Nesting Ecology and Conservation of King Cobras in the Himalayan State of Uttarakhand, India

FINAL PROJECT REPORT FOR THE RUFFORD FOUNDATION, UK

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Suggested citation: Dolia, J. 2020. Nesting ecology and conservation of King Cobras in the Himalayan State of Uttarakhand, India: final report submitted to the Rufford Foundation, UK

Cover photographs:

Front:

Top: (L) Female King Cobra guarding her nest; (R) A King Cobra's nest made from pine needles

Bottom: A hatchling King Cobra

Back:

A closeup of an adult male King Cobra

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ACKNOWLEDGEMENTS

First and foremost, I would like to thank the Rufford Foundation for funding this project, without which fieldwork would have been near impossible. I am grateful to the Uttarakhand State Forest Department for granting me permission to carry out this work, and also for honouring the locals who helped conserve the species. Special thanks are due to Dr. Tejaswini Patil (IFS, Conservator of Forests, South Kumaon) for providing logistical support and for taking personal interest in this project.

Among the locals, I especially thank Mr. Jagdish Tiwari, Mr. Rajendra Singh Gangola, Mr. Dayakishan Dani, Ms. Kamla Gangola and Mr. Kunwar Singh Gangola for providing information on the location of these nests and for helping us monitor them until hatching. Their cooperation and continued support were central to the success of this project. Several other individuals also made significant contributions to this project. My field assistant Krishna provided solid support during fieldwork. Without him, monitoring these nests and carrying out the various project activities would have been challenging and less fun! Ms. Tulsi Negi helped us organize awareness programmes in village schools and actively participated in some of them. Thanks to her networking skills and efficient working style, we were able to meet our target for the outreach-related activities. I thank Mr. Mohan Singh Karki and other staff at *Kumaon Vani* community radio for spreading our message, and for broadcasting my interview to help spread much-needed awareness regarding snakes and snakebite in this region. Mr. K.S. Sajwan helped us liaise with the Forest Department (FD) and also assisted with some of the fieldwork, for which I am deeply grateful. I am especially indebted to Mr. Anup Sah for his unwavering support in our effort to conserve King Cobras over the years, and for facilitating meetings with FD officials in Dehradun.

For the snake-awareness programmes, I thank the authorities of all the schools/inter-colleges we visited for letting us engage with their students and staff. Mr. Manish Rai, Mr. Gajindra Parasher and Ms. Divya Parasher helped with the translation of the audio-visual presentation (and outreach material) into Hindi. Last, but not the least, I thank the invisible ‘king’ cobras who quietly did their jobs and left, the dedicated ‘queen’ cobras, and their future ‘princes and princesses’ for inspiring me to carry out this work with ever greater fervour. These snakes are truly royal!

SUMMARY

During the annual nesting season of King Cobras in the Kumaon region of Uttarakhand, north India, we scientifically monitored and successfully protected two King Cobra nests. As both these nests were located quite close to human habitation, convincing the locals not to harm these potentially deadly snakes (and/or their nests) was indeed a challenge. These nests were first spotted by village folk during end May/early June 2018. One nest was interestingly composed of mango-leaf litter, a nesting material which we recorded for the first time. Unfortunately, we were unable to collect substantial data on female nesting behaviour, as one of the mother cobras was skittish and the other elusive. The cobras were last seen on their nests in early July, after which we placed a pair of data loggers at each nest site to record microclimate. For both nests, average nest temperature was significantly greater than average ambient temperature by 2–4 °C. Both nests maintained a high relative humidity of about 97%.

Hatching took place sometime in mid-August, a little sooner than anticipated. Of a total of 47 eggs (25 in Nest 1 & 22 in Nest 2), only one egg failed to hatch, resulting in a high overall hatching success of almost 98%. We collected 44 healthy King Cobra hatchlings from these nests for detailed morphometric measurements, after which they were released safely back in the wild. Mean hatchling total length and weight were 53.8 cm (SD= 2.2) and 24.3 g (SD=2.3) respectively.

We also got to know of a third King Cobra nest in mid-July 2018. Unfortunately, before we could visit this nest, miscreants had already destroyed it and damaged the eggs concealed within, proving that human disturbance is a real threat to this formidable yet vulnerable species. All the 40+ eggs (largest clutch size recorded by us so far) from this nest failed to hatch.

We also conducted 16 snake-awareness programmes at the grassroot level within the study area. In total, >1700 people (mostly students and young adults) were made aware of some common snakes occurring in the Kumaon region, and the importance of conserving them. Relevant outreach material in the form of two separate A2-sized posters was also distributed to these schools, to enable our audience to gradually internalize, and subsequently spread the knowledge, that was imparted to them.

INTRODUCTION

The King Cobra (*Ophiophagus hannah* Cantor 1836) is probably the most charismatic and iconic of all snakes. Being the world's longest venomous snake growing up to a maximum of 5.85 m (Whitaker & Captain 2004; Das 2015), it is not only a formidable predator, but potentially a flagship species too. Yet, there is a paucity of information regarding its local distribution and ecology, especially from the lesser-known parts of its distributional range, such as the Kumaon hills of Uttarakhand.

Although widespread in South/Southeast Asia, the King Cobra is usually considered an uncommon/rare snake in the majority of its range (Wall 1924; Smith 1943). Due to the existence of several colour/pattern morphs across King Cobra populations, taxonomists believe that the currently monotypic genus *Ophiophagus* may in fact represent a species complex (Das 2002).

Unfortunately, current ecological research on this charismatic snake is mainly restricted to the tropical forests of southern India (Agumbe Reserve Forest, Karnataka) and northeastern Thailand (Sakaerat Biosphere Reserve), at elevations typically below 800–1000 m above mean sea level. To try and bridge the existing information gap, we decided to conduct this study in a contrasting landscape, *i.e.* in the subtropical/temperate forests of Nainital in Uttarakhand, northern India, which are also home to this magnificent, yet rather elusive serpent.

Distribution in India

In India, the King Cobra is found in the Western Ghats of Tamil Nadu, Kerala, Karnataka, Goa, and southern Maharashtra (Whitaker & Captain 2004; Yadav & Yankanchi 2015). In the north, the species inhabits the Terai region of Uttar Pradesh (Whitaker & Captain 2004) and the Kumaon and Garhwal regions of Uttarakhand (Waltner 1975; Rasaily et al. 2008; Theophilus et al. 2008; Singh & Joshi 2016; Dolia 2018). In the east, it occurs in the states of Bihar, Jharkhand, West Bengal, Odisha, even extending southwards to northern Andhra Pradesh (Murthy & Murthy 2012; Balaji & Satyanarayana 2018). There is a single occurrence record of this species from Chhattisgarh too (Chandra et al. 2014). The species has been recorded from all the

seven states of northeastern India (Das et al. 2008; Stuart et al. 2012) and is also found in the Andaman group of Islands (Smith 1943; Whitaker & Captain 2004).

Habitat

The King Cobra is known to inhabit various types of habitat, such as the wet evergreen rainforests of the Western Ghats (Whitaker & Captain 2004), dry deciduous forests of the Eastern Ghats (Balaji & Satyanarayana 2018), grasslands of north-eastern India (Narayan & Rosalind 1989; Das et al. 2008), subtropical and moist temperate forests of Uttarakhand (Dolia 2018) and Sikkim (Bashir et al. 2010), estuarine mangrove swamps in coastal regions of eastern India, such as Bhitarkanika and Sunderbans (Whitaker 1978) etc. Although the King Cobra seems to prefer primary forests with heavy rainfall (Whitaker & Captain 2004), widespread habitat loss and fragmentation have probably forced this snake to adapt, and survive, in human-modified landscapes as well. For instance, this snake is often encountered in the tea estates of southern India and Assam; in Arunachal Pradesh and the Andaman Islands, the King Cobra can be seen in secondary forests close to riverbanks and around human habitation (Whitaker & Captain 2004). An agile climber, this elapid snake is often seen on top of trees, for basking or foraging purposes (Wall 1924; Das & Das 2018; Chan 2019), and is also known to be at ease in water.

Diet

An apex predator, the King Cobra mainly feeds on other snakes (Wall 1924; Daniel 2002; Whitaker & Captain 2004), thereby potentially playing a key role in regulating their population. It consumes both venomous and non-venomous snakes and can even turn cannibalistic (Smith 1943; Shankar & Whitaker 2013). While the non-venomous Indian Ratsnake (*Ptyas mucosa*) seems to be its preferred prey in India (Rao et al. 2013), the King Cobra has also been recorded feeding on venomous snakes such as the Spectacled Cobra (*Naja naja*), the Malabar Pit Viper (*Trimeresurus malabaricus*), the Hump-nosed Pit Viper (*Hypnale hypnale*) and the Northern Pit Viper (*Cryptelytrops septentrionalis*) (Bhaisare et al. 2010; Dolia 2018). Occasionally, pythons (*Python molurus, Malayopython reticulatus*) and monitor lizards (*Varanus* spp.) are also consumed (Wall 1924, Daniel 2002; Krishna 2002; Siler et al. 2011; Marshall et al. 2018a) by this formidable hunter.

Nesting

One unique and interesting feature of this ophidian is that the female King Cobra is the only snake in the world that constructs an aboveground nest for its eggs (Whitaker 1978; O'Shea 2018). The nest consists of a mound of leaf litter and organic debris, which is purposefully and meticulously gathered by the female cobra, over a few days, using the coils of her body (Lillywhite 2014). The nest is usually a compact, well-sealed unit presumably built to shelter the eggs from torrential rain and to maintain relatively stable incubation conditions (Leakey 1969). While this species is known to lay between 14–43 eggs in the wild (Whitaker et al. 2013; Hrima et al. 2014), a maximum clutch size of 56 eggs has been reported from a captive specimen, which was housed in an American zoo (Burchfield 1977). Following nest-construction, the female King Cobra guards her eggs for up to two months (Whitaker 1978), by sitting on top of the nest or staying in its immediate vicinity. This kind of protracted parental care is unusual for snakes in particular, and reptiles in general (Zug et al. 2001). Although the exact reason for nest attendance in this species is unknown (Greene 1997), deterring potential egg-predators such as mongooses and monitor lizards is the most likely explanation (Whitaker 1978). Behavioural thermoregulation by the attending female, however, cannot be ruled out.

Figure 1. Female King Cobra on her nest of pine (*Pinus roxburghii*) leaves, Nainital Dist., Uttarakhand

Conservation Status & Threats

According to IUCN's Red List of Threatened Species, the King Cobra is considered a 'Vulnerable' species, and its estimated global population decline is about 30% in the last 15-18 years (Stuart et al. 2012). In India, this snake features in the 'Schedule II (Part 2)' of the Wildlife Protection Act, 1972. However, ground realities throughout its distributional range are unfortunately different, as the King Cobra is often persecuted or killed at sight due to its perceived threat (Das et al. 2008; Murthy & Murthy 2012; Sy 2017; Marshall et al. 2018b; Thapa et al. 2019). Globally, the major threats faced by this species are habitat degradation, fragmentation caused by deforestation/agricultural expansion, and poaching for skin, meat and medicinal products, especially in China (Stuart et al. 2012). It is currently listed in 'Appendix II' of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Background to this study

The current study builds on work initiated by Manish Rai (my colleague), who discovered a King Cobra's nest in the foothills of the Kumaon Himalayas, Uttarakhand, in 2006. Although this snake is known to occur in the Himalayas (Home 1927; Smith 1943; Waltner 1975; Whitaker 1978), this was the first reported case of its nest from the Kumaon region of the Western Himalayas (Rasaily et al. 2008). Since that initial nest discovery, we have been able to monitor 17 other such nests in this region from 2009–2018. Apart from these nest records, there have also been regular sightings and rescues of mainly adult King Cobras in recent years, often in close proximity to human habitation, including in Nainital town. Our observations over the years have revealed that the subtropical/temperate forests of Kumaon provide suitable habitat for this species to live/breed in, and may even harbour a sizeable population of this ecologically important snake. However, quantitative data on its population size is not available and is hard, if not impossible, to collect.

STUDY AREA

The chosen study site for this project was the Nainital Forest Division (approx. 79° 15′–50′ E & 29° 11′–34′ N) of Uttarakhand in northern India. In terms of geographical relevance, the Himalayan state of Uttarakhand (Fig. 2) is important for King Cobras because it is likely to contain the northern limit of the species' known distribution and

includes the highest altitude (c. 2300 m; Mukteshwar) at which the species has been documented in India thus far (Dolia 2018).

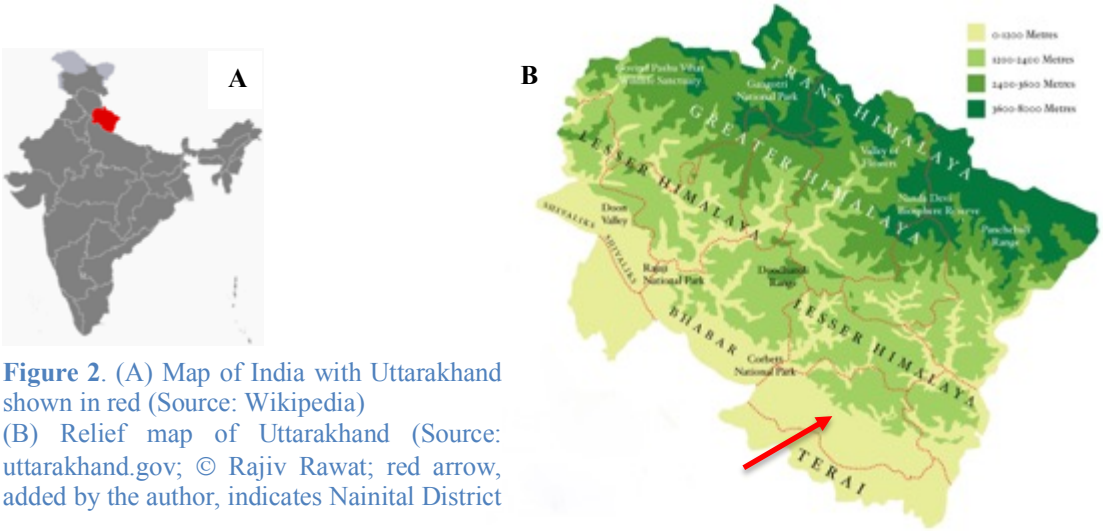

Figure 2. (A) Map of India with Uttarakhand shown in red (Source: Wikipedia)
(B) Relief map of Uttarakhand (Source: uttarakhand.gov; © Rajiv Rawat; red arrow, added by the author, indicates Nainital District

According to the Köppen-Geiger Climate Classification System, Nainital experiences a subtropical highland climate, with cool summers and dry cold winters with frequent frosts and occasional snowfall. Although latitudinally Nainital (29° 24′ N; 79° 28′ E) lies in the subtropical belt with heavy influence of the southwest monsoon, altitudinally (~ 2050 m) it is located in a temperate environment. Nainital receives its major rainfall between July and September, which also coincides with the nesting period of King Cobras in this region. Mean annual rainfall in Nainital district ranges from 1463-1648 mm (www.imdpune.gov.in). While July is typically the wettest month of the year receiving a mean precipitation of 514 mm, November is usually the driest month with a mean precipitation of 6.5 mm (https://data.gov.in; data period: 1951-2000).

The local coniferous and broadleaved forests in this region provide suitable nesting habitat for this snake. The majority of King Cobra nests monitored by us were composed of pine or oak leaves. Chir pine (*Pinus roxburghii*) and Baanj oak (*Quercus leucotrichophora*) are dominant trees at lower elevations (i.e. 1500-2100 m) of Kumaon, while at higher elevations (i.e. 2100-3000 m), coniferous species include *P. wallichiana* (Blue pine) and *Cedrus deodara* (locally called Deodar), and broad-leaved species include the oaks *Q. floribunda* (locally called Tilonj) and *Q. semecarpifolia* (locally called Kharsu) (Singh & Singh 1987). Unfortunately, many forests in the study region are highly disturbed/degraded due to anthropogenic pressures such as fuelwood/fodder collection, forest fires and deforestation for various purposes.

OBJECTIVES

The main objectives of this project were:

1. To protect and scientifically monitor King Cobra nests
2. To collect the hatchlings, record morphometric data, and release them safely
3. To conduct snake-awareness programmes, with special emphasis on King Cobras

METHODS

Locating nests

We mainly relied on information provided by locals to find King Cobra nests, because actively searching for them is neither feasible, nor practical. Similar studies elsewhere in India (e.g. Whitaker et al. 2013; Hrima et al. 2014) and Thailand (Leakey 1969) have also used this indirect method for locating King Cobra nests. Over the years, we have built an informal network of people in the study region, who are encouraged, and rewarded off late, to share information on sightings of this species with us. In order to broaden the effective search area for nests, I also gave a brief sound bite in Hindi (describing what a King Cobra nest resembles and whom to contact if a nest is found) to a popular community radio station called *Kumaon Vani* (90.4 MHz, FM). This radio station was set up in 2010 by TERI (The Energy and Resources Institute) in Mukteshwar (Nainital District). Its programmes are broadcasted to around 500 villages in the region, covering a population of nearly 350 thousand people who are mainly involved in agriculture (https://www.teriin.org/project/kumaon-vani-community-radio-904-mhz).

Recording nest microclimate

We used miniaturized automatic data loggers to record nest and ambient microclimate at nesting sites. After the female cobras were found to have abandoned their nests for good, we placed a pair of i-button data loggers (Brand: Maxim Integrated™; model # DS1923) at each nest site. While one logger was carefully placed beside the eggs within the nest chamber, the other one was placed in the immediate vicinity of the nest, in order to record hourly temperature/relative humidity (RH) values. Note that in order to

do this, at no point in time was any nest opened up by us prior to hatching (either to place the data loggers or to check the eggs), because maintaining its structural integrity was important for us. Data loggers were left in the field for little over a month, until hatching took place.

Nest and nest-site characteristics

In addition to measuring microclimate, we recorded the following characteristics for each nest:

- Curved diameter (in north-south/east-west directions; using a flexible measuring tape)
- Circumference of nest at base (using a flexible measuring tape)
- Height from the ground at centre of nest (using a rigid measuring tape)
- Wet/dry weights of nesting material (using a Pesola™ 40 kg digital hanging scale)
  - Wet weight was measured in the field
  - Dry weight was measured after sun-drying the nesting material
- Volume of nesting material (in a container with volume gradations marked)
  - Measurement taken after the nesting material was dry and compacted by hand

We recorded the following nest-site variables too:

- Percentage canopy cover (using a spherical densiometer; Brand: Forestry Suppliers; model A)
- Slope of terrain where nest was built (using a clinometer; Brand: Suunto; model: Tandem)
- Trees (and their girth at 130 cm from the ground) within a 10 m radius of the nest

Building nest enclosures

We raised temporary enclosures around the nests prior to hatching, in order to allow us to collect the hatchlings for detailed morphometric measurements. The enclosures were built using a sheet of thick plastic which encircled the nest on the sides, but was open to sky at the top (Fig. 3). While the top part of the sheet was tied to a framework of sticks, the bottom was tucked in firmly under the soil, so as to prevent any potential escape by the hatchlings. It is important to note that capturing King Cobra hatchlings

is often time-consuming/challenging/risky, especially if there are many potential hiding places for them within the enclosure, such as under a rock/boulder.

Figure 3. Temporary enclosure erected around Nest #1 to enable collection of hatchlings

Collection and measurement of hatchlings

The hatchlings were carefully collected from the field by me with the help of a snake-hook, after which they were temporarily kept in cloth bags (cotton pillow covers) and transported to the field station for detailed morphometric measurements. We collected the following data for all but two hatchlings:

- Total length (using the 'conscious tape' method; Fitch 1987)
- Tail length (same method as above)
- Girth at mid-body (using a thin cotton string and a measuring tape)
- Weight (using a Pesola™ spring balance; model: 60g Micro Line)
- Number of bands (visual count; cross-checked using photographs if required)
- Number of undivided subcaudal scales (visual count)

In addition, each hatchling was individually photographed against a white background to create a database for possible future identification. Hatchlings, which sported any unique/unusual band pattern were photographed in greater detail using a macro lens (Brand: Nikon; model: 105 mm F/2.8 G VR IF-ED).

Awareness programmes

For the snake-awareness programmes, we created a 45-slide presentation in Hindi (the local language), which was projected via a portable high definition Epson projector on a white wall/screen at each venue. After the presentation, relevant video clips showcasing King Cobras and their importance in the environment were also shown. Our target audience was mainly school/college going children and young adults.

The aim of this presentation was two-fold: (1) to provide basic facts regarding snakes found in India and Kumaon (2) to bring about an attitudinal shift in the common man's perception towards these highly misunderstood creatures. Considerable effort and multiple iterations went into the making of this presentation, to make it informative, interesting and relevant for our audience.

RESULTS

We were able to locate a total of three nests during the 2018 field season. However, one nest (#3 in chronological order) was unfortunately damaged by local miscreants prior to our first visit, and hence we have limited data on that nest. The informants of the first two nests were the same village folk who had also told us about a nest in their village in 2017, suggesting that our efforts to raise awareness regarding King Cobras, and rewarding the locals for their cooperation seemed to have paid off. Below are the salient results of this study, presented on a nest-wise basis, in the order in which they were found.

Nest #1

Figure 4. Female King Cobra lying on top of her nest made under a mango tree, which was surrounded by *Lantana camara* bushes. Location: Nainital District, Uttarakhand

Quick facts

- Nest first seen during — 4th week of May 2018
- Altitude of nest — 1079 m
- Nest mainly made of — Mango (*Mangifera indica*) leaves
- Approx. length of female cobra — 8–9 feet (visual estimate)
- Female cobra last seen on nest — June 30, 2018
- Number of eggs — 25
- Number of hatchlings — 25
- Hatching success — 100%
- Hatchlings first seen on — 16 August 2018
- Observed incubation period — 80–85 days
- Mean nest temperature — 28.04 °C
- Height of nest — 36 cm
- Circumference of nest — 410 cm
- Volume of dried nest material — 35 litres (0.035 m^3)
- Wet mass of nest material — 22.98 kg

Figure 5. Google Earth image showing location of Nest #1 (red square). Imagery date: 15/11/2018

A Brief Account

This nest was located in the Dhari Block of Nainital, and was first spotted by Kamla Gangola sometime during the last week of May. The nest was built under a mango tree, almost in complete shade, and was surrounded by the invasive *Lantana camara* shrub. While returning home, Kamla chanced upon a mound of dead leaves close to the boundary of her cultivated plot. Curious, she approached the mound for a closer inspection wondering who could have amassed these leaves into such a neat pile, which could be of potential use to her[1]. She also remarked how well swept the area immediately surrounding the nest appeared, as though somebody had used a broom or rake to gather the pile of dry leaves. When Kamla was close to the nest, she suddenly noticed a heaving movement from underneath the amassed leaves, and quickly realized that there was some creature hiding under it. She immediately informed her husband Jeevan, who was not far behind, and described to him what she had just observed. Jeevan was quick to realize that the mound of leaves was actually a snake's nest, and wisely warned her to stay away from it. When I interviewed the couple regarding this sighting, Jeevan told me that he had seen at least 4-5 such nests in this area while growing up. However, he was initially unaware of the fact that the architect of such nests were female King Cobras, until I told him so last year. This was the first time we recorded a nest made from mango leaf litter.

Access to this nest was relatively tough and time-consuming. It involved a 79 km ride on motorable road from our field station in Ramgarh, followed by a trek of nearly 11 km through undulating terrain (distances mentioned are for roundtrip travel). The nearest village house from this nest was only 70 m away (straight-line distance), and a stream locally called *Kalsa* (a tributary of river *Gaula*) flowed about 200 m west of the nest.

Figure 6. Village women carrying neatly stacked piles of leaf litter on their heads for domestic use

Figure 7. View of the valley and the meandering *Kalsa* near which Nest #1 was located

1. Note: Leaf litter, especially of pine or oak, is often used by the villagers in this region during winter to spread on the floor of their animal sheds for providing warmth/comfort to their livestock

Female cobra behaviour

Unfortunately we were unable to collect substantial data on female behaviour, as this individual snake was very skittish. We saw her only on three separate occasions, for a total observation time of less than two hours. She was wary of human presence, and used to disappear into the nearby bushes soon after anyone arrived. It was not feasible to install camera traps at this location due to multiple reasons. Prior to her departure, the cobra had shed its skin (sometime between June 27–30), which was visible on top of the nest.

Figure 8. Local village folk enjoying observing the nesting cobra through a pair of binoculars. The man with the binoculars is Mr. Kunwar Singh, whose house was less than 100 m from this nest

Microclimate data (Temperature)

Mean temperature inside the nest was almost 4.8 °C higher than mean temperature outside (i.e. ambient temperature). Paired t–test results confirm that this difference was statistically significant (t=126.37, df=852, p-value < 2.2 e^{-16}). The mean of the differences (i.e. average pairwise difference between 853 inside/outside temperature values) was 4.79 °C (95% confidence interval: 4.71–4.86 °C).

Table 1: Summary of temperature data of Nest #1; number of hourly readings=853 (approx. 36 days)

	Minimum Temperature (°C)	Maximum Temperature (°C)	Mean Temperature ± 1 Standard Deviation (°C)
Inside Nest	26.61	31.11	28.04± 0.80
Outside Nest	21.60	24.60	23.25± 0.61

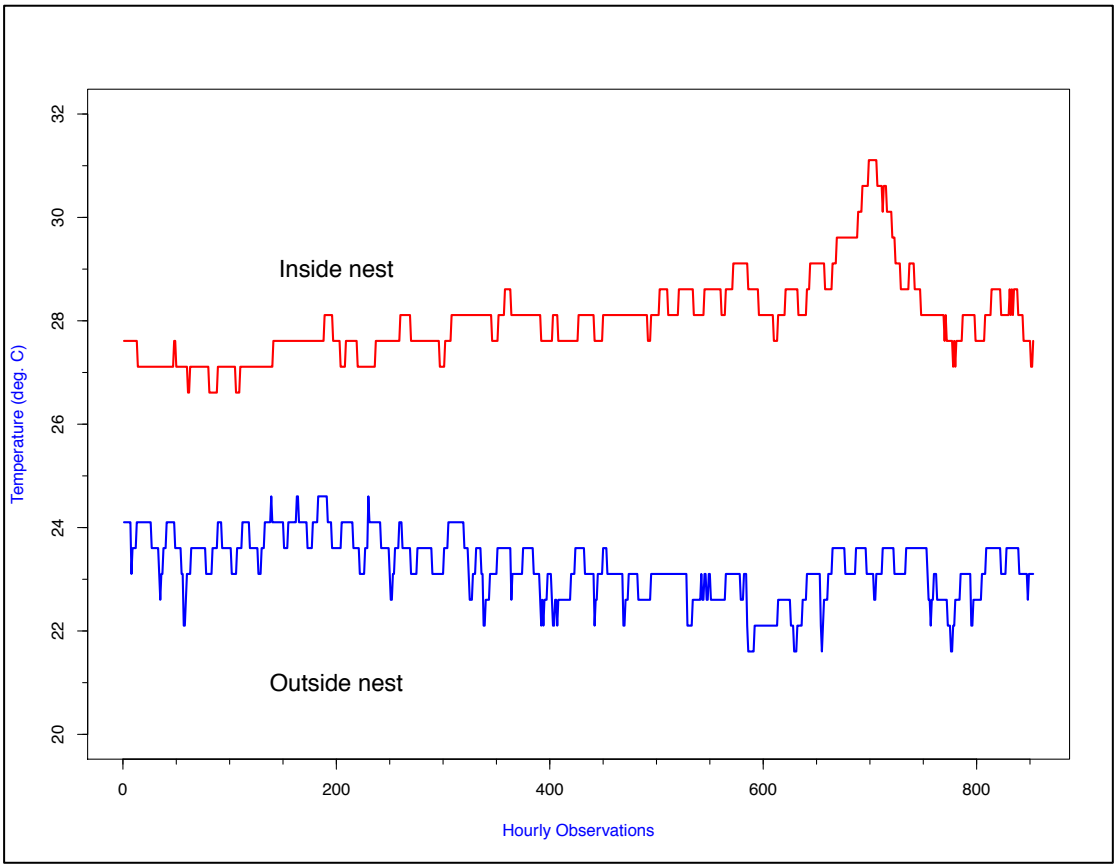

Figure 9. Time-series graph of nest (red line) versus ambient (blue line) temperature at Nest #1; x-axis values indicate number of hourly observations, and y-axis values indicate temperature in °C

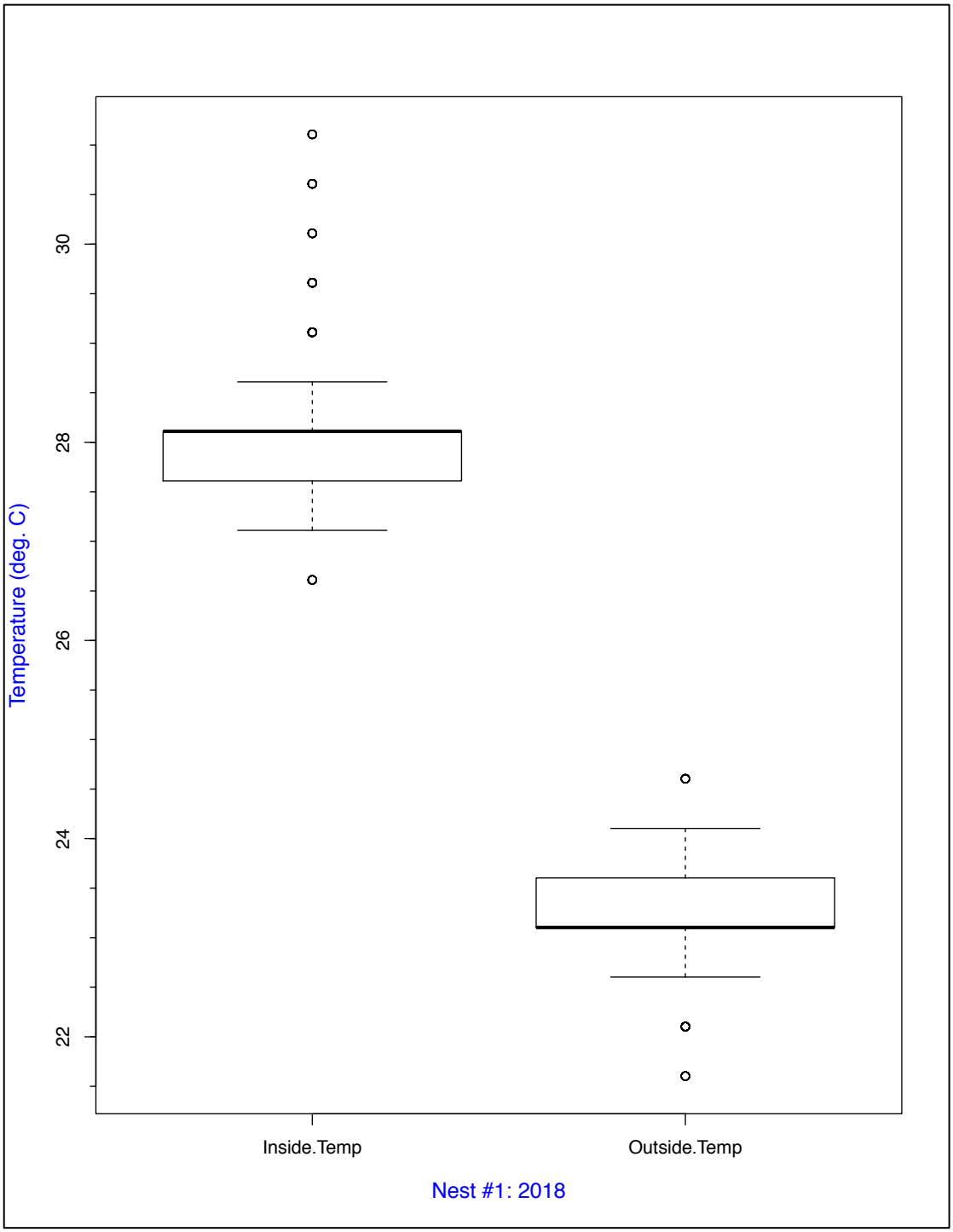

Figure 10. A box-and-whiskers plot comparing inside and outside temperatures of Nest 1. The bold horizontal line inside each box indicates the median value, the lower and upper limits of each box represent the 1st & 3rd quartiles (i.e. 25th & 75th percentiles) respectively, the whiskers indicate 1.5 times the interquartile range, and circles represent extreme values

Microclimate data (Relative humidity)

Mean relative humidity (RH) in the nest chamber was 97.18± 3.95 %, while mean RH outside the nest was 89.76± 7.41 %. Paired t-test results confirm that this difference was statistically significant (t=24.732, df=852, p-value < 2.2 e^{-16}). The mean of the differences (i.e. average pairwise difference between 853 inside/outside RH values) was 7.42 % (95% confidence interval: 6.83–8.01 %).

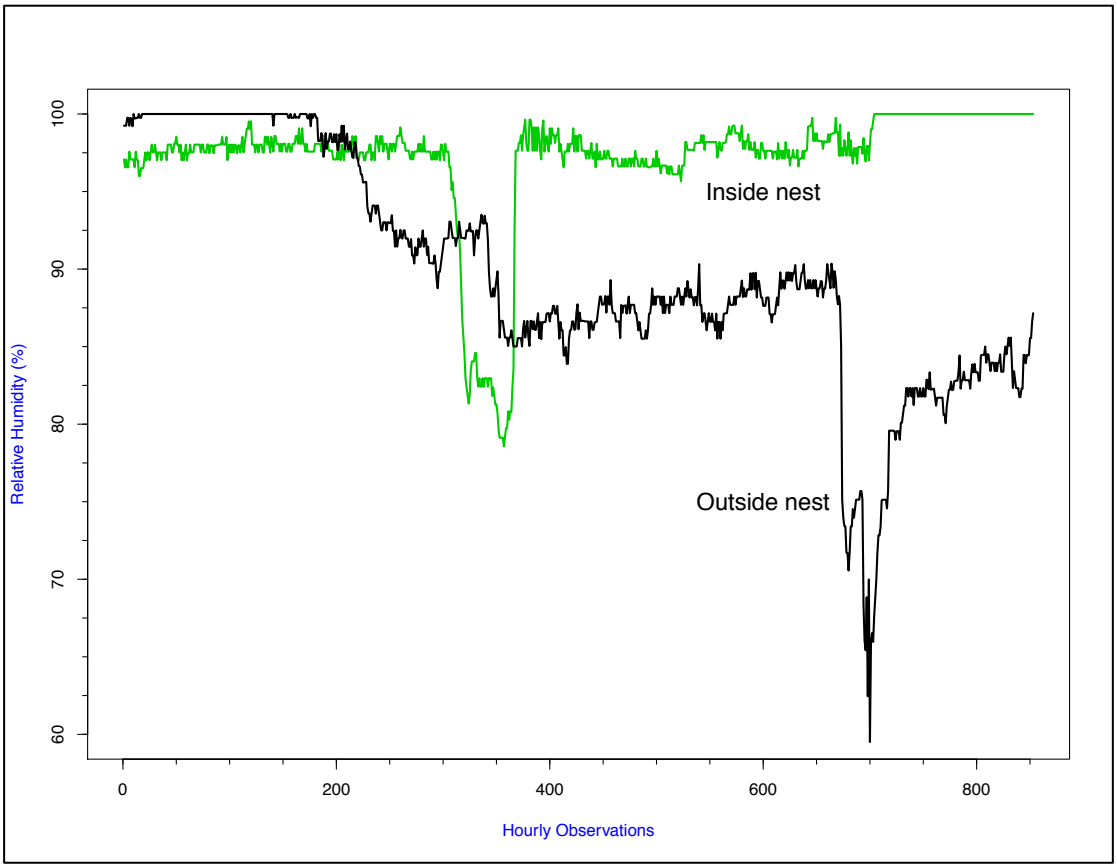

Figure 11. Time-series graph of nest (green line) versus ambient (black line) relative humidity at Nest #1; x-axis values indicate number of hourly observations, and y-axis values indicate RH in percentage values

Hatching and hatchling morphometry

This nest contained 25 eggs, all of which hatched successfully during the 2nd week of August. While some hatchlings had already undergone ecdysis (as indicated by the presence of shed skin within the nest enclosure), some others were in the process of doing so at the time of capture. The mean length of hatchlings was 54.9± 1.6 cm (range=50.5–57.0 cm), and mean snout-vent length was 45.7 ±1.6 cm (range=41.5–49.5 cm). Mean weight of hatchlings was 23.2 ±1.4 g (range=19.0–25.0 g). See

Appendix I for more details on hatchling morphometry.

Figure 12. Photograph of newly-born hatchlings inside the enclosure (Nest #1)

Figure 13. Photo of one of the hatchlings against a white background

Nest #2

Figure 14. King Cobra nest # 2 of field season 2018; this nest was made primarily of pine *(P. roxburghii)* leaves; the female cobra is not visible in the photograph. Location: Nainital district, Uttarakhand

Quick facts

- Nest first seen around — Mid-June 2018
- Altitude of nest — 1150 m
- Nest mainly made of — Pine (*P. roxburghii*)
- Hatchlings first seen on — 19 August 2018
- Number of eggs — 22
- Number of eggs that hatched — 21
- Hatching success — 95%
- Number of hatchlings collected — 19
- Mean nest temperature — 25.51 °C
- Height of nest — 64 cm
- Circumference of nest — 450 cm
- Wet/dry weights of nest material — 29.78/10.52 kg
- Volume of nest material — 74 litres (0.074 m^3)

Figure 15. Google Earth image showing location of Nest #2 (yellow square). Imagery date 15/11/2018

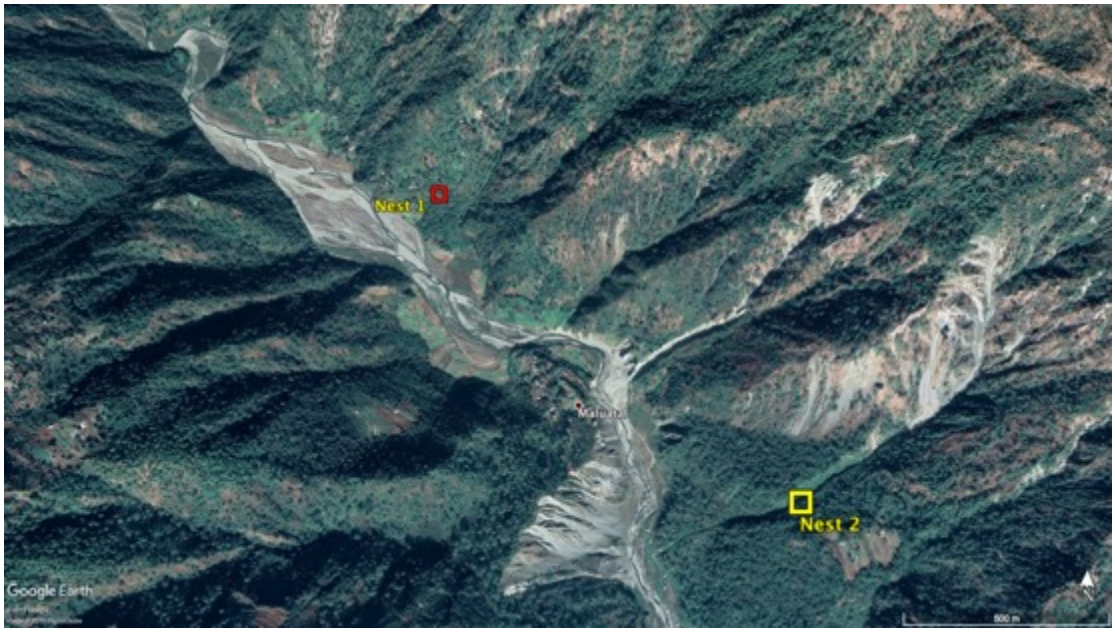

Figure 16. Google Earth image showing Nest #1 (red) and # 2 (yellow). Imagery date: 15/11/2018; the aerial distance between both these nests was 1.75 km

A Brief Account

This nest was located in the Bhimtal block of Nainital, and was first spotted by some local women in a forest patch near their village in early June. They informed their *sarpanch* (an elected village representative) regarding this nest, who subsequently went to check it out sometime between June 17–19. The nest was found in a patch of mixed forest bearing a south-eastern aspect, and was found within 50 m of a village walking path. The aerial distance between this nest and Nest #1 was only about 1.75 km (walking distance between them was approx. 2.5 km). Unlike the first nest, this nest was located in a relatively open spot, with lesser canopy cover, thus receiving more sunlight. A medium sized pine tree stood within three metres from the nest. Lantana bushes were present near this nest too. Several pieces of small to medium sized rock were scattered around this nesting site.

Figure 17. Photograph of the nest site area; location of nest is indicated by red arrow

We visited the nest for the first time on June 20, accompanied by two village folk. The female cobra was initially not visible. But, after close observation of the nest with binoculars, I could barely see her golden-brown body, well camouflaged among the nest material. We waited for over an hour that day, hoping that the snake would emerge from its nest, but in vain. This brief glimpse was our first and last sighting of this female King Cobra. She seems to have abandoned her nest in late June. No shed skin was visible around the nest site.

Figure 18. Zoomed-in photograph of Nest #2, with female cobra hiding among the leaves. Yellow arrows point to her barely visible body, which is well camouflaged against the nest material

Microclimate data (Temperature)

Mean temperature of this nest too was significantly greater than mean outside temperature (t=84.386, df=948, p-value < 2.2 e^{-16}), but the difference was not as pronounced as it was for nest #1. The mean of the differences (i.e. average pairwise difference between 949 inside/outside temperature values) was 2.21 °C (95% confidence interval: 2.15–2.26 °C).

Table 2: Summary data of temperature in Nest 2; number of hourly readings=949 (approx. 40 days)

	Minimum Temperature (°C)	Maximum Temperature (°C)	Mean Temperature ± 1 Standard Deviation (°C)
Inside Nest	23.55	29.05	25.51± 1.05
Outside Nest	21.12	27.13	23.30± 1.09

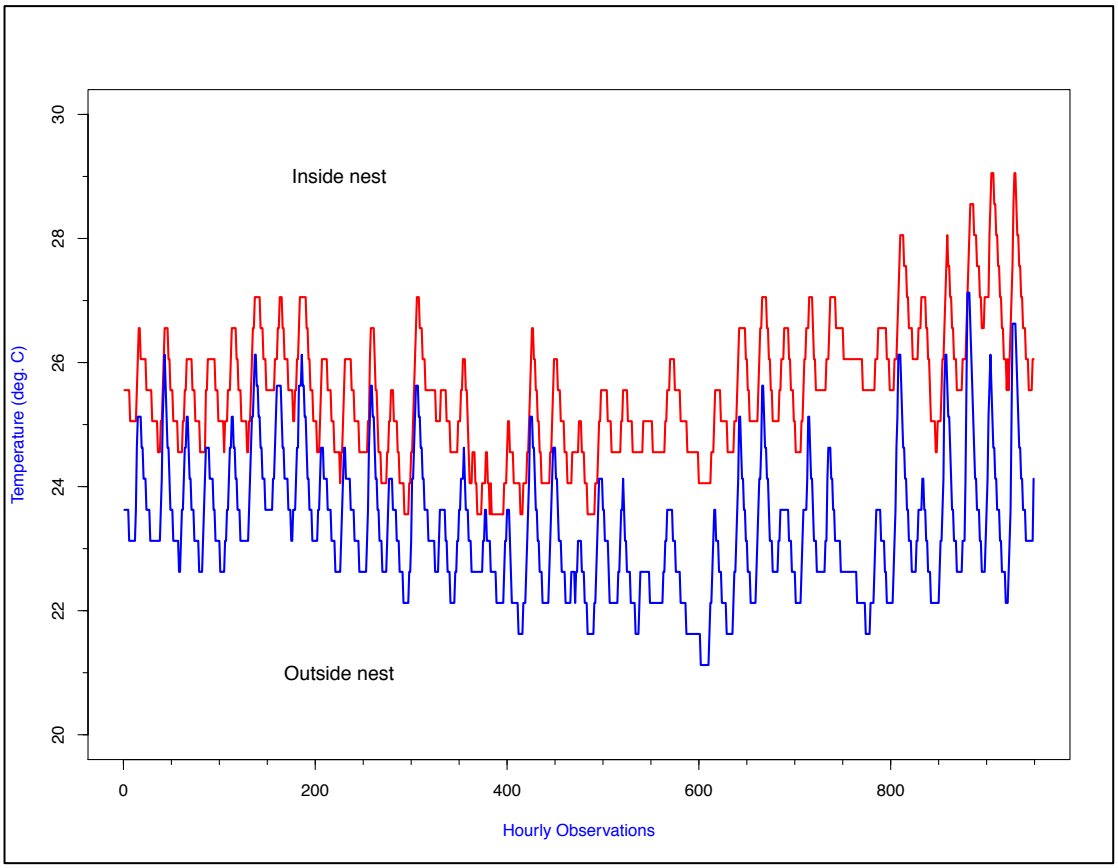

Figure 19. Time-series graph of nest (red line) versus ambient (blue line) temperature at Nest #2; x-axis values indicate number of hourly observations, and y-axis values indicate temperature in °C

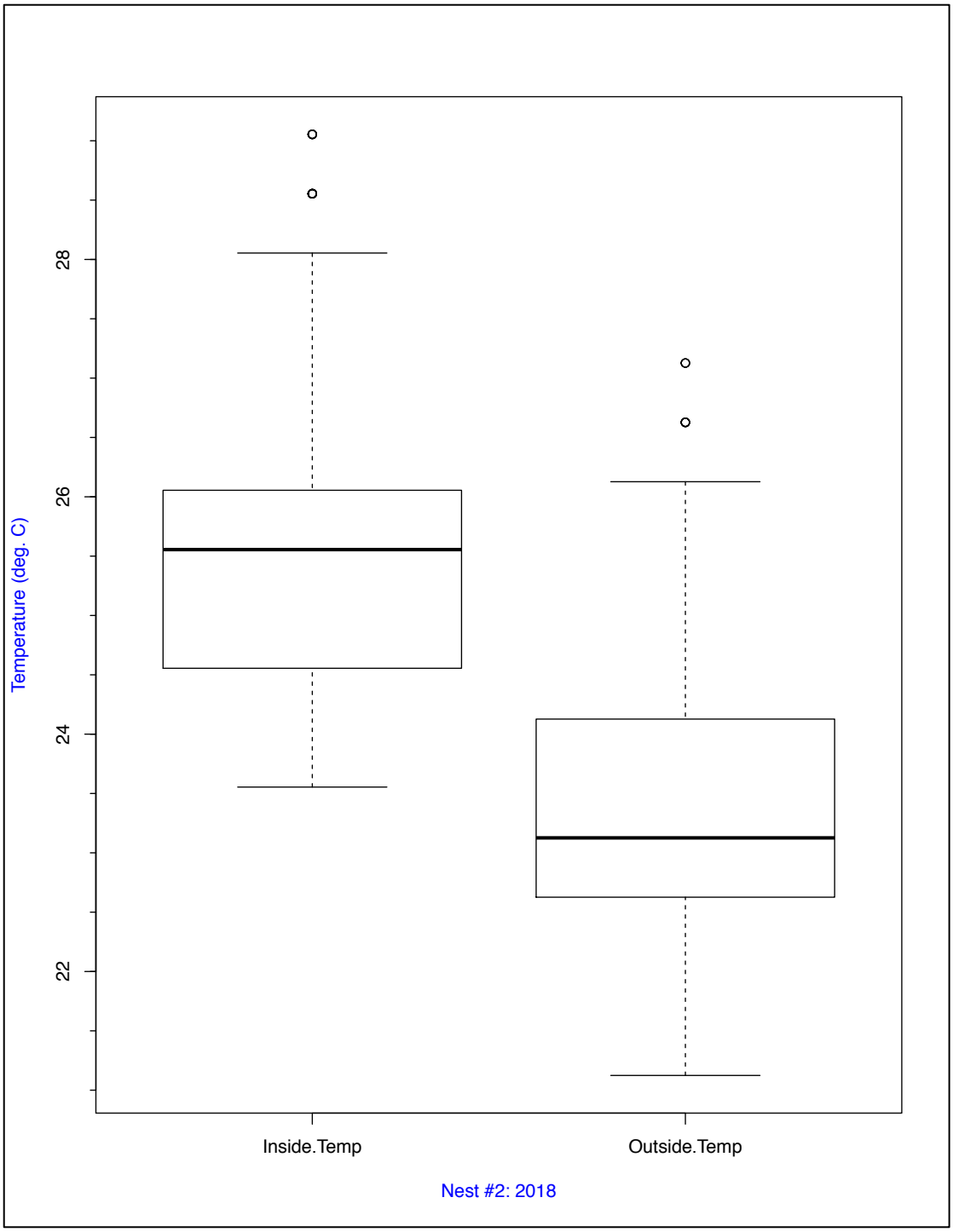

Figure 20. A box-and-whiskers plot comparing inside and outside temperatures of Nest #2. The bold horizontal line inside each box indicates the median value, the lower and upper limits of each box represent the 1st and 3rd quartiles (i.e. 25th and 75th percentiles) respectively, the whiskers indicate 1.5 times the interquartile range, and circles represent extreme values

Microclimate data (Relative humidity)

Mean relative humidity (RH) in the nest chamber was 96.66± 0.61 %, while mean RH outside the nest was higher by about 3 % (99.64± 0.81 %). Paired t-test results confirm that this difference was statistically significant (t= -97.448, df=948, p-value < 2.2 e^{-16}). The mean of the differences (i.e. average pairwise difference between 949 inside/outside RH values) was - 2.98% (95% confidence interval: - 3.04 to -2.92 %).

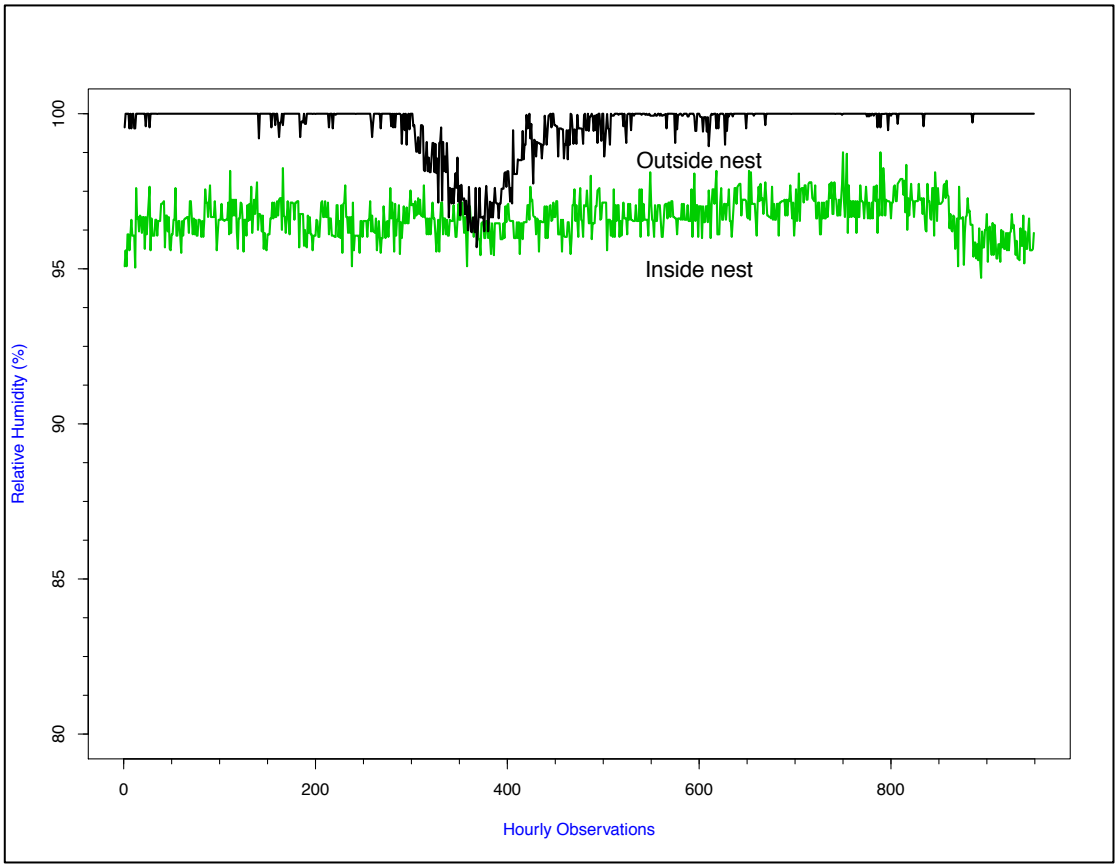

Figure 21. Time-series graph of nest (green line) versus ambient (black line) relative humidity at Nest #2; x-axis values indicate number of hourly observations, and y-axis values indicate RH in percentage values

Hatching and hatchling morphometry

This nest contained 22 eggs, of which 21 seem to have hatched successfully (based on a close inspection of the egg-shells). However, we could collect only 19 hatchlings from this nest. While one egg had unfortunately rotted, two hatchlings could not be found, despite us looking for them over three consecutive days. Making an enclosure for this nest was very challenging, as the ground on which it stood was stony (therefore hard to dig), and also because there were boulders around the nest. We did not want to move/break these boulders, as doing so may have compromised the structure of the

nest. Hence, we worked around them, but not entirely to our satisfaction. Therefore, the two hatchlings we could not find may have either somehow managed to escape from within the enclosure (possibly through an inadvertent gap at the base, which may have formed during the monthlong period), or they may have been hiding in some secure subterranean refuge, beyond our sight.

The mean length of the 19 hatchlings was 52.4 ±2.2 cm (range: 46.0–55.5 cm). Their mean snout-vent length (SVL) was 43.5 ±1.9 cm (range: 38.0–43.5 cm), and their mean weight was 25.8 ±2.4 g (range:16.5–25.8 g). Refer to Appendix II for more details on morphometry.

Figure 22. A close-up image of one of the hatchling King Cobras from Nest #2

Figure 23. Back hood photograph of the same hatchling

Nest #3 (Damaged nest)

Figure 24. Photograph of a battered King Cobra's nest, which was intentionally destroyed by local miscreants

Quick facts

- Nest first seen in — July 2018
- Altitude of nest — 1470 m
- Nest made of — Oak (*Q. leucotrichophora*) and Kaphal (*Myrica esculenta*) leaves
- Number of eggs (clutch size) — 40+
- Number of eggs that hatched — 0
- Volume of nest material — 97 litres (0.097 m^3)
- Wet weight of nest material — 38.95 kg

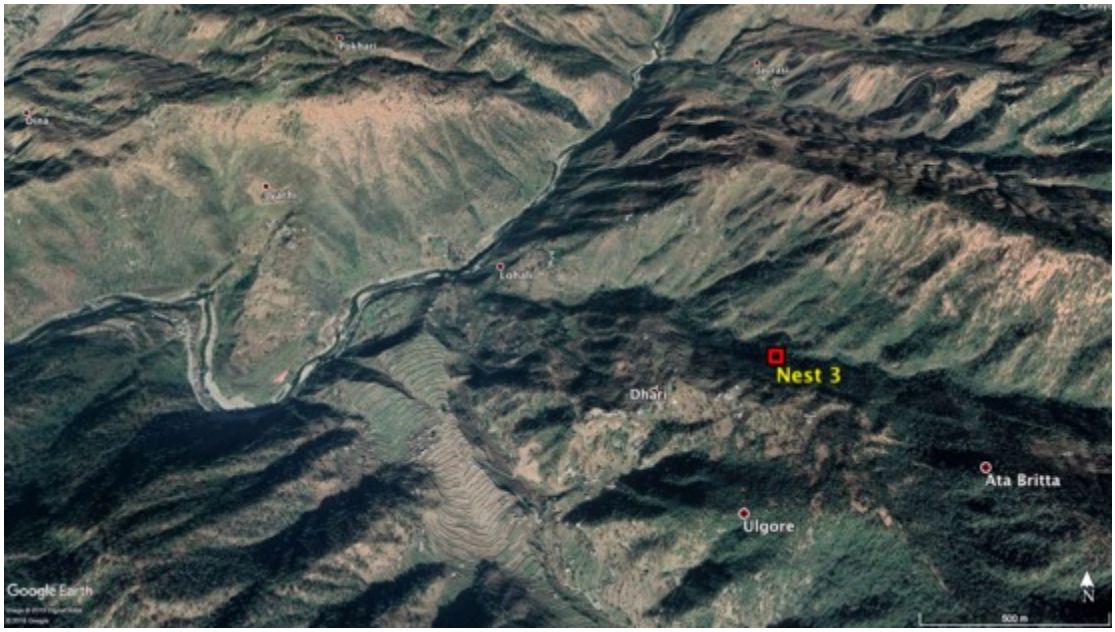

Figure 25. Google Earth image showing location of Nest #3 (red square). Imagery date 29/01/2019

A Brief Account

I got to know of another King Cobra nest through a fortuitous conversation with a local private car driver. My field assistant Krishna and I went to check the nest on the 18th of July. An elderly villager, who knew the exact location of the nest accompanied us from his house, which was a half-hour walk from this nest. The nest was found in a forest patch near Lohali Intercollege (Betalghat block, Nainital). Upon arrival, we found the nest to be badly damaged by some local miscreants, one of whom even had the temerity to smash a few King Cobra eggs contained within, which was revealed to us inadvertently by the elderly man! The female cobra was nowhere to be seen, and must have abandoned the nest due to the disturbance. The nest material was all ruffled up, and I was shocked and sad to see such blatant damage.

This relatively large nest was located under a Banj oak (*Quercus leucotrichophora*) tree within 10 m of a village path, on a north-facing slope. We noticed pieces of shed snake skin entangled in the Kaphal (*Myrica esculenta*) tree beside the nest, indicating that the female had undergone ecdysis before leaving. We collected her moulted skin, and also a few of her belly scales from the nest. We found seventeen damaged eggs strewn around the nest. I decided to not uncover the nest fully that day, and instead first report the matter to the concerned Forest Department (FD) officials.

I thus informed the DFO of Nainital and the Conservator of Forests (South Kumaon) regarding this incident. I also requested the latter to allow some FD officials to accompany me on my next visit to this nest, so that they can witness the damage first hand and also be present when I fully open up the nest. Exactly a week later we visited this nest again along with three FD staff and Dr. Bhardwaj (then chief veterinarian of Nainital Zoo). Our mission was to collect any undamaged eggs that we may find while uncovering the nest, and to get data on clutch size, weight and volume of nesting material. There was a slim chance of some eggs still being viable, in which case we had come prepared to take them back to Nainital for possible artificial incubation. The egg/eggshell count revealed that this nest contained 40 or more eggs, the largest clutch size we have seen so far! To our utter surprise, we also found a bunch of 18 egg-shells that were stuck together and seemed as though some of these eggs might have hatched! However, I was unable to tell whether these 'empty' eggshells were a result of successful hatching or whether some insects (or other invertebrates) had cleaned the contents of these eggs to perfection. Before leaving the nest site, we collected all the rotten eggs, empty egg-shells, and the nest material.

Figure 26. One of the 18 empty egg-shells we found from Nest #3. Although it seems like the egg hatched, it was probably eaten up clean by ants

Dissection of unhatched eggs

The following day, we dissected 10 of the unhatched/spoilt eggs to see at what stage of development the embryos (if any) were in. Five of these eggs looked infertile, as there was no embryonic formation whatsoever. One egg contained a relatively well-formed embryo, whose eyes, ventral and dorsal scales, and faint body bands were visible (Fig. 27). The umbilical cord, still attached to the yolk was noticeable as well. Three eggs contained semi-formed embryos, and one egg had dried up.

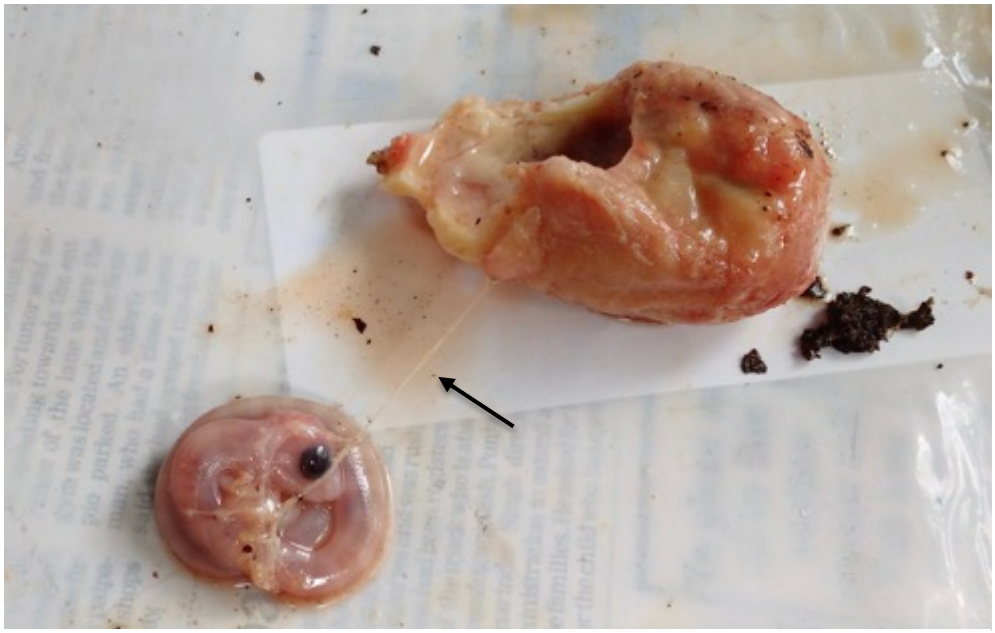

Figure 26. A dead King Cobra embryo attached to the egg yolk via the umbilical cord (indicated by black arrow)

Figure 27. A closeup image of a King Cobra embryo from a damaged nest

SNAKE-AWARENESS PROGRAMMES

An important component of this project was to share our knowledge and passion for snakes at the grassroots level, to try and bring about an attitudinal shift in the mindsets of local people, who largely fear and detest snakes. Our main target audience was school/college going children and young adults, because their minds are still pliable and because they are more likely to be future custodians of nature and wildlife in that region. We strongly believe that awareness and education should be central to any long-term effort at conserving wildlife. Towards this end, we carried out 16 snake-awareness and sensitization programmes in select schools in the study region.

The PowerPoint presentation used for the awareness programme was basically divided into two parts– the first part largely focused on providing basic information on snakes, such as a quick glance on their evolution, global *vs* regional snake diversity, introduction to some common snakes of India, tips for correct snake identification, ecological importance of snakes, facts *vs* myths, snakes in mythology, information on snakebite etc. The second part was more thought-provoking in nature, aimed at making the audience from a passive listener to an active and participatory one. Commonly held notions of danger were challenged, and people in the audience were urged to rationalize their fear for snakes and other wild animals. The presentation also touched upon ethical and legal aspects concerning snake conservation. It ended with practical suggestions– such as what to do if a snake is seen, how to avoid attracting snakes near homes, whom to call for help when a snake is accidentally encountered, what precautionary measures to take for avoiding snakebite etc. We wanted the children and their teachers to actively participate during these presentations, and hence we encouraged them to ask questions and clarify any doubts they may have regarding snakes. Also, as part of our outreach programme, we also designed and distributed two A3-sized posters in Hindi on snakes and snakebite. The first poster solely focused on the study species (i.e. King Cobra), whereas the second poster showcased some common venomous snakes of the region and basic first-aid to be followed in case of snakebite.

In total, we visited 15 different schools/inter-colleges and one community radio station, sensitizing over 1700 people (see table 3 for details). Although our initial target audience was students aged 15 and above, we could not help but include younger

students also. Often, the school authorities wanted everyone to profit from our novel, exciting and useful programmes, and so in many schools the youngest students were part of the audience too. We were happy to see that in most schools, even teachers and staff attended these programmes with great enthusiasm.

Overall, these awareness programmes seemed like a successful endeavour. The enthusiasm and willingness to learn among students and teachers was extremely heartening to witness. The programme also inspired some of the students so much, that they wanted to become part of our long-term project to conserve King Cobras in this landscape. After interacting closely with our target audience, I realized how much more work remains to be done in order to be able to conserve such maligned creatures as snakes more effectively in this region, and elsewhere in India. We hope to carry out many more such programmes in the coming years.

Table 3: Details of the 16 snake-awareness programmes we carried out in Nainital District

School/college/organization name	**Location**	**Classes who attended**	**No. of people who participated**
Global Academy	Talla Ramgarh	6–8	72
Govt. Girls Intercollege	Talla Ramgarh	10–12	50
Govt. High School	Malla Ramgarh	6–10	100
G.B. Panth Intercollege	Bhowali	11–12	72
Govt. High School	Mehragaon	4–8	85
Govt. Intercollege (Purnanand Tivari)	Chanfi	6–12	200
Govt. Upper Primary School	Maluatal	6–8	56*
Govt. Intercollege	Lohali	6–12	146
Govt. Girls Upper Primary School	Nathuakhan	6–8	37
Saraswati Shishu Vidya Mandir	Nathuakhan	4–8	133
Govt. High School	Devdwar	10–12	142
Govt. Intercollege (Dhan Sinh Negi)	Pyura	9–12	255
Govt. Intercollege	Lveshal	9–12	136
Govt. Intercollege	Mukteshwar	6–12	105
Govt. Intercollege	Gahna	9–12	109
Kumaon Vani Community Radio, TERI	Supi	-	8
TOTAL			**1706**

* Apart from school children, several inhabitants of Maluatal village also attended the programme

Below are some photographs taken during/after these awareness programmes:

Figure 28. **(Top)** Snake awareness programme at Global Academy School, Ramgarh; **(Bottom)** the boy students and me gathered for a photograph after the programme. Location: Nainital District, Uttarakhand

Figure 29. Students and staff of Govt. Intercollege (Gahna) gathered for a photograph after the programme. Location: Nainital District, Uttarakhand

Figure 30. Students of Govt. High School (Devdwar) gathered for a photograph after the snake-awareness programme. Location: Nainital District, Uttarakhand

Figure 31. Students of Govt. High School (Malla Ramgarh) during the snake-awareness programme. Location: Nainital District, Uttarakhand

Figure 32. Students and principal (far right) of Govt. High School (Malla Ramgarh) along with the school's display board, where our snake-awareness posters featured

Figure 33. Students and teachers keenly watching the snake-awareness presentation in Govt. Girls' Intercollege (Talla Ramgarh). Location: Nainital District, Uttarakhand

Figure 34. Distributing outreach material (poster on venomous snakes and snakebite first-aid) to teachers at Govt. Girls' Intercollege (Talla Ramgarh). Location: Nainital District, Uttarakhand

Figure 35. Students of Govt. Intercollege (Lveshal) attending the snake-awareness programme

Figure 36. Teachers and staff of Govt. Intercollege (Mukteshwar) and me (far left) after the snake-awareness programme. Location: Nainital District, Uttarakhand

Figure 37. Students of Govt. Intercollege (Lohali) gathered in the science classroom prior to the snake-awareness programme. Location: Nainital District, Uttarakhand

Figure 38. Some boys of Govt. Intercollege (Lohali) posing for a photograph on their picturesque campus after the programme. Location: Nainital District, Uttarakhand

MISCELLANEOUS NOTES

King Cobra Rescue

On the 30th of September, at around 15:30 hrs, I was returning by bus from Haldwani to Ramgarh, when I noticed a group of 10 to 15 people by the road, less than two kilometres from our field station. Upon enquiring, I found out that a snake had entered somebody's car, and that some people were desperately trying to catch it. As the bus could not stop so that I may assess the situation, I decided to head to our field station instead and return here with my snake-rescue equipment, hoping that the snake would still be there. After grabbing my equipment (snake hook, snake tongs, cotton bag), I immediately returned to that spot by motorcycle to try and rescue the snake, whose identity was yet unknown to me. As it turned out, it happened to be a sub-adult King Cobra that had entered somebody's car probably out of fear, and was apparently stuck there for long. Much before I arrived on the scene, the locals had called a school teacher from Mukteshwar, who has some basic experience in handling snakes. He, along with the help of some others, was apparently trying to catch the snake for well over two hours, but in vain. The King Cobra was positioned in such a manner inside the car's bonnet, that it was impossible to manoeuvre a snake hook or tongs in that limited space. After much time and effort, we finally managed to gently prod the snake to pop its head and forebody out from under the flank of the car, after which I managed to grab it by its neck, taking utmost precaution to not hurt it or endanger myself in the process. Despite securing the head of the snake, its body was still entangled among the various car components, mainly the radiator. I instructed the others to gently help me pull out the entire snake from the car. After about two minutes, the body of the cobra came free and we bagged it safely. I thanked the villagers (especially the person whose car it was) for not attempting to kill the snake, and instead for calling for help. We took the snake back to our field station for morphometric measurements (see table 4), before releasing it safely in the wild.

Table 4: Morphometric measurements of rescued sub-adult King Cobra

Total length (cm)	Snout-vent length (cm)	Tail length (cm)	Mid-body girth (cm)	Weight (g)	Head width (cm)	# of bands	Sex
200	164	36	10.5	820	2.5	53	Unknown

Figure 39. The car, along with its owner**,** in which the sub-adult King Cobra was found and successfully rescued from on 30/08/18. Location: Nainital District, Uttarakhand

Figure 40. Sub-adult King Cobra that we rescued from the inside the bonnet of the above car. Photograph taken before collecting morphometric data. Location: Nainital District, Uttarakhand

King Cobra murder

On the 28th of August 2018, while I was returning from fieldwork, I got a phone call from an acquaintance regarding the death of a King Cobra close to our field station in Ramgarh. Apparently, the snake had strayed into human habitation, where it was brutally killed by an elderly local person. When I returned to Ramgarh, I immediately rushed to the site where this gruesome act took place. An old man who lived nearby recounted the incident to me. An adult King Cobra was seen in his neighbour's garden that morning. Upon seeing it, his neighbour tried to kill it. The presumably frightened snake must have attempted to find refuge inside the garden's boundary wall (made of stone). Once the head and forebody of the snake was inside the stonewall, that person struck the latter part of its body hard using a long stick, thus killing the snake. He even had the audacity to try and burn parts of the snake, probably when it was still alive. Such an atrocity, unambiguously, reflects the deep-rooted fear and hatred that some of these people harbour for snakes in general, let alone venomous ones. While it is indeed disheartening to see such crude behaviour, I realize that only greater awareness and sensitization among the locals, coupled with strict enforcement of existing laws, may prevent such incidents from taking place again. I told the person recounting me the story that what his neighbour did was wrong and that he should have instead called for help.

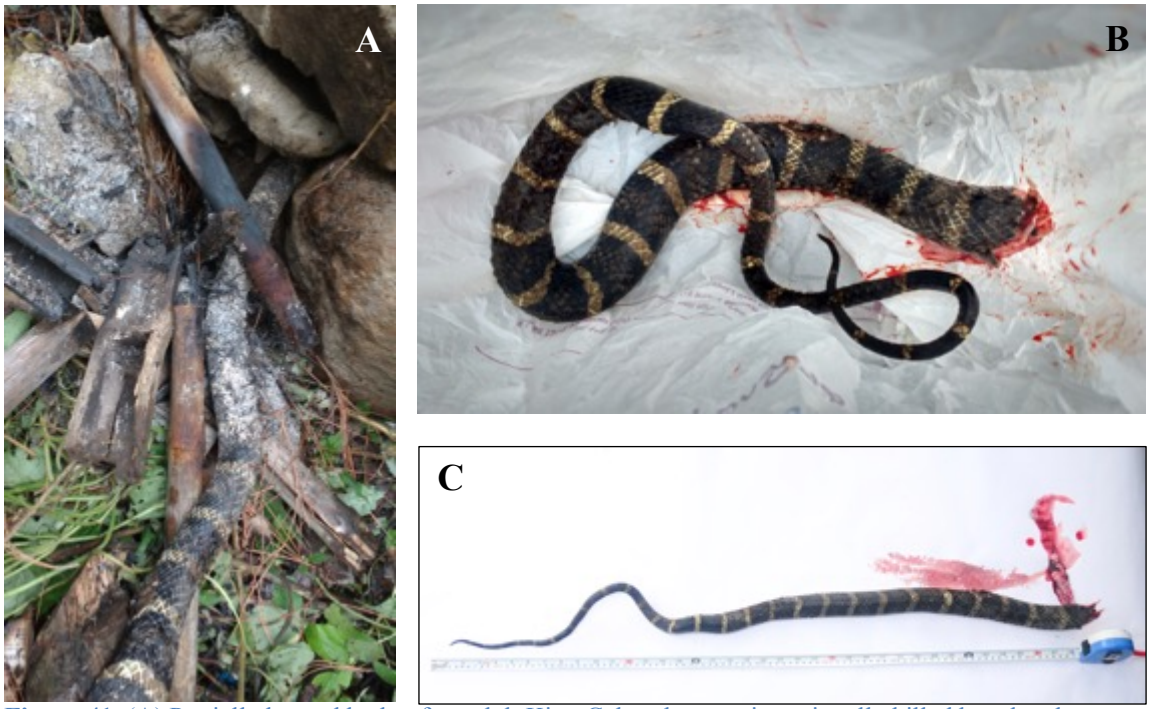

Figure 41. (A) Partially burned body of an adult King Cobra that was intentionally killed by a local person; (B, C) Severed tail of that dead King Cobra. Location: Nainital District, Uttarakhand.

RECOGNIZING & REWARDING LOCAL EFFORT

It is important to realize that although the law protects the King Cobra in theory, ground realities are very different. Without the knowledge and support of local communities, conserving the species, especially outside protected areas, would be impossible. It is also thanks to information provided by village folk (regarding nest site location) that we have been able to monitor 18 King Cobra nests in the Nainital Forest Division.

Thus, in 2016, I had approached the concerned Forest Department officers and convinced them to officially honour the locals who help us conserve King Cobras. The dual purpose behind this idea was to genuinely appreciate the contribution and participation of the locals, and to provide them with some meaningful incentive for possible future collaborations. To my knowledge, the Uttarakhand FD is the only state forest department in the country to follow this unique recognition cum reward programme for safeguarding King Cobras.

On the 8th of October 2018, during the annual Wildlife Week celebrations held at G.B. Pant High Altitude Zoo (Nainital zoo), the Uttarakhand FD (for the third consecutive year) honoured the nominated locals who helped us conserve this iconic species. In 2018, the following people received cash awards/mementos/certificates: Mr. Jagdish Chandra Tiwari, Mr. Rajendra Singh Gangola, Mr. Kunwar Singh Gangola, Mr. Krishna Kumar, Mr. Dayakishan Dani, Mr. Shiyanand and Mr. Mohan Singh Karki (manager of *Kumaon Vani* radio station). The Conservator of Forests for South Kumaon (Ms. Tejaswini Patil, IFS) was the chief guest at this function and the awards were handed over by the Divisional Forest Officer of Nainital (Mr. T.R. Bijulal).

Figure 42. Mr. Jagdish Tiwari receiving an award from the Conservator of Forests (South Kumaon) for his contribution towards King Cobra conservation. Location: Nainital Zoo, Uttarakhand

Figure 43. Local Kumaoni people (except far right) who were honoured by the Forest Department for King Cobra conservation in October 2018. Location: Nainital Zoo, Uttarakhand

CONCLUSION

On the whole, this project was a success as our main objectives were met. We were able to ensure protection of two nests, and we released 44 hatchlings back into the forest, thus contributing to the conservation of this vulnerable species.

The participation of locals in providing information on nests, and sharing their knowledge with us, was particularly encouraging. We realize that community participation, especially for safeguarding King Cobra nests found close to human habitation, is the key to the long-term conservation of this much-feared and maligned animal. Without the help and support of local people and the Forest Department, protecting these nests would have been difficult. Through this project, we further recognize the importance of teamwork between the various stakeholders (e.g. Forest Department, locals, researchers) for conservation to succeed.

Microclimate data from both nest sites clearly showed that mean nest temperatures were significantly warmer (by about 4 °C) than their counterparts. This result matches with our previous findings and highlights the main proximate advantage of nest building in this unique snake.

The awareness cum sensitization programmes that we conducted were much appreciated. Because we presented information in the local language, its effect was significantly greater. Many of the students asked intelligent and pertinent questions and some even wanted to join us as volunteers in the future! However, we realize that many more such similar grassroot level educational programmes must be carried out, for the long-term conservation of snakes in general, King Cobras in particular.

REFERENCES

Balaji, K., and Satyanarayana, J. E. (2018). King Cobra: Occurrence of *Ophiophagus hannah* in Papikonda National Park, Eastern Ghats, Andhra Pradesh. Reptile Rap # 183. (*In*): Zoo's Print **33** (3): 15-18.

Bashir, T., Poudyal, K., Bhattacharya, T., Sathyakumar, S., and Subba, J. B. (2010). Sighting of King Cobra *Ophiophagus hannah* in Sikkim, India: a new altitude record for the northeast. Journal of Threatened Taxa **2** (6): 990-991.

Bhaisare, D., Ramanuj, V., Shankar, P. G., Vittala, M., Goode, M., and Whitaker, R. (2010). Observations on a wild king cobra (*Ophiophagus hannah*), with emphasis on foraging and diet. IRCF Reptiles & Amphibians **17**(2): 95-102.

Burchfield, P. M. (1977). Breeding the king cobra at Brownsville Zoo. International Zoo Yearbook **17**: 136-140.

Chan, B. P. L. (2019). Predation attempt by King Cobra (*Ophiophagus hannah*) on Clouded Monitor (*Varanus nebulosus*) on Pulau Bintan, Riau Archipelago, Indonesia. Southeast Asia Vertebrate Records 2019: 11-13. ISSN : 2424-8525.

Chandra, K., Raha, A., Parida, A., Majumder, A., Dawn, P., and Singh, V. (2014). The first record of the King Cobra *Ophiophagus hannah* (Cantor, 1836) (Reptilia: Elapidae) from Chhattisgarh, Central India. Records of the Zoological Survey of India. **114** (3): 519-521.

Daniel, J. C. (2002). The Book of Indian Reptiles and Amphibians (Bombay Natural History Society). Oxford University Press, India. 238 pp.

Das, A., Nair, M. V., Ahmed M. F., and Sharma, P. K. (2008). Distribution of King Cobra (*Ophiophagus hannah*) in northeastern India with new altitudinal record and notes on its habitat. Tigerpaper **35** (4): 1-6.

Das, I. (2002). A photographic guide to snakes and other reptiles of India. New Holland Publishers Ltd., London, UK. 144 pp.

Das, I. (2015). A Field Guide to the Reptiles of South-East Asia. Bloomsbury Publishing.

Das, I., and Das, A. (2018). A Naturalist's Guide to the Reptiles of India, Bangladesh, Bhutan, Nepal, Pakistan and Sri Lanka. John Beaufoy Publishing Ltd. 176 pp.

Dolia, J. (2018). Notes on the distribution and natural history of the King Cobra (*Ophiophagus hannah* Cantor, 1836) from the Kumaon hills of Uttarakhand, India. Herpetology Notes **11**: 217-222.

Fitch, H. S. (1987). Collecting and life-history techniques. (In) R. A. Seigel, J. T. Collins, and S. S. Novak (eds.), Snakes: Ecology and Evolutionary Biology, pp. 143-164. MacMillan Publishing, New York.

Greene, H. W. (1997). Snakes: the evolution of mystery in nature. University of California Press. 351 pp.

Home, W. M. L. (1927). Hamadryads in the Kumaon Terai. Journal of the Bombay Natural History Society **32**: 610-611.

Hrima, V. L., Sailo, V. L. H., Fanai, Z., Lalronunga, S., Lalrinchhana, C., Zothansiama and H. T. Lalremsanga (2014). Nesting ecology of the King Cobra, *Ophiophagus hannah*, (Reptilia: Squamata: Elapidae) in Aizawl District, Mizoram, India. Issues and Trends of Wildlife Conservation in Northeast India: 268-274.

Krishna, S. B. (2002). *Ophiophagus hannah* (King Cobra). Diet. Herpetological Review **33**: 141.

Leakey, J. H. E. (1969). Observations made on king cobras in Thailand during May 1966. Journal of the National Research Council, Thailand **5**: 1-8.

Lillywhite, H. B. (2014). How snakes work: structure, function and behavior of the world's snakes. Oxford University Press, New York. 241 pp.

Marshall, B. M., Strine, C. T., Jones, M. D., Artchawakom, T., Silva, I., Suwanwaree, P., and Goode, M. (2018a). Space fit for a king: spatial ecology of king cobras (*Ophiophagus hannah*) in Sakaerat Biosphere Reserve, Northeastern Thailand. Amphibia-Reptilia **1**:1-16. DOI:10.1163/15685381-18000008.

Marshall, B. M., Strine, C. T., Jones, M. D., Theodorou, A., Amber, E., Waengsothorn, S., Suwanwaree, P., and Goode, M. (2018b). Hits Close to Home: Repeated Persecution of King Cobras (*Ophiophagus hannah*) in Northeastern Thailand. Tropical Conservation Science **11**:1-14.

Murthy, K. L. N., and Murthy, K. V. R. (2012). Sightings of King Cobra *Ophiophagus hannah* in northern coastal Andhra Pradesh. Reptile Rap **14**: 29-32.

Narayan, G., and L. Rosalind. (1989). King cobra in grassland; an unusual habitat. Journal of Bombay Natural History Society **87** (2): 309.

O'Shea, M. (2018). The book of snakes: a life-size guide to six hundred species from around the world. Ivy Press.

Rao, C. S., Talukdar, G., Choudhary, B. C., Shankar, P. G., Whitaker, R., and Goode, M. (2013). Habitat use of King Cobra (*Ophiophagus hannah*) in a heterogenous landscape matrix in the tropical forests of the Western Ghats, India. Hamadryad **36** (2): 69-79.

Rasaily, S., Rai, M., and Manoj Chandran. (2008). First ever sighting of king cobra nest in the Kumaon hills of Uttarakhand. The Indian Forester **134** (10): 1405-1408.

Shankar, P. G., and Whitaker, R. (2013). Cannibalism in wild and captive king cobras (*Ophiophagus hannah*) Cantor, 1836. Hamadryad **36** (2): 87-90.

Siler, C. D., Welton, L. J., Brown, R. M., Infante, C., and Diesmos, A. C. (2011). *Ophiophagus hannah* (King Cobra) diet. Herpetological Review **42** (2): 297.

Singh, A., and Joshi, R. (2016). A first record of the King Cobra *Ophiophagus hannah* (Reptilia: Squamata: Elapidae) nest from Garhwal Himalaya, northern India. Zoo's Print **31** (9): 9-11.

Singh, J. S., and Singh, S. P. (1987). Forest vegetation of the Himalaya. The Botanical Review **53** (1): 80-192.

Smith, M. A. (1943). The Fauna of British India, Ceylon and Burma, including the whole of the Indo-Chinese region. Reptilia and Amphibia, Vol. III (Serpentes). Taylor and Francis Ltd., London. 583 pp.

Stuart, B., Wogan, G., Grismer, L., Auliya, M., Inger, R.F., Lilley, R., Chan-Ard, T., Thy, N., Nguyen, T.Q., Srinivasulu, C. & Jelić, D. 2012. *Ophiophagus hannah*. The IUCN Red List of Threatened Species 2012: e.T177540A1491874. http://dx.doi.org/10.2305/IUCN.UK.2012-1.RLTS.T177540A1491874.en.
Downloaded on 18 Jan 2019.

Sy, E. Y. (2017). *Ophiophagus hannah* (King Cobra): Geographic distribution. Herpetological Review **48** (1): 130.

Thapa, K. B., Rana, N., and Shah, K. B. 2019. Distribution of King Cobra in Nepal. The Himalayan Naturalist **2** (1): 26-33.

Theophilus, E., Captain, A., Tillack, F., and Kuch, U. (2008). Reptilia, Elapidae, *Bungarus niger*: distribution extension and first record for the state of Uttarakhand, India, with notes on snakebites in the Gori River valley. Check List **4** (4): 404-409.

Wall, F. (1924). The hamadryad or king cobra, *Naia hannah* (Cantor). Journal of Bombay Natural History Society **30**: 189-195.

Waltner, R. G. (1975). Geographical and altitudinal distribution of amphibians and reptiles in the Himalayas. Part IV Cheetal **16**: 12-17.

Whitaker, N., Shankar, P. G., and R. Whitaker. (2013). Nesting ecology of the king cobra (*Ophiophagus hannah*) in India. Hamadryad **36** (2): 101-107.

Whitaker, R. (1978). Common Indian Snakes: a field guide. Macmillan India Limited, New Delhi, India, 154 pp.

Whitaker, R., and Captain, A. (2004). Snakes of India: The Field Guide. Draco Books. Chennai, Tamil Nadu.

Yadav, O., and Yankanchi, S. (2015). Occurrence of *Ophiophagus hannah* Cantor, 1836 (Squamata, Elapidae) in Tillari, Maharashtra, India. Herpetology Notes **8**: 493-494.

Zug, G. R., Vitt, L. J., and Caldwell, J. P. (2001). Herpetology: an introductory biology of amphibians and reptiles. Elsevier.

APPENDIX I

Morphometric measurements of King Cobra hatchlings from Nest #1

S. No.	Total length (cm)	Tail length (cm)	Mid-body girth (cm)	Weight (g)	# of bands	# of undivided subcaudal scales
1	52.0	8.5	3.5	20.5	47	4
2	56.0	9.3	3.0	24.5	50	-
3	54.0	8.9	3.1	23.0	52	13
4	54.0	9.6	3.5	23.0	54	1
5	53.0	9.0	3.4	23.0	55	6
6	55.0	9.5	3.0	23.0	53	8
7	56.0	9.5	3.1	24.5	59	6
8	56.0	9.5	3.5	24.5	50	4
9	55.2	8.7	3.0	22.0	53	5
10	55.5	10.0	3.5	23.5	59	9
11	55.0	9.5	3.2	24.0	59	8
12	56.0	8.5	3.3	23.5	52	3
13	55.5	9.0	3.2	25.0	53	3
14	56.0	10.0	3.2	24.0	59	5
15	57.0	10.0	3.5	25.0	55	10
16	57.0	7.5	3.8	24.0	50	1
17	55.0	9.5	3.2	23.5	54	4
18	57.0	10.0	3.5	22.0	57	7
19	53.0	9.0	3.0	19.0	59	6
20	55.0	9.5	3.2	23.5	58	7
21	54.0	8.5	3.2	23.0	51	4
22	54.0	8.5	3.1	22.5	49	6
23	55.0	9.5	3.1	21.0	58	8
24	57.0	9.5	3.2	23.5	58	9
25	50.5	9.0	3.3	24.0	53	13

APPENDIX II

Morphometric measurements of King Cobra hatchlings from Nest #2

S. No.	Total length (cm)	Tail length (cm)	Mid-body girth (cm)	Weight (g)	# of bands	# of undivided subcaudals
1	55.0	9.0	3.2	25.5	54	5
2	51.0	9.0	3.3	26.0	55	6
3	52.0	8.3	3.4	25.5	54	3
4	52.0	9.2	3.4	26.0	58	9
5	52.0	8.2	3.3	26.0	54	4
6	54.0	8.5	3.2	26.0	55	5
7	52.0	8.7	3.5	27.0	55	1
8	54.0	9.0	3.5	27.0	51	4
9	54.5	9.0	3.4	26.5	56	6
10	51.5	9.0	3.5	27.0	61	9
11	51.5	8.5	3.4	24.5	58	7
12	53.0	8.5	3.5	27.0	56	7
13	46.0	8.0	2.7	16.5	59	6
14	55.5	10.0	3.5	27.0	59	7
15	51.0	8.0	3.5	26.0	50	6
16	53.0	9.5	3.8	27.0	59	8
17	53.5	9.6	3.5	27.0	58	12
18	50.0	9.5	3.2	26.0	52	12
19	54.0	10.0	3.7	27.5	56	12