REPTILES & AMPHIBIANS

A Review of Malabar Pitviper, *Craspedocephalus malabaricus* (Jerdon 1854), Ecology from the Western Ghats of India and Notes on Feeding Behavior

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The family Viperidae comprises 374 venomous species assigned to four subfamilies: Azemiopinae, Causinae, Crotalinae, and Viperinae (McDiarmid et al. 1999; Uetz et al. 2023), of which pitvipers in the subfamily Crotalinae are the most widely distributed (Gloyd and Conant 1990; McDiarmid et al. 1999; Campbell and Lamar 2004). Pitvipers in the genera *Trimeresurus* Lacépède 1804 and *Craspedocephalus* Kuhl and van Hasselt 1822 are charismatic snakes and many morphologically and ecologically diverse species (Sanders et al. 2004). At least 48 known species are distributed across eastern and southeastern Asia (Gumprecht et al. 2004; Whitaker and Captain 2008; Wallach et al. 2014; Captain et al. 2019; Mirza et al. 2020). Fourteen species of *Trimeresurus* and eight species of *Craspedocephalus* have been recorded from India alone (Mirza et al. 2020; Uetz et al. 2023).

The Western Ghats of India is one of 34 biodiversity hotspots in the world and the second richest biodiversity zone in India (Myers et al. 2000). Six species of pitvipers have been reported from the Western Ghats, and all but *Craspedocephalus gramineus* are endemic to the area (Sawant and Shyama 2007). Three species, the Malabar Pitviper (*C. malabaricus*), Bamboo Pitviper (*C. gramineus*), and Hump-nosed Pitviper (*Hypnale hypnale*) are known from Goa. Of these, *C. malabaricus* and *H. hypnale* are endemic to the Western Ghats (Sawant and Shyama 2007). *Craspedocephalus malabaricus* is well known from the central and northern Western Ghats, from Mahabaleshwar and Koyna in Maharashtra to the Nilgiris and Elivalmalai Hills north of the Palghat Gap (Mallik et al. 2021).

Craspedocephalus malabaricus occurs in a variety of habitats including forests (e.g., west coast tropical evergreen, slightly moist teak forest, southern moist deciduous forest, south Indian subtropical savannah woodland, southern subtropical hill forest, southern secondary moist mixed forest, west coast semi-evergreen forest, moist bamboo brakes, and lateritic semievergreen forest), shola patches, riparian habitat, plantations, and human settlements in buildings such as sheds across the Western Ghats wherein an apparent preference is shown toward tropical evergreen rather than moist deciduous forest (Whitaker and Captain 2008; Ganesh et al. 2010; Sawant et al. 2010; Sawant and Jadhav 2013; Bhaisare and Pelling 2015). Vegetation plays a crucial role in concealing snakes from predators (Janzen 1976). The elevational range is listed as 200–1,300 m; however, in the Cotigao Wildlife Sanctuary in Goa, *C. malabaricus* has been recorded below 123 m asl, suggesting that the species occurs at elevations below 200 m (Sawant et al. 2010; Ganesh et al. 2010).

Craspedocephalus malabaricus is polymorphic, with basic color profiles varying between green, olive, brown, yellow, blue, reddish-brown and maroon, speckled with black and brown spots, which may or may not form a zigzag pattern along the dorsum (Whitaker and Captain 2008; Kanagavel et al. 2012). Polymorphism has been observed in most Indian vipers but has been understudied until recently. Pitvipers of the Western Ghats are known to be habitat specific, wherein their distribution is modulated by seasonal changes in temperature and humidity and not by detectability of species due to seasonal changes (Sawant et al. 2010; Kanagavel et al. 2012). Thus, the polymorphism exhibited by *C. malabaricus* might not be attributable to thermoregulation but instead is used for camouflage and additional factors like locality and habitat use might also influence color and pattern (Kark et al. 1997; Sawant et al. 2010; Kanagavel et al. 2012). An ideal habitat for any animal must meet its physical and physiological needs while maximizing the abundance of prey and minimizing exposure to predators and potential competitors (Reinert 1993; Eskew et al. 2009). In *C. malabaricus*, habitat appears to be more or less correlated to dorsal coloration,

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Figure 1. An adult Malabar Pitviper (*Craspedocephalus malabaricus*) in an ambush position (upper left), striking a Malabar Gliding Frog (*Rhacophorus malabaricus*) (upper right), and ingesting the frog (lower left and right). Photographs by Mayur Gawas.

green snakes tending to be more arboreal whereas brown individuals are more terrestrial (Whitaker 1978; David and Vogel 1998; Gumprecht et al. 2004). Differences in physical factors such as temperature and humidity have resulted in many taxa becoming highly specialized for either terrestrial or arboreal life and rarely venturing to alternative habitats (Plummer 1981; Luiselli et al. 2000; Vilt et al. 2000). Similarly, hygrothermal profiles in correlation with body mass drives arboreal height selection in this species (Sawant and Jadhav 2013). Excursions to the ground could be driven by the availability of prey (especially frogs, which are important food for *C. malabaricus*), searching for mates, and following pheromonal trails, which can result in males traveling considerable distances to locate females (Shine et al. 2004).

Ecological traits such as home range size, movement rates, and habitat selection can be influenced by prey availability, as predators modify various behaviors to optimize food acquisition (Pyke et al. 1977; Gittleman and Harvey 1982). *Craspedocephalus malabaricus* is inactive during the day, but becomes active nocturnally and feeds throughout the night (Sawant and Shyama 2007; Sagar 2016). Pitvipers are ambush-hunters rather than active-foragers, and select ambush sites to maximize foraging success based on prey availability (Chiszar et al. 1982; Reinert et al. 1984; Roth et al. 1999; Shine et al. 2002; Clark 2004). *Craspedocephalus malabaricus* feeds on small mammals, lizards, frogs, toads, and birds and their eggs but has been most frequently observed feeding on frogs in Goa (Sawant et al. 2010; Sagar 2016). Frogs are abundantly available in monsoon seasons but the density drastically decreases or concentrates in areas where water is available during dry winters and summers (Duvall et al. 1985; Sazima 1992; Sawant et al. 2010). Along the Western Ghats in Karnataka, these snakes have displayed diving behavior and apnea, a temporary suspension of external breathing, which was thought to provide some protection from possible predators and facilitate predation in riparian habitats (Bhaisare and Pelling 2015). One study (Aubret 2004) has suggested that snakes develop

apnea in response to using aquatic habitats, whereas another suggested that all reptiles possess that advantageous fundamental physiology to allow survival in an aquatic environment (Heatwole 1977).

Previous studies stated that the abundance of *C. malabaricus* varied significantly with the seasons. Although snakes did not show any changes in habitat preferences during different seasons, microhabitat use varied, allowing individuals to more closely approach their prey (Sawant et al. 2010; Sawant and Jadhav 2013). Another apparently adaptive strategy involved dietary shifts that enhance survival in changing, diverse, and novel environments (Voris and Voris 1983; Mushinsky 1987; Shine and Sun 2001). Seasonal shifts in habitat use are a common feature of the ecology of many snake species (Reinert 1993), and a few studies suggested that individual snakes actively select suitable subsets of their environment based on prevailing biotic and abiotic factors (Reinert 1984; Weatherhead and Charland 1985; Burger and Zappalorti 1988; Weatherhead and Prior 1992; Reinert 1993). Past studies on snakes suggested that the need to locate essential resources such as food, shelter, and gestation sites also influence habitat selection by snakes (Reinert 1993). Since snakes are predators, local distributions likely are influenced by prey abundance (Dar et al. 2008). Microhabitat use and activity patterns are important components of animal ecology (Sagar 2016). During monsoons, *C. malabaricus* is distributed throughout the habitat due to an increase in the abundance of prey such as frogs, but during summers and winters, when the prey base declines, both prey and snakes are restricted to certain microhabitats (Sawant and Jadhav 2013). These snakes have been observed demonstrating aestivation-like behavior during the dry summer season until it rains (MG, personal observations). However, not all individuals exhibit this behavior and further studies are required to understand the phenomenon.

Figure 2. A Malabar Pitviper (*Craspedocephalus malabaricus*) after capturing an adult male Bombay Bush Frog (*Raorchestes bombayensis*). Photograph by Mayur Gawas.

Many species within the region are decreasing in abundance because of habitat destruction, which could lead to extinction of those species. Therefore, identifying the factors that influence habitat selection is crucial in order to conserve these species (Sawant and Jadhav 2013).

At 2135 h on 22 July 2020, during surveys in Sural Village in the Madei Wildlife Sanctuary (15.66°N, 74.17°E), we observed a green adult *C. malabaricus* (total length ~65–70 cm) with a brown pattern on its back in an ambush position approximately 3 m above the ground (Fig. 1). The snake was perched near a puddle with Malabar Gliding Frogs (*Rhacophorus malabaricus*) and their nests. At exactly 2140 h, an adult male *R. malabaricus* jumped and perched on a branch directly opposite the *C. malabaricus* at an approximate distance of 30–35 cm. The snake moved its head slightly toward the frog but did not show any signs of striking toward it. At 2146 h, the frog moved to within 10–12 cm of the snake's head and the latter struck at the frog's head (Fig. 1). The subsequent struggle lasted for 7 min, after which the snake ingested the frog headfirst (Figs. 1). Complete ingestion took 8 min, after which the snake moved higher into the canopy.

We also observed feeding by *C. malabaricus* (total length ~35–40 cm) with a mixture of green, russet, yellow, white, and pale brown dorsal scales at 0130 h on 7 November 2020 in the Sural Beat of the Madei Wildlife Sanctuary (15.66°N, 74.17°E). The snake was perched 1.7 m above the ground on a small twig. Temperature and relative humidity were 23.27 °C and 60%, respectively. The snake was in an ambush position with its head directed toward an embankment some 8 cm away. An adult male Bombay Bush Frog (*Raorchestes bombayensis*) was crawling down the wet surface of the embankment near the snake's head. At 0143 h the snake struck the right fore- and hindlimb of the frog when it was ~7 cm away (Fig. 2). The struggle lasted for 6 min, until the snake captured the entire frog at 0159 h. Headfirst ingestion took 4 min, after which the snake remained on the same branch but with its head pointing away from the embankment.

In both the cases, the snakes initiated ingestion only after the frogs stopped moving, apparently giving the venom time to kill or at least immobilize the prey, minimizing any opportunity to escape.

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