

Observations on a Wild King Cobra (*Ophiophagus hannah*), with Emphasis on Foraging and Diet

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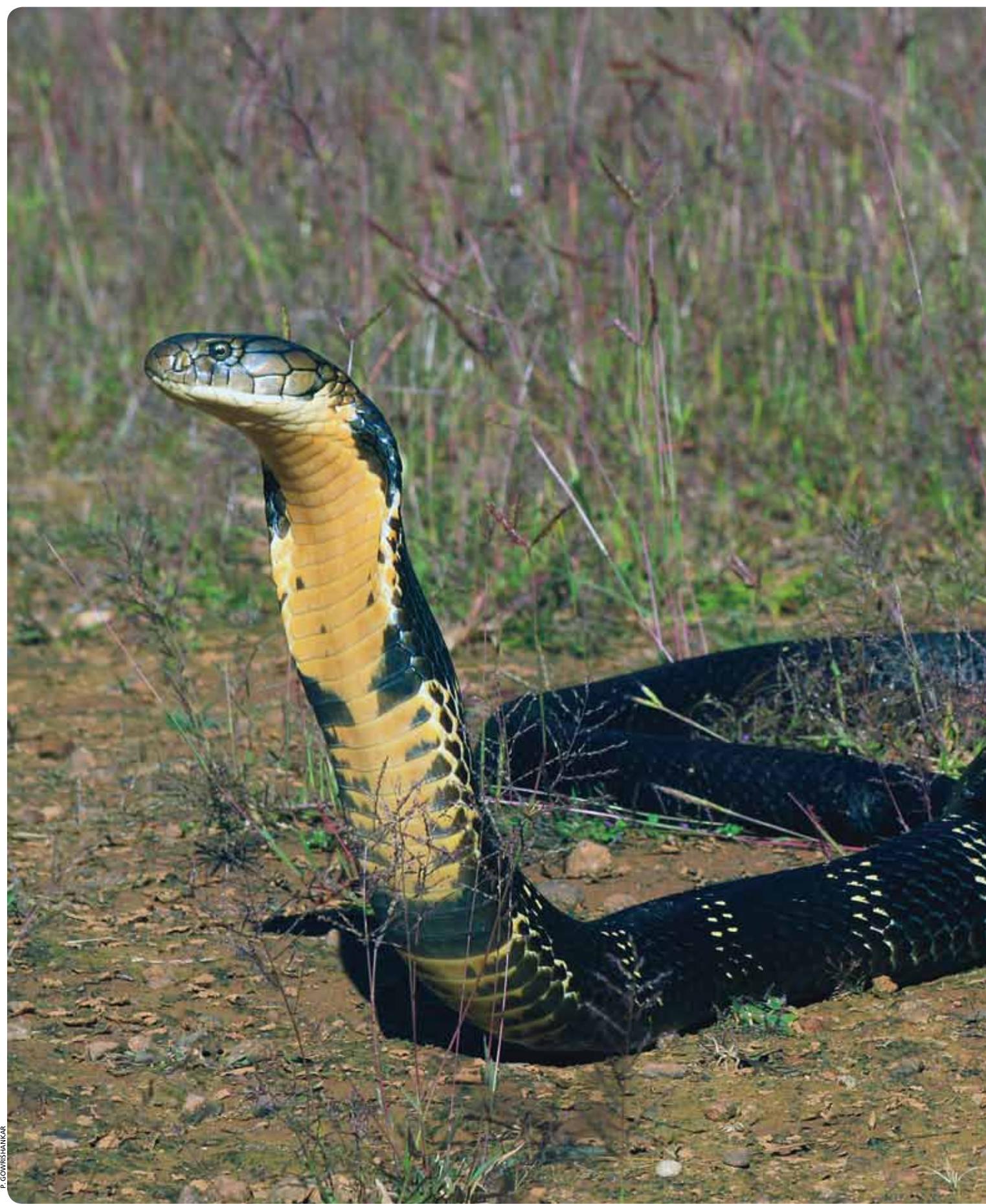
Since 2005, we have conducted research on King Cobras (*Ophiophagus hannah*) in the forests and plantations surrounding Agumbe Rainforest Research Station (ARRS) located in the Western Ghats of southern India. In March 2008, we started a radiotelemetry project and to date we have tracked four adult King Cobras (three males, one female) for varying periods. Although we have documented a number of interesting facets of King Cobra biology, this note is confined to observations made on a single male (M2) from June–November 2009. During this time, we observed M2 capturing and consuming 26 pit vipers (two Hump-nosed Pit Vipers, *Hypnale hypnale*, and 24 Malabar Pit Vipers, *Trimeresurus malabaricus*). We provide details of these remarkable observations, and briefly discuss them in the context of our ongoing efforts to understand and conserve these charismatic serpents.

King Cobras in southern India are distributed along the length of the Western Ghats (the chain of hills just inland from the western coastline of peninsular India), from the southernmost tip, called Kanyakumari (Black Rock Estate), north to Goa (Bondla Wildlife Sanctuary). The range

of King Cobras in this part of India coincides with areas of extremely high rainfall and corresponding wet deciduous, riparian, and evergreen rainforest (Smith 1943). The King Cobra is uncommon throughout its range, and most of its original habitat has been destroyed. In addition, King Cobras are



Radio tracking in the rainforest is challenging, with vegetation, hillocks, and even heavy rain interfering with signals.



P.GOVINDSHANKAR

M2, an adult male King Cobra of “average” size (3.21 m)



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M2 strikes and catches an adult female Malabar Pit Viper at midbody; the viper is trying to sink its fangs into the cobra.

typically killed on sight throughout most of their range. However, Hindus living in the Malnad region of Karnataka State, including our study area, the villages and Reserve Forests around Agumbe, actually worship King Cobras and the snakes are rarely harmed, even if they enter a residence. This tolerant attitude for the largest venomous snake in the world has not only facilitated our research and educational efforts, but also has provided us with over 100 opportunities to "rescue" King Cobras from human habitations (Shankar, in prep.).

As inferred by their scientific name, King Cobras feed primarily on snakes, including their own species (we have observed intraspecific predation in both captive and wild individuals). The only other prey reliably reported from the wild were two species of Monitor Lizards (*Varanus* spp.), the Common Indian Monitor (*V. bengalensis*; Smith 1943) and the Water Monitor (*V. salvator*; C. Traeholt, pers. comm.). Two of us (RW and PGS) have observed King Cobras over the past several decades, and we have found that adult snakes (mean total length [TL] of males ~300–400 cm; females ~225–275 cm TL) in the Western Ghats prey mainly on the ubiquitous Indian Rat Snake (*Ptyas mucosa*; mean TL ~175 cm, maximum TL ~350 cm, mean mass ~1,250 g). Although we commonly observe Indian Rat Snakes in open and swampy areas of both cultivated and wild land, we rarely observe them in deep forest. Unusually large male King Cobras (> 400 cm TL) are known to prey on Indian Pythons (*Python molurus*); one of us (RW) was shown photos of a male King Cobra killing and swallowing a medium-sized python (~210–240 cm TL), and a 366-cm individual killed and swallowed a 280-cm Reticulated Python (*Python reticulatus*; Shebbeare 1947).

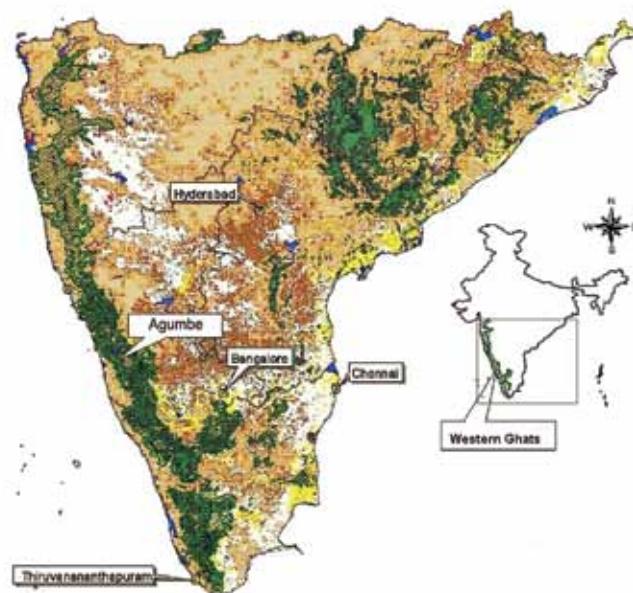
Some speculation (B.G. Fry, pers. comm.) suggests that King Cobras may be immune to the venom of viperids and elapids, and that they may

take special "precautions" when feeding on prey species with long fangs. Zoos around the world that exhibit King Cobras either condition them to eat dead rodents that have been prepared with odors from snakes and/or feed them snakes that have died on exhibit. This has resulted in a long list of venomous and non-venomous snakes, some as exotic as African Gaboon Vipers (*Bitis gabonica*), that have been fed to captive King Cobras (S. Pfaff, pers. comm.). However, an understanding of trophic ecology based on captive feeding records is less than satisfactory. King Cobras have been observed feeding on Banded Kraits (*Bungarus fasciatus*) in the wild (Saravanakumar, pers. comm.), and herein we describe what appears to be selective hunting of venomous pit vipers.

Methods

We obtained all feeding observations reported here while radiotracking "M2," a male (TL = 321 cm, mass = 4,900 g), into the coelomic cavity of which we implanted a 25-g temperature-sensitive radio transmitter (Model AI-2T, Holohil Ltd., Ontario, Canada). We released the snake one day after the surgery on 28 March 2009 at its exact point of capture (~1 km from the Agumbe Rainforest Research Station [ARRS]). Over the next two days, the snake moved 2.3 km, climbing down a steep escarpment that rendered radiotracking impossible. The signal was lost on 31 March, but recovered ten weeks later on 7 June after incredible perseverance by the tracking team. The snake had moved ~6 km straight-line distance from where it was lost, and we have tracked him every day since 10 June.

We radiotracked M2 each morning, staying with him throughout the day until nightfall. On days when the snake did not move (i.e., 20 consecutive days when shedding), we still obtained a fix every hour. At each fix, we recorded a suite of environmental parameters (e.g., ambient and body temperature, relative humidity, cloud cover), GPS coordinates, and habitat variables (e.g., canopy cover, dominant plant species, shelter type). If the snake was moving or visible when located, we made every effort to observe its behavior. Although our initial protocol was not to get too close to the snake for fear of influencing natural behavior or causing it to move or hide, we quickly learned that M2 did not seem to be disturbed by observers within a few meters, as long as trackers remained fairly still. The ability to



Agumbe, South India

Map of southern India showing the location of the Western Ghats and the Agumbe Rainforest Research Station.



M2 catches a Hump-nosed Pit Viper at midbody and proceeds to swallow it alive, doubled over, in a few short minutes.

closely approach the snake has enabled us to make the detailed observations reported on in this paper.

Our data indicate that King Cobras are primarily diurnal, although, on a few occasions, we tracked animals after dark and recorded some movements, once until 2200 h, but that was exceptional. M2 almost always found a shelter site well before sunset and sometimes as early as 1400 h. Depending on weather, such as rainfall, ambient temperature, and availability of sunlight, M2 typically emerged from his resting place around 0900 h (range = 0830–1200 h). We always stayed within the range of the radiotransmitter signal, because even short movements could result in losing the signal in the dense rainforest environment. In addition, this allowed us to infer changes in behavior of the snake by monitoring variations in signal intensity and rate. When feasible, we kept the snake under sporadic line-of-sight observation using binoculars. We took detailed notes describing all movement and behaviors observed, including what appeared to be obvious foraging behavior as revealed by increased tongue-flicking and apparent scent-tracking, presumably in response to prey odors.

Results and Discussion

During 2008, we tracked our first adult male King Cobra (M1) for more than 100 km over a nine-month period through a wide range of landscapes, much of it human-dominated (e.g., arecanut [betelnut] plantations, rice fields, and community forests). Unfortunately, we subsequently lost him. However, those data and others from over 100 “rescued” snakes suggests that at least some King Cobras “prefer” human-dominated landscapes. Perhaps King Cobras are drawn to man-made features because they attract rodents, which in turn provide for an increased relative abundance of Indian Rat Snakes.

During the first two months, we tracked M2 through a mix of dense intact forest, degraded community forests, and rarely plantations. However, at the onset of the monsoon in June, M2 moved into deep forest not far from ARRS, where he has remained, except for one brief period of 22 days when he retreated into a termite mound near farmlands on 20 September, emerging newly shed on 12 October. Between 7 June and 22 November, M2 moved 35.6 km through an area (which we are tentatively referring to as his “home range”) totaling 6.3 km².

We naively assumed that M2 would not be very active during the monsoon, because annual rainfall in Agumbe averages over 7,000 mm and has peaked at over 11,000 mm during the four-month monsoon season in June–September. We assumed that heavy and persistent rainfall would cause feeding to taper off until the return of warmer, dryer weather. However, M2 was first observed finding, killing, and eating a Malabar Pit

Viper (*Trimeresurus malabaricus*) on 6 July at the height of the rainy season. Over the following four and a half months, we observed M2 eating a total of 26 pit vipers, two of which were diminutive Hump-nosed Pit Vipers (*Hypnale hynale*).

Whether or not M2 moved on any given day usually depended on whether or not it was raining, rainfall intensity, and presence or absence of direct sunlight. On drier, sunnier days, M2 typically basked for 15–45 min before beginning to hunt. Foraging activity consisted of apparently purposeful searching, characterized by constant tongue-flicking and active probing of crevices, burrows, tree buttresses, and vegetative debris. Data from days on which we observed M2 feeding on one or more pit vipers (n = 23), he spent from 37 min to >7 h per day foraging (mean = 3.5 h/day).

When M2 apparently detected an odor trail of a pit viper, his foraging activity became visibly more intense, sometimes inducing “head jerking,” followed by sustained tongue-flicking along the presumed odor trail up to a height of 20 m in the canopy. On several occasions, pit vipers seemed alarmed by the close approach of M2, causing them to fall or launch from their perch (Malabar Pit Vipers are primarily arboreal, pers. obs.). A considerable amount of time spent foraging by M2 consisted of climbing in lower and mid-canopy. Of the 24 Malabar Pit Vipers consumed by M2, 17 (70.8%) were found and captured in trees, shrubs, vines, or dead branches, and seven (29.2%) were found and captured on the ground.

Our observations suggest that King Cobras are able to detect movement from relatively long range, perhaps as far as 50–100 m. We have observed King Cobras intently watching us as we moved through dense forest thickets. We also have observed a King Cobra that appeared to be watching a flock of herons flying overhead. However, their visual acuity may be poor, as they do not seem to easily recognize stationary objects, be they prey animals or potential threats (such as ourselves). India’s forest pit vipers are typically nocturnal ambush predators, remaining sedentary by day (pers. obs.). Indeed, we have observed pit vipers in the exact same location and even position for as many as seven days. King Cobras are unlikely to see a motionless pit viper. In fact, we observed M2 directly pursue and subdue pit vipers that he had disturbed, causing them to move. When unsuccessful at capturing the pit viper, M2 relied on chemosensory searching to follow the odor trail. We observed M2 lose the odor trail, such as when the pit viper fell into or crossed over water, but he persisted in his search until he picked up the trail again. Remarkably, he even seemed able to successfully find and follow odor trails in heavy rain. Although pit vipers would often remain motionless, they would invariably move when M2 got too close, thereby causing him to strike immediately.

In one startling two-hour episode recorded on video, we observed the King Cobra locating a large gravid female Malabar Pit Viper, causing it to fall from its perch about 15 m above the ground and try to evade capture.



Riparian habitat at the Agumbe Rainforest Research Station in southern India.



Adult female Malabar Pit Viper.

M2 promptly descended and followed the pit viper odor trail three times around and across a large, swift stream before finally catching and killing it. Although the pit viper was easily visible to us, M2 passed close to his prey several times, apparently so intent on picking up olfactory cues that he failed to see the snake. At one point, the odor trail was strong enough to induce M2 to bite a stone twice, providing further evidence of the prominence of olfaction over vision under some circumstances.

We also documented interesting prey handling behavior. In 16 of the observed prey captures, once M2 saw the pit viper, he approached the head end (Malabar Pit Vipers have a narrow neck and wide, triangular head characteristic of viperids) and grasped the smaller snake either just behind or directly on the head. Our observations of King Cobras feeding on Indian Rat Snakes indicate that they are not particular about which part of the body they grab, even though retaliatory bites from Indian Rat Snakes, including on the head of the King Cobra, commonly occur. Perhaps M2 was trying to avoid being bitten by the pit vipers. In nine of the predation events we observed, the King Cobra received what appeared to be a penetrating retaliatory bite. While the scales of a King Cobra probably prevent penetration, a pit viper presumably could pierce the interstitial skin between scales. When bitten by pit vipers, M2 invariably dropped his prey, waiting an average of 10 min until the pit viper was immobilized from being envenomated. Although Malabar Pit Viper venom has relatively low toxicity (Dhananjaya, pers. comm.), the bite of the Hump-nosed Pit Viper has caused kidney failure and occasional deaths in humans in Sri Lanka (de Silva 1990).

We observed M2 capturing a large, gravid female pit viper, grasping it at midbody, only to receive what appeared to be a penetrating bite on the side of the head. M2 immediately released the pit viper and, with head and

neck erect up to approximately 50 cm, appeared to watch the envenomated prey climb a nearby branch to a height of about 6 m. M2 remained motionless in this position for the next half hour, mouth partly open, without tongue flicking or reacting in any way. Even the pit viper, falling dead from a branch after 20 min, approximately 1 m away, and the approach of the tracker within approximately 3 m to check for swelling at the site of the bite (none was evident), did not elicit a response. After 30 min in this upright position, M2 came out of his apparent "trance" and immediately started searching for the pit viper, ignoring the dead snake in front of him and instead climbing (all the while vigorously tongue flicking) to the point where the snake fell. He then returned to the ground to eventually find and swallow the dead snake.

The maximum time for a pit viper to be consumed, starting with the point at which it was bitten and ending when it was swallowed, was 67 min and the minimum time was 4 min (mean = 14 min). In 16 predation events, M2 grasped the prey by the head or neck and, in a few cases, immediately swallowed it alive, completing the task within a few minutes. In the case of a small Hump-nosed Pit Viper (mean adult TL ~25 cm, mean mass <40 g), M2 simply grasped the snake at midbody and swallowed it while it was doubled over, without bothering to "jaw-walk" towards the head. Four pit vipers were grasped at midbody, three by the tail, and we failed to observe three other captures. Eleven of the snakes were still moving or clearly alive when swallowed, 12 were immobile and three we failed to see clearly.

We estimated 12 of the pit vipers to be ~60 cm TL (these were probably all females, several appeared gravid), five were approximately 45 cm TL (average adult male size), and seven were roughly 30 cm TL. We observed M2 eating two pit vipers per day on three separate days. The cobra frequently defecated after a swallowing episode.

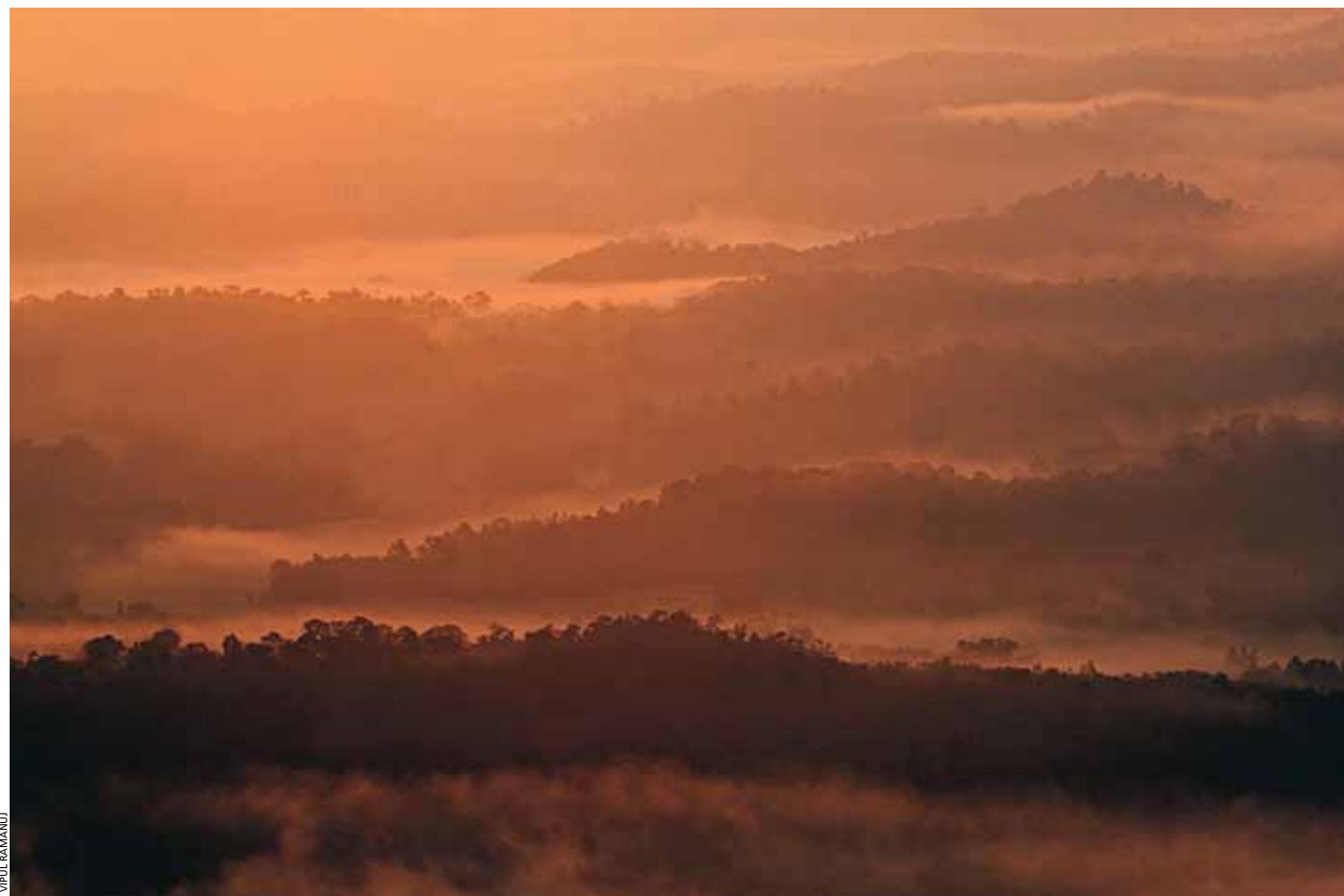
During this study, M2 spent approximately 50% of his active hours foraging/hunting for prey, in this case pit vipers. On one occasion, he spent over five hours continuously foraging before he located a pit viper to eat. He was not observed searching for, pursuing, or capturing any other species of snake during this time, despite the presence of other species similar in body mass to smaller pit vipers (see below). Since we followed M2 every day throughout his entire diurnal activity period, we almost certainly recorded the vast majority of predation events over the full 140-day period. During that time, our field team was with M2 for about 8 h per day for a total of 1,120 h. During this time, we observed M2 a total of 74.89 hours engaged in obvious foraging behavior that led to an actual predation event. On average, M2 consumed a pit viper every 5.38 days, and spent an average of 2.88 h foraging for each of the 26 pit vipers he caught and consumed.

In July–November, M2 primarily restricted his activity to deep forest. This period of time coincided with heavy rainfall in the Agumbe area. During rainy periods, we rarely observe snakes species that are known to be typical prey of King Cobras (e.g., Indian Rat Snakes). In addition, we have observed Indian Rat Snakes far more frequently in open meadows and agricultural lands, presumably with high prey densities, than in dense forest. In contrast, pit vipers are apparently more active during the monsoon season, as evidenced by our increased observations. Other snake species, which are typically visible during the rainy season in the vicinity of Agumbe, are Beddome's Keelback (*Amphiesma beddomei*), Large-eyed Bronzeback (*Dendrelaphis grandoculis*), and the Common Vine Snake (*Ahaetulla nasuta*); however, we did not observe M2 eating any of these species during the time in which he consumed the 26 pit vipers. Although pure speculation, perhaps King Cobras as a species (or M2 as an individual)

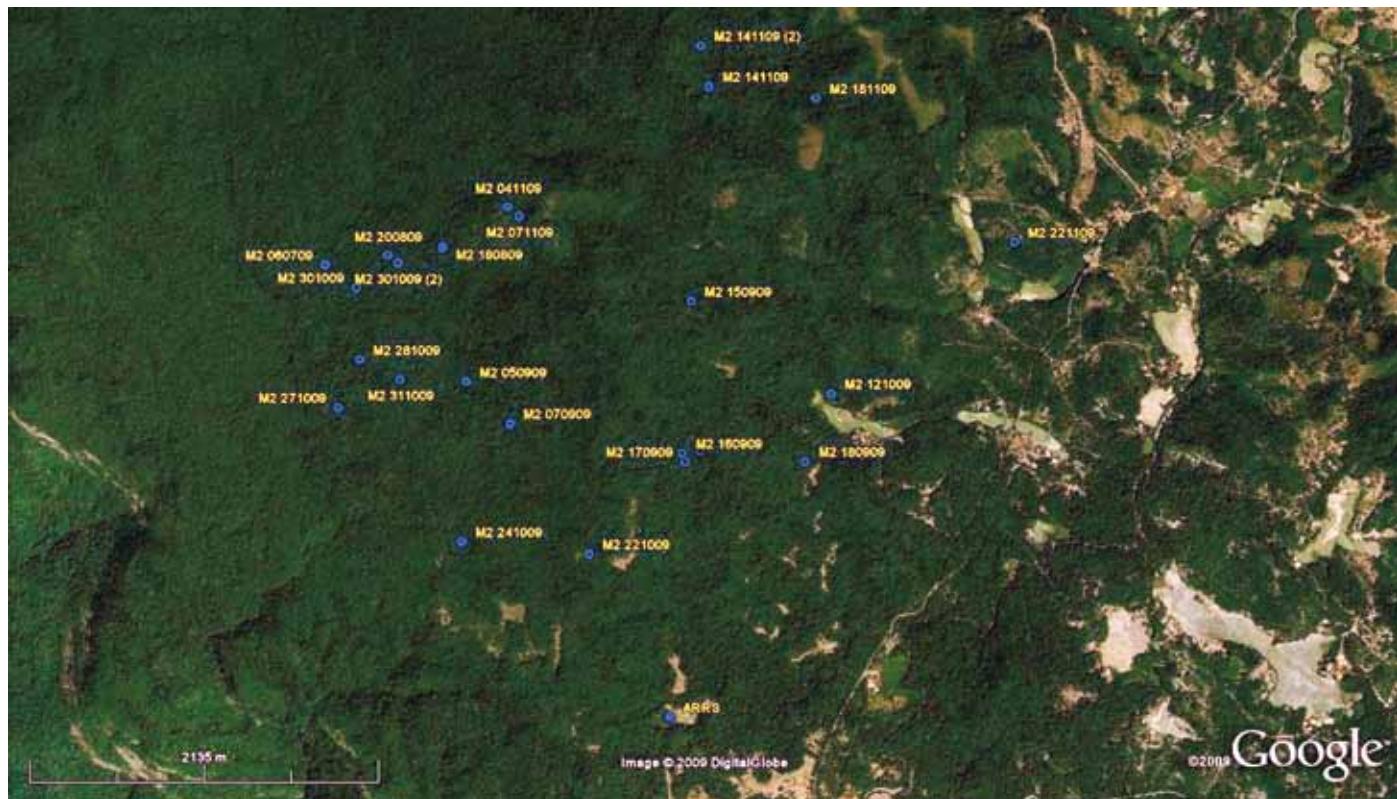
prefer pit vipers, or the odor trail of pit vipers is somehow easier to follow than those of other sympatric species.

Also interesting to consider is whether or not the pit vipers that M2 consumed could provide him with enough energy to maintain his health. When we captured M2 in early March, he weighed 4,900 g, which is an average mass for a healthy 321-cm King Cobra. If M2 consumed an average-sized adult Indian Rat Snake (~175 cm TL, ~1,250 g) his body mass to prey size would be approximately 4:1. A small sample of ten Malabar Pit Vipers captured in the vicinity of ARRS yielded an average TL of 45 cm and an average mass of 35 g. Although we were unable to obtain masses on the pit vipers consumed by M2, we estimated the range of their masses to be 30–60 g, which correlates to an average mass of approximately 50 g. Using this 50-g estimate, the mass ratio of predator to prey is roughly 98:1. If we add together the average approximated weights of all 26 pit vipers consumed, the predator-prey mass ratio is 3.77:1, which is approximately equal to that of a single Indian Rat Snake. One obvious question arising from this exercise is whether a total pit viper mass of 1,300 g is sufficient nutrition for a very active 5-kg King Cobra over a period of 18 weeks, not to mention a presumed increase in predation risk while moving.

Based on our observations, M2 apparently expended a great deal of energy searching, climbing (observed almost every day), and persistently and repeatedly following pit viper odor trails for what seemed to be a meager reward. However, M2 did not appear to have lost a significant amount of mass, nor did his body condition appear to suffer. Nevertheless, small snakes such as pit vipers, with the attendant need for large energy expenditure to find them, are unlikely to fulfill the nutritional requirements of such a large, active snake.



The rainforest habitat of the King Cobra at Agumbe in southern India.



Google Earth® image showing sites at which M2 was relocated. ARRS = Agumbe Rainforest Research Station.

Whether or not M2 will alter his foraging tactics during the upcoming mating season, when King Cobras of both sexes become much more active (judging from the dramatic increase in "rescue" calls received during the period of January–May), remains to be seen. Perhaps M2 will move into human-dominated landscapes, such as plantations and crop fields, where relative abundance of Indian Rat Snakes is apparently much higher.

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