KING COBRA TELEMETRY PROJECT, INDIA, 2009 – 2010. FINAL REPORT TO RIVERBANKS ZOO AND GARDEN CONSERVATION SUPPORT FUND and SUMMARY OF RESEARCH FINDINGS

King cobra (*Ophiophagus hannah*)

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CONSERVATION SUPPORT FUND APPLICATION

FINAL REPORT

Title of Project: **Ecology and Conservation of King Cobras in the Western Ghats of India**

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Project Categories (Please check all that apply):

- ☐ Management/Captive Breeding (*ex-situ)*
- ☐ Animal Welfare
- ☒ Conservation Education
- ☐ Animal Health
- ☒ Field Conservation (in-situ)
- ☐ Habitat Management
- ☐ Other - Describe

Project Abstract

The overall goal of the project is to learn as much as possible about the natural history and basic ecology of wild king cobras, and to use this information to better manage and conserve these incredible snakes and the habitats on which they depend. Although radiotelemetry is our primary tool for studying king cobras, we are also surgically implanting continuously recording miniaturized temperature dataloggers into snakes to examine thermal ecology and activity patterns. We began tracking two (one male and one female) translocated king cobras in March 2008. In late April, a wild king cobra killed and consumed the female. We have now tracked the male for over six months, during which time he has moved over 73 kilometers, undoubtedly a world record for snakes. In the relatively brief time we have been tracking king cobras, we have also encountered several wild king cobras interacting with our study animals. We have already documented an amazing array of behaviors, including male-male combat, mate guarding, courtship, mating, predation, and two instances of cannibalism. Support from Riverbanks Zoo will allow us to continue to track the

translocated male and to add a non-translocated individual to the study. Our goal is to eventually track 10-12 individuals (half translocated and half non-translocated) over the next several years. However, given the manpower needed to track an individual snake, it will take time to achieve an adequate sample size for statistical comparisons.

From a conservation perspective, our specific goal is to compare translocated and non-translocated snakes to see if translocation of "rescued" or "nuisance" snakes can be a viable conservation tool. Each year, our team at the Agumbe Rainforest Research Station (ARRS) removes 20-30 king cobras from the homes of local inhabitants. We receive calls requesting us to remove king cobras from as far as 60 kilometers distance. Although we always try to release snakes as close as possible to their original capture sites, it is not always practical depending on attitudes towards king cobras. In the vicinity of the village of Agumbe, where our research station is located, locals worship king cobras; therefore, wanton killing is not an issue, allowing us to release snakes where they were found.

Ultimately, our long-term goal is to work with local communities and state forestry officials to designate the area as a king cobra preserve, which would be the first-ever preserve set aside for a snake. Our research has brought a great deal of attention to the area, strengthening our efforts to obtain more stringent protection of these incredible snakes and their spectacular jungle environment.

We received the amount applied for, $5,000, from the Riverbanks Zoo and Garden's Conservation Support Fund, enough funding to pay for the salary and equipment of one team to track one snake for a six-month period and to purchase an additional transmitter that we have implanted into another adult male king cobra, which will be followed by a different team of trackers. The following is our final report on the usage of this generous grant.

INTRODUCTION

Studies on the king cobra (*Ophiophagus hannah*) were initiated by one of the authors (RW) in the Western Ghats and Andaman Islands during the early 1970s. However, it was not until a Memorandum of Understanding was signed between the Karnataka Forest Department and the staff of the Agumbe Rainforest Research Station in June, 2005 that a comprehensive research plan was formulated. The study of various aspects of the ecology of this, the world's largest venomous snake includes the use of radio telemetry (which started in 2008) to track the movements of the snakes in order to understand home range, territory and homing instinct, monitor its thermal regimen and observe behaviour.

This study has some of the world's most experienced herpetologists to provide advice and guidance. The telemetry project's Co-Principal Investigator, Matt Goode of the University of Arizona has been radio-tracking rattlesnakes for the past 20 years. A Project Advisor, Dr. Graham Alexander of the University of Witwatersrand, is currently radio-tracking pythons, puff adders, desert vipers and black mambas. Another Project Advisor, Dr. Jeffrey Lang (along with Co-PI, Romulus Whitaker) is currently radio-tracking the Critically Endangered Gharial in Uttar Pradesh. Another reptile telemetry study is being carried out by Dr. Kartik Vasudevan of the Wildlife Institute of India on the rare Travancore tortoise and cane turtle.

We anticipate a telemetry project duration of a minimum of five years in order to collect a sufficiently robust data set to come to scientifically valid conclusions on (among other things) the king cobra's habitat requirements and minimum home range, two of several parameters essential in the planning of conservation and management strategies for this snake.

While several papers are in the process of being written up for various international, peer-reviewed journals, it appears expedient to summarize some of the findings and observations, supplemented with photo-documentation of the king cobra project over the past few years. The king cobra research team is pleased to present this update and looks forward to a continued collaboration with the Karnataka Forest Department on this ground-breaking, first ever detailed study of the king cobra.

King Cobra Radiotelemetry Team
at the Agumbe Rainforest Research Station, March 2008

(From left)Neel Chattopadhyaya, Andy Casagrande, Romulus Whitaker, Matt Goode, Gowri Shankar, Charlie Painter, Mr.Brijesh Kumar(CF, Shimoga), Mr.Manjunath(ACF,Thirthahalli), Mr.Jagannath(RFO,Thirthahalli), Mr.Suresh(RFO, Megaravalli), Sandesh Kadu.

RESULTS

Effects of translocation

Radiotelemetry studies on a diverse array of taxa have clearly demonstrated that snakes maintain well-defined home ranges, which are likely mediated through a variety of sensory modalites, including chemoreception, celestial cue and landmark navigation (e.g., Gregory et al. 1987, Duvall et al. 1990, Reinert 1992, Goode et al 2009). The ability of snakes to home has been recognized for decades (Stickel and Cope 1947), and studies of snakes as diverse as tiny worm snakes (Barbour et al. 1969) to sea snakes (Shetty and Shine 2002) have demonstrated that snakes are clearly able to repeatedly return to locations within their home ranges. Removing ("rescuing") snakes from human habitations has become increasingly common, especially as humans have encroached on wild lands. Translocating "rescued" snakes has become the welcome alternative to killing them on sight,

however the fate of the snake, "set free in the forest", is rarely considered. Limited research on translocated snakes indicates that aberrant movement patterns (Dodd and Siegel 1991), and even death, may occur in up to 50% of individuals (Reinert and Rupert 1999), as they frantically try to home back to familiar surroundings. Although we presently do not have a large enough sample size to say for sure whether or not relocation affects survival or reproductive success of King Cobras, a comparison of two males, which we have tracked for longest periods of time, is both dramatic and indicative.

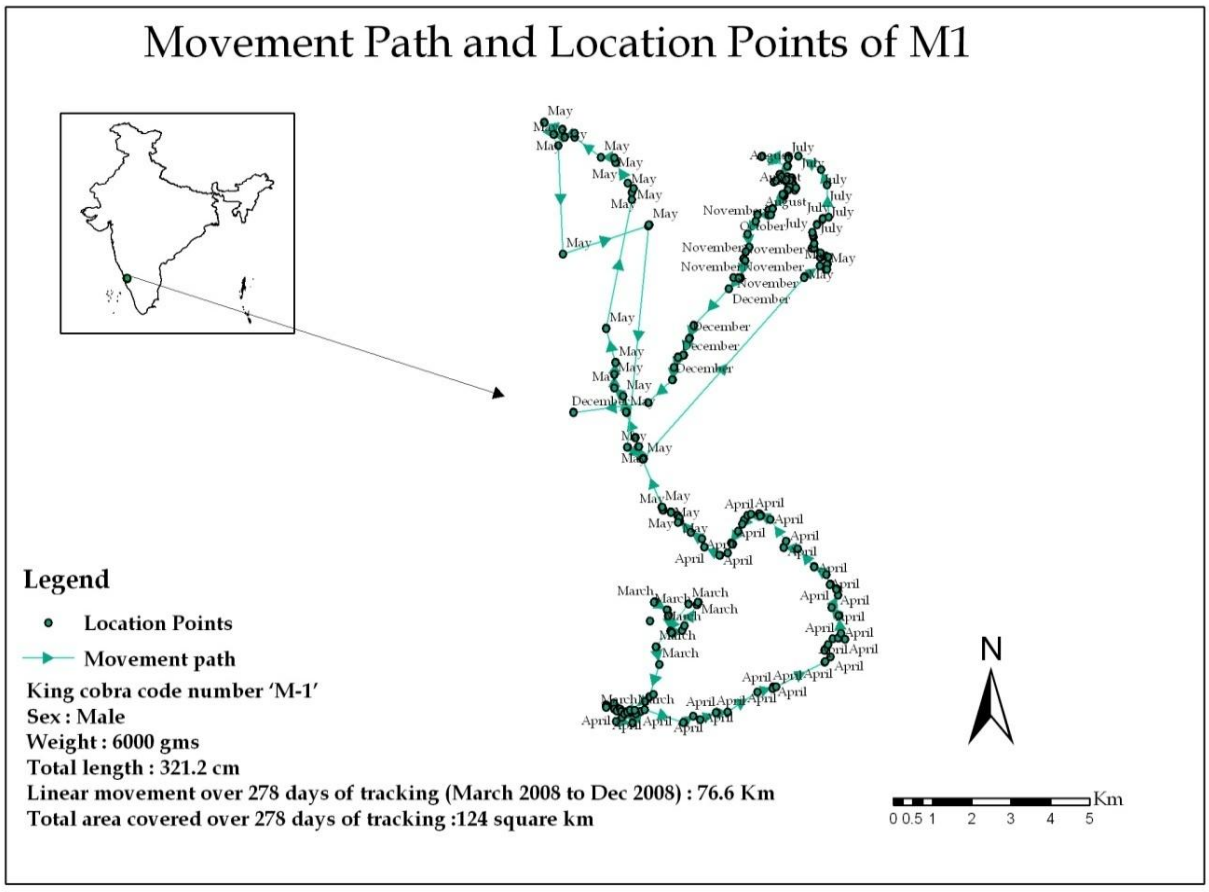
M1 – Translocated snake

We implanted a radiotransmitter into a translocated male King Cobra (ID = M1, mass = ca. 6,000 g, snout-vent length = 266 cm, tail length = 55 cm) in March, 2008. We tracked the snake for 298 days, during which time it moved a total linear distance of 76.6 km based on GPS coordinates. Because we tracked the snake as it moved between locations, we were able to reasonably estimate the total distance moved to be 91.2 km. We obtained estimates of actual distance moved by comparing the distance between successive locations to locations taken every 200 m, which yielded a correction factor of 1.2 km. Therefore, the total linear distance of M1 of 76.6 km multiplied by the correction factor of 1.2 km, equals 91.2 km total distance moved. Because snakes move in three dimensions, computing uphill and downhill movements would result in an even larger correction factor, which we plan to refine as additional data become available.

The "home range" of the snake (likely not the actual home range, because the snake was translocated), as computed using the minimum convex polygon method, which simply draws a straight line between the outermost locations, was 124 km^2.

We "rescued" M1 from a house > 40 km from Agumbe and released him ca. 2 km from ARRS at Agumbe. During the entire time we tracked M1, he days he exhibited straight-line, rapid strong movements, never returning to a fixed activity center. M1 travelled 6.1 km in a single day, which is possibly a world record for distance moved in a single day by any snake species. The rapid and incessant fixed-angle movements, zigzagging across a huge area, suggest that M1 was disoriented and unable to home back to familiar territory (Figs. 1, 2). These seemingly aberrant movements are precisely what would be predicted for a translocated snake based on other studies (Plummer and Mills 2000, Nowak et al. 2002, Butler et al, 2005); we predict that a larger sample size of translocated and non-translocated snakes will likely provide further support for these preliminary conclusions. The conservation implications of our extensive observation of movements of the first-ever translocated snake in India are obvious. With so many thousands of snakes being "rescued" and relocated to potentially unsuitable habitats all over the country, it seems likely that mortality in translocated snakes may be high.

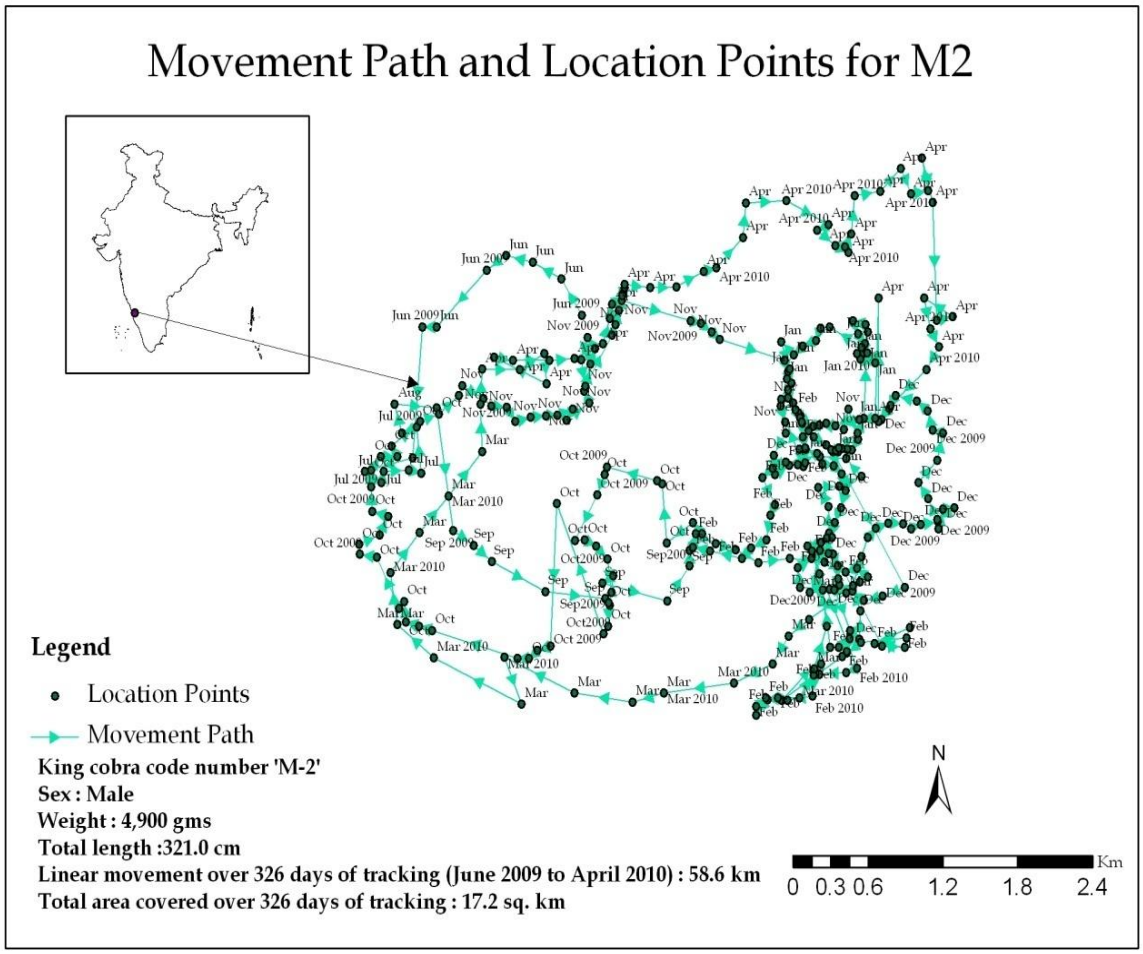
M1: Movement Graph: March ’08-December ‘08



M2 – Non-translocated snake

We implanted the non-translocated male (ID = M2, mass = 4,900 g, snout-vent length = 263 cm, tail length = 59 cm) in March, 2009. We tracked the snake for 326 days, during which time it moved 58.6 km actual distance, compared to 92.1 km for M1, the translocated snake.

M2 was rescued and released at his original point of capture ca. 2 km from ARRS. Over the next two days, the snake moved 2.3 km, climbing down the steep Agumbe escarpment where the signal was lost. We found the signal, 6 km away from where we lost it, ten weeks later, on 7 June, after incredible perseverance by the tracking team. During the 326 days we tracked M2 (we are currently still tracking the snake), he has utilized a definite center of activity, revisiting the exact same shelters and foraging sites multiple times. Remarkably, M2, and another male snake, M4, have both returned multiple times to the same termite mounds, where they evidently prefer to shed their skins during the roughly 20 day ecdysis cycle. M2's movements have covered a conspicuously circular area encompassing ca. 18 km^2 (and to which we are tentatively referring to as his "home range")(see Figure 3), about one-seventh the area covered by M1. We infer from these data that M2 is familiar with the area he has been using, and preliminary data indicate that he uses different habitats for seasonal prey preference (see *Diet).* In addition to his normal home range, it seems likely that male King Cobras follow female scent trails during the breeding season, meaning that they may be establishing transcient or temporary territories where they even defend access to females via male-male combat (Shankar et al, in review). Chippaux (2002) proposes that territory size (we prefer to call them home ranges due to social functions of territories that are not known to occur in snakes) in snakes should be proportionate to body size and energy requirements. In most snake species studied to date, male home ranges average three times greater than female home ranges, and searching for mates increases their contact, and therefore, potential conflict, with humans. Chippaux provides examples of "territory" size in several smaller snake taxa (*Vipera berus* (European Adder = 2 ha; *Coluber constrictor* (Black Racer) = 12 ha; Crotalids (rattlesnakes, USA) = 8-28 ha; *Bitis gabonica* (Gaboon Viper) = 0.8 – 1.6 ha, and they are predictably much smaller than our preliminary estimates for King Cobras.



Diet and predation

Large, active snakes, such as King Cobras, which may weigh up to 10,000 g, presumably require a considerable amount of prey to sustain themselves. In captivity, adult male King Cobras, averaging 350 cm in length and 6,500 g in mass, are known to consume an average of two to three adult rat snakes (*Ptyas mucosa*, Fitzinger, 1843) per month. The mean length/weight of a rat snake is 175 cm/1250 g (R. Whitaker, G. Shankar, unpublished data), which translates into roughly 30,000 g of prey per annum. Indian Rat Snakes and Spectacled Cobras (*Naja naja*, Linnaeus, 1758) are both confirmed prey species of King Cobras in our study area, and both species are particularly abundant near agriculture and human settlements, likely due to a high density of commensal rats. We suggest that the attraction of snakes that feed on rats associated with human habitations likely accounts for the frequency with which King Cobras need to be rescued. Indeed, preliminary analysis of our radiotracking data reveals that King Cobras spent an average of 22% of their time in landscapes created and/or dominated by humans.

Tracking M2 has led to important and unique insights into seasonal food preferences, which appear to be based on availability. During the height of the monsoon season (June-September) in Agumbe, both Indian Rat Snakes and Spectacled Cobras are less likely to be encountered compared to other times of the year. We naively assumed that M2 would be less active during the monsoon season, especially in Agumbe, where annual rainfall averages over 7,000 mm, peaking at over 11,000 mm. We also assumed that heavy and persistent rainfall would cause feeding to taper off until the return of warmer, dryer weather. However, we first observed M2 finding, killing, and eating a Malabar Pit

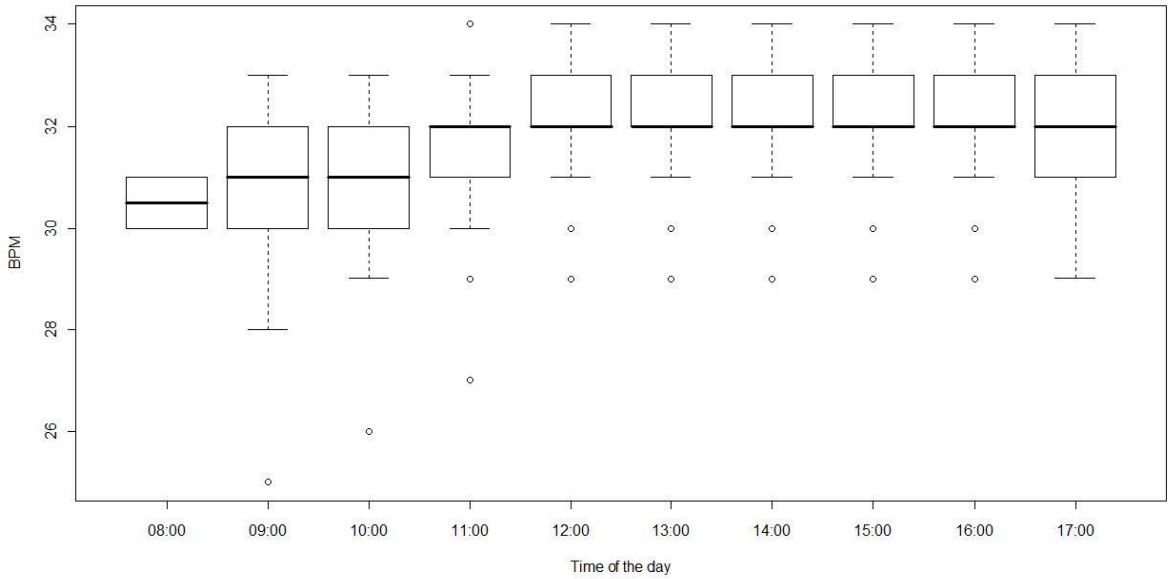
Viper (*Trimersurus malabaricus,* Jerdon, 1854) on 6 July, at the height of the rainy season. Over the following 135 days, we observed M2 eating a total of 26 pit vipers, two of which were diminutive Hump-nosed Pit Vipers (*Hypnale hypnale,* Merrem, 1820). At an average weight of ca. 50 g, these small "meals" totalled only about 1,300 g, the average weight of a single Indian Rat Snake. It seems unlikely that this seemingly small amount of prey would not comprise an adequate maintenance diet for a large, active snake averaging ca. 5,000 g over an 18-week period (Bhaisare et al, 2010). Given our almost moment-to-moment surveillance of M2, however, we are reasonably confident that our observations of predation comprise the vast majority of prey captured.

M2 killing a pit viper (*Trimeresurus malabaricus)* (note retaliatory bite)

Thermoregulation

We quantified body temperatures of radiotelemetered King Cobras every hour during their diurnal active phase (ca. 0800-1730). We calculated body temperatures from calibration curves supplied by the manufacturer for each transmitter, correlating pulse rates (beats per minute, BPM) to body temperature. Body temperatures were relatively low when snakes emerged from nocturnal shelters, but increased by mid-morning (ca. 1100 h, see Fig. 1) when snakes typically basked in direct or

dappled sunlight. M1 maintained body temperatures between 28.9-34.8°C ($\bar{x}$ = 32.3°C) throughout all seasons.



Graph 1. Box-plot showing increase in diurnal body temperatures, and mean basking time of King Cobra M1.

Shelter Sites

Both M1 and M2 frequently used termite mounds, tree buttresses, bushes and thick shrubs, fallen logs and canebrakes, burrows, trees, crevices (under rocks), leaf litter and bamboo thickets for temporary diurnal shelters and nocturnal resting sites. We plan to analyze time spent in various shelter sites relative to their availability, and in the context of thermal selection as we obtain more data on snake activity patterns, including time spent basking, foraging, and resting.

Cannibalism

Cannibalism has been frequently documented in snakes (cf., Mitchell 1986), and we have observed cannibalism in both wild and captive King Cobras on several occasions (also see under *Male combat*).

We translocated a female King Cobra (F1) implanted with a radiotransmitter that was released near Agumbe on the March 12, 2008. In two weeks, she covered a distance of ca. 1.5 km and was visited by two non-telemetered male King Cobras on March 28, 2008. On April 4, 2008, we observed F1 capturing, killing and consuming an Indian Rat Snake.

On April 17, 2008, we lost visual sightings of F1, and her signal appeared to be coming from the direction of a large, non-telemetered male King Cobra that we observed resting in a dense *Pandanus* stand where the female was last sighted. On April 18, 2008, we observed the male King Cobra, which had obviously recently fed, lying in a loose coil, and F1's signal continued to come from the direction of the male snake.

On April 27, 2008, we attempted to obtain a visual sighting of F1. Upon close approach, we found the decomposed body of F1, with the head and neck partially digested. Based on our observations, and an earlier, similar observation on a non-telemetered female (see *Male Combat*) we inferred that the non-telemetered male had killed, swallowed and regurgitated the female.

Male combat

We made opportunistic observations of male-male combat of non-telemetered male King Cobras in our study area. We observed several instances of male-male combat in 2007 (three times at one location), 2008 (one incident) and 2010 (twice at two locations). Although the frequency and duration of combat differed, a female King Cobra was always present, and combat always occurred during the breeding season.

In one case, in 2008, at Chokadabyle (35 km from Agumbe), male combat between the "resident snake" (which had been with a female for several weeks) and the intruder, the snake that "won" the contest approached the female, and after a brief courtship attempt, killed, swallowed and regurgitated her. Because we were unable to distinguish the male snakes from one another (neither were equipped with radiotransmitters), we were unsure as to which snake ingested the female. Given the relative frequency with which we have observed cannibalism (i.e., intraspecific predation), it seems likely that it may be a more common phenomenon than previously thought.

King cobra male combat on the edge of a village near Agumbe, South India

Courtship, mate guarding, and mating

During typical courtship in King Cobras, the male approaches the female and flicks his tongue over her body, while occasionally chin rubbing and head butting her (Whitaker, et al, 2005; Shankar, Whitaker and Whitaker, in review). When the female relents, she typically spreads her hood horizontally on the ground and usually coils her body. The male then moves over the length of her body with a jerking motion, finally lifting her tail with his tail to access the cloaca. We have observed mating to last from a few minutes to nearly an hour.

We observed mating behavior by M2 in April, 2010, which was the snake's first mating season after being telemetered. On April 7, 2010, we observed a female King Cobra approaching M2, appearing to chase him into a bush. We then observed M2 approaching the female from behind, remaining erect with his hood raised. The female also hooded up, facing away from M2. Soon after, we courtship behavior was observed, during which time M2 remained in close proximity to the female,

constantly flicking his tongue near to and on her body. The female then coiled up and hid her head under her body (submissive behaviour often observed by us), while M2 continued to rapidly flick his tongue, pushing at her coils while simultaneously twisting his tail with hers in an obvious attempt to mate. This behaviour lasted approximately 15 min, after which M2 began to move away, only to be followed by the female. They then separated but within an hour were together again and resumed courtship, which lasted roughly 20 min. We did not observe the female again after that day.

Ecdysis (skin shedding)

We released M1 on March 17, 2008 and tracked him for about nine months (278 days). We recorded behavioural data every day, allowing us to accurately ascertain timing and duration of ecdysis. M1 shed his skin three times over the nine-month period, remaining quiescent for a total of 32 days (7 days from April 28-May 5, 2008; 10 days from August 24-September 2, 2008; 15 days from November 1-15, 2008.

We released M2 on March 28, 2009. We have tracked the snake for over one year, observing ecdysis on four occasions (21 days from September 20-October 11, 2009; 20 days from November 24-December 12, 2009; 26 days from January 12-February 8, 2010; 20 days from March 3-23, 2010.

We were surprised at how often King Cobras shed their skin, considering many snake species, as adults, are known to shed only once or twice per year depending on growth rates. We plan to gain a better understanding of shedding duration and frequency as our sample size increases. It is important to understand factors responsible for ecdysis given its importance to the life histories of snakes that are forced to remain inactive and vulnerable to predation during the shedding cycle.

DISCUSSION

To date, we have tracked four male and one female King Cobras for varying periods of time. During this time we have observed several never-before-documented behaviours. For example, one translocated male snake moved over 90 km during a nine-month period, possibly a world record for snakes and a strong indication that translocated snakes spend considerable time and energy trying to 'home back' to their home range. In the relatively brief time we have been tracking king cobras, we have also documented a wide array of behaviours, including male-male combat, mate guarding, courtship, mating, predation, and two instances of cannibalism. Perhaps most importantly, we have documented habitat use by King Cobras in the mosaic of Reserved Forest, Revenue Forest, plantations, gardens, rice paddies, urban areas and private residences. Ultimately, these data will be used to inform the management of King Cobras, which is becoming increasingly important in the face of the ever-growing human population and associated habitat fragmentation. We hope that our ecological data, combined with our educational efforts, will lead to a greater understanding of the plight of King Cobras and the rainforest habitats on which they, and such a wide array of other species, depend. Most of our findings on the wild behaviour of King Cobras would not have been possible without the technology of radiotelemetry.

PUBLICATIONS ON THE KING COBRA (*Ophiophagus hannah*), by MEMBERS OF THE KING COBRA RESEARCH TEAM, PAST AND CURRENT

- Whitaker, R., 1980. King cobra notes. Hamadryad 5(1).
- Whitaker, R. and Farida Tampal, 1995. Maintenance of the king cobra (*Ophiophagus hannah*) in captivity. Zoo's Print 10(2).
- Whitaker, R. and I. Das, 1996. A Bibliography of the king cobra (*Ophiophagus hannah*) Smithsonian Herpetological Information Service (108).

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- Whitaker, R., 1984. A king is born
- International Wildlife 29, March-April.

- Dhiraj Bhaisare, Vipul Ramanuj, P. Gowri Shankar, M. Vittala, Matt Goode, and Rom Whitaker, 2010. Observations on a Wild King Cobra (*Ophiophagus hannah*), with Emphasis on Foraging and Diet (in press, Reptiles and Amphibians)

- P. Gowri Shankar and Nikhil Whitaker. Ecdysis in the king cobra (*Ophiophagus hannah*). Russian Journal of Herpetology Vol. 16, No. 1, 2009, pp. 1 – 5

<u>In Preparation</u>

- P. Gowri Shankar1, Romulus Whitaker1, Anju Reshma Devanur2 and S.R. Ganesh3 Intraspecific interactions in king cobras (*Ophiophagus hannah*) (Cantor, 1836) in the Agumbe region, Karnataka, India.

- P.Gowri Shankar 1 , Romulus Whitaker 1 , Prashanth P 2 , and S R Ganesh 2. Removal and relocation of king cobras (*Ophiophagus hannah*, Cantor, 1836), from human settlements in the Agumbe region, Karnataka, India.

- Romulus Whitaker , P.Gowri Shankar , Nikhil Whitaker. Notes of nests of the king cobra (*Ophiophagus hannah*, Cantor, 1836) in Shimoga District, Karnataka, South India.

- P. Gowri Shankar. A Case of cannibalism by king cobra (*Ophiophagus hannah*, Cantor 1836) in the wild.

Films produced on the king cobra telemetry project

Secret Life of the King Cobra, 52 minutes, 2008
A high definition video documentary on the telemetric study of the king cobra in a South Indian rainforest.
National Geographic Television
Romulus Whitaker, P. Gowri Shankar and Matt Goode, Consultants