



## Distribution and abundance of pit vipers (Reptilia: Viperidae) along the Western Ghats of Goa, India

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**Abstract:** The distribution and abundance of pit vipers in the Western Ghats namely *Trimeresurus gramineus* (Bamboo Pit Viper), *T. malabaricus* (Malabar Pit Viper) and *Hypnale hypnale* (Hump-nosed Pit Viper) was investigated in five wildlife sanctuaries of Goa from 2005 to 2009. Seasonal day-night data was collected based on band transect methods. All the pit viper species showed specific habitat preferences and their abundance changed with season. They were most abundant during monsoon. *H. hypnale* extended its range to the adjoining cashew plantations during the post monsoon and winter.

**Keywords:** Habitat preference, *Hypnale*, seasonal variation, *Trimeresurus*

## INTRODUCTION

Goa (14°51'-15°48'N & 73°41'-74°20'E) is a maritime state along the central west coast of Indian peninsula. The Western Ghats of India is one of the 34 biodiversity hotspots in the world (Myer et al. 2000). Goa (3702km<sup>2</sup>) occupies about 2% area of Western Ghats (Joshi & Janarthanam 2004) and its biodiversity is under threat due to deforestation (Myer 1990; Menon & Bawa 1997; Jha et al. 2000). Reptilian fauna is largely dominated by the Indo-Chinese element, relicts India's geological history. Approximately, out of 530 species of reptiles presently reported from India 197 comprises endemics, of these 98 endemics out of 260 species are reported from the Western Ghats (Daniel 2002). In spite of this high endemism, herpetofauna in India has received poor attention and has not been studied in detail (Vasudevan et al. 2001) and it is possible that a few of them have already been lost even before being reported (Dar et al. 2008). Pit vipers belong to the family Viperidae and subfamily Crotalinae, which is represented by 21 genera. Nineteen species of pit vipers have been reported from India (Bhide 2001) including seven from the Western Ghats (Kumar et al. 1998). All these species barring *Trimeresurus gramineus* are endemic to Western Ghats (Whitaker 1969; Whitaker & Captain 2004; Khaire 2006). Information on the distribution, abundance and present conservation status of pit vipers in Western Ghats is scanty.

## MATERIALS AND METHODS

The present study was conducted in Mhadei Wildlife Sanctuary (MWS: 208.48km<sup>2</sup>), Bhagwan Mahaveer Wildlife Sanctuary and National Park (BMWS & NP: 241km<sup>2</sup>), Bondla Wildlife Sanctuary (BWS: 8km<sup>2</sup>), Netravali Wildlife Sanctuary (NWS: 211.05km<sup>2</sup>), Cotigao Wildlife Sanctuary (CWS: 86km<sup>2</sup>) and in cashew *Anacardium occidentale* plantations within and adjoining areas of these protected areas (PA) (Fig. 1). Altitude of the study areas ranged from 20 to 800 m and consists of west coast tropical evergreen, cane brakes, wet bamboo brakes, west coast semi-evergreen, moist bamboo brakes, lateritic semi-evergreen forest, slightly moist teak forest, southern moist deciduous



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forest, southern secondary moist mixed deciduous forest, south Indian subtropical hill savannah woodland and southern subtropical hill forest (Champion & Seth 1968; Table 1). The ambient temperature usually fluctuates between 15 and 30 °C.

The distribution and abundance of pit vipers was studied in all the PAs mentioned above using band transect following Dahanukar & Padhey (2005). Surveys were carried out on foot in different seasons (summer - March to May, monsoon - June to October and winter - November to February) during June 2005 to January 2009. Surveys were conducted during both day and night in predetermined paths or roads (2500x20 m). Geographical position of each study area and location of each observation of the snake was recorded using a handheld geographical positioning system (GPS). Relative humidity and ambient temperatures of the observation sites were recorded using a hygrometer and mercury thermometer respectively.

Transects were traversed everyday for a week at each site by the researcher with the help of local volunteers. The transects were repeated five times per season. Visual inspection of shrubs, trees, ground and leaf litter was carried out for locating the snakes. All pit vipers encountered during the surveys were identified up to species level following Smith (1943), Murthy (1990) and Daniel (2002). The individuals were not marked, the snakes sighted on any single transect on successive days were identified based on the scale count and was not included to calculate the abundance. Abundance (number of individuals sighted in each study area) is represented as mean ± standard error. The mean abundance of the three species in each of the study sites and across seasons (summer, monsoon and winter) was tested to know whether the seasonal variation in each study site has any influence in abundance of the species, using two-way ANOVA.

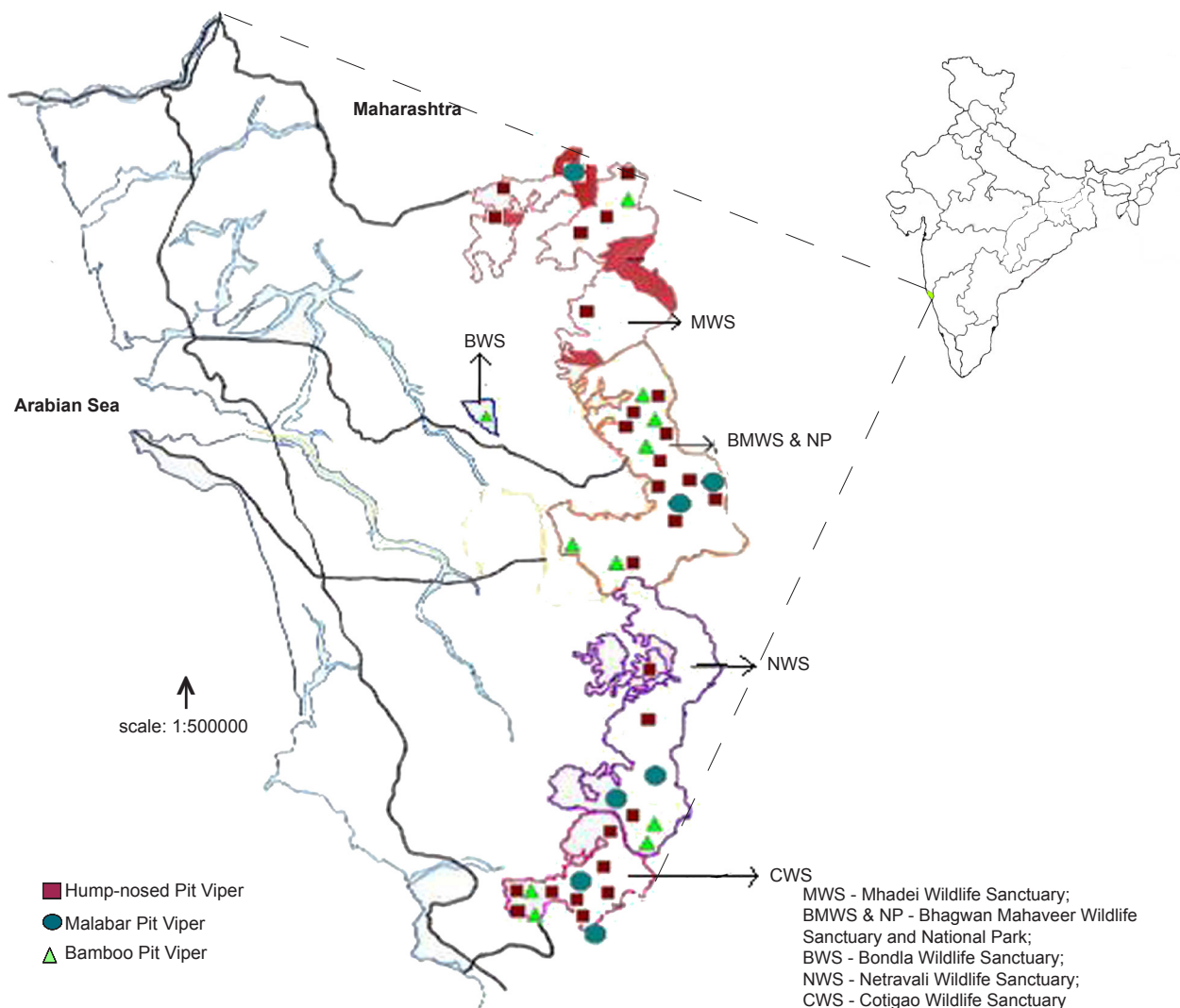


Figure 1. Map of Goa showing the distribution of pit viper species in the study sites

**Table 1. List of forest types present in the study areas.**

Forest type	Protected Area				
	MWS	BWS	BMWS & NP	NWS	CWS
West coast tropical evergreen	√		√	√	
Cane brakes	√	√	√	√	√
Wet bamboo brakes	√	√	√	√	√
Slightly moist teak forest	√		√	√	
Southern moist deciduous forests		√	√	√	√
South Indian subtropical savannah woodland	√		√	√	√
Southern subtropical hill forest			√	√	√
Southern secondary moist mixed forest	√	√		√	√
West coast semievergreen	√	√	√	√	√
Moist bamboo brakes	√	√	√		
Lateritic semievergreen forest	√	√	√		

## RESULTS

In all, 45 transects (CWS - 7, MWS - 12, NWS - 7, BWS - 4 and BMWS & NP - 15) were sampled to assess the species distribution and abundance of pit vipers. Three species of pit vipers, *T. gramineus*, *T. malabaricus* and *H. hypnale* were recorded during this study (Images 1, 2, 3). A total of 356 pit vipers were observed during this study. *H. hypnale* was the most abundant species contributing (46.63%, n = 166) followed by *T. gramineus* (28.09 %, n = 100) and *T. malabaricus* (25.28%, n = 90). The abundance of pit vipers varied in different study locations (Table 3).

All three species of pit vipers were observed in all the study locations, except the BWS, where only *T. gramineus* was found. However, the locals report the presence of *T. malabaricus* in BWS. The forests type preferred by each species of pit vipers is listed in (Table 2). The temperature and humidity of the area during the present study ranged from  $20.88 \pm 5.25$  °C to  $32.44 \pm 0.88$  °C and  $53 \pm 4\%$  to  $93 \pm 2\%$  respectively.

*T. malabaricus* was observed at an altitude above 200m and exhibited occurrence at higher elevation in all the sites except in CWS; where it was recorded below 200m thus occupying the range between 123 and 765 m. *Trimeresurus gramineus* and *H. hypnale* were found from 37 to 672 m and 35 to 672 m respectively (Fig. 2). *T. malabaricus* and *T. gramineus* were observed at (mean & SD)  $1.53 \pm 1.6$  m and  $1.45 \pm 0.68$  m above ground respectively, whereas, *H. hypnale* was mostly found on the ground (beneath leaf litter), but, occasionally found on shrubs and herbs (up to 0.39m) as well.

Distribution of pit vipers varied among seasons. During monsoon they were found in all 45 transects, whereas, in summer and winter they were observed in 35 transects which include transects having water bodies in the vicinity and transects in the cashew plantations, and were

**Image 1. Hump-nosed Pit Viper *Hypnale hypnale*****Image 2. Malabar Pit Viper *Trimeresurus malabaricus***



Image 3. Bamboo Pit Viper *Trimeresurus gramineus*

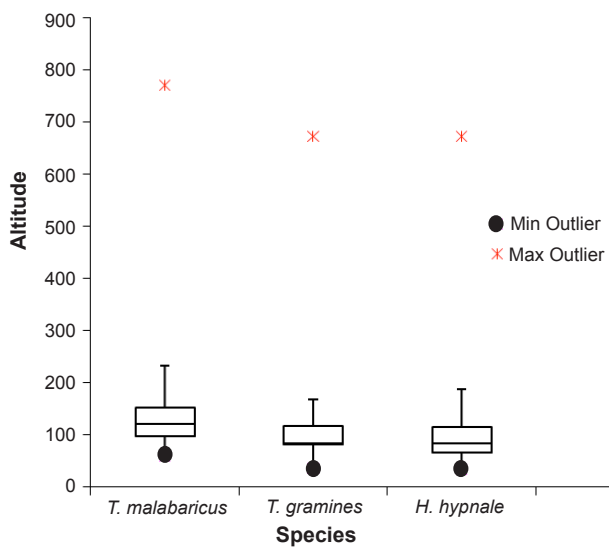


Figure 2. Graph showing mean  $\pm$  SD, min and max value of altitude (in m) at which the pit viper species were observed in Goa

restricted to patches near moist areas. *H. hypnale* moved to adjoining cashew plantations during post monsoons (September and October) and winter, their abundance was high during monsoon in all transects (Table 4). ANOVA showed that the abundance of pit vipers varied significantly with seasons [*T. malabaricus* ( $F = 3.20$ ,  $p = 0.00058$ ), *T. gramineus* ( $F = 3.20$ ,  $p = 0.00028$ ) and *H. hypnale* ( $F = 3.20$ ,  $p = 0.015$ )]. However, the abundance did not change significantly during each season when compared between sites.

**DISCUSSION**

Species in a reptile assemblage are not randomly distributed in space either horizontally or vertically, but occupy discrete microhabitat (Heatwole 1982). The distribution and abundance of all three species of pit vipers varied as their habitat-use was different. The *T. malabaricus* and *T. gramineus* are arboreal, whereas, *H. hypnale* is terrestrial in nature, however, a semi- arboreal behavior was also observed in *H. hypnale*. The present results augment the report of Murthy (1990). It was observed that most of the pit vipers were encountered in the regions having cool climate (segments of the transects with lower temperature and higher humidity) suggesting that the species prefer cool and moist places. Daltry et al. (1998) reported that the pit vipers typically remain motionless in areas with dense cover of undergrowth, suggesting this species is hygrophilic in nature. The three species remain highly camouflaged in their habitat and move very rarely exhibiting ambush behaviour.

*Trimeresurus malabaricus* predominantly occupied tropical semievergreen forests and rarely used moist deciduous forests. *Trimeresurus gramineus* and *H. hypnale* were observed largely in cane brakes, wet bamboo brakes, tropical semievergreen and moist

Table 2. List of forest types preferred by the pit vipers

Forest types	Pit viper species		
	<i>T. malabaricus</i>	<i>T. gramineus</i>	<i>H. hypnale</i>
West coast tropical evergreen	*	*	*
Cane brakes		*	*
Wet bamboo brakes		*	*
Slightly moist teak forest	*	*	*
Southern moist deciduous forests	*	*	
South Indian subtropical savannah woodland	*	*	*
Southern subtropical hill forest	*	*	*
Southern secondary moist mixed forest	*	*	*
West coast semievergreen	*	*	*
Moist bamboo brakes	*	*	*
Lateritic semievergreen forest	*	*	*

deciduous type of forest (Table 2). It was seen that all the three species were distributed in all study locations, barring BWS, where *T. malabaricus* and *H. hypnale* were not recorded during the present study. This could be due to the anthropogenic activities in and around the sanctuary as human disturbances can affect the snakes in terms of their distribution (Greene 1988; Peterson 1990; Brown 1993; Parent & Weatherhead 2000). Terrestrial and arboreal habitats differ profoundly in many ways including the types and amount of food availability, vulnerability to predators, and physical factors such as temperature and humidity. Those differences have resulted in many taxa becoming highly specialized for either terrestrial or arboreal life and rarely venturing to alternative habitat (Plummer 1981; Luiselli et al. 2000; Vilt et al. 2000). *Trimeresurus malabaricus* and *T. gramineus* remain camouflaged in the thick canopy of the trees at an average height of 3-5 m from the ground, which could help avoiding avian predators. Sometimes they were also encountered while crossing the roads at night hours during the monsoon. This could be due to the thigmothermic response to warm surfaces, such as asphalt roads at night in nocturnal crotalines (Klauber 1972). This excursion to the ground could be driven by the availability of prey, especially frogs which are important food of pit vipers and mate searching, pheromonal trail following may result in males traveling further and longer to locate females (Shine et al. 2004). Further, *H. hypnale* was occasionally sighted among small herbs exhibiting semi-arboreal habit. The occasional use of arboreal habitat offers a good opportunity for the snake as it might reduce the efforts or energy needed to thermoregulate or search prey. Similar observations are reported by Oliveira & Martins (2001) and Shine et al. (2005). *H. hypnale* and *T. gramineus* preferred a broader range of altitude as compared to *T. malabaricus*, however *T. malabaricus* was also found at lower altitude in CWS suggesting that it is the ideal habitat with suitable hygrothermal profile and prey base which is the basic factor influencing distribution of these species. Some researchers (Campbell & Solorzano 1992; Huang et al. 2007) consider ambient temperatures to be the most important environmental factor limiting the altitudinal distribution of reptiles.

The remarkable change in the shift in habitat by *H. hypnale* was seen during the present study, wherein it was observed that during post monsoon and winter they occupy the cashew plantations (n = 45) adjoining the PAs. It is mainly due to the leaf litter, thick bushes which provides ideal microhabitat, suitable hygrothermal conditions, prey availability, and predator avoidance. Cool and humid environment below leaf litter provides good microclimatic condition for the forest floor reptiles (Kumar 2001), which is the major prey base for pit vipers. According to Block & Morrison (1998) leaf litter depth is an important factor in habitat selection in amphibians and reptiles. Since snakes are predatory in nature, therefore

**Table 3. Observation of pit vipers in different study sites (Mean  $\pm$  SE)**

Study Area	Number of individuals of each species		
	<i>T. malabaricus</i>	<i>T. gramineus</i>	<i>H. hypnale</i>
CWS	7.75 (3.4)	7.25 (1.4)	9.5 (4.4)
BWS	0	2.75 (1.8)	0
MWS	8 (5)	5.25 (3.3)	9.75 (4.8)
BMWS & NP	3.5 (0.5)	3.75 (2.1)	14.5 (5.2)
NWS	3.25 (1.3)	4.75 (2.9)	7.75 (5.1)

**Table 4. Variation in the observation of pit vipers among different seasons in the Western Ghats of Goa (Mean  $\pm$  SE)**

Species	Season		
	Summer	Monsoon	Winter
<i>T. malabaricus</i>	1.75 (1)	17 (6.9)	3.25 (1.7)
<i>T. gramineus</i>	2 (1.08)	18.5 (9.6)	3 (1.7)
<i>H. hypnale</i>	9.5 (2.1)	24.75 (14)	7.25 (4.3)

their local distribution might be influenced by distribution of prey abundance (Dar et al. 2008). It was seen that all the three species exhibited patchy distribution during summer and winter, confined to areas in close proximity of water bodies, whereas, in monsoons they were distributed in all transects.

It was also seen that the abundance of all the three species varied in different seasons. The abundance was highest in monsoon compared to summer and winter. The highest abundance during monsoon was due to the suitable climatic conditions such as low temperature (22-24 °C), high humidity and rich prey base. In summer and winter the prey base (such as frogs) and suitable climatic conditions are restricted to patches in the vicinity of water bodies in the PAs. According to Sun et al. (2001) prey availability and abiotic factors, especially temperatures are the cues that drive seasonality in snakes.

It seems evident from the present study that pit vipers species are habitat specific and abiotic factors within the habitat such as seasonal changes in temperature and humidity, have influence on the distribution of these snakes. Hence, the protection of habitat is an important aspect in conservation of these species.

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