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Habitat utilization of endangered rhino horned lizard (*Ceratophora stoddartii*) (Sauria: Agamidae) in the Horton Plains National Park, Sri Lanka

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Abstract
The habitat utilization of *Ceratophora stoddartii* at the Horton Plains National Park was investigated using transect and quadrate sampling methods from September 2015 to September 2017. The results from 124 sightings of *C. stoddartii*, indicated that a major percentage (67.7%) of 84 sightings inhabited the montane cloud forests. This was followed by 40 sightings (32.3%) inhabiting in cloud forest die-back habitat of HPNP. The canopy cover, ambient temperature and ground vegetation cover were identified as the 3 important criteria in its habitat utilization (p<0.05, Man-Whiteney U test). Microhabitats with high vegetative cover (PC1, 0.527), shade and low amounts of bare soil were occupied by *C. stoddartii*. This arboreal lizard was mainly observed on tree trunks and branches for resting. The study resulted in discovering important data on its habitat utilization and highlights the importance of conserving this agamid which is highly adapted to inhabit montane cloud forests of Sri Lanka.

Keywords: Agamidae, Montane cloud forests, microhabitat, conservation, habitat preference, tropical reptile

1. Introduction
Knowledge of habitat use and requirements of a species' is an essential element for understanding its ecology and conservation biology [1, 2]. Habitat and microhabitat use may impact a number of aspects, such as individual physiology [1], population dynamics [3, 4] and processes at the community level [5, 6]. The necessity to determine the selection or avoidance of one particular microhabitat in relation to its availability has been recognized as a first step towards understanding ecological interactions between organisms and their environment [7]. Besides, this understanding also provides information about natural history and selective pressures [8] and is of great importance for carrying out actions oriented towards the conservation of endangered species [9, 10].
Agamids (Order: Reptilia), being ectotherms, generally do not prefer colder temperatures with demanding thermal requirements [11]. Despite the relatively small geographical area of the island, the unique topography with central highlands has resulted in creating different biogeographic / bioclimatic zones [12, 13], and altitudinal stratification [14, 15] with contrasting climatic conditions throughout the island ranging from warmer to colder climatic conditions. Most of the agamids found in the island are restricted to low (<900 m asl, 66.6%) and mid elevation up to 1500 m asl, 61.9%) areas while few (23.8%) are adapted to live in the higher elevations >1500 m asl. *Ceratophora stoddartii, Cophotis ceylanica and Calotes nigilabris* are the three agamids that inhabit montane cloud forests of Horton Plains National Park in the highland plateau (>1700 m asl) of Sri Lanka [16, 17, 18, 19,20].
The endemic rhino-horned lizard *C.stoddartii* (Gray, 1835) is categorized under the "Endangered" [21] category. This species is recorded from 1200–2300m asl. [22] in montane cloud forests [16, 18, 19, 23]. However, Udagedara & Karunarathna [24] recorded it from an isolated submontane forest in Kegalle district at an altitude of 1000 m asl. It is an arboreal agamid species that is easily distinguished from all other *Ceratophora* species by the presence of a prominent pointed rostral appendage, which is made up of the rostral scale with its unique *rhino-horn*" shape [19]. Work by Earlier researchers [18, 23, 25, 26] provide information regarding the habitat preference of *C. stoddartii*. During the present study we investigated its habitat utilization to generate much needed data for the conservation trough a long term and a systematic study.

2. Materials and Methods

2.1 Study area

The present study was carried out from September 2015 to September 2017 for a period of two years in Horton Plains National Park (HPNP), spending approximately 576 person - hours in the field throughout the study period. HPNP is located on the southern plateau of the central highlands of Sri Lanka (6°47'-6*50'N, 80°46'-80°50'E). This unique forest grassland ecosystem terrain is level to undulating and hill valley landform with a net work of streams. There are many hills arising from the plains and the well-known is the Kirigalpotha, arising from the western side of the plains. This is the second tallest mountain (2395 m asl) in the country. Horton Plains occupies an area of 3,160 ha which is contiguous with Peak Wilderness Sanctuary to the west [27]. This is a unique national park in Sri Lanka with discrete weather patterns and climatic conditions with an average annual temperature of ~15 °C. HPNP comprises of different vegetation types that includes the upper montane cloud forests, wet patana Grassland and a narrow ecotone belt in between these two vegetations. The cloud forest additionally comprises of forest die-back areas [28, 29]. Present study was conducted in the Cloud Forest, Cloud Forest Die-Back and Grassland habitats in the HPNP. In each of these habitat types, 100 m transects were marked and investigated monthly. Within the transects, only the lizards that were observed within 2m on either side of the line transect and up to a height of 3 m were recorded to reduce any possible bias caused by the variation in visibility. Census was carried out consecutively for two years covering all four climatic seasons, North-East (December-February), First inter-monsoon (March- April), South-West (May-September) and Second inter-monsoon (October-November) season that prevail in the island. The *C. stoddartii* observed were grouped into four maturity stage categories based on external morphology, secondary sexual characteristics, gender and SVL (Juveniles: <4cm, Sub-adults: 4-6 cm, Adult-famales: 6-8 cm, Adut males 7-10 cm). Lizards were hand captured when required to take measurements and to determine its gender.

2.2 Microhabitat availability

Microhabitat availability was measured by installing five 2x2 m quadrates randomly along each transect using a random number table. At each quadrate percentage cover of ground vegetation, leaf litter and bare soil was recorded. Ambient temperature and relative humidity at chest height [30] were measured using Kestrel 4000 pocket weather meter, USA. Soil characteristics such as soil penetration (using soil penetrometer - Land penetrometer INC.), soil pH and moisture content (using soil pH meter [Kelway soil acidity (pH) and moisture tester]) were also measured. A metal ruler was used to measure the leaf litter depth. A total of 70 lizard unoccupied quadrates were sampled during the study as control quadrates

2.3 Microhabitat use of *C. stoddartii*

Resting sites where *C. stoddartii* observed were categorized as ground, tree trunk, tree-branch and moss. The resting site when each *C. stoddartii* was first observed was recorded. To study the preferred microhabitat, 2x2 m quadrates were marked along each transects, using the point at which the lizard was sighted as the center. A total of 66 occupied quadrates were sampled. The following parameters in the 2x2 m quadrates were recorded.

Light intensity in the lizard's location was categorized and recorded as full sun light (75% or greater sunlight) dappled sun light (25% to 75% sunlight) and shade (less than 25% sunlight) [31]. At each quadrate percentage cover of ground vegetation, leaf litter and bare soil was recorded. Ambient temperature and relative humidity at chest height [30] were measured using Kestrel 4000 pocket weather meter, USA. Soil characteristics such as soil penetration (using soil penetrometer - Land penetrometer INC.), soil pH and moisture content (using soil pH meter [Kelway soil acidity (pH) and moisture tester]) were also measured. A metal ruler was used to measure the leaf litter depth.

2.4 Statistical Analysis

"Minitab version 17" statistical software package and Microsoft Excel were used for statistical analysis and graphical representation of results. Principal components analysis (PCA) together with Eigen analysis was performed to find out important microhabitat variables of occupied quadrates. Non parametric Mann-Whitney U-test at significance level (p = 0.05) was conducted to compare the microhabitat variables between occupied and unoccupied quadrates of *C. stoddartii.*

3. Results

3.1 Habitat preference of *C. stoddartii*

A total of 124 *C. stoddartii* were sighted and investigated during the transect surveys including 48 adult males, 44 adult females, 20 sub-adults and 14 juveniles (Fig 1). Cloud forest recorded the highest number of sightings (84, 67.7%) while Cloud Forest Die-back recorded 40 sightings (32.3%). *C. stoddartii* was not observed in the grassland habitat.

Fig 1: Different maturity stages of *C. stoddartii* recorded in Horton Plains National Park. (a-Adult male, b-Adult female, c-Sub-adult and d-juvenile)

3.2 Microhabitat preference *of C. stoddartii*

As shown in Table 1, when microhabitat variables of lizard occupied and unoccupied sites were compared, ground vegetation cover, canopy cover and ambient temperature differed significantly ($p<0.05$, Man-Whiteney U test) between the two quadrate types. Therefore, it can be concluded that ground vegetation cover, canopy cover and temperature (ambient) are the most important factors which determines the microhabitat preference and selection of *C. stoddartii*.

Table 1: Characteristics of available habitat variables vs. occupied microhabitats (*Significant at 0.05 level)

Variable	Random unoccupied quadrate (n=70)	Occupied quadrate (n=66)	Mann-Whitney U-test
	Mean ± SD	Mean ± SD	*p* value
Ground vegetation cover (%)	26.67 ± 21.20	39.85± 28.00	0.0037*
Canopy cover (%)	50.62 ± 16.88	59.20± 11.90	0.0001*
Temperature (ambient) (%)	21.259 ± 3.683	20.142 ± 2.912	0.0189*

3.3 Microhabitat utilization of *C. stoddartii*

First five axes of the PCA analysis of microhabitat variables of lizard occupied quadrates accounted for 70.4% of the total variance (Table 2).

Table 2: Eigen analysis of the Correlation Matrix

	Axis1	Axis2	Axis 3	Axis 4	Axis 5
Eigen value	2.2053	1.7123	1.5256	1.2236	1.0719
Proportion	0.200	0.156	0.139	0.111	0.097
Cumulative	0.200	0.356	0.495	0.606	0.704

The first principal component (PC1) was positively correlated with canopy cover (PC1, 0.500), bare soil cover (PC1, 0.514) and ground vegetation cover (PC1, 0.527) having the highest impact on PC1. The second component (PC2) gave high scores for both ambient temperature (PC2, 0.600) and substrate temperature (PC2, - 0.065). According to PC3 and PC4 soil pH (PC4, 0531), soil penetration (PC4, - 0.533) and leaf litter cover (PC4, 0.727) were significantly affecting the microhabitat structure (Table 3).

Table 3: PCA values of microhabitat variables

Variable	PC1	PC2	PC3	PC4	PC5
RH	0.238	0.467	-0.194	-0.058	-0.036
Canopy Cover (%)	0.500	0.138	-0.251	0.014	0.041
Litter depth (cm)	0.025	0.235	-0.151	-0.440	-0.576
Leaf Litter Cover (%)	0.043	-0.112	-0.055	0.727	-0.190
Soil Ph	0.211	-0.028	0.531	-0.280	-0.101
Soil moisture (%)	0.161	-0.044	0.119	0.281	-0.724
Bare soil (%)	0.514	0.016	-0.117	-0.097	0.124
Soil penetration (MPa)	-0.137	0.203	-0.615	0.090	0.050
Temperature (ambient)	0.234	-0.600	-0.164	-0.142	0.068
Temperature (substrate)	-0.065	-0.533	-0.391	-0.235	-0.242
Ground vegetation Cover (%)	0.527	-0.082	0.068	0.152	0.113

3.4 Resting site preference of *C. stoddartii*

Highest number of lizards was resting on branches (36%) while 32 % were resting on tree trunks. These two resting places accounted for 68% of sightings of lizards. Different types of mosses were used by 27% of lizards while least preferred resting site was recorded as ground (5%) (Fig. 2).

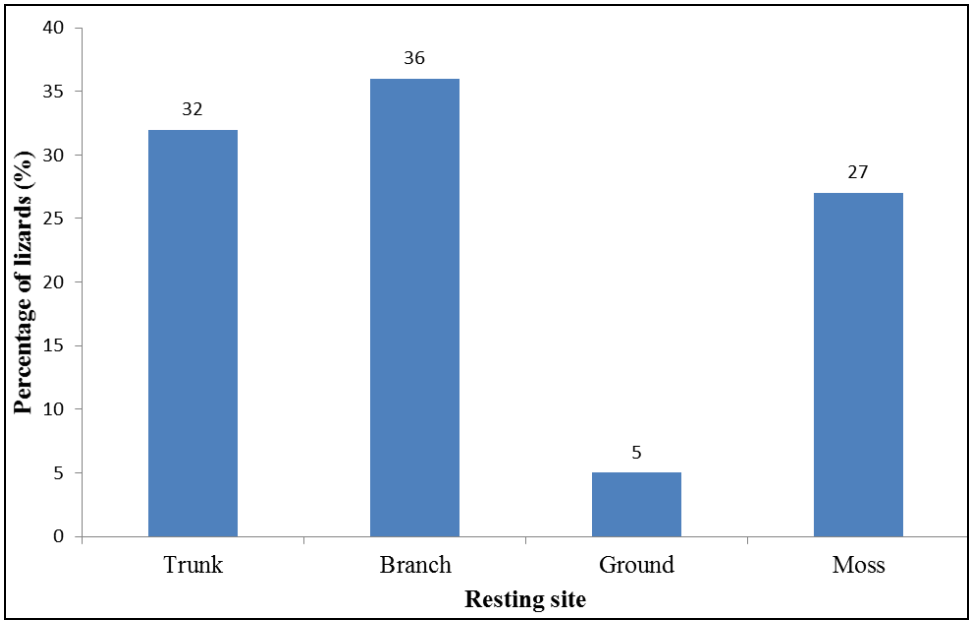

Fig 2: Resting site usage of *C. stoddartii*

3.5 Resting site preference of different maturity stages
Adult females and males were observed using all four resting sites. However, highest number of adult females was found to be resting on branches (36.4%) and males mostly preferred tree trunks as their resting site (64.2%). Sub-adults were sighted only on tree trunks (10%) and branches (90%). Juveniles were not observed resting on moss. Juvenile's most preferred resting type was ground with leaf litter cover (57.14%) (Fig. 3).

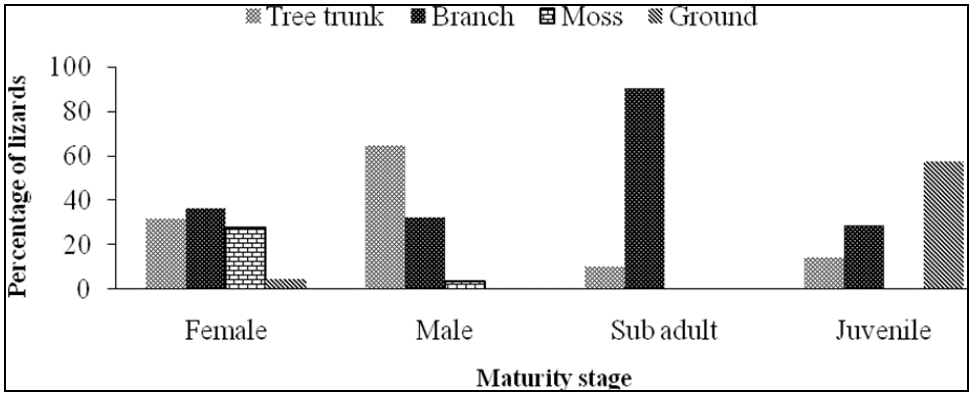

Fig 3: Resting site preference of different maturity stages

3.6 Resting height difference between maturity stages
Adult males were occupying highest level which was recorded to be 102.8 ± 46.8 cm on average. Sub-adults were observed at an average height of 69.2 ± 41.2 cm which was higher than average resting height of adult females (54.0 ± 29.3 cm). Lowest average resting height was recorded for juveniles (12.29 ± 41.2cm) (Fig. 4).

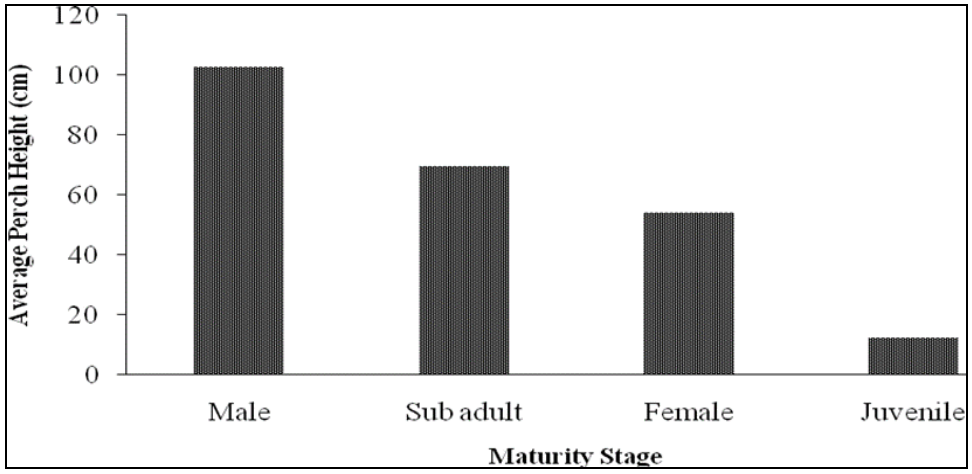

Fig 4: Average resting height of different maturity stages

3.7 Diurnal light intensity preference of *C. stoddartii*
In all three time periods considered, most preferred light condition of *C. stoddartii* was shade (68.2% of total sightings). 28.8 % of lizards were observed resting under dappled sun light. Lowest number of lizards was observed in direct sun light which was only 3.0% of total sightings (Fig 5). No significant temporal variation was observed in preferred light conditions throughout the day.

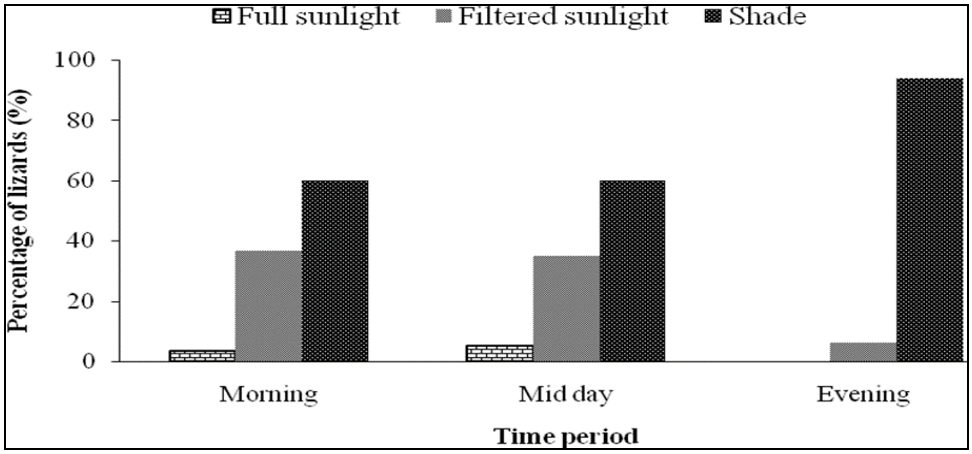

Fig 5: Diurnal light intensity preference

4. Discussion

The present study results indicate that *C. stoddartii* is a Cloud Forest adapted lizard that prefers Tropical Montane Cloud Forests of the island similar to previous observations made by Manamendra-Arachchi & Liyanage [16]; Pethiyagoda & Manamendra-Arachchi [23]; De Silva [25, 32]; Somaweera & Somaweera [19]. It was also recorded in the Cloud Forest Die-back habitat. This observation clearly suggests that *C. stoddartii* avoids the more thermally challenging grassland habitat where temperatures could go as low as 0 °C to upper limits of mid thirties whereas Cloud Forest and Cloud Forest Die-back provide them more stable temperature conditions with relatively minor fluctuations. However, temperature in Die-back areas (18.3 ± 3.7 °C) was slightly higher than in Cloud Forest (17.1± 3.8 °C). The canopy created by larger trees retains the moisture increasing the relative humidity values when compared to grasslands which are warmer (23.82 ± 4.2 °C) with low levels of RH. Moreover, availability of woody plants of the Cloud Forests better suits this arboreal lizard.

The significant contributions of canopy cover and ground vegetation to the PC1 axis indicates the close relationship of *C. stoddartii* with the Cloud Forest habitat. It selects microhabitats where canopy cover is dense enough to prevent the penetration of excessive solar radiation. Furthermore, microhabitats with ground vegetation cover were preferred by this lizard, which provide good refuge areas from predators while providing a rich microenvironment with many insect prey species. Ambient temperature and the substrate temperature were another two significant microhabitat variables according to PC2. This result again highlights the unique thermoregulatory requirements of this species. *C. stoddartii* prefers microhabitats with low ambient and substrate temperatures. The biological basis of this strange behavior for a lizard needs to be further investigated.

The presence of relatively larger trees as well as plants with low to medium levels of DBH was an important factor for *C. stoddartii* which spends most of its time resting vertically on a tree trunk or a branch. When weather conditions were too harsh they tend to take refuge inside the mosses that are abundant in the Cloud Forest. The ground was less frequently used by adult *C. stoddartii* except for the occasional hunting sprints to catch the escaping prey. However, one of us (AdS,) observed *C. stodartii* on the ground feeding on caterpillars and even on earth worms *(Pheretima taprobenia)* in the morning around 0830. When it descends to the ground it changes its green and brown colors to shades of brown and is well camouflaged with the leaf-litter [18].

Adult females showed a special tendency to rest among mosses. Mosses provide an insulating microenvironment, which helps the lizards escape the freezing temperatures of the night as well as high temperatures of day during warmer months of the year, reducing the effects of unpredictable temperature fluctuations of the Cloud Forests. This behaviour has not been observed by the previous workers. Sub-adults mainly preferred branches with thin stems which they could grasp (diameter, 1.9 ± 1.6 cm). Hatchlings which emerge from eggs laid in humus or among leaf litter were frequently occupying the ground where dead branch sticks and leaf litter well camouflaged them from the possible predators. Similar observations has made by Somaweera and Somaweera [19] and De Silva [18]. Juveniles were occupying the ground layers beneath the understory of *Coleus inflatus* and *Strobilanthes sp.* frequently foraging in search of small insect prey. In general the camouflage ability was effectively utilized by *C. stoddartii* by selecting microhabitats with substrates that resembled their body coloration. Tree barks with different shades (grays and browns) and mosaics of lichens & mosses provide the ideal background for *C. stoddartii* to merge with. Higher perch height of the adult males can be assigned as a feature of territorial defence and attracting the females. The selection of microhabitats with shade has a better choice on body temperature of some ectotherms, and on their thermal physiology [1]. According to Huey *et al*. [33], the type of shelter selected should correspond to the thermoregulatory needs of the animal. Therefore, activity of *C. stoddartii* at lower temperatures is an adaptive strategy, which allows the best resource use in its habitat. This has helped *C. stoddartii* to thrive in the challenging conditions of tropical montane Cloud Forsts of HPNP Sri Lanka.

5. Conclusions

C. stoddartii is well adapted to utilize the Tropical Montane Cloud Forest habitats which provide them suitable microhabitats to live and survive. It effectively utilizes the available habitat and microhabitat variables within the Cloud Forests to be one of the few lizard species that inhabit the high altitude montane Cloud Forests of Sri Lanka. Furthermore, this specialization of *C. stoddartii* to cloud forest habitats makes it even more vulnerable when compared to other species. However, the forest coverage in the montane areas of Sri Lanka is rapidly degrading due to numerous anthropogenic activities. In order to protect this unique endangered agamid, conservation of montane Cloud Forests of Sri Lanka should be given priority. The data generated by this study may become important if it comes to a stage where captive breeding/reintroduction is required to maintain healthy populations in the future. Illegal smuggling of this species for pet trade also needs to be addressed immediately.

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