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Rodent Surveys reveal good insights into the Snake Fauna in an Agro-Pastoral Ecosystem in Southern India

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Abstract
Rats and mice are among the foremost of agricultural pests that are plentiful in farmlands. Snakes are one of the most specialized natural rat-controlling predatory species, also equally prevalent in farmlands. We studied the snake fauna of agroecosystem in south-eastern India by gathering concomitant data on snakes, during rodent surveys wherein rodents were the main target taxa. From a one year long day-and-night survey focusing on rodents, we obtained 151 sightings of snakes belonging to 22 species (four of which are venomous). A total of 66 sightings representing 14 species were obtained in diurnal surveys, and 21 sightings representing 7 species were obtained in night surveys. As much as 64 sightings representing 20 species were obtained by chance encounters in the study site, but outside of the designated rodent survey duration. An uncommon snake *Sibynophis subpunctatus* was recorded. The colubrid *Ptyas mucosa* was the commonest encountered species during the day while at night it was the viper *Echis carinatus*. Estimated species diversity in Shannon-Wiener index was H = 1.218.

Keywords: burrows, farmlands, mice, rats, Tamil Nadu, venomous snakes, Villupuram

1. Introduction
Agro-ecosystems and associated pasturelands are an essential and major land users in rural India (Krishna, 2010). While some fauna have been better studied in such agro-ecosystems (e.g. birds; Ali, 1949; Rajashekara & Venkatesha, 2014), other, more elusive fauna were left behind. Snakes play a key ecological role by controlling rodent populations (Fitch, 1949; Bouskila, 1995; Kannan *et al.*, 1994; Kern & Kohler, 1991) and are hence acknowledged as an important component in agro-ecosystem (Shine & Bonnet, 2000). Though a small minority are venomous and capable of life-threatening envenomations on humans when untreated, their indiscriminate killings are consensually considered needless

and hazardous (Bates, 1984). About 10-50% of food crops get destroyed by rodents and several other related factors (Srivastava, 1975; Advani, 1987; Whitaker & Advani, 1983). Greaves et al. (1975) reported that lesser mole rats tend to collect and store 40 kg of grains per acre of land (2.5% of the crop) in Pakistan and in Kolkata, about 4000 kg of rice was estimated to be depraded by rodents in a year (Frantz, 1975; Prakash & Mathur, 1987). In addition, they spoil the stored grains with their faeces and urine. Snakes are the natural predator of rodents, despite raptors, monitors, mongoose, jungle cats and jackals predating rodents, none can enter a rodent burrow and hunt it there (Whitaker & Dattatri, 1986; Whitaker, 2006). Thus, snakes play indispensable and irreplaceable role in agro-ecosystems as biological pest-control agents. Consequently, the presence of snakes in and around cultivation areas reduces the usage of tons of chemical rodenticides such as Zinc phosphide, Aluminium phosphide, Warfarin, Calcium cyanide, Strychnine and other toxic substances (Murphy, 2002). With a variety of ecosystems and its copious microhabitats, the cultivation lands in Tamil Nadu support various snakes (Daniels, 2001). But very few studies have been done on snake fauna of India's agroecosystems.

The reptile diversity and assemblage structure of inland plains in the south-eastern India consisting of dry evergreen and mixed thorn scrub jungle (Kalaiarasan & Kanakasabai, 1999; Parthasarathy & Karthikeyan, 1997) is not yet studied completely (Ganesh & Chandramouli, 2007, 2011). Therefore, every new survey conducted in these places still continue to add more species and improve local knowledge about the snake fauna here (Ganesh & Chandramouli, 2011; Krishnakumar, 2014). In India, there are a few widespread snake species that occur in human-dominated (or human-modified) and agricultural ecosystems (Whitaker & Captain, 2008). These ecosystems attract several species of frogs, toads, lizards and rodents which eventually attract snakes to prey upon them. In south-eastern India, there have been a few studies in the Coromandel Coastal Plains such as Chengelpet (Aengals, 1999), Kalpakkam (Ramesh et al., 2013), Chennai, Chengaelpet, Thiruvallur, Kanchipuram (Kalaiarasan & Kanakasabai, 1999; Subramanian, 2001, 2002) and Mayiladuthurai (Kannan et al., 1994; Ganesh & Chandramouli, 2007). Whitaker & Lenin (2008) reported on the venomous snake population in an agro-ecosystem, largely pertaining to those being caught for venom extraction (see Whitaker & Andrews, 1995, 1996). Single species autecological studies were done on Daboia russelii in farmlands of southern India (Glaudas, 2021a, b). A recent study in southern India's dry inlands worked on the venomous snake occurrences across a habitat disturbance gradient (Janani & Ganesh, 2022).

Yet, ecological studies on the snake communities of the Coromandel Coastal Plains region, especially in relation to rodent occupancies are deficient. Based on a review of literature, it is evident that previously no study has been carried out on the snake assemblage of this region associating it with rodent occupancies. Therefore, to fill up this lacuna, we here present our study on snake community of an agro-pastoral site in the Coromandal Coastal Plains, estimated based on rodent surveys.

2. Materials and methods

Study Site: The study was conducted in Nadukuppam (12.178°N, 79.872°E, 33 m asl) a Panchayath village situated in Marakkanam Taluk of Villupuram District in Tamil Nadu, a part of the Coromandel Coastal Plains of southern India. This region is largely dominated by agricultural activity, growing paddy, watermelon, groundnuts, tapioca, banana, coconut, pulses, etc. The climate is generally hot and dry throughout the year. The minimummaximum diurnal air temperatures of this region range from 29°C to 39°C respectively. It receives rain mainly during the months of October-December through the Northeast monsoon. Average annual rainfall in this region is 1,300 mm (Parthasarathy & Karthikeyan, 1997).

Survey Methods: The present study was largely a by-product of rodent surveys undertaken in the study area carried out during several field trips conducted from December 2012 to December 2013. The entire area was scanned visually and prospective microhabitats, especially rodent burrows were dug in and checked. We conducted the survey during the day (6:00-16:00 h) and night (19:00-23:00 h) in order to document both diurnal and nocturnal snakes. Rodent surveys were done in daytime by digging rat holes and inspecting tree holes (in inundated conditions) akin to Diurnal Time Constrained Search Method (Ribeiro-Junior et al., 2008). At night, rodent surveys were visually conducted as the rodents were out and active above ground, akin to nocturnal Visual Encounter Method (Crump & Scott, 1994). Irula tribal field assistant was deployed during the rodent surveys for inspecting the habitat. Only time-honoured survey methods were adopted in the present work, but not area-honoured methods, since we needed to cover large land areas to locate rodent burrows and constraining to certain designated areas will preclude factoring-in rodent burrows sufficiently. At night, owing to compatibility with diurnal surveys, we used a time-honoured survey method of visual inspection. About 190 hours of survey were conducted, with 160 h done in daytime and 30 at night. In addition, the secondary evidence (i.e., tracks, scats, and sloughs) were also identified with the help of technical expertise of the Irula tribe. If any of these signs is observed in the field, then the nearby areas were inspected thoroughly. On sighting a live snake detail regarding species, microhabitat, size etc. were noted. Microhabitats were broadly classified into nine categories, namely ground vegetation, pond, plants/trees, bare ground, in burrows, stone pile, buildings, under leaf litter and 'others'. Snakes were photographed using Canon Powershot SX150 IS model. Identification of snake species was done using standard field guide (Whitaker and Captain, 2008). No snake was handled or caught during this purely visual study and no voucher specimens were taken. Data were also collected whenever snakes were opportunistically sighted. Such species records were pooled with that of other systematic methods to arrive at total species richness data. The substrate on which animal sighted were recorded to assess the microhabitat classification. Similar kind of microhabitats was grouped together and classified broadly into ground vegetation, pond, plants/trees, bare ground, burrows, stone piles, building, etc.

Data analysis: The relative abundance of the snake for day and night time surveys was calculated with respect to the total man-hours of search effort spent in the field. Snakes that were sighted opportunistically were not included for analysis of relative abundance since no time-constraint would apply here and hence, the sightings cannot be quantified per unit time surveyed. Encounter rate for each species was calculated as the sighting frequency of a species / total hours surveyed. The raw data were pooled together for analysis of species diversity and richness (dead sightings not included). Species diversity index was calculated using Shannon Wiener's index (Shannon & Weiner, 1949).

$$H' = - \sum Pi \ In \ Pi$$

Where, Pi = the proportion of the important value of the i^{th} species; pi = ni/N, ni = important value index of i^{th} species; N = the important value of the index of all species.

The species accumulation curve is an extensively used method for calculating the adequacy of sampling effort (Ramesh et al., 2013) and this was calculated using the Brillouin diversity index.

$$\mathrm{H} = \frac{lnN! - \sum ln\ n_i!}{N}$$

N= total number of species in i^{th} category, and ni = number of species in i^{th} category.

To envisage similarity and dissimilarity of the community composition between the microhabitats, a preliminary level test of Jaccard's similarity was carried out based on the occurrence of snake species across the many microhabitats. This was done using PAST software (Hammer et al., 2001).

For quantifying microhabitat associations, all live sightings of snakes were used, including opportunistic sightings. Dead snakes were understandably omitted from this analysis, since there could be chances of the carcass being displaced after death by some or other means. Microhabitats were scored as per the resting substrate on which every live snake was sighted, be it in terrestrial, fossorial, arboreal or aquatic situations.

3. Results

In all, 151 sightings of snakes were obtained representing 22 species belonging to five families in the present study (Table 1). The maximum number of species was detected during diurnal rodent survey (n = 66) and also opportunistically (n = 64). Among the five families, Colubridae was the most diverse, accounting for 14 species, followed by two species from each of the families Erycidae, Elapidae, Viperidae and one species from Typhlopidae (Table 1). The Brillouin Diversity Index was used to measure the adequacy of the sample sizes. The index values reached a plateau at 140th sighting, indicating that we have sampled adequately (Fig. 1). The overall relative abundance and encounter rate for the diurnal and nocturnal survey is given in Table 2. Regarding relative abundance, *Ptyas mucosa* (0.212) was relatively more abundant, followed by *D. russelii* (0.167) and D. tristis (0.106) in diurnal survey, whereas in nocturnal survey *Echis carinatus* (0.476) was the most abundant followed by *O. taeniolatus* (0.190). Estimated species diversity in Shannon-Wiener index was H = 1.218.

Table 1. Sightings and records of snakes obtained by various means in Nadukuppam

Species	**Total No. of Sightings**					
	Day	Night	Opportunistic	Pooled	Dead snake Sighted	Slough records
Indotyphlops braminus	4	0	0	4	0	0
Eryx conicus	3	0	1	4	0	0
Eryx johni	3	0	3	6	0	1
Coelognathus helena	4	0	0	4	0	0
Ptyas mucosa	14	0	7	21	1	25
Oligodon taeniolatus	0	4	3	7	1	2
Oligodon arnensis	0	0	3	3	0	0
Dendrelaphis tristis	7	0	6	13	0	3

Lycodon striatus	0	0	2	2	0	0
Lycodon aulicus	0	1	1	2	0	0
Lycodon fasciolatus	2	0	1	3	0	2
Dryocalamus nympha	0	0	3	3	0	1
Sibynophis subpunctatus	0	0	1	1	0	1
Fowlea piscator	6	2	3	11	0	4
Amphiesma stolatum	5	0	8	13	2	6
Atretium schistosum	2	0	1	3	0	2
Boiga trigonata	0	1	1	2	0	1
Ahaetulla oxyrhynca	1	0	2	3	0	0
Bungarus caeruleus	2	1	4	7	1	18
Naja naja	2	2	4	8	1	23
Daboia russelii	11	0	7	18	2	2
Echis carinatus	0	10	3	13	0	1
Total	66	21	64	151	8	92

The microhabitat association of this snake fauna is presented in Figure 2. The ground vegetation was the most used microhabitat (24%), followed by bare ground (21%), pond and stone piles (9 %) and others/miscellaneous (20%). The cluster diagram showing similarity in habitat use of the snake community is presented in the Figure 3, which shows that similar species composition exists between bare ground and pond (*Atretium schistosum*, *Bungarus caeruleus, Ptyas mucosa*), similarly, in burrows and stone piles (*B. caeruleus*, *N. naja*, *P. mucosa*); plants/trees and ground vegetation (*Ahaetulla oxyrhynca*, *Daboia russelii*, *Dendrelaphis tristis*) formed another group. The most dissimilar microhabitat was building, with four species, two of which (*Dryocalamus nympha* and *Lycodon fasciolatus*) were sighted only in and around buildings.

Table 2. Diurnal and nocturnal encounter rates and abundances of snakes in Nadukuppam

Species	**Diurnal survey**			**Nocturnal survey**		
	Sighting frequency (157.56 h)	Encounter rate per h	Relative abundance (n=66)	Sighting frequency (29.08 h)	Encounter rate per h	Relative abundance (n=21)
Indotyphlops braminus	4	0.025	0.061	0	0.000	0.000
Eryx conicus	3	0.019	0.045	0	0.000	0.000
Eryx johni	3	0.019	0.045	0	0.000	0.000
Coelognathus helena	4	0.025	0.061	0	0.000	0.000
Ptyas mucosa	14	0.089	0.212	0	0.000	0.000

Oligodon taeniolatus	0	0.000	0.000	4	0.138	0.190
Oligodon arnensis	0	0.000	0.000	0	0.000	0.000
Dendrelaphis tristis	7	0.044	0.106	0	0.000	0.000
Lycodon striatus	0	0.000	0.000	0	0.000	0.000
Lycodon aulicus	0	0.000	0.000	1	0.034	0.048
Lycodon fasciolatus	2	0.013	0.030	0	0.000	0.000
Dryocalamus nympha	0	0.000	0.000	0	0.000	0.000
Sibynophis subpunctatus	0	0.000	0.000	0	0.000	0.000
Fowlea piscator	6	0.038	0.091	2	0.069	0.095
Amphiesma stolatum	5	0.032	0.076	0	0.000	0.000
Atretium schistosum	2	0.013	0.030	0	0.000	0.000
Boiga trigonata	0	0.000	0.000	1	0.034	0.048
Ahaetulla oxyrhynca	1	0.006	0.015	0	0.000	0.000
Bungarus caeruleus	2	0.013	0.030	1	0.034	0.048
Naja naja	2	0.013	0.030	2	0.069	0.095
Daboia russelii	11	0.070	0.167	0	0.000	0.000
Echis carinatus	0	0.000	0.000	10	0.344	0.476

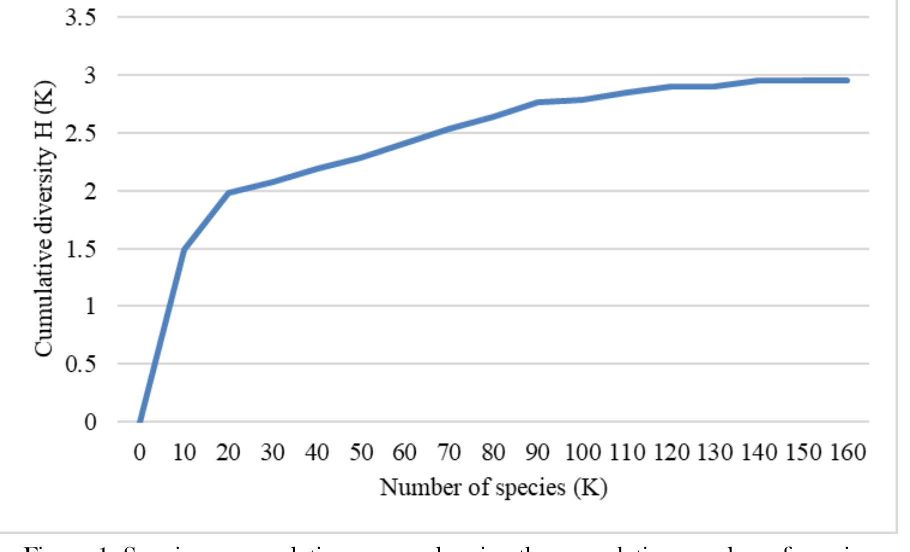

Figure 1. Species accumulation curve, showing the cumulative number of species recorded with cumulative number of sightings.

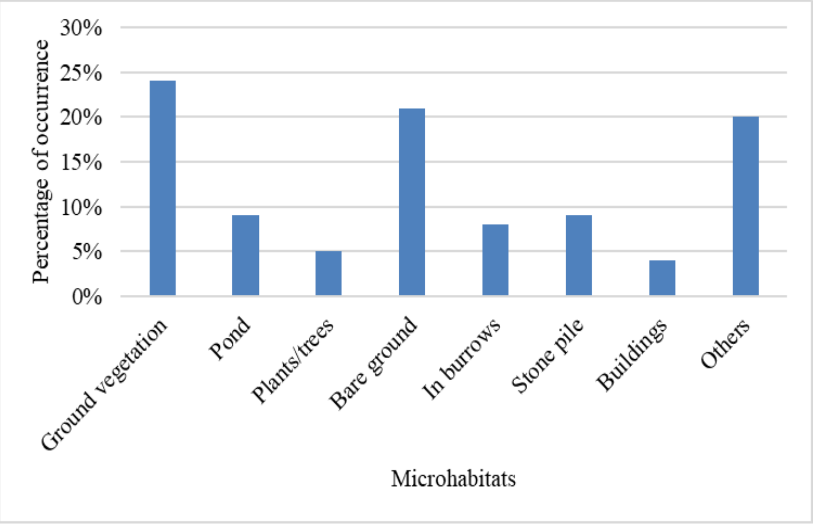

Figure 2. Break-up of the microhabitat associations of snakes in Nadukuppam

Table 3. Snake diversity reported in Coromandal Coastal Plains in Tamil Nadu, India.

Study area	Study duration	No. of snake species	Reference
Chengelpet, Kanchipuram & Tiruvellore districts	3 years	19	Kaliarasan & Kanakasabai, 1999
Chennai	not given	12	Subramanian, 2001
Chennai (Chembarambakkam)	1 year	12	Testan & Ramanibai, 2011
Chennai (Korattur)	5 years	13	Ganesh *et al.*, 2005
Chennai (Kovilapakkam)	not given	5	Subramanian, 2002
Kalpakkam (Nuclear Campus)	4 years	17	Ramesh *et al.*, 2013
Mayiladuthurai	4 months	13	Kannan *et al.*, 1994
Mayiladuthurai	2 years	15	Ganesh & Chandramouli, 2007
Mayiladuthurai	2 years	14	Nath *et al.*, 2012
Pondicherry (Ousteri lake)	3 years	13	Alexandar & Jayakumar, 2014
Rameshwaram	< 1 month	5	Ravichandran & Siliwal, 2010
Nadukuppam, Villupuram	1 year	22	This Work

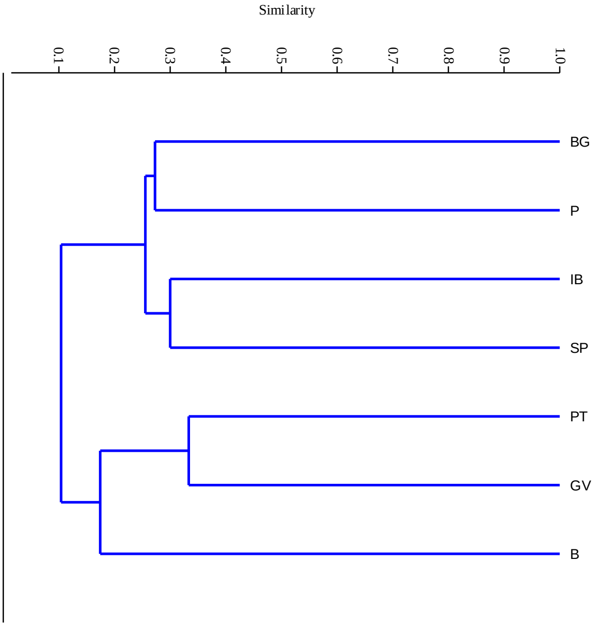

Figure 3. Cluster Analysis of the similarity of snake community among the different microhabitat type based on Jaccard cluster analysis. BG-Bare ground, P-Pond, IB-In burrows, SP- Stone piles, PT-Plants/Trees, GV-Ground Vegetation and B-Buildings.

4. Discussion

For a mostly agricultural landscape in northern Tamil Nadu, characterized by mosaic of rice paddies interspersed with wetlands, lake bund vegetations and human settlements, the snake fauna documented (n=22 species) is rather high compared to the existing studies (see Table 3). The total number of snakes sighted in previous literature ranged between 5 in Chennai (Subramanean, 2002) and Rameshwaram (Ravichandran & Siliwal, 2010) to 19 in Chengelpet-Thiruvallur-Kanchipuram districts (Kalaiarasan & Kanakasabai, 1999). Among these 22 species recorded, four are venomous and the rest 18 are non-venomous or semi-venomous. Despite, the Brillouin diversity index curve showing a levelling off, undetected species are likely present in our work too; such as *Grypotyphlops acutus* and *Calliophis melanurus* that are found throughout Peninsular India (Whitaker & Captain, 2008). Still, the recorded species richness (n = 22) in Nadukuppam was higher than other studies in Eastern inland plains of Tamil Nadu with similar vegetation and habitats (Table 3).

In accordance with literature, as the present study was on the snake assemblages in an agricultural landscape, the greatest number of sightings obtained was that of *P. mucosa*. Because *P. mucosa* is a habitat generalist and rodent eater, it is so much abundant in rice paddies and other agricultural pasturelands (Whitaker, 2006). During nocturnal surveys, *O. taeniolatus* was rather abundant. *Sibynophis subpunctatus* was found to be the least abundant species of all, with only one sighting of the snake was recorded under stone piles. This species is also evidently absent in most of the previous studies (see Ramesh et al., 2013 and references therein).

In terms of venomous snakes, we found that *D. russelii* (0.167) was the most abundant among all the four species. This is rather surprising since the highest sightings of venomous snakes in most studies were mostly that of elapids, but not vipers (Ganesh & Chandramouli, 2007; Janani & Ganesh, 2022). *Daboia russelii* has been found to occur in human-occupied and agro-ecosystems (Glaudas, 2021a, b). Yet, their populations among other venomous snakes, especially the elapids are not consensually superlative (SRG pers. obs.). During the nocturnal survey, *E. carinatus* was (0.476) sighted more frequently than other venomous snakes as the nocturnal survey was confined to the grassland located contiguous to paddy fields. We therefore considered it a habitat specialist and this may be a major reason to sight *E. carinatus* almost always in open grass patches.

Regarding the similarity of species composition in eight different microhabitats, since the previous studies did not elaborate on this aspect, as explicitly as we had done, direct comparisons could not be attempted. Additionally, during the present investigation, we found copulation of *Dryocalamus nympha* that is a new record for this species, that was published separately (Krishnakumar, 2014). Anthropogenic activities such as roadkill and killing out of fear were observed. *Naja naja* and *P. mucosa* were more likely to be involved in human-snake-conflict in the study area as they were encountered several times in and around houses.

Overall, these data suggest that species richness and diversity of snakes in this study is rather high compared to what were previously presented from the eastern Tamil Nadu region (Table 3). As future scope, this study hints at the need for more thorough studies to be conducted about the impact of pesticide and fertilizer used in farmland. Retaliatory killing and other conflicts involving snakes and human have not reported here. Yet, we believe that the general importance of understanding the negative impact of anthropogenic pressure on snakes could be critical. Especially, to enable farmland managers to make more informed and more environmentally sensitive decisions. Furthermore, we advocate non-intensive farmland management that produce hospitable grounds for snakes to persist. Our study reveals the advantage gained by viewing snakes as a pro-farming entity that serves our common interest by being a natural rat pest control agent, thereby reducing crop damage.

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Conflict of interests

The authors have no conflict of interest to declare.

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