REPTILES & AMPHIBIANS

Establishing a Baseline Trend and Diversity of Rescued Snakes in the Kali Tiger Reserve, Karnataka, India

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Abstract.—As human-snake encounters become increasingly frequent, snake rescuers play a significant role in protecting both snakes and humans. To improve the procedures of snake rescues in human-dominated areas and ensure greater accountability, providing structured protocols and establishing evidence-based snake-human encounter management is increasingly important. Herein we analyze snake rescues in and around the Kali Tiger Reserve, Karnataka, India, to identify trends and document the diversity of snake species encountered in human-dominated landscapes. Snake rescues by the Forest Department staff of the Kali Tiger Reserve from 2012 to 2022 involved 31 species in 22 genera, with *Ptyas* (29.3%), *Naja* (21.7%), *Chrysopelea* (9.9%), and *Python* (9.7%) being the most frequently rescued. The numbers of frequently rescued species is indicative of the overall quality of habitat, whereas the frequency of rescues of near-threatened species in the genera *Python* (278 rescues) and *Eryx* (54 rescues) demonstrates the importance of implementing effective conservation policies. We also highlight the need for proper record-keeping of rescues for further research and decision-making, monitoring survival of translocated individuals, and the need for educational awareness programs about threatened and venomous snakes directed to the area's human populations.

India is home to four different globally recognized biodiversity hotspots, where its rich variety of snake species are an integral part of its diverse wildlife (Myers et al. 2000; Whitaker and Captain 2004). With its varied terrain, climate, and vegetation, India provides ideal habitats for many snakes. Although snakes often are associated with danger and fear, only a small percentage (10–15%) of the approximately 323 Indian species are venomous, and only a few of those, the Spectacled Cobra (*Naja naja*), Common Krait (*Bungarus caeruleus*), Russell's Viper (*Daboia russelii*), and Saw-scaled Viper (*Echis carinatus*), are commonly found in close proximity to human habitation (Whitaker and Captain 2004; Aengals et al. 2018), where they account for most of the 46,000 snakebite-related deaths and 140,000 disabilities per year (Mohapatra et al. 2011; Laxme et al. 2019). However, snakes play important roles in ecosystems by controlling rodent populations and maintaining food chains. Except for Saw-scaled Vipers, most of the venomous species found in India feed on rodents that often are abundant around human settlements. This results in frequent interactions between these species and humans, which can lead to snakebite incidents. Data from rescues can be important when balancing the cost of snakebites against the benefits of rodent control.

Under the Indian Wildlife (Protection) Act of 1972, all snakes are legally protected and listed in Schedules I–IV (Vyas 2013). Nevertheless, many snakes are killed, especially in rural areas, where ignorance of environmental conservation, laws protecting snakes, and the significance of snakes in the ecosystem prevail. However, some individuals act wisely and instead of panicking, immediately seek assistance from professional snake rescuers, the Forest Department, or local non-governmental organizations (Vyas 2013).

Karnataka was one of 13 Indian states with a high prevalence of snakebite deaths, and approximately 2,400 deaths were attributed to snakebites in 2005 alone (Shreevanitha 2013). To address this issue, the Forest Department has conducted workshops to train some staff to rescue and relocate wild animals that pose a threat to humans or are found in human-inhabited areas. This initiative aims to reduce conflicts between humans and wild animals. However, a lack of communication and collaboration between ecologists and rescuers is a major concern that needs immediate attention. This gap

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poses a serious threat to the success of rescue operations, especially when dealing with wildlife species that require specific knowledge and expertise. The absence of a protocol to collect and record information (name, type, size, weight of the snake, along with the date, time, rescue and release locations) further aggravates the situation. Such a mechanism would enable ecologists and rescuers to communicate more effectively, share their knowledge, and coordinate their efforts to ensure the success of rescue operations and reduce the frequency of human-snake conflicts (Roshnath and Jayaprasad 2017).

In Kali Tiger Reserve, Forest Department staff have been actively engaged in the rescue of snakes since 2011 and maintain a database of snake rescues. We analyzed these rescue data to better understand annual trends in snake-rescue operations between 2012 and 2022 and the common snake species found in specific human communities to better manage evidence-based rescue operations and human-snake encounters.

Methods

The Kali Tiger Reserve (Fig. 1), one of five in the region, covers an area of approximately 1,495 km^2, elevations of 400–650 m asl and experiences a tropical monsoon climate with an average annual rainfall of 2,700–2,800 mm. The reserve supports thriving populations of an array of wild animals (MEE 2022); the diverse flora and fauna make it an ecologically significant region and a hotspot for wildlife conservation efforts. A total of 66 reptilian species have been documented in the reserve, 41 of which are snakes and ten of which are venomous (Pai 2022).

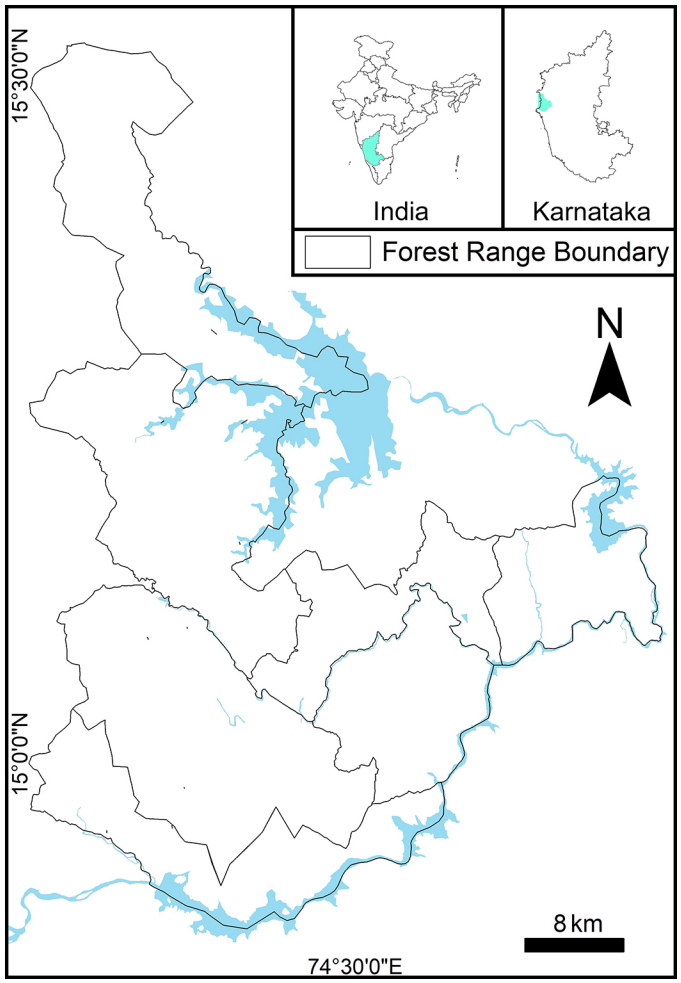

Figure 1. Location of the Kali Tiger Reserve, Karnataka, India.

Data collection.—We contacted all Forest Department staff that are actively involved in snake rescues in the Kali Tiger Reserve. With the exception of a few staff members, no systematic protocols for keeping records of snake-rescue operations were in place when rescue operations began in 2012; this resulted in a scarcity of reliable data during the initial period of the operation. Despite those challenges, we used the available data to generate a baseline analysis. However, with the establishment of systematic rescue management and the implementation of dedicated staff training programs, the situation improved and staff have started maintaining records of each rescue since 2016. To collect information on the snake-rescue program, a request note and a form were distributed among forest staff. The form was specifically designed to compile data on snake rescues that occurred between the years 2012 and 2022. The information requested in the form included the rescuer's name and contact details, the species of snakes rescued, and the dates of rescues.

To ensure accuracy in our analyses, we chose to base our study on genera rather than species. While the staff are skilled at identifying snakes, we acknowledge that misidentifications of certain species within some genera can occur due to similarities in appearance (e.g., the four species in the genus *Boiga* that have been recorded in the area) and the staff's limited knowledge of taxonomy.

Results

We collected data on 2,648 snake rescues over the 10 years of our study. Trends include an increase from 56 rescues in 2012 to 444 in 2022 for an average of over 280 cases per year, and an increase in the number of rescuers, which has grown from one in 2012 to 15 in 2022 (Fig. 2). Increases in both were consistent after 2017.

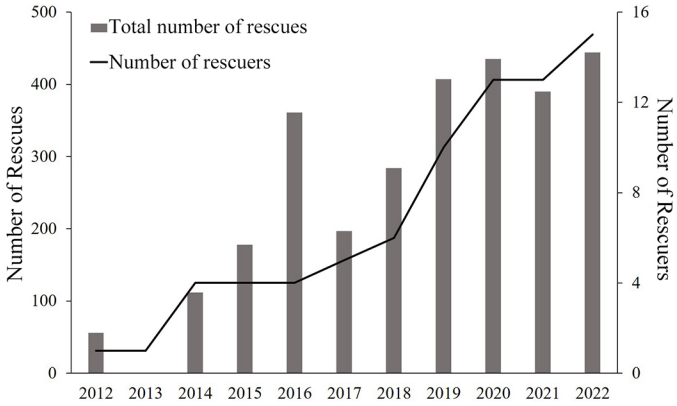

Figure 2. Trends of snake rescues in Kali Tiger Reserve from 2012 to 2022.

Table 1. Species of snakes found during rescue operations in the Kali Tiger Reserve, Karnataka, India, from 2012 to 2022, with IUCN Red List status, size range, habitat, and activity period (Whitaker and Captain 2004). IUCN Red List Status: LC = Least Concern, NT = Near Threatened, VU = Vulnerable, NE = Not Evaluated, DD = Data Deficient.

Species	IUCN Red List Status	Size (cm)	Habitat	Activity Period
Aquatic Forest Snake *Rhabdops aquaticus*	LC	80–90	Terrestrial, Aquatic	Nocturnal
Ashok's Bronze-backed Treesnake *Dendrelaphis ashoki*	LC	70–102	Arboreal	Diurnal
Banded Kukri Snake *Oligodon arnensis*	LC	40–55	Terrestrial	Diurnal, Crepuscular
Beaked Blindsnake *Grypotyphlops acutus*	LC	Max. 60	Terrestrial, Burrowing	Diurnal, Nocturnal
Checkered Keelback *Fowlea piscator*	LC	100–120	Terrestrial, Aquatic	Diurnal, Nocturnal
Collared Catsnake *Boiga nuchalis*	LC	120–130	Arboreal	Nocturnal
Common Catsnake *Boiga trigonata*	LC	80–90	Arboreal	Nocturnal
Common Krait *Bungarus caeruleus*	LC	120–170	Terrestrial	Nocturnal
Common Sandboa *Eryx conicus*	NT	50–80	Terrestrial, Burrowing	Diurnal, Nocturnal
Common Wolfsnake *Lycodon aulicus*	LC	70–90	Terrestrial, Arboreal	Nocturnal
Forsten's Catsnake *Boiga forsteni*	LC	160–180	Arboreal	Nocturnal
Giri's Bronze-backed Treesnake *Dendrelaphis girii*	LC	70–105	Arboreal	Diurnal
Green Keelback *Rhabdophis plumbicolor*	LC	60–90	Terrestrial	Nocturnal
Hump-nosed Pitviper *Hypnale hypnale*	LC	28–38	Terrestrial	Nocturnal
Indian Ratsnake *Ptyas mucosa*	LC	180–220	Terrestrial	Diurnal
Indian Rock Python *Python molurus*	NT	400–700	Terrestrial, Arboreal	Diurnal, Nocturnal
King Cobra *Ophiophagus hannah*	VU	350–450	Terrestrial, Arboreal	Diurnal
Malabar Pitviper *Craspedocephalus malabaricus*	LC	Max. 65	Arboreal	Nocturnal
Montane Trinket Snake *Coelognathus helena monticola*	LC	100–140	Terrestrial	Diurnal, Nocturnal
Northern Vinesnake *Ahaetulla borealis*	NE	Max. 85	Arboreal	Diurnal
Ornate Flying Snake *Chrysopelea ornata*	LC	100–170	Arboreal	Diurnal
Red Sandboa *Eryx johnii*	NT	80–100	Terrestrial, Burrowing	Diurnal, Nocturnal
Russell's Viper *Daboia russelii*	LC	100–120	Terrestrial	Diurnal, Nocturnal
Southern Bronze-backed Treesnake *Dendrelaphis chairecacos*	DD	90–115	Arboreal	Diurnal
Spectacled Cobra *Naja naja*	LC	100–200	Terrestrial	Diurnal
Streaked Kukri Snake *Oligodon taeniolatus*	LC	45–60	Terrestrial	Diurnal, Crepuscular
Striped Coralsnake *Calliophis nigrescens*	LC	Max. 127	Terrestrial	Nocturnal
Striped Keelback *Amphiesma stolatum*	LC	60–80	Terrestrial	Diurnal
Thackerey's Catsnake *Boiga thackerayi*	NE	100–110	Arboreal	Nocturnal
Travancore Wolfsnake *Lycodon travancoricus*	LC	72–75	Terrestrial, Arboreal	Nocturnal
Whitaker's Boa *Eryx whitakeri*	NT	Max. 80	Terrestrial, Burrowing	Diurnal, Nocturnal

A total of 31 species in 22 genera were rescued (Table 1). The most frequently rescued genera (Fig. 3) were *Ptyas* (844), *Naja* (623), *Chrysopelea* (286), and *Python* (278), which represent 29.3%, 21.7%, 9.9%, and 9.7% of all rescues, respectively. On the other hand, few rescues involved the genera *Daboia*, *Amphiesma*, *Rhabdophis*, *Ahaetulla*, *Calliophis*, *Grypotyphlops*, and *Rhabdops*. Seven of the rescued genera (*Naja*, *Ophiophagus*, *Daboia*, *Bungarus*, *Hypnale*, *Calliophis*, and *Craspedocephalus*) are venomous, and snakes in the genera *Python* (Indian Rock Python) and *Eryx* (sandboas) are listed as Near Threatened on the IUCN Red List (IUCN 2023). Indian Rock Pythons were rescued 278 times, Common Sandboas 40 times, Whitaker's Sandboas 13 times, and a Red Sandboa only once. The King Cobra (*Ophiophagus hannah*) was the only species listed as Vulnerable on the IUCN Red List (IUCN 2023); 82 rescues were documented during the ten-year period.

Of the five most frequently rescued genera, *Ptyas* and *Naja* generally increased (Fig. 4), with annual averages of 84 and 62, respectively. In 2012, *Ptyas* was rescued only 18 times, but this number increased to 129 in 2022, with the highest number of rescues (129) occurring in 2016 and 2022. Similarly, *Naja* was rescued 17 times in 2012, but this number increased to 90 in 2022, with the highest number of rescues (109) in 2020. *Chrysopelea* was rescued an average of 28 times per year (3 in 2012 to 45 in 2016 and 2022), whereas *Python* was rescued an average of 27 times per year (2 in 2012 to 41 in 2016 and 2022) and *Lycodon* was rescued an average of 17 times per year (4 in 2012 to 29 in 2022).

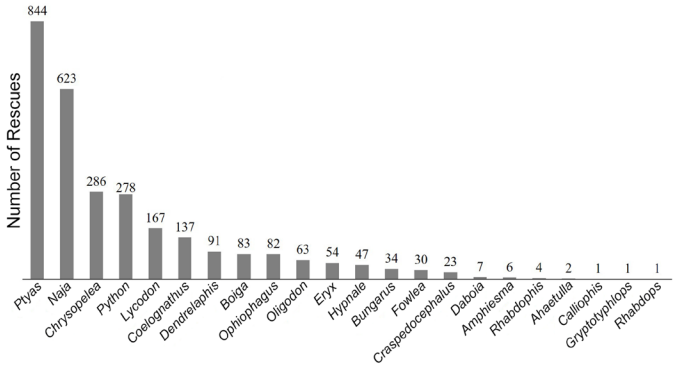

Figure 3. Numbers of each genus of snakes encountered during rescues in the in Kali Tiger Reserve, Karnataka, India, from 2012 to 2022.

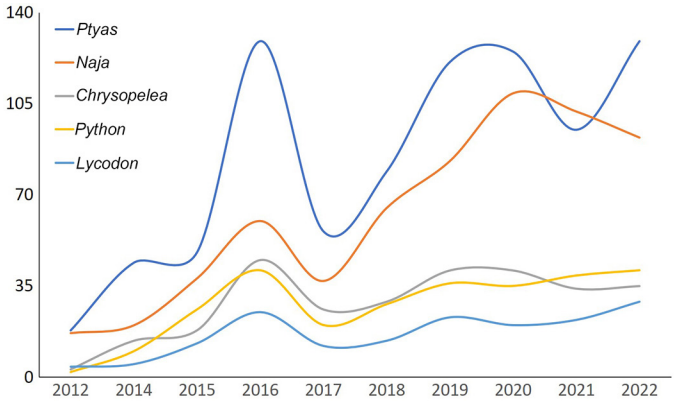

Figure 4. Trends in the numbers of the five most frequently rescued genera of snakes in the Kali Tiger Reserve, Karnataka, India, from 2012 to 2022.

Discussion

As human populations grow and expand into previously undeveloped areas, more interactions between humans and wildlife, including snakes, are inevitable. Additionally, changes in weather patterns and temperature might cause snakes to move into areas where they were not previously found, leading to increases in the frequencies of interactions. More instances of snakes being encountered are unavoidable and they lead to more snakes needing to be rescued. The increase in the number of available rescuers can be attributed to factors such as the appointment of dedicated staff to each range, training for rescue operations, the implementation of a well-organized rescue-management system, and the enhancement of rescue infrastructure. Finally, the efforts made by the department to raise awareness of snake-rescue services have resulted in an increased number of people reporting snake sightings and seeking assistance for their removal. Another factor for increases in snake rescues might be local increases in snake populations. However, no empirical studies or research to date support the hypothesis that increased encounters, even in part, are a result of increased numbers of snakes.

The high rates of rescues of snakes in the genera *Ptyas* and *Naja* indicate that these two species of snakes are abundant and frequently function as human commensals in the area. Although *Naja* is highly venomous, it is often rescued because of associated religious beliefs. Local residents hesitate to harm or kill this species due to its sacred status (Allocco 2013; Yuan et al. 2020)nagas are ambivalently imaged: they are divine beings with the capacity to bless as well as to curse. In addition to their primary association with fertility, these divinized non-human animals are perceived as particularly receptive to women's concerns (healing and familial prosperity and instead prefer to call rescuers to relocate it. However, the situation is different for vipers and the krait, which are perceived as deadly by locals. Instead of calling rescuers, people often kill all snakes presumed to be venomous. Consequently, different attitudes toward different snakes can affect the likelihood of rescuers being summoned. Nevertheless, the number of different snake species rescued clearly reflects the diversity of snakes that interact with humans — and that diversity highlights the suitability of the habitats in the reserve and the need for conserving both the habitats and their inhabitants. Also imperative is the need to create more awareness among local people about these species so that they will inform the Forest Department as quickly as possible when they encoun-

ter snakes of any species. The analysis of frequently rescued species also will be helpful for forest managers in developing rescue-management strategies for the most frequently encountered snakes and understanding their behaviors and tendencies to occur in and near human habitations will lead to evidence-based conservation management strategies.

The snake-rescue operation conducted by forest staff is not only a valuable voluntary service to society but also contributes to the conservation of snakes. However, the data collected are not uniform and lack scientific guidance from professionals. As a result, gaps exist in the maintenance of proper scientific documentation and a comprehensive database of snake rescues and relocations. Accurately recording times and dates of rescues will provide insights into temporal patterns of species in human-dominated areas and recording exact locations will help us analyze specific habitat associations. At this time, the paucity of such information is a significant flaw of the current system. Therefore, collecting comprehensive, standardized, and complete data is crucial for proper analysis and interpretation and needs to be emphasized when training rescuers.

When rescuing snakes, one must also consider species-specific characteristics (Achille 2015; Martin et al. 2022). Different species vary considerably in size and level of toxicity, which can affect how they should be handled during a rescue operation. Consequently, developing species-specific standard operating protocols and protective measures for each type of snake that might be encountered is crucial. In addition to training rescuers to maximize their own safety, releasing rescued snakes into suitable habitat is important both for the sake of the snake and to minimize future unwanted human-snake interactions (Ashraf and Menon 2005). Rescue experts and ecologists together should prepare a protocol for releasing snakes that maximizes the likelihood of survival. So, in addition to suitable habitat, diurnal snakes should be released during the day, whereas nocturnal snakes should be released in the evening or at night.

Every year, a substantial number of snakes of different species are removed from human-dominated habitats; however, the consequences of such translocations are not yet fully understood. Currently, survival rates and status of the relocated individuals are not monitored, and further studies on the fates of translocated snakes are critical. The use of Passive Integrated Transponder (PIT) tags can help researchers prepare a database of individual rescued snakes, collecting information regarding survival, health, and movements (Zydlewski et al. 2001; Gibbons and Andrews 2004; Ousterhout and Semlitsch 2014; Oldham et al. 2016). Monitoring movements of released snakes, for example, can determine if the same individuals or snakes released into particular habitats are rescued repeatedly, so proper guidelines can be developed for relocations that avoid such scenarios.

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