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Niche partitioning and resource utilizations among three, sympatric agamid lizards in Gingee hills-Southern Eastern Ghats, India

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Abstract
We are reporting the ecological differences between three sympatric Indian agamids from Gingee hills between November 2015 to March 2016. In the present study, we have employed Visual Encounter Method (VES), target species namely, *Sitana ponticeriana*, *Psammophilaus dorsalis*, and *Calotes versicolor*. In this study, we examined agamid niche partitioning and microhabitat habitat utilizations. We also determined the environmental factors that drive agamid distribution in this region. We show that temperature and humidity affect agamid distribution and partition their niches. The occurrence of *Sitana ponticeriana*, *Psammophilaus dorsalis*, and *Calotes versicolor* ranged in temperatures between 30 to 35 °C, 29 to 34 °C and 28 to 33 °C, respectively. The humidity of the locations the three agamids occurred ranged from 52 to 65%, 49 to 65% and 48 to 65%. In addition, we also measured the activity budget of the three agamids and their elevational preference. This study shows niche partitioning between these three common Indian agamids.

Keywords: Agamid, microhabitat, temperature, humidity, activity budget, conservation

Introduction
Agamid is a widespread group and also a good model for community ecological studies (Pianka 1973) [14]. Also, agamid is very common and they occur almost in all-terrain ranging from harsh sheets of the desert to tropical rain forests (Pianka and Pianka 1976) [15]. In India, there have not been many ecological studies conducted on lizards. A few notable examples include studies on *Salea anamallayana* (Deepak and Vasudevan 2008) [5], *Sitana* spp. (Rao and Rajabai 1972; Pal *et al*., 2010; Subramanean and Reddy, 2010) [21, 16, 25], *Otocryptis beddomii* (Chandramouli 2009) [2], *Draco dussumierii* (Sreekar *et al*. 2013) [24], *Ophisops lechenaultii* (Karthik *et al*. 2018) [9, 10] and *Psammophilus* spp. (Radder *et al*. 2006; Shanbag *et al*. 2006) [20]. While some studies like Venugopal (2010) [26] studied the population ecology of not just one species, but a few species of lizards together, as a community. Community-wide ecological studies had been performed many decades ago in order to understand the reptilian ecology (Pianka 1970, 1971; Pianka and Pianka 1976) [12, 13, 15]. A few notable studies have discussed agamid ornamental display and behavior strategies of *Calotes versicolor* (Shanbhag 2003; Pandav *et al*. 2007) [22, 17], *Psammophilaus dorsalis* (Balakrishna and Achari 2014; Radder *et al*. 2006a) [1, 20] and *Sitana ponticeriana* (Pal *et al*. 2010; Kamath 2016) [16, 11]. Further, Patankar *et al*. (2013) [18]; Pandev *et al*. (2007) [17]; Radder *et al*. (2006b) [6] has done remarkable ethogram study on *Sitana* cf. *ponticeriana*, *Calotes versicolor*, and *Psammophilaus dorsalis* respectively. But a very few studies have discussed microhabitat association e.g Pal *et al*. (2010) [16] for *Sitana ponticeriana* and Radder *et al*., 2005 for *Psammophilaus dorsalis*. Interestingly, these lower vertebrates are perfect models for testing ecological oriented hypotheses. In the present study, we selected three agamid species namely: *Calotes versicolor*, *Psammophilaus cf. dorsalis* and *Sitana ponticeriana*. These agamids are very common and occur syntopically in the study area Gingee Hills, which is a part of southern Eastern Ghats (Karthik *et al*. 2018) [9, 10]. These agamids share many ecological and evolutionary attributes such as diurnal habit, niche overlap, ornamental display, insectivorous diet and sexually-dimorphism (Das 2002; Daniel 2002) [4, 3]. However, these agamids have few differences in their ecology – the major one being the habitat usage: with one being arboreal (*Calotes versicolor*), rupicolous (*Psammophilaus cf. dorsalis*) and terrestrial (*Sitana ponticeriana*) respectively (Das 2002; Daniel 2002) [4, 3]. In the present study, we chose three agamid lizards because of their similarity in ecological attributes and their syntopical occurrence in the study area.

Materials and Methodology

The study was conducted between November 2015 to March 2016 in Gingee Hills (12º 14' N, 79º 23' E & Altitude c.a. 600m), a part of Eastern Ghats (Fig.1.). The dominant vegetation is a thorny scrub jungle and tropical dry deciduous forests, tropical dry evergreen and rocky biotopes. The area experiences temperature from 30° to 38 °C and during winter season c.a. 24 °C and mean annual rainfall of 700mm (Karthik *et al*. 2018) [9, 10]. The present survey was performed intensively in order to investigate the terrane and subterranean herpetofauna species. We employed visual encounter method (Heyer *et al*. 1994) [7] for the study and collected field data by looking in all possible ground covers such as leaf litter, rock, tree (<5m), shrub/plant (>5), grass, pool (natural/artificial) and human habitation. We also collected the following variable for statistical analysis: species name, number of individual, microhabitats, temperature, humidity, age-class, species activity, and altitude. The analysis was performed by using the statistical package SPSS, Past 3.16 (Hammer 2017) [6] & MS Office excel for charts and graphs.

Results

We observed a total of (n) =872 individuals belonging to three species namely (*Calotes versicolor* n=293, *Psammophilaus cf. dorsalis* n= 442 & *Sitana ponticeriana* n=137). All lizards belong to family Agamidae and are common and occur syntopically in the study area. Figure 2 shows the microhabitat utilization by the agamids. The microhabitat is widely occupied by *Psammophilaus dorsalis* building n=1.2, Grass n= 0.3, Leaf litter n= 0.7, Plant n=0.6, Tree n=0.9 and Rock n= 2.6. Similarly, *Calotes versicolor* Grass n=1.3, leaf litter n=0.8, Plant n=2.3, Tree n= 0.9 and Rock n=1.2 and *Sitana ponticeriana* Grass n=1.9, Leaf litter n=1.5, Plant n=0.7, Rock n=1.1. We compared our microhabitat dataset with their evolutionary niche formation which shows that *Psammophilaus dorsalis* is a saxicolous member (91% prefers in rocky habitats) while *Calotes versicolor* is arboreal member (80% prefers in plant/shrubs mean >5m) and *Sitana ponticeriana* is a member of ground-dwellers (60% prefers in the grass & 26% prefers in leaf litter). We also tested the agamid distribution and their association with environmental parameters (Temperature, Humidity & Elevation). Figure. 3. Shows the agamid association with temperature and humidity along with their congregation. The following agamid distribution pattern influenced by their exogenous factor viz *Sitana ponticeriana* (ranging 30±35 °C & 52±65%), *Psammophilaus dorsalis* (ranging 29±34 °C & 49±65%) and *Calotes versicolor* (ranging 28±33°C & 48±65%). Table 1 shows the number of agamids observed with reference to their activity pattern along with the age-class. A Total of 439 *Psammophilus dorsalis* individuals were observed among which 77.7% were basking, 19% moving and 3.5% while resting. Following *Calotes versicolor* 293 individuals were observed in which 79% were basking, 17% moving and 3% while resting and *Sitana ponticeriana* 137 individuals were observed in which 10% of them basking and 90% in moving condition (Table 1). Further, the observation are divided into categorical zone namely: (i) forenoon (ii) afternoon & (iii) nocturnal. Most of the agamid were observed during forenoon sampling efforts (0600-1200) (except *Calotes* >n=30) and during the afternoon sampling efforts (1200-1800) all three agamids were active moderately and during dark hours (< 1800) their activity was gradually diminutive (Fig. 3.). We also looked into their gradient range with reference to their distribution. Here, we are highlighting the elevational ranging pattern and their Mean ± SD of the following agamid: *Calotes versicolor* elevational ranging from 60 to190m (119±23.5), *Psammophilaus dorsalis* elevational ranging from 90 to 380m (175±95) and *Sitana ponticeriana* elevational ranging from 80 to 140m (121±23) (Fig. 4.).

Discussion

Indian agamid is less focused when it comes to ecological perspectives but for the species conservation it is more indeed to science. Here, we light the microhabitat association of agamid (*C. versicolor*, *S. ponticeriana* & *P. dorsalis*) and their exogenous correlation. Figure. 1. Shows the microhabitat association of *C. versicolor*, *P. dorsalis*, and *S. ponticeriana* which is clearly supporting their evolutionary niche e.g. *C. versicolor* arboreal (see Pandev *et al*. 2007) [17], *P. dorsalis* rupicolous (see Radder 2006a; Venugopal 2010) [20, 26] and *S. ponticeriana* terrestrial (see Pal *et al*. 2010; Kamath 2016) [16, 11]. Figure. 2 and 3 shows the testing the exogenous variable with agamid distribution and our observation in *Sitana ponticeriana* temperature and humidity (>35° & > 65% RH) association supports earlier observation made by Pal *et al*. (2010) [16]. *Sitana ponticeriana* shows their distribution pattern influenced by temperature and humidity range with variance of (R^2=60%), Subsequently, *Psammophilaus dorsalis* (R^2=54%) and *Calotes versicolor* (R^2=52%). Which is obviously giving a combined insight of these agamid lizards and their temperature and humidity preference. In term of species activity budget, a total of 293 individuals of *Calotes versicolor* were observed in which 79% were basking, 17% moving and 3% while resting, *Sitana ponticeriana* 137 individuals have observed in which 10% of them basking and 90% in moving condition (Table 1). In case of *Sitana ponticeriana* the term "Moving" possibly refers to "Foraging" as mentioned in earlier observation by Pal *et al*. (2010) [16]. Further, the observation has been divided into zone categories viz. (i) forenoon (ii) afternoon & (iii) nocturnal. Most of the agamid were observed during forenoon sampling (0600-1200) (except *Calotes* >n=30). During the afternoon zone (1200-1800) the agamid was active moderately and during nocturnal hours (< 1800) the agamid active gradually diminutive (Fig. 3). It clearly shows that no agamid is not active during dark hours (<1800). This absolutely explicates the endogenous influence on agamid (could be thermal regulation or changes in the internal clock). Also, our observation enlightens the elevation pattern of these agamids (see Fig. 3.). *Calotes versicolor* (Mean ASL >190), *Psammophilaus dorsalis* (Mean ASL >380) and *Sitana ponticeriana* (Mean ASL >140). This is the primary documentation that emphasizes niche partitioning and exogenous influence of agamid distribution. However, our sampling statically does not support as strongly as compared with Pal *et al*. (2010) [16]. Nevertheless, the long term monitoring or seasonal sampling can give insights on the endogenous factors and their influence on these agamids species.

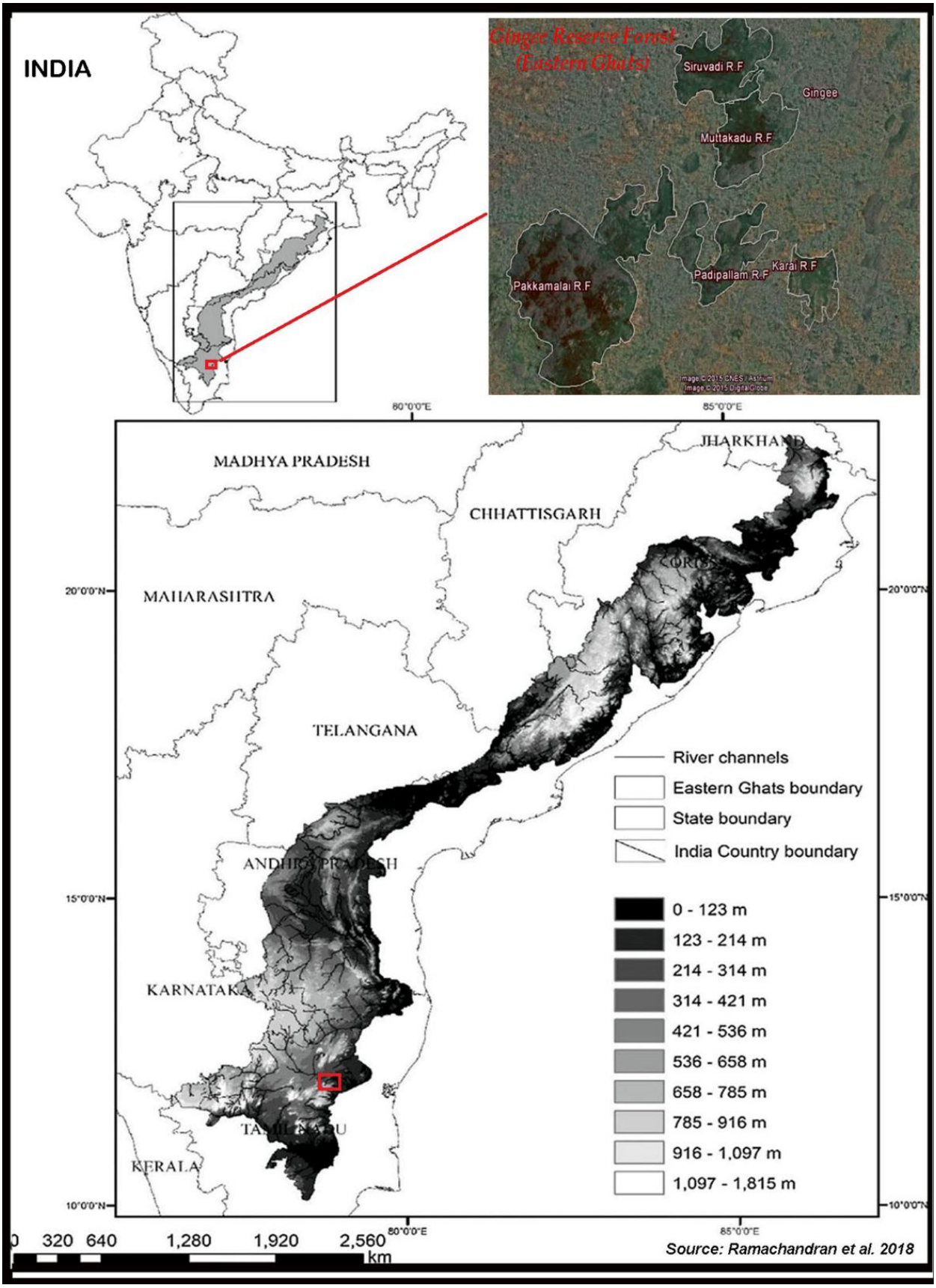

Fig 1: Showing the location of Gingee hills, Southern Eastern Ghats

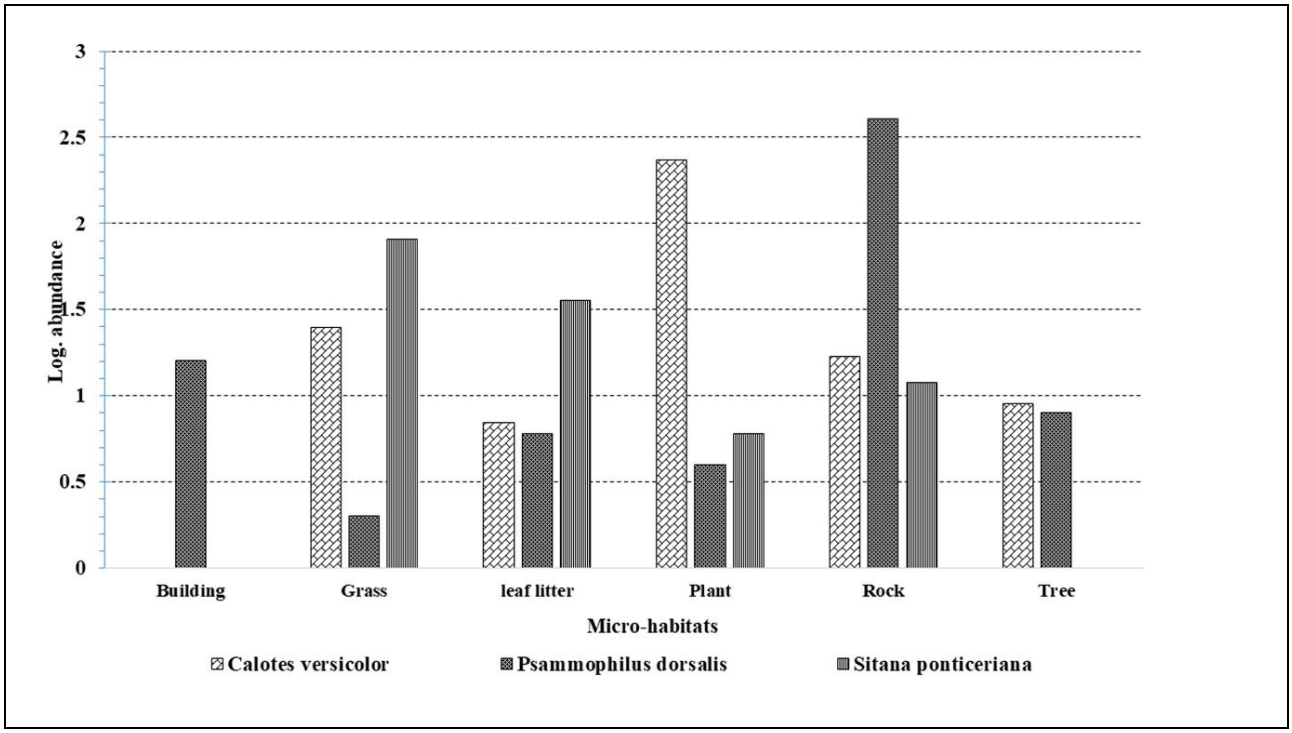

Fig 2: The number in individual observed in various microhabitats

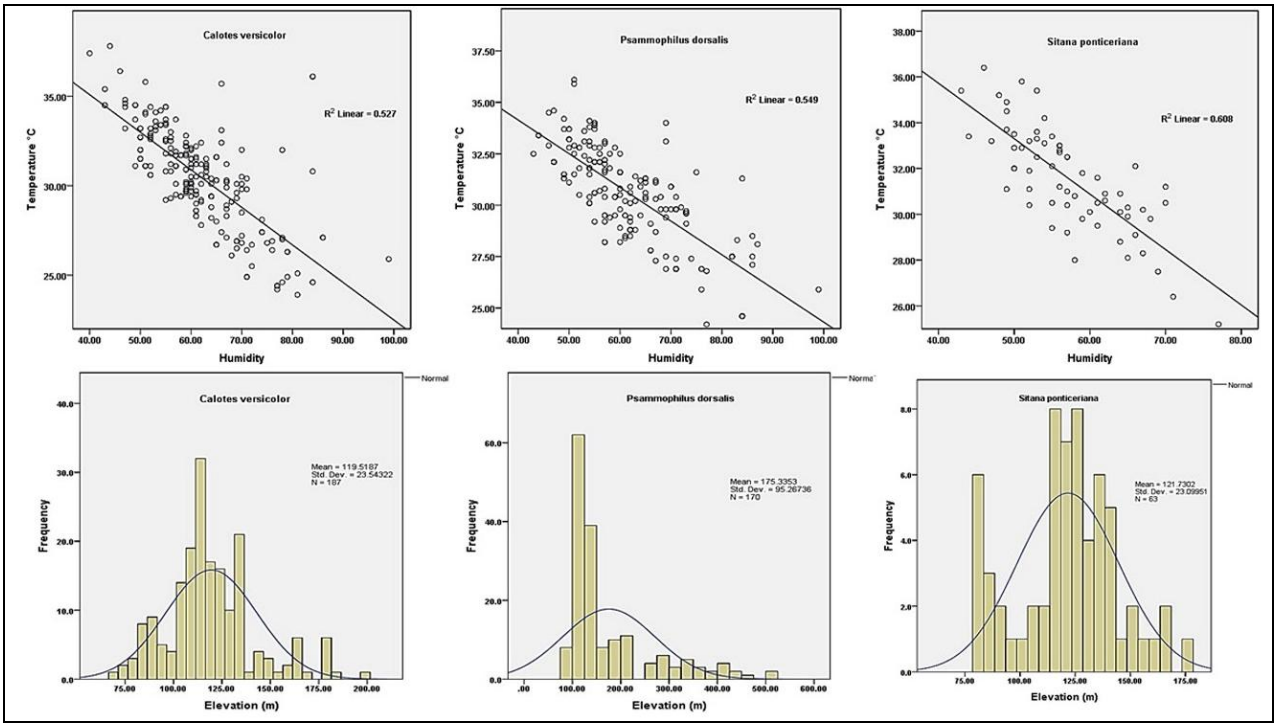

Fig 3: Showing the association between the abiotic factors and agamids

Table 1: Number of agamid recorded in relation to their activity patterns

Syntopic Species	Age-class	Spp. activity		
		Basking	Moving	Resting
Psammophilus dorsalis (N=439)	Adult	254	57	14
	Sub adult	57	8	1
	Juvenile	30	18	0
Calotes versicolor (N=293)	Adult	125	30	5
	Sub adult	76	13	4
	Juvenile	32	8	0
Sitana ponticeriana (N=137)	Adult	4	89	0
	Sub adult	2	6	0
	Juvenile	9	27	0

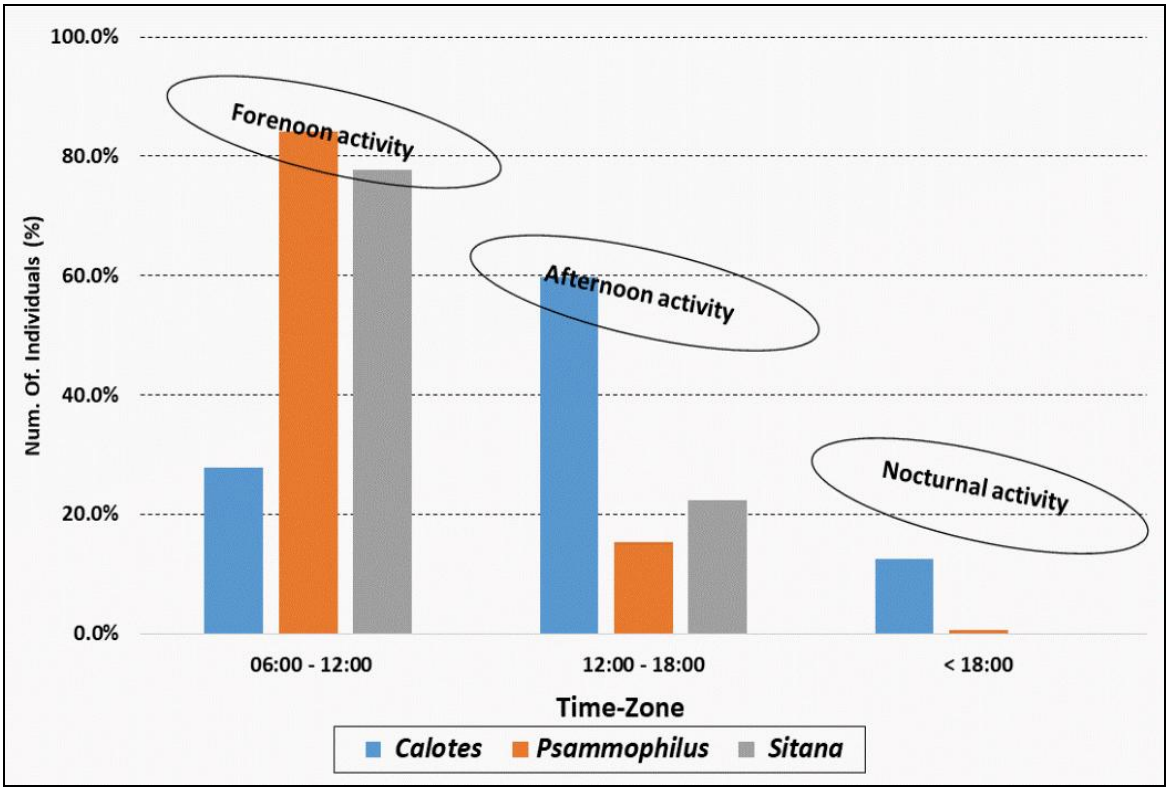

Fig 4: Number of agamid recorded in relation to a different category of time zone

Fig 5: Showing the imago's of three syntopic agamid from Gingee hills, Southern India

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