found to inhabit Bengaluru Urban District (Table 1). Fifteen of these species were not reported in Nicholson (1874) and, thus, are new records for Bengaluru: *Grypotyphlops acutus*, *Indotyphlops braminus*, *I. porrectus*, *Uropeltis jerdoni*, *Python molurus*, *Eryx johnii*, *Sibynophis subpunctatus*, *Boiga flaviviridis*, *B. nuchalis*, *Dendrelaphis tristis*, *Lycodon fasciolatus*, *L. flavicollis*, *L. striatus*, *Platyceps bholanathi*, and *Craspedocephalus gramineus*. The majority of the 33 species inhabiting Bengaluru are listed as 'Not Evaluated' or 'Least Concern' by the International Union for Conservation of Nature (IUCN, 2021); however, two species are considered 'Near Threatened'. All of the species are protected by the Indian Wildlife Protection Act (1972), with one species under Schedule I, five species under Schedule II, and the remaining 27 species under Schedule IV. Eight species are protected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES): one under Appendix I, four under Appendix II, and three under Appendix III.

Species accounts

Family Typhlopidae Merrem, 1820

Grypotyphlops acutus (Dumeril and Bibron, 1844) - Beaked Worm Snake (Fig. 2A).

Grypotyphlops acutus is known only from two records in Bengaluru: one was found moving in an agricultural field after rain during November of 2014, and the other was found under a rock in natural habitat during June of 2016.

Indotyphlops braminus (Daudin, 1803) - Brahminy Worm Snake (Fig. 2B)

Indotyphlops braminus is a fairly abundant snake throughout the year in all habitat types, including highly urbanized areas. It can be found under rocks or moving on the surface after rain. This species is also frequently encountered in bathrooms of buildings during the monsoon season.

Indotyphlops porrectus (Stoliczka, 1871) - Slender Worm Snake (Fig. 2C)

Indotyphlops porrectus is an uncommon snake that is often confused with *I. braminus*. It can be differentiated by its longer, slenderer appearance, and by the presence of white markings on the ventral part of the tail. This species is found under rocks in agricultural fields, natural habitat at the outskirts of the city, and in pockets of undeveloped habitat within the city.

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Table 1: Checklist of the snakes of Bengaluru Urban District including occurrences by habitat type documented in this study, historical abundances, and species status and protection rankings.

Family	Taxon	Common Name	Developed	Agricultural	Natural Habitat	Nicholson, 1874 - Abundance	IUCN	WPA Schedule	CITES
Typhlopidae	*Grypotyphlops acutus* (Dumeril and Bibron, 1844)	Beaked Worm Snake	0	1	1	-	LC	IV	-
	Indotyphlops braminus (Daudin, 1803)	Braminy Worm Snake	14	19	12	-	LC	IV	-
	Indotyphlops porrectus (Stoliczka, 1871)	Slender Worm Snake	0	1	2	-	NE	IV	-
Uropeltidae	*Uropeltis jerdoni* (Ganesh et al. 2021)	Jerdon's Shieldtail	1	11	3	-	LC	IV	-
Pythonidae	*Python molurus* (Linnaeus, 1758)	Indian Rock Python	2	2	3	-	NT	I	Appendix I
Boidae	*Eryx conicus* (Schneider, 1801)	Rough-scaled Sand Boa	2	2	4	*Gongylophis conicus* - Moderately common	NE	IV	Appendix II
	Eryx johnii (Russell, 1801)	Red Sand Boa	0	3	1	-	NT	IV	Appendix II
Sibynophiidae	*Sibynophis subpunctatus* (Dumeril, Bibron and Dumeril, 1854)	Dumeril's Black Headed Snake	0	9	4	-	NE	IV	-
Natricidae	*Amphiesma stolatum* (Linnaeus, 1758)	Buff-striped Keelback	5	45	4	*Tropidonotus stolatus* - Very common	NE	IV	-
	Atretium schistosum (Daudin, 1803)	Olive Keelback	5	4	6	*Atretium schistosum* - Moderately common	LC	II	Appendix III
	Fowlea piscator (Schneider, 1799)	Checkered Keelback	93	93	121	*Tropidonotus quincunciatus* - Very common	NE	II	Appendix III
	Rhabdophis plumbicolor (Cantor, 1839)	Green Keelback	1	4	6	*Tropidonotus plumbicolor* - Moderately common	NE	IV	-
Colubridae	*Ahaetulla oxyrhyncha* (Bell, 1825)	Sharp-nosed Vine Snake	7	15	17	*Passerita mycterizans* - Moderately common	NE	IV	-
	Boiga flaviviridis Vogel and Ganesh, 2013	Yellow-green Catsnake	0	0	1	-	NE	IV	-
	Boiga ruchalis (Gunther, 1875)	Collared Catsnake	0	1	0	-	NE	IV	-
	Boiga trigonata (Schneider, 1802)	Common Catsnake	1	3	4	*Dipsas gokool* - Very common	LC	IV	-
	Coelognathus helena (Daudin, 1803)	Common Trinket Snake	5	33	4	*Cynophis helena* - Moderately common	NE	IV	-
	Dendrelaphis tristis (Daudin, 1803)	Common Bronzeback Tree Snake	3	9	3	-	NE	IV	-
	Liopeltis calamaria (Gunther, 1858)	Calamaria Reed Snake	0	0	2	*Cyclophis calamaria* - Moderately common	NE	IV	-
	Lycodon aulicus (Linnaeus, 1758)	Indian Wolf Snake	0	11	1	*Lycodon aulicus* - Very common	NE	IV	-

Table 1: continued.

Family	Taxon	Common Name	Developed	Agricultural	Natural Habitat	Nicholson, 1874 - Abundance	IUCN	WPA Schedule	CITES
Colubridae	*Lycodon fasciolatus* Shaw, 1802	Russell's Wolf Snake	14	63	2	-	NE	IV	-
	Lycodon flavicollis Mukherjee and Bhupathy, 2007	Yellow-collared Wolf Snake	0	2	1	-	NE	IV	-
	Lycodon striatus (Shaw, 1802)	Barred Wolf Snake	1	3	1	-	NE	IV	-
	Oligodon arnensis (Shaw, 1802)	Banded Kukri	8	24	2	Simotes russellii - Moderately common	NE	IV	-
	Oligodon taeniolatus (Jerdon, 1853)	Variegated Kukri	4	9	0	Oligodon subgriseus - Moderately common	LC	IV	-
	Platyceps bholanathi (Sharma, 1976)	Nagarjunasagar Racer	0	0	1	-	DD	IV	-
	Platyceps plinii (Merrem, 1820)	Banded Racer	3	2	0	Zamenis fasciolatus - Very common	NE	IV	-
	Ptyas mucosa (Linnaeus, 1758)	Oriental Ratsnake	104	199	16	Ptyas mucosus - Very common	NE	II	Appendix II
Viperidae	*Daboia russelii* (Shaw and Nodder, 1797)	Russell's Viper	113	136	4	*Daboia elegans* - Not common	NE	II	Appendix III
	Echis carinatus (Schneider, 1801)	Saw-scaled Viper	0	4	8	*Echis carinata* - Not common	NE	IV	-
	Craspedocephalus gramineus (Shaw, 1802)	Bamboo Pit Viper	0	0	2	-	LC	IV	-
Elapidae	*Bungarus caeruleus* (Schneider, 1801)	Common Krait	4	23	5	*Bungarus arcuatus* - Not common	NE	IV	-
	Naja naja (Linnaeus, 1758)	Spectacled Cobra	248	140	6	*Naga tripudans* - Very common	NE	II	Appendix II

Family Uropeltidae Muller, 1832

Uropeltis jerdoni Ganesh et al. 2021 - Jerdon's Shieldtail (Fig. 2D)

Records exist only from agricultural or natural habitat on the outskirts of the city, particularly in areas with a higher water table (like parts of southern Bangalore). It is found under rocks or on the move after rain and is most active during the monsoon and post-monsoon seasons between June and November. As with other Uropeltids, this species likely aestivates deep underground for the rest of the year (Rajendran, 1985; Cyriac and Kodandaramaiah, 2019), and being fossorial, it likely has a greater risk of extinction (Cyriac and Kodandaramaiah, 2018).

Family Pythonidae Fitzinger, 1826

Python molurus (Linnaeus, 1758) - Indian Rock Python (Fig. 2E)

Python molurus is an uncommon snake in Bengaluru; however, it can be found occasionally in undisturbed habitat, especially in the southern parts of the district bordering the Bannerghatta National Park. The few records from developed areas are from rescue calls for individuals that stray into residential areas. Since it is a large-bodied (up to 750 cm) and conspicuous snake, detection probability is likely much greater in human-inhabited areas.

Family Boidae Gray 1825

Eryx conicus (Schneider, 1801) - Rough-scaled Sand Boa (Fig. 2F)

This species is not frequently encountered as it is fossorial and primarily nocturnal. It is most active between April and September, during which time it may stray into residential areas. *E. conicus* is more common on the outskirts of the district, primarily in rocky terrain, where it can occasionally be found resting between stones. One individual was found on a truck transporting sand to Kengeri in July 2016.

Eryx johnii (Russell, 1801) - Red Sand Boa (Fig. 2G)

Eryx johnii is uncommon in all habitat types and encountered rarely due to its fossorial behavior. It is occasionally seen after rain in agricultural areas and in natural habitats. Due to superstitious beliefs that keeping this snake brings luck, it is often collected illegally and sold. As this species' value is often dependent on the weight of the specimen, several accounts exist of sellers injecting them with toxic substances such as mercury to fetch a higher price, often resulting in the death of the snake soon after. Many individuals have been confiscated from snake charmers in the city.

Family Sibynophiidae Dunn, 1928

Sibynophis subpunctatus (Dumeril, Bibron and Dumeril, 1854) - Dumeril's Black-headed Snake (Fig. 2H)

This species is known from scattered records from the western and southwestern part of the district, between Bannerghatta National Park and Savandurga forests. It is apparently absent from developed areas but can be found in leaf litter or under shaded rocks in natural or agricultural habitats.

Family Natricidae Bonaparte, 1838

Amphiesma stolatum (Linnaeus, 1758) - Buff-striped Keelback (Fig. 3A)

Amphiesma stolatum is uncommon in developed regions, but common at the edges of agricultural fields, especially under fallen debris and rocks. Two color morphs are found in Bengaluru: one with red inter-scale coloration and the other with blue inter-scale coloration (the red morph is more common). It is most active between May and September.

Atretium schistosum (Daudin, 1803) - Olive Keelback (Fig. 3B)

Atretium schistosum is found in many of the less polluted water bodies throughout the district, usually in the vegetation at the shallow edges of lakes and ponds. It is occasionally seen in small tanks in urban backyards where it feeds on guppies (*Poecilia reticulata*), the tadpoles of the Asian toad (*Duttaphrynus melanostictus*), and odonate naiads (Kalki, pers. obs.).

Fowlea piscator (Schneider, 1799) - Checkered Keelback (Fig. 3C)

Fowlea piscator is an extremely abundant species. It is found in almost all water bodies, including highly polluted lakes and drainage systems in urban areas. It can be seen basking on rocks or vegetation surrounding water in the morning, found under rocks or in the water from noon to evening, and seen actively foraging for frogs and fish along the banks of water bodies at night. In Bengaluru, *F. piscator* has been recorded feeding on *Duttaphrynus melanostictus* and *Cnemaspis mysoriensis* (Kalki, 2021a) and is one of the few snakes to frequently swallow prey feet/tail first. *Fowlea piscator* often comes on to dry land to forage and likely gets transported fair distances by flowing water during heavy rains. It is active throughout the year. Whitaker and Captain (2004) speculate that this species is perhaps the most abundant in the country. Our data agree on it being common, but it likely does not dominate our records given that it prefers aquatic habitats and does not enter buildings with the same frequency as *Naja naja*, *Ptyas mucosa*, or *Daboia russelii*.

Rhabdophis plumbicolor (Cantor, 1839) - Green Keelback (Fig. 3D)

Scattered records of *Rhabdophis plumbicolor* exist from pockets of remnant natural or agricultural habitats from all over the district. Anecdotal reports from veteran snake catchers indicate that this species used to be much more common but has since declined in numbers, perhaps due to habitat fragmentation by urbanization. It is a crepuscular species usually observed amongst herbaceous understory vegetation.

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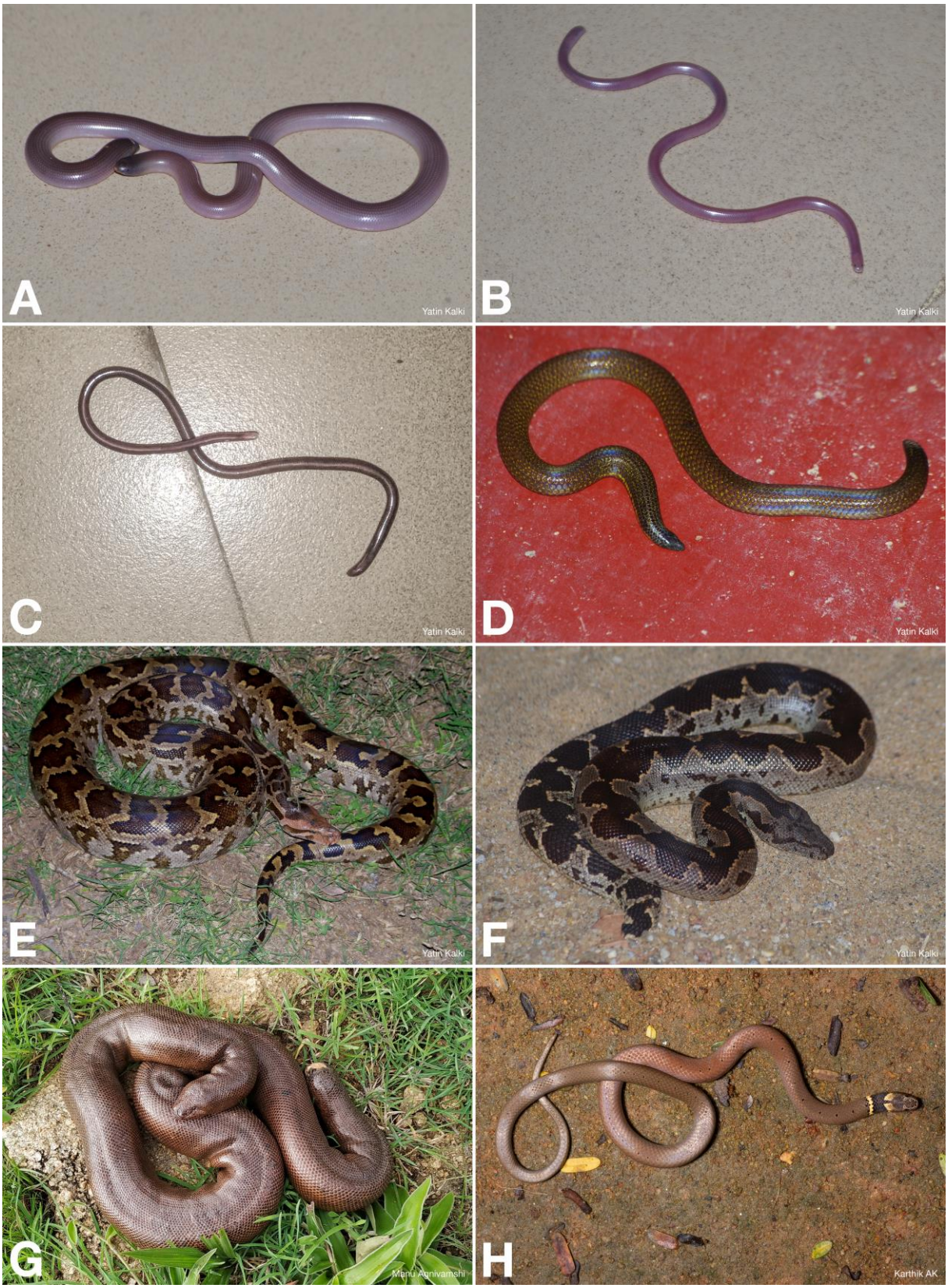

Figure 2: Typhlopidae: *Grypotyphlops acutus* (A), *Indotyphlops braminus* (B), *Indotyphlops porrectus* (C); Uropeltidae*: Uropeltis jerdoni* (D); Pythonidae: *Python molurus* (E); Boidae: *Eryx conicus* (F), *Eryx johnii* (G); and Sibynophiidae: *Sibynophis subpunctatus* (H).

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Figure 3: Natricidae: *Amphiesma stolatum* (A), *Atretium schistosum* (B), *Fowlea piscator* (C), and *Rhabdophis plumbicolor* (D).

Family Colubridae Oppel, 1811

Ahaetulla oxyrhyncha (Bell, 1825) - Sharp-nosed Vine Snake (Fig. 4A)

Ahaetulla oxyrhyncha is uncommon in developed habitats but fairly common in agricultural and natural habitats. It feeds primarily on birds and lizards (Kalki and Weiss, 2020). This species was previously considered *A. nasuta*, a species that is now considered endemic to Sri Lanka (Mallik et al., 2020). Due to its excellent camouflage and habitat preferences, this species does not often come into conflict with people. In natural areas, it is frequently mobbed by birds such as bulbuls (*Pycnonotus* spp.), sunbirds (*Leptocoma*, *Cinnyris* spp.), flowerpeckers (*Dicaeum* spp.), prinias (*Prinia* spp.), tailorbirds (*Orthotomus sutorius*), warblers (*Phylloscopus*, *Acrocephalus*, *Iduna* spp.) and babblers (*Turdoides* spp.) often in mixed-species flocks (Gonsalves, pers. obs.).

Boiga flaviviridis Vogel and Ganesh, 2013 - Yellow-green Cat Snake (Fig. 4B)

This species is only represented by a single record from the extreme southern extent of the district. Further surveys in the Bannerghatta National Park and Ragihalli State Forest will probably lead to the documentation of more individuals. It is known to occur more frequently further beyond city limits (e.g., Ramanagara, Kanakapura, and Tumkur districts).

Boiga nuchalis (Gunther, 1875) - Collared Cat Snake (Fig. 4C)

A single record of this species exists from the southwestern edge of the city. This species is known from both the Western and Eastern Ghats (Ganesh and Arumugam 2015), so it is possible that it occurs more widely around Bangalore as well. The cryptic habits, arboreal tendencies, and naturally low abundances of *Boiga* members, in general, mean that detecting this species is particularly difficult and heavily subject to observer bias (Savidge, 1988; Boback et al., 2020).

Boiga trigonata (Schneider, 1802) - Common Cat Snake (Fig. 4D)

Boiga trigonata is extremely rare in developed areas and uncommon in agricultural and natural habitats. Most records are from the southern part of the district. It is suspected to be common but rarely encountered (Whitaker and Captain, 2004), likely because of its nocturnal and arboreal nature. *B. trigonata* can be observed on trees, bushes, and fences, or crossing roads at night. It is most active from July to October.

Coelognathus helena (Daudin, 1803) - Common Trinket Snake (Fig. 4E)

This species is found in all types of habitats in the district but at relatively low densities. It is occasionally found in developed areas around houses; however, it is more common in agricultural and natural habitats and is frequently found dead on roads. *C. helena* has semi-arboreal habits but is primarily terrestrial in nature.

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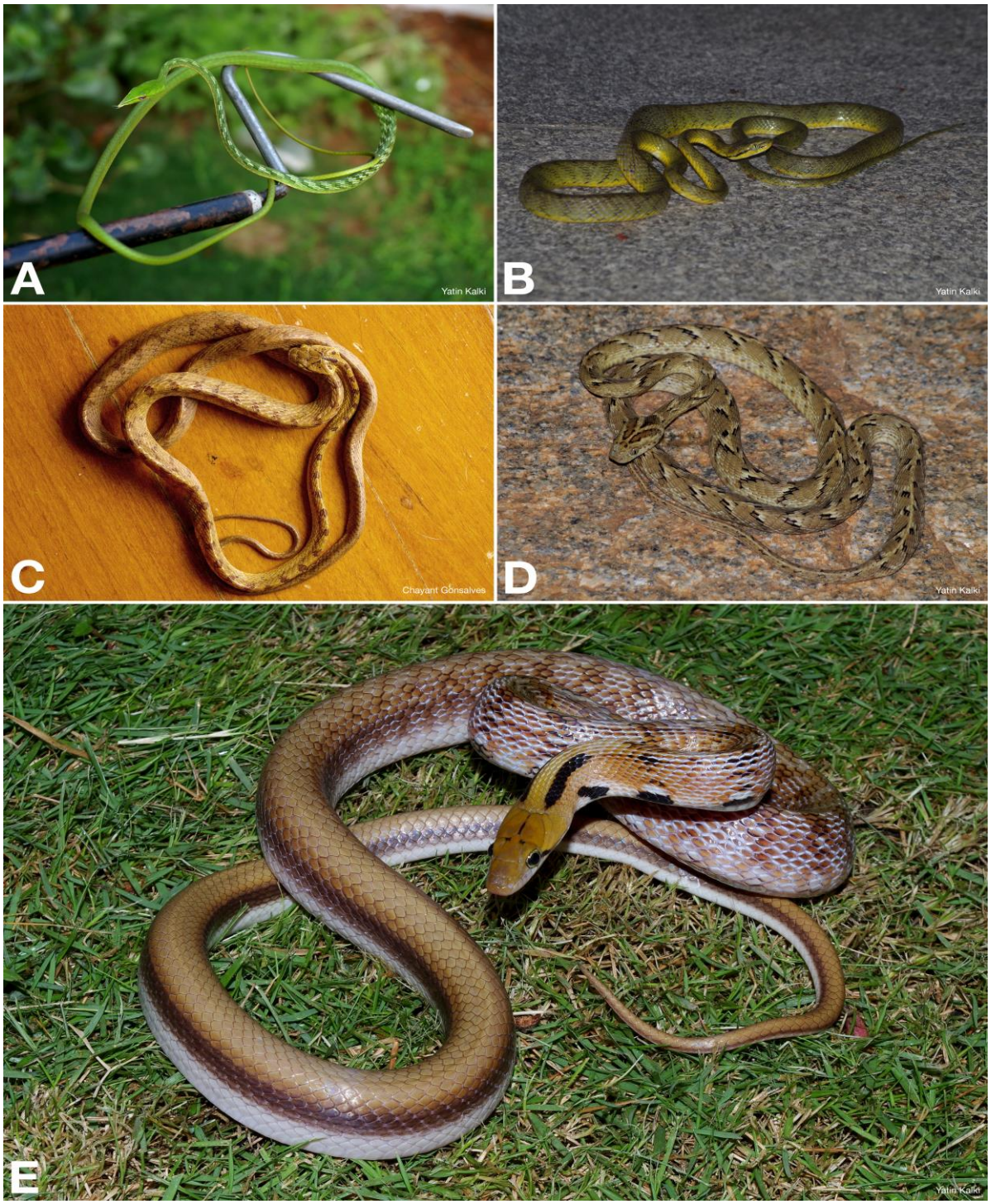

Figure 4: Colubridae: *Ahaetulla oxyrhyncha* (A), *Boiga flaviviridis* (B), *Boiga nuchalis* (C), *Boiga trigonata* (D), and *Coelognathus helena* (E).

Dendrelaphis tristis (Daudin, 1803) - Common Bronzeback Tree Snake (Fig. 5A)

Dendrelaphis tristis is extremely rare in developed areas, but more common in agricultural and natural habitats. It is usually seen on trees or bushes. The few records in developed areas were individuals that had entered homes through windows and balconies. It is occasionally mobbed by birds-prinias (*Prinia* spp.), tailorbirds (*Orthotomus sutorius*), warblers (*Phylloscopus*, *Acrocephalus*, *Iduna* spp.), white-eyes (*Zosterops palpebrosus*), sunbirds (*Leptocoma*, *Cinnyris* spp.), flowerpeckers (*Dicaeum* spp.) and bulbuls (*Pycnonotus* spp.)—during the day (Gonsalves, *pers obs.*).

Liopeltis calamaria (Gunther, 1858) - Calamaria Reed Snake (Fig. 5B)

This species is only known from two confirmed records at the southern extent of the district. Surveys in Bannerghatta

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National Park, Ragihalli State Forest, Bada Manavarthe Kaval Reserve Forest, and Sanvanadurga State Forest will probably yield more records. Anecdotal data suggests that this species was more common even a few decades ago within city limits.

Lycodon aulicus (Linnaeus, 1758) - Indian Wolf Snake (Fig. 5C)

Lycodon aulicus is less common than *L. fasciolatus*. It is known from a handful of records from agricultural and natural habitats in the southern and south-western parts of Bengaluru Urban District. It can be identified by its relatively heavier build, clearly defined collar around the neck, and the absence of dark spots on the labial scales (Ganesh and Vogel, 2018).

Lycodon fasciolatus Shaw, 1802 – Russell's Wolf Snake (Fig. 5D)

Lycodon fasciolatus is found in all habitat types. It is often encountered at night hunting geckos on walls and the sides of houses in developed areas and occasionally found under rocks, tree bark, and in rock crevices in agricultural and natural habitats. This species is known to feed on *Hemidactylus parvimaculatus* and *H. frenatus* in urban areas (Kalki, pers. obs.). By far, it is the most frequently encountered Wolf Snake species in Bengaluru, although it is often misidentified as *L. aulicus*. *L. fasciolatus* was formerly referred to as *L. anamallensis*, but was recently reclassified (Deepak et al., 2021).

Lycodon flavicollis Mukherjee and Bhupathy, 2007 - Yellow-collared Wolf Snake (Fig. 5E)

This species is known from a few records in natural areas in the southwestern part of the district. One isolated record from a highly developed part of northern Bengaluru city may be the result of accidental or deliberate relocation. *L. flavicollis* is known to be more common on the outskirts of the city, particularly around Ramanagara district.

Lycodon striatus (Shaw, 1802) - Barred Wolf Snake (Fig. 5F)

Figure 5: Colubridae: *Dendrelaphis tristis* (A), and *Liopeltis calamaria* (B), *Lycodon aulicus* (C), *Lycodon fasciolatus* (D), *Lycodon flavicollis* (E), and *Lycodon striatus* (F).

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Numerous scattered records of this species exist from different parts of the district, predominantly from agricultural habitat. *Lycodon striatus* seems to have a widespread distribution but occurs at relatively low densities.

Oligodon arnensis (Shaw, 1802) - Banded Kukri (Fig. 6A)

Oligodon arnensis is found in developed, agricultural and natural habitats, but absent from highly urbanized areas. It is often found in and around gardens near houses, where they have been observed feeding on *Cnemaspis mysoriensis* (Kalki, pers. obs.). In natural areas, it can be found under rocks and is frequently seen dead on roads due to vehicular mortality. It is most active between May and August.

Oligodon taeniolatus (Jerdon, 1853) - Variegated Kukri (Fig. 6B)

This species is found in the same habitats as *Oligodon arnensis*, but less frequently in developed areas. Most records of this species are from the eastern and southern parts of Bengaluru. Further outside the city, it seems to be more common than *O. arnensis* (Gonsalves, pers. obs.).

Platyceps bholanathi (Sharma, 1976) - Nagarjunasagar Racer (Fig. 6C)

Platyceps bholanathi is known from a single record at the southwestern extent of Bengaluru Urban District (Lokesh et al., 2021). It inhabits rocky hills with exposed boulders and can be found basking on rocks during the day or under rocks at night. Its scattered distribution across most South Indian states suggests that this species is widespread and associated with rocky hillocks. More extensive exploration of such habitats around Bangalore will likely yield further records.

Platyceps plinii (Merrem, 1820) - Banded Racer (Fig. 6D)

Very few records of this snake exist in Bengaluru—three are known from developed areas in the northern part of the city (2014 and 2016) and another two from agricultural areas on the outskirts of the district (2017 and 2019). It is probably present in natural habitats as well, but not easily encountered. This species was formerly known as *Argyrogena fasciolata*, but was recently reclassified (Deepak et al., 2021).

Ptyas mucosa (Linnaeus, 1758) - Oriental Rat Snake (Fig. 6E)

Ptyas mucosa is common in all habitat types, including highly urban areas. In developed areas, this species is seen most often basking in trees during the day, or foraging in backyard gardens. It is also encountered frequently along the edges of agricultural fields. At night, it usually sleeps in rodent burrows, termite mounds, or coiled up in trees. In urban Bengaluru, *P. mucosa* has been recorded feeding on rats, birds, bats, and toads (Kalki, 2021b).

Family Viperidae Oppel, 1811

Daboia russelii (Shaw and Nodder, 1797) - Russell's Viper (Fig. 7A)

Similar to *Naja naja*, this species is very common in developed and agricultural habitats, and less common in natural habitats. It is usually nocturnal, but occasionally active by day during the winter months—November through January. Juveniles begin appearing in early August. One adult specimen was recorded feeding on a large black rat (*Rattus rattus*) in a highly urban area (Kalki, pers. obs). Adults have occasionally been observed being mobbed by birds—prinias (*Prinia* spp.), tailorbirds (*Orthotomus sutorius*), warblers (*Phylloscopus*, *Acrocephalus*, *Iduna* spp.), white-eyes (*Zosterops palpebrosus*), sunbirds (*Leptocoma*, *Cinnyris* spp.), flowerpeckers (*Dicaeum* spp.) and bulbuls (*Pycnonotus* spp.)—in rural areas (Gonsalves, pers. obs.).

Echis carinatus carinatus (Schneider, 1801) - Saw-scaled Viper (Fig. 7B)

This species is absent in developed areas but can be found in agricultural and natural habitats on the outskirts of the district. This is one of the species most frequently seen dead on roads due to vehicular mortality in the southern and western parts of the district. Anecdotal evidence from rescuers suggests that this species was encountered more frequently up to two decades ago and is rapidly disappearing from the city limits.

Craspedocephalus gramineus (Shaw, 1802) - Bamboo Pit Viper (Fig. 7C)

Craspedocephalus gramineus is known from only two records at the southwestern extent of Bengaluru Urban District, near Bannerghatta National Park. It is seen more frequently in the surrounding districts of Ramanagara, Kolar, Tumkur, and Krishnagiri on forested hillocks and in surrounding agricultural areas. It is usually seen sitting in the ambush position on bushes and trees and has been observed being mobbed by birds—prinias (*Prinia* spp.), tailorbirds (*Orthotomus sutorius*), warblers (*Phylloscopus*, *Acrocephalus*, *Iduna* spp.), white-eyes (*Zosterops palpebrosus*), sunbirds (*Leptocoma*, *Cinnyris* spp.), flowerpeckers (*Dicaeum* spp.) and bulbuls (*Pycnonotus* spp.)—in Ramanagara district (Gonsalves, pers. obs.). *C. gramineus* was previously a member of the genus *Trimeresurus*, but has since been reclassified (Mallik et al., 2021).

Family Elapidae Boie, 1827

Bungarus caeruleus (Schneider, 1801) - Common Krait (Fig. 7D)

This species is very common in agricultural fields, where it preys on snakes and frogs, but less common in developed areas. It can be found on roads at night in natural habitat.

Naja naja (Linnaeus, 1758) - Spectacled Cobra (Fig. 7E)

This is the most common snake species in developed and agricultural habitats, but it is less abundant in natural habitats. It can be found even in the most urbanized areas and is the species most frequently

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encountered on snake rescue calls. Breeding occurs in February through March and hatchlings begin appearing in late May. Adults have frequently been recorded feeding on Asian toads (*Duttaphrynus melanostictus*), black rats (*Rattus rattus*), and three-striped palm squirrels (*Funambulus palmarum*) in urban areas (Kalki, 2020). Juveniles have been seen preying on juvenile Asian toads (*D. melanostictus*) and spotted house geckos (*Hemidactylus parvimaculatus*; Kalki, pers. obs.). This species has been observed utilising sewer systems within cities to avoid detection.

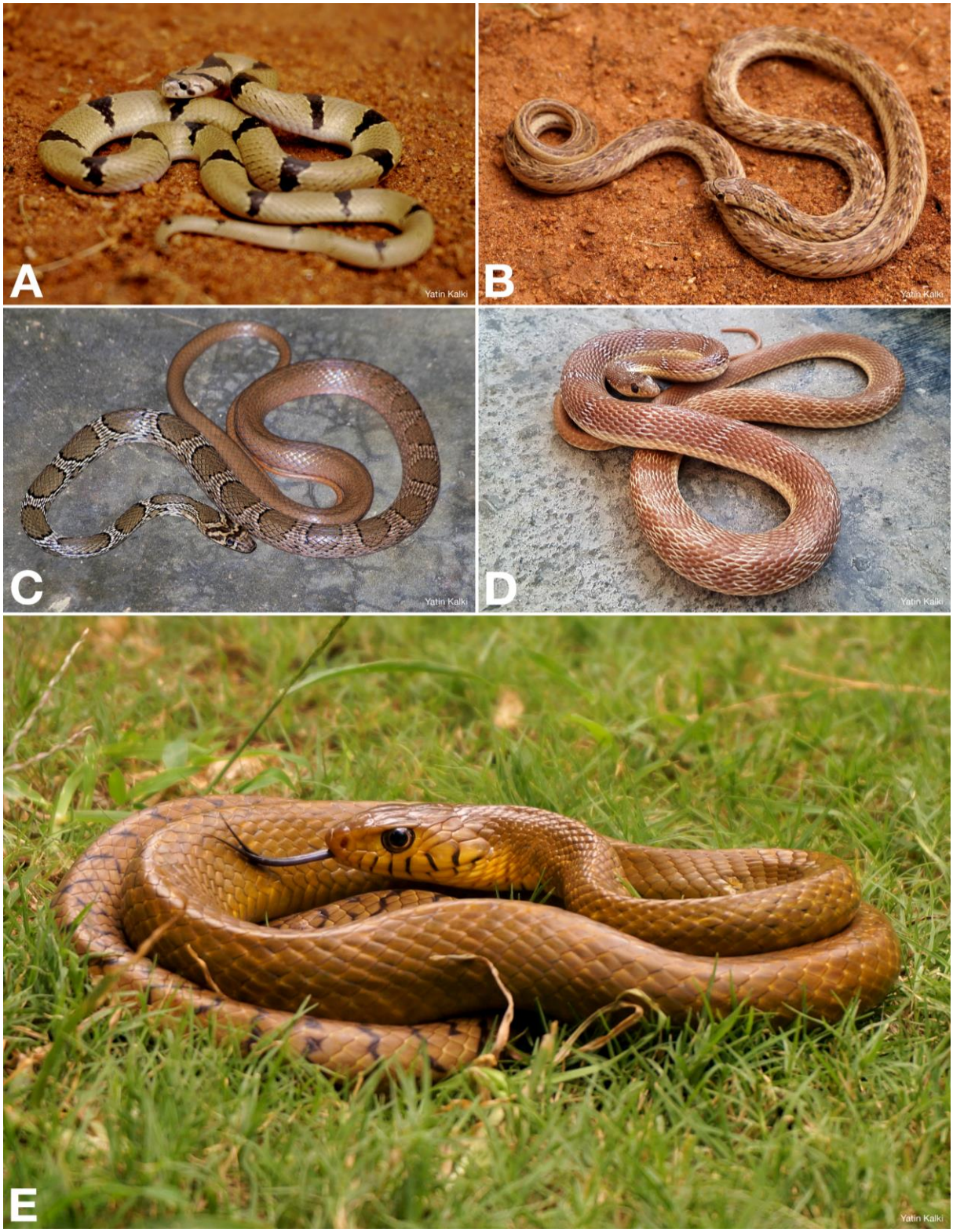

Figure 6: Colubridae: *Oligodon arnensis* (A), *Oligodon taeniolatus* (B), *Platyceps bholanathi* (C), *Platyceps plinii* (D), and *Ptyas mucosa* (E).

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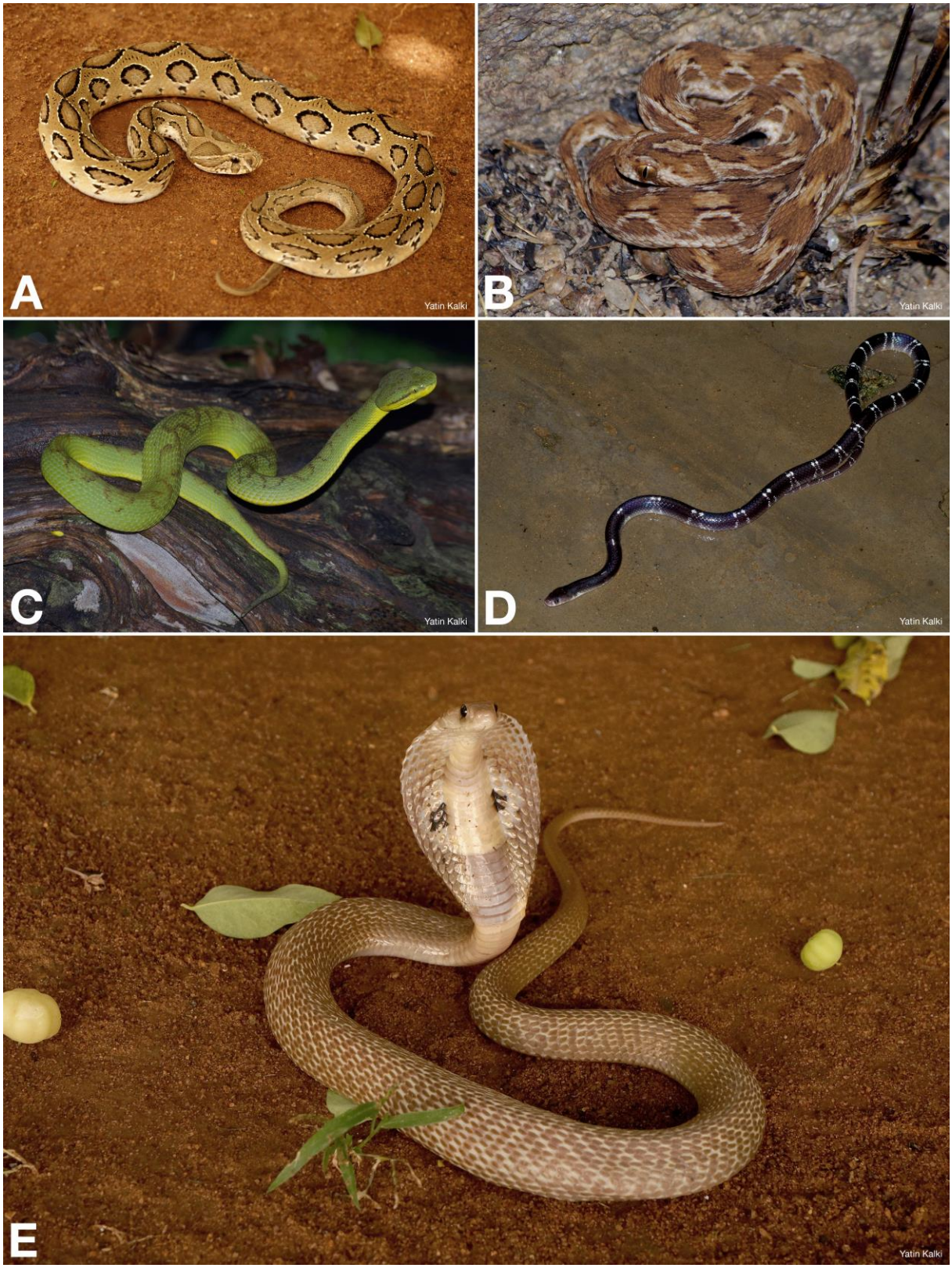

Figure 7: Viperidae: *Daboia russelii* (A), *Echis carinatus* (B), *Craspedocephalus gramineus* (C); *Elapidae*: *Bungarus caeruleus* (D), and *Naja naja* (E).

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Discussion

There are only a few studies that have attempted to construct checklists of snake species for smaller spatial scales like districts or cities in India. Our checklist of 33 species for Bengaluru is considerably larger than similar checklists compiled for other regions: 20 species in western Orissa (Pradhan et al., 2014) and 26 species in Nanded city, Maharashtra (Jadhav et al., 2018). This discrepancy is probably the result of sampling methods; both of those studies only utilized data from snake rescuers and did not conduct field surveys. In our study, some secretive species were detected only through field surveys and were never encountered on rescue calls before (e.g., *Platyceps bholanathi*, *Indotyphlops porrectus*, *Boiga flaviviridis*, *Lycodon flavicollis*, etc.)

This study documented 15 additional snake species in Bengaluru Urban District that were not mentioned in the Nicholson (1874) checklist. None of the species from the families Typhlopidae, Sibynophiidae, Uropeltidae, and Pythonidae were recorded in Nicholson (1874). One boid, 4 colubrids, and 1 viperid were also missing from that list, not including the 3 species that were described after 1874. Of the 18 species that were reported in Nicholson (1874), most have undergone taxonomic revision (see Table 1). The abundances of each species mentioned by Nicholson (1874) are also no longer reflective of the observed occurrences in Bengaluru at present. Nicholson (1874) stated that *Amphiesma stolatum*, *Boiga trigonata*, *Fowlea piscator*, *Lycodon aulicus*, *Naja naja*, *Platyceps plinii*, and *Ptyas mucosa* were very common. Our data indicate that *N. naja*, *P. mucosa*, and *F. piscator* continue to be three very commonly encountered snake species in Bengaluru, but *B. trigonata*, *L. aulicus*, *A. stolatum*, and especially *A. fasciolata* were found to be quite uncommon.

It seems likely that the populations of the latter four species have declined over the last century with increasing urbanization, expansion, and development in Bengaluru (Chandrashekar et al., 2003; D'Souza and Nagendra, 2011); however, it is hard to make definitive statements for the causality of these species declines without quantitative data with which to compare. It is also possible that Nicholson (1874) misidentified other *Lycodon* spp. as *L. aulicus*, erroneously inflating the abundance of that taxon. *Ahaetulla oxyrhyncha*, *Atretium schistosum*, *Coelognathus helena*, *Eryx conicus*, *Liopeltis calamaria*, *Oligodon arnensis*, *Oligodon taeniolatus*, and *Rhabdophis plumbicolor* were all considered moderately common by Nicholson (1874). Our data from 2014 to 2020 suggest that all of these species are less than moderately common, indicating similar declines in populations over the last century. Nicholson (1874) labeled *Bungarus caeruleus*, *Daboia russelii*, and *Echis carinatus carinatus* as uncommon. While *B. caeruleus* and *E. c. carinatus* continue to be uncommon species to this day, *D. russelii* is now the third most common snake species in Bengaluru, particularly in developed areas. Whereas the populations of many other species seem to have declined considerably, the populations of *D. russelii* seem to have benefited from development, perhaps due to the increased abundance of rodent prey available around human habitations (Chernousova, 2011; Hassell et al., 2017). It is important to note that all of India's "Big Four" medically significant snakes—the Spectacled Cobra (*Naja naja*), Common Krait (*Bungarus caeruleus*), Russell's Viper (*Daboia russelii*), and Saw-scaled Viper (*Echis carinatus*)—occur within Bengaluru Urban District. Karnataka state suffers approximately 2,400 annual snakebite deaths and these four species are responsible for the vast majority of snakebite mortality (Mohapatra et al., 2011). Furthermore, *N. naja* and *D. russelii* constitute 41.5% and 18.9% respectively of the snakes encountered by humans in urban Bengaluru city (Kalki, unpub. data), cumulatively making 60.4% of Bengaluru's human-snake encounters potentially deadly. Given the widespread occurrence of both species throughout most of the country, it is likely that they exhibit a similar trend in other Indian cities. Given the trend of increased urbanization favoring populations of *N. naja* and *D. russelii* and that Bengaluru Urban District is the third most populous district in India—with a population size of over 12 million (Macrotrends, 2020)—we are likely to see an increase in human-snake conflict as time progresses.

There are a few other snake species that may potentially occur in Bengaluru Urban District but have not yet been recorded or confirmed. There is an unconfirmed observation of a *Calliophis melanurus* (Shaw, 1802) specimen found by a snake rescuer on the Indian Institute of Science campus several years ago. This observation, if confirmed, would add one more venomous species to the Bengaluru Urban checklist, and thus warrants further investigation. We have documented *Dryocalamus gracilis* and *Lycodon deccanensis* in the rocky hills of the neighboring Tumkur District (Kalki et al., 2020), so these two species potentially occur in similar habitat 80 km away within the Bannerghatta National Park and Ragihalli State Forest in the Bengaluru Urban District. We have also documented *Psammophis longifrons* and *Elachistodon westermanniin* the tropical thorn forests of Tumkur District (Kalki and Gowda, 2021). There is a possibility of these species occurring in the patch of tropical thorn forest habitat in the western part of Bengaluru Urban District. *Psammophis condanarus* (Merrem, 1820) has been recorded from the Mysore Plateau (Ali, 1943; iNaturalist 36156908), so it may potentially occur in Bengaluru Urban District. Further surveys are required to confirm the presence of these species and potentially add to the checklist of the snakes of

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Bengaluru Urban District. Despite being one of the largest urban cities in India, Bengaluru harbors incredible ophidian diversity that needs to be studied in greater detail.

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Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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