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Distribution, Natural History and the Conservation Status of Hemiphyllodactylus typus and Lepidodactylus lugubris (Reptilia: Gekkonidae) in Sri Lanka

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Abstract

Sri Lanka has a rich assemblage of gekkonid fauna. Among Sri Lankan geckos, rare species such as *Hemiphyllodactylus typus* and *Lepidodactylus lugubris* are poorly studied; both are considered vulnerable in national conservation assessments. Detailed ecological studies are needed for robust conservation assessments of these species, especially with the focus on island-wide distribution and microhabitat requirements. This study was conducted via patch sampling to record relative abundance and distribution of *H. typus* and *L. lugubris* based on random walks to 82 locations representing the three major bioclimatic zones of Sri Lanka. Morphological characteristics, behavior, and habitat use of the focal species were recorded. A total of 17 and 14 individuals of *H. typus* and *L. lugubris* were found, respectively, which indicated the low abundance of both species. Both species were nocturnal, arboreal, and did not den with conspecifics; they mostly preferred close-canopy, dense woody vegetation having mature moss-covered tree trunks with peeling barks and crevices over built-up environments. No records on oviposition were noted for either species. Both species were sluggish in their movements, even when disturbed. Currently known populations of both species occur in severely fragmented unprotected small forest patches. Therefore, habitat loss and fragmentation threaten these populations unless protected areas of Sri Lanka are expanded and functional connectivity is established.

Keywords: dry zone, ecology, gecko, hotspot, lizards, morphology, taxonomy, threats.

Introduction

Western Ghats and Sri Lanka is known as 34th biodiversity hotspot in the world due to its unique assemblages of floral and faunal communities and endemism (CEPF, 2007). Among the diverse reptile community of the island (~210 species), the diversity of geckos (Family Gekkonidae) is remarkable; 44 species have been described so far which accounts for 20% of the overall reptilian species richness (Bauer *et al*., 2007; Bauer *et al*., 2010; Wickramasinghe, 2012). Gekkonidae is the second most diverse lizard family, and have successfully exploited a wide variety of habitats across a multitude of global biomes such as arid and semi-arid deserts, rainforests, savannah grasslands, woodlands, scrublands and even built-up environments (Pianka and Pianka, 1976; Pianka and Huey, 1978; Vitt *et al*., 2009; Karunarathna and Amarasinghe, 2011a; Pincheira-Donoso *et al*., 2013). Habitat divergence evident among Sri Lankan geckos also bear testimony for their ecological success (Batuwita and Bahir, 2005; Karunarathna and Amarasinghe, 2010, 2011b, 2012). In Sri Lanka, 44 species (8 genera) of geckos have been recorded of which 35 species (~80%) are endemic (De Silva, 2006; Manamendra-Arachchi *et al*., 2007; Somaweera and Somaweera, 2009; Batuwita and Pethiyagoda, 2012; Vidanapathirana *et al*., 2014).

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According to the Uetz and Hallermann (2014), 32 species of genus *Lepidodactylus* Fitzinger, 1843 and 15 species of genus *Hemiphyllodactylus* Bleeker, 1860 are limited to the Tropical Asia and South Pacific Islands. Each of these genera is represented by only one species in the island, the Indo-Pacific Tree Gecko, *Hemiphyllodactylus typus* Bleeker, 1860 and the Mourning Gecko, *Lepidodactylus lugubris* Dumeril & Bibron, 1836. Currently, these two species have been recorded in few inland and coastal localities (Deraniyagala, 1929, 1932, 1953; Smith, 1935; Ginige, 1994; Manamendra-Arachchi, 1997; Batuwita, 2000; Somaweera *et al*., 2001; Batuwita and Alagiyawadu, 2004; Somaweera and Somaweera, 2009; Karunarathna and Amarasinghe, 2010, 2012). However, studies on general ecology, natural history, systematics, and conservation of these species are limited in Sri Lanka. Both genera have been extensively studied in Southeastern Asia and Pacific Islands, especially on their reproductive ecology, biogeography, social environment, intraspecific interactions, behavior, and foraging ecology; these investigation revealed that both *H. typus* and *L. lugubris* occupying distinct habitats and geographical regions have evolved contrasting behavioral patterns and life history strategies (Brown and Sakai, 1988; Hanley *et al*., 1994; Short and Petren, 2008; Javed *et al*., 2010; Zug, 2010; Fisher *et al*., 2013; Holden *et al*., 2014).

To improve the understanding about these geckos *H. typus* and *L. lugubris*, it is imperative to investigate their natural history, distribution and ecology throughout their native geographic range, especially in areas where these species are understudied. Objectives in this study were to (1) reassess the overall island-wide distribution of the focal species in Sri Lanka; (2) make observations on their behavior, habitat associations, and general ecology; (3) assess threats encountered by the focal species within their distribution range in the island and (4) to provide recommendations for science-based conservation of the focal species. Ecological information on these species will help to understand their niche divergence patterns and phenotypic plasticity across multiple geographies, life history variations and responses to habitat complexity.

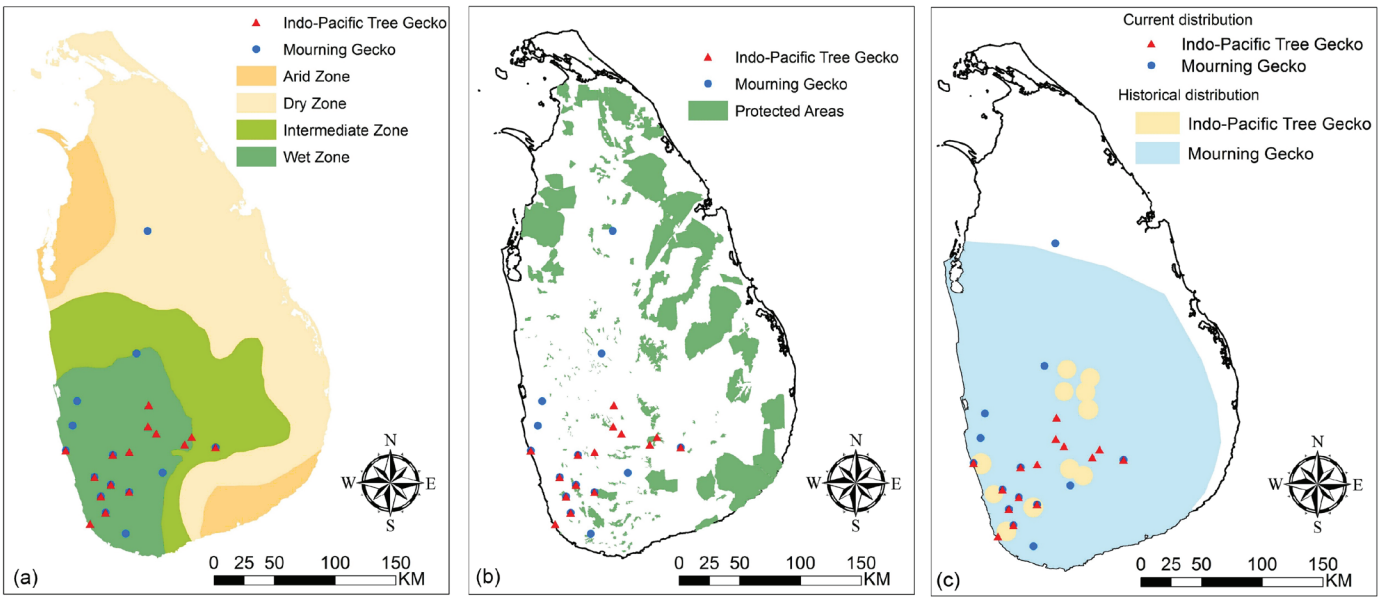

Figure 1: Current distribution patterns of *Hemiphyllodactylus typus* (triangles) and *Lepidodactylus lugubris* (circles) in major climatic zones and protected area network of Sri Lanka. (a) Occurrence of both focal species in the current study at three major bioclimatic zones of Sri Lanka, (b) Occurrence of both focal species in the current study with respect to the existing protected area network (IUCN and UNEP-WCMC, 2015) of Sri Lanka, and (c) comparison of current and historical (Somaweera and Somaweera, 2009) distribution of focal species.

Materials and methods

Data were collected from 82 random and opportunistic field visits to different locations representing three major bioclimatic zones (wet zone, dry zone, and intermediate zone) of Sri Lanka (Figure 1) during 2004-2013 period. The localities were screened in evenings (16:00 h - 19:00 h) and at night times (20:00 h - 24:00 h), when these animals are active. The survey was based on patch-sampling method from randomly selected locations, after first visually encountered focal species/taxa, then actively searched by thoroughly screening of microhabitats such as logs, leaf litter, tree trunks, understory, mid-story foliage, rock-outcrops, earthen crevices, and tree trunks. In addition, build-up environments such as human-inhabited buildings and houses were screened.

Figure 2: Dry mixed evergreen forest habitat in Mihintale buffer zone (dry zone).

A total of 82 sites were patch-sampled. Detailed meristic and morphometric features (dorsal, ventral and lateral body coloration, color patterns, shapes of blotches, scale counts, scale morphology and relative position, south-vent length, tail length, head width, jaw depth, limb length) were recorded. Each captured specimens were photographed with Canon EOS 40D and Nikon D90 SLR digital cameras. The observed individuals were subsequently released to the site of capture. Species were identified using standard taxonomic literature, identification keys, and photographic guides (Das and De Silva, 2005; Deraniyagala, 1953; Somaweera and Somaweera, 2009; Takeda and Ota, 1992). Behavioral observations were carried out on ten individuals of each species at a minimum distance of 2 m between the observer and the focal animal, to minimize any disturbance. A standard thermometer, hygrometer, and lux meter were used to record ambient temperature, relative humidity, and light intensity, respectively, at the site of capture for all focal species.

Figure 3: Well-shaded forest habitat in Kalugala buffer zone (wet zone).

Results

Hemiphyllodactylus typus (Bleeker, 1860)

Indo-Pacific Gecko / Oceanic Gecko

Morphology: This species is relatively smaller and slender (adult HL 7–8 mm, SVL 28–38 mm, and TL 30–35 mm). Generally, dorsal side of the body and limbs are brownish grey, to brown while the dorsal aspect of the tail coloration varied from cream to yellow (Figure 4). A wide 'O' shaped, black patch is present on the occipital area with two median, cream white-colored spots and seven semi-ovular brownish markings on the dorsum with two small lateral stripes. Lateral aspects of limbs and body are brownish-grey with scattered black spots and no lateral conical tubercles. The ventral surface of the head, body and limbs are beige to orange or yellow in color and the gular area is speckled in tiny black spots. The ventral surface of the tail is orange in color, especially in juvenile specimens. Limbs are short and depressed; in males, an angular row of 12-16 preanofemoral pores are present.

Ecology: During the study, 11 adults, five subadults and one juvenile were recorded. From May to June, gravid females carrying one or two eggs were observed. Being arboreal, *H. typus* mostly occurred on moss-covered mature tree trunks (eight individuals in eight separate sites) with peeling bark; on five occasions. This species occupied build-up environments such as cement walls in tea estate bungalows, that have relatively low human occupancy (Table 1). During the dry season, in three instances, it was found in fossorial habitats such as underneath rocks and logs (Table 1). Twelve individuals were observed in three different microhabitat types (seven on tree trunks, three underneath rocks and logs, and two on cement walls) in the wet zone. Five individuals were found in two different microhabitat types (two on cement walls, two on ground and one on tree trunks) of the intermediate zone. The above-mentioned microhabitats were wet, cool, and humid where, temperature of the resting surface varied between 24.8–27.2 ˚C, light intensity and the humidity from 0–295 lux and 67–82%, respectively. According to current observations, they were less active on exposed parts of vertical surfaces, but more active on relatively dark and concealed areas.

H. typus is active during the evening and night (18.00 h–19.00 h and 20.00 h–21.00 h). When disturbed, slowly retreated into the crevices in the tree trunk or underneath the tree bark, but never sought refuge on the ground. *H. typus* is a solitary hunter and never forage with multiple conspecifics. They ascend along tree trunks or other vertical substrates up to 4 m at an average speed of ~0.02 ms^{-1}. *H. typus* co-occurred with other gecko species in the same habitat such as *Hemidactylus depressus, H. frenatus, H. pieresii, H. parvimaculatus, Lepidodactylus lugubris* and *Gehyra mutilata*. It was observed a single adult *H. typus* predated by a relatively larger Sri Lanka house gecko- *Hemidactylus parvimaculatus.*

Distribution: Distribution record during the study as follows; Ratnapura (6˚42'26.17" N and 80˚22'53.07" E / 70 m a.s.l), Kukulugala (6˚41'11.22" N and 80˚15'29.02" E / 280 m a.s.l), Nanperial estate (6˚45'42.01" N and 80˚47'25.72" E / 1380 m a.s.l), Belihuloya (6˚42'37.01" N and 80˚47'12.08" E / 609 m a.s.l), Mungasthenna (6˚41'44.03" N and 80˚47'09.09" E / 534 m a.s.l) in Ratnapura district; Matugama (6˚31'15.31" N and 80˚07'23.00" E / 80 m a.s.l), Panadura (6˚43'06.01" N and 79˚54'33.71" E / 12 m a.s.l), Yagirala (6˚22'38.63" N and 80˚10'15.97" E / 120 m a.s.l), Kalugala (6˚27'55.83" N and 80˚14'41.09" E / 140 m a.s.l) in Kalutara district; Nawalapitiya (7˚03'20.16" N and 80˚31'29.09" E / 650 m a.s.l) in Kandy district; Sinharaja (6˚24'36.60" N and 80˚22'50.18" E / 360 m a.s.l), Telwatta (6˚10'24.04" N and 80˚05'26.61" E / 12 m a.s.l), Beraliya (6˚15'31.14" N and 80˚12'18.88" E / 160 m a.s.l) in Galle district; Koslanda (6˚44'32.99" N and 81˚01'12.18" E / 700 m a.s.l), Ohiya (6˚49'04.00" N and 80˚50'38.56" E / 1600 m a.s.l) in Badulla district; Maskeliya (6˚50'36.35" N and 80˚34'49.66" E / 1300 m a.s.l), Nortonbrige (6˚53'52.10" N and 80˚31'08.24" E / 1100 m a.s.l) in Nuwara Eliya district.

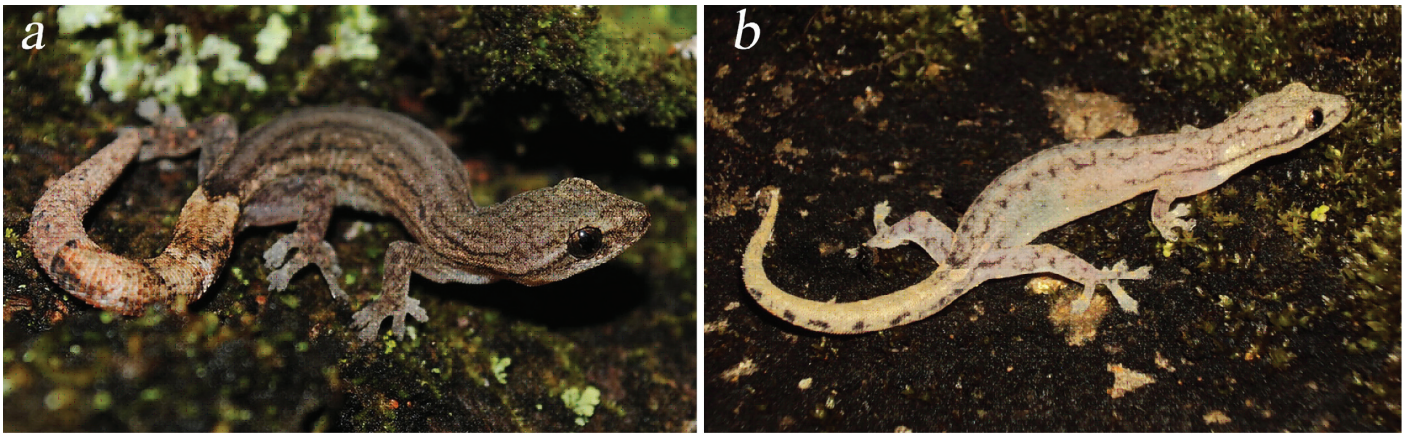

Figure 4: Morphologically similar two individuals of *Hemiphyllodactylus typus* in Sri Lanka (a. Nanperial estate near Balangoda / b. Matugama).

Table 1: Relative abundance of *H. typus* and *L. lugubris* at different habitats types in Sri Lanka.

Habitat type	Relative abundance of focal species	
	H. typus	*L. lugubris*
Arboreal habitats (tree trunks, tree crevices)	8 (47.1%)	9 (64.3%)
Built-up environment (houses, other buildings)	6 (35.3%)	3 (21.4%)
Fossorial habitats (leaf litter, woody debris)	3 (17.6%)	2 (14.3%)

***Lepidodactylus lugubris* (Dumeril and Bibron, 1836)**

Mourning Gecko / Scaly-finger Gecko

Morphology: This species is medium-sized and robust (adult HL 10–12 mm, SVL 35–45 mm and TL 35–40 mm). The color of the body, limbs, and the dorsal side of the tail is varied from brownish grey to dark brown, with an oblique dark line in the interorbital area and in between the eye and the nostrils. There is a wide 'W' shaped black patch on the occipital area with two dorsolateral black lines. Five to seven scattered, doubled 'W' shaped brownish markings are present on the dorsum with small 8-10 stripes. These stripes are brown in color and compressed to the 'W' shaped patches along the tail (Figure 5). Lateral side of the limbs, the body, and the tail are light brown with scattered minute black spots. The lateral margin of the tail has small conical tubercles. Ventral surfaces of the head, the body, and the limbs are beige to cream in color, but the gular area has covered in small black spots and the ventral surface of the tail is bright yellow in color. Dorsal body scales are granular and uniform in size and males had 25-31 preanofemoral pores.

Ecology: This species was only recorded from 14 forested habitats and anthropogenic habitats adjoining the forest edges of wet, intermediate and dry zones (Figure 2). A total of 13 adults and one sub-adult were found in this survey. All the adults were found in dry, shaded, cool vertical surfaces of large trees, and cement walls. The ambient temperature of the surrounding areas was 28.5–29.8 ˚C and the humidity was 65–78%. The microhabitats occupied by this species were mostly arboreal (11 individuals), underneath peeling tree bark and tree trunk crevices. In addition, it was reported from built-up environments such as relatively dark corner of wooded ceiling inside houses, on cement walls and gaps in the window frames of houses (three individuals). During the dusk and night (18:00 h–22:00 h) the temperature of the study areas were varied between 27.3 ˚C - 28.5 ˚C. The light intensity and the humidity on the sites of capture were 0–287 lux and 72–88% respectively. They were slowly (~0.05 ms^{-1}) ascending vertical rock outcrops up to 5 m height. *L. lugubris* is nocturnal and remained inactive diurnally.

During daytime, *L. lugubris* was found within the forest floor leaf litter. The body coloration and the skin pigmentation patterns may have enabled them to camouflage within the leaf litter. Further, *L. lugubris* could move through forest-floor leaf litter with much agility. During April to May, gravid females carrying two or three eggs were observed but not the juveniles or eggs. This species avoids exposed areas of vertical or horizontal surfaces, and their activities have restricted to darker corners of different substrates. *L. lugubris* was co-occurred with many other geckos including *Hemidactylus depressus, H. frenatus H. parvimaculatus, H. pieresii, Hemiphyllodactylus typus* and *Gehyra mutilata*.

Distribution: Distribution records during study are as follows; Makandura (6˚33'11.25" N and 80˚37'35.68" E / 230 m a.s.l), Kukulugala (6˚41'11.23" N and 80˚15'29.10" E / 280 m a.s.l) in Ratnapura district; Matugama (6˚31'15.29" N and 80˚07'23.04" E / 80 m a.s.l), Panadura (6˚43'06.13" N and 79˚54'33.72" E / 12 m a.s.l),

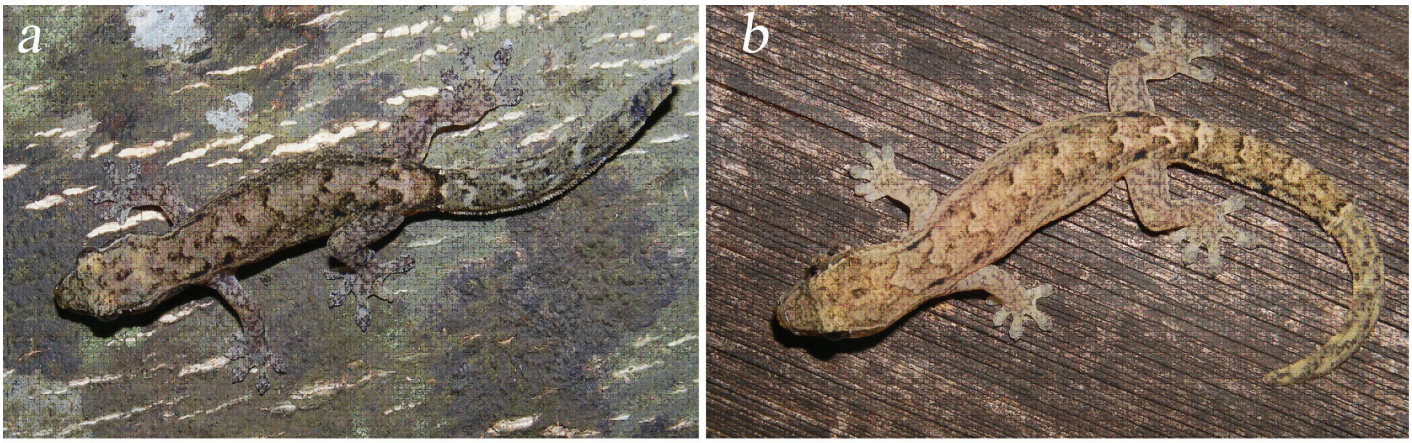

Figure 5: Morphologically similar two individuals of *Lepidodactylus lugubris* in Sri Lanka (a. Panadura/ b. Mihintale).

Yagirala (6˚22'38.60" N and 80˚10'15.56" E / 120 m a.s.l), Kalugala (6˚27'55.81" N and 80˚14'41.12" E / 140 m a.s.l) in Kalutara district; Mawathagama (7˚26'19.75" N and 80˚26'02.30" E / 200 m a.s.l) in Kurunegala district; Sinharaja (6˚24'36.60" N and 80˚22'50.18" E / 360 m a.s.l), Yakkalamulla (6˚06'06.02" N and 80˚21'11.39" E / 45 m a.s.l), Beraliya (6˚15'31.12" N and 80˚12'18.72" E / 160 m a.s.l) in Galle district; Malambe (6˚54'08.88" N and 79˚57'39.82" E / 25 m a.s.l) in Colombo district; Ganemulla (7˚05'08.29" N and 79˚59'37.85" E / 20 m a.s.l) in Gampaha district; Mihintale (8˚20'49.81" N and 80˚30'55.93" E / 180 m a.s.l) in Anuradapura district; Koslanda (6˚44'32.95" N and 81˚01'12.22" E / 700 m a.s.l) in Badulla district.

Discussion

Throughout wet, intermediate, and dry zones of Sri Lanka, these nocturnal, arboreal geckos appeared to be mostly restricted to closed-canopy forests and the forest borders. Somaweera and Somaweera (2009) noted that these species are relatively common in mangrove vegetation and coastal habitats. *H. typus* has previously been recorded from coastal plains of the wet zone in Sri Lanka and certain parts of the central highlands. This is the first observation from the intermediate zone of Sri Lanka. *L. lugubris* has been previously recorded mostly from wet and intermediate zones (Das and De Silva, 2005; Somaweera and Somaweera, 2009). Current observations confirm the occurrence of this species in the dry zone of Sri Lanka. Both species were sympatric in wet and intermediate zones. Further, previous records indicated that *H. typus* is distributed up to 900 m a.s.l. However, this study revealed that *H. typus* exists up to 1600 m a.s.l. while *L. lugubris* is up to 700 m a.s.l.

Both species of geckos are considered as rare although they have a broad distribution in Sri Lanka as well as in the world (Zug, 2010). This survey also supported this claim since it was found only 14 individuals of *L. lugubris* and 17 individuals of *H. typus* from this extensive island-wide survey. Although historical records suggested that both focal species had an extensive geographical range in Sri Lanka, current study revealed that the actual distribution was patchy and discontinuous in both species (Figure 1b) (Deraniyagala, 1939). In their foraging habitats and refuge sites, the focal species did not occur in close proximity to two other sympatric gecko genera, *Hemidactylus* and *Gehyra*. Members of these genera are large sized (60-90 mm in SVL), arboreal, nocturnal, and are likely to interact with the focal species. The larger body size may provide the competitive superiority over the focal species (Newbery, 2007; Hoskin, 2011). Larger gecko species are also known to predate on the smaller ones such as *H. typus* and *L. lugubris* (Dame, 2006). Further, focal species have avoided exposed substrates in their habitats, could be an adaptive predator avoidance behavior (Lima, 1990). During the survey, all individuals of both focal species were always observed in isolation and none of them were appeared to be communal with conspecifics. This observation suggested territoriality or intraspecific

competition within both gecko species. Many species of arboreal lizards are highly territorial and compete for food with conspecifics, and activity defend their retreat sites (Bustard, 1969).

Even though thoroughly examined all potential oviposition sites including tree crevices, trees barks, and under fallen and logs, it could not found any eggs or observations on ovipisition during this decade-long survey. Absence of eggs indicated at least a temporary reduction in their reproductive success for both species. Further, low numbers of juveniles recorded for both species during our survey provide credence for our speculations.

At global scale, both focal species exist as female-only monosexual populations that reproduce parthenogenetically as well as bisexual populations that reproduce sexually (Zug, 2010). In Sri Lanka, both types of populations are known to exist (Das and De Silva, 2005; Takeda and Ota, 1992). When alarmed, individuals of both species curled-up their tails towards their body. When disturbed, individuals of both species moved slowly away from the source of disturbance. Rapid evasive responses such as leaping or jumping (Somaweera and Somaweera, 2009) were not observed in our survey.

Habitat loss and fragmentation might be the most prevalent threats to both species as for most of the reptile fauna of Sri Lanka (De Silva, 2006; Wickramasinghe, 2012; Karunarathna and Amarasinghe, 2013). These geckos have first been listed as endangered (IUCN-SL and MENR-SL, 2007), and later downgraded as vulnerable (MOE, 2012). However, there were no population viability analyses or quantifiable distribution records at the time of the Red List assessment to justify the change in the conservation status. Although both of these species are considered human commensals (Cheke, 2010), there are no substantial evidence to suggest that they have successfully adapted to anthropocentric habitats and anthropogenic disturbances. Since found these species mostly in heavily-wooded habitats, it is likely that they are sensitive to anthropogenic disturbances. In addition, construction of paved roads may obstruct metapopulation dynamics of these species and even result in road kills (Trombulak and Frissell, 2001).

Based on the observations of the current study, anthropogenic habitats such as unmanaged home gardens and less-intensive agro-forestry ecosystems such as multi-crop subsistence farming and organic farming with soil conservation strategies might provide some refuge for these species. The current distribution of both focal species largely fall outside Sri Lanka's protected area network and some of the protected areas that support these species are smaller in size (<6 km^2) and severely fragmented (Figure 1c). The protected area network in the wet zone lowlands of Sri Lanka needs to be expanded to include some of the unprotected forest landscapes and to facilitate functional connectivity among small habitat fragments (Crooks, 2006; Beier, 1998).

The study strongly suggest that an extensive population survey through mark and recapture method be conducted in the same habitats to investigate the long-term persistence of these species in these highly altered anthropocentric landscapes. Lack of robust, reliable life and natural history information on these species, particularly their habitat preferences, raises substantial conservation concerns. Hence, it is important to initiate long-term research on these species to collect information on their reproductive biology, growth, foraging, behavior, habitat selection, and population dynamics. Moreover, *H. typus* and *L. lugubris* have been identified as a species complex distributed across South and South-East Asia (Buden, 2007; Das and De Silva, 2005; Grismer *et al*., 2013; Somaweera and Somaweera, 2009). Batuwita and Alagiyawadu (2004) mentioned that specimens from coastal zones are slender bodied whereas those from the central hills are robust. Given the long-term reproductive and geographic isolation, the Sri Lankan *H. typus* and *L. lugubr*is populations may represent a distinct race that has diverged from those in Asian mainland and other Southeast Asian islands. Molecular phylogenetic studies and other morphometry-based taxonomic studies are needed to test such hypotheses. The findings of the current study would provide baseline data for future studies to explore population ecology and life history strategies of these species in detail.

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