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Microhabitat preferences and guild structure of a tropical reptile community from the Western Ghats of India: implications for conservation

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Abstract

Microhabitat characteristics can be used as a proxy to predict the community structure of associated organisms and evaluate their vulnerability to habitat degradation. Microhabitat-specific and ectothermic taxa (like many reptiles) are among the best models to study responses to changing habitats and climate. We examined the niche breadth and guild structure of reptiles from Agasthyamalai Hills in the southern Western Ghats of India based on microhabitat use data. We recorded a total of 47 reptile species from 1,554 observations comprising two major orders and 11 families. Niche breadth analysis revealed that 45% of reptiles are microhabitat specialists, indicating the importance of protecting their habitats with all structural attributes. Cluster analysis grouped reptile species into four major guilds based on microhabitat preferences. The forest floor-dwelling guild was the largest group with 25 species, followed by the semi-arboreal guild with 12 species. The floor-dwelling guild also exhibited both the highest number of microhabitat specialists ($n = 11$) and globally threatened species ($n = 3$), highlighting the need for preserving ground cover characteristics such as leaf litter, boulders, and open ground for conserving reptiles in the region. Considering the microhabitat specializations within the community, we recommend a dynamic approach to monitor abundance, diversity, and habitat quality across the Agasthyamalai landscape to better conserve its rich reptile diversity.

Introduction

Understanding species-habitat relationships and fine-scale distributions including microhabitat preferences are critical in biodiversity conservation (Michael *et al.* 2010). In regional conservation planning, an ecosystem approach is more effective in preserving species and associated habitats rather than focusing on only rare species (Hierl *et al.* 2008; Harvey *et al.* 2017; Marini *et al.* 2019). A guild-based approach can reveal habitat associations, requirements, and behavioural adaptations of different species of a community, which ultimately helps in implementing effective habitat conservation across multiple species (Bishop & Myers 2005). However, most of such functional analyses are restricted to bird communities (Holmes *et al.* 1979; Nally 1994; Caprio *et al.* 2009; Korňan *et al.* 2013) and have rarely been addressed in herpetofauna (Inger *et al.* 1987; Michael *et al.* 2010; Michael *et al.* 2015). A recent study on temperate Australian reptiles highlighted that guild-based analysis is useful for developing habitat management strategies for multiple species in human-modified landscapes (Michael *et al.* 2015).

Reptiles are more associated with habitat structure than vegetation composition (Webb & Shine 2000; Garden *et al.* 2007). Narrow distribution limits and niche requirements make reptiles highly susceptible to threats such as habitat loss and degradation (Gibbons *et al.* 2000). Being ectotherms, reptiles are often adapted to specific microhabitats and associated microclimatic conditions, so availability and preference for microhabitats can be indirect evidence of resource limitation (Abrams 1980; Whitfield & Pierce 2005). Collecting microhabitat data is important for executing effective habitat management and conservation strategies for reptiles (Michael *et al.* 2015).

In this study, we examined microhabitat preferences of a tropical reptile community to understand community structure and inform targeted habitat management strategies within the Western Ghats biodiversity hotspot of India. The Western Ghats, also known as the Sahyadri, is one of the richest biodiversity hotspots in the world and is also a UNESCO World Heritage site (Myers *et al.* 2000). This region covers an area of 140,000 km^2 and stretches 1,600 km along the western coast of the Indian Peninsula (Rodgers *et al.* 2002). These mountains are often ignored in conservation planning, have high species endemism, with 62% of reptile species endemic to the region (Das *et al.* 2006). Also, studies show substantial evidence of local

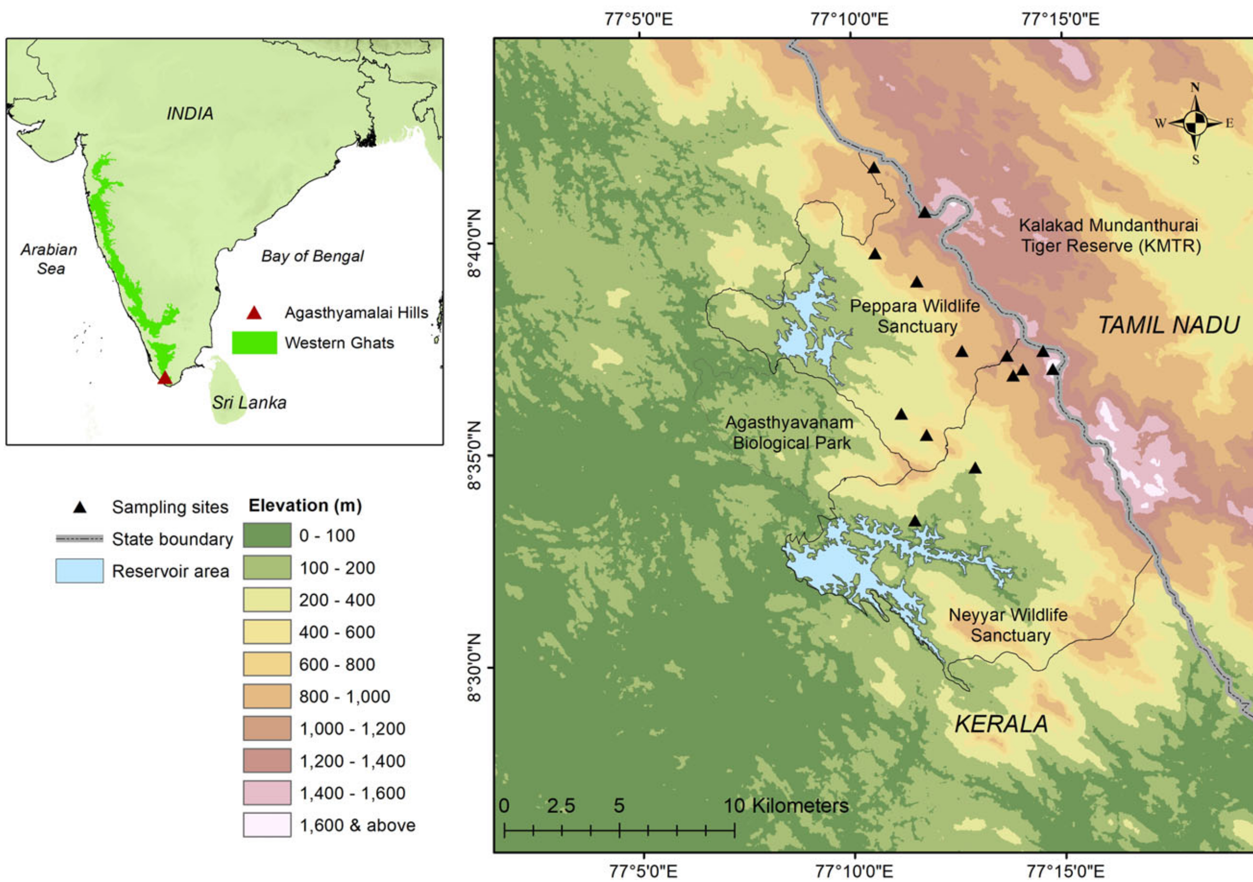

Figure 1. Sampling sites within Agasthyamalai Hills and study area location within the Indian Peninsula (inset).

endemism in the partially isolated hill ranges of the Western Ghats (Inger *et al.* 1987). However, microhabitat preferences of reptiles are not well-known, limited to very few species in this region (Inger *et al.* 1987; Chandramouli 2011). Nevertheless, recent discoveries and new distribution records of reptiles (Jins *et al.* 2014; Pal *et al.* 2018; Mallik *et al.* 2019; Deepak *et al.* 2020) establish the southern Western Ghats as a key region harbouring many unexplored base lineages of reptiles that need urgent and tailored conservation efforts. One such conservation priority zone within the southern Western Ghats biodiversity hotspot is the Agasthyamalai-Periyar landscape (Das *et al.* 2006). This landscape is subject to significant pressure from different anthropogenic activities such as tourism and other human interventions resulting in habitat degradations (Jose *et al.* 2011; Panigrahi & Jins 2018).

In this context, we categorize reptiles into generalists and specialists with respect to their microhabitat use, evaluate the guild structure of the community based on microhabitat preferences, and derive conservation implications based on microhabitat associations.

Methods

Study site

We conducted this study in Agasthyamalai Hills (8.4°–8.8°N and 77.0°–77.4°E), part of the Agasthyamalai Biosphere Reserve (ABR), at the southern end of the Western Ghats. The western slope (windward side) of the Agasthyamalai Hills was the focal study area, comprising of two major protected areas—Neyyar and Peppara wildlife sanctuaries in the Kerala State (Figure 1). The focal study area covers an area of approximately 250 km^2 with elevation ranging from 50–1,868 m a.s.l. The windward side of the Agasthyamalai Hills receives high rainfall (2000–5000 mm annually) with two to three dry months annually (Ramesh *et al.* 1997; Varghese & Balasubramanyan 1999).

The Agasthyamalai region is well-known for its high plant diversity and endemism (Nayar 1996; Manju *et al.* 2009). The vegetation of the area changes significantly with elevation and supports four major vegetation types: (1) southern moist mixed deciduous forest (<400 m a.s.l.); (2) west coast semi-evergreen (400–600 m a.s.l.); (3) west coast tropical evergreen (600–1200 m a.s.l.); and (4) southern hilltop tropical evergreen (>1200 m a.s.l.) (Champion & Seth 1968). The deciduous and evergreen forests up to 1200 m a.s.l. are comprised of tall trees ranging from 10–35 m in canopy height. In contrast, the hilltop forest is dense, stunted evergreen vegetation with canopy height reaching a maximum of up to 10 m, mixed with open rocky and grassy areas (Varghese & Balasubramanyan 1999).

Data collection

We sampled reptile communities in Agasthyamalai Hills from April 2012 to December 2014 using time-constrained visual encounter surveys (VES), covering all major habitats and elevation gradients (100–1,868 m a.s.l.). VES is a time-constrained technique (Campbell & Christman 1982; Crump & Scott 1994), which involves surveying an area or habitat for a prescribed time and systematically searching for animals in all possible microhabitats. The total search time was expressed in person-hours and each sample consisted of a 1-hour search by two people (i.e. two person-hours). Sampling was restricted to 08h00 and 18h00, and searches involved turning rocks and fallen logs, racking through leaf litter, scanning vegetation, branches, and bark of trees. When possible, we identified all individuals to species; however, we classified taxonomically uncertain species as unknown or comparable (*cf.*) species at the genus level for analyses. We recorded microhabitat use for each species based on the substratum used by a particular individual at the time of observation. We conducted a total of 1,304 VES person-hours, and details of sampling effort in each elevation zone are provided in the supplementary file (Table S1).

We assigned all species observations to 15 broad microhabitat categories representative of the study area (Inger *et al.* 1987). The 15 microhabitats identified include (1) on tree buttress (BT); (2) in rock crevice (RC); (3) on open ground (OG); (4) on ground with grass or herb cover (GG); (5) in tree hole (TH); (6) inside water (IW); (7) in leaf litter (LL); (8) on log (OL); (9) on rock (OR); (10) on shrub stem (OS); (11) on tree trunk (TT); (12) under tree bark (UB); (13) under soil surface (UG); (14) under log (UL); and (15) under rock (UR).

Data analysis

All statistical analyses were carried out in the R statistical language (R Core Team 2019) with various packages (see below).

Niche breadth

To determine specialists vs. generalists based on microhabitat use, we conducted a niche breadth analysis. We calculated niche breadth using the CRAN package 'spaa' (SPecies Association Analysis) (Zhang *et al.* 2013) using frequency distributions of species under different microhabitat categories. We used Levin's measure of niche breadth (Pianka 1973), derived from Simpson's diversity index (Simpson 1949).

$$B = \sum_{i=1}^{n} Pi^2$$

where B is the microhabitat niche value, Pi is the proportion of i^{th} microhabitat category; B varies from 1 to n based on the Pi values. We classified species with B value <2 as microhabitat specialists and ≥2 as microhabitat generalists based on a natural break in the histogram of niche breadth values (Figure 2). Species with less than two observations were excluded from classifying specialists and generalists (Michael *et al.* 2015). In the present analysis, species with less than five observations were classified as 'predicted specialists or generalists' given the limited data.

Guild structure

For guild analysis, we used standardized frequencies (percentage) instead of actual counts to avoid biases due to large variations in the number of observations of different species in different microhabitat categories (Michael *et al.* 2015). We then created a Bray–Curtis dissimilarity matrix from these standardized frequency distributions. We conducted hierarchical cluster analysis on this distance matrix using the 'single linkage' method (nearest neighbour clustering) which generates clusters based on the minimum distance between the species (Pianka 1980). We carried out these analyses using the 'vegan' package in R code (Oksanen *et al.* 2013) and categorized species groups into guilds based on general characteristics of the clusters generated (Michael *et al.* 2015).

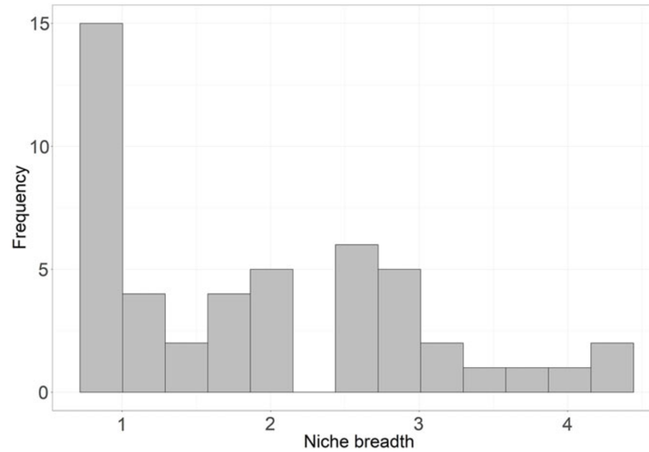

Figure 2. Frequencies of niche breadth values of all reptiles observed during the study.

Results

We recorded 47 reptile species from 1,554 observations comprising two major orders (Squamata and Testudines) and 11 families. These 47 species consisted of 24 lizards, 22 snakes and one tortoise (*Indotestudo travancorica*). Overall, nearly half (47.55%) of observations were attributed to two skink species: *Eutropis macularia* ($n = 548$, 35.26%) and *Sphenomorphus dussumieri* ($n = 191$, 12.29%). Five species were observed only once during the sampling period, four of which were snakes and the other was a lizard (*Varanus bengalensis*). We obtained microhabitat data for all 1,554 observations and calculated niche breadths. After excluding species with less than two observations, we were able to include 42 species (1,549 observations) in our analysis.

Niche breadth

Niche breadth values varied from 1.00 to 4.44 based on differences in microhabitat use among species (Table 1). We classified 19 (45%) species as microhabitat specialists and 23 (55%) species as generalists. Specialists included nine lizards, nine snakes, and one tortoise species. Family Pareidae (Xylophiinae) showed relatively high niche breadth ($B = 2.67$); however, this family was represented by a single species, *Xylophis captaini*, which is a burrowing and litter-dwelling snake. Family Gekkonidae exhibited the highest average niche breadth ($n = 7$, $B = 2.53$), followed by Scincidae ($n = 8$, $B = 2.49$) and Agamidae ($n = 8$, $B = 2.28$). Although we included 42 species (with at least two observations) for categorizing specialists or generalists, we classified 18 species with less than five observations as 'predicted specialists or generalists' (Figure 3).

Guild classification

Hierarchical clustering classified reptiles into four main guilds based on microhabitat utilization: (1) arboreal; (2) semi-arboreal; (3) forest floor-dwelling; and (4) rock-dwelling (Figure 3). Of these, the forest floor-dwelling guild formed the largest group with 25 species (9 snakes, 15 lizards, and a tortoise), including subgroups such as litter-dwelling, open ground-dwelling, and burrowing

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Table 1. List of reptile species (from VES), with number of observations (#), niche breadth (B), and microhabitat categories.

Scientific name		Common name	#	*B*	Microhabitats
SQUAMATA					
GECKONIDAE					
1	*Cnemaspis cf. australis* Manamendra-Arachchi *et al.* 2007	Southern day gecko	83	4.39	BT, CR, HT, LL, OG, OR, TT, UR
2	*Cnemaspis smaug* Pal *et al.* 2021	–	48	2.65	BT, CR, OL, OR, TT, UB, UL, UR
3	*Cnemaspis littoralis* Jerdon 1853	Coastal day gecko	52	1.27	BT, LL, OS, TT
4	*Cnemaspis maculicollis* Cyriac *et al.* 2018	–	2	1.00	UR
5	*Cnemaspis nairi* Inger *et al.* 1984	Ponmudi day gecko	16	3.88	BT, CR, HT, LL, OR, TT, UR
6	*Cnemaspis beddomei* Theobald 1876	Beddome's day gecko	3	1.00	UR
7	*Cnemaspis sp.*	–	35	3.17	BT, CR, HT, LL, OL, TT, UR
8	*Hemidactylus cf. frenatus* Duméril & Bibron 1836	Asian house gecko	17	2.86	BT, HT, OL, TT, UB, UR
AGAMIDAE					
9	*Calotes calotes* Linnaeus 1758	Common green forest lizard	17	3.25	GG, LL, OG, OS, TT
10	*Monilesaurus ellioti* Günther 1864	Ellioti's forest lizard	82	2.87	BT, CR, LL, OG, OL, OR, OS, TT
11	*Calotes grandisquamis* Günther 1875	Large-scaled forest lizard	4	2.67	TT, OS, OR
12	*Calotes nemericola* Jerdon 1853	Nilgiri forest lizard	2	2.00	OS, TT
13	*Calotes versicolor* Daudin 1802	Indian garden lizard	55	3.50	BT, GG, LL, OG, OR, OS, TT
14	*Draco dussumieri* Duméril & Bibron 1837	South Indian flying lizard	22	1.00	TT
15	*Agasthyagama beddomii* Boulenger 1885	Indian kangaroo lizard	105	1.76	LL, OG, OR
16	*Psammophilus dorsalis* Gray 1831	South Indian rock agama	78	1.20	CR, GG, OR, UR
SCINCIDAE					
17	*Eutropis carinata* Schneider 1801	Common keeled skink	33	4.44	BT, CR, GG, LL, OG, OR, TT
18	*Eutropis clivicola* Inger *et al.* 1984	Mountain skink	3	1.80	OG, LL
19	*Eutropis macularia* Blyth 1853	Bronze grass skink	548	1.17	BT, CR, GG, LL, OG, OR, OS, TT, UR
20	*Kaestlea travancorica* Beddome 1870	Travancore cat skink	4	2.67	GG, LL, OR
21	*Lygosoma punctata* Gmelin 1799	Spotted supple skink	2	1.00	UR
22	*Ristella guentheri* Boulenger 1887	Günther's cat skink	13	2.77	CR, LL, OG, UG, UR
23	*Ristella travancorica* Beddome 1870	Travancore cat skink	35	2.45	LL, UL, UR
24	*Sphenomorphus dussumieri* Duméril & Bibron 1839	Dussumier's litter skink	191	3.61	BT, CR, LL, OG, OL, OR, OS, TT
VARANIDAE					
25	*Varanus bengalensis* Daudin 1802	Bengal monitor	1	1.00	OR
GERRHOPILIDAE					
26	*Gerrhopilus cf. beddomii* Boulenger 1890	Beddome's Worm Snake	2	2.00	UG, UR
UROPELTIDAE					
27	*Teretrurus sanguineus* Beddome 1867	Western shieldtail	11	1.42	UG, UR
28	*Uropeltis liura* Günther 1875	Ashambu shieldtail	2	2.00	UG, UR
COLUBRIDAE					
29	*Ahaetulla travancorica* Mallik *et al.* 2020	Travancore vine snake	7	1.69	GG, OS
30	*Ahaetulla isabellina* Wall 1910	–	13	1.35	GG, OS
31	*Proahaetulla antiqua* Mallik *et al.* 2019	–	2	1.00	OS
32	*Boiga sp.*	–	2	2.00	OS, TT

(*Continued*)

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Table 1. (*Continued*)

Scientific name		Common name	#	*B*	Microhabitats
33	*Boiga cf. thackerayi* Giri *et al.* 2019	Thackeray's cat snake	4	2.67	CR, OR, OS
34	*Boiga nuchalis* Günther 1875	Collared cat snake	1	1.00	OS
35	*Boiga trigonata* Schneider 1802	Common cat snake	1	1.00	UR
36	*Dendrelaphis grandoculis* Boulenger 1890	Large-eyed bronzeback tree snake	3	1.80	OS, TT
37	*Lycodon travancoricus* Beddome 1870	Travancore wolf snake	2	1.00	UR
38	*Ptyas mucosa* Linnaeus 1758	Indian Rat snake	8	1.28	OG, OS
39	*Fowlea cf. piscator* Schneider 1799	Checkered keelback	1	1.00	IW
40	*Hebius beddomei* Günther 1864	Beddome's keelback	7	2.88	LL, OG, OR
41	*Hebius monticola* Jerdon 1853	Montane keelback	2	2.00	OG
PAREIDAE (Xylophiinae)					
42	*Xylophis captaini* Gower & Winkler 2007	Captain's wood snake	4	2.67	LL, UG, UR
ELAPHIDAE					
43	*Ophiophagus hannah* Cantor 1836	King cobra	1	1.00	OG
	VIPERIDAE				
44	*Hypnale hypnale* Merrem 1820	Hump-nosed pit viper	6	1.80	LL, OG
45	*Trimeresurus macrolepis* Beddome 1862	Large-scaled green pit viper	2	1.00	OS
46	*Trimeresurus malabaricus* Jerdon 1854	Malabar pit viper	20	2.78	BT, LL, OG, OL, OR, OS
TESTUDINES					
TESTUDINIDAE					
47	*Indotestudo travancorica* Boulenger 1907	Travancore tortoise	2	1.00	LL

species. The arboreal guild was comprised of four lizard species. The semi-arboreal guild consisted of twelve species, including eight snakes and four agamid lizards. The rock-dwelling (cryptozoic) guild was comprised of a single species, *Psammophilus dorsalis,* which is found exclusively on rock or within rock crevices. Based on niche breadth values, the forest floor-dwelling group contained the maximum number of specialists ($n = 11$), followed by the semi-arboreal group ($n = 5$). Moreover, an exclusively litter-dwelling group ($n = 6$), within the forest floor-dwelling guild, contained five specialists, three of which are listed under IUCN-threatened species classifications: *Agasthyagama beddomii* (Endangered), *Eutropis clivicola* (Endangered), and *Indotestudo travancorica* (Vulnerable) (see Figures 3 and 4).

Discussion

We found that many reptiles in the study area have relatively narrow niche breadths, making them potentially more vulnerable to habitat degradation than habitat generalists with larger niche breadths. The presence of a high number of specialists ($n = 19$) highlights the significance of the Agasthyamalai landscape for reptile conservation. As habitat fragmentation and disturbances are already reported from the region (Ramesh *et al.* 1997; Jose *et al.* 2011), further degradation of microhabitats may increase the susceptibility of reptiles to population decline and affect the survival of many habitat specialists.

Our cluster analysis revealed that forest floor-dwelling reptiles (both open ground and leaf litter species) dominate the reptile community in this study area. We also found that the forest floor guild contains more microhabitat specialists ($n = 11$) and is a group that is likely to be most vulnerable to habitat degradation like forest fires. Most of the species in this guild have strong associations with leaf litter. For example, some of the IUCN-threatened species observed in this study, *Agasthyagama beddomii* (Endangered), *Eutropis clivicola* (Endangered), and *Indotestudo travancorica* (Vulnerable), are exclusively found in leaf litter microhabitats (Jose *et al.* 2007; Deepak & Vasudevan 2015) (Figure 4). Additionally, most of the skinks reported in our study also depend on leaf litter for breeding and foraging activity. Thus, the conventional practice of leaf litter removal from the forest edges during fire-lining may severely impact litter-dwelling species (Jose *et al.* 2007; Chandramouli 2011).

As spatial complexity is one of the major factors that determine reptile diversity (Pianka 1967; Bars-Closel *et al.* 2017), microhabitat analysis gives insights on community patterns and can potentially help in identifying species that are vulnerable to habitat degradations. The guild-based approach has important application in understanding reptile community structure and habitat requirements, and developing effective habitat management strategies (Inger & Colwell 1977; Michael *et al.* 2015). This study aimed to evaluate microhabitat use in a tropical reptile community, rather than simply investigating species diversity. In doing so, our findings serve as a potential conservation tool for developing effective landscape management strategies for the region. For implementing practical conservation strategies, it is important to integrate species' ecologies into spatial planning that involves modelling dynamic ecological processes across space and time (Opdam *et al.* 2001; Harvey *et al.* 2017). In this perspective, our approach

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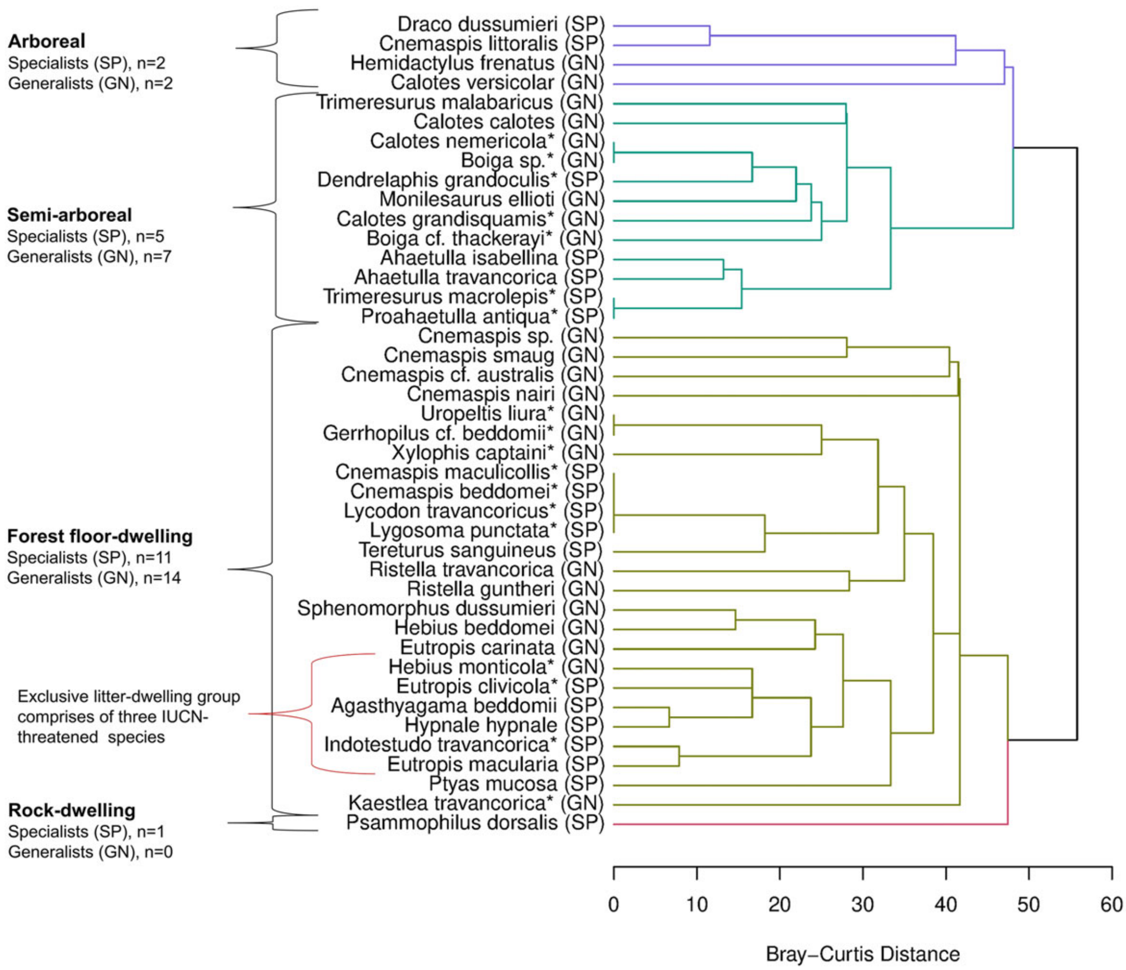

Figure 3. Cluster diagram depicting guild structure of reptiles based on microhabitat use. Assemblages of specialists (SP) and generalists (GN) within each guild are also shown (species with <2 observations were not included). *'Predicted specialists/generalists' (species with less than 5 observations).

Figure 4. Exclusively litter-dwelling and threatened species in the study area: (a) *Agasthyagama beddomii* (Endangered); (b) *Eutropis clivicola* (Endangered); and (c) *Indotestudo travancorica* (Vulnerable).

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Figure 5. (a) Burnt grassland and adjacent evergreen forest patch (at 800m a.s.l.) in the core area of Agasthyamalai landscape with the Agasthyamalai peak in the backdrop; (b) Dumping of plastic and other wastes by tourists.

of identifying species with similar microhabitat use patterns could be helpful in multi-species conservation planning at the landscape levels. For instance, in our study, forest floor species constituted 60% of the total species, highlighting the importance of leaf litter and open ground habitats for a diverse range of reptile species. A similar study on the herpetofaunal assemblage in the Ponmudi Range (a mountain range within the southern Western Ghats) reported a high proportion of reptiles and amphibians that used forest leaf litters and rocks as their major microhabitats (Inger *et al.* 1987). There are a few studies that demonstrate a significant impact of habitat degradation on reptile diversity (Gillespie *et al.* 2015; Theisinger & Ratianarivo 2015). A study on Australian rainforest frogs also suggested that guild-based analyses are useful in identifying specific causal factors for population declines due to habitat degradation, as ecological guilds with more specialists and limited microhabitat resources are susceptible to changes in habitats (Williams & Hero 1998).

The Western Ghats of India is a biodiversity hotspot extremely vulnerable to anthropogenic disturbances including forest fragmentation and annual forest fires because of high human population density (Kodandapani *et al.* 2008). During our surveys, we observed isolated forest fire events and the dumping of plastic and other waste within the core areas of ABR. These observations corresponded with the presence of tourists in the region (see Figure 5) suggesting a certain impact of tourism-related activities in the core areas. However, the same was not quantified in the present study and needs further detailed investigation. There are some landscape-level assessments from the southern Western Ghats showing a considerable amount of forest fragmentation and degradation due to human disturbances (Parthasarathy 1999; Giriraj *et al.* 2010; Jose *et al.* 2011). A study from the northern part of Agasthyamalai range showed significant changes in forest types between the years 1971 to 2009 where a large area of evergreen patches transformed to semi-evergreen and moist deciduous forests due to disturbances (Jose *et al.* 2011). It is understood that such changes in forest types could largely affect habitat structure by changing spatial complexities including microhabitat availabilities. Additionally, removal of leaf litter and forest degradation have also been reported as a threat to herpetofauna from different parts of the Western Ghats, including the Agasthyamalai landscape (Jose *et al.* 2007; Chandramouli 2011). For example, the endangered and endemic (to the southern Western Ghats) Indian Kangaroo Lizard, *Agasthyagama beddomii* is found only in the evergreen or semi-evergreen habitats where the leaf litter composition is one of the major limiting factors for its presence (Jose *et al.* 2007; Chandramouli 2011). Such habitat and microhabitat specialists will be severely impacted by habitat degradations over the years. Considering the potential impact of existing tourism activities and human interventions in the region (Panigrahi & Jins 2018), we recommend management plans to protect these habitats from further degradation. Protecting the structural attributes of these habitats would ultimately conserve many such habitat specialists and endemic reptiles in the southern Western Ghats.

Conclusion

Our study demonstrates that microhabitat is a crucial element of ecosystem complexity and can serve as a proxy to predict the community structure of associated herpetofaunal taxa. In our study, 45% of reptile species in this area of the Western Ghats were microhabitat specialists with relatively narrow niche breadth. The 42 reptile species utilized 15 distinct microhabitat types, clustered into four guilds. In addition to these findings, we also found that 60% (25) of the species were forest floor dwellers with a significant number of specialists, including globally threatened species. Our results demonstrate potential effective implementations of microhabitat data for improved and comprehensive forest management practices, as opposed to conventional current management practices in eco-sensitive regions of the Western Ghats. The data generated in the present study along with existing information about microhabitat specialists might help us understand how they could be severely impacted by the degradation of different forest types in the region. Given the sampling constraints and limited duration of the present study, we were unable to collect a sufficient number of observations for many species. We believe that further investigations in the area would help in determining the microhabitat specializations and conservation importance of many reptiles found in the region. Although our study area is within the protected area network of Agasthyamalai Biosphere Reserve (ABR), we observed the area to be under sustained pressures from high anthropogenic activities especially tourism, thus making the landscape more prone to habitat degradation and forest fires. Hence, we recommend a dynamic approach to monitor habitat quality and regulate human interventions in this landscape to sustain the health of the habitat for the conservation of all the native and endemic species including the rich diversity of reptiles.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S0266467422000190

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