

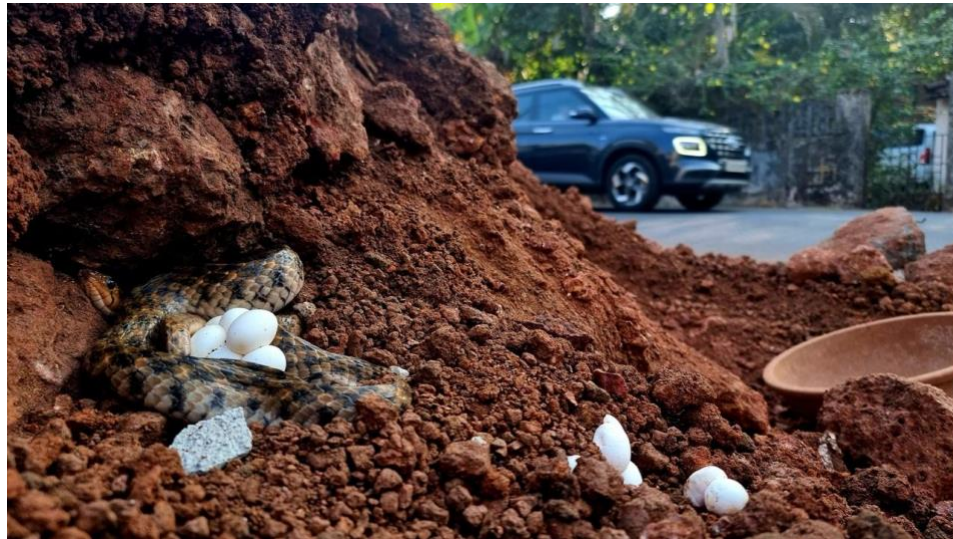
Human-snake Conflict and Co-existence in Goa, India

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This thesis is dedicated to the loving memory of my father, Col. (Retd.) Ajaypal Singh Attre, who gave me my love for animals. You may not be physically present here, but wherever you are, I know you are smiling (only in the way that you do) that I finally made it over the fence.

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Author's declaration

All chapters were conceptualised, analysed and written by Shaleen Attre, with editorial suggestions made by the PhD supervisors R. A. Griffiths, M. Poudyal and I. Bride. Chapter 3 was undertaken with support from researchers outside the direct supervisory team, as outlined below.

Chapter 3's rescue data was provided by the Goa Forest Department. Using Generalised Additive Modelling as the best method to further analyse the data was borne of a conversation with Dr Dave J. I. Seaman, who also provided support on GAMs and climate data extraction from Google Earth engine. Advice on local ecological knowledge was provided by Benhail Antao. Data extraction, cleaning and analysis was done by Shaleen Attre with editorial support from R A Griffiths, M. Poudyal, I. Bride and D. J. I. Seaman.

All photographs used in this thesis are by the author, unless credited otherwise.

Cover photo (checkered keelback with her fresh clutch, in a construction site by the side of a busy residential area in North Goa): Benhail Antao

Preface

I never set out to work with snakes. I was studying English literature when I began working as an animal rescuer. That work eventually pulled me deeper into conservation, first through outreach and urban conflict, and later into issues like wildlife crime and human-wildlife conflict. Human-snake conflict, in particular, kept coming back. It was everywhere, and yet almost no one was really studying it. Unlike many other conservation problems, snakebite sat uncomfortably at the junction of human suffering, ecological fear, and institutional neglect. I saw how poorly it was understood, how frequently it was fatal, and how rarely it was studied in a sustained, systems-oriented way, barring a few researchers.

My early work involved building awareness, conducting outreach, and co-founding IndianSnakes- a voluntary initiative dedicated to improving snakebite response and reducing mortality. Over time, it became clear that while public discourse around snakes was growing, research on snakebite itself remained sparse, fragmented, and deeply disconnected from what was happening on the ground. This disconnect, between what was practiced, what was researched, and what was applied, was where my research took root. I had spent years working in landscapes where snakebite response meant chaos- scrambling for antivenom, navigating rural referrals, trying to get victims the care they needed before it was too late. Domestic animals died unnoticed. Survivors left hospitals with no follow-up or support. Even basic first aid was often wrong. The ethos and ethics behind rescues, the intention to protect both people and snakes, was often lost in the noise, especially when systems failed the very communities we claimed to serve.

Goa was not my original field site. The original plan was to work in Chhattisgarh, but the COVID-19 pandemic disrupted those plans. Amid lockdowns, logistical challenges, and personal upheavals, I turned to Goa, where I had some existing networks and could work safely and meaningfully. What started as a fallback site quickly revealed something unexpected: a region with high reported bite rates, but unusually low recorded mortality. Rescuers were present, as in many parts of India, but here, community knowledge, structured healthcare, and quiet systemic function seemed to be working in tandem. It was a story I had never seen before.

As a single female researcher working through a pandemic and navigating difficult personal terrain, this project was not easy. But it was possible, because of the people on the ground who opened their homes, shared their stories, and helped me see the system from the inside out because they believed in the worth of the research I was doing.

This thesis reflects over a decade of immersion in snakebite mitigation, grounded in both professional practice and academic inquiry. It is a product of field insight, lived experience, and the trust of the communities, doctors, rescuers, and officials who made this research possible. It is also a quiet reminder that in the spaces between science and society, between fear and empathy, there is room for something better- for coexistence, care, and change.

Abstract

Human-wildlife conflict is increasingly recognised as a major challenge in conservation policy and practice, but remains narrowly framed around visible encounters with large, charismatic species. In contrast, snakebite envenomation, despite causing over 100 times more human deaths annually in India than elephants and tigers combined, remains largely excluded from both conservation frameworks and human-wildlife conflict discourse. In India, as well as globally, snakebite remains one of the most neglected challenges at the intersection of public health and biodiversity governance, even though India accounts for nearly half of the global burden of recorded deaths. Treated primarily as a medical emergency, snakebite sits at an uneasy intersection of health systems, ecological disruption, and ethical coexistence, rendering it both politically and institutionally invisible. While policy attention has grown in recent years, mitigation continues to focus narrowly on clinical treatment and species removal. Ecological, veterinary, and socio-cultural dimensions remain largely excluded, despite the need for a One Health approach that recognises snakebite as a conflict that also results in the deaths of both domestic animals and snakes, impacting animal welfare, rescue systems, and broader coexistence dynamics.

This thesis investigates the layered dynamics of human-snake encounters in Goa based on a mixed-methods study that combines five years of public health facility data, six years of rescue and climate records, and 68 in-depth interviews with stakeholders such as doctors, rescuers, veterinarians, community members, and government officials. Two seasonal frequency peaks, during and after the monsoon, merged consistently across human bites, domestic animal deaths, and snake rescues. Generalised Additive Models applied to multi-species rescue data revealed that while rainfall, humidity, and temperature shaped overall patterns of snake rescues, species-specific behaviours such as mating, nesting, and neonate dispersal drove distinct rescue peaks. When interpreted alongside detailed interviews with rescuers, these models showed a striking alignment between local ecological knowledge and modelled trends, demonstrating that retrospective rescue data, when ecologically contextualised, can inform species-sensitive mitigation planning. Goa's relatively low recorded level of human mortality was supported by relatively good decentralised antivenom access, ambulance response, and public trust in government services. However, long-term morbidity is undocumented, psychological trauma is

unaddressed, and migrant and informal workers remain structurally excluded from outreach and emergency care. Also, veterinary snakebite is entirely absent from policy frameworks. Interviews revealed that pet and livestock deaths from snakebite are common and often deeply distressing, with owners frequently describing emotional trauma, economic loss, and frustration at the absence of veterinary care or institutional recognition. Unlike animal deaths caused by tigers or leopards, which trigger financial compensation and formal response, snake-related losses remain entirely outside the scope of human-wildlife conflict governance. This exclusion reinforces a systemic double standard in how conflict is recognised, whose suffering is acknowledged, and which species are seen as the state's responsibility. Snake rescues have played a central role in reducing retaliatory and precautionary killings, but now risk reinforcing dependency on removal and undermining coexistence. With no legal clarity, rescue practices remain uneven, some grounded in conservation ethics, others shaped by public pressure, lack of institutional support, or social media performance. This has led to inconsistent training, arbitrary translocations, and growing emotional fatigue among rescuers. These patterns reflect deeper tensions around legitimacy, institutional accountability, and the uneven burden placed on informal actors to mediate human-wildlife conflict in the absence of state systems.

This thesis is the first to empirically connect human, animal, and ecological dimensions of snakebite conflict in India, demonstrating why coexistence strategies must move beyond charismatic species and address the systemic realities of overlooked human-wildlife interactions. By combining ecological modelling, institutional analysis, and grounded qualitative insights, it reframes snakebite as a biodiversity conflict shaped by infrastructure, species behaviour, policy absence, and unequal access to care. The findings show that snakebite conflict results in a spectrum of preventable suffering, of people, livestock, pets, and even protected snakes, shaped by systemic neglect and governance gaps. In doing so, it contributes to a multi-layered framework for understanding how neglected forms of conflict impact both human and animal wellbeing, and why biodiversity governance must integrate coexistence, care systems, and community knowledge as core components of response. Finally, it challenges prevailing assumptions about which people, species, and systems are prioritised in conservation policy and calls for more inclusive, ecologically grounded approaches to managing biodiversity conflict in India and beyond.

COVID-19 Impact Statement

I, Shaleen Attre, kindly request the examiners to note how the COVID-19 pandemic impacted my thesis.

I was awarded a scholarship under the Global Challenges Doctoral Centre (GCDC) in early March 2020, just before the COVID-19 pandemic was declared. I was living in New Delhi, India with my family at that time. My PhD officially began in September 2020, but due to international travel restrictions, visa centre and embassy closures, and the high cost of travel and quarantine, I was unable to relocate to the UK as planned.

My original research was designed around fieldwork in Chhattisgarh, India, comparing public hospital systems to NGO and community-led interventions in neighbouring areas. However, the COVID-19 pandemic made this plan unfeasible. The state experienced extended lockdowns, high mortality rates, and severe strain on healthcare systems, especially in rural districts. At the same time, Maoist insurgency activity escalated during the pandemic, including a deadly ambush in April 2021. As a female researcher from Delhi, conducting independent fieldwork in these regions posed serious logistical and safety risks. In the months that followed, repeated attempts to pivot to other field sites in India were also unsuccessful due to new outbreaks, lockdowns, or sudden regional travel bans that made sustained access unsafe and unviable.

Throughout 2020–2022, institutional travel and fieldwork clearances were further delayed by internal university processes, as standard risk assessments needed to be adapted for candidates based in their country of domicile, which was also their field site, during a global pandemic. Access to collaborators and government offices was also limited during this time. These delays cumulatively impacted the structure and pace of the project, requiring significant redesign and rescopeing.

During this period, New Delhi was badly affected by the pandemic in India. While working remotely from home, I navigated an environment marked by daily fatalities, overwhelmed healthcare systems, and widespread personal and public grief. Ambulances, cremations, and

urgent requests for oxygen and plasma were part of the immediate soundscape of daily life. As the youngest and healthiest member of my household, I also took on responsibility for acquiring supplies and supporting vulnerable family members, even as I contracted COVID-19 during one such outing. For several weeks I volunteered during this time to assist with sourcing plasma, oxygen, hospital beds, and cremation materials for friends, colleagues, and community members. Although these efforts fell outside the scope of my academic work, they were inseparable from the conditions under which research was being attempted.

It was only by September 2021 that I was able to begin preliminary fieldwork in Goa after redesigning the project and obtaining the required ethics clearances. However, the second wave in India in 2021, followed by the Omicron wave in 2021–2022, resulted in multiple lockdowns and disruptions. I contracted COVID-19 multiple times during fieldwork and was required to isolate each time, leading to a cumulative loss of several weeks of research activity between 2021 and 2022, which also curtailed my time on the University campus since I could only travel 4-6 weeks a time in 2022 and 2023 and had to keep returning to the field.

In parallel, I undertook significant personal and caregiving responsibilities following my father's cancer diagnosis in October 2021. As a primary caregiver, I had to navigate frequent travel between the field site and Delhi, while also taking precautions to avoid exposing him to COVID-19 as an immunocompromised patient. His passing away in November 2022, was followed by the loss of a close friend and field consultant in April 2023, due to complications suspected to be linked to long COVID, from when we had contracted it together during my fieldwork. This loss further impacted my capacity to complete fieldwork within the initial timeline, while affecting the data collection and coordination.

Fieldwork was ultimately completed in February 2024, following an extended period of redesign, disruption, and personal loss. I returned to the UK shortly after to begin analysing my data and writing up, while feeling the sustained impact of the pandemic on both the timeline and structure of the research. A six-month COVID extension offered by the university was applied for and granted, followed by a student visa extension to support thesis submission within the revised timeline.

Despite these challenges, the restructured project was completed in full, and all major research objectives were successfully achieved. This was only possible because of my supervisors' unwavering support in helping me navigate each of these challenges. Their guidance and advocacy throughout the process, from the earliest disruptions in 2020, through administrative barriers, fieldwork delays, and ultimately the COVID extension, played a vital role in sustaining the project and enabling me to complete the work despite the cumulative toll of the past five years.

Author signature:

A handwritten signature in blue ink that reads "Shaleen" with a long horizontal stroke underneath.

Date:

8th April, 2025

Main supervisor signature:

A handwritten signature in blue ink, appearing to be "N. Smith" or similar, with a stylized, cursive script.

Date:

8th April, 2025

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Chapter 1

Introduction

1.1 Global Context: Snakebite and Human-Snake Conflict in the 21st Century

1.1.1 Snakebite Envenomation: A Global Public Health Crisis

Snakebite envenomation is a major yet historically overlooked global health and conservation challenge. Since its designation as a Category-A Neglected Tropical Disease (NTD) by the World Health Organization in 2017, snakebite has been recognised as responsible for an estimated 81,000 to 138,000 deaths each year, with more than 400,000 survivors left with long-term disabilities or disfigurement (Gutiérrez et al., 2017; WHO, 2017a; Longbottom et al., 2018). Despite this heavy burden, snakebite receives far less attention than other diseases with comparable mortality, such as dengue or schistosomiasis, and remains underfunded and under-prioritised in global health discourse (Gutiérrez et al., 2017; Williams et al., 2019).

The global distribution of snakebite risk is shaped by stark socioeconomic disparities. The most severely impacted populations predominantly reside in low- and middle-income tropical regions of sub-Saharan Africa, South and Southeast Asia, and Latin America, where access to medical care, anti-snake venom (ASV), trained personnel, and surveillance infrastructure is severely limited (Kasturiratne et al., 2008; Gutiérrez et al., 2013; 2017; Longbottom et al., 2018). Many victims of snakebite live more than an hour away from the nearest healthcare facility, increasing the likelihood of fatal or debilitating outcomes (Longbottom et al., 2018).

These challenges are compounded by chronic underreporting and misdiagnosis, which obscure accurate estimations of the true snakebite burden and further inhibit the allocation of appropriate health resources (Chippaux, 2017; Suraweera et al., 2020; Alcoba et al., 2022). In many affected areas, cases go undocumented due to fragmented surveillance systems, the use of traditional healers, or the social stigma attached to seeking formal care. As a result, snakebite mortality and morbidity remain invisible in many national and international health datasets, reinforcing a cycle of neglect and reactive response (Gutiérrez et al., 2017; Bhaumik et al., 2022).

1.1.2 Human-Snake Conflict (HSC) Within Global Human-Wildlife Conflict (HWC) Discourse

While snakebite has gradually entered public health discourse, human-snake conflict (HSC) remains marginal within broader conservation and human-wildlife conflict (HWC) frameworks. Global HWC literature and policy mechanisms continue to prioritise large-bodied, charismatic megafauna, such as elephants, tigers, and bears, which elicit public sympathy and receive significant conservation funding (Nyhus, 2016). These species, however, account for a fraction of the human fatalities caused by snakes each year, yet dominate policy, media attention, and funding allocations (Gulati et al., 2021).

By contrast, snakes are widely feared, poorly understood, and often persecuted, occupying an ambiguous position in conservation and public health. The exclusion of snakes from conventional HWC narratives has led to fragmented and inadequate mitigation approaches that address neither public health risks nor conservation concerns. Unlike megafauna that typically trigger conflict near protected or forest areas, human-snake encounters occur at much larger and more frequent scales across agricultural fields, rural areas and increasingly, urban settlements (Vaiyapuri et al., 2013; Malhotra et al., 2021). Their ecological anonymity, cultural vilification, and cryptic behaviour make them difficult to include in conventional conflict frameworks. Consequently, mitigation efforts remain fragmented, with few strategies that simultaneously address public health and conservation goals (Babo Martins et al., 2019).

A growing body of research argues for the inclusion of snakes within HWC frameworks, highlighting the dual conservation and human safety dimensions of the issue (Malhotra et al., 2021). The frequent misidentification and fear-driven killing of harmless or mildly venomous snakes contribute to biodiversity loss and undermine ecosystem stability (Pandey et al., 2016; Coelho et al., 2019; Castillo-Huitrón et al., 2020; Durso et al., 2021). Integrating snakes into broader conservation and public health frameworks is increasingly viewed as essential for reducing human mortality and promoting sustainable coexistence. While much of the global focus remains on snakebite as a health emergency, the ecological significance and conservation neglect of snakes demand parallel attention.

1.1.3 Emerging Risks: Urbanisation, Land-Use Change, and Climate

Variability

The scope of human-snake conflict is expanding rapidly due to intersecting anthropogenic drivers of urbanisation, land-use transformation, and climate change. Rapid urban expansion, agricultural intensification, mining and deforestation have degraded and fragmented snake habitats, bringing them into closer proximity with humans (Zacarias and Loyola, 2019; Glaudas, 2021). Urban areas, farmlands, construction zones, and waste areas provide prey and shelter, attracting snakes and increasing the likelihood of unintended encounters (Malhotra et al., 2021).

In parallel, climate change is altering the distribution, seasonal activity, and behaviour of many snake species. Ecological niche modelling studies have shown that rising global temperatures and changing rainfall patterns are projected to expand the ranges of medically important snakes into new areas, including densely populated zones with low preparedness (Yañez-Arenas et al., 2016; Longbottom et al., 2018). These shifts increase the probability of snakebite incidents in regions previously considered low risk, especially where health systems remain unprepared.

Yet, the urban and peri-urban dimensions of snakebite risk are still under-studied in both conservation biology and public health planning (Heathcote et al., 2019; Malhotra et al., 2021). As snakes continue to adapt to fragmented and disturbed environments, conflict patterns will likely intensify. These ecological transitions coincide with persistent social misconceptions and inadequate preparedness, amplifying risk for both humans and snakes (Murray, Martin and Iwamura, 2020; Goldstein et al., 2021).

In sum, the rising frequency of human-snake interactions is not simply a rural or medical issue alone or an ecological inevitability but a product of socio-environmental change (Malhotra et al., 2021). It is a multidimensional problem shaped by urbanisation, land-use change, ecological dynamics, and structural inequities. These dynamics demand coordinated, evidence-based strategies that health systems, community engagement, behavioural change and conservation policy, grounded in local contexts and guided by cross-disciplinary research, to prevent avoidable human deaths and ensure the survival of ecologically important snake populations,

particularly in emerging frontline regions such as India.

1.2. Why Snakes Matter: Ecological, Conservation, and One Health Significance

Snakes are a vital yet often overlooked component of global ecosystems. As meso-predators, they play an important role in regulating prey populations, particularly rodents, thereby contributing to ecological balance and supporting agricultural productivity (Whitaker and Shine, 2000; Beaupre and Douglas, 2011; Schuett et al., 2022). By limiting the need for chemical pest control, snakes indirectly promote environmental sustainability in both natural and agricultural landscapes. Additionally, snakes serve as bioindicators- species whose sensitivity to habitat disturbance, pollution, and climatic variability makes them useful proxies for ecosystem health (Beaupre and Douglas, 2011).

Despite their ecological significance, snakes remain among the most persecuted and misunderstood vertebrates. Public hostility toward snakes is often rooted in deep-seated cultural fears, myths, and frequent misidentification. Studies from multiple regions have shown that non-venomous and mildly venomous snakes are frequently mistaken for dangerous species and killed unnecessarily (Roshnath and Divakar, 2019; Castillo-Huitrón et al., 2020; Bateman et al., 2021). Even in communities frequently exposed to snakes, where residents may be familiar with common species, fear-driven killings persist. These are often exacerbated by deeply ingrained cultural fears, misinformation, and a lack of access to reliable species identification tools, highlighting the gap between exposure and true snake literacy (Barua, Bhagwat and Jadhav, 2013).

This widespread persecution contributes to local population declines, particularly for large-bodied snakes such as cobras and pythons that are more visible and perceived as threats. Whitaker and Shine (2000) highlighted that human-induced mortality, including retaliatory/fear-based killings, roadkill, and habitat loss, is a leading cause of decline in elapid populations across

agricultural landscapes. Yet, such impacts rarely feature in national conservation policies or wildlife conflict frameworks, where the emphasis remains on larger, more charismatic fauna.

Recent scholarship has started to call for more integrated, evidence-based approaches to snake conservation and public health (Malhotra et al., 2021). A One Health perspective, linking human, animal, and environmental health, offers a promising framework for simultaneously addressing snakebite envenomation and conservation needs (Babo Martins et al., 2019). However, practical implementation of such frameworks remains rare. Even within wildlife conservation efforts, snakes are often excluded from funding, planning, and policy prioritisation due to their perceived low appeal (Malhotra et al., 2021). This institutional invisibility, compounded by accelerating habitat fragmentation and climate change, places many snake species at increasing risk of range contraction and local extinction (Zacarias and Loyola, 2019; Yousefi et al., 2020). These pressures are altering snake distributions, behaviour, and the frequency of human-snake encounters. Without sustained attention to snake ecology and public perception, efforts to reduce snakebite burden and promote human-wildlife coexistence will remain incomplete.

1.3 Snakebite Conflict and Mortality in India

India is recognised as the global epicentre of snakebite envenomation, accounting for over 50% of all global snakebite-related deaths- approximately 58,000 fatalities per year (Mohapatra et al., 2011; Suraweera et al., 2020). In contrast, elephant and tiger attacks were responsible for an average of just over 600 deaths per year, over 2019-2024 (PIB, MoEFCC, 2024). Yet these megafaunas receive considerable conservation and media attention, despite the scale of snakebite fatalities in India being greater, as illustrated in Figure 2.1, in Chapter 2. Yet, snakebite has historically remained marginal in policy, media, and academic conservation discourse, often framed narrowly as a rural occupational hazard rather than a conservation or One Health concern. It was only in 2020 that the Indian government began officially listing snakebite under HWC frameworks and the Guidelines for Mitigating Human-Snake Conflict came out in 2023 (MoEFCC, 2023). Notably, while compensation exists for predation from big cats and other megafauna (Karanth, Gupta and Vanamamalai, 2018), no such provision currently exists for

snakebite-related livestock deaths, highlighting a persistent blind spot in both Forest Department and Animal Husbandry compensation policies (Malhotra et al., 2021).

India's snake fauna is among the most diverse globally, with over 275 species recorded and at least 60 considered medically important (Whitaker, Captain and Ahmed, 2004; Whitaker, 2015; Laxme et al., 2019). Yet clinical treatment protocols and antivenom production remain focused on the “Big Four” of peninsular India: the cobra (*Naja naja*), Russell's viper (*Daboia russelii*), common krait (*Bungarus caeruleus*), and saw-scaled viper (*Echis carinatus*) (Simpson and Norris, 2007; Whitaker and Whitaker, 2012; Whitaker, 2015). These species are broadly categorised based on venom type- hemotoxic (affecting blood and tissue) and neurotoxic (affecting the nervous system)- with clinical implications that vary widely across species and individuals. Research increasingly shows this narrow focus, on just these four species, to be inadequate. Envenomation from species such as the hump-nosed pit viper (*Hypnale hypnale*), bamboo and Malabar pit vipers (*Trimeresurus* spp.), and the king cobra (*Ophiophagus hannah*), along with numerous species from East, Northeast and the islands, often fall outside the coverage of existing polyvalent antivenoms, leading to poor treatment (Gajbhiye et al., 2023; Kakati et al., 2023; Laxme et al., 2019; Simpson and Norris, 2007; Sirur et al., 2022; Sirur et al., 2022; Whitaker, 2015). Although the WHO has published expanded lists of medically important snakes (Warrell et al., 2013; WHO, 2017b), national response systems have yet to align with this broader ecological and clinical reality (Laxme et al., 2019). This misalignment compromises treatment efficacy and may reinforce public hostility toward lesser-known or misidentified species excluded from formal response structures.

Beyond ASV gaps, India's snakebite burden is worsened by infrastructural and health system limitations. Many rural and peri-urban areas lack well-equipped health centres, reliable ambulance transport, or clinicians adequately trained in snakebite management (Williams et al., 2019; Suraweera et al., 2020). Even when ASV is accessible, treatment delays, adverse reaction fears, and poor protocol adherence often result in preventable fatalities or long-term disability (Bhargava et al., 2020). These clinical barriers are compounded by behavioural and cultural factors, including persistent reliance on traditional healers, use of unproven first-aid techniques

(such as tourniquets or venom extraction), and social stigma associated with hospitalisation (Ralph et al., 2019; Bhargava et al., 2020).

India's growing network of voluntary snake rescuers adds a critical but under-recognised dimension to the country's HSC landscape. Although state Forest Departments are technically mandated to respond to wildlife conflict cases, including snake rescues, in practice, their involvement varies widely by region, and capacity constraints often lead to a reliance on community-based or voluntary rescuers. In multiple states, local rescue networks have emerged as first responders to snake encounters, removing snakes from homes, schools, and farms, often operating outside formal health or forest department structures. These responders play a crucial role in defusing conflict and preventing snake killings, especially in urban and peri-urban settings (Roshnath, 2017; Mukherjee, 2023; Kuttalam et al., 2025). However, as Malhotra et al. (2021) notes, these networks operate with little regulation, training, or institutional support, and are largely absent from formal public health and conservation frameworks. Their role presents both opportunities and challenges: while they can support ethical coexistence and rapid response, the lack of ecological training and post-release monitoring raises concerns about long-term efficacy and unintended consequences.

From a conservation perspective, the continued marginalisation of snakes from most HWC frameworks is striking. Despite performing vital ecosystem functions and being listed under various Schedules of India's Wildlife Protection Act, 1972 (WPA, 1972), snakes remain largely absent from mainstream conservation planning, particularly in the design and approval of civil and linear infrastructure projects. Their ecological roles are rarely accounted for in environmental impact assessments, and mitigation measures often overlook the specific vulnerabilities of reptilian fauna. Their persecution through roadkill, habitat degradation, and fear-driven killings contributes to local population declines, yet these losses are seldom documented or addressed in policy (Whitaker and Shine, 2000; Salim et al., 2024). Malhotra et al. (2021) further argue that ecological factors, such as species behaviour, seasonality, habitat use, and urban encroachment, must be integrated into snakebite mitigation strategies if long-term coexistence is to be achieved.

Moreover, structured awareness around snakebite remains absent from most public health and school curricula in India. Few formal programmes exist to teach prevention strategies, first-aid protocols, or even basic species identification. This gap persists despite high mortality rates and rising incidence of bites in rapidly urbanising and fringe landscapes. Simultaneously, climate change and land-use transformation, including deforestation, infrastructure expansion, and agricultural intensification, are altering snake behaviour and distribution, bringing snakes into greater proximity with human populations (Narayanan and Bindumadhav, 2019; Zacarias and Loyola, 2019).

In sum, India's snakebite crisis cannot be understood solely as a medical emergency- it is a multifaceted socio-ecological challenge. Despite India's central role in the global snakebite mortality burden, there remains a lack of integrated, evidence-based, and ecologically informed mitigation strategies. Addressing this crisis will require moving beyond short-term treatment to embrace long-term frameworks of prevention, community engagement, and policy integration- one that includes rescuers, ecological knowledge, and vulnerable human and animal populations alike (Malhotra et al., 2021; Bhaumik et al., 2022).

1.4 Literature Gaps and Research Rationale

1.4.1 Global Literature Gaps and Mitigation Evidence

Despite growing international recognition of snakebite envenomation as a serious health and conservation concern, the global body of literature remains disproportionately focused on burden estimation, clinical case studies, and retrospective analyses. Far fewer studies assess the real-world efficacy, ecological impact, or social relevance of mitigation interventions (Bolon et al., 2019; Malhotra et al., 2021; Bhaumik et al., 2022; Gajbhiye, Munshi and Bawaskar, 2023).

The author conducted a literature review for this thesis, which was published under co-authorship in Malhotra et al. (2021), under the section "*Promoting co-existence with venomous snakes: evaluating mitigation methods for human-snake conflict*". The review examined 68 studies published globally between 2010 and 2020, and a key concern identified was the

widespread absence of evaluation frameworks for snakebite mitigation methods. (To read the full excerpt and the list of reviewed papers, please refer to Supplementary Sheet S1, Section III). The review found that most studies focused on problem identification, such as venomous species distribution, mortality burden, or knowledge gaps, but very few examined whether interventions such as awareness campaigns, rescue systems, or first-aid education had resulted in measurable changes in mortality, behaviour, or attitudes.

Globally recommended preventive strategies, such as sleeping off the ground, wearing protective footwear, or improving hygiene and lighting, are often proposed in guidelines (Jacobsen, 2014; Samuel et al., 2020), yet their local adaptation and uptake remain poorly understood. Longitudinal assessments of behavioural change are rare, and there is little empirical consensus on which measures translate effectively across different socio-ecological contexts (Malhotra et al., 2021).

The review also found that the role of snake rescue as a conflict mitigation tool remains especially under-evaluated. Rescue, relocation, and translocation are widely practiced across multiple countries, but few studies have monitored outcomes, such as post-release survival, reduced retaliatory killing, or long-term community impact (Harvey et al., 2014; Ramesh and Nehru, 2019). Most significantly, no published study has yet demonstrated the effectiveness of rescue as a long-term strategy to reduce snakebite incidence or mortality.

Further, there is limited global literature on snake-related mortality in domestic animals, even though these losses may have major economic consequences for rural and agrarian households (Herrera et al., 2017; Bolon et al., 2019). Social perception studies also remain scarce: only a handful of papers explore how fear, disgust, or mythologies shape attitudes toward snakes and affect mitigation uptake (Barua, Bhagwat and Jadhav, 2013; Henke et al., 2019; Castillo-Huitrón et al., 2020). Interventions such as audiovisual education or controlled exposure have been trialled in a few countries but require context-specific evaluation and long-term monitoring (Quesada-Acuña and Pérez-Gómez, 2020).

Taken together, these gaps reflect a striking disconnect between the multidimensional nature of human-snake conflict and the narrow disciplinary approaches often used to study it. There is an urgent need for interdisciplinary, evidence-based, and ecologically grounded mitigation models that consider both public health and conservation perspectives.

1.4.2 India's Shortfalls in Evidence and Mitigation

India, while contributing the largest proportion of global snakebite deaths (Suraweera et al., 2020), is not exempt from these global literature gaps. Several recent studies, including Bhaumik et al. (2022) and Gajbhiye, Munshi and Bawaskar, (2023), have highlighted the fragmented nature of India's snakebite response systems and called for better monitoring of antivenom distribution, community awareness, and treatment access. However, these studies primarily remain burden-focused or retrospective, and few have examined the contextual effectiveness of mitigation interventions in the field.

As Malhotra et al. (2021) and later Bhaumik et al. (2022) noted, there is little published work in India that evaluates the outcomes of key mitigation strategies such as rescuer engagement, outreach campaigns, school-based education, or first-aid training. Snake rescues, carried out by both government-authorised and voluntary networks, are increasingly common across India, yet post-release outcomes and public safety impacts remain unmonitored (Mukherjee, 2023). Similarly, the exclusion of livestock mortality from snakebite-related HWC frameworks underscores a major oversight in both wildlife and animal husbandry policy (Malhotra et al., 2021).

Social complexity also remains under-addressed. Studies rarely account for how variables such as caste, gender, occupation, or migration status influence treatment-seeking behaviour or vulnerability to snakebite (Longkumer et al., 2016; Dandona et al., 2018; Samuel et al., 2020; Vaiyapuri et al., 2022). Even widely recommended practices, such as gumboot use, may fail in areas where local habits, barefoot walking, or economic constraints limit behavioural change

(Samuel et al., 2020; Malhotra et al., 2021; Carter et al., 2024). As Malhotra et al. (2021) argued, prevention strategies must be grounded in both ecological and social realities.

Although studies (Laxme et al., 2019; Vanuopadath et al., 2020; Sirur, Balakrishnan and Lath, 2022; Sirur et al., 2022; Gajbhiye, Munshi and Bawaskar, 2023) have advanced the clinical discussion by highlighting species-specific antivenom gaps, there remains limited integration of ecological factors such as seasonal activity, habitat overlap, and species misidentification into treatment protocols and policy design (Roshnath and Divakar, 2019; Zacarias and Loyola, 2019; Yousefi et al., 2020; Goldstein et al., 2021; Malhotra et al., 2021).

This thesis directly addresses several of these persistent gaps by empirically examining one state's experience with snakebite mitigation: Goa. Drawing on over 100 in-depth interviews and 32,000 rescue records, it evaluates both medical and ecological dimensions of mitigation, including awareness, treatment access, species patterns, rescue dynamics, and the largely unexamined burden of domestic animal mortality. By integrating conservation science with public health and social systems analysis, the study aims to contribute a more holistic and field-grounded framework for understanding and addressing snakebite risk.

1.5 Why Goa: Regional Study Site Justification

Goa, located on the western coast of India, is the country's smallest state by area (3,702 km²) but hosts a remarkable convergence of ecological richness, socio-cultural complexity, and evolving development patterns (ZSI, 2008). Bounded by Maharashtra to the north and Karnataka to the east and south, and flanked by the Arabian Sea to the west, Goa is divided into two districts (North and South Goa) and twelve talukas (sub-districts), as shown in Figure 1.1. While Goa is often overlooked in broader snakebite literature due to its small size (Suraweera et al., 2020), this underrepresentation, combined with its ecological richness and evolving development profile, makes it a strategically valuable site to study both human-snake conflict (HSC) and mitigation.



Figure 1.1: Administrative map of Goa, India

This map marks the two main districts- North and South Goa and the respective talukas, therein, along with the main administrative towns within. Map credit: Maximilian Dörrbecker, CC BY-SA 2.0

Ecology and Biodiversity

Goa lies within the Western Ghats-Sri Lanka biodiversity hotspot (Myers et al., 2000), with varied ecosystems including estuarine mangroves, coastal plateaus, lateritic scrub, moist deciduous forests, and semi-urbanised forest fringes. The Zoological Survey of India (ZSI, 2008) documented 56 species of snakes in Goa across varied ecological zones, though that checklist may now be subject to revision. These include all members of the medically significant “Big Four”, as shown in Figure 1.2- Russell’s viper (*Daboia russelii*), saw-scaled viper (*Echis carinatus*) spectacled cobra (*Naja naja*) and common krait (*Bungarus caeruleus*). In addition, Goa is home to several other venomous and medically important species, like the hump-nosed pit viper (*Hypnale hypnale*) and king cobra (*Ophiophagus hannah*), which are not currently covered by polyvalent ASV (Simpson and Norris, 2007; Laxme et al., 2019; Gajbhiye, Munshi and Bawaskar, 2023). A complete list of the most commonly interacted-with species, including WHO classifications of medical importance, is provided in Supplementary Sheet S1, Section I.

Beyond snakes, the state’s diverse forest and wetland ecosystems support notable faunal assemblages, including leopard (*Panthera pardus*), gaur (*Bos gaurus*), slender loris (*Loris lydekkerianus*), Malabar civet (*Viverra civettina*), and multiple amphibian and lizard endemics (ZSI, 2008). Economically and ecologically significant flora includes teak (*Tectona grandis*), cashew (*Anacardium occidentale*), mangroves (*Rhizophora* spp.), and lateritic scrub vegetation (ZSI, 2008).



Figure 1.2: The medically significant “Big Four” venomous snakes from the Goan landscape.

Top row (hemotoxic species): Russell’s viper (Daboia russelii) and saw-scaled viper (Echis carinatus).

Bottom row (neurotoxic species): spectacled cobra (Naja naja) and common krait (Bungarus caeruleus).

Photos (saw-scaled viper and spectacled cobra): Benhail Antao.

Cultural and Historical Context

Goa’s institutional, religious, and land-use landscapes have been profoundly shaped by over 450 years of Portuguese colonial rule, ending with its annexation into the Indian Union in 1961. This colonial past continues to influence the state’s religious demography, property systems, and patterns of urbanisation (Gracias, 1997; Kandolkar, 2020; Silva, Nielsen and Bedi, 2020). As per the 2011 Census, Goa’s religious composition includes approximately 66% Hindus, 25% Christians, and 8% Muslims (DPSE, 2023). Urbanisation intensified after the 1980s, first through tourism and later through high-end real estate development targeting metropolitan elites (Kandolkar, 2020). These changes have triggered major habitat alteration, increased built-up areas, and created new ecotones between human and wildlife domains.

This shift has resulted in increased reliance on migrant labour from other Indian states for both agricultural tasks and construction work. These groups frequently reside in peri-urban settlements and labour colonies where proximity to vegetation and makeshift housing may increase human-snake encounters.

Demographic Profile

According to the Goa Statistical Handbook 2021–22 (reflecting 2011 Census data) (DPSE, 2023), Goa's population stood at 1,458,545, comprising 739,140 males and 719,405 females, with a sex ratio of 973 females per 1,000 males. The state boasts one of the highest literacy rates in India at 88.7%, well above the national average of 72.98%, with male literacy at 92.6% (India: 80.88%) and female literacy at 83.9% (India: 64.63%). Goa's population density is 394 persons per square kilometre, with urban talukas like Salcete, Bardez, and Mormugao seeing the highest concentrations. Newer census data is currently unavailable as the 2021 census data was postponed due to the pandemic (Babu and Kumar, 2023).

Agricultural and Livestock Landscape of Goa

Goa's rapid transition from agrarian to service- and tourism-oriented development has reshaped its labour and demographic profile. While agriculture is no longer the principal livelihood, rice paddies, coconut plantations, and cashew orchards still occupy substantial land areas (TERI, 2015). As of 2021, only 8.6% of the population was engaged in agriculture (DPSE, 2023). Rice (*Oryza sativa*) remains the state's principal crop, with a 2021–22 average yield of 4,224 kg/ha, peaking at 5,122 kg/ha in Bicholim. Plantation crops such as cashew, coconut, and areca nut are widespread, especially along forest edges and hilly regions (TERI, 2015).

Livestock rearing remains a complementary livelihood. As of the 20th Livestock Census, conducted in 2019, (DPSE, 2023), Goa supported 60,247 cattle, 27,207 buffaloes, 9,446 goats, and 35,480 pigs, along with over 350,000 poultry birds, primarily concentrated in rural talukas such as Sattari, Quepem, and Canacona. Livestock-rearing, particularly backyard poultry, piggery, and dairy operations, remain common in many parts of rural and peri-urban Goa and continue to influence human-wildlife overlap and exposure to snakebites. The state has 248

active dairy cooperatives, although milk and feed inputs are frequently sourced from outside Goa due to limited local production capacity.

Despite this, Goa's agricultural base is shrinking due to rapid urbanization, mining-related degradation, and declining interest in farming among younger generations. As noted by TERI (2015), pasture lands are under pressure and animal husbandry faces high input costs, with feed and veterinary resources often procured from outside the state. The combined result is an increase in migrant labour performing essential agricultural, plantation, and construction work, often in high-risk snakebite zones and without robust institutional safeguards.

This demographic and economic profile, marked by a transition from traditional rural livelihoods to service-oriented and tourism-driven economies, supplemented by migrant workers, makes Goa an important site to examine the intersections of land-use change, human mobility, public health systems, and wildlife conflict.

1.5.1 Healthcare and Infrastructure

Goa has one of the most developed public health systems in the country, with relatively high per capita health spending and infrastructure coverage. The state operates a multi-tiered health network that includes Goa Medical College (GMC), two district hospitals, two sub-district hospitals, four urban health care centres and 30 community and primary health centres, and a network of rural sub-centres. Emergency care is supported by the 108-ambulance system, and both public and private institutions contribute to secondary and tertiary treatment access. Health indicators such as maternal and infant mortality are lower than the national average (DPSE, 2023).

The education sector mirrors this pattern: Goa's school enrolment ratios exceed 95%, with widespread access to public and private schools at primary and secondary levels. These institutional strengths make Goa well-suited for evaluating awareness levels, healthcare referral chains, and the integration of snakebite into broader emergency health frameworks, without assuming either success or failure.

1.5.2 Climate and Seasonality

Goa experiences a tropical monsoon climate with marked seasonal variation in rainfall, humidity, and temperature. While detailed breakdowns of climate periods are provided in Supplementary Sheet S1, Section II, four main phases broadly shape both human activity and snake ecology: the monsoon (June–September), post-monsoon (October–December), dry season (January–April), and pre-monsoon (May). Seasonal temperature ranges between 24–35°C, and monthly rainfall during peak monsoon exceeds 700 mm. These fluctuations are significant predictors of snake activity and bite incidence, as documented in previous ecological and epidemiological studies (Chaves et al., 2015; Goldstein et al., 2021).

1.5.3 Why Goa Made an Ideal Case Study

Goa presents a distinctive and under-analysed case for examining snakebite envenomation and human-snake conflict in India. Its combination of high snake diversity (including species not covered by current antivenom formulations), rapid ecological change, active human-snake interface, and relatively strong health systems make it an ideal landscape to interrogate prevailing assumptions about snakebite burden and mitigation. While not representative of all Indian states, Goa’s scale and accessibility allow for detailed qualitative and quantitative analysis, and its policy visibility offers potential for broader applicability. Importantly, no prior study has attempted an integrated evaluation of mortality, morbidity, ecological dynamics, rescue systems, and policy in the state, despite its relevance as both a biodiversity hotspot and a public health outlier. This thesis positions Goa not as a model, but as a microcosm to test what works, what does not, and what remains invisible in the broader discourse on snakebite and coexistence.

1.6 Research Aims

This thesis investigates how human-snake conflict and coexistence is experienced, mitigated, and represented in Goa, India. The thesis combines quantitative and qualitative approaches to examine HSC analysing patterns of snakebite envenomation in humans and domestic animals, rescue dynamics, public responses, and their implications for conservation and public health.

Through a mixed-methods approach, the research aims to:

1. Examine the structural and systemic factors that have contributed to reduced human snakebite mortality in Goa;
2. Identify patterns of seasonality, land use, and species-specific conflict in shaping human-snake encounters;
3. Analyse the social, ethical, and logistical dynamics of snake rescue and translocation practices;
4. Document the often-overlooked impacts of snakebite on livestock and domestic animals;
5. Evaluate how public perception, awareness, and behavioural change intersect with mitigation strategies;
6. Situate snakebite within broader frameworks of human-wildlife conflict, One Health, and coexistence, using Goa as a conceptual lens for interdisciplinary engagement.

These aims reflect both the specificities of the Goan landscape and the wider challenges of addressing snakebite as a complex ecological, medical, and socio-political issue in India.

1.7 Thesis Outline

Chapter 2 investigates whether Goa has experienced a measurable reduction in human snakebite mortality and identifies the structural, medical, and behavioural mechanisms contributing to any shifts. Using a mixed-methods approach that combines public health facility-level data from 2019–2023 with 65 stakeholder interviews, the chapter assesses the role of community awareness, pre-hospital response systems, and decentralised medical infrastructure. It also examines ongoing challenges, including species misidentification, gaps in antivenom use and referral chains, the absence of morbidity tracking, and limited access to support for migrant and informal labour populations. While Goa’s geographic and institutional context is distinct, the chapter reflects on its relevance for other states aiming to strengthen snakebite mitigation through integrated health and awareness systems.

Chapter 3 presents a multi-year analysis of snake rescue patterns in Goa, based on over 32,000 records collected by the Forest Department between April 2016 and March 2022. It examines seasonal and species-specific trends, with particular attention to how rescue patterns vary across districts and between venomous and non-venomous species. Using Generalized Additive Models (GAMs), the chapter assesses the relationship between climatic variables, particularly rainfall, humidity and temperature, and rescue frequencies for key species. Qualitative insights from rescuers are also used to further understand observed trends, including changes in land use, urban expansion, and shifts in public behaviour that may influence human-snake encounters.

Chapter 4 presents a qualitative analysis of how snake rescues shape human-snake relationships in Goa, addressing the core research question: do snake rescues foster coexistence, or do they reinforce public dependency on removal as the primary response to conflict? Based on 68 stakeholder interviews, the chapter examines the historical evolution of rescues, their perceived role in mitigating conflict, and the unintended consequences of normalising removal. It explores systemic challenges such as the absence of formal regulation, diverging ethical perspectives among rescuers, burnout, and gender-based barriers to participation. The chapter also highlights how digital media, architectural design, and public education influence rescue dynamics, and proposes a structured coexistence-oriented framework for ethical and sustainable rescues.

Chapter 5 addresses the largely overlooked impact of snakebite envenomation and predation on domestic animals in Goa. Drawing on 56 in-depth interviews with veterinarians, animal owners, rescuers, and policymakers, the chapter examines systemic gaps in veterinary infrastructure, inconsistent antivenom access, and the absence of compensation frameworks. It explores species-specific trends, emotional and economic responses to animal fatalities, and the role of human behaviour, particularly retaliatory killings and treatment delays, in shaping outcomes. The chapter calls for integrating veterinary snakebite into human-wildlife conflict frameworks and policy reform to support both animal welfare and conflict mitigation.

Chapter 6 synthesises findings across the thesis to examine Goa's shifting landscape of human-snake conflict and mitigation. It integrates insights from both quantitative and qualitative chapters to assess the effectiveness, limitations, and unintended consequences of current

interventions. The chapter reflects on the broader implications for snakebite policy, public health, and conservation, situating Goa within national and global discourses on neglected tropical diseases, human-wildlife conflict and coexistence. It concludes by identifying priorities for future research, policy development, and interdisciplinary collaboration.

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Chapter 2

Mitigation of Snakebite Envenomation: Human Mortality and Morbidity in Goa, India

2.1 Abstract

Snakebite envenomation remains a neglected public health issue in India, with an estimated 58,000 deaths annually. While national strategies such as the 2024 National Action Plan for Prevention and Control of Snakebite Envenoming (NAPSE) have outlined broad mitigation goals to lessen envenomation deaths, few studies have empirically evaluated systemic factors contributing to reduced mortality. This chapter investigates whether Goa has seen a measurable decline in snakebite fatalities and, if so, what structural, behavioural, and institutional mechanisms underlie this shift.

Using a mixed-methods approach, the chapter draws on verified government/public facility-level data from 2019–2023 and 65 semi-structured interviews with stakeholders i.e., health-care professionals, rescuers, survivors, public health officials, forest department staff, migrant workers and community members. Between 2019 and 2023, 5,487 medically attended snakebite cases and 40 confirmed deaths were reported in, with year-wise variations shaped by changes in hospital reporting structures and rural fatality documentation. Qualitative findings attributed these outcomes to three intersecting pillars: early and widespread community awareness, rapid pre-hospital response via the 108-ambulance system, and timely medical care supported by decentralised antivenom access and a reliable hospital referral network.

However, persistent gaps remained: delayed triage, underutilised district ventilator capacity, poor species identification training, lack of post-bite morbidity tracking, and no formal compensation for victims. Migrant workers and informal labourers remain particularly vulnerable, often invisible in official records.

While Goa's geographic and institutional context limits direct replicability, the study shows how decentralised care and sustained public engagement can reduce snakebite mortality. Findings highlight the need to embed snakebite within broader public health, occupational safety, and conservation systems.

2.2 Introduction

Snakebite envenomation (SBE) remains one of the most neglected but deadly public health challenges in India and globally. The World Health Organization (WHO) designated it a priority Neglected Tropical Disease in 2018, citing an estimated 81,000 to 138,000 global deaths annually, with over 400,000 survivors suffering long-term disabilities such as paralysis, amputations, and chronic pain (Gutiérrez et al., 2010). The burden of SBE falls disproportionately on rural populations in low- and middle-income countries (LMIC), where delays in treatment access, reliance on traditional healers, and inconsistent antivenom availability exacerbate the risks (Bhargava et al., 2020; Menon et al., 2022). A range of interlinked factors drive these risks. Studies have shown that travel delays, lack of emergency transport, under-resourced rural health systems, and misidentification of envenomation symptoms all contribute to poor outcomes (Sharma et al., 2013; Sharma et al., 2016; Mukherjee and Mackessy, 2021; Kakati et al., 2023). In many rural regions, cultural norms and limited trust in formal medicine still lead victims to initially approach traditional or faith healers, delaying biomedical treatment when time is critical (Pandey et al., 2016; Barnes et al., 2021). These delays are compounded by the absence of clinical training at the primary level, poor referral coordination, and inconsistent antivenom availability in peripheral health centres (Roberts et al., 2022; Gajbhiye et al., 2023). Together, these barriers continue to drive high fatality rates across much of India and South Asia.

As per reports, India carries the highest global burden of snakebite deaths (Roberts et al., 2022). Based on verbal autopsy data from the Million Death Study and its updated literature, it is estimated that between 2000 and 2019, 1.2 million people died of snakebites in India, an average of nearly 58,000 deaths per year, representing almost half of the global total (Mohapatra et al., 2011; Suraweera et al., 2020). These deaths disproportionately affect agricultural workers, women, and children in rural areas, where access to timely and appropriate treatment remains limited.

Despite this, snakebite mortality continues to receive limited public attention, especially when compared to more visible forms of human-wildlife conflict. For instance, between 2019 and

2024, India officially recorded 3,076 deaths due to elephant and tiger attacks combined (PIB, MoEFCC, 2024), averaging just over 600 deaths per year (Table 2.1). In contrast, snakebites are estimated to cause 70–90 times more deaths annually (Figure 2.1) yet receive far less national policy attention and compensation coverage. Compensation schemes for wild animal attacks offer up to ₹10 lakh per victim under flagship programs like Project Tiger and Project Elephant (PIB, MoEFCC, 2024), while snakebite deaths lack any equivalent, dedicated, national-level compensation mechanism.

Table 2.1: Annual human deaths involving elephant and tiger “conflict” in India from 2019-2024 (PIB, MoEFCC 2024)

Species	2019-20	2020-21	2021-22	2022-23	2023-24	Total
Elephant	574	444	520	583	606	2727
Tiger	49	49	59	110	82	349
Total	623	493	579	693	688	3076

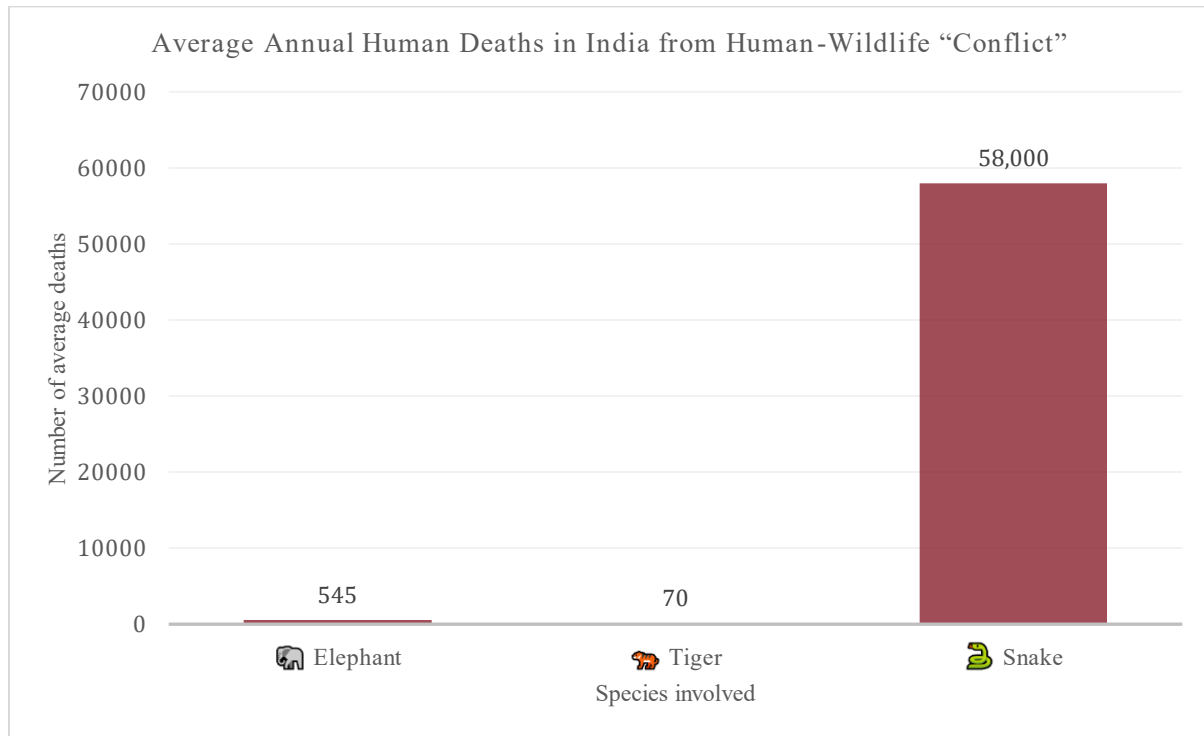


Figure 2.1: Average annual human deaths from snakebites vs. elephant and tiger “conflict” in India
Based on publicly available official wildlife conflict data (PIB, MoEFCC 2024) and national mortality estimates from Suraweera et al. (2020)

This disconnect reflects broader weaknesses in India’s snakebite surveillance systems. Centralised data platforms such as the Central Bureau of Health Intelligence (CBHI) and the Health Management Information System (HMIS) are widely acknowledged to underreport both cases and deaths, particularly in rural and non-hospital contexts (Salve, Vatahati and Hallad, 2020; Rubeshkumar et al., 2021). Independent estimates such as those from the Million Death Study, while more comprehensive, rely on retrospective verbal autopsy data and lack state-level granularity into the mitigation methods. As a result, few studies have been able to rigorously evaluate where and why mortality may be declining, or which systems are most effective in reducing deaths.

Over the last five years, several mitigation strategies have been piloted in various Indian states, including community education, referral chain strengthening, anti-snake venom (ASV) training, and rescue networks (Vaiyapuri et al., 2013; Gajbhiye et al., 2023; Munshi et al., 2024). The

National Action Plan for the Prevention and Control of Snakebite Envenoming (NAPSE) launched by the Ministry of Health and Family Welfare in 2024 outlines a comprehensive policy framework, urging states to develop localized strategies aligned with national goals. However, as summarized by Malhotra et al. (2021) and acknowledged in a recent Cochrane review protocol (Bhaumik et al., 2022), no peer-reviewed study has yet demonstrated a clear, causal link between specific interventions and reduced snakebite mortality. Most literature remains descriptive, focused on implementation goals or perceived awareness, rather than measured outcomes.

In this landscape, Goa represents a valuable outlier. Though absent from national burden estimates, the state is home to the four medically important venomous snakes called the Big Four (ZSI, 2008)- the spectacled cobra (*Naja naja*), common krait (*Bungarus caeruleus*), Russell's viper (*Daboia russelii*), and saw-scaled viper (*Echis carinatus*)- and consistently records hundreds of cases each year (Narvencar, Favas and Dias, 2020).

Offering grounded evidence where much of the national literature has remained speculative, this chapter investigates a central research question if snakebite mortality in Goa declined over time, and if so, what systemic factors have contributed to this reduction?

Using a mixed-methods approach, it draws on verified public facility-level data (2019-2023) and qualitative interviews with key stakeholders including rescuers, doctors, public health officials, and community members. While national strategies such as the National Action Plan for Prevention and Control of Snakebite Envenoming (NAPSE, 2024) outline ambitious goals, few studies have examined how such measures take shape in practice. By focusing on Goa, this chapter aims to offer context-specific insights into the structural, medical, and social mechanisms influencing snakebite outcomes and what they might reveal for broader mortality reduction efforts in India.

2.3 Methods

This chapter employed a mixed-methods approach to investigate the structural, systemic, and sociocultural factors influencing human snakebite mortality in Goa, integrating quantitative data extraction from facility-level records with qualitative insights from key stakeholders. The aim was to triangulate patterns across reporting systems, treatment pathways, and lived experiences, and to capture institutional, clinical, and community-level dynamics not evident in numerical datasets alone (Bhargava et al., 2020; Menon et al., 2022).

2.3.1 Quantitative Data Sources and Analytical Framework

Snakebite case and mortality data were obtained from the Goa Directorate of Health Services (DHS), which maintains annual records from Primary Health Centres (PHCs), Community Health Centres (CHCs), Urban Health Centres (UHCs), Sub-District Hospitals (SDHs), District Hospitals (DHs), and Goa Medical College (GMC). Verified, facility-level reports were available for the years 2019-2023. In 2022, a new category, “rural deaths”, was introduced, encompassing fatalities that occurred outside the government facilities, likely being deaths at the community level. The 2023 dataset included new mortality classifications such as “brought dead” and “left against medical advice” (LAMA), in alignment with the National Action Plan for Prevention and Control of Snakebite Envenoming (NAPSE, 2024).

Case Fatality Rates (CFR) were calculated by dividing the total number of reported deaths each year by the number of medically attended snakebite cases recorded that year. Where possible, CFRs were disaggregated by district, hospital tier, and year. Due to the exclusion of Goa Medical College data in 2023, CFR estimates for that year are likely underestimated. No morbidity tracking was available in the DHS dataset.

$$CFR (\%) = \frac{(Total\ snakebite\ deaths\ (hospital + rural, where\ available))}{Total\ medically\ attended\ snakebite\ cases} \times 100$$

Because Goa Medical College (GMC), the state's primary referral and treatment centre, was omitted from the 2023 dataset, that year's CFR was calculated, but excluded from final comparisons.

To contextualise Goa's surveillance and mortality patterns within national reporting frameworks, state data were also compared against figures reported by the Central Bureau of Health Intelligence (CBHI) for the same years. These were publicly available national statistics in the annual National Health Profile reports. The snakebite cases and deaths noted within these reports were based on ICD-10 code T63.0 (WHO, 2019) submissions by individual states, capturing only hospital-reported snakebite deaths, sorted by gender, and lacked disaggregation by facility type or location (CBHI, 2025).

Additionally, spatial comparisons were conducted across districts and talukas (sub-division of the district) to examine potential variation in incidence and mortality. This was supplemented by publicly available infrastructure data from the Goa government websites, including the distribution of PHCs and CHCs, UHCs, SDHs, DHs and GMC to see whether health system access might explain geographic differences in outcomes.

2.3.2 Data Collection and Stakeholder Selection

A preliminary study was conducted from September to October 2021 to establish a baseline understanding of human-snake interactions in Goa. The main phase of fieldwork was conducted between February 2022 and January 2024, covering both North and South Goa across rural, peri-urban, and urban settings to reflect diverse treatment access pathways, public health responses, and awareness levels.

Semi-structured, open-ended interviews formed the primary mode of qualitative data collection, allowing respondents to articulate their experiences and perceptions without constraint, and reducing the likelihood of interviewer bias (Campbell et al., 2013; Bryman, 2016). A total of 68 unique interviews were conducted using snowball and convenience sampling to reach individuals with firsthand or professional experience related to snakebite (refer to Supplementary Sheet, S0

for baseline interview questions for select stakeholders). Out of these, 65 interviews were selected for in-depth thematic analysis, based on the presence of relevant insights across one or more research objectives. These were distributed across the following stakeholder groups:

- Doctors and healthcare workers (n = 5): Clinical treatment, emergency care protocols, anti-snake venom use, referral chains, and challenges in envenomation management.
- Private Snake rescuers (n = 12): Observations of bite scenarios, victim response behaviour, rescue-to-treatment gaps, species-specific trends, rescue logistics, species encounters, community awareness, and their own envenomation experiences.
- Community members and snakebite survivors (n = 30): lived experiences as victims, witnesses, or relatives of snakebite victims, treatment-seeking patterns, traditional beliefs, and survivor burden.
- Forest Department staff (n = 6): Institutional rescue infrastructure, response coordination, and observations of rural mortality or underreporting, community engagement, and logistical constraints.
- Public health officials and surveillance officers (n = 2): Health system preparedness, facility-level reporting practices, and gaps in surveillance infrastructure.
- Herpetologists and educators (n = 4): Species ecology, awareness interventions, public engagement strategies, species-specific risk and exposure patterns and non-Big Four risk visibility.
- Security guards and migrant workers (n = 6): Occupational exposure risks, knowledge gaps, treatment barriers, and infrastructural limitations.

Given the overlapping roles of several interviewees, such as rescuers who were also bite victims, or community members who relayed accounts of fatalities, stakeholders were not artificially siloed for quantitative representation. Instead, their insights were included across all relevant themes to preserve the qualitative depth and contextual complexity of each narrative.

2.3.3 Interview Protocol and Data Management

All interviews were recorded with prior informed consent, ensuring anonymity unless explicit permission was given for attribution (Bryman, 2016). The primary mode of data collection was audio recordings, with consent obtained on record. In cases where interviewees were uncomfortable with recording, written notes were taken instead. Interviews were conducted in English, Konkani, and Hindi, depending on participant preference.

2.3.4 Data Processing and Thematic Analysis

The recorded interviews were translated and transcribed into English using TurboScribe, an AI-powered transcription tool based on Whisper (Python-based voice recognition and translation). All transcripts were manually edited and verified for accuracy before thematic analysis (Belotto, 2018).

Interview data were categorised based on stakeholder roles and manually coded to identify recurring themes. An initial attempt was made to use NVivo for coding and thematic analysis (Campbell et al., 2013), but due to the complexity of challenges spanning multiple overlapping research themes, a manual thematic analysis approach was ultimately adopted using structured categorisation in Excel (Kiger and Varpio, 2020).

Using a structured thematic analysis approach (Clarke and Braun, 2017), interview data were categorised into nine key themes aligned with the study's research objectives:

- Surveillance and Underreporting: Gaps in hospital-level reporting, private sector data exclusion, and discrepancies between state and national datasets.
- Treatment-Seeking Behaviour and Awareness: Shifts in community trust, traditional vs biomedical pathways, and the role of rescuers and awareness campaigns.
- Pre-Hospital Care and Ambulance Access: Functioning and limitations of the 108-ambulance system, geographic inequities, and delays in emergency response.
- Medical Infrastructure and Referral Chains: ICU and ventilator access, referral systems, triage patterns, and hospital-level resource constraints.

- Species Identification and ASV Use: Misidentification, dry bite over-treatment, non-Big Four species risks, and variation in clinical training.
- Morbidity and Long-Term Impacts: Post-bite recovery, physical disability, economic fallout, and the absence of structured rehabilitation or mental health support.
- Marginalised and Migrant Vulnerability: Access barriers, occupational risk, and invisibility in official systems for migrant workers and informal labourers.
- Education, Myths, and Misinformation: Persistence of myths, knowledge gaps in newer populations, and limits of current outreach.
- Policy and Compensation Frameworks: Gaps in medico-legal case classification, lack of post-bite support, and efforts to institutionalise compensation or medico-legal status.

Interview quotes were recorded alongside stakeholder categories (e.g., doctor, rescuer, survivor), research theme, and contextual summaries in a structured database. This system allowed flexibility in tagging overlapping insights without artificially siloing narratives based on singular identities or roles.

By integrating facility-level data with first-hand narratives, this mixed-methods approach enabled both systemic mapping and granular insight into Goa's snakebite mortality outcomes, while also identifying hidden gaps and underreported survivor burdens invisible in aggregate metrics alone.

2.3.5 Ethical Clearance

Ethics clearance was obtained in September 2021 from Ethics Committee of the School of Anthropology and Conservation, University of Kent (approval number: 16-PGR-20/21).

TurboScribe was chosen because all files are encrypted at rest. None of the audio files contain identifiable information about the interviewee unless they explicitly gave permission to use the same. Access to the files is strictly controlled only to the account holder and once the account is deleted, all data is automatically deleted. No third party has access to the files, nor are they retained by TurboScribe. The files were only uploaded for the purposes of the transcriptions and

the account deleted as soon as the text files were ready. All qualitative data has been securely stored on university servers and personal secured hard drives, and no identifiable personal information has been retained unless explicit permission was granted.

2.4 Results and Discussion

2.4.1 Understanding Goa's Snakebite Burden: Status Quo and Gaps

Between 2019 and 2023, Goa's Directorate of Health Services (DHS) compiled verified, facility-level annual data on medically attended snakebite cases and fatalities across the public/government health system, the state's tertiary referral centre. Data analysis of these records showed that from 2019 to 2022, Goa reported 4,533 snakebite cases and 36 confirmed deaths, yielding a four-year case fatality rate (CFR) of 0.79% (excluding 2023) (Table 2.2). Mortality varied across years, with the highest CFR of 1.16% recorded in 2020, a period that coincided with the beginning of widespread COVID-19 disruptions. Similar treatment delays and diagnostic bottlenecks were reported during the pandemic in other Indian states (van Oirschot et al., 2021; Bhaumik, Norton and Jagnoor, 2023; Gajbhiye et al., 2023; Munshi et al., 2024). In contrast, 2022 recorded the lowest number of hospital deaths (n=2), but an additional seven deaths were newly recorded under the category of "rural deaths," highlighting the likelihood that out-of-hospital fatalities were underrepresented in previous years.

Table 2.2: Snakebite cases and mortalities reported by the Directorate of Health Services, Goa from 2019-2023

Year	Cases	Hospital Deaths	Rural Deaths	Total Deaths	CFR (%)
2019	1177	6	—	6	0.51
2020	1123	13	—	13	1.16
2021	1046	8	—	8	0.76
2022	1187	2	7	9	0.76
2023	954	4*	—	4*	0.42*
Total	5487	33	7	40	0.73*

**Note: 2023 data exclude all cases from Goa Medical College (GMC). Fatality figures for 2023 are likely underestimated and therefore, the total CFR is just an estimate.*

The 2019-2021 period offered the most detailed facility-level breakdown. During these three years, 3,346 snakebite cases and 26 deaths were reported across all tiers of Goa's public health system. Of these, North Goa accounted for 1,238 cases and 2 deaths, while South Goa recorded 1,168 cases and 8 deaths. The remaining 940 cases and 16 deaths were treated at GMC. Since GMC was considered a "neutral" territory, with referrals from both districts, without a detailed breakdown of the cases' origin in GMC, inferences concerning district-specific snakebite burden cannot be made. A detailed breakdown by district, taluka (sub-division of the district) and hospital is provided in Supplementary Sheet 2 (referred to as S2 from this point), Section 1, Table S2.1. Due to the absence of the latest taluka-level population data in state and national records, incidence rates could not be calculated per 1,000 population. While previous studies (Salve, Vatahati and Hallad, 2020) have used the 2011 census for population-based analyses, India's decennial census scheduled for 2021 was indefinitely postponed due to the COVID-19 pandemic, which means no updated demographic data are currently available (Babu and Kumar, 2023). In the absence of a reliable basis for extrapolation, this study avoided per capita calculations to maintain methodological rigour.

In 2023, Goa's reporting system expanded to introduce new mortality-related categories, including "brought dead" (n=3), "left against medical advice" (LAMA; n=57), and "clinically suspected snakebite deaths" (n=2), in keeping with suggestions from the National Action Plan for Prevention and Control of Snakebite Envenoming (NAPSE, 2024). These classifications, absent in earlier years, revealed previously unrecorded mortality and suggest that CFRs based solely on hospital-reported deaths may underestimate the true burden. As the State Surveillance Officer (SSO), who also serves as the State Epidemiologist, confirmed, "We have no standard data collection form for snakebite cases across hospitals yet. We need a system to capture history, species, and treatment." He further noted that private hospitals are not obliged to report snakebite cases, creating a persistent potential gap in the surveillance structure.

These limitations likely explain discrepancies between hospital-level records and field-reported cases by rescuers and communities. As highlighted by Mohapatra et al. (2011) and Suraweera et al. (2020), such data gaps also affect classification accuracy. The SSO acknowledged, "Right

now, hospitals are not distinguishing between hemotoxic and neurotoxic cases in their records,” meaning that even among documented cases, envenomation patterns were often missed or generalised. Interview analysis revealed that hospitals typically relied on symptom-based clinical assessment rather than confirmed species identification, a practice aligned with the intended use of India’s polyvalent antivenom (Simpson and Norris, 2007). As several physicians noted, patients often arrived without having seen the snake or without photographic or physical evidence. In such cases, bite type was inferred from clinical symptoms, such as neurotoxic or hemotoxic signs, and treatment was administered accordingly, as was also reported in literature from Goa and other states (Narvencar, 2006; Narvencar, Favas and Dias, 2020; Jayathilaka and Weeratunga, 2024).

Qualitative findings further indicated that records on post-treatment morbidity, such as necrosis, amputations, or long-term disability, were poorly maintained or not shared with the state surveillance system. The absence of morbidity data is a consistent limitation across national reporting platforms and reflects a broader gap in snakebite burden assessments (Malhotra et al., 2021; Menon et al., 2022). Despite these constraints, Goa’s CFR remained comparatively low. Data analysis indicated that even when rural deaths were included, the average CFR across most years stayed below 1%, substantially lower than estimates from other Indian states such as Maharashtra, Kerala, Tamil Nadu, or Assam, where hospital-based studies and verbal autopsy reports have indicated higher fatality rates, particularly in rural or delayed-treatment contexts (Suchithra, Pappachan and Sujathan, 2008; Mohapatra et al., 2011; Suraweera et al., 2020; Kakati et al., 2023; Dhikav et al., 2025).

These disparities were further underscored when comparing Goa’s dataset to national platforms such as the Central Bureau of Health Intelligence (CBHI) and the Health Management Information System (HMIS). Both systems rely on hospital-submitted ICD-10 codes (specifically, T63: “toxic effect of contact with venomous animals”, under which T63.0 is “snake venom”) (WHO, 2019), but do not account for variation in state-level reporting practices (Suraweera et al., 2020; Rubeshkumar et al., 2021). For instance, CBHI data for Goa reported only 10 deaths between 2019 and 2022, compared to 36 deaths documented by the state, more

than a threefold difference (S2, Section II, Table S2.2). As Suraweera et al. (2020) noted, such underestimation stems from systemic blind spots, particularly in rural and non-hospital contexts.

These methodological and reporting differences make cross-state comparisons difficult. Direct comparisons with other states are therefore not advisable, as few states maintain comparable, granular datasets, and most rely solely on underreported national systems such as CBHI. Differences in reporting structures, inclusion criteria, and death classification further limit equivalency (Suraweera et al., 2020; Rubeshkumar et al., 2021; Bhaumik, Norton and Jagnoor, 2023). This further reinforces the value of detailed, state-level records in understanding localised trends and treatment outcomes.

Taken together, Goa's snakebite burden appeared relatively low and stable, especially when compared to national estimates. But critical gaps remained in the surveillance of private-sector treatment, non-hospital deaths, and long-term morbidity. These challenges are not unique to Goa but illustrate broader weaknesses in India's snakebite data infrastructure (Bhaumik et al., 2022; Menon et al., 2022). Nonetheless, Goa's investment in granular facility-level reporting offers a valuable case study in how decentralised systems can improve burden estimation and inform public health response.

2.4.2 Structural and Systemic Factors Reducing Mortality

Qualitative and quantitative analysis of snakebite outcomes in Goa suggests that the state's comparatively low mortality is not attributable to any single intervention, but rather to a series of reinforcing structural, behavioural, and policy-level shifts over the past two decades. These transformations coalesced across three interdependent pillars: (1) community awareness and treatment-seeking behaviour; (2) pre-hospital access to care through the 108-ambulance system; and (3) the development of reliable medical infrastructure and referral chains. While Goa's small geographic size, including district administration size, played an enabling role, interviews indicate that earlier decades were marked by frequent fatalities, limited ambulance access, and widespread use of faith-based treatments. Thematic analysis revealed how the state's trajectory

shifted across time, resulting in more timely hospital access, symptom-based diagnosis, and ultimately, reduced snakebite mortality.

Community Awareness and Treatment-Seeking Behaviour

Qualitative analysis revealed that one of the earliest and most influential systemic shifts in Goa's snakebite response was the transformation in public attitudes and treatment-seeking behaviour. A generational divide was consistently observed across stakeholder interviews, with older respondents recalling erstwhile widespread reliance on traditional remedies and younger individuals displaying higher trust in biomedical care. As one senior Forest Department rescuer recounted, "Twenty years ago, only 30-40% of people would go to the hospital. Most people went to Ayurvedic healers, *tantra*, or *mantra*. But that is not (effective) for venom. You need anti-venom. That is why the death rate was so high back then. Now, hardly anyone goes to faith healers."

Interview data indicated that this shift appears to have been catalysed in the late 1990s and early 2000s, well before the formal prioritisation of snakebite as a public health issue at the national level. This echoes broader trends across South Asia, where local awareness often preceded national policy recognition (Pandey et al., 2016). In Goa, interviewees indicated that the initial wave of awareness efforts was largely community driven. Both interview data and observational insights showed community stakeholders such as private rescuers, herpetologists, doctors and Forest Department officials frequently conducted formal and informal sessions in public spaces like schools, and community halls. Early messaging focussed on identifying common venomous and non-venomous snakes and seeking hospital care instead of turning to faith healers or herbal practitioners. Over time, the scope of these efforts expanded. Interviewees described how awareness sessions began addressing common myths, such as sucking out venom, tying tight tourniquets, or applying turmeric, and focused on proper first aid, calling rescuers, preventing snakebites and transporting victims without delay. This was consistent with findings from other states where grassroots education and outreach helped dismantle deep-rooted beliefs (Carter et al., 2024). In Goa, community members described earlier practices, while noticing a shift in attitudes saying, "People in my village used to give some leaves to snakebite victims before

taking them to the hospital. I do not know if it worked.” One Forest Department rescuer recalled, “My mother used herbal medicine. Then another local healer removed the fangs. I was taken to a healer, not a hospital (...) it took 8 months for me to heal. I was lucky not to lose my leg,” while noting that when he was bitten a second time as an adult, they went straight to the district hospital.

Analysis shows that by the late 2000s, infrastructural and technological developments, such as affordable mobile phone access, increased network coverage, and social media platforms, began reinforcing these messages parallelly. Several rescuers and Forest Department staff highlighted the use of WhatsApp and Facebook to circulate awareness materials or coordinate responses. Similar improvements in other states have been credited with enhancing community-level education and reducing treatment delays (Vaiyapuri et al., 2022). As one Forest Department staff member put it, “Now, when I hear of any snakebite case, everybody goes to the hospital. At least here in Goa.” This trust in biomedical care was echoed by healthcare professionals. One doctor noted, “Education, education. Suppose something happens, no, they won’t go to a traditional healer, they will immediately come to the [Goa Medical] College.” Similarly, the SSO remarked, “Unlike other states, Goa sees fewer cases of people going to faith healers for snakebites. Most victims seek hospital treatment, which is a major reason why deaths are lower.”

Goa’s trajectory is notable, with data analysis indicating that that this shift in treatment-seeking behaviour appears to have emerged organically from within the community, rather than being driven by national NGO campaigns or externally funded health missions. This contrasts with other parts of India, such as rural Maharashtra and Odisha, where cultural beliefs and limited outreach continue to delay hospital care (Munshi et al., 2024). Finally, interviews reflected a strong public trust in Goa Medical College (GMC) as the definitive referral centre for serious cases- a trust not always found in other states. In Assam, for instance, lack of confidence in overburdened tertiary facilities has been reported as a barrier to timely care (Kakati et al., 2023). These comparisons suggest that Goa’s success was not simply a matter of geography or population size, but the result of reinforcing social, informational, and institutional credibility.

Ambulance Access and Pre-Hospital Response

Analysis indicated that the second systemic pillar contributing to Goa's relatively low snakebite mortality was the expansion of emergency transport services, particularly the introduction of the free 108-ambulance network, called so because it denotes the caller dialling 108 from their phones to get access. Prior to 2012, interviewees noted that patients, especially from rural areas, were largely dependent on private vehicles or neighbours for transport. This often resulted in critical delays. One doctor explained, "Otherwise, you go shout to the neighbours, please help, arrange a car, [especially in] remote areas." Rescuers echoed these accounts, noting that such delays contributed to avoidable fatalities in earlier years.

Interview analysis indicated that the launch of the 108-ambulance system between 2012 and 2015 marked a substantial shift in pre-hospital care. Operated through a centralised dispatch system with GPS tracking and trained paramedics, 108 ambulances became available across Goa's talukas, reducing transport times and ensuring that even remote villages gained rapid access to medical facilities. "Now we have 108 ambulances. I can dial 108 from here from my phone and it will be here in minutes," explained one Forest Department rescuer. "Before this, people would delay reaching the hospital, which led to deaths".

These accounts were consistently supported across stakeholder groups. A herpetologist observed, "The introduction of 108 ambulances around 2012-2015 was a game-changer. Before that, getting help in remote areas was much harder." Another stated plainly, "It changed everything. People in remote villages could now get to hospitals much faster." The SSO likewise described Goa's 108 system as "free and well-equipped," with trained paramedics capable of managing emergency response and triaging snakebite victims for appropriate care.

While few peer-reviewed studies have rigorously evaluated the impact of ambulance services on snakebite outcomes in India, the broader literature consistently highlights the importance of timely transport. A systematic review by Kelly et al. (2016) found that longer travel times are often associated with poorer health outcomes across a range of conditions. Similarly, Syed et al. (2013) underscored transport as a major barrier to healthcare access for rural and low-income

communities. In a non-randomised study in southern Nepal, the introduction of emergency transport alongside community education was associated with a decline in snakebite case fatality rates from 10.5% to 0.5% (Sharma et al., 2013), a trajectory echoed in Goa. Studies such as Narvencar (2006), from GMC, have recorded that there is a correlation between severe envenomation and a delay in bringing snakebites patients to the hospital, which also indirectly support faster logistical support.

Interview analysis indicated that by 2023, the 108-ambulance network was widely regarded as one of Goa's most effective systemic reforms, for multiple health crisis not just snakebites. Stakeholders across districts consistently credited faster transport with saving lives, particularly in rural areas where alternative options were previously limited. As one rescuer succinctly noted, "Mostly, there's little chance of actually dying, because now the system has 108 (ambulance) which shifts the patient directly." While challenges remain, analysis shows that the 108-ambulance network has significantly narrowed the critical time window between bite and treatment, contributing directly to reduced mortality.

Medical Infrastructure and Referral Chains

Analysis indicated that the third systemic pillar contributing to Goa's reduced snakebite mortality was the development of a reliable and tiered medical infrastructure, supported by referral pathways that prioritised timely escalation of care. Interview analysis confirmed that while Goa's small geographic size enabled relatively short travel distances to health facilities, this alone did not ensure survival in earlier years. Most respondents recalled a time when limited ambulance access, lack of ventilator availability, and insufficient first-line response often led to preventable deaths, even after victims reached a hospital.

Both qualitative and quantitative data indicated, that over the past decade, however, improvements in structural health capacity have supported a more dependable system of snakebite care. Goa's public health network is anchored in a decentralised model comprising PHCs, CHCs, UHCs, and SDHs, and then DH and GMC. Interviews indicated that ASV is available at most PHCs, allowing basic treatment and stabilisation before patients are referred

upward. As the SSO noted, “In Goa, ASV has always been available at the PHC level. The (national) snakebite program is new, but Goa already had ASV available at the PHC level. The difference now is that there is formal funding and structured training. All PHCs have always at least 10 vials of ASV, and we ensure there are no stockouts.”

Data showed that referral systems were particularly critical in severe cases especially involving neurotoxic envenomation from species such as the spectacled cobra or common krait, where ventilator support could become necessary. In such cases, the patient was quickly referred to the nearest district hospital or directly to the state’s tertiary centre, Goa Medical College (GMC) (Refer to Fig 2.2 for a schematic representation). GMC was consistently described across interviews as the definitive referral centre for severe envenomation. Its reputation was rooted not only in its facilities and clinical expertise but also in the visible public trust it commanded. Both qualitative and observational data indicated that GMC was the preferred hospital for complex snakebite cases, not only for residents of Goa, but also for patients from border districts in Karnataka and Maharashtra, who often found it faster to reach GMC than facilities in their own states. As one herpetologist explained, “GMC has a stellar track record. Patients come from Karwar, and even Maharashtra because of its expertise.”

Interviews revealed that private hospitals, by contrast, did not constitute a formal part of the state’s snakebite treatment pathway and were introduced into the informal referral system in recent years. While the 108-ambulance system was permitted to transport patients to private facilities when GMC beds were unavailable, these referrals were temporary. As one doctor confirmed, “Even [ambulances] have permission to take directly to other hospitals where ventilator may be.” Government policy allowed the cost of such treatment to be reimbursed, and patients were typically transferred back to GMC once beds became available. However, qualitative data showed that private hospitals were neither mandated to stock antivenom nor obliged to report snakebite cases. As a result, patients who approached them directly were frequently redirected to government facilities. “Private hospitals are not obliged to report snakebite cases,” the SSO confirmed, highlighting a persistent gap in both treatment and surveillance. Observational data confirmed this pattern, with most private hospitals, barring a

few exceptions, preferring to transfer snakebite patients to the public sector. The few that still treated snakebites were commended by patients for their medical expertise. A private doctor confirmed that they saw about 10 cases a year in a major hospital and that those who could afford to pay came directly to the hospital, whereas those who could not always had the option of free/subsidised treatment at the government hospitals. He broke down the private costs saying, “If the patient requires ICU, it's a minimum of ₹15 to 20,000 a day. But if the patient is stable and not requiring ICU, it is much less, maybe ₹5,000 a day.”

This disjuncture between structural readiness and functional utilisation has been documented elsewhere in South Asia. In rural Nepal, for instance, delays in accessing hospitals and underuse of peripheral facilities contributed significantly to high snakebite mortality; when transport and triage systems were strengthened, fatality rates declined sharply (Sharma et al., 2013). In Costa Rica, Hansson et al. (2013) used spatial modelling to show that merely increasing antivenom supply was insufficient and access outcomes improved only when paired with strengthened referral logic and clinical capacity at the primary level. Within India, Mukherjee and Mackessy (2021) similarly noted that PHCs may stock antivenom, but staff often lack training or confidence to administer it in complex cases, leading to avoidable delays. A study in Assam found that overburdened tertiary hospitals and weak lower-tier systems eroded public trust and contributed to care delays (Kakati et al., 2023).

These patterns reflect a broader literature on healthcare access inequities. As Solomon et al. (2020) and Syed, Gerber and Sharp (2013) note, structural access is shaped not only by distance but also by transport, triage capability, and institutional trust, factors that disproportionately affect rural and underserved communities. In Goa's case, institutional consolidation around GMC, while not without its limitations, appeared to benefit from sustained public credibility, efficient referral pathways, and relatively equitable access across the state's districts.

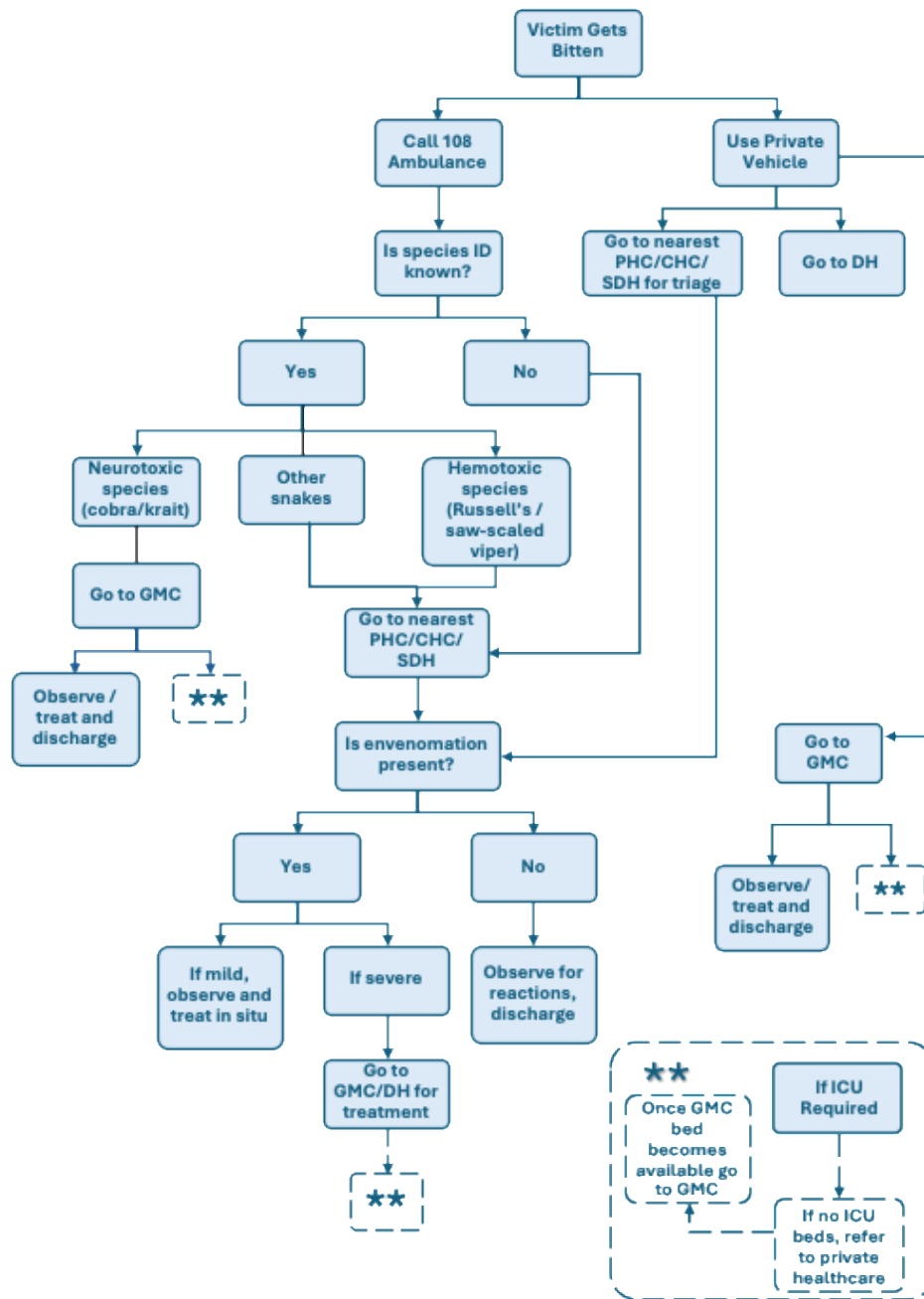


Figure 2.2: Schematic representation of typical referral and treatment pathways following a snakebite in Goa, India.

This flowchart is based on qualitative interviews and facility-level data and represents a generalised pathway from bite incident to medical admission. Actual decision-making may vary based on species identification, location, transport availability, facility protocols, and patient condition.

2.4.3 Contextualising Risk and Species-Specific Exposure

Demographic and Spatial-Temporal Risk Exposure

Qualitative data analysis revealed that snakebite risk in Goa is shaped by a complex interplay of demographic, spatial, behavioural, and ecological factors. Thematic findings aligned strongly with the first and only published epidemiological study on Goa's snakebite burden by Narvencar, Favas and Dias (2020), which analysed 156 envenomation cases at Goa Medical College between 2016 and 2017. That study reported that 76% of victims were male, most between the ages of 20–59, and nearly 70% were not engaged in agriculture- comprising students, housewives, the unemployed, or retirees. This diverges significantly from national assumptions that rural farmers form the majority of snakebite victims, as reflected in national and state-based literature (Mohapatra et al., 2011; Vaiyapuri et al., 2013; Suraweera et al., 2020; Kakati et al., 2023; Munshi et al., 2024; Salim et al., 2024; Dhikav et al., 2025).

Interview data strongly reinforced this deviation. Risk exposure in Goa was not primarily tied to agricultural or forest-based work, but to domestic, peri-domestic, and informal labour environments. Women were frequently mentioned in cases of indoor bites. As one family member recalled, “So early morning she was going to cook in the kitchen and then she put her hand in the box to remove some utensils. There was a cobra there which bit her.” Others were bitten while sweeping, stepping outside barefoot, or cleaning areas with poor visibility. “A man nearby was bitten because he stepped on a snake at night. He didn’t even see it.” Children also emerged as a frequently mentioned but underrepresented group. One rescuer recounted, “This eight-year-old girl was bitten because she went into a storeroom to pick up a toy... If more people knew that, less people would get bitten.” These accounts illustrate how everyday behaviours, especially in dimly lit or cluttered spaces, could lead to high-risk encounters, often within or adjacent to the home. It also emphasised the absence of basic precautionary awareness as habit, such as checking containers or dark corners, that could prevent such encounters. Migrant workers and informal labourers were repeatedly seen as a vulnerable group, in the interview as well as observational data. Their exposure often occurred in industrial compounds, gardens, or construction zones, typically outside of formal surveillance systems. One rescuer noted, “I’m trying to get DHS data on snakebite cases from industrial areas, especially for

housekeeping and garden staff.” A community member described one incident, “Somebody got bitten by a cobra apparently and then they all panicked, and they shut down work for one week on the site.” Such cases underscore how habitat disturbance during construction, or residence in informal structures, increase exposure risk in ways that are neither occupationally classified nor officially documented. “When the plot is being cleared, you see a lot of snakes. They find eggs, and things like that,” one architect added.

Snake rescuers themselves were repeatedly identified in the interview data as a high-risk group, not simply due to their proximity to snakes, but due to handling practices and gaps in safety infrastructure. One Forest Department rescuer stated, “I was handling a cobra. The bag had a small hole. It slipped out and bit me.” He delayed seeking treatment, first returning home, then proceeding to Chicalim SDH and eventually GMC. He recounted his second bite, though milder, required hospital attention, saying, “Second time, it was a light bite. Doctor told me not to take risks, come and show it.” Another experienced rescuer described more severe envenomation saying, “Once it was a Russell’s viper. Second time with a cobra, it was a respiratory failure. It was in a very bad condition. The doctor injected a huge amount (of anti-venom). My respiration stopped. So, I went to Manipal (a national private hospital chain) because there was no ventilator (available in government facility).” Another case frequently cited in interviews involved a rescuer from North Goa who, due to repeated free handling of snakes over the years, had both lost and suffered severe disfigurement to multiple fingers on both hands as a direct result of snakebites. These testimonies reveal how training gaps, overconfidence, lack of protective gear, and informal response protocols amplify risk for rescuers even when their knowledge of snake behaviour is otherwise high, themes which have been further explored in Chapter 4.

Data showed that spatially, bite risks were almost uniform across both rural and urban contexts, mirroring Narvencar, Favas and Dias's (2020) finding that 54.5% of bites occurred in rural settings and 45.5% in urban ones. Interview data, however, suggested that location alone was not the key variable, rather, environmental features such as debris piles, open drains, dark storage spaces, or rodent activity were stronger predictors of risk. “You see more snakes where there are rats, and rats are where there is garbage. It’s all connected,” a rescuer noted. Another added,

“You keep the place clean; snakes don’t stay. But if rats are there, they will come.” These observations align with broader literature linking sanitation, waste management, and snake presence in urban and peri-urban environments (Menon et al., 2022).

Architecture and landscape design also emerged as relevant factors. One architect explained, “Modern houses, snakes don’t enter. With old Goan houses, the Indo-Portuguese houses, there are more entry points. Gaps between the roof and the wall, sometimes holes in the walls because they are so old... so they do enter.” Another added, “People (from outside the state) are buying properties in Goa in green, pristine areas, then saying ‘no snakes should come here.’ But you can’t have both.” These urban growth patterns with influx of new residents from other states was also reported in Kandolkar (2020), though field observations and interview data indicated a potential increase during and after the pandemic as hybrid working patterns became more normalised, for economically advantaged sections of society. These statements reveal how both economically vulnerable and upwardly mobile populations are increasingly exposed to snakebite risks, either due to poor structural conditions or due to landscape change driven by real estate expansion. Interviewees flagged a widespread lack of awareness among new migrants and homeowners regarding basic safety protocols, emergency contacts, or species identification, indicating that educational gaps span income levels.

Interview data indicated that the mechanisms of bite were largely accidental. Most incidents occurred while stepping on snakes in poorly lit areas, retrieving items from storage, or sweeping outdoor spaces. As one herpetologist explained, “Street lighting has changed dramatically. In the past, yellow sodium lamps made it difficult to see at night, increasing the chances of stepping on a snake.” Post-bite responses, such as photographing the snake for hospital identification, were mentioned in interviews, but offered no preventive value. Data analysis, including observational insights, however, also identified inebriation, primarily alcohol-induced, as a risk factor that impaired awareness. Findings from this study and published literature (Adukauskienė, Varanauskienė and Adukauskaitė, 2011) showed that alcohol consumption often reduced a person’s ability to notice a snake, misjudge distance, or misidentify the species, leading to handling accidents.

The data also revealed an emotional dimension to perceived risk, informing behaviour. Even among individuals who had never personally experienced a bite, awareness of someone who had, often a neighbour, friend, or family member, shaped behaviour and fear responses. A herpetologist summarised this saying, “Most people in Goa have never been bitten, but they all know someone who has. That alone makes them fearful.” This form of second-hand trauma suggests that snakebite risk is not only about individual exposure but is embedded in community memory.

Seasonal and temporal patterns of risk were also highlighted. Both interview data Narvencar, Favas and Dias (2020) confirmed a monsoon spike in cases (June–August), as well as a second cluster between October and February. A senior forest department rescuer noted this saying, “Russell’s viper bites start increasing from October. Every year, same season.” This pattern aligns with field observations and published literature on Russell’s viper breeding seasons (Glaudas, 2021) and rescue trends discussed in Chapter 3 and is consistent with winter season viper activity in other western Indian states (Dhikav et al., 2025). Interview data also showed an overlap with veterinarians of Goa also noting similar seasonal patterns in domestic animal bites, which has been explored in Chapter 5. Although national snakebite literature often focuses on the monsoon (Mohapatra et al., 2011; Suraweera et al., 2020; MoEFCC, 2023; NAPSE, 2024), these findings emphasise the importance of region-specific monitoring across the full annual cycle.

In sum, while national narratives often associate snakebite with rural, agrarian male populations, during the monsoon (Suraweera et. al., 2020), the Goa datasets illustrate that risk is highly contextual. This diversity underscores the need for tailored investigation, awareness and preparedness strategies that reflect local realities and knowledge rather than relying solely on national-level generalisations.

Species Involved

Species-specific trends were closely linked to the environmental and behavioural context of each bite. Interview and observational data from this study revealed consistent patterns across Goa

suggesting that Russell's vipers and then spectacled cobras were among the most frequently involved in venomous bites, followed by common kraits, and then saw-scaled vipers. Russell's viper was frequently encountered in outdoor scenarios such as by the road, in gardens etc., as was also noted in a Karnataka based radio-telemetry study (Glaudas, 2021). Cobras were consistently linked to indoor incidents, especially in kitchens, storage spaces, and low-light settings. Kraits were associated with night-time bites indoors, particularly during sleep or barefoot movement, all consistent with literature also noting their painless bites and delayed symptoms (Law, Agrawal and Bhalla, 2014; Rodrigo, Kirushanthan and Gnanathasan, 2017). Saw-scaled vipers, while not recorded in the Narvencar, Favas and Dias (2020) hospital data, were described by rescuers in gardens, construction sites, and urban plots, underscoring their cryptic and underreported presence. Bites from non-venomous and mildly venomous snakes were also reported, however observational data indicated that people were less likely to seek medical attention for those. Few of the common species mentioned by people included the arboreal green vine snake (*Ahaetulla nasuta*), and the checkered keelback (*Fowlea piscator*). Species frequently encountered by people in Goa have been further explored in Chapter 3.

While terrestrial species accounted for all the reported bites, marine snake species (*Hydrophis* spp.) were also discussed, though not linked to any confirmed recent incidents. According to the literature bites and envenomation from sea snakes are rare (Whitaker, 2015), though a recent paper from the east coast of India warranted greater investigation as their study showed a high fatality rate (Patra et al., 2025). However, observational data and interviews with multiple rescuers and herpetologists, as well as doctors, indicated either they had not heard of anyone ever getting bitten or that the only bites that they knew of happened a very long time ago. One rescuer, who clarified, "I have asked around, and I don't know of any fishermen getting bitten around here in Goa. Nobody I spoke to remembers anything in recent memory," confirming that while present, sea snakes pose no known threat in current human-snake interactions on this coast. This is even though the handling methods increase the potential of a bite as stated by a rescuer, who has been working with the fishing community for several years, "All the fishermen I know think sea snakes don't bite. They just pull them up and throw them back. Although migrant workers do work on these boats, all the boats here in Goa will have a local Captain, who will

normally have experience and knowledge, generally passed down through generations.” NAPSE (2024) has acknowledged the venomous nature of the sea snakes, with no available anti-venom, along the coasts of India, and included a section encouraging states to hold awareness sessions with fishermen about the dangers of free-handling sea snakes.

Together, these findings demonstrate that Goa’s snakebite profile cannot be reduced to a single demographic, seasonal, or occupational narrative. Risk is shaped by a multi-layered combination of behavioural routines, ecological displacement, housing design, sanitation conditions, and gaps in public awareness. Populations such as women, children, migrants, and rescuers remain underrepresented in formal surveillance systems and are largely invisible in national-level risk frameworks. Snakebite mitigation must be regionally grounded, as is being emphasised in emerging literature (Malhotra et al., 2021; Bhaumik et al., 2022). Goa’s exposure profile illustrates the limitations of applying national generalisations to local realities and underscores the need for context-specific strategies that reflect how, when, and where bites occur.

Envenomation Profiles and Clinical Presentations

In the interview and observational data analysis, bite sites most frequently presented were the feet and hands. Some cases of mishandling also resulted in bites on the neck, as people draped the snake around their neck. According to Narvencar, Favas and Dias (2020), GMC data from Goa indicated that hemotoxic symptoms dominate snakebite envenomation cases, though no such distinction was apparent in the interview data analysis. The Narvencar, Favas and Dias (2020) study said 76.9% of patients presented with hemotoxic signs such as local swelling, bleeding, and coagulopathy, presumed to be Russell’s viper bites, while neurotoxic presentations (from cobras and kraits) accounted for only 4.5% of cases. Interview data from ICU physicians confirmed that hemotoxic cases often involved complications, including internal bleeding and renal failure. One ICU doctor explained, “Mostly, when they die, you know, they go in multi-organ failure. Especially kidney failure,” highlighting the systemic burden associated with severe hemotoxic bites. Another observed, “We have got problem for haemolytic. Because, you know, you touch them, they bleed,” describing the clinical challenge of managing coagulopathic patients. Many of the patients’ interviews confirmed these symptoms, normally indicating

swelling and pain as the initial symptoms' onset. Data also showed the importance of taking a full medical history, especially if alcohol consumption was suspected, since symptoms including coagulation could be masked or exacerbated, making clinical correlation and an accurate timely diagnosis difficult. This has been corroborated in trauma literature, where ethanol intake has been shown to alter clotting profiles and contribute to hypocoagulable states (Spoerke et al., 2010).

Neurotoxic cases, though slightly less common, presented distinct risks due to their subtle early symptoms, as has been documented in published medical studies (Del Brutto and Del Brutto, 2012). ICU staff noted that patients bitten by kraits often arrived without local swelling or pain but later developed respiratory distress. "Snakebite patients mostly have got a normal lung... they recover fast actually on the ventilator, comparatively," one doctor observed, referencing the use of ventilatory support in neurotoxic cases despite initially unremarkable physical signs. These accounts are consistent with broader clinical literature on *Bungarus* spp., which often cause delayed-onset neuromuscular paralysis without initial pain (Simpson and Norris, 2007; Law, Agrawal and Bhalla, 2014). Doctors also noted that cobra bite complications seemed to settle in much faster than kraits, emphasising the need for any confirmed or even suspected cobra bite to be taken to the hospital immediately.

Some envenomation cases resulted in cytotoxic outcomes, including tissue necrosis and eventual amputation. One ICU doctor noted that such outcomes occurred "mostly... when there is a peripheral" bite location, indicating that envenomation to extremities could lead to irreversible tissue damage if not treated promptly. Data showed that although Goa's public health system ensures free access to acute treatment, comprehensive post-ICU care and rehabilitation for such injuries has limitations (covered in Section 2.7).

These envenomation presentations link closely with the behavioural and ecological patterns described above but also reveal a second layer of challenge- how clinical teams in Goa identify, treat, and manage complex cases.

Although rarely acknowledged in public health discussions, interviews revealed there was substantial psychological burden associated with snakebite, based entirely on fear of death. As one rescuer put it, “People are getting better at identifying snakes, and realising that snakes can be non-venomous, but for a large population, every snake is still a cobra.” Data revealed this to be a regular occurrence wherein non-venomous or dry bite patients (where no venom is injected by the snake) experienced psychosomatic symptoms, with one doctor noting, “Very often, there is at least... How do I put it? Probably at least one or two symptoms do manifest in almost all the dry bite cases. To something like a full-blown panic attack.” In multiple cases, victims collapsed before venom could even take effect. One Forest Department rescuer recalled, “A woman in Cortalim was bitten. She collapsed within minutes- fear, not venom, killed her.” Another described fear-driven panic after a dry bite, “Even I thought I was going to die, even though I knew it was a dry bite.” Several respondents observed that community myths, memories of prior deaths, and visual trauma from witnessing others’ suffering compounded these effects. As one rescuer put it, “Many people don’t die from venom. They die from fear.”

2.4.4 Clinical Challenges and Gaps

Medical Infrastructure and Emergency Care Gaps

While Goa’s medical infrastructure and emergency response systems have enabled important improvements in snakebite outcomes, interview analysis revealed persistent weaknesses across multiple tiers of care. These gaps were particularly acute at the emergency triage level, in ventilator access and ICU coordination, and in under-resourced rural or island contexts. Despite the overall strength of the referral system described in earlier sections, systemic bottlenecks continued to persist the timeliness and effectiveness of clinical response, especially for severe or neurotoxic cases.

Multiple interviewees described delays at the casualty level even after victims reached public hospitals. Interviews indicated that triage decisions were often based on the visible severity of symptoms, and in cases where swelling or bleeding was not immediately apparent, snakebite victims were sometimes deprioritised, as coagulation tests were awaited. Several rescuers and some retired doctors recalled instances in which patients had to wait in casualty despite

confirmed envenomation or were moved prematurely to general wards due to ICU bed shortages. A case of an 8-year-old girl dying was highlighted in multiple interviews, with suggestions of hospital delay and negligence being responsible for her death, after a cobra bite (Figure 2.5). During peak periods, particularly in the monsoon and post-monsoon months, public hospitals experienced overcrowding and staffing constraints, creating additional strain on emergency response. As one ICU doctor noted, “If we get suppose 10 calls and we get 10 patients admitted at one shift, it is not possible.” These conditions affected not only admission decisions but also downstream recovery, as patients were transferred out of ICU, sooner than ideal, to make space for incoming critical cases. To manage bed availability, doctors reported relying on visual improvement and the presence of family support in general wards, “One is cross infection. Yeah. And second one is being near their dear ones, you know, they really recover fast.”

A related concern raised by some retired public doctors was the absence of intermediary intensive care units. Interview data showed that once patients were stabilised in ICU, they were transferred directly to general wards without transitional monitoring, raising the risk of relapse or infection. As one clinician emphasised, “Actually, instead of another district hospital, GMC needed intermediary ICU. Because when these patients are all right, they directly go to the ward.” This gap in step-down care was signalled by multiple medical professionals as a structural weakness in the system, particularly for envenomation cases requiring continued observation.

The most persistent infrastructure bottleneck, in the thematic analysis, involved access to ventilator-equipped ICU beds. While GMC remained the primary referral centre for all severe snakebite cases, interview analysis confirmed that few other facilities in Goa had reliable ventilator support. This was especially critical for neurotoxic bites, where respiratory failure could occur without early visible symptoms. In such cases, delays in initiating ventilation could prove fatal, which came out in the interview data as has been well established in existing literature as well. Doctors reported that ICU beds at GMC were often occupied by long-term neurosurgical patients or head injuries, making it difficult to accommodate new envenomation

cases. As one retired physician stated, “Mostly, when a head injury patient comes, you know, they remain for longer time. So, snakebite patients can’t always be admitted immediately.” Interview data showed that although district hospitals were finally equipped with ventilators during the COVID-19 pandemic, as with other hospitals during the pandemic (van Oirschot et al., 2021), these remained underutilised after the crisis due to staff shortages. As one doctor explained, “According to some reports, ventilators only properly came in because of COVID but had no manpower. During COVID, manpower used to come from GMC. After that was over, then they were just lying idle.” Others noted that plans for ICU expansion were underway, but implementation had been delayed, “Finally, now they have come that they are establishing a full-fledged unit of ICU there. Very shortly, manpower will be there. That is what I read latest.” These findings suggested that while physical infrastructure may exist at the district level, functional capacity remained limited due to human resource gaps, such as training and deployment of critical care personnel. A doctor highlighting that importance of trained staff said, “It is managing a patient on a ventilator, which is the tough part. Because I’m an intensivist, so I know. So, you can kill a patient on a ventilator. The snake bite may not kill you.”

Geographic inequities further compounded problems. On islands such as Chorao, interviewees confirmed that no facility with stocked anti-venom or staff trained to manage envenomation cases existed. Victims had to be ferried to mainland centres, with the land access via bridge adding at least a half hour delay in travel time, introducing unavoidable delays during a critical treatment window. Interviews indicated that residents of such areas had little option but to bypass nearby local clinics entirely and travel directly to GMC. As one herpetologist described, “Some people also just don’t trust the PHCs when it comes to snakebites. They go straight to GMC, even if it’s far.” This trust in a single tertiary facility, while understandable, also placed a disproportionate burden on GMC and contributed to triage bottlenecks. A few villages deep inside some rural landscapes also showed inequitable access, in the data, with a lack of mobile network coverage and distance to the nearest PHC being cited as much as two hours. Even when ICU beds at GMC were unavailable, emergency referrals to private hospitals were subject to procedural limitations. Interviews with doctors confirmed that such transfers were allowed only when routed through authorised channels. “The moment bed is available; we give

them admission on priority basis. And that bill is paid by the government,” one physician attached to a private hospital explained.

Taken together, the data indicated that while Goa had made notable advances in emergency snakebite treatment, the system remained fragile under strain. Triage delays, ICU overcrowding, uneven ventilator access, and geographic disparities in care continued to pose challenges the effectiveness of the referral chain, particularly for neurotoxic envenomation and rural patients. These structural bottlenecks highlight the need for not only physical infrastructure but sustained investment in staffing, training, and regional distribution of emergency care capacity. These issues are also commonly seen across other parts of India as well, where the unequitable access to equipped medical care, especially in areas where the facilities are at considerable geographical distance from each other, is often the cause of high fatality rates (Narvencar, 2006; Chincholikar, Bandana and Swati, 2014; Majumder et al., 2014; Bhaumik, Norton and Jagnoor, 2023; Munshi et al., 2024).

Species Identification and Anti-Snake Venom Use Challenges

Interview and observational data analysis revealed persistent challenges in the identification of snake species, rational use of antivenom, and training of medical personnel. These gaps, though longstanding in the broader Indian context, emerged as particularly relevant in Goa given the presence of the “Big Four” species and other medically significant snakes such as the hump-nosed pit viper (*Hypnale hypnale*) and Malabar pit viper (*Craspedocephalus malabaricus*) (ZSI 2008). Respondents offered divergent views on the role of species identification in clinical decision-making, but most acknowledged the absence of structured training and the risks of inappropriate ASV administration.

Almost all stakeholders acknowledged species identification mistakes being made when certain species looked very similar to each other, such as the non-venomous wolf snake and venomous krait, a venomous Russell’s viper and a non-venomous python and some even confused a non-venomous rat snake with a venomous spectacled cobra, when the latter’s hood was not up. This unreliability not only posed a danger in the field, with potential of species being incorrectly

handled but also complicating correctly assessing exposure and reaching a hospital on time and being able to effectively communicate the bite.

To combat these issues, doctors and rescuers described a variety of approaches to species identification. In most cases, patients arrived without a confirmed species ID, and treatment proceeded based on symptom recognition and if the doctor was unsure of the ID, they would send via WhatsApp to a rescuer or a snake identification group for a quick confirmation. However, interview data revealed that this was not always consistent. In one case, a rescuer reported that a live cobra had to be transported inside an ambulance to the hospital because the attending physician insisted on species confirmation, even though another SDH had already given him 10 vials of ASV during transfer as a precaution. Other rescuers explained that even when the snake was brought in or photographed, misidentification often occurred, especially due to reliance on local or regional names, which may vary region to region, sometimes denoting different species under the same name.

Doctors themselves expressed uncertainty in some cases. As one treating physician explained, “There is a fear of administering ASV, there is a fear of starting ASV. And very often the level of training... We are still learning how to treat a lot of different snakebites.” Another emphasised the danger of inappropriate ASV use in cases involving species not covered by the current formulation, “For those [snakes] not covered by ASV, we need to know to recognise them and not give ASV, because you unnecessarily stand a risk of anaphylaxis and serum sickness.” These accounts reflected a wider anxiety among physicians, as they felt some of their peers lacked formal training in snakebite symptomatology and relied on caution or institutional pressure to guide treatment.

The polyvalent ASV currently in use across India is manufactured using venom from Big Four specimens collected in Tamil Nadu (Whitaker, 2015; Senji Laxme et al., 2019). However, growing literature has raised concerns about regional variation in venom composition and reduced effectiveness of the Tamil Nadu-derived ASV in other states (Simpson and Norris, 2007; Senji Laxme et al., 2019). Despite these national concerns, interviews in Goa indicated that the

current polyvalent formulation appears to be clinically effective for the state's Big Four species. One senior doctor stated, "Yes, we use it. It seems to work well for the snakebite cases here." Another private intensivist claimed that their hospital had not lost a snakebite patient in recent years, agreeing that the ASV seemed to be effective against the Goan Big Four.

However, multiple respondents highlighted the presence of medically important species beyond the "Big Four", for which the current ASV provides no protection. The hump-nosed pit viper, for example, was confirmed by the SSO and multiple rescuers and herpetologist as being present and an increasing medically significant snake in Goa. These bites are known to cause significant clinical effects, including hemotoxicity and renal complications, in southern and western India but are not covered by the polyvalent ASV, as is also noted for the Malabar pit-viper (Senji Laxme et al., 2024; Sirur et al., 2022; Sirur et al., 2022). Similarly, king cobra and sea snake bites, though rare, remain outside the scope of current treatment options (Whitaker, 2015). Interview analysis revealed that in such cases, treatment remains purely symptomatic, often delivered without clear species confirmation, increasing the risks of both over- and under-treatment. These concerns echo national findings that highlight the clinical risks of administering Big Four polyvalent ASV in regions with high prevalence of species like *Hypnale hypnale*, *Trimeresurus* spp., and *Bungarus sindanus*, which are not effectively neutralized by the current formulations (Gajbhiye et al., 2023). The continued reliance on outdated venom sources and the lack of regional specificity in ASV manufacturing remain systemic blind spots in India's snakebite treatment infrastructure.

Data from the epidemiological study at Goa Medical College, Narvencar, Favas and Dias (2020) found that only 16.7% of snakebite cases had a confirmed species ID, based solely on patient reporting. The study also found that 95.5% of patients received ASV, even though 18.6% had only local symptoms and might not have required antivenom. Notably, 20.8% of patients developed reactions, including hypotension, rash, and anaphylaxis. These findings underline the risks of blanket ASV use in the absence of confirmed envenomation or species diagnosis. Interview and observational data highlighted a pattern of antivenom administration even in suspected dry bite cases, as was seen in the case shown in Figure 2.3. Rescuers described cases

where patients presented with no local or systemic symptoms but were still given ASV “just to be safe,” reflecting a lack of clinical confidence or institutional pressure. This practice raises concerns about unnecessary exposure to ASV risks such as anaphylaxis, as well as wastage of a limited resource. As Simpson and Norris (2007) emphasise, syndromic management remains essential in regions where species ID or venom-type diagnostics are unavailable. However, dry bites must be clinically differentiated through careful observation of symptom onset, a process that requires both time and training. Interview analysis indicated that such watchful waiting was often bypassed in Goa’s emergency settings, especially during high-pressure or uncertain cases, which was sometimes compounded by the presence of families insisting on immediate treatment.



Figure 2.3: A rescuer presenting with a dry bite from a spectacled cobra in 2022

The rescuer was administered 10 vials of ASV in an SDH, transferred to GMC and released after observation, when no signs of active envenomation were seen.

Finally, respondents consistently pointed to the lack of structured clinical training and continuing medical education (CME) on snakebite management. Although some training sessions were sporadically carried out “in both North and South Goa districts (...) doctors, nurses, and paramedics were trained in ASV administration, reaction management, and proper referral protocols,” as confirmed by the SSO, other herpetologists and doctors, most interviewees

acknowledged that more formal CME programs on species ID, envenomation types, and rational ASV use were urgently needed. A doctor noted that, “Identification of snakes is not much of a curriculum when we study.”

The absence of diagnostic tools to identify venom type further complicates treatment decisions. Without venom-specific tests, all treatment relies on symptom presentation, which may be subtle or delayed in neurotoxic bites, particularly krait cases. This creates a challenging environment where early symptoms may be missed, species ID may be wrong, and treatment decisions are shaped by institutional pressures, fear of litigation, or limited training.

Taken together, the data suggests that while Goa’s polyvalent ASV is functioning adequately for Big Four species, some systemic gaps remain. These include inadequate species identification, no capacity to treat non-Big Four bites, inappropriate ASV administration in dry or misidentified cases, and a lack of clinical protocols to guide rational care. Without addressing these training and systemic barriers, risks will persist for both patients and providers, especially in a state where medically important but non-covered species are increasingly being reported.

2.4.5 Living with Snakebite: Morbidity, Economic Fallout, and Systemic Blind Spots

While Goa’s relatively low case fatality rate suggests strong emergency response and treatment systems, interview and literature analysis revealed that survivorship itself is not the end of the snakebite experience. For many victims and their families, the consequences of envenomation extended well beyond the acute phase, often resulting in prolonged physical impairment, financial strain, psychological trauma, and gaps in institutional accountability. These post-bite challenges, though not captured in most official datasets, constituted a critical component of Goa’s snakebite burden.

Morbidity Beyond the Hospital: Physical, Economical and Mental Health

As highlighted in Section 2.4.1, state-level records did not capture long-term morbidity indicators such as necrosis, amputation, chronic pain, or renal damage. Interview analysis confirmed that once the acute crisis passed, most victims were discharged without structured follow-up. One victim, bitten by a Russell's viper 27 years ago, described the protracted nature of her recovery, "It kept oozing, and eventually it healed... Now, 26–27 years later, the wound is packed, but I'm still bandaging it and keeping it clean" Another rescuer recalled a bite from seven years ago and the time it took to recover from a cobra bite (Figure 2.4), saying, "Even after getting discharged, I couldn't walk properly for months. It took almost half a year for my leg to fully recover. Even now when it gets cold, the area still feels tight and pulls." These cases suggested that while hospital care may prevent death, it does not always prevent disability in some form or degree. Trust in the medical system also forms a crucial component, which can underscore effective treatment and encourage other community members to also get treated. The family of the lady with the 27-year-old bite, explained it took so long for the bite to get effective treatment because the lady experienced considerable pain, discomfort and curtailed movement for several years, losing trust in the hospital, saying, "She never went to the district hospital again, but she's gone to many other doctors, including herbal medications." After more than 26 years of a gaping wound on her foot, she finally found a private doctor whose treatment has started to make a difference.



Figure 2.4: The scar on a snake rescuer's foot, seven years after he was accidentally bitten while handling a cobra in Goa, India

Healing from the bite took several months before the victim could walk normally again, with tightness at the bite site still experienced by them.

The Narvencar, Favas and Dias (2020) study noted that 56.4% of patients experienced complications, and 7.69% required surgical intervention. Despite this, no mechanism existed for tracking long-term morbidity post-discharge, an omission mirrored in national datasets (Malhotra et al., 2021; Bhaumik et al., 2022; Menon et al., 2022; Gopal et al., 2023; NAPSE, 2024). This was acknowledged by the SSO as well saying, “Goa's mortality rate from snakebites is low- maybe 1 or 2 deaths a year- but morbidity cases are high. We have data on deaths, but we don't have enough tracking of morbidity- things like necrosis, amputations, or long-term effects.” While the NAPSE (2024) also mentions morbidity as a severe outcome of snakebites, there was no plan available to even trace it. None of the suggested data collection forms for the states included any classifications for morbidity monitoring.

Economic fallout also emerged as one of the most consistent post-bite concerns raised by interviewees. While emergency treatment at Goa Medical College and public hospitals was reported to be free or subsidised, indirect costs, such as travel, wage loss, caregiving burdens, or private follow-ups, were frequently cited as sources of financial hardship. One rescuer explained, “One full month I was in the hospital. And even after that, I couldn't work properly for months.” Others described skipping rehabilitation or returning to work prematurely due to financial pressure.

Observational and interview data indicated patterns of mental health being affected and its consequences not being fully understood by the victims, their families, communities or even the system. This is a major systemic gap, especially in a country like India where access to affordable and effective mental therapy remains fragmented and/or expensive, especially since there remains stigma attached to it in some parts (Shidhaye, 2020; Weaver et al., 2023). The need for mental-health support for victims, their families and communities are supported by international literature documenting post-traumatic stress disorder (PTSD) and psychological morbidity following envenomation. In Sri Lanka, Williams et al. (2011) found that over 20% of snakebite survivors met criteria for PTSD, while in Nigeria, Habib et al., (2021) recorded significantly higher rates of psychological distress and social impairment among victims. More recently, Gou et al. (2024) reported PTSD prevalence of nearly 68% among snakebite victims in

China, with low education and limited social support identified as major risk factors. Similar studies have also emerged in India tracking victims of other human-wildlife conflict, reporting PTSD, using alcohol and other substances as common coping mechanisms (Jadhav and Barua, 2012).

In Goa, while no such study has been conducted, interviews strongly suggested that mental trauma persisted well beyond hospital discharge, especially in cases of long recovery or death of a family member. This dimension remains poorly understood and entirely untracked within existing public health systems.

Social Inequities and Marginalised Risk

Interview data also revealed how systemic vulnerabilities intersected with caste, class, migration status, and geography. Multiple rescuers and doctors indicated that migrant workers, especially those employed in construction or security, were at heightened risk of exposure, often lacked awareness of emergency services, and delayed treatment due to uncertainty or mistrust. As the SSO noted, “The percentage of migrants in snakebite cases is likely higher than locals, but we don’t have official data yet.” Several security guards interviewed in North Goa admitted that they did not know where to go in case of a bite, even after witnessing recent fatalities in their area, as their employers had never given them basic safety instructions.

In the case of the 8-year-old girl who died of a cobra bite in 2021 (Figure 2.5), one of the rescuers who had been present at the scene emphasised that her family were migrants with limited resources, “She was the daughter of a really lovely family from Gujarat.” He further speculated on the differential treatment the family may have received, “If it had been a middle demographic, Goan... there’s no way that things would have gone in the way that they did” These accounts suggested that both class and migrant status could be influencing care quality and amplified the socio-economic consequences of snakebite, also documented in wider literature looking at healthcare access to migrant workers in India (Adhikary et al., 2020).

Policy Gaps: Compensation and Data Infrastructure

Interview analysis underscored the absence of a systemic framework to support survivors or families of snakebite victims. The State Surveillance Officer confirmed that Goa does not currently classify snakebite as a medico-legal case (MLC) by default, nor does it link it to compensation schemes under either occupational hazards or wildlife conflict categories, saying, “Snakebite is both an occupational hazard and a human-wildlife conflict issue in Goa, especially for farmers and labourers in forested areas. (...) We are trying to shift all snakebite cases to Medical Legal Cases (MLCs) so that any future compensation schemes can be implemented properly.” Goa currently does not offer any form of financial compensation for snakebite victims or their families but as the SSO confirmed, “discussions are ongoing.” This stands in contrast to a few other Indian states that have begun integrating snakebite fatalities under wildlife conflict compensation or occupational hazard frameworks and giving compensations (MoEFCC, 2023; NAPSE, 2024). However, since no states have morbidity tracking, disabilities from snakebites are not being supported anywhere in India, either as a one-time payout or a longer scheme. Interestingly, compensations from big cats are given in some states upon injury or disability, with the amount corresponding accordingly (Karanth, Gupta and Vanamamalai, 2018). In some states compensation was contingent on the presence of the tiger outside the Protected Area (Chowdhurym et al., 2016). Interview data analysis revealed that parallel gaps in surveillance persist. Although Goa has made progress in standardising public hospital data, private hospitals are still under no obligation to report snakebite cases or deaths. Given that several respondents described seeking private follow-up care, this blind spot may obscure both morbidity and mortality trends, hiding many vulnerable victims.

Support mechanisms for human-snake conflict, and human-wildlife conflict in general, need to look at different resource support which needs to include financial as well as long-term mental health support. When an incident occurs, it is not experienced in isolation by the victim but the whole family unit, in both mortality and morbidity cases, and there are visible and indirect consequences (Barua, Bhagwat and Jadhav, 2013). Without such support mechanisms, many survivors and victim’s families reported prolonged hardship extending a long time.

2.4.6 Education, Awareness, and the Limits of Behavioural Change

Data analysis indicated that one of the most effective shifts in Goa's snakebite response was the rise in public awareness and treatment-seeking behaviour, particularly over the past two decades. As detailed in Section 2.4.2, interviews across districts revealed that hospital preference had overtaken traditional healing practices in most areas, contributing directly to reduced fatalities. However, interview analysis also highlighted the limits of this behavioural change. Awareness, while widespread in principle, remained uneven in practice, particularly among migrant workers and geographically isolated communities.

One recurring theme was the gap between general knowledge and specific preparedness. Interviewees confirmed that while most people in Goa had heard about antivenom and the importance of hospital treatment, they were still unclear on how to prevent a bite, or what to expect during treatment. As one rescuer observed, the bite of the 8-year-old girl (Figure 2.5) could have been avoided by simply checking dark areas, an awareness measure now widely recommended, but not always practiced, especially by new or mobile populations, who may simply not be cognizant of the risks.



Figure 2.5: Bite marks from a spectacled cobra bite on an 8-year-old child's hand

The bite occurred in Goa, India, when the girl was looking for a toy in her house's storeroom, in 2021, where a cobra was taking shelter in a dark corner. (Photo: Benhail Antao)

These gaps were especially pronounced among migrants, who often lacked both access to safety information and trust in the public health system. Security guards and construction workers interviewed across multiple locations admitted that they would not know whom to contact in case of a bite. As one rescuer explained, “If you’re a migrant worker in a rented place, nobody tells you anything about first-aid or hospitals.” These findings suggested that traditional awareness campaigns may not reach new populations effectively, and that messaging needs to adapt to changing demographics and urban growth patterns.

Another persistent issue was the continued influence of myths and misinformation. Despite greater hospital-seeking behaviour, interviewees across stakeholder categories reported ongoing misconceptions about first aid, antivenom use, and snakebite outcomes. One community member

noted, “Some people say antivenom makes you sicker. So, some still prefer to go to the temple first before the hospital.” A rescuer similarly shared saying, “The antivenom is bad for erectile dysfunction. It's not good for my head and body.” These statements, though medically unverified, reflect how rumours and personal experiences shape treatment choices, even among those with hospital access.

Several interviewees also described delayed treatment due to misplaced confidence in self-treatment or spiritual practices. In one case, a rescuer insisted he had sucked the venom out himself after a cobra bite and refused ASV, requiring a hospital to obtain his written consent for discharge, though likely he simply got lucky with a dry bite. In another, a fatality was reported after a bite victim was first taken to a temple. These examples underline the fragile trust that still exists around biomedical care, particularly in cases where side effects, past trauma, community memory or spiritual beliefs are involved.

At the same time, interview data also captured more nuanced, blended approaches to healing. In one case, a family, whose relative survived a cobra bite, credited the gods for her recovery but crucially, they rushed her to the hospital first. As the translator noted, “They weren’t foolish enough to leave everything to the gods. Being literate and having lived in Goa with snakes among their midst for several generations, through the awareness campaigns, they understood the importance of the hospital.” This reflects a more complex reality: spiritual belief does not always preclude scientific treatment but rather coexists with it when awareness has been internalised.

In sum, data shows while Goa’s public health system has made substantial strides in promoting hospital-based treatment, education gaps persist, particularly in vulnerable or overlooked populations. Myths about first aid and antivenom remain, and the emotional legacy of snakebite continues to influence behaviour. As the SSO noted, “We need more public awareness campaigns to teach people how to avoid snakebites and what to do in case of a bite.” These findings highlight the need for targeted awareness strategies that move beyond general messaging, adapt to demographic shifts, and address both cultural memory and practical

knowledge. Without such evolution, behavioural change may plateau, leaving new generations of at-risk individuals underprepared.

2.5 Conclusion: Toward Systemic Snakebite Mitigation and Goa's Relevance for India

Analysis of Goa's snakebite burden reveals that while the state's case fatality rate has remained comparatively low in recent years, this outcome cannot be attributed to a singular intervention. Instead, it reflects a combination of geographic, institutional, and behavioural factors that collectively improved access to care and trust in treatment systems. These include the rollout of the 108-ambulance network, availability of antivenom at the PHC level, improved referral chains, relatively high literacy, and shifts in public awareness, all contributing to faster treatment-seeking and reduced mortality. Goa's response to snakebite, while not without its limitations, offers a compelling example of how mortality can be reduced through a combination of decentralised data systems, rapid emergency referral, and sustained community awareness. The state's relatively low case fatality rate, achieved without radical structural overhauls, demonstrates that coordinated public health strategies can deliver life-saving outcomes even in resource-constrained settings.

At the same time, the chapter highlights structural factors that are not easily replicable. Goa's small geographic size and road connectivity enabled more efficient ambulance transport and inter-hospital referrals. Its relatively high literacy rate, dense public health network, and longstanding NGO involvement offered enabling conditions not uniformly present in more rural or densely populated states. Moreover, as subsequent sections have shown, critical gaps persist even in Goa, from the absence of morbidity tracking and compensation to species-specific treatment limitations and private sector blind spots, as well equitable inclusion of vulnerable groups.

In this context, Goa's experience does not serve as a perfect model, but rather as a proof of concept. It illustrates how multi-tiered improvements in emergency response, public engagement, and infrastructure can collectively bring down mortality, even in a setting with the Big Four and other medically significant species. As the National Action Plan for Snakebite Envenoming (NAPSE, 2024) moves toward state-specific implementation, Goa's trajectory may offer strategic insights, particularly in scaling up ambulance networks, decentralising antivenom access, and investing in training and public awareness. However, the gaps documented in this chapter also serve as critical reminders that success cannot be measured solely by deaths averted, and sustainable snakebite mitigation must account for the full spectrum of survivorship, equity, and systemic preparedness. These omissions point to a broader national challenge: snakebite continues to be treated primarily as a clinical emergency, rather than a systemic health and social issue. For India to achieve its snakebite mortality reduction goals, and meet the ambitions of the National Action Plan for Snakebite Envenoming, reflective of the bigger WHO goals (WHO, 2017), policy and public health discourse must extend beyond acute care. Snakebite must be integrated into long-term planning across healthcare, occupational safety, social equity, and conservation. Goa's trajectory underscores that meaningful progress is possible. But to replicate and scale such gains, snakebite must be embedded into the broader systems thinking it deserves.

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Chapter 3

Seasonal Drivers of Snake Rescue Trends in Goa, India

3.1 Abstract

Despite being a widespread human-wildlife conflict strategy in India, snake rescues remain poorly studied in terms of their ecological and seasonal drivers. This study presents the first long-term mixed-methods analysis of six years (April 2016 – March 2022) of snake rescue data from Goa, integrating Generalised Additive Models (GAMs) with in-depth interviews with rescuers to assess how climate, species behaviour, and human perception shape removal trends.

Species-specific behaviour, particularly mating, neonate dispersal, and habitat shifts, drive rescue peaks more strongly than climate alone. While temperature, rainfall, and humidity influence trends, rescues increase during key life-history stages, particularly for spectacled cobras, Russell’s vipers, and checkered keelbacks. Rat snakes, spectacled cobras, and Indian rock pythons accounted for the highest number of rescues, highlighting the overrepresentation of non-venomous species in removals. The data also reveal urbanisation-driven increases in rescues, particularly for bronzeback tree snakes and pythons.

This study also integrates local ecological knowledge (LEK) from Goa’s rescuers, which revealed that rescue trends were shaped not only by snake ecology but also by detection biases, habitat change, and public attitudes. Despite reducing retaliatory killings, rescues disproportionately involve non-venomous species, while medically significant snakes like kraits and saw-scaled vipers remain underreported. The lack of post-release monitoring and standardised reporting further limits understanding of whether rescues genuinely mitigate conflict or reinforce a cycle of removals.

The findings suggest that increasing rescues do not necessarily indicate rising snake populations but instead reflect heightened human detection, awareness, and habitat disturbances. Recognising these drivers can help develop more targeted awareness strategies that reduce unnecessary removals and support long-term coexistence strategies.

3.2 Introduction

Across India and many other countries, human-snake interactions are frequently managed through removal and translocation, often in response to concerns about snakebite risk and human-wildlife conflict (Shine and Koenig, 2001; Harvey et al., 2014; ckck, Morzillo and Christoffel, 2020). These interventions, commonly termed as “rescues”, aim to prevent retaliatory killings and mitigate potential encounters, particularly in urbanised areas where people may be unfamiliar with snakes and perceive all encounters as dangerous (Whitaker and Shine, 2000; Pandey et al., 2016). However, while some removals are necessary for safety (Salim et al., 2024), many occur due to fear and misinformation, even when the snake poses no direct threat (Samuel et al., 2020; Malhotra et al., 2021). This raises important questions about whether proactive education and seasonal risk awareness could reduce unnecessary removals and promote coexistence (Jesudasan and Abhilash, 2019).

Despite the widespread use of removals as a conflict management tool (Kuttalam et al., 2025), long-term studies examining how seasonality and climate influence human-snake interactions remain limited (Brown and Shine, 2002; Eskew and Todd, 2017; Malhotra et al., 2021). While some research has integrated human-snake interaction data with environmental patterns to examine snakebite risk (Chaves et al., 2015; Goldstein et al., 2021), others have primarily focused on species distribution models to predict habitat suitability rather than analysing recorded removals (Yañez-Arenas et al., 2014; Yousefi et al., 2020; Martinez et al., 2024). Climate change is increasingly altering species distributions, seasonal activity patterns, and the frequency of human-wildlife encounters (Zacarias and Loyola, 2019; Trivedi and Desai, 2008; Yañez-Arenas et al., 2016). Understanding how climate-linked variables shape human-snake interactions at the local level is critical to anticipating future risks and designing adaptive conflict mitigation strategies.

In India, particularly, there has been little work assessing these patterns using empirical datasets spanning multiple years (Malhotra et al., 2021). Without such data, human-snake conflict

management remains reactive rather than proactive, relying on removals rather than targeted awareness efforts that could encourage coexistence (Togridou et al., 2019).

Furthermore, all snake species in India are legally protected under the Wildlife Protection Act (WPA) of 1972 (WPA, 1972; Whitaker, 2018), meaning that removals must involve the Forest Department (FD) (Karanth, Gupta and Vanamamalai, 2018). Unauthorised handling, relocation, or translocation is illegal, reinforcing the need for structured, standardised data collection (Whitaker and Shine, 2000; Malhotra et al., 2021). However, India lacks a centralised database for tracking snake rescues, making it difficult to assess the true scale of removals, the role of awareness interventions, or their impact on human-snake conflict mitigation (Bennett et al., 2017; Ramesh and Nehru, 2019; Malhotra et al., 2021). While the Ministry of Environment, Forest, and Climate Change (MoEFCC) introduced the 2023 for Mitigating Human-Snake Conflict (MoEFCC, 2023) emphasising awareness as a key intervention, no study has quantitatively assessed in India how seasonal rescue trends could inform these strategies at a local or national level (Menon et al., 2022).

Without a clear understanding of what drives rescues, whether it is climatic shifts, species-specific behaviour, or human perception, management strategies risk being reactive rather than evidence-based, potentially reinforcing cycles of unnecessary removals rather than fostering coexistence. The structured Goa FD records provide a unique opportunity to analyse how seasonality and climate influence recorded interactions (Spence-Bailey et al., 2010). As the largest organised and legally mandated government authority handling human-snake interactions in Goa, the Forest Department's records represent the most consistent and systematically maintained dataset available. While removals by private rescuers also occur in large numbers, they are fragmented across small, uncoordinated factions and remain undocumented. This makes FD data the best available resource for identifying long-term trends in human-snake interactions, even if absolute numbers are underestimated.

This chapter examines how seasonality and climate influence human-snake interactions by analysing six years of rescue records in Goa, along with qualitative interviews. By identifying

relationships between rescue trends, climatic variables, and species-specific activity patterns, it explores the extent to which observed interactions align with known ecological behaviour and whether seasonal rescue peaks may also reflect patterns in human reporting and response.

Through that central question, the chapter addresses the following:

- When are snake rescues most common in Goa, and how do seasonal patterns vary across species?
- To what extent are rescue peaks shaped by ecology, behaviour, climatic factors, or human perception and detection?
- How do urbanisation, rescuer activity, and reporting structures influence which species are encountered and recorded?
- Do rescue records reliably reflect species activity and ecological risk, or are they biased toward more visible and frequently misidentified species?
- What insights can a combined modelling and qualitative approach offer for interpreting seasonal human-snake interactions and informing mitigation efforts?

This study presents the first known integration of long-term rescue records, climate data, and qualitative insights to assess seasonal trends in human-snake interactions in India. Analysing Forest Department records from April 2016 to March 2022, it uses Generalised Additive Models (GAMs) to evaluate how temperature, humidity, and rainfall correlate with snake encounter reports. The findings provide critical empirical data to support more proactive, evidence-based mitigation strategies for human-snake conflict.

3.3 Methods

This study employed a mixed-methods approach to examine snake rescue trends in Goa, combining quantitative analysis of rescue data with qualitative insights from stakeholder interviews (Bryman, 2016; Bennett et al., 2017; Ibbett et al., 2023). The quantitative component analysed six years (April 2016 – March 2022) of rescue records to assess seasonal and climatic

influences on snake rescues using GAMs (Murase et al., 2009). The qualitative component drew on semi-structured interviews conducted as part of a broader study on human-snake interactions, with only the portions relevant to rescue trends, species encounter frequencies, and seasonal variations extracted for analysis in this chapter (Ibbett et al., 2023).

Both methods were integrated to ensure that statistical trends were interpreted within ecological and social contexts (John et al., 2012). The integration of these datasets allowed for a more comprehensive understanding of how seasonality, climate, and human activity patterns influenced rescue frequencies. The following sections detail data collection, processing, and analysis methodologies for both components.

3.3.1 Quantitative Data

Data Collection and Preparation

Rescue data spanning six years (April 2016 – March 2022) was obtained from the Goa Forest Department. This dataset included records of reptile, avian, and mammal rescues, with a focus on snake rescues. The data was sorted by month, year, and district (North and South Goa) following state administrative boundaries. A map of Goa's administrative boundaries can be found in Figure 1.1, in Chapter 1.

Species identification in rescue records was inconsistent, reflecting challenges in field identification (Salim et al., 2024), varied expertise among recorders, and non-standardised naming conventions (Henke et al., 2019). To ensure consistency and accuracy in statistical analyses, a standardised classification system was applied. This involved retaining species-level identification where possible while grouping certain taxa at the genus level when identification was ambiguous or inconsistently recorded (Glaudas, 2021).

Where identification was unambiguous, records were retained at the species level. These included:

- Rat snake (*Ptyas mucosa*)
- Spectacled cobra (*Naja naja*)

- Russell's viper (*Daboia russelii*)
- Indian rock python (*Python molurus*)
- Whitaker's boa (*Eryx whitakeri*)
- Checkered keelback (*Fowlea piscator*)
- Striped keelback (*Amphiesma stolatum*)
- Forsten's cat snake (*Boiga forsteni*)
- Common krait (*Bungarus caeruleus*)
- King cobra (*Ophiophagus hannah*)
- Bamboo pit viper (*Trimeresurus gramineus*)
- Green vine snake (*Ahaetulla nasuta*)
- Saw-scaled viper (*Echis carinatus*)
- Malabar pit viper (*Craspedocephalus malabaricus*)
- Hump-nosed pit viper (*Hypnale hypnale*)
- Dog-faced water snake (*Cerberus rynchops*)
- Beddome's cat snake (*Boiga beddomei*)
- Banded racer (*Argyrota fasciolata*)
- Ornate flying snake (*Chrysopelea ornata*)
- Trinket snake (*Coelognathus helena*)
- Dumeril's black-headed snake (*Sibynophis subpunctatus*)

However, due to inconsistencies in reporting and the absence of standardised species identification protocols during rescues, some taxa were grouped at the genus level where species-level resolution was unreliable (Kuttalam et al., 2025). These included:

- Wolf snake (*Lycodon* spp.)
- Kukri snake (*Oligodon* spp.)
- Coral snake (*Calliophis* spp.)

Additionally, an "Other Snakes" category was used for ambiguous records where species identification was unclear or where multiple species were recorded together in a single entry (e.g., "rat snake and Whitaker's boa"). This ensured that unidentifiable or mixed records did not

skew the species-level analysis. Further classifications, including venom status and WHO medical significance categories (Sirur et al., 2022; Sirur et al., 2022; WHO, 2017) were assigned based on established literature and expert consensus. The full classification table, detailing these attributes for key species is available in Supplementary Sheet S1 (henceforth referred to as S1), Section I, Table S1.1.

Duplicate records, such as multiple rescues of the same species at the same location and date, were consolidated to avoid overrepresentation. This ensured that each recorded rescue reflected a distinct event rather than repeated entries of the same individual. Rescue count, used as the dependent variable in the statistical models, was calculated after removing duplicate records. Rescue events were first cleaned and aggregated by month, species, and district (North and South Goa) to facilitate summary analyses and visualisation. For the GAMs, monthly rescue counts were modelled against state-level averages of temperature, humidity, and rainfall, ensuring consistency with the spatial resolution of the climate data.

Climate Data Sources and Processing

To assess the influence of climate on snake rescues (Martinez et al., 2024), three key monthly variables were extracted: mean temperature (°C) from MODIS satellite data (Yu et al., 2022), relative humidity (%) from the ERA5 reanalysis dataset (Vanella et al., 2022), and total rainfall (mm) from CHIRPS precipitation estimates (Funk et al., 2015, Ver Hoef and Boveng, 2007). These datasets provided high-resolution climate information across Goa. To ensure spatial alignment between rescue records and climate variables, a shapefile of Goa was created, dividing the state into North and South districts. The shapefile was uploaded to Google Earth Engine, where climate data was overlaid and extracted for each district, ensuring consistency in spatial analysis and rescue records (Srinivasulu, Srinivasulu and Srinivasulu, 2021).

Data Processing and Statistical Analysis

All data processing and trend visualisations were conducted using Microsoft Excel and running R (v4.4.2, 2024-10-31). Excel was used for initial data cleaning, basic trend visualisation, and exploration of seasonal patterns in rescue frequencies over time. RStudio was used for statistical

modelling, specifically applying Generalised Additive Models (GAMs) using the ‘mgcv’ package (Wood, 2017) to assess nonlinear relationships between climate variables and rescue counts. Additional data manipulation and visualisation were performed using the ‘dplyr’ and ‘ggplot2’ packages (Wickham et al., 2019). GAMs allow for nonlinear relationships between predictors and rescue counts, making them particularly suitable for ecological time-series data.

To examine the effects of seasonality and climate on species-specific rescue trends, Generalised Additive Models (GAMs) with a Poisson distribution were applied, modelling species-wise monthly rescue counts against predictor variables of month, temperature, humidity, and rainfall. The Poisson family is commonly used for count data (Zuur et al., 2009) and was appropriate given the non-negative, integer nature of the response variable. Model diagnostics were used to assess dispersion and confirm model suitability. GAMs were used to examine the influence of seasonality and climatic factors on snake rescues, accounting for potential non-linear relationships between these predictors and rescue numbers. Unlike linear models, which assume a constant rate of increase or decrease, GAMs allow for greater flexibility in detecting complex trends that may fluctuate across different seasons or environmental conditions.

Collinearity Checks and Predictor Selection

Since temperature, humidity, and rainfall are often correlated, collinearity was assessed prior to model selection using Pearson correlation coefficients. Rainfall and humidity were highly correlated ($r = 0.78$), indicating redundancy when both were included in the same model. Based on this, humidity and rainfall were never included together in the same model to avoid multicollinearity issues.

A two-step model selection approach was applied separately for each species:

1) Testing Individual Predictors (Month + One Climate Variable)

- Poisson GAMs were fitted with month (seasonality) as a constant and each climate variable (temperature, humidity, rainfall) separately.

- Model performance was compared using Akaike Information Criterion (AIC) (Wagenmakers and Farrell, 2004), and the variable with the lowest AIC was retained for further refinement.

2) Finalising the Best Model for Each Species

- The best-performing single-predictor model was expanded to include an additional climate variable (e.g., temperature + humidity) where appropriate.
- If an additional predictor resulted in a lower AIC, it was retained in the final model, unless collinearity issues were detected.

Addressing Overdispersion and Model Selection

Overdispersion, where variance exceeds the mean, was assessed by examining the ratio of deviance to degrees of freedom in the Poisson GAM. A ratio of 4.44 confirmed overdispersion, prompting tests of alternative models to determine if a better fit could be achieved (Ver Hoef and Boveng, 2007; Cox, West and Aiken, 2009; Cameron and Trivedi, 2013). A full list of the alternative models that were run are available in Supplementary Sheet S3 (henceforth referred to as S3), Section I.

Final Model and Interpretation

The final model equation was:

$$\text{rescue_count} \sim s(\text{month}, k = 6) + s(\text{temperature}, k = 6) + s(\text{humidity}, k = 6)$$

or

$$\text{rescue_count} \sim s(\text{month}, k = 6) + s(\text{temperature}, k = 6) + s(\text{rainfall}, k = 6)$$

where:

- Month (Categorical, 1–12) accounts for seasonal variation.
- Temperature (°C, standardised) represents climatic influence on snake movement and human encounters.

- Humidity (% , standardised) captures moisture-related effects on rescues.
- Rainfall (mm, standardised) assesses whether precipitation affects snake movement or rescue patterns.

Continuous climate predictors (mean temperature, relative humidity, and total rainfall) were z-standardised using the `'scale()'` function in R. This ensured that all smoothing terms in the GAMs were fitted on comparable scales, improving numerical stability and interpretability. Standardisation also avoids smoothing penalties being affected by differences in measurement units or data range (Wood, 2017).

The models tested the effects of month, temperature, humidity, and rainfall on rescues. Several statistical outputs help interpret these relationships. The effective degrees of freedom (EDF) indicate the complexity of the relationship between a variable and rescue numbers. A low EDF ($\sim 1-2$) suggests a linear effect, where rescues increase or decrease steadily as the variable changes. A high EDF (>3) suggests a non-linear relationship, where rescues fluctuate at different thresholds rather than following a smooth trend.

The chi-square (χ^2) statistic measures the strength of association between each predictor and rescue trends. Higher χ^2 values indicate a stronger effect, meaning that changes in temperature, rainfall, or month are more strongly linked to fluctuations in rescues. The p-value determines statistical significance, with values below 0.05 confirming that the predictor has a meaningful influence on rescues.

Additional measures were used to assess the overall fit of each model. The deviance explained (%) represents how much variation in rescues is captured by the model, with higher values indicating stronger predictive power. Model selection was based on the Akaike Information Criterion (AIC), where lower values indicate a better-fitting model.

All GAM plots display the predicted log rescue rate, with the model intercept $\exp(\text{Intercept})$ corresponding to baseline rescue levels. Higher values indicate an increase in rescues relative to baseline, while lower values indicate a decrease. Each smooth function is modelled independently, meaning y-axis scales may differ between predictors. However, all effects should be interpreted relative to the baseline log rescue rate ($\exp(\text{Intercept})$). While some studies centre smooth plots at zero to highlight only deviations from the mean effect, retaining the intercept here allows for more intuitive interpretation of the absolute predicted trends across species. This approach is especially useful given that the Forest Department dataset, though incomplete, remains the most structured and consistent record of human-snake interactions available in Goa. The rescue counts modelled here reflect observable trends from this dataset and are not intended to represent total population-level rescues.

Species Ranking and Selection for GAM Analysis

Species included in the GAM analysis were selected based on total rescue frequency recorded across all of Goa over the full six-year period (April 2016 to March 2022). The dataset was ranked by species, month, and district to identify the most frequently rescued species. Initially, species with at least 100 total rescues, over the six-year period, were considered. However, preliminary GAM results showed that species with fewer than 300 total rescues led to high deviance and overfitting, reducing model reliability. Therefore, to maintain statistical robustness, only species with more than 300 recorded rescues over the full dataset were included in the final GAM analysis. This criterion yielded a final selection of nine species for GAM analysis. These were the rat snake, spectacled cobra, Indian rock python, Whitaker's boa, Russell's viper, checkered keelback, wolf snake, bronzeback tree snake, and common krait. However, since the wolf snake records were at a genus level (*Lycodon* spp.), they were excluded from the final selection.

Although the saw-scaled viper (*Echis carinatus*) is medically significant, it was excluded due to insufficient rescue data (<300 records statewide over six years).

3.3.2 Qualitative Data

This chapter draws on a subset of qualitative data collected as part of a broader study on human-snake interactions and rescue dynamics in Goa. A preliminary phase was conducted from September to October 2021 to establish a baseline understanding of human-snake interactions, followed by the main fieldwork between February 2022 and January 2024. Interviews were conducted across both North and South Goa, spanning rural, peri-urban, and urban locations to reflect diverse ecological and social contexts.

A total of 68 semi-structured, open-ended interviews were carried out using snowball and convenience sampling to reach individuals with direct or professional experience related to snake rescues, encounter patterns, and ecological observations. For this chapter, only material relevant to rescue frequency, seasonal activity, species encounter trends, and climate-linked movement was extracted for thematic analysis.

The following stakeholder groups contributed to these themes:

- Forest Department officials: observations on seasonal fluctuations in rescue calls, jurisdictional differences, and reliance on private rescuers
- Private rescuers and Herpetologists: species-specific encounter peaks, behavioural triggers for rescues, climatic influences on snake visibility, ecological perspectives on snake movement, breeding periods, and habitat-linked emergence patterns
- Community members and migrant workers: perceived seasonal risks, frequency of encounters across monsoon and dry seasons, and changes in local snake presence
- Security guards and informal responders: first-hand seasonal encounter accounts in residential or commercial spaces
- Veterinarians and clinicians: select insights linking rescue trends to bite cases or species visibility during certain months

Interview Protocol and Data Management

All interviews were recorded with prior informed consent, ensuring anonymity unless explicit permission was given for attribution (Bryman, 2016). The primary mode of data collection was audio recordings, with consent obtained on record. In cases where interviewees were uncomfortable with recording, written notes were taken instead. Interviews were conducted in English, Konkani, and Hindi, depending on participant preference.

Data Processing and Thematic Analysis

The recorded interviews were translated and transcribed into English using TurboScribe, an AI-powered transcription tool based on Whisper (Python-based voice recognition and translation). All transcripts were manually reviewed for accuracy before thematic coding (Belotto, 2018). Using a structured thematic analysis approach (Clarke and Braun, 2017), qualitative analysis focused on five core themes aligned with the chapter's objectives:

- Seasonal variation in snake rescues
- Changes in species-specific activity across months
- Influence of mating and breeding periods on rescue peaks
- Climatic conditions (rainfall, humidity, temperature) affecting snake detectability
- Human activity patterns shaping encounter likelihood and reporting

Coding was manually done using Excel to identify patterns and link interview insights with observed statistical trends from the GAM models. Thematic insights were then used to interpret patterns observed in the GAM models, contextualising seasonal peaks, explaining mismatches across species, and identifying potential detection biases or human behaviour effects not captured in rescue records alone.

3.3.3 Ethical Clearance

Ethics clearance was obtained in September 2021 from Ethics Committee of the School of Anthropology and Conservation, University of Kent (approval number: 16-PGR-20/21). TurboScribe was chosen because all files are encrypted at rest. None of the audio files contain

identifiable information about the interviewee unless they explicitly gave permission to use the same. Access to the files is strictly controlled only to the account holder and once the account is deleted, all data is automatically deleted. No third party has access to the files, nor are they retained by TurboScribe. The files were only uploaded for the purposes of the transcriptions and the account deleted as soon as the text files were ready. All qualitative data has been securely stored on university servers and personal secured hard drives, and no identifiable personal information has been retained unless explicit permission was granted.

3.4 Results

3.4.1 Overall Rescue Trends

Between April 2016 and March 2022, a total of 30,567 snake rescues were recorded across North and South Goa. Rescue counts varied across years, ranging from 3,668 rescues in 2017–18 to 6,383 rescues in 2021–22 (Table 3.1). While fluctuations occurred, linear regression analysis indicated no statistically significant increase in rescue counts over time ($\beta = 363.9$, $p = 0.093$), suggesting that the observed fluctuations may reflect natural variability rather than a consistent directional trend.

Table 3.1: Total snake rescues recorded in North and South Goa by rescue year (April–March, 2016–2022)

Rescue Year	North Goa	South Goa	Total Rescues
2016–17	2,491	2,521	5,012
2017–18	1,785	1,883	3,668
2018–19	2,796	2,243	5,039
2019–20	2,311	2,424	4,735
2020–21	2,488	3,242	5,730
2021–22	2,495	3,888	6,383
Total	14,366	16,201	30,567

Note: Data reflects all snake rescues recorded in the Goa Forest Department dataset. Rescue year is defined from April to March to align with seasonal analyses.

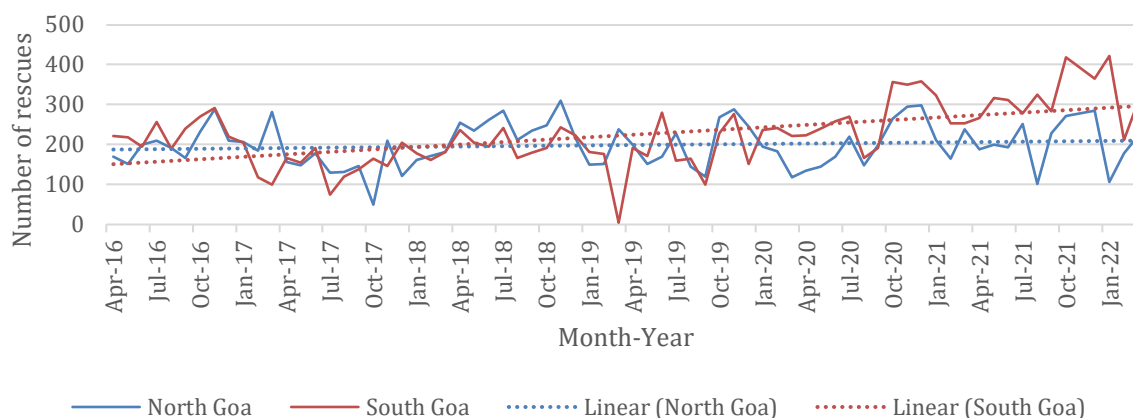


Figure 3.1: Total number of monthly snake rescues recorded in North Goa and South Goa from April 2016 to March 2022.

Linear trendlines added for visual reference. Note: No statistically tested linear trend is applied in the main analysis, and apparent trends should be interpreted cautiously given non-significant regression results ($p = 0.093$)

3.4.2 Species Classification and Rescue Numbers

A total of 26 snake species were recorded in the dataset. However, the actual number may be higher, as some species were grouped at the genus level due to identification inconsistencies. Across all recorded rescues, species were categorised into three groups based on venom classification: venomous, non-venomous, and mildly venomous. A total of 11,034 rescues involved venomous snakes, which included both WHO Category 1 species- those considered highly venomous with high medical risk- and Category 2 species, which are venomous but associated with lower recorded human exposure in India. In contrast, non-venomous species accounted for the majority of rescues, with 19,254 individuals recorded. A smaller subset of 279 rescues involved mildly venomous species, which are not listed under WHO classifications but are recognised for possessing weak venom with limited medical significance. Full classification criteria and species-level categorisation are provided in S1, Section I.

3.4.3 Rescue Numbers Across Species

Among the recorded species, rescues were highly skewed toward a few dominant species. The 17 most frequently rescued species accounted for most recorded rescues, as shown in Table 3.2. A full list of all the 26 species is available in S3, Section II, Table S3.1.

Table 3.2: List of all the species rescued in North Goa and South Goa from April 2016 to March 2022 by the Goa Forest Department

Sr. No.	Common Name	Scientific Name	North Goa Rescues	South Goa Rescues	Total Rescues	% of Total Rescues
1.	Rat snake	<i>Ptyas mucosa</i>	3773	4620	8393	27.5
2.	Spectacled cobra	<i>Naja naja</i>	2725	5584	8309	27.2
3.	Indian rock python	<i>Python molurus</i>	2300	2113	4413	14.4
4.	Whitaker's boa	<i>Eryx whitakeri</i>	1528	834	2362	7.7
5.	Russell's viper	<i>Daboia russelii</i>	1145	1068	2213	7.2
6.	Checkered keelback	<i>Fowlea piscator</i>	619	535	1154	3.8
7.	Wolf snake	<i>Lycodon</i> spp.	370	613	983	3.2
8.	Bronzeback tree snake	<i>Dendrelaphis tristis</i>	727	237	964	3.2
9.	Common krait	<i>Bungarus caeruleus</i>	204	98	302	1.0

10.	Trinket snake	<i>Coelognathus helena</i>	95	95	190	0.6
11.	Forsten cat snake	<i>Boiga forsteni</i>	57	126	183	0.6
12.	King cobra	<i>Ophiophagus hannah</i>	57	58	115	0.4
13.	Striped keelback	<i>Amphiesma stolatum</i>	38	50	88	0.3
14.	Kukri	<i>Oligodon</i> spp.	32	36	68	0.2
15.	Green vine snake	<i>Ahaetulla nasuta</i>	35	21	56	0.2
16.	Bamboo pit viper	<i>Trimeresurus gramineus</i>	39	1	40	0.1
17.	Saw scaled viper	<i>Echis carinatus</i>	24	11	35	0.1

3.4.4 Regional Variations and Species Distribution Observations

Rescue numbers were not evenly distributed across Goa, with South Goa recording a total of 16,201 rescues compared to 14,366 in North Goa (Table 3.1). However, species-specific rescue patterns differed substantially between the two districts (Table 3.2).

In North Goa, the most frequently rescued species were rat snakes (3,773 rescues), spectacled cobras (2,725 rescues), and Indian rock pythons (2,300 rescues). In contrast, South Goa recorded more spectacled cobra rescues (5,584 rescues) than North Goa, with rat snakes (4,620 rescues) and Indian rock pythons (2,113 rescues) also among the most encountered species. Additionally, Russell's vipers (1,068 rescues) and Whitaker's boas (834 rescues) were more frequently

recorded in South Goa than in the northern district.

To assess whether species-wise rescue distributions differed significantly between districts, a chi-square test was conducted using the top 10 most frequently rescued species. The test revealed a highly significant difference ($\chi^2 = 1461.9$, $df = 9$, $p < 0.001$), confirming that observed regional variations in rescue counts were not due to chance.

While all recorded species were present in both districts, some showed notably uneven distributions (refer to Table 3.2). Spectacled cobras were far more common in South Goa, with 5,584 rescues compared to 2,725 in the North. In contrast, Whitaker's boas and bronzeback tree snakes were rescued more frequently in North Goa. King cobras and trinket snakes exhibited a nearly equal distribution across the two districts. Bamboo pit vipers were almost exclusively recorded in North Goa, accounting for 39 of the 40 total rescues. Common kraits were also more prevalent in the North (204 vs. 98), while Forsten's cat snakes showed the opposite trend, with 126 rescues in the South compared to 57 in the North. Ornate flying snakes, though rare overall, were more commonly found in the South (21 vs. 3), whereas coral snakes were more frequently recorded in North Goa (refer to S3, Section II, Table S3.1).

Despite these variations, no species was exclusive to either district, indicating a broad geographic presence across Goa for all species recorded. Several less frequently rescued species, such as green vine snakes, striped keelbacks, and kukri snakes, were recorded in low numbers across both districts (Table 3.2). These rescues were often incidental and involved arboreal or cryptic species entering residential areas, as noted by rescuers.

3.4.5 Seasonality and Generalised Additive Models (GAMs)

To examine the influence of climatic seasonality on snake rescues, Generalised Additive Models (GAMs) were fitted for eight species with sufficient rescue records across the six-year period (April 2016 to March 2022). As species-specific ecological data for Goa remains limited, the statistical outputs were contextualised using field observations and interview data collected

during this study. To facilitate cross-species comparison, the eight modelled snakes were grouped into venomous and non-venomous categories based on WHO classification and clinical significance. The following sub-sections present GAM results for three venomous species (spectacled cobra (*Naja naja*), Russell's viper (*Daboia russelii*) and common krait (*Bungarus caeruleus*), followed by five non-venomous species (rat snake (*Ptyas mucosa*), Indian rock python (*Python molurus*), Whitaker's boa (*Eryx whitakeri*), checkered keelback (*Fowlea piscator*) and bronzeback tree snake (*Dendrelaphis tristis*). Only the best fitting models, with the lowest AIC, were chosen for the final analysis. All models included month, temperature, and either humidity or rainfall as predictor variables (Table 3.3). AIC comparisons for all Poisson GAM models are provided in S3, Section III-A (Table S3.2). Corresponding monthly rescue graphs for the eight species are presented in in S3, Section III-B (Figures S3.1-3.8.). For a detailed breakdown of Goa's climate, see S1, Section II.

Table 3.3: Summary of Generalised Additive Models (GAMs) assessing the effects of seasonality and climate variables on monthly snake rescue counts in Goa

For each species, the table presents the effective degrees of freedom (EDF), chi-square statistic (χ^2), and significance level (p-value) for each predictor included in the best-fitting model (lowest AIC), with deviance explained (%) reported as a measure of model fit. Monthly rescue count was modelled as the dependent variable for all species. Month was included as a standard predictor in every model and is listed first. Additional predictors (temperature, humidity, or rainfall) are arranged in descending order of influence based on χ^2 values.

Species	Predictor	EDF	Chi-Square (χ^2)	p-value	Deviance Explained (%)	AIC
Spectacled Cobra	Month	4.93	313.77	<0.001	23.50%	2546.296
	Temperature	4.89	258.88	<0.001		
	Rainfall	4.62	80.27	<0.001		
Russell's Viper	Month	4.59	36.87	<0.001	51.10%	1227.431
	Humidity	4.17	40.88	<0.001		
	Temperature	2.87	9.97	0.0377		
Common Krait	Month	4.4	28.16	<0.001	35.70%	586.431
	Rainfall	4.6	15.94	0.0178		
	Temperature	4.15	10.17	0.0894		
Rat Snake	Month	4.97	264.2	<0.001	39.20%	2553.762
	Temperature	4.74	153.6	<0.001		
	Rainfall	4.92	130.3	<0.001		
Indian Rock Python	Month	4.89	87.58	<0.001	61%	1557.858
	Temperature	4.78	150.68	<0.001		
	Humidity	4.61	69.97	<0.001		
Whitaker's Boa	Month	4.59	36.87	<0.001	51.10%	1227.431
	Humidity	4.17	40.88	<0.001		
	Temperature	2.87	9.97	<0.0377		
Checkered Keelback	Month	4.93	51.94	<0.001	35.40%	936.6318
	Humidity	4.41	42.24	<0.001		
	Temperature	3.17	17.89	0.00225		
Bronzeback Tree Snake	Month	1	14.77	<0.001	31.80%	991.0702
	Temperature	4.9	168.2	<0.001		

A. Venomous Species

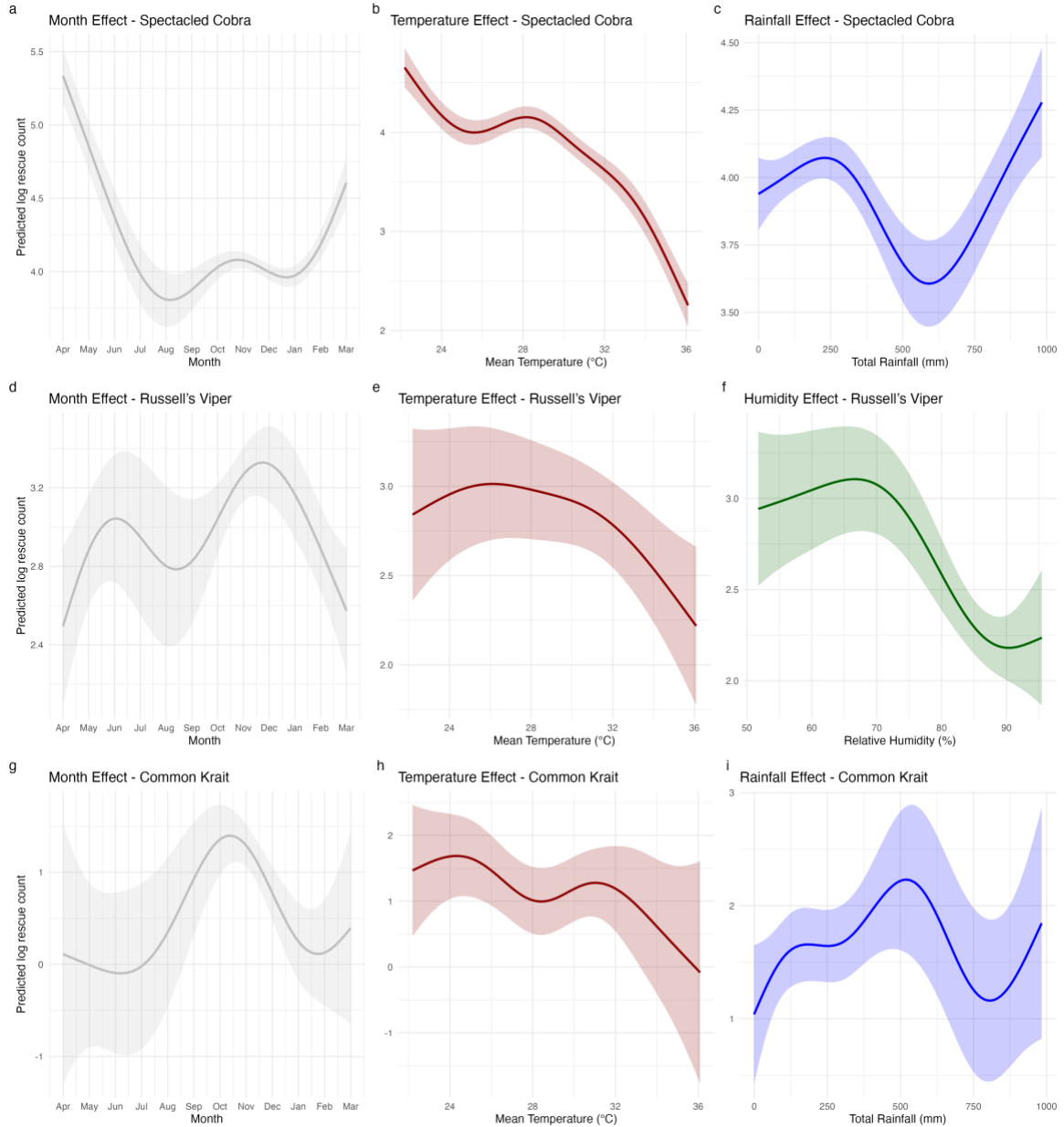


Figure 3.2: Generalised Additive Models for seasonal and climatic effects on venomous snake rescues in Goa. Predicted smoothed effects of month, temperature, rainfall/humidity on (a–c) spectacled cobra rescues, (d–f) Russell's viper rescues, and (g–i) common krait rescues, based on GAM outputs. Shaded bands indicate 95% confidence intervals. Y-axis represents predicted log rescue count from each GAM, while holding other predictors at median values.

Spectacled cobra (Naja naja)

The best-fitting GAM included month, temperature, and rainfall as predictors, explaining 23.5% of the deviance in spectacled cobra rescue counts (Table 3.3). Month had the strongest effect on rescue trends, followed by temperature and rainfall. Spectacled cobra rescues occurred throughout the year but showed marked seasonal variation. Rescues declined steadily from June through August, reaching the lowest levels during the monsoon, before rising again in October–November. A second, more consistent increase was observed from January through March, peaking in April, indicating a bimodal seasonal pattern. Rescue probability was highest at moderate temperatures (~22–28°C) and declined sharply at higher values. Similarly, rainfall showed a complex relationship, with rescues initially stable or slightly reduced during moderate rainfall (300–600 mm) but increasing under higher rainfall conditions (refer to Figure 3.2, a-c).

These seasonal fluctuations correspond with field observations from rescuers, who reported increased cobra sightings during the early monsoon, followed by fewer rescues during the peak rainfall period. The observed rainfall patterns also aligned with interview insights describing snakes being displaced from burrows during the first heavy rains. Interview data further attributed the subsequent decline in rescues both to logistical challenges, such as reduced visibility and limited access during flooding, and to a pattern in which snakes were said to “settle down” after the initial displacement.

Additional increases in March–April were often linked by rescuers to the mating season. Rescuers reported that hatchlings typically emerge between mid-June and August–September. Interview data and field observations suggested that the subsequent rise in rescues during October–November may reflect juvenile dispersal and increased chance encounters with humans.

Russell’s viper (Daboia russelii)

The best-fitting GAM included month, humidity, and temperature as predictors and explained 51.1% of the deviance in rescue counts (Table 3.3). Month had the strongest effect, followed by humidity and temperature. Russell’s viper rescues showed a clear seasonal pattern, increasing from October and peaking between November and December, followed by a decline from

January onward. A modest secondary rise occurred between May and July, before rescues dropped during the monsoon months (refer to Figure 3.2, d-f).

Rescues were most likely during periods of moderate humidity (~65–75%), declining at higher values. Temperature also had a non-linear effect, with rescues increasing at moderate temperatures (~26–30°C) and declining at higher levels. Fewer rescues were recorded during March and April, coinciding with the late dry season in Goa. Interview data did not provide a consistent explanation for this dip. However, this period corresponds with the region's hottest and driest conditions, with average temperatures reaching ~35°C and humidity levels dropping to 50–70% (refer to S1, Section II).

Interview data supported the observed seasonal peaks, with rescuers reporting increased activity just before and during the mating season (October–December, tapering off in January). The secondary rise in rescues between May and July was possibly linked to neonate births, as rescuers observed that Russell's vipers in Goa typically give birth during late May to early July.

Common krait (Bungarus caeruleus)

The best-fitting GAM included month, rainfall, and temperature as predictors and explained 35.7% of the deviance in rescue counts (Table 3.3). Month had the strongest effect on rescue trends, followed by rainfall, while temperature showed a weaker trend that was not statistically significant.

Common krait rescues showed a moderate seasonal pattern. Rescue counts were low between May and July, reaching their lowest values in June, before increasing toward a peak in September–November. A small decline followed between November and January, though rescue numbers remained higher than during early monsoon. Rainfall showed a non-linear influence, with rescues increasing at moderate levels (~400–600 mm), declining slightly around ~750 mm, and then rising again beyond 800 mm, although confidence intervals widened at those extremes. Temperature effects were weaker but suggested a gradual decline in rescues above 32°C (refer to Figure 3.2, g-i). Despite their nocturnal habits and relatively elusive nature, interview data

indicated that krait activity increased toward the end of the monsoon, particularly in September–October. While mating was rarely observed, rescuers noted combat behaviour during this period, which may have contributed to the seasonal spike in rescue calls.

B. Non-Venomous Species

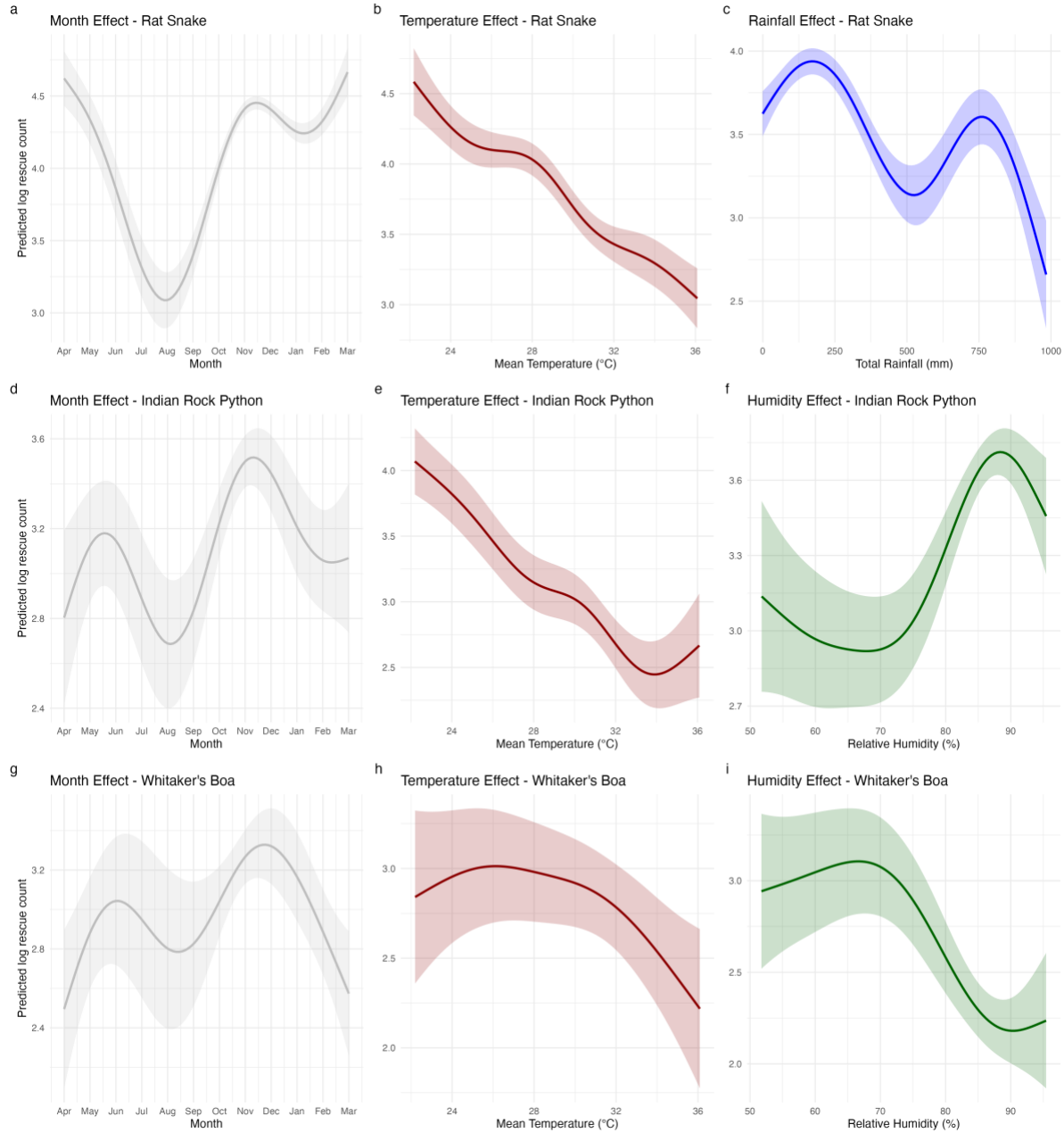


Figure 3.3: Generalised Additive Models for seasonal and climatic effects on non-venomous snake rescues in Goa (I)

Predicted smoothed effects of month, temperature, rainfall/humidity on (a–c) rat snake rescues, (d–f) Indian rock python, and (g–i) Whitaker's boa rescues, based on GAM outputs. Shaded bands indicate 95% confidence intervals. Y-axis represents predicted log rescue count from each GAM, while holding other predictors at median values.

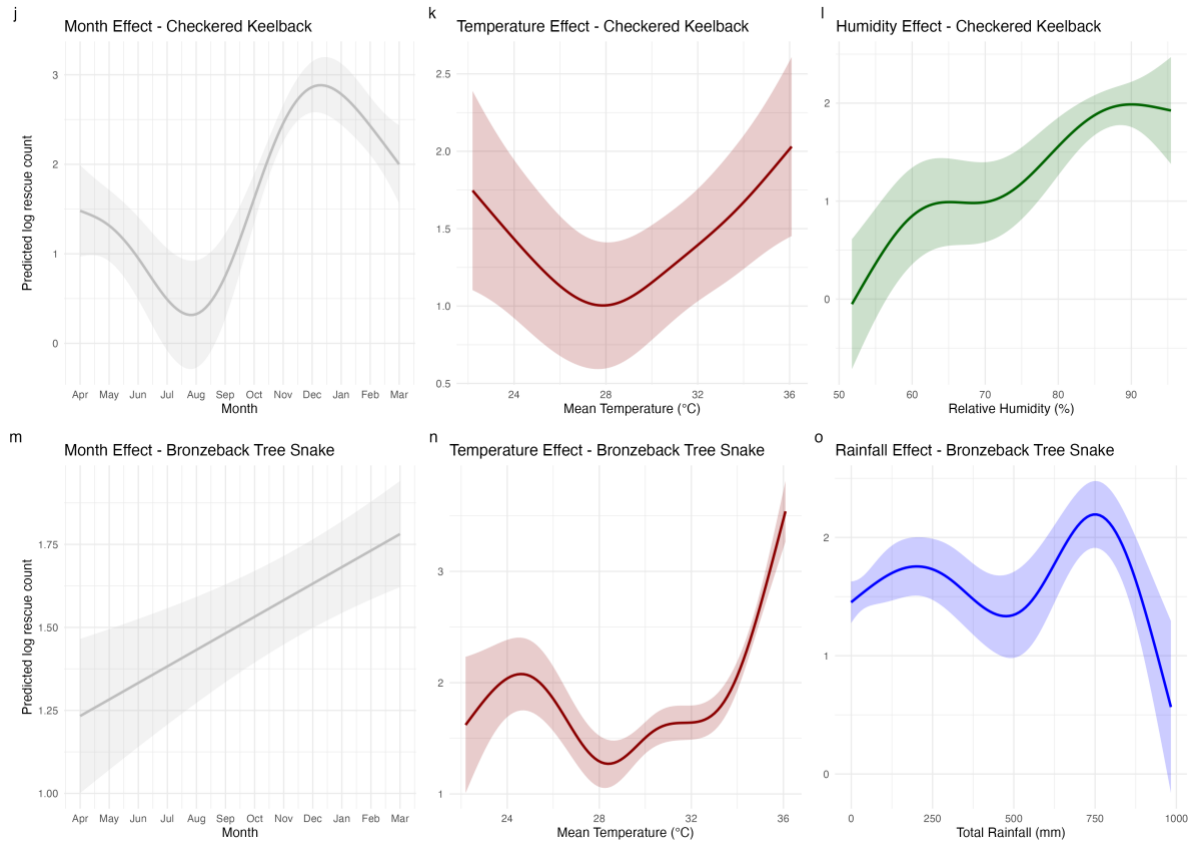


Figure 3.4: Generalised Additive Models for seasonal and climatic effects on non-venomous snake rescues in Goa (II)

Predicted smoothed effects of month, temperature, rainfall/humidity on (j–l) checkered keelback rescues and (m–o) bronzeback tree snake rescues, based on GAM outputs. Shaded bands indicate 95% confidence intervals. Y-axis represents predicted log rescue count from each GAM, while holding other predictors at median values.

Rat snake (*Ptyas mucosa*)

The best-fitting GAM included month, temperature, and rainfall as predictors, explaining 39.2% of the deviance in rescue counts (Table 3.3). Month had the strongest influence, followed by temperature and rainfall. Rescues peaked during the pre-monsoon months, particularly in March and April. After a decline during the monsoon (July–August), rescue calls increased again from October onwards, with a slight dip in January–February, though staying well above the baseline (refer to Figure 3.3, a–c).

Temperature showed a significant negative relationship with rescues, with activity declining steadily above approximately 28°C. Rainfall effects were non-linear, with peak just below ~250 mm, after which rescues remained relatively stable under moderate rainfall (~300–600 mm), increased at ~750 mm, and declined again at very high rainfall levels (>850 mm).

Rescuers noted that peak activity during the dry season coincided with male-male combat between February and April, likely indicating the mating period. The post-monsoon increase was partially attributed to the emergence of neonates between July and September in the interview data.

Indian rock python (Python molurus)

The best-fitting GAM included month, temperature, and humidity as predictors, explaining 61.0% of the deviance in rescue counts (Table 3.3). Temperature had the strongest effect on rescue trends, followed by month and humidity.

Python rescues exhibited a bimodal seasonal pattern, with a first increase in May–June, a decline during the monsoon (July–August), and a more pronounced peak between October and December. Rescue numbers tapered off in January–February but remained above early monsoon levels. Temperature showed a strong negative association with rescues, with activity declining steadily above ~28°C. Humidity showed a non-linear effect: rescues were lowest at mid-range humidity (~65–75%) and peaked above ~85% (refer to Figure 3.3, d-f).

Interview data supported the seasonal patterns, with rescuers reporting that pythons typically mate between October and January, with a few late cases observed in early February. Hatchling emergence was noted between mid-May and July, by rescuers, which corresponds with the early monsoon increase in rescue calls.

Whitaker's boa (Eryx whitakeri)

The best-fitting GAM included month, humidity, and temperature as predictors and explained 51.1% of the deviance in rescue counts (Table 3.3). Month had the strongest effect, followed by humidity and temperature.

Rescue activity exhibited two seasonal peaks, one during May–June and another during October–December, with a decline from January, with the lowest points in March and April. Humidity had a non-linear effect: rescues increased up to ~70–75% relative humidity, then declined at higher levels. Temperature effects were weaker, with rescues gradually declining above ~30°C (refer to Figure 3.3, g-i).

Interview data aligned with these patterns to some extent. Juvenile Whitaker's boas were most reported between May and July, and in some years during January. The overall pattern was less consistent than for other species, and rescuers noted that interpretation of seasonal peaks may be influenced by reporting variation over the years. Rescuers did not consistently observe courtship aggregations, though pairs were occasionally encountered together.

Checkered keelback (Fowlea piscator)

The best-fitting GAM included month, humidity, and temperature as predictors, explaining 35.4% of the deviance in rescue counts (Table 3.3). Month had the strongest influence, followed by humidity, with temperature showing a weaker but significant effect.

Rescue activity followed a bimodal seasonal pattern, with a smaller peak in April–May and a more prominent peak in December–January. Rescue counts dropped sharply during the monsoon (July–August) and rose steadily through the post-monsoon period. Humidity showed a strong positive non-linear association, with rescue counts increasing from ~50% to ~85% relative humidity and levelling off thereafter. Temperature effects were U-shaped, with the lowest rescue counts around 28°C, and higher number of rescues observed at both lower and higher extremes (refer to Figure 3.4, j-i).

Interview data indicated that checkered keelbacks remain active during the monsoon near water bodies but are less likely to enter human-dominated spaces during this time. The December–February rescue peak closely aligned with interview reports, as rescuers frequently encountered keelbacks in households and other built environments during this period. These sightings were commonly attributed to females moving to drier areas to lay eggs, beginning in December and peaking between January and February. Hatchling emergence was occasionally reported in March–April, though the mating season remains unclear.

Bronzeback tree snake (Dendrelaphis tristis)

The best-fitting GAM included month, temperature, and rainfall as predictors and explained 31.8% of the deviance in rescue counts (Table 3.3). Month was modelled as a linear term (edf = 1), with rescues increasing steadily from April through March.

Temperature had the strongest effect among climate variables. Rescues increased between ~23–26°C, dipped slightly around 26–30°C, and then rose sharply beyond 30°C. Rainfall effects were non-linear: rescues remained relatively stable at lower rainfall levels (~0–600 mm), peaked between 700–800 mm, and declined thereafter (refer to Figure 3.4, m-o).

Interview data supported the seasonal increase, with rescuers reporting that bronzeback mating typically occurred in March–April, followed by about 4-6 weeks of gestation. Multiple individuals were sometimes observed together at rescue sites, including cooler indoor spaces like air-conditioned units.

3.5 Discussion

3.5.1 Patterns of Snake Rescues

This chapter examined seasonal rescue trends in Goa across eight snake species using six years of Forest Department records, supported by qualitative interviews. While GAMs provided insight into seasonal and climatic correlates of snake rescues, the outputs must be interpreted

with care. Rescue data is not a neutral proxy for snake activity; rather, it reflects the intersections of ecology, human detection, perception, and the structure of rescue systems. For some species, GAMs captured peaks that aligned with known behavioural patterns, such as hatchling dispersal or breeding aggregation. In other cases, the models showed limited seasonal variation or peaks that did not clearly correspond to identifiable ecological triggers. These mismatches underscored the difficulty of interpreting rescue patterns in the absence of detailed behavioural baselines, and the need for a hybrid approach that combines modelling with field-based knowledge.

The models also carried methodological limitations. While GAMs are useful for smoothing seasonal curves and detecting broad climatic correlations, they are less effective in capturing sharp disruptions caused by ecological events or human activity. One such example was an increase in cobra rescues in May during a cyclone year, which was likely driven by flooding and displacement but did not emerge as a strong pattern in the smoothed output. Interview data repeatedly pointed to land clearance, construction, and rainfall as drivers of snake visibility, yet these variables act as event-based triggers rather than consistent predictors and may not be adequately represented in models designed for gradual trends.

In some species, particularly those common in urban areas, the observed seasonal peaks may be shaped more by reporting frequency than actual activity levels. For instance, in arboreal snakes encountered within buildings, rescues may be triggered by perceptions of infestation when multiple individuals are seen together, even if the animals are behaving normally within their breeding period. These interpretive challenges underline the importance of integrating field-based knowledge and behavioural context with model outputs. This example illustrates a core theme of the chapter: that rescue patterns are co-produced by ecological, perceptual, and infrastructural drivers.

District-level variations, such as the high number of rescues of species like Whitaker's boa or Forsten's cat snake in North Goa, raised further questions. These counts did not necessarily align with prior assumptions of rarity and may reflect regionally specific differences in habitat access, detection likelihood, or reporting consistency. Although the dataset used here included only

Forest Department rescues district-level differences also warrant caution. The unexpectedly high number of rescues for certain species in North Goa, such as Whitaker's boa or Forsten's cat snake, may not reflect true differences in abundance. While the dataset analysed in this chapter included only Forest Department records, both interview data analysis and field observations indicated that North Goa was known to have more active private rescuer networks. Interview data suggested that such patterns are often shaped by uneven visibility, access, and rescue response capacity, rather than ecological distribution. These caveats reinforce the need to avoid overinterpreting rescue frequency as a measure of species presence.

Recent studies have highlighted the challenges of interpreting rescue or conflict data without contextual ecological baselines, particularly when behavioural triggers, landscape shifts, or detection biases are at play (Kuttalam et al., 2025). Studies have also warned against using conflict or rescue data as standalone indicators of abundance or behaviour, especially in the absence of corroborating ecological baselines (Shine and Koenig, 2001; Ruddle and Davis, 2013). In this chapter, combining quantitative modelling with local ecological knowledge allowed for a more nuanced interpretation of seasonal trends. While the data could not confirm species abundance or risk, it did reveal meaningful interaction patterns when viewed through both ecological and socio-spatial lenses. These findings underscore the importance of species-specific and regionally grounded frameworks, which will be further explored in the final section of this discussion.

3.5.2 Behavioural Ecology, Rescue Patterns, and Species-Specific Drivers

Spectacled cobras were the second highest rescued species, and the GAM analysis showed a broad seasonal peak in spectacled cobra rescues from June to October, coinciding with the monsoon and post-monsoon period. Temperature and rainfall were both positively associated with rescue frequency. Interview data suggested that the early monsoon period prompted adult cobras to shift shelters, increasing their visibility. Post-monsoon peaks were attributed to hatchling emergence, although the dataset lacked metadata to confirm age-class. As one rescuer noted, "Monsoons bring more cobras. We get many baby cobra rescues." Field accounts also

mentioned that snakes tended to “settle” after initial displacement, potentially explaining the tapering seen later in the season. In interviews, this “stabilisation” referred to a perceived reduction in surface movement and visibility once snakes found shelter, along with a decline in emergency calls after the early influx. The absence of systematic tracking of juveniles versus adults represented a key gap in both the quantitative and qualitative datasets (see Section 3.5.4 for data limitations). However, the GAM’s smoothed curve did not reflect sharp inter-annual spikes. For example, in May 2021, raw rescue data showed a marked spike in cobra encounters following Cyclone Tauktae, which struck Goa just before the onset of the southwest monsoon (Kannaujiya, Rai and Malakar, 2024). Analysis of the interview data indicated that unlike the gradual shelter-shifting typically seen during early rains, the cyclone brought sudden and widespread flooding, likely inundating cobra burrows and subterranean refuges across the region. This abrupt displacement may have flushed out multiple individuals simultaneously, especially neonates or breeding adults sheltering underground. Although ecologically plausible, this short-term surge was not captured by the GAM output due to its smoothing functions, which are designed to detect gradual, recurring seasonal patterns. Such cases illustrate the need to interpret model outputs in conjunction with local weather events and verified field accounts, particularly when dealing with extreme climatic anomalies.

Russell’s vipers, though highly venomous, were not as frequently rescued as cobras. GAM results showed a clear seasonal pattern in Russell’s viper rescues, with a rise beginning in October, peaking between November and December. One rescuer explained, “October onwards, we get many Russell’s viper rescues. They are found in pairs,” indicating that reproductive activity may also contribute to seasonal variation in rescues. This closely aligned with findings from Glaudus (2021), who noted that the breeding period for Russell vipers in Karnataka was late fall to early winter and highlighted an increase in both snake activity and human detectability during this period.

A second, more modest increase from May to July. Rescuers consistently linked the seasonal rise to neonate births in early summer. Interview data also showed that barring the cobra, the number of neonates of this species tended to be in high numbers. One rescuer reported a time when he

had to rehabilitate a gravid female, and she gave birth to 47 individuals in one go. The March–April dip in rescues, evident in the GAM plot, remained difficult to interpret. Neither model outputs nor interview data provided a definitive explanation, though increasing temperatures could be a possible explanation. This decline may reflect decreased human detection or reporting rather than a biological reduction in snake activity. The lack of age-class metadata in rescue records made it difficult to determine whether observed seasonal peaks reflected adult or neonate individuals. Recording such information is particularly important for species like the Russell’s viper, given emerging evidence that neonates of this species may be more toxic than juveniles or adults (Senji Laxme et al., 2024). However, due to considerable intraspecific variation in venom composition across different regions (Gopal et al., 2023), further research is needed to establish whether this pattern holds consistently and to assess its relevance across other medically important species.

The medical and economic significance of Russell’s viper is well established in Goa. As described in Chapters 2 and 5, seasonal spikes in rescues corresponded with increases in human envenomation and domestic animal bites. Interview data also suggested a notable spatial shift in the species’ distribution. Rescuers reported an increase in sightings along urban fringes, coastal belts, and tourism-heavy areas. “There is a huge increase in Russell’s vipers all over the place. Even in places where they weren’t found before,” one rescuer noted. Several respondents pointed to poor waste management and rodent abundance near hospitality zones as key drivers of this shift. These observations suggest that both ecological and anthropogenic factors, particularly changes in prey availability and landscape disturbance, may be influencing the species’ movement into new habitats and increasing its visibility within human-dominated areas. Interview data and GAM output both indicated that Russell’s viper rescues peaked during periods of moderate temperature, particularly between 26–30°C. This pattern aligns with published literature on Russell’s viper basking behaviour in open, sunlit habitats (Glaudas, 2021), suggesting that increased visibility during these months may drive higher rescue calls. However, this frequency remains low relative to cobras. While Narvencar, Favas and Dias (2020) reported Russell’s viper as one of the leading causes of snakebite admissions in Goa, especially in the second half of the year, they were not proportionally represented in rescue

records. This discrepancy may reflect habitat use, differences in human activity, or underreporting in specific regions, and underscores the limitations of using rescue frequency as a proxy for species risk.

Krait rescues were among the least frequent but showed a narrow seasonal peak between September and October. GAM results revealed a weak association with climatic variables, although humidity showed a modest positive effect. Despite their medical significance, kraits remained largely absent from rescue reports for most of the year, especially when compared to the rescue records of other venomous species like the spectacled cobra. Interview data helped contextualise this pattern. Rescuers noted that kraits often entered homes post-monsoon, sometimes appearing near campfires or sleeping areas, yet rarely triggered panic unless seen directly. “They come out at night, but they’re quiet,” one rescuer observed, adding that people often did not realise the snake’s presence. No hatchling emergence patterns were clearly observed in the field, nor were they evident in the data. Importantly, rescuers described kraits preying on smaller snakes such as wolf snakes, suggesting that their entry into human spaces may sometimes be tied to prey availability. This introduces a possible prey-predator ecological dynamic that is absent in the rescue records. Literature on seasonal or reproductive behaviour for kraits in western India remains sparse, making LEK and observation-based insights especially critical. Although Goa did not record a lot of krait bites (Narvencar, Favas and Dias, 2020), it still shows the importance of snake-proofing the house by sealing potential entry points, especially given the kraits elusive nature and venom profile.

Rat snakes had the highest number of rescues among all species analysed. GAMs indicated a clear seasonal peak from June to September, with a smaller rise in February–March. Rescue frequency was positively associated with both rainfall and temperature. Interview data aligned the pre-monsoon peak with mating behaviour, including male-male combat. Several rescuers described “two snakes fighting,” a behaviour that often-triggered public alarm and unnecessary removal. The analysis of the interview data set attributed the post-monsoon rise to juvenile emergence, although age-class was not recorded in the dataset. Goa’s tourism season also peaks post-monsoon last well into January (Trichur, 2013). “Tourist season means more garbage, more

rats, more snakes,” one rescuer noted, suggesting that urban rodent availability may be influencing rat snake movement and visibility. Another possible explanation emerging from the analysis was the overall demographic shift in Goa, with an influx of tourists and migrants from other states who may not share the same cultural outlook toward snakes, perceiving them as immediate threats rather than long-term inhabitants, leading to increased rescue calls.

Misidentification also appeared to inflate rescue numbers. Rescuers frequently reported cases where rat snakes were mistaken for spectacled cobras due to their size and rapid movement. In areas where snake ID skills were limited, this led to over-reporting and skewed perceptions of risk. Despite being non-venomous, rat snakes were removed at high rates, underlining how fear, misidentification, and species visibility together shape rescue trends.

Rescue patterns for Indian rock pythons showed a bimodal seasonal trend, with peaks in the early monsoon and again in the post-monsoon months. Interview data helped contextualise both. The May–June increase was consistently linked by rescuers to hatchling emergence, particularly around farms and gardens. One rescuer noted that “in summer, pythons are the most common calls,” referring to this early-season spike. The more pronounced October–December peak coincided with observed adult mating activity, though field observations saw mating activity during February as well. Another rescuer explained, “During winter, we get a lot of calls for pythons. They get stuck in gutters.” These quotes pointed to encounters driven not only by ecological behaviour, but also by python size, visibility, and proximity to human spaces. Despite being non-venomous, pythons often triggered rescue calls due to their perceived threat to pets or livestock. Field observations confirmed that Indian rock pythons are increasingly adapted to urban environments in Goa. Rescues were regularly reported from dense residential areas, including Panjim city and tourist zones such as Baga, where pythons were observed preying on domestic cats and taking shelter in drains, gardens, and poultry sheds. Although both rescue peaks aligned well with known life history phases, the dataset lacked age or reproductive metadata to confirm the class of individuals being encountered, a limitation discussed further in Section 3.5.4.

Rescue patterns for Whitaker's boa revealed a clear bimodal rhythm, but interpretation of this trend required careful integration of field insights. Juveniles were frequently encountered between May and July, consistent with the birth period reported by (Lobo and Sreepada, 2015). However, interview data also documented juvenile rescues in January, raising the possibility of multiple birthing periods or regional variation in reproductive timing. Raw rescue counts appeared elevated in March and April across certain years, but this was not strongly reflected in the smoothed GAM output, possibly due to irregular effort or sparse early reporting. Rescuers noted limited activity in South Goa during earlier years, where fewer volunteers were active, potentially underrepresenting the species' true distribution. Unlike other snakes where large mating groups or combat behaviour may be observed, rescuers typically encountered only isolated pairs of boas, and no consistent signs of courtship aggregations. This species remains ecologically understudied, with much of the behavioural data drawn from captive contexts. The observed seasonal trends in rescue activity offer rare but valuable insight into its life history, while also highlighting the limitations of using rescue records in the absence of systematic field monitoring.

Seasonal peaks in keelback rescues were shaped by reproductive activity and shifts in habitat use, but also by human detection and reporting. While the GAM revealed a bimodal seasonal pattern, with a distinct December–January peak, interview data provided deeper context. Rescuers frequently encountered keelbacks in households and other built environments during this period, often interpreting these as gravid females seeking drier spaces to lay eggs. Interview data indicated that egg-laying typically began in December, peaked in January–February, and was followed by occasional hatchling sightings in March–April. These movements frequently prompted public concern. Rescuers described the snakes as more defensive during the early days of egg-laying, which heightened fear and led to removals. As one rescuer explained, “they flatten themselves and can be aggressive... people don't want hatchlings around either.” This aligns with the higher rescue frequency during the dry season, when reproductive behaviour brings keelbacks into closer proximity with human spaces. Interestingly, interview data also clarified why monsoon rescues remained low despite the species being active. Keelbacks were frequently observed near water bodies during the rains, but were less likely to enter built environments,

reducing the chance of being noticed or reported. These seasonal differences in habitat use and visibility may help explain why GAM output showed low rescue counts during the monsoon, followed by a steady post-monsoon rise. The mating season for this species remains unclear, as neither interview data nor existing literature provided consistent observations. Additionally, the lack of sex or reproductive status in rescue logs made it difficult to confirm whether observed individuals were gravid females or post-laying individuals. Nevertheless, the seasonal rescue peaks, particularly the post-monsoon visibility, appear to reflect a combination of reproductive movement, defensive behaviour, and human sensitivity to potential snake presence near dwellings.

Among the most urban-associated species in this dataset, bronzeback tree snakes exhibited a pronounced seasonal peak in March. While the GAM output suggested a temperature-driven rise in rescues, interview data indicated that this pattern was more closely tied to the species' breeding season. During this period, rescuers frequently reported multiple individuals found sheltering together, often in shaded artificial spaces such as split air conditioning units. As one rescuer described, "We often find 7–9 individuals inside split AC units, where they prefer the lower temperatures to breed." This increase in visible individuals often led to public reports based on perceived "infestation", despite the species being non-venomous and typically unthreatening. The spatial concentration of rescues in North Goa was attributed by rescuers to factors such as higher housing density, abundance of prey such as lizards in human settlements, reduced tree cover, and greater public familiarity with rescue services. Although not recorded in the Forest Department dataset, interview data also revealed that many bronzeback encounters are now reported through photo or video, without physical handling. These unlogged interactions further distort the apparent patterns in rescue data. Interview data reported that bronzebacks were rarely rescued from industrial zones, which some rescuers linked to lower prey availability and reduced canopy cover in such areas. Overall, the March rescue spike appears to reflect a combination of reproductive timing, habitat modification, and urban reporting dynamics, rather than increased biological activity in response to temperature alone. This example underscores the importance of integrating qualitative insight when interpreting rescue records, particularly for species that thrive in human-altered environments.

Other Medically Significant Species

Saw-scaled vipers (*Echis carinatus*), although medically important, were rarely recorded in Goa's formal rescue data. Rescuers noted that they were typically encountered outdoors, under rocks, in gardens, or industrial areas, where their cryptic behaviour reduced their visibility. As one rescuer noted, "We usually find them outside, under debris. People don't notice them unless they almost step on them." Similarly, hump-nosed pit vipers and Malabar pit vipers appeared infrequently in official records, often handled informally by private rescuers or left unreported altogether. These cases illustrate how formal rescue data alone can underestimate true species presence, particularly for cryptic, nocturnal, or habitat-specific snakes.

Cryptic or Rarely Reported Species: Sea Snakes, Vine Snakes, and Others

In addition to medically significant but underreported snakes, several species known to occur in Goa were almost entirely absent from the rescue dataset. These included sea snakes (*Hydrophis* spp), vine snakes (*Ahaetulla* spp.), Forsten's cat snake (*Boiga forsteni*), and several small colubrid or nocturnal species. Their absence does not necessarily reflect rarity, but rather habitat preference, cryptic behaviour, or low likelihood of being detected and reported by the public, as well as signalling species identification issues in data reporting.

Rescuers and field observations confirmed that sea snakes occasionally wash ashore during the monsoon or after storms, particularly along the southern coastal belt. However, they are rarely handled by rescuers or reported through formal channels, possibly due to lack of familiarity or the assumption that marine species fall outside terrestrial rescue jurisdiction. Vine snakes were described by multiple rescuers as once common but now rarely seen, particularly in areas experiencing deforestation or canopy loss. As one rescuer noted, "We used to get a lot of green vine snakes, but now we barely see them. It's either urbanisation or people don't report them." This trend may signal a real decline, or it may reflect changes in human attention and reporting priorities.

Forsten's cat snake, though often regarded as uncommon, was unexpectedly frequent in parts of North Goa, suggesting either a local population hotspot or a more consistent rescuer effort in that region. Its nocturnal, arboreal behaviour likely contributes to its underreporting in other areas. Together, these examples reinforce a key limitation of rescue datasets: the absence of a species in formal records may reflect detectability, habitat access, or volunteer distribution rather than true ecological patterns. These findings highlight the need to treat absence data cautiously, especially in biodiversity assessments relying on citizen- or rescuer-reported encounters.

Emergent Themes: Visibility, Perception, and Reporting Biases

Across all species examined, several key themes emerged. First, rescue frequency does not directly represent ecological abundance or risk but rather reflects snake visibility and public perception. Highly visible species (cobras, pythons, rat snakes, bronzebacks) are disproportionately rescued due to fear, misidentification, and interactions with urban structures. Conversely, medically significant but cryptic species (kraits, saw-scaled vipers, pit vipers) are consistently underreported, highlighting biases in detection and formal reporting. Second, reproductive cycles and hatchling dispersal significantly shape rescue peaks, often misinterpreted as population increases. Lastly, regional variations in rescuer distribution and urbanisation underscore how human infrastructure and awareness systems critically shape recorded rescue data. These insights collectively caution against interpreting rescue data as straightforward ecological indicators, instead underscoring their value as reflections of human-snake interface dynamics.

3.5.3 Urbanisation, Land-Use, and Regional Variation in Rescues

While Goa's overall rescue counts were higher in South Goa (16,201 rescues) than in North Goa (14,366 rescues), the distribution of individual species showed clear and statistically significant spatial variation. These differences did not follow a single geographic pattern, suggesting that rescue frequency is shaped by a combination of ecological presence, land-use features, and human-mediated factors such as reporting and access.

For example, spectacled cobras and rat snakes were more frequently rescued in South Goa, while bronzeback tree snakes and Whitaker's boas showed higher rescue frequencies in North Goa. In the case of the bronzeback, as expanded in the section above, rescuer interviews attributed this pattern to urban infrastructure, particularly the presence of split air conditioning units as summer sheltering and breeding sites. Interview analysis also showed that North Goa's higher housing density and more consistent rescuer coverage may also explain the higher frequency of photo- or video-based reporting, which was not captured in formal datasets but influences rescue calls. Similarly, construction activity and habitat disturbance emerged as key drivers across species, in the qualitative analysis, with even the MoEFCC (2023) acknowledging them as drivers of HSC. Multiple rescuers and community members noted in the study that land clearing, hill cutting, and new colony development frequently displace snakes, leading to rescues from garages, staircases, and even multi-storey balconies. Interview data showed that these trends were particularly associated with tourist areas such as Baga, Calangute, and Vasco, where species such as Russell's viper and python were increasingly found, which was also corroborated through field observations. In these locations, the combination of construction debris, rodent abundance due to food waste, and reduced vegetative cover provided ideal conditions for certain species to thrive, as suggested in both interviews and broader literature (Glaudas, 2021; MoEFCC, 2023; Kuttalam et al., 2025).

However, interpreting these patterns requires caution. The dataset only included rescues logged by the Forest Department, and does not account for private rescues, which are more common in North Goa and may inflate perceived species frequency. This limitation is particularly relevant for species like Forsten's cat snake and Whitaker's boa, which were unexpectedly more common in the North despite being considered regionally restricted or infrequently encountered. Importantly, some apparent absences may reflect differences in detection and reporting, rather than ecological reality. For instance, species like the green vine snake or saw-scaled viper appeared only occasionally in the dataset, but rescuers noted that cryptic behaviour, low detection rates, misidentification, or low public awareness could all contribute to underreporting. The same applies to sea snakes, which rescuers confirmed are rarely handled despite occasional landfall.

Overall, these findings reinforce that rescue frequency is not a proxy for abundance, and that regional analysis must account for both ecological and human variables. Land-use patterns, urban fear, rescue accessibility, and species visibility all interact to shape what is recorded and what is not.

3.5.4 Interpreting Data Gaps and the Role of Local Ecological Knowledge

While the dataset used in this study represents one of the most extensive formal rescue records available for the region, several key limitations constrain its ecological interpretability. Most notably, species misidentification, particularly between juveniles of similarly patterned snakes (e.g., juvenile pythons and Russell's vipers), was frequently raised by rescuers as a source of error. In addition, the data lacked basic ecological metadata such as age class, sex, precise release location, and post-rescue monitoring, making it difficult to assess whether encounters were one-off events or part of recurring patterns involving the same individuals. No information was available on whether snakes were gravid, whether eggs were collected, or whether the sighting was verified through photo or physical capture. This absence of detail restricts the ecological value of the records and limits the ability to design targeted mitigation responses. Moreover, the dataset includes only rescues logged by the Goa Forest Department. Several interviewees reported that a number of private rescues, especially in North Goa, are not formally recorded, which could introduce a spatial and numerical bias, especially with low-risk or urban-adapted species such as bronzebacks or wolf snakes, which may be rescued informally without official logging.

The question of when a rescue is necessary also emerged as a critical theme in the interview data. People frequently call for removals based on the mere presence of a snake, even when it poses no immediate risk. One rescuer explained, "Sometimes they call us because there is a snake in their garden, but it is not trapped or cornered. It would have left on its own." This underscores a fundamental gap in public understanding of snake movement and behaviour. Many urban rescues involve snakes that are not threatening but are removed due to fear, reinforcing the idea that snakes do not belong in shared human spaces. While growing awareness has increased reliance

on humane rescue rather than killing, the shift toward long-term tolerance and coexistence remains limited. As Chapter 4 further explores, this pattern raises questions about how rescues are socially framed and whether they serve conservation goals or simply respond to fear. Another unresolved issue is whether repeated removals from the same area meaningfully reduce conflict. Some rescuers described cases in which snakes, especially cobras and pythons, were removed multiple times from the same locations. One rescuer noted, “We sometimes get called back to the same place to remove a snake, and we don’t know if it’s the same one or another that moved in after the first was taken away.” Without release site data or tracking, it remains unclear whether rescues are preventing future encounters or merely displacing the problem. This concern has also been raised in recent literature (Malhotra et al., 2021), which questioned whether removals create a false sense of resolution in the absence of broader habitat or awareness interventions.

Despite these limitations, qualitative interviews and field observations provided essential context for interpreting model outputs. Interview analysis clarified species-specific behaviour not evident from GAMs, such as egg-laying in checkered keelbacks, neonate emergence in Russell’s vipers, or aggregation behaviour in bronzebacks. Rescuers helped explain anomalies such as high March–April rescues of Whitaker’s boa or the post-cyclone spike in cobra rescues in May 2021–patterns that were not fully captured in the statistical models but were ecologically coherent when examined through local insight.

Such observations form a body of local ecological knowledge (LEK), built through sustained field experience, informal monitoring, and intimate interaction with both species and human communities. The value of integrating LEK into conservation science has been consistently emphasised in interdisciplinary literature (Brosius and Hitchner, 2010), though Ruddle and Davis (2013) also caution about maintaining completely transparency and raising accountability when incorporating LEK in any study. In India, where snake ecology remains understudied and formal field baselines are rare, such knowledge is particularly vital.

This study's hybrid approach, linking long-term rescue records, climatic predictors, and qualitative insight, enabled a more grounded understanding of seasonal rescue patterns and their drivers. It also demonstrated that rescue data are not ecological data in any straightforward sense. They are shaped by visibility, public perception, fear, rescue accessibility, and infrastructure. Still, when contextualised appropriately, they offer valuable clues about interaction hotspots, risk timing, and species-specific dynamics.

Beyond Goa, the chapter offers a methodological model for other regions seeking to interpret conflict patterns in the absence of long-term ecological monitoring. Particularly in landscapes with high human population density, limited ecological research, and escalating snakebite burden, the triangulation of modelling and LEK can support species- and season-specific strategies. However, as this chapter argues, such approaches must be matched by stronger data infrastructure, standardised logging of rescues, post-release tracking, and recognition of the role that community-level observers play in shaping the human-wildlife interface.

3.5.5 Conservation, Conflict Management, and Future Directions

The patterns observed in this study raise important questions about the long-term role of rescues in conservation and conflict mitigation. While rescues serve an immediate and humane response to human-snake encounters, their effectiveness as a long-term management strategy remains uncertain. In many cases, they address symptoms, such as visibility or fear, rather than the underlying ecological and social drivers of conflict. This has implications not only for snakes, but for the sustainability of human-wildlife coexistence frameworks more broadly (Malhotra et al., 2021).

One concern is that frequent removals, particularly of non-venomous species like rat snakes, bronzebacks, or pythons, may disrupt local predator-prey dynamics. These snakes play a key role in controlling rodent populations, and their displacement from urban and peri-urban landscapes could alter ecological balances in ways that are difficult to (Goldstein et al., 2021). Several

rescuers raised concerns that such vacuums might allow venomous species to occupy the same spaces, potentially increasing risk to humans over time.

Another issue is whether repeated removals from the same sites lead to meaningful conflict reduction. Rescuers described cases where snakes, particularly cobras and pythons, were removed multiple times from the same location. Without data on release sites or post-rescue movement, it is unclear whether such interventions prevent further encounters or simply displace conflict. Some individuals may return to familiar territories, while others may fail to survive. This gap highlights the need for post-rescue tracking using tools such as radio telemetry and mark-recapture methods, which have proven useful in similar contexts (Rao et al., 2013; Low, 2018; Marshall et al., 2020).

The relationship between rescues and habitat change is equally important. Urban expansion, land clearing, and tourism-driven development continue to fragment habitats, creating microenvironments that draw snakes into closer proximity with people. For instance, bronzebacks were frequently rescued from AC units in urban buildings, while Russell's vipers were increasingly found near waste-rich hospitality zones. These locations may function as "rescue hotspots" not because of snake density, but due to anthropogenic drivers such as food waste and habitat disruption. If such dynamics are left unaddressed, rescues risk becoming a reactive tool that unintentionally reinforces human-snake encounters (Malhotra et al., 2021). Climate change is likely to exacerbate these challenges. Altered rainfall patterns, extreme weather events, and shifts in prey availability may drive changes in snake distribution and behaviour. Cyclone Tauktae, which caused a spike in cobra rescues in May 2021, illustrates how sudden climatic events can intensify human-snake interactions. Over time, warming temperatures and altered seasonal windows may further increase the frequency and unpredictability of such encounters. Integrating rescue data with long-term climatic datasets will be essential to assess whether snake movement and conflict patterns are shifting under climate pressure (Zacarias and Loyola, 2019; Martinez et al., 2024).

Despite these concerns, the rise in humane rescues represents a substantial shift in public behaviour. As rescuers repeatedly emphasised, the shift from killing to calling a trained responder marks an important cultural transition. However, as further discussed in Chapter 4, this shift has not yet led to widespread acceptance of coexistence. Many rescues, especially of non-threatening or misidentified species, occur not because of risk, but due to fear or public insistence. This may entrench dependence on rescue systems without promoting ecological understanding or tolerance (Malhotra et al., 2021).

Moving forward, conflict mitigation must embrace proactive and evidence-based strategies. Community education campaigns aligned with seasonal cycles, such as dispersal or egg-laying periods, could reduce panic-driven rescues. Small-scale habitat interventions, such as improved waste management, sealing burrows, or providing alternative shelters, may reduce encounter likelihood without requiring removal. Standardised rescue reporting, particularly regarding age class, location, and release site, would significantly increase the ecological value of the data. Integrating private rescuer logs into centralised platforms would improve spatial accuracy and policy relevance.

3.6 Conclusion

The analysis demonstrates that seasonal fluctuations in rescues are not solely driven by climate but are also strongly influenced by species reproductive cycles, habitat use, and human detection biases. Peaks in rescues align closely with neonate dispersal, mating seasons, and habitat disturbances rather than being purely a response to temperature or rainfall. This highlights the importance of integrating species behaviour into conflict mitigation planning to develop more effective, science-based management strategies.

At the same time, the study raises key ecological concerns about the effects of repeated removals. The disproportionate removal of non-venomous species raises the possibility of altered predator-prey dynamics, while the lack of data on post-release survival limits our ability to assess whether removals reduce conflict or simply displace individuals. Additionally, the

absence of standardised data collection, particularly among private rescuers, results in significant knowledge gaps regarding how human-snake conflict is evolving in Goa.

Current efforts have successfully reduced retaliatory killings but rescues alone cannot replace a broader coexistence framework. Future strategies must prioritize community education, habitat conservation, and evidence-based policy to shift from reactive removals to proactive mitigation. Standardised reporting and long-term post-release monitoring will be critical in refining conflict management strategies.

Ultimately, snake rescues should be seen as the lowest-hanging fruit of coexistence- a visible and humane tool that has successfully shifted public behaviour. But to serve conservation goals meaningfully, they must evolve into one part of a broader strategy. With stronger data infrastructure, climate-aware planning, and community engagement, rescues can move from reactive removals to proactive coexistence, supporting both human safety and the long-term conservation of Goa's diverse snake fauna.

3.7 References

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Chapter 4

Challenges and Impacts of Snake Rescues on Human-Snake Interactions in Goa

4.1 Abstract

Snake rescues have become a dominant strategy for mitigating human-snake conflict (HSC) in India, yet their long-term effectiveness remains largely unexamined. While rescues are widely perceived as an ethical alternative to fear-based or retaliatory killings, concerns have emerged about whether they promote coexistence or reinforce dependency on removals as the default response. This study investigates the drivers, challenges, and consequences of snake rescues in Goa, India, drawing on 68 in-depth interviews with key stakeholders, including Forest Department officials, private rescuers, herpetologists, veterinarians, community members, architects, and security guards.

While rescues have significantly reduced retaliatory killings and fear-based killings, they have also normalised removals, creating a cycle of dependency that discourages in-situ tolerance of snakes. The unregulated nature of snake rescues, compounded by the absence of a legal framework in the Wildlife Protection Act (WPA), 1972, has led to inconsistent rescue practices, untrained rescuers, and arbitrary translocations, with little monitoring of survival outcomes. Furthermore, urbanisation and habitat fragmentation are increasing human-snake interactions, making effective conflict mitigation strategies even more critical. Financial and social incentives further complicate the rescue landscape, with some rescuers prioritising social media visibility over conservation ethics, while others experience severe burnout due to the relentless demand for removals.

The study proposes a structured rescue framework to enhance regulation, prioritise education, and integrate coexistence strategies into rescue operations. Key recommendations include formal training and certification for rescuers, mandatory reporting protocols, improved public awareness on species identification, gender-inclusive recruitment of rescuers, and first responder training for security guards and medical professionals. By shifting the focus from reactionary removals to structured coexistence strategies, this study highlights the need for systemic policy interventions to ensure that snake rescues contribute meaningfully to human-wildlife conflict mitigation in Goa and beyond.

4.2 Introduction

Across India and many other countries, snake rescues have emerged as a dominant tool for managing human-snake conflict (HSC) (Malhotra et al., 2021). Rescues are widely regarded as an alternative to killings, aiming to mitigate immediate risk to humans while preventing unnecessary mortality of both venomous and non-venomous species (Shine and Koenig, 2001; Malhotra et al., 2021; Kuttalam et al., 2025). However, the long-term impact of rescues remains underexamined, particularly in terms of whether they contribute to fostering human-snake coexistence or primarily reinforce a cycle of removal as the default response to snake encounters (Jesudasan and Abhilash, 2019; Pooley, Bhatia and Vasava, 2021).

Human-wildlife conflict mitigation strategies should ideally move beyond short-term harm reduction to creating conditions for sustainable coexistence (Nyhus, 2016; Pooley, Bhatia and Vasava, 2021). While snake rescues have undoubtedly reduced fear-based killings in many regions (Jesudasan and Abhilash, 2019; Keener-Eck, Morzillo and Christoffel, 2020b), their effectiveness as a long-term conflict mitigation tool remains debatable (Shine and Koenig, 2001; Keener-Eck, Morzillo and Christoffel, 2020a). The ideal of coexistence requires a shift in human perceptions- moving beyond viewing snakes solely as threats, to recognising their ecological role (Coelho et al., 2019). If rescues primarily function as a means of extraction rather than education, they may inadvertently reinforce the notion that snakes do not belong in human spaces, ultimately undermining coexistence efforts (Pooley, Bhatia and Vasava, 2021; Salim et al., 2024).

Furthermore, the ecological viability of large-scale removals and translocations remains unclear. Many translocated snakes exhibit homing behaviour, leading them to attempt to return to their original location, often crossing hazardous environments in the process (Low, 2018; Wolfe, Fleming and Bateman, 2018). Others may fail to adapt to their new habitat, facing increased predation and mortality (Carter et al., 2024; Harvey et. al, 2014). However, most rescue operations lack structured follow-up mechanisms, making it difficult to assess survival rates, displacement stress, and long-term adaptation (Wolfe, Fleming and Bateman, 2018; Malhotra et

al., 2021). Without such data, the long-term effectiveness of rescues as a conservation tool remains in question.

By law, all snakes in India are protected under the Wildlife Protection Act of 1972, which mandates that only authorised personnel handle and relocate them (WPA, 1972; Whitaker, 2018). Despite this, numerous unauthorised rescuers operate independently, often without oversight regarding their methods, release sites, or ethical considerations (Malhotra et al., 2021; Salim et al., 2024; Kuttalam et al., 2025). While some of these rescuers work with genuine conservation intent, the lack of standardised training and monitoring raises concerns about improper handling, ineffective relocations, and even potential risks to public safety (Shine and Koenig, 2001).

The prevalence of unregulated rescuers also complicates data collection, as many removals remain undocumented (Whitaker and Shine, 2000; Roshnath, Kunhiraman and Rajan, 2018; Keener-Eck, Morzillo and Christoffel, 2020a). This makes it challenging to assess the full scale of snake removals. Simply put, snake rescues were originally intended to protect snakes from being killed. Ironically, their widespread availability may now be driving a dependency on removals, reducing tolerance and inadvertently reinforcing human-snake conflict (Pooley, Bhatia and Vasava, 2021; Salim et al., 2024).

Goa is home to the Big Four (ZSI, 2008), and a rescue network, involving both the Forest Department and private rescuers. While such rescue systems exist in other states as well, (Roshnath, Kunhiraman and Rajan, 2018; Salim et al., 2024), just like Goa, there has been no systematic evaluation of the long-term effects of snake rescues on public perception and conflict mitigation (Keener-Eck, Morzillo and Christoffel, 2020a; Pooley, Bhatia and Vasava, 2021). While Chapter 2 demonstrated that targeted awareness reduced snakebite mortality (Menon et al., 2022), it remains unclear whether rescues have similarly contributed to fostering coexistence in this state. Additionally, Goa has seen massive land use change over the years (TERI, 2015; Sutheeshna, 2021) raising the question of whether urban expansion and habitat loss have increased the frequency of human-snake encounters, necessitating more rescues (Narayanan and Bindumadhav, 2019; Parkin et al., 2020; Barhadiya et al., 2024).

Goa therefore presents an opportunity due to its high urban expansion rates, rapid land-use changes, and a dense rescue network involving both state and private actors. The coexistence of urban, semi-rural, and forested landscapes makes it an ideal location to examine how different socio-environmental contexts shape human-snake interactions and the role of rescues in mitigating conflict. Understanding these dynamics in Goa can provide insights for refining snake rescue strategies and human-wildlife conflict mitigation policies both within India and globally.

In the case of snake rescues, this raises a fundamental question: are removals helping communities adapt to living alongside snakes, or are they reinforcing the perception that snakes are incompatible with human-dominated environments?

Therefore, under this overarching question, this study aims to answer:

- Have rescues successfully reduced retaliatory snake killings, and if so, to what extent?
- Do rescues contribute to long-term conflict management, or do they primarily serve as a short-term solution?
- To what extent do rescues foster coexistence, or do they reinforce the notion that snakes do not belong in human spaces?
- How do social media and unauthorised rescuers shape public perceptions and practices related to rescues?
- What challenges do rescuers face in balancing removal with education, and how does this affect public awareness?
- Does urbanisation play a key role in driving snake rescue?
- What lessons can be drawn for broader human-snake conflict mitigation strategies?

By integrating qualitative insights from rescuers, community members, and conservation practitioners, against the quantitative data/insights from the Forest Department (as examined in Chapter 3), this study provides an empirically grounded analysis of whether rescues function as a meaningful step toward coexistence or if they perpetuate cycles of removal without addressing underlying fears and misconceptions.

By exploring these dynamics in Goa, this chapter aims to provide insights that inform future policy recommendations, training programs for rescuers, and community-driven conservation initiatives. Findings from this study can be used to develop more effective, evidence-based approaches to human-snake conflict mitigation, not only in India but also in other regions where snake removals remain a primary management tool.

4.3 Methods

This study employed a qualitative approach to examine the role of snake rescues in shaping human-snake interactions in Goa. Given the lack of structured research on snake rescues in India, qualitative data collection was prioritised to capture stakeholder insights on rescue practices, ethical considerations, and broader socio-ecological dynamics.

4.3.1 Data Collection and Stakeholder Selection

A preliminary study was conducted from September to October 2021 to establish a baseline understanding of human-snake interactions in Goa. Following this, fieldwork was conducted from March 2022 to February 2024. The study site encompassed both North and South Goa, covering urban, semi-urban, and rural landscapes, reflecting the diversity of human-wildlife interactions in the state.

The primary mode of data collection was semi-structured, open-ended interviews, which allowed interviewees to share their experiences in their own words, minimising interviewer bias (Campbell et al., 2013; Bryman, 2016). A total of 68 in-depth interviews were conducted, using snowball sampling and convenience sampling to reach relevant stakeholders (Ibbett et al., 2023). The stakeholder categories included:

- Forest Department officials (n = 5): insights into regulatory challenges, reliance on private rescuers, and enforcement of legal frameworks.

- Private rescuers (n = 12): diverging rescue philosophies, ethical considerations, financial struggles, field experiences, snake encounters in hotels and restaurants, guest panic, and policy responses from management.
- Herpetologists (n = 5): ecological perspectives on snake translocations, species-specific behaviours, and conservation challenges
- Community members (native and migrant populations) (n = 24): varying perceptions of snake rescues, tolerance levels, and long-term changes in human-snake interactions.
- Security guards (n = 4): first responders in residential complexes and commercial properties, handling encounters without formal training.
- Veterinarians (n = 10): medical treatment of rescued snakes, observations on human-wildlife conflict, and cases of retaliatory killings linked to pet attacks.
- Architects (n = 1): urban infrastructure influencing snake presence and mitigation strategies.
- Doctors and medical professionals (n = 5): species misidentification, panic-driven removals, and gaps in medical knowledge about snakebite management.
- Government policy experts (n = 2): legal ambiguities in the Wildlife Protection Act, interpretation of MOEFCC guidelines on human-snake conflict, National and State Snakebite Programme and enforcement challenges.

Interview quotes were recorded alongside stakeholder categories (e.g., doctor, rescuer, architect), research theme, and contextual summaries in a structured database (refer to Supplementary Sheet, S0 for baseline interview questions for select stakeholders). This system allowed flexibility in tagging overlapping insights without artificially siloing narratives based on singular identities or roles.

4.3.2 Interview Protocol and Data Management

All interviews were recorded with prior informed consent, ensuring anonymity unless explicit permission was given for attribution (Bryman, 2016). The primary mode of data collection was audio recordings, with consent obtained on record. In cases where interviewees were

uncomfortable with recording, written notes were taken instead. Interviews were conducted in English, Konkani, and Hindi, depending on participant preference.

4.3.3 Data Processing and Thematic Analysis

The recorded interviews were translated and transcribed into English using TurboScribe, an AI-powered voice-to-text transcription tool built on Whisper (Python-based voice recognition and translation). All transcripts were manually edited and verified for accuracy before analysis (Belotto, 2018).

The interviews were categorised based on the interviewees' roles and then manually coded to identify recurring themes. This study initially attempted to use NVivo for coding and thematic analysis, given its widespread use in qualitative research (Campbell et al., 2013). However, after spending several weeks attempting to structure the data through NVivo, it became evident that the software was not the most effective tool for this dataset. The complexity of human-snake interactions, spanning multiple overlapping research themes across different stakeholder categories (Belotto, 2018), required a more fluid and intuitive approach to mapping connections between responses.

Instead, a manual thematic analysis approach was adopted using structured categorization in Excel, which significantly clarified the emerging patterns and chapter framework (Kiger and Varpio, 2020). The familiarity with interview data played a crucial role in this decision; after conducting and reviewing each interview, manually coding allowed for a more accurate identification of thematic links, ensuring that no nuance was lost in software-driven categorization. Using a thematic analysis approach, key themes were mapped onto the study's research questions to ensure alignment with broader analytical objectives (Clarke and Braun, 2017). All data were manually entered into structured Microsoft Excel worksheets, where each entry recorded an interview identification tag, location, stakeholder category (e.g., rescuer, doctor, veterinarian), theme, primary research question it addressed, exact quote, and contextual summary of the response.

To facilitate cross-analysis across different chapters, themes were further grouped into family themes and sub-themes, allowing for pattern recognition and deeper comparative insights. The thematic analysis identified key areas relevant to the study's research objectives, which were systematically categorised as follows:

1. Evolution of Snake Rescues: Examining the shift in public attitudes from retaliatory killings to removals and its implications for conservation.
2. Normalisation of Removals: Investigating how rescues have become the default public response, leading to reduced tolerance for coexisting with snakes.
3. Ethical Dilemmas and Unregulated Rescues: Assessing the absence of standardised training, the role of rogue rescuers, and the challenges posed by the lack of regulatory oversight.
4. Translocations and Ecological Impact: Exploring homing behaviour, increased mortality risks, and the conservation consequences of frequent snake relocations.
5. Financial and Social Motivations for Rescuers: Analysing the intersections of economic sustainability, social status, sensationalism, and rescuer burnout.
6. Urbanisation and Snake Encounters: Understanding how habitat fragmentation, roadkill, and infrastructure expansion influence snake rescue patterns.
7. Housing and Security Guard Perspectives: Examining how architectural differences between Indo-Portuguese houses and modern apartments shape human-snake interactions, with a focus on the role of security guards as untrained first responders.
8. Gender and Snake Rescue: Identifying barriers for women in snake rescue and the need for gender-inclusive training and representation in conservation efforts.
9. Digital Tools and Awareness: Assessing the role of WhatsApp and social media in improving species identification, public awareness, and coexistence strategies.
10. Legal Ambiguities and Policy Gaps: Analysing how the Wildlife Protection Act (WPA) does not formally recognise “rescue” as a legal category and the implications for governance.

11. Proposed Framework for Structured Rescues: Presenting recommendations for a Goa-specific regulatory framework to standardise ethical rescue practices, improve oversight, and integrate education-based interventions.

The themes provided a structured framework for qualitative analysis, ensuring that stakeholder perspectives were systematically mapped onto the study's core research questions. These themes were compared with existing literature, policy and laws on wildlife and human-snake conflict allowing for contextualisation within broader conservation policy discussions.

4.3.4 Ethical Clearance

Ethics clearance was obtained in September 2021 from Ethics Committee of the School of Anthropology and Conservation, University of Kent (approval number: 16-PGR-20/21).

TurboScribe was chosen because all files are encrypted at rest. None of the audio files contain identifiable information about the interviewee unless they explicitly gave permission to use the same. Access to the files is strictly controlled only to the account holder and once the account is deleted, all data is automatically deleted. No third party has access to the files, nor are they retained by TurboScribe. The files were only uploaded for the purposes of the transcriptions and the account deleted as soon as the text files were ready. All qualitative data has been securely stored on university servers and personal secured hard drives, and no identifiable personal information has been retained unless explicit permission was granted.

4.3.5 Quantitative Data

The quantitative data of venomous and non-venomous snake rescues presented in this chapter follows the same methodology as detailed in Chapter 3 (Seasonal drivers of snake rescue in Goa), where data collection, processing, and analytical procedures are outlined in full. No additional modifications were made to the dataset for this chapter.

4.4 Results and Discussion

4.4.1 The Evolution of Snake Rescues in Goa- From Conservation to Convenience

Before Organised Rescues: Local Snake Handlers and Folk Practices

Interview analysis indicated that earlier human-snake interactions in Goa were often shaped by systems of reverence and symbolic coexistence, with some practices said to be dating back hundreds of years. Data revealed that among some older Konkani communities, snakes, particularly cobras, were deeply embedded within cultural and religious traditions. These associations were not framed through formal conservation discourses but were reflected in locally rooted beliefs and ritual practices.

Interviews revealed that cobras were reported to hold sacred associations with folk deities such as *Brahmini Maya*, one of the *Sapta Matrikas*, whose iconography includes hooded snakes, and *Vetar*, a deity of the forests and sea, depicted with cobras adorning his crown and armbands. Interview data further suggested that in some communities, termite mounds were historically worshipped as manifestations of the deity *Sateri*, later linked to cobra presence due to the species' known use of such mounds for shelter.

Analysis showed that these cultural framings appeared to be reinforced through household rituals and oral traditions. Respondents described the presence of snake-related hymns, stories inscribed on grinding stones, and the common practice of avoiding the direct use of the word “snake,” instead substituting kinship terms such as *mama* (uncle). One herpetologist explained that, unlike the idol-based practices in other parts of India, women in certain Goan communities traditionally painted cobras on their kitchen walls during *Nag Panchami*, a tradition reportedly still followed in a few households today. Many of these findings were also noted in Borkar (2006), who further gave descriptions of lamps being lit in Goan households in a special corner for snakes as a guardian of the territory. A herpetologist explained the relevance of that saying, “Every evening, people would put a lamp in a corner they believed to be a snake’s place. It was actually a practical way to avoid stepping on snakes at night.”

While these beliefs did not necessarily eliminate fear or conflict, analysis suggested that they offered an alternative lens through which snakes were normalised as part of shared human spaces. However, these practices diminished over time, with several respondents attributing the erosion of traditional knowledge to demographic shifts, urbanisation, and declining engagement with natural surroundings. As one expert noted, “People now don’t go out for walks with sticks. Earlier, everyone knew to watch their steps in nature. Now that connect is being broken.”

With the decline of such embedded cultural systems, findings indicated that snake encounters were increasingly resolved through immediate killing, motivated by fear and a lack of alternative options. Data showed, however, in some communities, informal snake handlers existed who were individuals with basic snake-catching skills, called upon when available. These were not professional rescuers, but local men known for handling snakes as a personal skill, often self-taught relying on trial-and-error experience rather than formal knowledge of snake behaviour.

Several interviewees described how, before organised rescues, people depended on local handlers like Lawrence from Panjim, widely known for his dramatic snake-catching abilities. According to one rescuer, “Lawrence was active from the 1980s till at least the early 2000s. He used to claim to smell the venom based on species from the bite, and that snakes would come on his whistle. He carried snakes in his pockets and basically made a business out of scaring people and making them believe he was the only one who could get rid of the snakes from their properties. This was before proper organised rescues, and people didn’t have other professionals to rely on.”

Beyond local handlers, reports also revealed that in those days, folk rituals and superstition-based solutions were also common. Interviewees said that some individuals charged money for “protective measures,” such as sprinkling coloured rice around homes to ward off snakes and these practices, though rooted in local beliefs, lacked any ecological basis. As one respondent described, “People would rather rely on these men with coloured rice than believe that keeping their gardens clean would reduce snake encounters.”

Although these handlers provided an alternative to immediate killings, they were highly localised and unreliable, with respondents noting that outside of these individuals, most snakes were simply killed due to fear and lack of awareness.

The Formalization of Snake Rescues as a Mitigation Strategy

As awareness of snake conservation grew in the late 1990s and early 2000s, data showed that informal snake handling began to give way to structured rescue operations. Findings from this study indicated that the shift from killing to removal was largely shaped by early conservation efforts, particularly through the intervention of the Goa Forest Department (GFD), NGOs, and independent rescuers. One herpetologist, reflecting on the shift in public attitudes, remarked, “I’ve grown up looking at a stage where every snake that people saw, except the cobra probably, people would kill, you know, to a point now where any snake that they see, people would basically pick up the phone and want it taken away.”

Analysis showed that at the forefront of this transition was the Goa Forest Department (GFD), which began handling snake rescues on an ad-hoc basis before eventually formalising a statewide response system. A senior GFD officer recalled how, in the early years, they relied on a single designated rescuer to handle snake calls, saying, “More than 20-22 snake calls in a day. In which area? All over Goa. I used to be the only person in the forest department in Goa. In Panjim, I used to go to Mollem, Pernem. I used to go anywhere. I used to go anywhere in Mahdei. I used to go to Valpoi.”

However, interview data indicated, that as the demand for rescues grew, the GFD recognised the need for a structured approach. Interviewees described this period as a turning point when organised response systems took shape. One rescuer detailed the trajectory stating, “From 1995 to 2002, we started doing proper snake rescues. From 2002 to 2012, it really shot up, with many people involved.” The GFD, in response, created a 24/7 mobile rescue squad to reduce snake killings and provide an official alternative to unregulated removals. A retired senior official described this shift remarking, “We have a mobile squad in North Goa and South Goa which deals with all capture of captive animals, more particularly snakes, because people tend to kill

the snakes. So as not to kill the snakes, we have this squad, and they are on call 24 hours, 365 days.”

Analysis of the data demonstrated that by the late 2000s, snake rescues were no longer limited to isolated cases handled by individuals. Instead, the GFD had expanded its network, covering multiple regions to handle rescues across North and South Goa more efficiently. A forest officer detailed, “We have got in Pernem, Panaji, Bicholim, Valpoi, Ponda, Margao, and multiple teams handling rescues. We have got a central veterinary hospital and a wildlife rescue centre at Bondla.”

Data indicated that in addition to government efforts, NGOs and private rescuers played a crucial role in shifting public perception. According to the data, throughout the early 2000s, conservationists worked to change attitudes by emphasising the ecological role of snakes and the importance of proper snakebite treatment. One veteran rescuer described how early awareness campaigns were fundamental in reducing fear-based killings saying, “Every day we used to go to school or college. We used to cover a lot of things. People used to ask me to do a snake awareness program. I didn’t want to show a snake, but I wanted to say something. Many people have done it. This has brought a lot of awareness in Goa.”

Analysis of interview data suggested that areas with active education initiatives tended to report more rescue calls, indicating a potential link between awareness efforts and increased reliance on rescues. A rescuer described how targeted school programs led to spikes in rescue requests in those areas asserting, “Whenever we do an awareness program in a school, for the next few months, we get more calls from that area.”

Findings showed that this reinforced the idea that calling a rescuer was the ‘right’ response to encountering a snake, rather than killing it. It also set the foundation for long-term change, particularly among younger generations. One medical professional, who had overseen snakebite cases for decades, observed a noticeable decline in killings since organised rescues became widespread stating, “Ever since NGOs became active, killing has reduced.”

A Forest Department officer corroborated this trend, noting that rescues had successfully curbed retaliatory killings declaring, “People have a tendency to kill the snake. That is a wrong thing. But now for the last 4-5 years, I have not seen any snake being killed because they know we are here.” Similarly, a private rescuer pointed out that the increasing presence of trained rescuers had contributed to a decline in killings observing, “At least ever since the pandemic and before 2 years prior to that. I think in the last 5 years, the number of rescuers has increased overall, and that’s helped the number of kills reduce.”

Interviews indicated that while retaliatory and fear-based killings have declined, they have not been eliminated. Some respondents noted that despite increased awareness, snakes were still killed sometimes, particularly in areas where access to rescuers was limited or when perceived threats to livestock and pets arose. Many community members and rescuers also said that it was mostly the older generation that insisted on killing the snake, but the younger generation insisted on calling the rescuer.

The Shift from Conservation to Convenience

Findings from this study confirmed that while snake rescues in Goa were initially introduced as a conservation-driven strategy to prevent retaliatory killings, they since evolved into a widely expected service, fundamentally altering human-snake interactions. Analysis showed that the GFD, private rescuers, and NGOs played a critical role in shifting public perception, providing an alternative to killing snakes. However, as rescues became more accessible, their purpose shifted from emergency intervention to routine removal.

Analysis also indicated that where rescues were once a last-resort intervention, they were now the default response to a snake sighting, regardless of whether the species posed a threat. A senior herpetologist, who has been involved in conservation for over three decades, reflected on this shift saying, “By 2018-19, we saw rescues plateau after a dramatic rise in demand, and now some of us question if rescues are even necessary in many cases where the snake is still being removed.” Veteran rescuers concurred that this shift in behaviour was not an intended outcome but rather an unintended consequence of making rescues widely available. One herpetologist

noted, “Now we worry that it’s being overused. People expect someone to come pick up the snake, and if one person doesn’t, they will call another.”

Analysis of the interviews indicated that as rescues became more frequent and easier to access, public tolerance for snakes declined, with removals being treated as the norm rather than a situational decision. Data showed that a key factor reinforcing this expectation was the increasing reliance on digital platforms. WhatsApp, social media networks, and helplines streamlined rescue coordination, making it easier for people to request removals at the first sight of a snake. One veteran rescuer remarked, “WhatsApp has changed everything. Now, people post a snake photo, and rescuers respond instantly. It’s increased the number of rescues significantly.”

Another rescuer described the post-pandemic shift to virtual communication commenting, “Ever since the pandemic, it’s become very virtual. A lot of WhatsApp calls, a lot of video calls, a lot of photos and videos before attending it, which I think is great, but it also means people don’t even consider leaving the snake alone first.” While social media has enabled rapid access to rescuers and facilitated species identification in some cases, interview analysis indicated that this convenience may have unintentionally reinforced public dependency on rescues. Rather than rather than increasing awareness, technology may have reinforced dependency on rescues, making removals an instant solution rather than an opportunity for education. This echoed concerns raised by Malhotra et al. (2021), who noted that despite their growing popularity, rescue-based interventions are rarely assessed for their long-term impact and may simply offer short-term removals without shifting deeper attitudes or behaviours.

4.4.2 Rescuer Availability and the Erosion of Coexistence

While accessibility to rescuers is crucial for human safety, findings suggested that 24-hour availability has had unintended consequences. Data showed that the GFD established a structured, round-the-clock service, ensuring rapid responses to snake encounters. However,

private rescuers, who often operate independently, outpaced the government's response time, leading to even greater demand for removals.

A GFD official explained, "We have a mobile squad that operates 24/7, but sometimes people don't wait. They call private rescuers because they are closer or respond immediately." While this efficiency was beneficial, analysis indicated, it has also contributed to a culture where removals were treated as a given. Some rescuers and herpetologists noted that for years, the GFD was perceived as unreliable in certain areas, leaving people with no option but to kill the snake or call a private rescuer. This further entrenched the idea that every snake must be relocated rather than left alone.

The Diverging Approaches of Rescuers

Despite the growing expectation of removals, not all rescuers approached the process the same way. Thematic analysis revealed a clear divide between those who prioritised education and coexistence, were in the minority, and those who focussed purely on removals. One rescuer who integrated education into his work explained, "If I get a call, I first try to convince them to leave the snake alone unless it's venomous. But some rescuers just remove it without explaining anything." In contrast, others admitted that removals had become routine, with little attempt at awareness-building, with one rescuer reflecting, "People expect the snake to be taken away. They're not interested in learning why it's there or if it's harmless."

Analysis of the data demonstrated that this variation in approach had broader implications for the effectiveness of rescues as a conflict mitigation tool. While some rescuers actively educated communities, others inadvertently reinforced dependence on removals, rather than promoting tolerance. This pattern has also been observed in other parts of the country and the critique on the importance of rescues needing to act as conduits of awareness has been highlighted by a few studies (Mukherjee, 2023; Salim et al., 2024). It was also taken note in the latest Guidelines for HSC mitigation as well, by the MoEFCC in 2023, in which the role of the rescuers as community educators for tolerance was highlighted.

Interview analysis revealed religious beliefs as another factor influencing human-snake interactions in Goa, though their role was inconsistent across communities. Some respondents noted that cobras, particularly, were often spared due to their religious significance in Hinduism, where they are associated with Lord Shiva. As one rescuer explained, “Sometimes, if we find a cobra, they say that it belongs to God... so we release it near a tree or shrine.” Another respondent noted, “Some people say killing a snake is bad karma, so they let it go. Others say, if it’s near the house, it must be removed.”

However, religion was not universally invoked to protect snakes. Rescuers described instances where religious leaders facilitated coexistence, but also cases where snakes were killed due to religious fears or misinterpretations. A rescuer recalled an incident where a Christian priest and nuns burned a live constrictor, believing it to be a threat, while another described a Hindu priest actively encouraging snake releases near sacred trees. As one rescuer summarised, “I’ve seen Hindus killing cobras just the same as I’ve seen Christians killing cobras. Sometimes, I use religion to the snake’s advantage, but it works both ways.”

These findings suggested that while religious narratives can promote tolerance in some cases, they were not a reliable determinant of coexistence. Instead, they were often leveraged selectively, sometimes reinforcing conservation, and other times enabling persecution. Borkar (2006) made a case for an eco-theological base for Goa, based on the religious and cultural syncretic nature of the Goa. However, the analysis from this chapter partially supported his theory and further reinforced the need for structured, education-driven awareness efforts that emphasised snake ecology over cultural interpretations, ensuring that coexistence was guided by conservation science rather than selective beliefs alone.

The Need to Reframe Rescues

Findings indicated that Goa’s rescue model needs to evolve beyond a reactive removal-based service into a proactive coexistence-first strategy. While rescues were introduced to protect snakes and humans alike, their widespread availability outpaced efforts to integrate education-driven solutions.

This study's analysis concurred with theories in published literature that by shifting from automatic removals to selective, education-based interventions, rescues can better balance human safety and conservation goals, ensuring that removals are only conducted when necessary rather than by default (Shine and Koenig, 2001). While there is little debate about the need to remove a venomous snake trapped inside a house (Salim et al., 2024), (see Figure 4.1), the insistence on allowing non-venomous snakes to remain within their natural territory is still uncommon. Data from this study showed that in Goa a small but dedicated group of rescuers were actively encouraging tolerance, however, they remained in the minority. The majority of rescues were removals, largely due to public expectation, rather than actual need, which aligned with findings from a few studies such as Salim et al. (2024). Interview data indicated that in many cases, the simple presence of a snake, even in an outdoor space, was sufficient to trigger a rescue call. As a result, the term 'coexistence' was sometimes conflated with not killing a snake, rather than a true acceptance of shared space. While some areas in Goa exhibited strong tolerance, overall, data suggested that removals remained the expected norm.



*Figure 4.1: A spectacled cobra in a defensive posture inside a residential building
Such encounters often trigger urgent calls for removal, driven by fear and public visibility. (Photo: Benhail Antao)*

4.4.3 Common Challenges and Ethical Dilemmas of Snake Rescue

While animal rescues have played a critical role in reducing retaliatory killings, their implementation in different contexts has raised several operational, ethical, and ecological

concerns (Shine and Koenig, 2001; Pyke and Szabo, 2018; Mukherjee, 2023). These findings on the broader concepts of rescue find some relevance within this Goan study as well, where the absence of standardised protocols, the over-removal of non-venomous species, and the challenges associated with translocation emerged as significant issues. Additionally, data indicated that the increasing commercialisation of rescues further complicated the landscape, raising questions about the long-term sustainability of this mitigation strategy.

Legal Ambiguities in Snake Rescues: The Absence of Formal Recognition in the Wildlife Protection Act

Despite their widespread role in mitigating human-snake conflict, snake rescues in India exist in a legal vacuum due to the absence of formal recognition within the Wildlife Protection Act (WPA), 1972 (last amended 2022). The Act does not define “rescue” as a distinct conservation or conflict mitigation activity. Instead, all forms of handling wild animals, including capturing, relocating, or even removing a snake from a human dwelling, technically fall under the definition of “hunting” (WPA, 1972). By law, handling snakes requires explicit permission from the Chief Wildlife Warden, under Section 11 and Section 12 (WPA 1972) yet data showed that in practice, rescues operated largely through verbal approvals in Goa, rather than a structured regulatory framework. This was even though many species of snakes, including some of the most commonly rescued such as spectacled cobra, rat snake, Russell’s viper and Indian rock python are in Schedule I of the WPA 1972, along with the tiger and leopard, affording them the highest legal protection.

A lack of formal recognition and standardised licensing means that any individual can claim to be a rescuer, regardless of expertise or training (Malhotra et al., 2021). The data indicated that without an official certification system, rescue approaches varied widely. Some rescuers prioritised education and coexistence, advocating for snakes to be left undisturbed where possible. Others, however, focused solely on removals, reinforcing the public expectation that every snake must be extracted. One rescuer described the inconsistencies in permissions, stating, “If you have to speak to the person first and tell them that it needs to be here, then you don’t have to get involved in that issue of looking like a criminal when the snake is being released.”

Another noted that while many operate with the implicit backing of the GFD, the absence of a legal framework leaves them vulnerable to scrutiny or legal challenges should their actions be questioned.

A senior GFD official acknowledged these challenges, saying, “No, nobody has authority, except those who are wildlife wardens, but we are trying to bring them [rescuers] in. We are trying to register them amongst us.” While this suggests a willingness to integrate private rescuers into an official system, efforts to do so remain informal and inconsistent, echoing patterns across regions of India as well, which have been highlighted by only a few studies in recent years (Malhotra et al., 2021; Salim et al., 2024).

The Challenges of Decentralised Rescues

Due to limited personnel and resources, analysis of the data indicated that the GFD relies heavily on private rescuers to meet the high demand for snake removals. One rescuer described the consequences of attempting to impose stricter regulations, stating, “When the Forest Department tried to clamp down on rescues, they were flooded with calls. They had to turn back to private rescuers, or else people would have just killed the snakes themselves.” This highlighted a fundamental tension in rescue governance. While the absence of legal oversight creates risks, overregulation without structured alternatives could lead to an increase in retaliatory killings rather than better conflict management (Whitaker, 2018).

Although formalising rescues is necessary, interview findings indicated that abrupt enforcement without viable alternatives could disrupt existing mitigation efforts, leaving both rescuers and the public in a state of uncertainty. The FD, caught between public demand and regulatory constraints, continued to depend on informal networks to manage human-snake interactions. This reinforces the decentralised nature of rescues in Goa, where removals have become the expected norm rather than a last resort.

Unlike large mammal rescues, which follow strict protocols and documented tracking, snake rescues remain largely informal and undocumented in most parts of the country (Malhotra et. al.

2021), with data from Goa showing the same pattern. Thematic analysis showed that most removals of snakes were not recorded, making it impossible to track trends in human-snake interactions or assess their impact on local populations. The lack of a centralised database, which includes the private rescuers as well (refer to Chapter 3 for bifurcation in reporting systems), means that authorities have no clear record of how many snakes are removed, what species are most frequently encountered, or where they are released. This absence of oversight complicates conservation assessments, leaving critical gaps in understanding how rescues influence snake populations over time (Whitaker and Shine, 2000; Rao et al., 2013).

Analysis of the data showed that this regulatory vacuum also led to unethical practices among some rescuers who exploited the system for financial gain or social recognition. While many rescuers operated on a voluntary basis, others monetised rescues, charging for removals despite the absence of formal payment structures. A resident noted, “Some rescuers charge ₹2000 or ₹3000 per call. If people don’t have the money, they sometimes leave the snake where it is.” A few rescuers who also coordinated responses with compatriots from other states said they had heard of similar observations there, with the assumption being that, though illegal, it was being seen as a quick way to make some money, by a select group of people, since there was always an abundance of snake calls and gaps in many states’ response.

Interviewees reported instances of deliberate scams, where certain individuals stage snake removals to extort money. One rescuer described this, stating, “There have been several cases where unethical rescuers were doing this. They would take snakes with them and say, ‘Oh, we’ll search the house close to the home, pull something out, and take money for it.’ It’s a racket.”

Without standardised training, licensing, or accountability mechanisms, such practices remain unchecked, undermining the integrity of conservation-based rescues. The lack of oversight also fuelled concerns about improper handling, particularly among self-proclaimed rescuers with limited expertise. One resident recalled witnessing unsafe practices, “They might have a bag, but not always a hook. One time, they put the snake in a plastic bottle.”

These findings indicated that while snake rescues serve an essential conflict mitigation function, the absence of regulation left room for ethical violations, safety risks, and conservation failures.

Unnecessary Removal of Non-Venomous Species

According to the data analysis, a big unintended consequence of the normalisation of rescues is the widespread removal of harmless, non-venomous snakes. Goa Forest Department records from April 2016 – March 2022 indicated that 19,254 non-venomous snakes were removed, compared to 11,034 venomous species. The most frequently rescued species were the rat snake, spectacled cobra, Indian rock python, Whitaker’s boa and Russell’s viper, with non-venomous species dominating annual rescue data (Refer to Chapter 3 for a breakdown and seasonal drivers).

Several rescuers and officials noted this trend, highlighting that many removals were unnecessary, driven by fear and habit rather than actual risk. One rescuer remarked, “There was a time when a rescuer was not called for a rat snake. Now everything is being caught.” Similarly, another rescuer commented on the public’s declining patience when encountering snakes, “Now people call even if a rat snake is just passing through their garden. They don’t even wait to see if it leaves on its own.”

Additionally, frequent removal of non-venomous species can have unintended ecological consequences (Shine and Koenig, 2001). As harmless species like rat snakes and checkered keelbacks are relocated, their absence creates a void in local ecosystems, potentially altering prey-predator dynamics. The persistent removal of non-venomous species raises the question that since rescues are meant to mitigate human-snake conflict, does relocating non-venomous snakes serve any conservation purpose, or does it merely reinforce intolerance?

The growing normalisation of non-venomous removals indicated a shift away from coexistence and conservation-based conflict mitigation toward a removal-centric approach. Data findings indicated that this might ultimately increase long-term human-snake conflict rather than reduce it. Instead of fostering coexistence, it reinforced the belief that all snakes must be physically removed, perpetuating intolerance rather than reducing conflict.

The Ecological and Ethical Concerns of Translocations

The translocation of rescued snakes, particularly venomous species, presents significant ecological and ethical challenges (Low, 2018; Wolfe, Fleming and Bateman, 2018). While removals may offer an immediate solution to human-snake conflict, translocation disrupts individual survival, increases stress, and can be fatal in many cases (Rao et al., 2013). Existing research on snake translocations suggests that relocated individuals may exhibit homing behaviour, attempting to return to their original locations, which can increase mortality risks due to roadkill, predation, and environmental stress (Rao et al., 2013; Low, 2018; Wolfe, Fleming and Bateman, 2018). However, there is a significant gap in species-specific studies for many commonly rescued snakes in India (MoEFCC, 2023; Mukherjee, 2023), including those frequently relocated in Goa. Analysis of this study's interview data revealed that post-release monitoring is virtually non-existent, making it difficult to assess the survival, site fidelity, or ecological impact of relocated individuals. A Forest Department official admitted that their approach prioritises human safety over snake welfare, stating, "Venomous snakes are put deep in the jungle. You cannot take a chance coming into habitat time and again."

While this method minimises immediate human encounters, it fails to address whether the relocated snake can survive in an unfamiliar habitat, a concern that has been highlighted in rescue studies globally as well (Shine and Koenig, 2001). One herpetologist who has been rescuing snakes in Goa for decades noted, "Some individuals keep coming back, getting displaced again and again."

Additionally, the findings revealed that some rescuers deliberately released non-venomous snakes closer to their original locations, rather than translocating them far away. One rescuer stated, "If I feel that the person might make an issue with it being released in the same spot, I tell them prior to going there only."

A few other rescuers admitted intentionally misleading residents to prevent unnecessary translocations, "People would say, please take it to Cotigao and I would say, yeah, sure, I'll take it to Cotigao (which is far away) and then I'd find the nearest suitable place and then release it."

These accounts highlight the constant negotiation between rescuers, public expectations, and ecological best practices, revealing the complex ethical landscape of snake relocations. This raises a critical question about snake rescues prioritising in-situ tolerance rather than large-scale removals.

4.4.4 Challenges Faced by Rescuers

While rescuers play a crucial role in mitigating human-snake conflict, their work is fraught with challenges that extend beyond the act of handling and relocating snakes (Salim et al., 2024). Thematic analysis shows that both private and Forest Department rescuers face significant financial, social, and personal risks, many of which go unrecognised by the public. These challenges affected the sustainability of snake rescues as a mitigation strategy, raising concerns about how long such a model can function without structural support.

Public Pressure and Safety Risks

Analysis revealed that rescuers frequently navigated high-pressure situations where they balanced ethical considerations with public demands. Such pressures have been seldom studied, though Salim et. al. (2024) in their surveys noted public pressure as a factor that rescuers in Tamil Nadu sometimes face. In Goa, similar pressures were expressed by the rescuers wherein community members insisted on translocations, even when a snake posed no immediate threat. Some rescuers described situations where they were coerced into removals, facing verbal abuse or even physical intimidation if they refused, saying, “Some villages say, ‘If you don’t find the snake, we will beat you.’ This happens with forest department rescuers.”

Analysis indicated that even when rescuers attempted to educate the public on coexistence, they said, their advice was often disregarded. Data showed that in some cases, crowds formed, making ethical handling difficult. A rescuer who has been active in the state for over 20 years lamented, “People don’t want to hear ‘leave the snake alone.’ They just want it gone. And after years of doing this, I sometimes wonder, what’s the point? (...) They sometimes shout at us and even though we also feel like losing our temper, we try to maintain our cool and preserve our dignity. We can’t speak to them in the way they sometimes treat us.” For GFD rescuers,

additional bureaucratic pressures also shaped their approach. A private rescuer sympathised with their situation saying, “But since they work for a government body, they’re kind of stifled in a way... Because there’s a chance they might lose their job.”

Interview and field observational data also showed a substantial difference in the number of male vs female rescuers. These gender gaps were also noted by Salim et. al. (2024), whose survey-study showed that in Tamil Nadu very few women were involved in snake rescue. In this chapter, interview data showed that a few female rescuers pointed the lack of safety and the prevalent gender bias when they go for rescues. One cited the most common reason of field conditions becoming unsafe was not the snakes but inadvertent damage to the ego of the men who might have called for a handler, saying, “The people who had called for the rescues, the reporters, they would laugh, and sometimes they would not let me touch the snake or would mock me. Some of the people had their egos hurt because a smaller person, a little girl in their opinion, had come to rescue what they, as so-called macho men, were scared of.” Another who eventually stopped doing rescues said, “In Vasco, there are no female rescuers, and one of the biggest problems in being a female rescuer there was the late-night rescues. Going alone would be a big safety risk even though Goa is, by and large, a safer state than other places like Delhi. A lot of men were hesitant to take me along for rescues because I was a girl.” The rescuer summed up the situation pointing to the high attrition rate among female rescuers saying, “The situation otherwise in general for female rescuers can be very hostile, and I was not always met with warm reception, even from other rescue volunteers.”

These accounts highlight that rescuers do not operate in isolation. Public expectations and social pressures often force them into actions that may not align with ecological best practices, also forcing them to compromise with their own ethics or pressurise them into leaving the field altogether.

Equipment, Training, and Infrastructure Gaps

Thematic analysis indicated that despite handling venomous species in high-risk environments, many rescuers, including those working with the Forest Department, lack proper safety

equipment. Some government rescuers recounted having to buy their own gear in the past, and even today, a few operate with outdated or insufficient equipment, “We had to fight for proper uniforms and hooks. First, we used to buy them ourselves. Now, at least we get some support, but payments are still late.” Senior department officials however insisted in the interviews that proper equipment was being provided to all the department rescuers.

Interviews also suggested that even for those with access to equipment, there were gaps in training, particularly among newer recruits. Some rescuers were hesitant to handle vipers or navigate cluttered environments due to fear or inexperience. A community member who regularly called rescuers to remove snakes from his house said, “There were a couple of times when the forest department guys didn’t want to go in because they weren’t sure where the snake was.”

Meanwhile, private rescuers often relied on personal funds or community donations for gear, as per the analysis. Some described cases where they had seen rescuers using improper handling methods due to a lack of training or access to suitable equipment.

The lack of standardised protocols for both equipment provision and training meant that rescue quality is inconsistent, with some rescuers better equipped than others to handle potentially dangerous situations.

Financial Struggles and Job Insecurity

Thematic analysis highlighted a recurring concern that, for both private and forest department rescuers, financial instability was a significant issue. It showed that most government rescuers, despite working under the GFD, were hired on daily wages without long-term job security. This meant that they only got paid for the days worked, based on a fixed number of hours, and not on a fixed monthly salary. Only a few rescuers were employees of the Forest Department, with salaries and benefits being given as permanent government employees. Private rescuers on the other hand were not entitled to any income from the Forest Department and the only payments afforded to them were reimbursement for expenses that were previously agreed upon, such as

veterinary bills when taking injured wildlife to a private veterinarian with no other option available.

Payments, especially the private rescuers' reimbursements, were often delayed for months, and there were no provisions for medical insurance or compensation in case of injury. A GFD rescuer who had been doing this for almost 10 years said, "We are on daily wages. No job security, no benefits, but we risk our lives every day." A private rescuer who has been working closely with the GFD for several years, also commented on the need for more support for the rescuers saying, "They need proper bank accounts, medical insurance, life insurance, compensation, and then they would probably feel more secure in their jobs instead of just being daily wagers."

In addition to financial insecurity, some GFD rescuers expressed frustration over the public's perception of their work. Several reported being accused of corruption or not doing enough, despite handling dangerous rescues under difficult conditions. One rescuer while expanding on this said, "People tell me, you are a forester. You don't do anything. You just eat money. They don't believe we actually work. They think we are corrupt."

Meanwhile, private rescuers, typically motivated by personal passion, frequently carried out rescues at their own expense, as also observed during fieldwork. While some accepted donations, they faced social scrutiny if they requested payment for their services. One said, "We don't charge, but if people give something, we take it. We have to spend on fuel, equipment, everything ourselves."

Thematic analysis suggested that for government rescuers, the lack of financial security and absence of medical insurance further compounded stress levels. Private rescuers also faced difficulties obtaining comprehensive medical coverage, as insurance providers often excluded high-risk professions or charge prohibitively high premiums. Given the inherent dangers of handling venomous snakes, rescuers were required to declare their profession when purchasing insurance, which can significantly limit their options for coverage. "There is no insurance, no backup. If something happens to us, that's it. We are on our own. Yes, GMC and the District Hospitals provide free anti-venom and are the best-equipped facilities for snakebites in the state.

However, beyond the availability of treatment, rescuers face an additional challenge, there is no financial safety net. Even with access to medical care, we are left to manage lost wages, long-term recovery, and medical costs that extend beyond anti-venom treatment,” said a private rescuer while reflecting on the private rescuer’s predicament as well as of those forest department rescuers who are daily wagers. When the Forest Department rescuers were asked why they chose to stay in this profession, in addition to the notion of service, they acknowledged that jobs were very difficult to come by for their skillsets. They also stuck around in the hope that something would change and the possibility of becoming a permanent government employee, with benefits, seemed worth the wait at times. The general precariousness of job availability and security in Goa expressed in the interviews corresponds to the Annual Report of the Period Labour Force Survey (2023-24) (MSPI, 2024), wherein the unemployment rate of Goa was shown as double the national average.

These financial burdens raise concerns about whether the current model of rescues is sustainable in the long run. Without institutional support, many rescuers struggle to continue their work, with many private rescuers with alternate incomes to support themselves taking it on as a hobby, according to veteran rescuers.

The Influence of Social Media on Snake Rescues

Social media has transformed the landscape of snake rescues in India, influencing both public perception and rescuer behaviour (Malhotra et al., 2021; Pyne et al., 2024), with the same being reflected in Goa as well. While these platforms played a role in spreading awareness, interviews’ analysis suggested they also contributed to a culture of visibility, where the act of rescuing was increasingly tied to personal recognition.

Several rescuers expressed frustration that social media prioritised status over conservation, leading to an influx of individuals eager to become rescuers for prestige rather than ecological responsibility. One experienced rescuer noted, “Many rescuers don’t want to give this up because of the cult status. Social media has made it even worse. It’s about limelight, not conservation.” The analysis and field observations thus demonstrated that, despite there being no

direct financial remuneration in many cases, some saw social media as a quick way to become “influencers” and gain either social or actual monetary currency through those means.

Interview analysis also showed that the rapid rise in new rescuers, many of whom lack proper training, further reinforced this concern. One respondent described the shift in motivations among younger rescuers noting, “Now it’s come to another generation where they themselves want to be rescuers... but boosting their own egos with social media.” Another rescuer pointed out that the sheer increase in rescue numbers does not necessarily indicate expertise, commenting, “So many people rescuing all of a sudden doesn’t really mean that you are a good rescuer. There is a hastiness to become one.” Salim et. al. (2024) had noted in their study that the bulk of rescuers were young, unmarried males and noted that some of them leveraged rescues on social media as a quick way to get famous. The emergence of such rescuers, as this thesis’s analysis shows, is tied in with several safety concerns not just for snakes but for rescuers as well. Chapter 2 had clearly demonstrated the prevalence of snake bites amongst rescuers, predominantly happening because of lack of training and a disregard for ethics. The findings further confirmed that the pressure, to perform for an audience, resulted in increased bite incidents, particularly among those prioritising social media over safety. One rescuer observed, “It’s very common for rescuers to get bitten because they were obsessed with social media fame.”

The emphasis on high-profile rescues and social media visibility also influenced how rescues are conducted, according to the analysis of the data. Some rescuers admitted that handling practices, which should be minimal to reduce stress on the snake, have been altered to cater for online audiences. “Handling should be minimal, but some rescuers do it for show. Social media has made this worse.”

This trend has significant conservation and ethical implications, as gleaned from the thematic analysis. Some rescuers emphasised that while social media can be a powerful tool for education, its effectiveness depends on how it is used. “I think social media is playing a key role, in my opinion. It’s somewhat aiding conservation and helping educate people. Because it can amount

to the same whether you do it in person or using social media as a tool or conducting awareness programs or even doing nature trails and walks.”

However, as field observations also underscored when rescue content prioritised spectacle over responsible conservation messaging, it could reinforce harmful practices, both by fuelling unnecessary removals and by encouraging reckless behaviour among untrained individuals.

The Wildlife Crime Control Bureau (WCCB) recognised this risk as early as 2014, issuing an advisory cautioning against public displays of wildlife handling/hunting on social media platforms that frame such actions as “acts of bravery”, as this can encourage copycat behaviour and stimulate dangerous human-wildlife interactions (WCCB, 2014). These concerns remain highly relevant in the context of snake rescues, where visibility often overshadows conservation ethics.

Analysis of the data, therefore, showed that while social media has amplified the visibility of snake rescues, it has also shifted focus toward high-profile removals rather than education-based interventions. However, as section 4.4.7 later illustrates, when used correctly as a tool, it can augment awareness and tolerance as well.

4.4.5 The Role of Media in Public Perceptions of Snake Rescues

Public attitudes toward snakes have been shaped by various factors, including community awareness programs, education, and mass media (Roshnath and Divakar, 2019; Keener-Eck, Morzillo and Christoffel, 2020b; Pooley, Bhatia and Vasava, 2021). While rescue operations have provided an alternative to snake killings, the way these rescues are represented, particularly in mainstream and social media, has further influenced public responses to human-snake encounters (Jesudasan and Abhilash, 2019).

Analysis of the interview data suggested that television programs like National Geographic’s *Snakes SOS: Goa’s Wildest*, (streaming on Disney+Hotstar, an India-based web streaming platform), played a role in shaping public perception, with some individuals citing the show as

an eye-opener that encouraged tolerance. This reality-tv show, which first aired in 2021, followed a Goan couple as they attended rescue calls and educated the public. One community member noted, “Before, we would panic. Now, we just call Ben (the rescuer) and wait.” Another resident described how watching such programs helped them distinguish venomous from non-venomous species, reducing unnecessary fear-driven removals. The producers of the show, also residents of Goa, made a note of the increase in messages they received from the general public appreciating the Goa-focused conservation message, highlighting that some had never even thought of snakes as sentient beings that should be rescued. However, while positive portrayals could foster coexistence, analysis and field observations showed that media could also reinforce sensationalism. Rescuers highlighted concerns that some social and local media content, particularly staged rescues and exaggerated narratives, had fuelled a hero culture around removals rather than promoting in-situ tolerance.

This dual impact of media, both as a tool for education and a driver of unrealistic expectations, parallels broader challenges in rescue governance. As discussed earlier, the normalisation of rescues had shifted removals from an exceptional intervention to an expected service, and media representation may have contributed to this shift. While this chapter focuses on structural and operational challenges in rescue frameworks, the role of media in shaping human-snake interactions warrants further examination.

4.4.6 Burnout and Long-Term Sustainability of the Service

However, thematic analysis showed a pressing concern. Beyond the pressures of public visibility, rescuers also face a more immediate challenge- burnout. Although the term is often used informally, burnout is widely recognised in academic literature as a serious occupational health condition, particularly in professions involving sustained emotional labour and high-stakes decision-making. It is formally defined as a work-related syndrome marked by emotional exhaustion, depersonalisation, and a diminished sense of personal accomplishment (Maslach and Leiter, 2016). In the medical and emergency care sectors, where rapid responses and moral responsibility for life-or-death outcomes are constant, burnout has been associated with reduced

performance, mental health deterioration, and increased attrition (West, Dyrbye and Shanafelt, 2018). Conservation and wildlife response professions share many of these pressures, often without institutional infrastructure. Studies on service workers and conservation biologists have highlighted that burnout frequently arises from cumulative stress, emotional fatigue, work-life imbalance, and a lack of institutional recognition or support (Cordes, Dougherty and Blum, 1997; Maslach, Leiter and Schaufeli, 2008; Ramos et al., 2017; Burns, 2020).

These dynamics were also reflected in Goa's rescue landscape. Interview data suggested that burnout among rescuers was not an abstract concern, but a lived reality. Many rescuers, especially those who emphasised education and coexistence, experienced significant burnout due to the relentless demand for removals, questioning the sustainability of their work. Some described how they had shifted from awareness-based rescues to quick removals simply due to exhaustion, with one saying, "Earlier, I used to explain to people why the snake was there, how they could avoid attracting more. Now, I barely have time. Too many calls, too many removals."

Thematic analysis suggested that the cumulative burden of unpredictable calls, public pressure, and the emotional weight of potentially fatal consequences led to strained relationships, disrupted sleep, and severe mental stress. One rescuer commented, "It's not just a rescue, it's a lifestyle. No sleep, no money, and if you refuse a call, people turn against you. Plus, we can't take a chance that they might kill the snake, which sometimes they hint might happen if you say you can't turn up. We just can't take the risk." As discussed in Section 4.4.4, the absence of medical insurance or job security compounded financial and emotional stress, particularly for those facing dangerous rescues without a financial safety net.

Interview data showed that those who were most committed to promoting coexistence were often the first to quit due to frustration with public attitudes. A herpetologist said, "People don't want education, they want removals. And after a while, it gets exhausting. I just hand most calls over to the Forest Department now, unless it's right next to my house or no one has gone for hours." These findings echo broader literature on the psychological impacts of wildlife response work. Research on oiled wildlife responders (Yeung et al., 2021) found that even short-term response

work can induce compassion fatigue, with resilience linked to formal training and organisational support, factors largely absent in Goa's rescue landscape.

Similarly, Englefield et al. (2019), in their study on Australian wildlife carers, documented that grief, burnout, and financial strain were common, especially among older female volunteers, most of whom worked without institutional backing. In their sample, the longer someone had been in wildlife care and the more animals they lost, the higher the severity of grief experienced, paralleling anecdotal accounts from Goan rescuers who described emotional exhaustion after years of removals and snakebite cases.

These patterns are not unique to rescue contexts. Ramos et al. (2017), surveying conservation biologists across Asia, found that burnout, often arising from work-family conflict and the emotional burden of conservation struggles, was a primary predictor of job dissatisfaction and attrition from the field. This highlights that emotional sustainability must be built into conservation systems, especially those involving high-risk, high-emotion work like snake rescues. Without mental health support or systemic reform, ethical rescuers may continue to exit the field, leaving a vacuum filled by less accountable actors.

These findings suggest that the current model of snake rescues is not only failing to promote coexistence in many pockets of the region but is also unsustainable for those carrying it out. Without structural reforms, such as fair wages, mental health support, and clear rescue protocols, burnout will continue to drive ethical rescuers away, leaving the field increasingly dominated by those seeking social status or financial gain rather than conservation.

4.4.7 Urbanisation and the Changing Landscape of Human-Snake Conflict in Goa

Urbanisation in Goa has accelerated rapidly over the past three decades, transforming vast expanses of agricultural land, forests, and undeveloped spaces into residential complexes, commercial hubs, and linear infrastructure such as roads and highways (TERI, 2015; Sutheeshna,

2021). While urban expansion has brought economic growth and modern housing, it has also resulted in habitat fragmentation and displacement of wildlife, including snakes, a pattern being observed in some parts of the country, yet reported in very few studies (Menon et al., 2022), though it has been formally recognised by the MoEFCC in the 2023 mitigation guidelines as a possible leading cause. Analysis of this chapter's data also showed similar patterns, revealing that snakes are being pushed into human-dominated spaces, altering human-snake interactions and, in turn, driving an increase in rescue operations.

The Link Between Land-Use Change and Increased Snake Rescues

Analysis of the interviews showed a noticeable shift in snake encounters, particularly in areas that had undergone recent urban development. One long-time resident described how snake sightings changed following construction activity in his neighbourhood commenting, "This full area was covered with fields, but then people sold off their land to builders. Now, we see more snakes." A community member who had increased his frequency in calling rescuers said, "I feel like since they started building that new colony, we have more snakes here." Another resident, whose home was located near a large construction site, noted that snake encounters were far less common before the development project began, "In the early years when we moved here, there were more snakes, or rather we had sightings, but in the last few years, there have been virtually none."

These observations align with the ecological principle of displacement, where species that once thrived in natural habitats are forced into adjacent areas, including human settlements, in search of shelter and food (Parkin et al., 2020). Herpetologists noted that checkered keelbacks used to be common in urban areas, "But now they're disappearing. You still see them in rural and agricultural landscapes, but not as much in cities." A private rescuer who has been actively handling snake rescues in North and South Goa echoed this observation, pointing out that different species were appearing in different parts of the state in ways that were not historically recorded, saying, "What you see sometimes is a difference in the kind of species we get. We're also noticing a change in species being found in certain places. Like Calangute, a North Goa

tourist town, has more cobras and Russell's vipers now. We're also getting cases of Russell's vipers on the beach in some areas."

"We've seen Russell's vipers coming in recently, I think over the past 5 years. They weren't there before. It used to be mostly cobras and rat snakes", said another community member. Commenting on Goa's capital, Panjim, another community member said, "Suddenly now python populations have increased, which are presumably coming from the areas which have been razed in the hills, near Nagali Hill and Dona Paula."

Similarly, a herpetologist with extensive field experience in Goa, explained that linear infrastructure projects such as highways were fragmenting snake habitats, increasing both sightings and rescues. He said that over the years, he had gathered lots of anecdotal evidence on the linear infrastructure affecting snake conflict. He, also, pointed out the increasing incidences of snakes being caught in the fishing nets, normally used for fencing or lying discarded after use, as they moved from one region to the other (see figure 4.2). This had also led to a steady increase in human-snake encounters and rescues. Some community members also commented on road construction saying they have "seen more snakes near our houses, since it started." Increased infrastructure not only displaced snakes but also made roadkill a major cause of mortality, with a rescuer stating, "The major reason for roadkill is widening of roads. Village roads turn into highways, which increases speed."

While it is well established that deforestation and urbanisation increase human-wildlife conflict (Menon et al., 2022, MoeFCC, 2023), these insights highlight that Goa's urban growth is fundamentally reshaping snake distribution, necessitating more rescues not because of increased snake populations but due to increased human encounters with displaced individuals.



Figure 4.2: Snakes caught in fishing or “ghost” nets in Goa

These nets are referred to as “ghost” nets because they are often nearly invisible, making it difficult for snakes to detect them. Typically made of tough nylon that cannot be bitten through, they entangle the snake further as it struggles to escape. Cutting snakes out of such nets often requires rescuers to forgo thick safety gloves, as the small, sharp tools needed for disentanglement are difficult to handle with protective gear. The process is physically risky for the rescuer and highly stressful for the snake and if not done carefully, can result in injury.

Photos: Top row- spectacled cobra caught in a “ghost” net.

Bottom row- Indian rock pythons caught in different types of fishing net. (Python photos: Benhail Antao)

Construction Sites as Conflict Hotspots

Construction activity emerged as a significant driver of human-snake encounters in Goa, in the thematic analysis. When land is cleared for housing developments, the removal of vegetation, rocks, and debris eliminates natural refuges for snakes, forcing them to seek shelter in the nearest available locations (MoEFCC, 2023), often in human residences, gardens, and unfinished

buildings. Several rescuers and residents highlighted this phenomenon in the interviews. An architect added, “In one of the areas close by, they started a construction. Somebody is building a house, so there are construction workers on this site. One day somebody got bitten by a cobra apparently, and then they all panicked and shut down work for one week.”



Figure 4.3: A spectacled cobra at an active construction site in Goa (Photo: Benhail Antao)

A security guard working in a housing society near an emerging development also described how he regularly encountered displaced snakes, saying, “They come from the garden. Mostly, we see them on the main road trying to cross. That’s when they get run over.” Another security guard, similarly, employed in a housing society near a construction site, had encountered multiple snakes at his worksite. He described how he would instinctively pick them up and throw them back into the construction site, only to realise during the interview, that they were venomous Russell’s vipers, and he had been mistaking them for pythons or boas.

Another long-time rescuer further commented on how rapid construction is pushing snakes into residential areas, saying, “Earlier, I used to get 20-25 calls. Now I get one or two. People think snakes have disappeared, but they are just pushed further out due to construction.”

These testimonies suggest that construction activity does not reduce the overall snake population but rather forces it into new spaces, altering the way humans and snakes interact. This shift has increased the number of rescues, with snakes now being more visible and more likely to encounter people, thereby triggering removal requests.

The MoEFCC (2023) guidelines emphasise on minimising habitat disruption, recommending State Forest Departments (SFDs) should conduct pre-construction ecological assessments to identify high-risk zones and ensure buffer areas for displaced wildlife. They also recommend establishing science-based advisories for real estate developers, requiring consultation with wildlife experts and conservationists before undertaking large-scale land modifications. These assessments would enable landscape-level mitigation strategies, such as preserving green corridors, avoiding excessive ground clearance, and implementing compensatory afforestation where necessary.

The Role of Garbage and Rodents in Snake Encounters

The analysis of the interview also suggested that urbanisation had also altered prey availability, further increasing snake encounters in human settlements. Several rescuers and herpetologists noted that the rise in garbage accumulation had led to an increase in rodent populations, which, in turn, attracted more snakes to urban areas, with one rescuer saying, “We have too many rats, so of course, we get snakes. We can’t stop them from coming.” Another herpetologist added, “We’ve never had as much of a rodent challenge as we do now, and this is directly related to garbage. The more rodents you have, the more snakes will come.”

Certain species, such as rat snakes and cobras, are particularly drawn to areas with high rodent densities (Barhadiya et al., 2024), explaining why some regions were now experiencing more frequent snake encounters. A herpetologist warned that failure to address this issue would only escalate conflict, asserting, “Rodents are like a magnet for snakes. And this is happening again. We have certain snake species increasing in specific areas because of changes in rodent populations.”

The relationship between urban waste management and human-snake interactions is a critical but often overlooked factor in human-snake conflict mitigation strategies. If cities do not implement better garbage disposal systems and instil education and awareness about keeping their environment clean, rodent populations will continue to grow, fuelling more snake encounters and rescues. Highlighting the magnitude of Goa's waste management problem, Chomal et al. (2024) found that South Goa produces approximately 198 metric tons of waste daily, with nearly equal proportions of wet (51%) and dry (49%) waste. Their study showed that residential and commercial activity, intensified by tourism, forms a major share of this waste load. Analysis of this chapter's interview data indicated that poor waste disposal practices in commercial and residential areas have played a key role in influencing snake encounters. A herpetologist stated, "The more rodents there are, the more snakes you get. In some places, snake sightings have increased simply because of poor garbage management."

One rescuer specifically pointed out that coastal urban expansion, including tourism-driven development, had contributed to a rise in snake sightings in some areas, in some cases signalling a minor shift from their preferred habitats, stating, "With the increase of beach restaurants and improper disposal of waste, I think Russell's vipers are really thriving."

To address this, awareness programs must emphasise that keeping one's immediate environment clean is a direct and effective way to reduce the likelihood of attracting snakes (Roshnath and Divakar, 2019; Salim et al., 2024). While structural waste management improvements are needed, behavioural change at the individual and community level remains key to reducing snake encounters linked to food waste and rodents.

Traditional vs. Modern Housing: How Architecture Affects Snake Presence

Thematic analysis highlighted that Goa's Indo-Portuguese houses, with their open verandas, tiled roofs, and ventilation gaps, provided multiple entry points for snakes, making encounters more common in older homes compared to modern, sealed apartments. Unlike contemporary construction, which prioritised airtight insulation and secure entry points, these traditional homes were designed to encourage natural airflow and passive cooling, which inadvertently created

more potential hiding spots for snakes. A local architect noted, “Modern houses, snakes don’t enter. I feel with the old Goan houses, the Indo-Portuguese houses, there are more entry points.”

These structures often included attics, lofts, and wooden beams, all of which provided safe, undisturbed shelter for arboreal and semi-arboreal species such as bronzeback tree snakes, vine snakes, wolf snakes and even cobras. In contrast, modern gated complexes and high-rise buildings had fewer such access points, making snake encounters rarer inside the homes themselves but more frequent in gardens, basements, and parking areas. A veterinarian working in Goa also supported this observation saying, “Almost all the cases of dogs encountering snakes are from gardens and bungalows. In apartments, this rarely happens inside the house.” At the same time, some species are adapting to the buildings in unexpected ways, with one rescuer stating, “Snakes are now found even on 4th or 5th floor balconies. They climb up trees and enter. We frequently get calls to fish 7-10 bronzebacks out of AC units in the summer, who’ve gotten in there to mate.”

Structural design plays a critical role in determining the frequency of snake encounters inside homes. Modifications to older Indo-Portuguese houses, such as sealing ventilation gaps, reinforcing tiled roofs, and reducing dense ground vegetation, can significantly limit entry points and lighting pathways and keeping the grass short can increase visibility, reducing accidental encounters. A combination of heritage conservation strategies and modern architectural adaptations, along with preventative behaviour adaptation, can proactively prevent human-snake encounters without necessitating removals.

Security Guards as Untrained First Responders in Snake Encounters

Thematic analysis also revealed that security guards in urban residential complexes, commercial properties, and construction sites frequently encountered snakes, often becoming the first responders in human-snake interactions. Despite their proximity to high-risk environments, they lacked formal training in snake identification, safe handling, or emergency response. Data showed that unlike other urban personnel, such as municipality workers or Forest Department officials, security guards were expected to act without any institutional support or structured

protocols. Interviews conducted for this study indicated that security agencies provided no formal guidance on dealing with wildlife encounters, leaving guards to rely on their own instincts or misinformation when confronted with a snake.

Analysis of the interview data also suggested that many security guards working in Goa's urban areas were migrants from other states, further complicating their ability to correctly identify local species. One security guard, originally from Assam, admitted his complete unfamiliarity with Goa's snake fauna, stating, "I have seen black ones. But I don't know the snakes over here. In my village, we call it Dura, it's a different kind of red snake." Another security guard working near a construction site recounted how he had removed multiple snakes from residential premises, only to later learn that some were venomous Russell's vipers, saying, "I picked up snakes in my village, but not here. I didn't know this one was different." Such misidentifications not only put the guards themselves at risk of envenomation, but also increased the likelihood of unnecessary removals, as even non-venomous species are indiscriminately relocated due to fear and uncertainty.

Data analysis also showed that the absence of formalised training meant that security guards often attempted removals themselves, even when lacking the necessary skills to do so safely. In gated communities, residents frequently expected guards to act as wildlife responders, assuming that snake removal was a part of their duties. However, findings confirmed that most guards remained unaware of professional rescue services, having no knowledge of first aid or hospital referral systems, and were often left to improvise in the event of a snakebite. One guard, when asked what he would do in a medical emergency, admitted, "No, I don't know where to go if a snake bites. The agency has not told us anything." Such responses highlight a critical gap in urban human-snake conflict mitigation, where those most likely to encounter snakes are least equipped to handle them (Mukherjee, 2023).

Beyond their lack of training, interview data also suggested that security guards often experienced pressure from both employers and residents to manage wildlife encounters, despite their limited expertise. One rescuer familiar with urban rescue trends noted that guards

frequently removed snakes without realising the risks involved and handling species that should require professional intervention. In many cases, guards relied on makeshift containment methods or even physically restrained the animal, increasing the probability of both injury and snake mortality. A security guard working in a residential complex admitted that most snake sightings inside the premises resulted in removals because they did not know what else to do. He said, “If a snake comes in the building, they call us. If it’s outside, they don’t call.” This distinction underscores how snakes outside human-occupied spaces are tolerated, but once inside, their removal becomes non-negotiable, reinforcing the cultural perception that human spaces and wildlife cannot coexist.

Analysis clearly showed that the absence of clear institutional protocols means that when faced with a snake, guards are left with only two options: removing it themselves or waiting for an external rescuer. Since many were unaware of whom to contact, the former was often the default choice. Guards expressed a willingness to receive training, if it were made available. One security guard acknowledged that education would benefit both themselves and the public, stating, “If the agency arranges training, we will do it. It is good to learn something like this.”

4.4.8 Beyond Removals: A Coexistence-Driven Framework for Snake Rescues in Goa

Shifting Toward a Solution: Can Coexistence Models Work?

While snake rescues in Goa have largely been removal-driven, the data suggests that an alternate model, one that prioritises education and identification awareness, has been successfully fostered coexistence in some areas. However, such approaches remain underexplored in published literature, with Malhotra et al. (2021) noting that almost no studies, globally, have evaluated the long-term success of coexistence models in human-snake conflict mitigation.

Findings from this study indicated that although in the minority, communities that received repeated awareness interventions, whether through rescuers, social media engagement, or educational programs, showed greater tolerance for it. Data indicated that these communities

exhibited a clear shift in behaviour, from immediate panic-driven removals to passive acceptance or informed decision-making.

One rescuer highlighted this transformation, stating, “Now, people send me a picture first. If it’s non-venomous, they leave it alone.” Another rescuer noted that in army camps where frequent rescues were initially conducted, regular awareness efforts had normalised snake presence, stating, “Initially, they would say ‘If you don’t come, we will kill it.’ But now, they manage and don’t call unnecessarily.”

While earlier sections noted concerns about performativity and misinformation in social media representations of rescues, interview data also highlighted its constructive use in promoting coexistence. Some rescuers described how digital platforms, particularly WhatsApp groups, have become tools for real-time species identification and informed decision-making. As one rescuer noted, “People send me a picture first. If it’s non-venomous, they leave it alone.” Another added, “There’s a number of people on the group from that area and they’ll very regularly post photos of whatever it is... rat snakes, bronzebacks, keelbacks.” These platforms, when used effectively, provided immediate access to expertise, reducing unnecessary removals and reinforcing public confidence in identification-based tolerance.

Data also showed that in some areas, tolerance extended beyond isolated incidents. As one herpetologist observed, “There are villages like Koparden in Sattari where people never call for rescues. They just let snakes be.” In one household, a community member recalled, “One night, my mother was on the rocking chair. She felt a snake pass by her feet but didn’t react. It just moved along.” These cases, while rare, demonstrate a quiet, lived form of coexistence, one that does not rely on formal interventions like removals but on local norms and inherited comfort with sharing space.

Interview data also highlighted that such attitudes, while waning, are sometimes being revived through awareness sessions that deliberately reconnect Goans with their cultural memory. One rescuer described how “in certain villages, people talk about *Zyagetyo Sorop* which means a kind

of resident snake. A territorial cobra that lives in the same space for years. Some people think it protects them.” Rather than dismissing these beliefs, a few rescuers actively draw on them during outreach, using them as a culturally grounded entry point for promoting peaceful cohabitation.

Analysis showed that the effects of awareness were particularly visible in younger generations and peer learning networks. A community member reflected, “If a snake topic comes up, I would definitely tell my friends about what I learned (in the awareness session),” while another noted, “Kids now grow up knowing snakes are part of the ecosystem.”

Though coexistence remains fragile and uneven, these examples suggest that with sustained support, even deeply embedded fears can be reworked into frameworks of tolerance. Awareness-based interventions, whether in-person or digital, have demonstrably influenced public perception, leading to reduced reliance on removals. This finding contrasts with studies such as Keener-Eck, Morzillo and Christoffel (2020b) and Kontsiotis, Rapti and Liordos (2022), which found that attitudes toward coexistence are often shaped by perceived risk, with venomous snakes typically eliciting more negative responses. In Goa, however, tolerance occasionally extended even to medically significant species under certain circumstances. That said, these efforts remain sporadic and are yet to be integrated into a systematic, institutional framework.

A Goa-Specific Framework for Ethical and Sustainable Snake Rescues

Given Goa’s unique challenges, widespread dependence on rescues, lack of regulatory oversight, and varying rescuer ethics, a structured, multi-tiered framework is needed. Implementing such a framework, where rescuers are certified, the public is trained, and community-based awareness is prioritised, will create a more sustainable human-snake conflict mitigation system. This system must be developed in collaboration with the Forest Department, experienced rescuers, medical professionals, veterinarians, and community leaders, ensuring it is both enforceable and sustainable (MoEFCC 2023).

1. Certifying and Recognizing Ethical Rescuers

To ensure consistent and ethical practices, the Forest Department should introduce a certification system for snake rescuers. A formal registry would help regulate rescue activity, while offering trained individuals' legal recognition and institutional support. Ethical rescuers who prioritise coexistence and follow established protocols should also be granted access to equipment and financial assistance. This would professionalise rescue work and deter unqualified or opportunistic interventions.

2. Education and Digital Tools for Snake Identification

Misidentification of non-venomous snakes remains a major driver of unnecessary rescues. Public education, through schools, community workshops, and hospital programs, should prioritise basic snake ID skills. Digital platforms like WhatsApp groups have already reduced panic-driven removals by enabling rapid expert verification. Scaling up such tools can help communities make informed decisions and avoid default removals.

3. Gender Inclusion: More Women Rescuers and Outreach

Women remain underrepresented in rescue work, yet their participation is vital in culturally sensitive contexts. Structured training and mentorship programs for women can improve accessibility, normalise female involvement, and broaden community engagement. Interview data analysis highlighted the exclusion women face in male-dominated networks, underscoring the need for targeted inclusion efforts to build a more diverse and effective conservation workforce.

4. First Responder Training for Security Guards, Lifeguards and Medical Professionals

First responders, including security guards, lifeguards, and medical personnel, often lack training in handling snake encounters. Security staff should be trained to identify snakes and contact certified rescuers rather than attempting removals. Providing them with basic snake identification training, emergency response guidance, and access to certified rescue networks would reduce unnecessary removals and enhance both public safety and conservation outcomes. Goa's lifeguard training model can be expanded to other groups. Basic snake ID and coexistence

modules for doctors and veterinarians can also help prevent misinformation and reduce fear-based removals.

5. Strict Regulation of Unverified Rescuers and Public Reporting for Misconduct

Unverified rescuers operating outside ethical guidelines pose a significant risk, as they often conduct removals without proper protocols, mishandle venomous species, or engage in staged rescues for social media visibility. A regulatory mechanism should be established to monitor rescuer conduct and provide the public with a formal channel for reporting misconduct.

However, the Forest Department must strike a balance, tightening oversight while still allowing ethical rescuers to operate effectively. Additionally, rescuers engaging in reckless handling, illegal wildlife trade, or unauthorised removals must face strict action, in alignment with existing wildlife protection laws and advisories from the WCCB.

6. Institutionalising Reporting and Documentation

A mandatory reporting and documentation system is essential for tracking rescue trends, identifying high-risk areas, and informing conservation policy. This would require all rescues to be logged with key details, including species involved, location, reason for removal, and release site. The absence of structured documentation currently prevents conservationists from understanding the long-term impact of removals on snake populations (Whitaker, 2018; Malhotra et al., 2021). A standardised data collection protocol would enable evidence-based decision-making, allowing authorities to shift from reactive removals to proactive conservation strategies.

4.5 Conclusion: Rethinking the Role of Snake Rescues in Goa

This study highlights the evolving role of snake rescues in Goa, from a conservation tool that reduced retaliatory killings to an over-relied-upon removal system that risks undermining coexistence. While rescues have undoubtedly prevented snake mortalities, the growing public dependency on removals has shifted them from an emergency response to an expectation, reinforcing the idea that snakes do not belong in human spaces. The lack of legal recognition,

standardised training, and regulatory oversight has further led to inconsistent handling practices, unregulated translocations, and ethical concerns surrounding indiscriminate removals.

To address these challenges, a structured rescue framework is essential, integrating rescuer certification, standardised protocols, and strict oversight of unverified removals. Additionally, education-based approaches, including public awareness programs, digital snake identification tools, and first responder training, must become central to mitigation efforts. Encouraging gender inclusivity in rescue networks and mandating proper documentation would further improve conservation outcomes, ensuring that rescues prioritise coexistence rather than reinforcing removal culture. As a herpetologist succinctly put it, “People need to understand that this is urban biodiversity. We need to start seeing these snakes as part of the city, not something that has to be removed.”

Ultimately, snake rescues must evolve from reactive removals to a structured, evidence-based coexistence strategy. Without intervention, unregulated rescues will continue to reinforce fear and dependency, making conflict resolution unsustainable. However, with a science-driven, education-first approach, Goa can transform snake rescues into a long-term conservation model, ensuring both human safety and the protection of its native snake populations.

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Chapter 5

Snakebite Envenomation and Predation in Domestic Animals in Goa, India

5.1 Abstract

Despite the significant impact of snakebite on domestic animals, research on envenomation and snake-related mortality in pets and livestock remains globally underreported and poorly documented. In India as well, no centralised dataset exists for snakebite-related deaths in domestic animals, leaving veterinary responses fragmented and unsupported by national policy frameworks. This study examines the veterinary, economic, and human-wildlife conflict dimensions of snakebite mortality in domestic animals through a qualitative analysis of 56 in-depth interviews with key stakeholders such as veterinarians, pet owners, livestock keepers, forest department officials, herpetologists, snake rescuers, and community members across Goa. The research identifies gaps in treatment accessibility, policy failures, and human responses to snakebite-related animal mortality.

Findings indicate that systemic gaps in veterinary infrastructure, inconsistent anti-snake venom (ASV) stocking, and the absence of standardised treatment protocols have contributed to preventable mortality in domestic animals. While some government veterinary facilities provide ASV on demand, most do not stock it regularly, leaving private practitioners as the primary source of treatment. This results in treatment delays, financial barriers, and increased dependence on individual veterinary clinics rather than an integrated response. While dogs are the most frequently treated for envenomation (primarily from Russell's vipers and cobras), python predation disproportionately affects cats, poultry, and small pets, triggering intense emotional reactions, retaliatory killings, and heightened human-wildlife conflict. The emotional toll on owners of companion animals is also profound, with retaliatory snake killings, aggression toward veterinarians, and public frustration over veterinary constraints frequently reported. Livestock deaths attributed to snakebite are often recorded without verification, either to facilitate compensation claims or due to diagnostic limitations. Redressal is only provided by the Animal Husbandry Department for livestock purchased under the government Kamdhenu scheme. Unlike big cat predations, no compensation exists for snakebite-related animal losses under the ambit of Forest Department.

Key recommendations include snakebite data being documented, mandatory ASV stocking in veterinary hospitals, expansion of emergency veterinary care services, structured compensation schemes for privately owned livestock and pets, and greater integration of veterinarians into wildlife conflict mitigation strategies, along with awareness on responsible pet ownership. Without these interventions, snakebite mortality in domestic animals will remain poorly documented, poorly managed, and largely ignored within India's broader wildlife policy landscape.

5.2 Introduction

Snakebite envenomation is a significant yet overlooked aspect of human-wildlife conflict, with major implications for public health, rural livelihoods, and veterinary care (Babo Martins et al., 2019). While human snakebite mortality has been increasingly studied and integrated into national health policies, envenomation in livestock and domestic animals remains poorly documented (Bolon et al., 2019). Despite being a common issue in many rural and agrarian economies, systematic epidemiological data on snakebite-related animal deaths are largely absent, leading to an underestimation of its economic and social impact (Bolon et al., 2019).

Global assessments indicate that snakebites frequently affect domestic animals, particularly in regions where venomous snakes overlap with agricultural and pastoral landscapes. The first global scoping review of snakebites in domestic animals came out in 2019, suggesting that cattle, sheep, goats, pigs, horses, and dogs are among the most commonly affected species, with envenomation and predation leading to possibly high economic losses (Bolon et al., 2019). In the Central Pacific region of Costa Rica, an estimated 10,000 cattle deaths per year are attributed to snakebites, though this figure was merely an observation by the authors (Herrera et al., 2017). Similarly, community-reported data from Nepal and Cameroon suggests that snakebite-related livestock losses may be widespread yet remain unrecognised in national compensation schemes (Bolon et al., 2021). Most studies on snakebite in domestic animals remain limited to small-scale

clinical reports or locally limited rather than large-scale epidemiological assessments (Dykgraaf, Pusterla and Hoogmoed, 2006; Bolon et al., 2019; Serruya et al., 2024).

Veterinary research on envenomation in companion and leisure animals, primarily dogs and cats, has been disproportionately concentrated in high-income countries, particularly in the United States, Australia, and Europe (Hill, 1979; Peterson, 2006; Cullimore, Lester and Swindells, 2013). Many such studies focus on clinical management (Holloway and Parry, 1989; Leisewitz et al., 2004; Ananda et al., 2009; Rodríguez et al., 2016) rather than economic impact, leaving major gaps in understanding the broader consequences of snakebite-related pet mortality in low- and middle-income countries (Bolon et al., 2019). No studies to date have systematically assessed the financial or emotional burden of pet envenomation in snakebite-endemic regions.

Despite India being one of the most severely affected countries in terms of human snakebite deaths (Mohapatra et al., 2011; Suraweera et al., 2020), there is no comparable dataset on snakebite mortality in livestock or companion animals. Veterinary research in India has largely focused on clinical case reports of cattle and small ruminants (Bhikane et al., 2020), with no systematic epidemiological assessments to quantify envenomation rates, mortality patterns, or economic consequences. This lack of data parallels a broader global trend, where snakebite in domestic animals remains largely unrecorded and underreported, contributing to a critical gap in human-wildlife conflict research.

Veterinary treatment infrastructure for snakebite cases remains inconsistent worldwide, with significant gaps in anti-snake venom (ASV) access and standardised treatment. Unlike human hospitals, which in many countries maintain ASV under national health policies (Bolon et al., 2019), veterinary clinics lack similar regulatory frameworks, leading to variable ASV availability across regions (Bolon et al., 2021). Studies suggest that veterinary ASV access is often dependent on private supply chains rather than government mandates, making treatment delays more likely (Bolon et al., 2019). Additionally, standardised protocols for veterinary envenomation cases remain poorly established, with treatment approaches varying significantly across regions and practitioners (Bolon et al., 2019).

The economic burden of snakebite-related mortality in animals remains poorly quantified, as existing literature primarily focuses on human healthcare costs rather than financial losses incurred by livestock farmers or pet owners (Bolon et al., 2019; 2021). While government-backed livestock insurance schemes exist in some regions, there is no clear indication that snakebite-related deaths are systematically covered anywhere (Bolon et al., 2021). In contrast, structured compensation programs exist for large carnivore predation (Karanth, Gupta and Vanamamalai, 2018), raising questions about why snakebite-related losses remain unaddressed.

This chapter addresses these critical gaps by examining snakebite-related mortality in domestic animals and livestock in Goa, India. It explores veterinary response challenges, economic consequences, the absence of structured compensation, and human perceptions of snakebite-related deaths. Specifically, this chapter examines:

- The prevalence and veterinary response to snakebite envenomation in domestic animals and livestock.
- Challenges in treatment availability, including ASV access and emergency veterinary care.
- Economic implications of snakebite-related livestock and pet mortality, including gaps in compensation mechanisms.
- Public attitudes toward snakebite-related animal deaths, retaliatory killings, and broader human-snake conflict, particularly in contrast to large carnivore-related conflicts.

By providing empirical data on snakebite incidents in animals, this research contributes to a broader understanding of snakebite as a neglected component of human-wildlife conflict, highlighting the need for improved veterinary policies and mitigation strategies.

5.3 Methods

This study employed a qualitative approach to examine the impact of snakebite on domestic animals in Goa, with a particular focus on veterinary challenges, economic consequences, and

human responses to snakebite-related animal mortality. Given the absence of structured epidemiological data on snakebite in livestock and companion animals in India, qualitative data collection was prioritised to capture veterinary insights, pet and livestock owner experiences, and systemic policy gaps (Bolon et al., 2019).

5.3.1 Data Collection and Stakeholder Selection

A preliminary study was conducted between September and October 2021 to establish a baseline understanding of veterinary treatment for snakebite cases and the broader challenges in domestic animal management. The main phase of fieldwork occurred from March 2022 to February 2024, covering both North and South Goa, and incorporating urban, semi-urban, and rural areas to reflect the diversity of human-animal interactions and veterinary accessibility.

Semi-structured, open-ended interviews were the primary data collection method, allowing participants to share their experiences without restriction, thereby reducing interviewer bias (Campbell et al., 2013; Bryman, 2016). A total of 68 in-depth interviews were conducted using snowball sampling and convenience sampling to reach relevant stakeholders (Ibbett et al., 2023) (refer to Supplementary Sheet, S0 for baseline interview questions for select stakeholders). Out of these interviews relevant insights were extracted for data analysis from the selected stakeholder groups (n = 56), which were:

- Veterinarians (n = 10): Insights into snakebite treatment protocols, ASV availability, emergency care limitations, and economic barriers to treatment.
- Pet owners (n = 7): Emotional and financial burden of treating snakebite in companion animals, responses to snake encounters, and retaliatory actions.
- Current and former Forest Department officials (n = 5): Perspectives on livestock compensation frameworks, policy gaps, and enforcement challenges.
- Current and former animal husbandry department officials (n = 2): Governance issues, legal frameworks, and the role of veterinary care in human-wildlife conflict policies.

- Snake Rescuers (n = 16): Observations on snakebite trends, veterinary referral patterns, and human-wildlife conflict mitigation.
- Herpetologists (n = 5): Insights into snake ecology, behaviour, and patterns of human-animal interactions.
- Domestic animal rescuers (n = 3): Cases of snakebites in community animals, shelter animals, rehabilitation efforts, and public awareness.
- Community members (including poultry owners) (n = 8): Perceptions of snakebite, attitudes toward snake presence, and coexistence challenges, economic impact of snake predation, mitigation efforts, and interactions with rescue networks.

5.3.2 Interview Protocol and Data Management

All interviews were recorded with prior informed consent, ensuring anonymity unless explicit permission was given for attribution (Bryman, 2016). The primary mode of data collection was audio recordings, with consent obtained on record. In cases where interviewees were uncomfortable with recording, written notes were taken instead. Interviews were conducted in English, Konkani, and Hindi, depending on participant preference.

5.3.3 Data Processing and Thematic Analysis

The recorded interviews were translated and transcribed into English using TurboScribe, an AI-powered transcription tool based on Whisper (Python-based voice recognition and translation). All transcripts were manually edited and verified for accuracy before thematic analysis (Belotto, 2018).

Interview data were categorised based on stakeholder roles and manually coded to identify recurring themes. As in previous chapters, an initial attempt was made to use NVivo for coding and thematic analysis (Campbell et al., 2013), but due to the complexity of veterinary challenges spanning multiple overlapping research themes, a manual thematic analysis approach was ultimately adopted using structured categorisation in Microsoft Excel (Kiger and Varpio, 2020).

Using a structured thematic analysis approach (Clarke and Braun, 2017), key themes were mapped onto the study's research objectives and categorised as follows:

1. Species-specific snakebite trends: Identifying which domestic animals (dogs, cats, poultry, livestock) were most affected and examining species-specific vulnerabilities.
2. Medical and logistical challenges in veterinary treatment: Assessing ASV availability, emergency care barriers, and diagnostic challenges.
3. Economic burden of snakebite on domestic animals: Evaluating treatment costs, financial burden on pet owners, and gaps in livestock compensation.
4. Emotional and behavioural responses to snakebite mortality: Investigating grief, frustration, and retaliatory killings of snakes.
5. Veterinary perspectives on policy gaps: Analysing the disconnect between veterinary challenges and existing animal welfare and wildlife conflict mitigation policies.
6. Impact of public awareness and changing attitudes: Evaluating how awareness campaigns and rescuer interventions have influenced responses to snakebite-related animal deaths.
7. Pet responsibility and mitigation strategies: Exploring responsible pet ownership and recommendations for snake-proof yet snake-friendly enclosures.

All data were systematically entered into Microsoft Excel, recording each interview's identification tag, stakeholder category (e.g., veterinarian, rescuer, livestock owner), theme, relevant research question, exact quote, and contextual summary. This manual system ensured a more fluid, intuitive mapping of connections between responses, aligning qualitative insights with the study's core research objectives while allowing flexibility to integrate emerging themes not initially anticipated.

By structuring the thematic analysis within the broader context of human-wildlife conflict research, this study provides empirical insights into veterinary snakebite management, economic

and emotional burdens on animal owners, and policy gaps in Goa's current mitigation strategies. This structured approach ensures that stakeholder perspectives are systematically mapped onto the study's objectives while also allowing for comparisons with existing conservation policies, veterinary frameworks, and human-wildlife conflict literature.

In addition to qualitative interviews, compensation records from the Goa Forest Department (2020–2023) were reviewed to assess whether livestock or pet owners had received financial redress for snakebite-related animal losses. These records were obtained through direct engagement with Forest Department officials during the data collection process.

The review of compensation records was not intended for statistical analysis but served as documentary verification to cross-check interviewee claims regarding the absence of structured compensation.

5.3.4 Ethical Clearance

Ethics clearance was obtained in September 2021 from Ethics Committee of the School of Anthropology and Conservation, University of Kent (approval number: 16-PGR-20/21). TurboScribe was chosen because all files are encrypted at rest. None of the audio files contain identifiable information about the interviewee unless they explicitly gave permission to use the same. Access to the files is strictly controlled only to the account holder and once the account is deleted, all data is automatically deleted. No third party has access to the files, nor are they retained by TurboScribe. The files were only uploaded for the purposes of the transcriptions and the account deleted as soon as the text files were ready. All qualitative data has been securely stored on university servers and personal secured hard drives, and no identifiable personal information has been retained unless explicit permission was granted.

5.4 Results and Discussion

5.4.1 Species-Specific Trends in Snakebite Mortality

The data analysis of interviews showed that unlike human cases, where at least some records are maintained, veterinary snakebite incidents are not systematically documented and likely

underreported, creating uncertainty about the true scale of snakebite impacts on domestic animals in Goa. None of the clinics maintained robust records but could recall approximate number of cases that were treated. Nevertheless, thematic analysis of veterinarian, rescuer, and pet owner interviews provides insight into species-specific trends, behavioural risk factors, and seasonal variations. Analysis of interview data indicated dogs, cats, poultry and livestock (cattle, pigs, goats) as the primary animal groups affected by snakes, either through envenomation or predation, or occasionally both. Geographically, veterinarians from more urban areas like Panjim appeared to report slightly higher case numbers, though this likely reflects improved veterinary access rather than higher snakebite frequency. A veterinarian noted, “We get lots of snakebites even though the areas are now getting urbanised. Before, we got them from villages- now the same places have buildings, but the snakebites haven’t decreased.” This ties in with broader challenges noted about snakebite-related mortality among domestic animals, where they remain difficult to quantify accurately due to fragmented and inconsistent veterinary reporting (Bolon et al., 2019).

Data analysis suggested that an average of 5–15 cases were reported annually per clinic. In Panjim alone, four veterinarians in a 5-km radius confirmed similar figures, suggesting at least 30–40 cases being treated annually in the capital. However, veterinarians confirmed that most of those cases were coming from suburban hilly or forested areas outside the city or from other towns and not necessarily within the more built-up or densely urbanised parts of the city. Analysis also indicated that veterinary access drove reporting patterns, as peri-urban areas had limited veterinary facilities stocking anti-snake venom. This trend was further emphasised by veterinarians in South Goa, who noted similar patterns of case clustering in Margao. One Margao-based veterinarian explained, “Till today, I am one of the only vets in South Goa who started carrying anti-venom. People travel from far just to get ASV because many places don’t stock it.” Another veterinarian added more on this commenting, “Most people don’t know where to take their animals if there’s a snakebite. If you are in Panjim, you have choices. In other places, people don’t always have that option.” Interview data also showed that the veterinarians noted cases primarily coming in from urban areas than rural ones.

Data analysis revealed that pet dogs were the most frequently reported domestic animal victims of snakebites in Goa, primarily involving Russell's vipers and cobras. In many cases, snakes were also often found to be a casualty of the encounters. One vet explained the lack of confirmed krait bites saying that most of those cases are harder to diagnose and kraits being nocturnal in nature, quite often escape the notice of the owners to get a confirmation on the species. Most bite incidents involved dogs kept outdoors in spaces like farms, bungalows or houses with compounds and/or those performing guard duties, rather than pets confined to apartments, resulting in increased exposure to snakes. Although pedigree breeds, such as German Shepherds and Dobermans, were frequently reported, veterinarians clarified that this representation was driven by their role as being popular breeds for guard dogs rather than breed-specific vulnerability. As one veterinarian stated, "Most cases involve pedigree dogs because they are kept as pets and guard dogs. I've noticed a lot of Rottweilers and Dobermans coming in, but I equally see Indian dogs. The common factor isn't breed. It's that they're kept outdoors as guard dogs."

Findings from interview data indicated a recurring pattern across multiple veterinarians, suggesting that dogs exhibited varied behavioural responses to snake encounters. While some dogs exhibited learned avoidance behaviours after an initial bite, others repeatedly encountered snakes without any noticeable avoidance learning. A veterinarian noted, "I've personally noticed similar dogs or almost the same dogs coming in every year." Another senior veterinarian explained this further saying, "Most dogs that get bitten once become cautious. But we've had one Doberman that was bitten three times. It kept going after snakes because of its drive to protect its owner." Another veterinarian also noted that when those dogs tended to survive, some owners got complacent about subsequent bites compounding difficulties in survival. Results denoted that puppies were particularly vulnerable due to their curiosity and smaller body size, resulting in rapid fatal outcomes post-bite. One veterinarian remarked, "Puppies usually don't survive because they wander off, get bitten, and die before they reach us." Community dogs-free-roaming animals without specific ownership but generally cared for by local residents, and commonly referred to as "street" or "stray" dogs- were rarely reported in veterinary records. One veterinarian explained, "I don't get community dogs with snakebites." Another described a

specific case where a community dog bitten by a snake “ran into the woods before help could reach.” Whether this lower reporting reflects fewer bites, lower veterinary care access, or lack of dedicated individual caretakers remains uncertain. As a rescuer stated, “Community dogs may also get bitten, but those cases probably often go unreported.” However, analysis also showed a differing viewpoint wherein some community members, rescuers and veterinarians believed that community dogs, or sometimes called as “Indie” dogs, knew when to avoid snakes as a learned survival instinct.

Analysis of interview data showed that neurotoxic envenomation (primarily cobra bites) was noted to be rapidly fatal in most cases, with few dogs surviving to reach treatment, with most succumbing to asphyxiation and veterinarians reported the primary common symptom to be a blue tongue, especially when the animal was brought in dead. Conversely, Russell’s viper envenomation allowed a wider treatment window but often led to extensive tissue necrosis, kidney damage, and prolonged recovery times. In the case of Russell’s viper bites, the data indicated that envenomation showed symptoms such swelling at the bite site, which tallies with published records of hemotoxic bites in animals (Ananda et al., 2009) as well as humans (Narvencar, Favas and Dias, 2020). Analysis showed that the site of the bites reported for dogs were consistently on the front with most bites reported on the face and neck. Veterinarians suggested that these bite patterns were consistent with defensive rather than aggressive strikes, particularly given the absence of bites on the back. However, they also cautioned that bite location influences treatment urgency, as bites to the head or neck allow venom to reach vital organs more quickly.



Figure 5.1: Dog-snake encounters in Goa, India

Field observations and interview data revealed a common belief that community or “Indie” dogs tend to avoid snakes; however, most bite cases recorded in this study involved pet dogs, who were often bitten while defending their owners.

Left to right: A puppy maintaining distance from a coiled python at sunrise. A pet dog fatally injured a spectacled cobra but was bitten in the process and later died, as the owner attempted to access veterinary care with antivenom, with support from a rescuer. A chained guard dog alerting its owner to the presence of a Russell’s viper in the yard. (Photos: Benhail Antao)

Interview data suggested cats either avoid venomous species instinctively or succumb rapidly, thus rarely being brought in for treatment. Snakebite cases in cats were rarely documented, reflecting underreporting rather than low actual incidence, with a few veterinarians speculating that cats might also have a proclivity to run away and hide when traumatised. Veterinary insights emphasised difficulty in diagnosing cat bites. Smaller feline body size and rapid venom progression contributed to high mortality, with one veterinarian commenting, “If any cats were brought in, they were not surviving, presumably because of smaller body mass.” One vet described a neurotoxic bite saying, “A colony cat died suddenly with a blue tongue, likely from a krait bite or maybe even cobra bite, but no bite marks were visible.”

Results found that pet owners documented repeated feline encounters with snakes, and other wildlife, driven by curiosity and predatory instincts (see Figure 5.1). One respondent who runs a

rescue centre highlighted the problem commenting that a few of their cats were repeat offenders in predating on snakes, sometimes bringing in the same snake indoors repeatedly. She further said, “We have rescued several snakes from our cats. They have also brought in scorpions. And they have brought in monitor lizards.” These patterns align with wider concerns in conservation biology, where domestic cats are now recognised as both high-risk prey in conflict-prone areas and significant predators of native wildlife. In the UK, for instance, over 90 million prey animals, including millions of reptiles and amphibians, are estimated to be brought home by pet cats annually (Woods et al., 2003). In densely populated urban areas, such as parts of Goa, the dual role of cats as predator and prey highlights the complex ecological entanglements that shape urban human-wildlife interfaces.

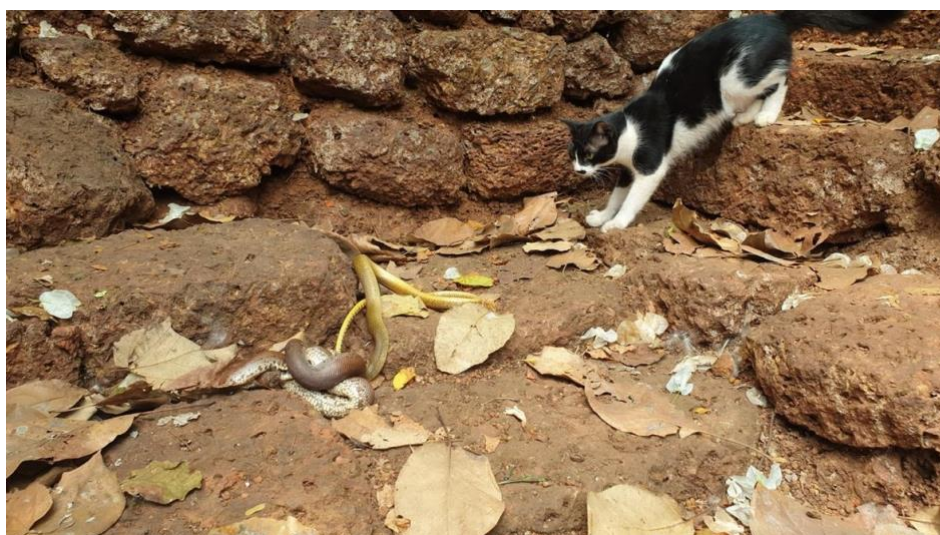


Figure 5.2: An adult cat approaching two non-venomous snakes (rat snake and Whitaker's boa) in Goa, India. While cats are often the prey for pythons, and face risk of envenomation from venomous snakes, they are equally adept at being predators for many other species of snakes. (Photo: Benhail Antao)

Analysis of interview data and field observations consistently identified python predation as a notable threat to cats, with many missing cats assumed by the community as having fallen prey to pythons than to any other imminent danger such as road accidents. Cat owners acknowledged that when cats go missing, they were not sure if it was a snakebite or python predation. Findings from the data clearly indicated multiple predation events, with one community member

describing, “We heard a lot of noise and when we ran outside, the python was trying to grab one of our cats.” Python predation represented a significant emotional stressor, driving human-snake conflict and influencing public perceptions negatively toward pythons. These interactions also reflect complex spatial and behavioural dynamics typical of human-wildlife interfaces, where domestic animals act as both sentinels and victims of wildlife presence. As Pooley, Bhatia and Vasava (2021) argue, acknowledging the full spectrum of multispecies entanglements is vital to rethinking coexistence and moving beyond simplistic human-versus-wildlife binaries.

Interview and observational data also consistently indicated poultry predation, frequently cited by rescuers and community members. A rescuer noted this saying, “Everybody has poultry in Goa. It’s a regular occurrence that a monitor lizard or python will come and swallow a few.” Another rescuer highlighted how pythons frequently prey on domestic animals, stating that, “Most people have their livestock and stuff, so they are always coming in for that. Even domesticated birds and stuff. Or domesticated animals, like cats and dogs.” Cobra predation on poultry eggs was also explicitly noted, distinct from python predation but similarly frequent. Poultry farmers reported regular incidents of pythons entering coops to prey on birds and cobras targeting eggs explicitly, indicating consistent predator-prey interactions. Seasonal patterns of snake predation in poultry were not clarified in the available data.

Reports of venomous snakebite incidence in large livestock such as cattle and buffaloes were low (less than 2-3 cases annually per veterinary clinic), with identification often difficult due to limited diagnostic options and misreporting. As with other pet animals, no specific records were maintained by the Animal Husbandry Department or the private vets. Veterinarians reported rarely treated pig and goat snakebite cases which could be attributed not as a low frequency of bite, or simply as the animal not being considered as valuable enough for treatment by the owners. A forest department official explained this saying, “Pigs are bitten by cobras. They die on the spot. But people don’t bother going for post-mortems.”

Seasonal patterns also emerged in the data analysis with veterinarians reporting a pronounced increase in snakebite incidents during the post-monsoon months (October–December). Russell’s viper bites, in particular, showed a strong seasonal peak during this period, with multiple

veterinarians explicitly associating this increase with Russell's viper activity patterns. One veterinarian noted, "I have more cases of hemotoxic bites in dogs from Russell's vipers around the Christmas holidays." Another added, "Most bite cases of domestic animals I was getting were in October, November, and December, and they were almost all Russell's vipers." These patterns were also seen across human snake envenomation cases (Narvencar, Favas and Dias, 2020), as highlighted in Chapter 2 as well in the snake rescue data in Chapter 3. Unlike the cases of dog bites, no clear seasonal pattern was evident for cat snakebite, though suppositions could be made about similar timelines. Python predation cases also did not show any seasonal variations, with cases recorded throughout the year without explicit veterinary consensus on seasonal peaks.

5.4.2 Challenges in Domestic Animal-Snake Conflict Mitigation

Medical and Logistical Challenges

Thematic analysis of veterinary interviews identified multiple infrastructural, logistical, and diagnostic challenges in the treatment of domestic animal snakebites in Goa, significantly impacting survival outcomes. Respondents revealed inconsistent availability of ASV across veterinary clinics. Unlike human healthcare facilities, veterinary clinics are not mandated to stock ASV, leaving veterinarians reliant on private procurement. Veterinarians consistently reported that government veterinary centres do not keep ASV in stock, a fact corroborated by current and former State Animal Husbandry department officials, who confirmed that ASV is only purchased from pharmacies if, and when, required. Officials from the Animal Husbandry department clarified that previously stocks of anti-venom went unused and "caused problems with the auditors." One private veterinarian highlighted this disclosing, "Government veterinary centres do not stock anti-snake venom. They send people to private clinics like mine for it."

The unavailability of ASV is further compounded by variability in stocking even among private clinics. Results showed that some veterinarians, aware of limited shelf-life and high cost, keep minimal supplies. One veterinarian described this practice, stating, "Generally what I do, since anti-venom is expensive, and we don't require it regularly, so I keep around four vials... Usually

that is sufficient. Suppose even two dogs come at a time, at least we can start treatment.”

However, analysis indicated that this limited stock can be insufficient if more severe or simultaneous cases arise. The practical issues of limited ASV availability were consistently echoed, as another veterinarian explained, “Anti-venom availability is better now, but many vets still don’t stock it. The clinic for Worldwide Veterinary Services in North Goa always stocked anti-venom but would be very far for many people in an emergency. Owners waste time calling 15–20 clinics before finding one that has it.” In contrast, one private South Goa veterinarian noted that his clinic maintains larger stocks due to their recognition as one of the district’s primary ASV sources, always keeping up to 100 vials available.

Veterinary interviews indicated significant practical challenges in ASV administration, particularly concerning brand consistency and compatibility. Veterinarians emphasised that mixing different ASV brands within the same treatment significantly increased the risk of severe allergic reactions and even fatalities. One veterinarian stated, “If I mix and match brands, I will get a reaction. I lost one patient that way. After that, I never mixed brands again.” Another veterinarian reinforced this noting, “We never mix brands between doses to avoid reactions.” This constraint places additional challenges on veterinary treatment, requiring careful management of ASV supplies and limiting options during emergencies when ASV availability is already restricted. Beyond immediate ASV administration, results also indicated the critical importance of prolonged supportive veterinary care to manage delayed complications, particularly organ damage associated with viper bites. Veterinarians emphasised that Russell’s viper envenomation cases frequently required antibiotics, liver tonics, and intravenous fluid therapy for upwards of a week post-bite. One veterinarian explicitly emphasised this risk disclosing, “Necrosis is severe. After 10 days, kidney and liver failure set in. Without antibiotics and liver tonics, the animal collapses.” Another veterinarian explicitly confirmed this extended treatment necessity, stating, “If treatment is incomplete, 8 to 10 days later, they can succumb to kidney or liver failure.” Such long-term management represents a further infrastructural and financial challenge, compounding barriers to complete treatment.

Results also highlighted the lack of 24-hour emergency veterinary services further complicating treatment for snakebites, which often require immediate intervention. Analysis also underlined logistical constraints faced by pet owners attempting to access emergency care outside standard clinic hours. A veterinarian recounted, “There are no government ambulance services for animals... the government says they want to start, but even now, 40 years later, we don’t even have an X-ray at the government veterinary hospital.” Another noted that the lack of nighttime veterinary services could be fatal, saying, “The owner didn’t want to disturb the doctor at night. By the time they came in the morning, I couldn’t find a vein, and the dog died.” Another veterinarian similarly emphasised how pet owners had limited choice but to wait, “If they get across a vet who is available by chance, then it’s fine. Otherwise, they wait until morning.” This limited emergency infrastructure was repeatedly cited by veterinarians as a significant barrier to timely veterinary intervention, directly compromising animal survival outcomes. Additionally, veterinarians reported barriers in procuring adequate ASV supplies such as pharmacies often refusing veterinary prescriptions, with one veterinarian explaining, “A lot of pharmacies say, ‘I am sorry, this is not a veterinary pharmacy,’ making it difficult for us to access essential drugs.” Another veterinarian highlighted the systemic failure in ASV availability, stating that even he and his daughter, both veterinarians, did not have ASV stocked when his own cat was bitten. Results also highlighted a lack of any repository listing which pharmacy would have ASV, making it difficult to trace in the first place.

Analysis also showed that diagnostic challenges also significantly hamper effective veterinary care. Veterinarians identified substantial difficulties in identifying snakebites, due to the frequent absence of clear bite marks, especially in heavily furred animals, wherein even bee stings could be mistaken for snakebites by the owners or vice versa. As one veterinarian explained, “Most people don’t come to know [it’s a snakebite] ... There are no lesions which you can see, especially if it’s a furry dog.” The reliance on symptomatic recognition rather than definitive diagnostic tests introduces uncertainty and delays. Findings also emphasised the critical importance of coagulation tests to identify hemotoxic envenomation, particularly from Russell’s vipers. Hemotoxic envenomation presents with swelling at the bite site and abnormal blood clotting times, whereas neurotoxic envenomation (cobras and kraits) manifests in rapid paralysis

and cyanosis (blue tongue in affected animals). One veterinarian described this diagnostic complexity, “Owners sometimes bring the dead animal, saying it’s a snakebite, but unless we see the snake, it’s hard to say. We go by symptoms, but it’s not always clear.” Results indicated that while performing basic clotting tests was considered critical by all veterinarians, it was also not consistently possible, due to inadequate infrastructure and staffing, particularly during nighttime emergencies.

Data analysis also showed that training and expertise among veterinarians to manage snakebite cases varied widely, possibly due to the absence of standardised guidelines. Patterns from the data revealed frustrations being expressed by veterinarians regarding insufficient formal training and reluctance by some peers to handle snakebite cases due to liability concerns or inadequate knowledge. As one veterinarian stated, “A lot of vets don’t keep anti-venom because they don’t know how to use it or are afraid of liability.” Some veterinarians indicated they administered ASV immediately without waiting for clotting tests, while others preferred preliminary diagnostic tests to confirm envenomation, creating inconsistencies in clinical practice.

Interview analysis also revealed significant gaps in public awareness and first-aid knowledge among pet owners, often resulting in treatment delays. Some community members had no idea that snakebites could be treated or that anti-venom could be used for dogs, and didn’t know if their vet even carried it. A vet recalled a case saying, “We’ve had cases where pet owners tied a tourniquet too tightly for too long, causing the leg to rot. One dog’s leg actually fell off before they even reached us.” Many owners initially rely on traditional or home remedies rather than immediate veterinary intervention. A veterinarian described this issue saying, “Most pet owners try home remedies like turmeric instead of rushing their pet to a vet after a snakebite.” Another vet expanded on this saying, “We’ve had a lot of marination happening, a lot of turmeric application... which makes things very difficult for us. You can’t visualise anything with all that turmeric. It’s everywhere.” Additionally, some reliance on local healers persisted, further delaying appropriate veterinary care, “There’s a famous woman in Vasco who gives small pills for snakebites, but nobody knows what they contain. People are still misled by these treatments.”

This reliance on traditional treatments contrasts starkly with the shift towards evidence-based medicine documented for human snakebite treatment in Chapter 2.

Economic Impact: Treatment Costs and Compensation

Thematic analysis, complemented by observational insights, indicates that snakebite-related mortality and predation incidents among livestock and domestic animals in Goa carry significant economic consequences, although these impacts are inconsistently addressed through existing compensation mechanisms. To contextualise these patterns across species, Table 5.1 summarises the most commonly involved snakes, estimated caseloads, survival rates, and how each animal type is valued and treated in response to snakebite-related incidents.

Table 5.1: Species-wise overview of snakebite-related domestic animal mortality in Goa

Based on interviews and field observations, this includes common snake species involved, estimated case frequency, survival rates (if treated), and how the perceived value of different animal types, both personally and systemically, possibly shapes treatment-seeking behaviour, reporting practices, and access to compensation.

Animal Type	Common Snake Species Involved	Estimated Cases (Per Vet / Year)	Survival Rate (If Treated)	Perceived “Value” of Animal
Dogs	Russell’s viper and cobra, sometimes krait or saw-scaled viper (envenomation)	5–15	High (if treated)	Mixed: Strong emotional attachment; treatment from snakebite often costly (~8,000-9,000 INR). Purchase cost of animal vary, if not adopted (10,000-1,00,000 INR); upkeep involves an ongoing financial and care commitment.
Cats	Python (predation), cobra and krait (suspected envenomation)	Rarely reported	Low	Primarily emotional: Often roam freely; many die before treatment is possible. Costs usually low, but care access is limited, especially in rural areas.
Livestock (Cattle, Buffaloes, Goats)	Russell’s viper and cobra (envenomation)	2–3 (under-reported)	High (if treated)	Primarily financial: Animal values range from 10,000-2,00,000 INR. Reliant on government vets, who often lack ASV; treatment access remains inconsistent.
Poultry	Python (predation), cobra (egg theft)	Frequent	Not applicable	Low perceived value: No emotional attachment. Minor losses usually go unreported. Economic significance arises only in rare cases involving high-value breeds like Kadaknath. Some farmers use nets or makeshift barriers, which may unintentionally harm snakes.

Many livestock owners in Goa were marginal farmers with limited income and poor access to veterinary or extension services, making emergency care unaffordable or inaccessible. This was particularly evident in rural areas of North Goa, where cattle accounted for over two-thirds of livestock, but veterinary outreach remained sparse and underfunded (Reddy et al., 2017). Findings revealed that for livestock owners, structured compensation was primarily available under government schemes, notably the Kamdhenu scheme, but access to financial redress depends on whether the animal was bought under the government subsidy. Compensation was only meted out by the Animal Husbandry department and the Forest Department was not involved in the case of snake bites and only brought in for larger mammal conflict. A veterinarian outlined this conditional compensation framework saying, “Most cows and buffaloes are bought under the Kamdhenu scheme, where the government provides subsidies and insurance. If the animal dies, the insurance payout first clears the loan, and then the insurance company compensates the government, and the farmer’s loan is waived off. But if the animal was bought privately, the farmer must fight for compensation.” The data also indicated that the bureaucratic complexity involved in claiming snakebite-related livestock losses frequently discouraged farmers from pursuing compensation, though conversely the analysis of veterinary and animal husbandry insights also noted inaccuracies, with deaths sometimes falsely reported as snakebites to simplify compensation claims. One Forest Department rescuer highlighted this challenge explicitly, stating, “If you go to claim compensation for a snakebite death, they will ask you for so many papers, you’ll give up halfway. That’s why many families don’t even apply.” Further, interview data indicated that some veterinarians misattributed unexplained livestock deaths to snakebite to facilitate compensation claims, potentially skewing official mortality records. A veterinarian stated, “A lot of vets, when they find a cow or buffalo dead and can’t determine the cause, they simply write ‘snakebite’ in the report. Official figures can thus be misleading.” These inconsistencies highlight how institutional failures and lack of trust in formal mechanisms not only discourage legitimate claims but also drive informal workarounds, behaviours which mirror broader conservation conflict patterns where inefficiencies lead to erosion of institutional legitimacy (Barua, Bhagwat and Jadhav, 2013; Redpath et al., 2013).

Poultry predation, notably by pythons and cobras, though also affected by monitor lizards, emerged frequently in veterinary and community interviews. Analysis indicated that poultry losses, although frequent, were economically tolerated by poultry farmers due to their comparatively minor economic impact per incident. A rescuer illustrated this tolerance saying, “Poultry farmers don’t care about snakes eating their chickens. One python also ate six rabbits, and they didn’t bother claiming anything.” The only time economic losses were reported was when relatively rare and expensive breeds of chickens were involved such as the Kadaknath. Data revealed that while broiler and layer breeds were easily replaceable due to subsidies, the more expensive breeds were often out of pocket for farmers, making their loss economically significant.

Thematic analysis also revealed that comparisons between snakebite-related livestock deaths and predation by large carnivores (e.g., leopards) showed a notable gap in policy. Structured compensation schemes exist for big cat attacks (Karanth, Gupta and Vanamamalai, 2018), but no equivalent policy framework compensates for livestock losses due to snakebite. An analysis of the compensation data from 2020-2023 of human-wildlife conflict, provided by the Forest Department, also confirmed this with no compensation recorded for snakebites. As one Forest Department official explicitly stated, “Right now, compensation is only for big cat attacks. I have suggested that we extend it to snakebite victims as well.” The compensation data for livestock, provided by the Forest Department, varied from 5000 to 50,000 INR, or occasionally more, depending on the breed of the animal. However, it must be noted that these payments were all from the Forest Department and not the Animal Husbandry, though records were maintained there as well. The 2024 report by the Ministry of Environment, Forest and Climate Change (PIB, MoEFCC, 2024) showed that loss of property/crops, from tigers and elephants, which presumable included livestock also, indicated the State/UT government to adhere to their individual norms, whereas any death or injury to a person could be guided by the centrally sponsored schemes of the MoEFCC, ranging up to 10,00,000 INR. These disparities in response and recognition reflect broader trends in conservation and conflict discourse, where losses involving non-charismatic species, such as snakes, rodents, or small carnivores, are often excluded from formal compensation schemes and policy narratives (Barua, 2014; Gulati et al.,

2021; Malhotra et al., 2021; Pooley, Bhatia and Vasava, 2021). Unlike high-profile attacks by leopards or elephants, the slow and often unseen toll of snakebite on domestic animals remains largely invisible within institutional frameworks, despite its widespread occurrence and deep social impacts.

Despite such proposals for larger mammals, economic redress for snakebite remains underdeveloped or unimplemented, leaving affected farmers at a financial disadvantage. Results also showed that veterinary clinics, particularly private practitioners, often lacked the capacity to treat livestock snakebite cases, forcing them to prioritise smaller animals. Several veterinarians expressed frustration at having to turn away livestock cases, despite recognising the economic hardship faced by farmers. The lack of structured government intervention places the responsibility of treatment entirely on private clinics, which in turn are constrained by supply chain limitations and bureaucratic barriers to ASV procurement.

Thematic analysis of veterinary interviews indicated that in the case of companion animals, the economic burden related to pet snakebite incidents primarily stems from the high cost of veterinary treatment. Veterinary interventions, including ASV, intravenous fluids, antibiotics, and intensive supportive care, were found to typically range between 5,000-10,000 INR, per case, representing a substantial financial burden for pet owners. Analysis of interviews showed this as a consistent economic barrier, with veterinarians explicitly noting how costs influence decisions about pursuing treatment. One veterinarian stated, “Clients who cannot afford it might stop treatment before they even start. As soon as they hear the estimate, they decide against it.” Another veterinarian further expanded on this saying, “Treating snakebites is expensive. Anti-snake venoms are more expensive now. They are 4 to 5 times the price they used to be. One vial of anti-venom is 650-750 INR. A full treatment with fluids, injections, and ICU care can cost thousands. Many owners don’t want to or can’t pay after the pet is treated.” This cost barrier was further complicated by the absence of structured compensation or insurance coverage explicitly available for pet snakebites, leaving pet owners fully responsible for all expenses incurred. Results indicated that for some owners, cost considerations force difficult choices regarding treatment. One veterinarian explained this saying, “I’ve had cases where people want to treat

their dog, but when they hear the cost, they hesitate. Some go ahead, but others just take the dog back home.”

Analysis showed that this financial disparity could be particularly pronounced in rural areas, where fewer veterinary clinics stock ASV and economic constraints are more significant. One veterinarian explained, “For rural owners, ₹10,000 is a big amount. Some will try, but if their dog doesn’t improve fast, they often discontinue treatment.” The absence of emergency veterinary services further exacerbates financial burdens, as owners may need to travel long distances to access treatment, often incurring additional transport costs.

Observational insights from fieldwork further indicated an additional dimension to pet-related economic burdens. Larger, expensive pedigree breeds, often selected by owners as guard dogs to simultaneously provide security and serve as status symbols, appeared particularly vulnerable to snakebite due to their frequent outdoor exposure. Consequently, the economic and emotional stakes of losing these animals to snakebite-related incidents were disproportionately high, compounding owners’ financial and emotional burdens significantly.

While analysis suggests that predation by snakes on pets is possibly less frequent than poultry predation, these incidents also carried considerable emotional significance for owners. No formal mitigation strategies or economic redress mechanisms exist, highlighting a notable policy oversight. Even in national-scale estimates of human-wildlife conflict costs, such as Gulati et al. (2021) snakebite often remains unclassified or grouped under miscellaneous categories, despite its widespread and lethal impact on both humans and animals. This oversight reinforces systemic biases that favour charismatic megafauna while neglecting pervasive but less visible threats like snakebite.

5.4.3 Frustration, Conflict, and Responses to Snakebite and Snake Predation Losses

Analysis showed that the loss of a domestic animal to snakebite, compounded with the economic impact, triggered emotional distress, and conflict between pet owners, veterinarians, and the

wider community. Results indicated that while livestock owners generally view snakebite-related deaths through a financial lens, pet owners experience deep personal attachment, leading to desperation for treatment, heightened frustration with veterinary access, and, in some cases, violence toward medical staff. Results also highlighted that this emotional response quite often drove retaliatory killings of snakes, particularly in cases involving python predation or repeated snakebite incidents. As Barua et al. (2013) argue, the “hidden dimensions” of human-wildlife conflict, including psychosocial stress, grief, disrupted livelihood routines, and bureaucratic fatigue, remain poorly addressed. This aligns with Treves and Bruskotter’s (2014) findings that tolerance for predatory wildlife is shaped not only by material loss, but by complex social and emotional dynamics, including perceived institutional failure and lack of responsive support. In Goa, this erosion of tolerance was especially visible in cases where snakebite fatalities occurred despite owners’ efforts to seek treatment, fuelling resentment toward both snakes and veterinary staff. As with predator conservation globally, maintaining public tolerance requires more than awareness, it demands visible, reliable support systems that prevent people from feeling abandoned in moments of crisis.

Thematic analysis indicated that the emotional stakes of losing a pet differed significantly from those of losing livestock. Pet owners view their animals as family members, rather than economic assets, shaping their willingness to seek treatment at any cost. A veterinarian emphasised this distinction, stating, “It’s not about cost. It’s emotional attachment.” This aligned with broader patterns observed by another senior veterinarian, who noted that, “From the perception point of view, people are very closely attached to their dogs and cats and cattle. So, they do try to treat.” The willingness to seek treatment for pets is therefore not just a financial decision, but an emotional one. Research increasingly recognises the significant contribution of companion animals to human wellbeing, with recent studies quantifying pet companionship as having life satisfaction impacts comparable to social relationships or financial security (Gmeiner and Gschwandtner, 2025). Consequently, the loss of a pet to snakebite may not only be emotionally devastating but also represent an unacknowledged loss to household wellbeing and mental health.

As thematic analysis showed the above economic and emotional distress, combined with the lack of accessible and timely treatment for snakebites, ended up adding to the frustration and distress experienced by the owners. Treatment delays and limited ASV availability intensified emotional distress, often leading to hostility and anger toward veterinarians and clinic staff. A veterinarian highlighted a major systemic failure in veterinary services, noting that, “Here 24-hour vet clinics don’t exist because no one wants to take the risk. Many vets have been attacked by pet owners at night when emotions run high.” The absence of emergency veterinary care then creates a bottleneck, particularly in cases where ASV is unavailable or delayed. Another veterinarian recalled a case where a security guard was physically assaulted by a pet owner after their dog died outside a veterinary hospital. The incident reflects a broader misplacement of blame, where rather than directing anger toward systemic failings in veterinary care, individuals react impulsively toward those closest to the crisis- veterinarians, hospital staff, and even security personnel. Another veterinarian noted that pet owners often become aggressive when they perceive that their animal is not receiving immediate attention, with some physically threatening staff in emergency situations. These reactions are indicative of the emotional weight placed on pets, particularly in cases where people feel that their only companion animal has been lost due to inadequate veterinary care.

In contrast, results indicated that livestock owners tended to prioritise compensation rather than treatment, demonstrating a stark difference in emotional attachment. As an animal husbandry official pointed out, “For cows, the farmer only cares about the money. If the animal dies, they want compensation. No emotional attachment like pet owners.” This pragmatic approach means that livestock snakebite deaths often do not trigger the same level of frustration, urgency, or retaliatory action.

Results showed that the emotional attachment with companion animals also influenced post-bite behaviour. Data analysis indicated that some pet owners became hyper-vigilant after a snakebite incident, changing their animal-handling practices. However, others failed to learn from repeated incidents, assuming their pet would survive future bites. These contrasting responses demonstrate that while some individuals take preventive steps, others unknowingly increase the

risk of future snakebite fatalities. Similar data could not be obtained for livestock. Cross-comparison of responses highlighted that some community members expressed concerns about mitigation for their small animals and poultry with solutions such as netting the place off, mostly commonly by fishing nets, even though conversely the data showed that rescuers attributed nets as a leading cause of morbidity and mortality for snakes.

Thematic analysis also revealed that while retaliatory snake killings had reduced, they were still reported, particularly in rural areas where snakebite fatalities occur frequently. A senior veterinarian confirmed this saying, “The first instinct is always to kill the snake. They kill it first, then bring the dead snake and the bitten animal to me.” This immediate response suggests that many people do not distinguish between defensive snakebites and aggressive attacks, instead treating all cases as threats requiring elimination. Similarly, another vet noted that, “They show a photo of the snake. They don’t bring it. But, yes, they kill it.” This indicates that while some individuals may want to confirm the identity of the snake, they often act pre-emptively by killing it before seeking veterinary intervention.

However, the results also showed that not all pet owners react with violence. Some recognise that killing the snake does not change the outcome of the bite. A vet observed this shift in attitudes over time, stating, “Earlier, people used to bring in the dead snake with their bitten pet. But in the last year, I’ve not had a single owner do that. People are learning they don’t need to kill the snake.” This change is partly attributed to public awareness efforts and an increased understanding of snake ecology, which was seen as part of a broader trend across the state, as demonstrated in previous chapters as well.

Analysis suggested that increased rescuer presence allowed individuals to call for assistance rather than taking matters into their own hands. A rescuer further emphasised the role of rescue teams in mitigating retaliatory killings, stating, “The availability of rescuers has made a difference. People don’t kill snakes like before.”

While venomous snakes were often killed in reaction to a pet’s death, results showed that pythons were especially targeted for a different reason: predation. Pet owners tend to perceive

pythons as an active, ongoing threat, rather than a one-time defensive attacker. A senior herpetologist noted that, “People react very emotionally when a python eats a pet cat or dog. That’s when they really want the snake gone.” Thematic analysis, compounded by observational insights suggested that visibility of python predation makes it feel more invasive and personal than a venomous bite, reinforcing the desire for removal or retaliation in the case of companion animals. Analysis suggested that the repeated predation of animals increased conflict between people and pythons, particularly when an individual lost multiple pets to python attacks over time. Vikas, Athreya and Limaye (2022), expanded on this theory in their paper on human-leopard conflict, noting that cultural beliefs in India can mediate tolerance, but they are fluid, context-dependent, and vary by species. While leopards, like snakes, may be revered or tolerated due to spiritual associations, any species may evoke greater fear, frustration, or neglect, highlighting the inconsistent moral hierarchies at play in human-wildlife interactions.

Results indicated that the misidentification of non-venomous snakes further contributed to unnecessary killings. A veterinarian observed, “I have had cases where people killed a python thinking it was a cobra attacking their pet.” This highlights the lack of awareness regarding snake behaviour and species identification, leading to indiscriminate killings even when a snake poses no venomous threat.

Despite these fears, results also showed that some members of the public accepted python predation as a natural part of the ecosystem. A vet with a domestic animal rescue organisation noted a clear distinction between those who understood ecological dynamics and those who viewed pythons as a “menace”, stating, “Feeders (of community animals) never ask for relocation of pythons, but the public does. They think the world belongs only to humans.” This suggests that people who actively engage with stray or community animals or wildlife in general are more likely to tolerate coexistence, while others demand intervention. Additionally, results also showed that misconceptions about the role of pythons in controlling stray populations have fuelled debate over their presence. Another vet actively working for domestic animal rescues reported, “People ask if pythons help control stray dog populations. But really, how many can they eat? A few out of dozens born every six months.” This finding suggests that pythons have a

minimal impact on stray populations, despite public perception that they serve as a natural control mechanism. This misconception may discourage efforts to implement more structured sterilisation programs, as outlined in the Animal Birth Control (ABC) Guidelines of 2011 under the Prevention of Cruelty to Animals Act (Srinivasan, 2013).

Thematic analysis also indicated that snake-related conflicts affecting domestic animals differ from other human-wildlife conflict cases, particularly those involving larger carnivores. A forest department official explained the differences in compensation-seeking behaviour, noting that, “For leopards, they ask us to trap the animal. For snakebite, they accept the loss.” Similarly, another forest department official reiterated that “For leopards, they apply for compensation immediately. But for snakebites, they just accept the loss.” This indicates that people expected intervention for large predators like leopards but not for snakes. Analysis showed that unlike leopard attacks, snakebites were often seen as an inevitable part of rural life, reducing the likelihood of government intervention.

Results also showed that the perceived fairness of the conflict also influences reactions. A vet explained why leopard predation generates greater outrage than snakebite-related deaths, stating, “The snake, at least the dog barks and goes to the snake to get bitten. Whereas here, the poor dog is asleep and is picked up and taken out. So, it’s being cheated by nature.” This suggests that people feel more emotionally violated by a predation event where the animal had no chance to defend itself, compared to a snakebite where an interaction occurred.

Beyond leopards, crocodiles have also been the source of conflict over pet predation. A senior veterinarian described a recent incident telling, “We had a case where a crocodile took a Labrador retriever from the banks of a lake. People were outraged, but the crocodile remained there.” Unlike with snakes, there was no retaliation, but the outrage demonstrated the heightened emotional response to pet predation.

5.4.4 Broader Systemic and Individual Responsibilities

The core characteristics of human-wildlife conflict typically include unpredictable wildlife-caused harm, social and economic loss, breakdowns in institutional response, and retaliatory behaviours (Redpath et al., 2013).

Although snakebite is rarely acknowledged in national or global HWC discourse, it shares all these characteristics. The deaths of livestock and pets due to snakebite, coupled with the absence of compensation, poor veterinary access, and reported retaliatory killings, thus represent a critical but under-recognised axis of human-wildlife conflict in India. These incidents also underscore that snakebite-related conflict often results in mutual harm, with both domestic animals and snakes suffering injury or death. While animal deaths or resulting emotional responses from owners are occasionally recognised by veterinary systems, snake fatalities from domestic animal encounters remain largely invisible, unrecorded, and rarely acknowledged in policy frameworks. Even the latest HSC mitigation guidelines from the Ministry of Environment, Forests and Climate Change (MoEFCC, 2023) sees no mention of this. Given that many of these snake species are also protected under Schedule I of the Wildlife Protection Act 1972 (WPA, 1972), not recognising domestic animal-snake encounters as a concerning aspect of wildlife conflict and conservation is a grave oversight.

The management of snakebite in domestic animals in Goa is hindered by systemic failures in veterinary infrastructure, inconsistent ASV stocking, and the absence of standardised treatment protocols. Analysis indicated that these deficiencies exacerbated preventable mortality and place an increasing strain on veterinarians, who are already struggling with limited resources and unsustainable caseloads. With livestock cases deprioritised due to financial constraints and emergency care remaining unavailable, veterinary professionals were forced to turn away cases they would otherwise treat, further deepening gaps in care. These deficiencies reflect wider systemic challenges in veterinary public health across India. Despite the growing relevance of One Health frameworks, veterinary service delivery in India remains underdeveloped, especially in rural areas where farmers often struggle with poor access, inadequate staffing, and treatment delays (Ghatak and Singh, 2015). As Shanmathy, Gopi and Beulah (2018) note, the economic

burden of animal healthcare falls disproportionately on smallholder farmers, yet the public sector's capacity to deliver accessible and quality veterinary services continues to erode due to fiscal and infrastructural constraints.

This systemic neglect is compounded by the absence of political will, particularly in livestock care. As one veterinarian noted, "I find a lack of political will, a lack of policy will... (they say) insurance will cover it. Why are you so worried?" This statement captures the disconnect between policy frameworks and real-world implementation, where financial provisions exist on paper but remain inaccessible due to bureaucratic inefficiencies, logistical barriers, and a general disregard for veterinary concerns.

The economic burden of snakebite-related animal losses is unevenly distributed. While government-subsidised livestock technically qualify for compensation, bureaucratic obstacles discourage many farmers from applying. Privately owned livestock and pets receive no financial support, forcing owners to bear the full burden of treatment costs or forego care altogether. This contrasts sharply with structured compensation schemes for big cat attacks (Karanth et al., 2018), reinforcing a fundamental policy oversight in Goa's approach to human-wildlife conflict.

Beyond economic challenges, the emotional toll of snakebite cases is profound. While livestock losses are largely perceived through an economic lens, pet owners often form strong emotional bonds with their animals and experience significant emotional distress when their companion animal is affected, which can result in retaliatory killings of snakes, frustration toward veterinarians, and aggression toward hospital staff. However, growing awareness and structured education efforts are gradually shifting public attitudes. Yet, these changes remain fragile. Without better integration of veterinary care into wildlife conflict mitigation, emotional volatility will continue to drive unnecessary snake killings and strain conservation efforts. The solution is not only better treatment access but also education and structured intervention to reshape human-snake interactions in the long term.

A critical but often overlooked aspect of mitigation is responsible pet ownership, particularly in the case of cats, which are both predator and prey in human-snake interactions. Results showed

that while dogs are often bitten when defending territory or protecting their owners, cats frequently engage with snakes due to their hunting instincts. Veterinarians, rescuers and community members reported cases of cats repeatedly bringing home snakes, highlighting the risk of predation-driven interactions, a pattern that has seen considerable global concern (Moseby, Peacock and Read, 2015), though there are no equivalent studies in India. Dog and cat “ownership” is also complicated in India with the concept of “community animals” and field observations showed a greater likelihood of indoor-outdoor animals, without responsible ownership, being accepted as the norm. However, observations also showed a substantial number of “pets”. Unlike dogs, which can and should be supervised in enclosed compounds, a possible approach for cats is to keep them indoors at all times. However, research from the UK has shown that cat owners vary significantly in their attitudes toward confinement and predation, with many opposing blanket restrictions despite expressing concern about wildlife impacts (Crowley, Cecchetti and McDonald, 2020). Field observations also found similar sentiments existed in Goa as well. These findings suggest that any mitigation strategies, such as “catios” or indoor confinement using snake-proof enclosures, must be locally adapted, owner-sensitive, and coupled with education on both animal welfare and wildlife protection. Their ambiguous position in conservation discourse, valued as companions, but ecologically disruptive, further complicates efforts to integrate them meaningfully into human-wildlife conflict frameworks.

However, snake-proof enclosures must also be snake-friendly, as the widespread use of ghost nets and poorly designed barriers, to protect poultry, has led to significant snake mortality, as indicated by results. Well-designed enclosures should not only prevent snakes from entering but also ensure that poultry, cats and other small pets do not roam freely, reducing their risk of predation, road accidents, and conflicts with wildlife.

Ultimately, the failures in snakebite management for domestic animals reflect a broader neglect of veterinary concerns within Goa’s policy landscape. Addressing these gaps requires urgent governmental intervention, including:

- Mandatory ASV stocking in all veterinary clinics and government animal hospitals.

- Establishing emergency veterinary clinics and ambulance services with 24 hour coverage.
- Expanding compensation frameworks to include privately owned livestock and pets.
- Formally integrating veterinarians into wildlife conflict mitigation policies, ensuring that snakebite in domestic animals is recognised as a key component of broader human-wildlife interactions.
- Records being mandated across all government and private clinics for snakebite cases
- Awareness sessions to include messaging for domestic animal keepers on mitigating snake conflict including prevention, first aid, emergency medical care and responsible pet ownership.

5.5 Conclusion

As with many other forms of human-wildlife conflict, the impacts of snakebite on domestic animals in Goa are shaped not only by the biological risk posed by snakes, but by the structural absence of veterinary support, compensation, and public health integration. This triadic structure, of ecological hazard, affected stakeholders, and systemic neglect, is consistent with patterns described across conflict involving large carnivores, crop damage, and zoonotic disease (Barua, Bhagwat and Jadhav, 2013; Redpath et al., 2013).

Without correct recognition and immediate systemic intervention, veterinarians will remain overburdened, preventable mortality will persist, and economic losses will escalate. However, beyond economics, snakebite-related animal deaths represent a deeper crisis, one of governance, animal welfare neglect, and systemic failure to integrate animal welfare and veterinary care within human-wildlife conflict mitigation. Farmers and pet owners alike depend on their animals, whether as a source of livelihood or companionship, yet current policies fail to recognise these losses as legitimate concerns. Despite existing financial provisions, bureaucratic inefficiencies, poor veterinary infrastructure, and a lack of political will have left both economic and emotional burdens solely on individuals, reinforcing inequities in how different types of wildlife conflict

are addressed. Goa's governance must shift from reactive crisis management to proactive policy interventions, prioritising structured ASV availability, emergency veterinary care, and a compensation framework that recognises snakebite-related animal mortality as an integral part of human-wildlife conflict management.

At the same time, these encounters often result in the unrecorded death of snakes, many of which are protected species, highlighting that current frameworks not only fail humans and their animals, but also neglect wildlife conservation responsibilities. Without these structural changes, both animals and the people who depend on them, whether for livelihood or companionship, will continue to suffer due to avoidable systemic failures.

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Chapter 6

General Discussion and Conclusion

6.1 Thesis Synthesis

This thesis set out to investigate how human-snake conflict, including snakebite, rescue practices, and domestic animal mortality, manifests in Goa, India. The study examined both systemic mitigation strategies and socio-cultural dynamics, with a focus on evaluating what forms of intervention are working, which gaps persist, and how coexistence with medically significant snakes can be made more ethical, equitable, and ecologically informed. The chapters that follow were developed not as standalone investigations, but as thematically and empirically linked inquiries that evolved in response to layered field realities.

Chapter 2 examined human mortality due to snakebite envenomation in Goa, combining five years of health department data with qualitative interviews, with existing literature (Narvencar, 2006; Narvencar, Favas and Dias, 2020), revealing two distinct peaks of bite cases in Goa during and after the monsoons. While recorded mortality remains relatively low compared to national estimates, the research revealed that this success is context-dependent. Timely access to treatment, facilitated by geographic compactness, ambulance infrastructure, and hospital proximity, has helped keep fatalities low. However, long-term morbidity, economic fallout, and survivor trauma remain largely undocumented in Goa. Similar shortcomings have been highlighted in national policy frameworks (Bhaumik, Norton and Jagnoor, 2023; NAPSE, 2024). The study also emphasised that behaviour change around treatment-seeking appears to have occurred due to both community-driven awareness and the reliable availability of public sector care. However, prevention behaviours (e.g. use of footwear or torches) remain inconsistent. Importantly, interview data highlighted that seasonal and recently arrived migrant populations, especially those without historical familiarity with snakes, remain more vulnerable due to gaps in access to information and services. These gaps point to a clear need for inclusive, multi-lingual outreach across Goa, reinforcing previous research that emphasises the importance of trust and localised health communication in behavioural change (Williams et al., 2011; Ralph et al., 2019; Menon et al., 2022).

These insights shaped the framing of Chapter 3, which explored the ecological and seasonal dynamics of snake rescues by analysing the Forest Department's multi-year snake rescue data,

through Generalised Additive Modelling (GAMs). The data revealed two distinct annual peaks in rescues, corresponding to species-specific cycles of reproduction and monsoon-driven movement. Qualitative interviews with experienced rescuers and forest personnel further provided detailed ethological insights that remain largely absent from formal records, furthering the validity and necessity of combining local knowledge with quantitative findings to understand human-wildlife conflict. One of the most important takeaways from this chapter is that species behaviour and seasonality are not uniformly distributed across India, and thus, mitigation must be grounded in the local ecological knowledge of each community/region. What applies to Goa's semi-urban and coastal habitats may not translate to forested or arid regions elsewhere. This supports a call for district-level ecological diagnostics, particularly in states with high snakebite burdens. Whilst Chapter 2 identified systemic gaps in snakebite response, Chapter 3 showed that these rescues are not random but seasonally patterned and ecologically predictable, offering an entry point for proactive prevention. These findings echo the theories supported by other studies on integrating snake ecology in human-snake conflict (Murray, Martin and Iwamura, 2020; Goldstein et al., 2021; Malhotra et al., 2021; Gajbhiye et al., 2023).

Chapter 4 deepened the inquiry by turning to the ethics and social realities of snake rescue work. Drawing on psychology and gendered performance theory (West et al., 2016; Frank, Glikman and Marchini, 2019; Pooley, Bhatia and Vasava, 2021), the chapter argued that “rescue” as a concept requires critical rethinking. It also challenged the assumption that rescue automatically equals conservation. In many cases, quick removals may inadvertently erode opportunities for long-term cohabitation and deepen public dependency on external actors. Still, the evidence from Goa also supports the conclusion that ethical, education-oriented rescue models can thrive, particularly when supported by peer networks and trust-based community relationships. It examined the motivations, emotional toll, and social dynamics surrounding rescue in Goa, revealing a fractured landscape: some rescuers frame their work as ecological stewardship and public education, while others are driven by performance, social validation, or as a response to institutional neglect. The chapter also linked back to Chapter 3's ecological insights by showing how species-specific knowledge is held informally by rescuers yet is underutilised in state planning. Simultaneously, it echoed Chapter 2's findings on structural strain by highlighting how

the emotional and logistical burden of rescue work is intensified by a lack of formal support and burnout, compromising long-term sustainability, mirroring findings in other global studies on the effect of burnout on service providers and wildlife (Cordes, Dougherty and Blum, 1997; Burns, 2020).

Chapter 5 analysed snakebite envenomation and predation in domestic animals, an often-overlooked axis of human-snake conflict. Found to be completely absent in formal records, it documented the death and injury of pets and livestock due to snakebite, through qualitative interviews, showing that veterinary response remains patchy, expensive, and unsupported by state mechanisms. Unlike losses from other wildlife species (e.g., tigers or leopards), snakebite-related animal deaths are not recognised in India's conflict compensation schemes (Karanth, Gupta and Vanamamalai, 2018; PIB, MoEFCC, 2024). The chapter also drew attention to a key dimension of One Health logic: that human, animal, and ecological systems are interconnected, and that neglecting animal morbidity in snakebite mitigation frameworks creates both ethical and epidemiological blind spots. Chapter 5 also linked back to Chapter 2 and Chapter 3 by highlighting the absence of state compensation or surveillance, as well as similarities in the bite and rescue seasons and to Chapter 4 by revealing how rescuers and private veterinarians often become the only bridge between affected animal owners and fragmented response systems.

The thesis maps the contours of human-snake conflict in Goa not as a single event (a bite, a rescue, a death), but as a complex web of ecological dynamics, infrastructural asymmetries, emotional labour, and policy neglect. Rather than treating mortality, ecology, rescue, and animal loss as separate phenomena, the thesis reveals their deep linkages, underscoring the need for integrated solutions. Together, these chapters argue that coexistence with venomous snakes requires more than tolerance. It demands systems that acknowledge ecological specificity, socio-cultural complexity, and institutional responsibility and informed public understanding as a foundation for lasting behavioural and policy change. Goa, while exceptional in some ways, serves as a lens through which broader national gaps and possibilities can be understood. The findings reinforce the need for regionalised planning, cross-sectoral collaboration, and ethical engagement at all levels of mitigation- from medical response to rescue practice and long-term

ecological planning. In doing so, they offer a layered response to the question: How can snakebite and human-snake conflict be understood, mitigated, and ethically engaged with in a rapidly urbanising and ecologically diverse Indian state?

6.2 Contributions to Practice, Policy, and Academic Understanding

6.2.1 Contributions to Practice and Policy

One of the clearest practical insights from this research lies in Goa's unusually low snakebite mortality, an outcome made possible not by awareness alone, but by the convergence of system functionality, geographic compactness, and community trust. Interview data consistently indicated that the shift toward medical treatment was sustained not simply because people were told to avoid traditional healers, but because they had access to responsive public services: a functional ambulance network, accessible hospitals, and a referral system that worked. This infrastructural reliability enabled a singular message- "(when you get bitten,) go to hospital" -to take root across communities, including among migrant workers and new settlers.

However, this behavioural shift was selective. While hospital-seeking has increased, preventive behaviours such as the use of torches, protective footwear, or clutter reduction remain inconsistently practiced, particularly in under-resourced or transient communities, as has been noticed in other snakebite affected areas (Ralph et al., 2019). Interviewees pointed out that poverty, housing structures, and mobility often made it difficult to follow basic prevention guidelines, even when the knowledge was present. This disconnect reinforces a critical lesson: awareness does not automatically translate into action, especially in the absence of structural support. Future outreach must therefore go beyond one-size-fits-all messaging and be grounded in regionally adaptive, multilingual strategies that accommodate socioeconomic and linguistic diversity, particularly among migrants and informal workers.

Another major contribution lies in documenting the unacknowledged morbidity and psychological toll associated with snakebite. Interviews revealed that even non-fatal bites often result in long-term nerve damage, work loss, and emotional trauma, including fear, stigma, and

PTSD. These impacts remain absent from state surveillance systems and are entirely missing from India's snakebite mitigation policies (MoEFCC, 2023; NAPSE, 2024) and the WHO's Neglected Tropical Disease (NTD) frameworks (WHO, 2017). The thesis highlights survivor experience as a public health and policy blind spot, calling for trauma-informed care, physiotherapy access, and follow-up protocols to be incorporated within public health planning. It also reinforces that declining mortality figures alone should not be mistaken for full systems success. Along with this, this thesis also highlights the impact of fear of even seeing a snake and psychosomatic symptoms of snakebites on a person's wellbeing and prognosis, which is often missed in the discourse on fatalities concentrating on direct envenomation.

Aside from the impacts of snakebite on humans, the thesis further exposes a major blind spot in veterinary preparedness. Pet and livestock deaths due to snakebite were frequently described in interviews as traumatic, emotionally devastating events, experienced as significant household losses. Yet these deaths remain untracked by formal data systems and are excluded from existing conflict compensation frameworks. In contrast to high-profile species like tigers, leopards, or elephants, where livestock losses routinely trigger compensation, investigation, and media attention, snakebite-related animal deaths are normalised and institutionally invisible. This inconsistency reveals a systemic double standard in how India prioritises wildlife conflict, as is being with the impact of snakebite on livestock only recently being noted in the global literature (Bolon et al., 2019).

Without veterinary protocols, training, or antivenom access, animal snakebite cases are currently managed, if at all, through private clinics, informal networks, or euthanasia. The result is a fragmented and inaccessible care ecosystem that fails to meet the ethical and economic needs of affected households. This research calls for the urgent integration of veterinary preparedness into national and state-level snakebite mitigation plans, aligned with a One Health framework that treats human and animal welfare as interdependent. Compensation mechanisms, triage protocols, and animal bite surveillance must be developed in parallel with human-focused interventions.

Beyond domestic animal losses, this research also surfaces the often-overlooked reality that many snakes, often protected under Schedule I of the Wildlife Protection Act, are themselves

killed in these encounters. Yet, these deaths remain ecologically unacknowledged, legally invisible, and culturally normalised. Retaliatory killings, pre-emptive striking of snakes by frightened pet owners, and unintentional injuries caused by poultry barriers are rarely documented or addressed in conservation planning. This reflects a deeper asymmetry in conflict narratives, where human or livestock losses prompt institutional response, but snake deaths are rarely seen as losses at all. Including non-human fatalities in human-wildlife conflict policy frameworks is not only an ethical imperative but a conservation necessity.

Ecological and infrastructural factors also emerged as critical yet under-recognised drivers of snakebite risk. Urbanisation, land-use change, and poor waste management are altering species encounter patterns, increasing rodents and bringing their predators, including Russell's vipers, into densely populated areas. Rescuers consistently described encountering snakes in unexpected spaces, from beaches to construction sites to household compounds. These shifting zones of human-snake interaction are not adequately captured in current policy frameworks, which continue to treat snakebite as a rural or agricultural problem. Nor are they reflected in species distribution models (SDMs), which often exclude built environments despite growing evidence of urban human-snake conflict.

As climate change accelerates habitat disruption, flooding, and temperature variability, these ecological pressures are expected to intensify, increasing human-snake contact in ways that reactive policy frameworks are not equipped to address. District-level planning that incorporates species ecology, land-use forecasting, and climatic vulnerability is urgently needed to proactively mitigate future conflict. Changing climate, lifestyle-driven migration, and urban sprawl are reshaping demographic and ecological landscapes across India. Goa, once seen primarily as a tourist destination, is increasingly absorbing settlers from urban centres seeking escape from climate stress, heat, or overdevelopment, often without corresponding infrastructural adaptation or risk awareness. This demographic shift demands updated outreach strategies and ecological preparedness, not only for traditional rural populations but also new peri-urban and climate-linked settlers.

Finally, the thesis highlights the role of rescuers not just as technical responders but as informal educators, ecological monitors, and community translators of risk. While their contributions are often under-recognised in science and policy (Malhotra et al., 2021), rescuers in Goa consistently demonstrated long-term species knowledge, engagement in public outreach, and the ability to mediate between communities and state systems. At the same time, many reported systemic burnout, emotional fatigue, and ego-driven tensions within rescue culture. Performance pressure, especially under the influence of social media, was linked to risky or unsustainable practices. Some rescuers articulated frustration at the lack of institutional support, even as they absorbed the emotional and logistical burden of repeated interventions. The emergence of ethical, education-oriented rescue models in Goa offers promising alternatives, but these require formal recognition and resourcing if they are to be sustained and replicated. These include legal recognitions and adequate framing under the requisite laws.

6.2.2 Contributions to Academic and Conceptual Understanding

This thesis contributes to a growing academic recognition that human-wildlife conflict is neither species-neutral nor socially uniform. By focusing on snake envenomation, a form of biochemical conflict often excluded from mainstream conservation literature, as well as understanding the visibility of predation by large species like the python, the study reframes the boundaries of what constitutes “conflict” and challenges long-standing assumptions about visibility, legitimacy, and policy attention in Indian wildlife management.

First, it makes a direct argument for positioning snakebite within the human-wildlife conflict (HWC) discourse. While elephants, tigers, and leopards dominate conflict narratives due to their physical visibility and media salience, snakebite has remained siloed as a purely biomedical issue. Yet the findings here reveal snakebite to be no less disruptive: it causes human and animal death, trauma, livelihood loss, and sustained fear. By including domestic animal mortality within this frame, the thesis expands the HWC paradigm to include forms of violence that are less visible but equally impactful, particularly at the household level. While compensation frameworks exist for large mammals, they remain absent or unevenly applied in snakebite cases.

Second, the study contributes to debates on what coexistence actually entails. Drawing on Pooley et al.'s (2021) critique, the thesis argues that Goa presents not a model of harmonious cohabitation and coexistence, but one of expedient avoidance. The presence of rapid response systems has, in many cases, reinforced a model of externalised coexistence, where tolerance is achieved not through adaptation or ecological understanding, but through removal. This reframes coexistence not as a social ethic, but as an infrastructural workaround, raising questions about the sustainability and ethics of long-term conflict mitigation models.

Third, the thesis introduces a conservation psychology lens to the study of snake rescue, an area that remains largely unexplored. Chapter 4 highlighted how masculinity, public performance, and social media exposure intersect with rescue practice, creating dynamics of validation, burnout, and ethical compromise. These findings contribute to a growing recognition that conservation work is emotionally and socially embedded, and that responder well-being must be taken seriously if ethical practice is to be sustained.

Fourth, the thesis flags gaps in scientific knowledge, particularly in relation to species ecology. One underexplored concern in current rescue practices is the potential for ecological disruption through frequent removal of common non-venomous species such as rat snakes and bronzeback tree snakes (Rao et al., 2013; Low, 2018). These snakes play a vital role in controlling rodent populations (Goldstein et al., 2021), and their repeated extraction from peri-urban and rural landscapes may unintentionally create ecological vacuums. Such vacuums could alter local predator-prey dynamics and open niches for other species, including potentially venomous snakes, to move into human-modified spaces. This concern was strongly highlighted in the thesis' analysis, where rescue data revealed a strong skew toward certain species, while others, like kraits and saw-scaled vipers, remain underreported. It is striking that India still lacks peer-reviewed urban ecological studies on important species such as the spectacled cobra (*Naja naja*) or common krait (*Bungarus caeruleus*) or even the saw-scaled viper (*Echis carinatus*), some of the country's most medically important snakes. By analysing multi-year rescue data and integrating rescuer observations, the study generated species-seasonal patterns using GAMs, a methodological contribution rarely seen in Indian herpetological conflict studies. This revealed

seasonally predictable patterns in species movement and conflict, providing an alternate method where species telemetry data might be absent. These findings offer a replicable framework for forecasting rescue surges in monsoon-linked periods, particularly in urbanising landscapes where SDMs often fall short. These insights call for a more pluralistic conservation science that validates informal, situated knowledge (Ibbett et al., 2023). Chapter 3 documented rescuers' consistent, longitudinal observations about seasonal movement, species-specific risk zones, and changing habitat preferences. These insights, though often dismissed as anecdotal, are vital ecological data. Their inclusion demonstrates the value of pluralistic knowledge systems, where local and experiential expertise can complement formal research to inform risk modelling and early warning systems.

Fifth, the thesis reinforces the necessity of a One Health framework (Babo Martins et al., 2019), one that bridges human, animal, and environmental systems. Snakebite mitigation cannot be the domain of the health ministry alone. It requires coordinated involvement from veterinary departments, forest services, disaster response teams, and local governance. As the findings show, each of these actors plays a role in shaping outcomes, yet without shared platforms, these roles remain siloed and reactive. The One Health framing here is not theoretical, but grounded in lived failures: untreated animals, missing morbidity data, unanticipated urban conflict zones, and misaligned compensation schemes.

Finally, this study contributes methodologically by demonstrating the value of qualitative, adaptive research in conservation conflict contexts. The use of semi-structured interviews, long-term engagement, and reflexive fieldwork enabled the capture of emotional nuance, power dynamics, and layered lived realities including fear, trust, identity, and ethical dilemmas (Spradley, 1979; Chowdhurym et al., 2016). These facets are rarely accessible through biomedical surveys or herpetological monitoring alone. The thesis also draws attention to asymmetries in who speaks and who is heard in HSC discourse, where dominant male rescuers may receive visibility and legitimacy, while survivors, often from lower-income or migrant communities, remain institutionally unheard. This underscores the need for more inclusive, justice-oriented approaches in both academic research and policy design. It also warrants more

research on method designs themselves, possibly including the voices of interdisciplinary researchers and institutions from different socio-economic backgrounds, as well as a literature review to assess the evolution of such methods and the current lacunas.

In sum, this thesis offers not only empirical findings but conceptual and methodological tools for rethinking how snakebite is framed, studied, and addressed. It pushes for a vision of coexistence that is infrastructurally supported, ecologically informed, ethically accountable, and inclusive of both human and non-human suffering. It also invites a broader reconsideration of whose knowledge counts, whose labour is valued, and what forms of conflict deserve our academic and institutional attention.

6.3 Methodological Reflections and Researcher Positionality

This research was shaped not only by its empirical aims but also by the dynamic realities of fieldwork access, adaptation, and embedded engagement in a socio-culturally distinct setting. After the original project, a clinical experimentation across two districts of an East Indian state was shelved, the project was restructured into a deep ethnographic inquiry in Goa. This methodological pivot, prompted by COVID-19 restrictions, administrative limitations, and emerging field insights, was not simply a logistical revision, but a realignment with the sensitive and layered nature of snakebite as a human-wildlife conflict.

Rather than relying on structured surveys or standardised tools that risked flattening trauma and context, the research adopted a qualitative, semi-structured approach grounded in conservation ethnography (Spradley, 1979; Clarke and Braun, 2017; Jolly et al., 2022). This allowed the research to capture nuance, contradiction, and socio-cultural texture across stakeholder groups including survivors, rescuers, doctors, veterinarians, forest staff, and community members. This approach was particularly important in a domain like snakebite, where trauma, power, and belief are deeply entangled, and where narratives are often shaped by fear, guilt, or stigma.

The researcher's positionality also profoundly influenced access and interpretation. As a non-Goan woman affiliated with a UK-based university, the researcher was initially viewed with hesitation by some stakeholders, particularly within government departments or forest offices. Gatekeeping, bureaucratic uncertainty, and gendered perceptions shaped the early stages of access. However, these barriers were eventually overcome. Trusted local rescuers acted as social brokers, introducing the researcher and reinforcing credibility. However, these barriers were not dismissed as noise; rather, they became part of the analytical lens. They mirrored the very dynamics of institutional trust, authority, and scepticism that shape community engagement with snakebite systems in Goa. Relationships deepened, the quality of interviews changed and respondents became more candid, critical, and reflective. These shifts reinforced the value of long-term, relational fieldwork, especially in research domains involving trauma, care, and contested authority (Edwards and Holland, 2013; Mahanty, Chann and Suong, 2023). The process of earning access, rather than demanding it, was also reflective of the social negotiations that communities themselves undertake in trusting or resisting snakebite response systems. Recognising these parallels helped the researcher interpret responses not just as data points, but as situated expressions of place, identity, and memory. With time, access was granted by both the Directorate of Health Services and the Forest Department, enabling detailed interviews and verification of institutional practices.

The use of local consultants and translators, initially perceived as a potential limitation, emerged as a significant strength. These collaborators played an instrumental role not only in language translation, but in contextual interpretation, emotion-sensitive facilitation, and the brokering of trust. As others have observed in conservation and ethnographic research (Margulies and Karanth, 2018; Ibbett et al., 2023; Mahanty, Chann and Suong, 2023), such intermediaries are often essential to accessing and interpreting complex field environments. They helped decode silences, translate idiomatic phrasing, and navigate caste, gender, and power dynamics that may not be immediately visible to an outsider.

This positional reflexivity also informed how data was handled, analysed, and represented. Certain narratives, such as unverifiable species ID claims or exaggerated accounts of snake

behaviour, were critically examined and excluded when necessary. The goal was not to sanitise local narratives, but to maintain empirical rigour while recognising the affective and folkloric layers of human-snake relationships. Here, the research drew on methodological insights from conservation ethnography and public health research, which caution against either romanticising or dismissing local knowledge (Campbell et al., 2013; Bennett et al., 2017).

Crucially, the research sought to amplify voices that are often marginal in conservation studies. In addition to dominant male rescuers or institutional actors, the study actively included migrant workers, women survivors, junior veterinary staff, and community members whose perspectives have historically been peripheral. This aligns with broader calls in the literature to interrogate who is heard, who is excluded, and how power is mediated in the construction of conservation narratives (Margulies and Karanth, 2018; Ibbett et al., 2023).

Ultimately, the methodological approach was iterative, reflexive, and grounded in humility. It allowed the thesis to remain open to contradiction, shaped by context rather than pre-fixed categories. In reframing snakebite not just as a public health crisis but as an ecological, emotional, and institutional terrain, this methodology became not only a research tool- but a central axis of insight.

Of course, like any study, this also had limitations. The limited geographic and regional scope, given Goa's small size, as well as temporal limitations leading to a lack of longitudinal tracking on bite outcomes formed some of the obvious restrictions, which could not be avoided given the situation and time limitation of a PhD research.

6.4 Future Research Directions

This thesis has outlined a layered and field-based account of human-snake conflict in Goa, yet several dimensions of the problem remain underexplored, both regionally and nationally. Future research must extend beyond mortality tracking and hospital data, and instead build

interdisciplinary frameworks that include animal health, survivor outcomes, behavioural change, and ecological forecasting. The following six areas offer promising directions for future inquiry.

6.4.1 Behavioural Change and the Dynamics of Awareness Uptake

One critical avenue lies in examining how, why, and for whom awareness campaigns translate into sustained behavioural change. While Goa demonstrated a clear shift toward hospital-based treatment, other preventive behaviours remained unevenly adopted. Future research should focus on the selective uptake of behaviour change, particularly across different demographic groups such as informal workers, migrants, and peri-urban populations. Longitudinal studies that track the impact of outreach interventions over time could identify which communication methods, messengers, and formats are most effective in different cultural and linguistic contexts.

Moreover, awareness interventions must be studied not only for knowledge retention, but also for their influence on trust, agency, and perceived risk. Collaborations with behavioural scientists and public health communication experts may help refine message design to bridge the gap between information and action.

6.4.2 Species Ecology, Rescue Ethics, and Urban Landscapes

Despite the prominence of spectacled cobras and kraits in India's envenomation burden, ecological research on these species in urban and peri-urban landscapes remains nearly absent. Future studies should prioritise species-specific investigations, particularly into seasonal movement, prey dynamics, reproductive behaviour, and human-modified habitats. This is particularly urgent for cryptic species like the common krait, where fatal bites often occur indoors and species presence is under-reported.

Additionally, the ethics of rescue must be critically re-examined. The lack of post-release monitoring systems raises questions about the welfare of non-venomous species routinely displaced from their home ranges. Studies are needed to evaluate the long-term impact of rescue interventions, both on snakes and human communities, and to develop ecological guidelines for

when, where, and how rescues should occur. Capture-mark-recapture and telemetry studies for species like the cobra and python could be highly useful in these cases, and ideal to implement in a state like Goa. Research into alternatives to removal, including humane urban design adaptations, improved waste system management, and preventative infrastructure planning, can enable cohabitation or mitigation without displacement. These approaches call for stronger integration of urban planning principles into snakebite risk reduction, particularly in rapidly growing peri-urban landscapes.

6.4.3 Rescue Networks, Burnout, and Performance Culture

This thesis documented the social and emotional labour embedded in snake rescue, highlighting tensions around public visibility, masculinity, and social media-driven validation. These dynamics are under-theorised in conservation literature, yet they shape how rescue is practiced, experienced, and institutionalised.

Future research should investigate the psychological and structural conditions that support or erode ethical rescue practices. Cross-state comparative studies could examine how access to training, recognition, or financial support impacts sustainability and well-being among rescuers. Equally important is the study of burnout, especially among those navigating constant public demands with limited institutional backing. Integrating conservation psychology into the study of community responders could offer critical insights into emotional sustainability and ethical rescue systems.

6.4.4 Veterinary Snakebite and Conflict Compensation

Veterinary snakebite remains one of the least addressed dimensions of human-snake conflict. Pet and livestock deaths are frequent but undocumented, and veterinary preparedness, both in terms of clinical protocols and infrastructure, is almost entirely absent from state snakebite plans.

Future research should investigate veterinary case management, including mortality rates, barriers to treatment, and the feasibility of animal-specific antivenom access. This also includes

the need for spatial data on animal bite hotspots, veterinary staff capacity, and access to first-response tools in rural areas. In parallel, policy studies are needed to understand why compensation frameworks for wildlife conflict systematically exclude snakebite-related animal losses. Research into the political economy of compensation could illuminate how species hierarchies shape which conflicts are rendered visible, and which are left unaddressed.

6.4.5 District-Level Risk, Infrastructure, and Preparedness

One of the clearest takeaways from this thesis is the need for snakebite mitigation strategies that are grounded not in broad state-wide assumptions, but in district-level diagnostics. Goa's relatively compact geography and health system functionality enabled detailed mapping of seasonal bite trends, rescue hotspots, and treatment accessibility. However, most Indian states are ecologically and demographically diverse, and require granular, site-specific planning. Future studies must integrate species presence, bite epidemiology, human population density, and infrastructure access to develop actionable risk profiles.

This is particularly urgent in high-burden or climate-vulnerable regions, where snake-human encounters are likely to increase due to land-use change, ecological degradation, and urban expansion. As this thesis showed, shifting snake encounters, are already outpacing static rural assumptions embedded in policy and infrastructure design. Yet rescue data, bite reports, and habitat changes remain disconnected from mainstream planning.

Future research must focus on combining ecological modelling with real-time rescue and bite data to identify emerging hotspots and enable proactive interventions. Such diagnostics can inform block- and panchayat-level preparedness, including the integration of species-specific education materials, multilingual warning systems, and emergency referral pathways. Local health centres and veterinary clinics must be equipped not only with ASV access but with clear treatment protocols, first-response checklists, and district-wide coordination mechanisms.

These needs are not theoretical. In states with large rural populations and poor public health penetration, bottom-up approaches offer the most scalable and culturally relevant pathway to risk reduction. This includes visual materials in local languages, context-specific prevention messages, and partnerships with rescuers or frontline actors, available and visible across all prominent public places. Rather than relying on top-down templates, future snakebite mitigation must be rooted in local realities, ecological, infrastructural, and social.

Goa's experience underscores that detailed, district-level planning is not just possible but essential. As the landscape of conflict shifts due to both environmental and anthropogenic pressures, static assumptions about risk, response, and visibility will leave gaps unaddressed. The next phase of research and policy must build systems that are flexible, decentralised, and ecologically attuned.

6.4.6 Mental Health, Morbidity, and the One Health Imperative

Perhaps the most under-recognised dimension of snakebite is its long-term human toll. Survivors frequently face nerve damage, chronic pain, PTSD, depression, and long-term work loss, yet none of these outcomes are currently tracked by the Indian surveillance system. There is an urgent need for research that centres mental health, disability, and survivor rehabilitation within the snakebite discourse.

This includes investigating the potential for trauma-informed care, post-treatment counselling, and integrated survivor support services. Studies must also explore how stigma, economic vulnerability, and family-level trauma shape post-bite experiences. Such work would significantly enrich the One Health framework, which currently focuses on zoonotic pathogens and ecological connectivity but remains weak on lived health outcomes and long-term recovery.

In parallel, animal health must be fully integrated into One Health approaches, not only as vectors or reservoirs, but as victims of conflict in their own right. Veterinary response, like human healthcare, must be made anticipatory, regionally sensitive, and institutionally supported.

6.5 Conclusion: Toward a New Ethic of Coexistence

This thesis has argued that snakebite is not merely a medical emergency, but one of India's most under-recognised forms of human-wildlife conflict. Through field-based analysis in Goa, it traced how envenomation, rescue, trauma, animal death, and ecological change intersect, often invisibly, across everyday life. What emerges is not a singular crisis, but a layered system of risk, response, and resilience.

Coexistence, in this context, is not a given. It is negotiated daily through fear, trust, habit, and infrastructure. In Goa, declining mortality has been achieved not solely through education, but through accessible care and functional systems. Yet gaps remain, particularly for migrants, animals, and survivors. Rescue, while vital, can also enable avoidance rather than adaptation. Systemic neglect, from veterinary treatment to mental health, reinforces a hierarchy of whose suffering counts. Snakebite persists as a routine emergency: frequent, preventable, and yet rarely prioritised. Its impacts, especially on survivors and animal owners, represent invisible burdens that fall outside the frame of most policy, health, and conservation narratives.

What this Goa study shows is that change is possible but must be intentional, embedded, and inclusive. Snakebite mitigation, to be effective cannot remain fragmented across sectors or divorced from lived experience. It demands a new ethic, one that values ecological specificity, recognises silent traumas, and integrates local knowledge with institutional responsibility.

The challenge ahead is not only technical, but conceptual. We must broaden how conflict is defined, whose voices are heard, and what counts as care. This thesis offers one case study toward that end. The work now lies in building systems, and solidarities, that do not wait for loss to prompt reform.

6.6 References

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Supplementary Sheet – S0

Baseline interview questions for select stakeholders

I. Snake Rescuer Baseline Interview Guide

Date of Interview: _____

Name / ID: _____

Location: _____

Follow up needed: _____

1. How long have you been rescuing snakes, and what motivated you to begin this work?
2. How have public perceptions of snakes and snake rescuers changed over the years?
3. How has government cooperation (e.g., Forest Department) changed over time? Any current gaps?

Snakebite Incidents

4. Have you personally experienced a snakebite?
5. Have you witnessed snakebites involving others? How do people generally react?
6. Differences in hospital readiness and response?

Spatial and Species Trends

7. What are some key areas most affected by snake encounters or rescues?
8. Which snake species are most commonly involved? Any challenges in species identification?
9. Do the same areas report repeated calls or translocation failures?

Human-Wildlife Interface and Attitudes

10. How do people respond when you reach a rescue site (e.g., livestock loss)?

11. Have you dealt with pet or livestock snakebites?
12. Any incidents involving fishermen or sea snakes?

Traditional Practices and Awareness

13. Are traditional remedies (homeopathy, Ayurveda) still used?
14. Do tantriks or snake charmers influence local beliefs?
15. Common myths you encounter?

Infrastructure, Data, and Practice

16. Is rescue/bite data maintained properly? Differences across private and government systems?
17. Do private rescuers charge? How is this received?
18. Regional differences in rescue calls (north/south, tourist vs. rural)?

Outreach and Impact

19. What impact (if any) has your awareness work or media presence had on public understanding?

II. Doctor / Healthcare Provider Baseline Interview Guide

Date of Interview: _____

Doctor Name / ID: _____

Hospital / Facility: _____

Epidemiology and Case Burden

1. How many snakebite cases do you encounter per year?
2. Which species are most commonly involved? (e.g., cobra, Russell's viper)
3. Proportion of venomous vs. non-venomous bites?

Treatment-Seeking Behaviour

4. Has treatment-seeking increased in recent years?
5. Do patients prefer private over public hospitals? What explains this difference?

Mortality and Morbidity

6. Approximate number of annual snakebite deaths?
7. Main reasons for mortality or complications?
8. Are autopsies done? What if the death occurs in a private hospital?
9. Seasonal or monthly spikes in cases?
10. What kinds of bites are most common? (accidental, handling, stunts)

Infrastructure and Hospital Capacity

11. Is antivenom storage and cold chain management adequate?
12. Are there delays or gaps in treatment administration?
13. What is the average duration of hospital stay?
14. How are fatal cases handled? (reporting, documentation)

Knowledge and Training

15. What is the level of awareness about snakebites among medical staff?
16. Is there any knowledge about snake species among healthcare providers?

Suggestions and Public Messaging

17. Common myths you encounter from patients or families?
18. What core messages should be reinforced? (e.g., “Do not panic”)
19. How can the current system be improved?

III. Community Members baseline interview Guide

Date of Interview: _____

Name / ID: _____

Location: _____

Follow up needed: _____

1. Are you afraid of snakes? (Who cannot even see photos?)
2. Can you identify any snake species?
3. What snake species do you know of?
4. Are you aware of first aid or treatment for snakebites?
5. Have you ever seen a snake?
6. Have you ever been bitten by a snake? (Most: No)
7. Do you know anyone who has been bitten?
8. What myths or beliefs have you heard about snakes?

IV. Veterinarian Baseline Interview Guide

Date of Interview: _____

Doctor Name / ID: _____

Hospital / Facility: _____

1. Which animals do you treat?
2. How long have you been treating animals?
3. Do you see any snakebite cases in domestic animals?
4. How many cases a year do you see?
5. Is there a pattern to when you might get more cases in a year?
6. Do you know which snake has bitten the animal?
7. What would be the survival rate?
8. What are some of the most common problems you encounter while treating the animal?
9. How do the owners react after their pet has been bitten?

10. Have you ever faced any antagonism?
11. What are your observations about domestic animal bites?
12. How many vials of anti-venom do you keep?
13. Any observations about anti-venom?

Supplementary Sheet – S1

I. Categories of snakes according to WHO classifications

WHO Category 1 (Highly Venomous, Frequent Human Envenomation)

“Highest medical importance Definition: highly venomous snakes which are common or widespread and cause numerous snakebites, resulting in high levels of morbidity, disability or mortality.” (WHO, 2017)

- Spectacled cobra (*Naja naja*)
- Russell’s viper (*Daboia russelii*)
- Common krait (*Bungarus caeruleus*)
- Saw-scaled viper (*Echis carinatus*)
- Hump-nosed pit viper (*Hypnale hypnale*) (southwest India only)

WHO Category 2 (Venomous, Medically Significant but Lower Recorded Human Exposure)

“Secondary medical importance Definition: highly venomous snakes capable of causing morbidity, disability or death, but: (a) for which exact epidemiological or clinical data may be lacking; and/or (b) are less frequently implicated (owing to their activity cycles, behaviour, habitat preferences or occurrence in areas remote from large human populations).” (WHO, 2017)

- King cobra (*Ophiophagus hannah*) (south, northeast, Andaman Islands)
- Bamboo pit viper (*Trimeresurus gramineus*) (south India only)
- Malabar pit viper (*Trimeresurus malabaricus*) (southwest India only)
- Coral snakes (*Calliophis* spp.)

Mildly Venomous Species (Not WHO Classified)

These species possess rear-fanged venom but are not classified by WHO due to their low medical significance.

- Beddome's cat snake (*Boiga beddomei*)

- Dog-faced water snake (*Cerberus rynchops*)
- Forsten’s cat snake (*Boiga forsteni*)
- Green vine snake (*Ahaetulla nasuta*)
- Ornate flying snake (*Chrysopelea ornata*)

These species are classified as mildly venomous due to their rear-fanged venom, which is not considered medically significant. However, this classification does not align with the WHO framework, which categorises only highly venomous species into Category 1 and 2 based on documented human envenomation.

Table S1.1: Species-level classification of snakes rescued in Goa (2016–2022), including venom status, activity pattern, and WHO medical significance.

Species	Venom Present	Venom status	Scientific Name	Family	WHO Category	Refined Notes
Rat snake	No	Non venomous	<i>Ptyas mucosa</i>	Colubridae	Non-venomous	Non-venomous, poses no threat to humans.
Spectacled cobra	Yes	Venomous	<i>Naja naja</i>	Elapidae	Category 1	Highly venomous, part of India's 'Big Four', causes significant snakebites.
Russell’s viper	Yes	Venomous	<i>Daboia russelii</i>	Viperidae	Category 1	Highly venomous, part of India's 'Big Four', causes significant snakebites.
Whitaker’s boa	No	Non venomous	<i>Eryx whitakeri</i>	Boidae	Non-venomous	Non-venomous, harmless sand boa species.
Indian rock python	No	Non venomous	<i>Python molurus</i>	Pythonidae	Non-venomous	Non-venomous, large constrictor, poses no threat to humans.
Bronzeback tree snake	No	Non venomous	<i>Dendrelaphis tristis</i>	Colubridae	Non-venomous	Non-venomous, arboreal species, not dangerous to humans.
Checkered keelback	No	Non venomous	<i>Fowlea piscator</i>	Natricidae	Non-venomous	Non-venomous, commonly found near water bodies, no medical significance.
Kukri	No	Non venomous	<i>Oligodon</i> spp.	Colubridae	Non-venomous	Non-venomous, small snake with strong jaws, but no venom threat.
Wolf snake	No	Non venomous	<i>Lycodon</i> spp.	Colubridae	Non-venomous	Non-venomous, often mistaken for kraits, harmless.
Common krait	Yes	Venomous	<i>Bungarus caeruleus</i>	Elapidae	Category 1	Highly venomous, part of India's 'Big Four', causes significant envenomation.

King cobra	Yes	Venomous	<i>Ophiophagus hannah</i>	Elapidae	Category 2	Highly venomous, the longest venomous snake, but human encounters are rare.
Saw scaled viper	Yes	Venomous	<i>Echis carinatus</i>	Viperidae	Category 1	Highly venomous, part of India's 'Big Four', responsible for many bites.
Bamboo pit viper	Yes	Mildly venomous	<i>Trimeresurus gramineus</i>	Viperidae	Category 2	Venomous, bites can be medically significant but less frequent.
Green vine snake	Yes	Mildly venomous	<i>Ahaetulla nasuta</i>	Colubridae	Mildly venomous	Mildly venomous, rear-fanged, not dangerous to humans.
Trinket snake	No	Non venomous	<i>Coelognathus helena</i>	Colubridae	Non-venomous	Non-venomous, harmless colubrid.
Forsten cat snake	Yes	Mildly venomous	<i>Boiga forsteni</i>	Colubridae	Mildly venomous	Mildly venomous, rear-fanged, mild venom, not dangerous.
Striped keelback	No	Non venomous	<i>Amphiesma stolatum</i>	Natricidae	Non-venomous	Non-venomous, commonly found near water bodies.
Other snakes	N/A	N/A	(Varied species)	(Varied)	N/A	Varied venom status, dependent on species.
Banded racer	No	Non venomous	<i>Argyrogena fasciolata</i>	Colubridae	Non-venomous	Non-venomous, fast-moving, harmless racer species.
Ornate flying snake	Yes	Mildly venomous	<i>Chrysopelea ornata</i>	Colubridae	Mildly venomous	Mildly venomous, rear-fanged, non-lethal to humans.
Coral snake	Yes	Venomous	<i>Calliophis</i> spp.	Elapidae	Category 2	Venomous, highly potent neurotoxin, dangerous if bitten.
Hump-nosed pit viper	Yes	Venomous	<i>Hypnale hypnale</i>	Viperidae	Category 2	Venomous, bites can be medically significant.
Malabar pit viper	Yes	Mildly venomous	<i>Craspedocephalus malabaricus</i>	Viperidae	Category 2	Venomous, hemotoxic venom, but envenomation cases are fewer.
Dumeril's black headed snake	No	Non venomous	<i>Sibynophis subpunctatus</i>	Colubridae	Non-venomous	Non-venomous, harmless to humans.
Dog-faced water snake	Yes	Mildly venomous	<i>Cerberus rynchops</i>	Homalopsidae	Mildly venomous	Mildly venomous, weak venom, not dangerous to humans.
Green keelback	Yes	Non venomous	<i>Rhabdophis plumbicolor</i>	Natricidae	Mildly venomous	Mildly venomous, produces weak toxins, not dangerous.
Beddome's cat snake	Yes	Mildly venomous	<i>Boiga beddomei</i>	Colubridae	Mildly venomous	Mildly venomous, rear-fanged, not dangerous.

Note: WHO Categories based on WHO (2017) guidelines for medical significance. Mildly venomous species are those with rear-fanged venom and low or no clinical risk to humans.

II. Climate of Goa

Goa experiences a tropical climate with distinct seasonal variations in temperature, humidity, and rainfall, which influence both snake activity and human encounters. The region's climate can be broadly categorised into four key periods, as extrapolated from the MODIS, CHIRPS and ERA5 datasets, (discussed in Chapter 3):

- Monsoon (June–September): Characterized by heavy rainfall (monthly averages exceeding 500 mm, peaking in July at ~750 mm), high humidity (92–95%), and lower temperatures (24–28°C).
- Post-Monsoon and Early Winter (October–December): Rainfall declines, and humidity gradually reduces (dropping to ~60–80% by December). Temperatures stabilize (~29–31°C in October, dropping slightly to ~28–30°C in December).
- Dry Season (January–April): Marked by low humidity (50–70%), minimal rainfall, and rising temperatures (peaking at ~35°C in April).
- Pre-Monsoon (May): The hottest period of the year (~34°C, humidity ~75–85%), with occasional pre-monsoon showers.

III. Excerpt of Toxicon paper, written by the author:

Promoting co-existence between humans and venomous snakes through increasing the herpetological knowledge base

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6. Promoting co-existence with venomous snakes: evaluating mitigation methods for human-snake conflict

Human-Snake Conflict (HSC) includes not just mortality and morbidity of humans but also mortality of livestock and domestic animals due to snakebites, as well as mortality of snakes (many of them non-venomous) that are killed in retaliation and/or out of fear. While many studies have looked at the problem of this Neglected Tropical Disease, there are very few published studies which have looked at solutions, specifically in terms of outreach and raising awareness (Roshnath and Divakar, 2019).

Again, using India as a globally significant example (accounting for over 50% of global snakebite deaths; Suraweera et al., 2020), the National Snakebite Management guidelines in India (National Snakebite Management Protocol, 2008), as well as other papers, have repeatedly cited various mitigation techniques (Ralph et al., 2019). These include using protective gear (gumboots, long trousers) when working in the fields, maintaining hygienic surroundings, using mosquito nets, and not sleeping on the ground (Jacobsen, 2014; Rodrigo et al., 2017; Samuel et al., 2020). Other techniques also identified as contributing to high mortality include application of incorrect first-aid methods such as cutting or burning the bite site, attempting to suck the venom out, or going to faith-healers instead of trained medical professionals (Bhargava et al., 2020), incorrect identification of snakes and inability to distinguish between venomous and non-venomous snakes (Longkumer et al., 2016; Pandey et al., 2016; Bolon et al., 2020; Durso et al., 2021). However, given the large number of snakebites, which will be much greater than the number of deaths resulting, there is surprisingly little published information on which mitigation techniques have been most useful in practice.

We conducted a literature review to assess mitigation tactics for HSC in India and the rest of the world, published in journals and articles between 2010 and 2020 (for methods and a list of reviewed papers, see Supplementary Information). The 68 selected papers were broken down into five categories corresponding with the region, species and the themes/recommendations identified within each (Table 2). To facilitate greater understanding of past, present and possible future human-snake conflict problems, these were further placed into three broad categories of current HSC issues including human mortalities due to snakebites, livestock/domestical animal mortality due to snakebites and modelling and predictions of human-snake conflict. The majority of papers (over 73%) reviewed focussed on human mortality (Williams et al., 2019), with almost all papers focussed on problem identification. Training of doctors to treat snakebites was included in 24 papers (over 35%), with detailed infographics on identifying snakebites based on the symptoms given (Jesudasan and Abhilash, 2019; Michael et al., 2019; Musah et al., 2019). A majority (over 60%) of those 24 papers also included recommendations for more research and ramping up infrastructure for production and distribution of antivenoms.

Table 2. Results of a literature review of mitigation tactics for Human-Snake Conflict (HSC) published in journals and articles between 2010 and 2020. Figures indicate the number of times a theme has been covered in 69 selected articles (note that a single article may include more than one theme).

A		B		C		D		E	
Models of outreach & awareness/ mitigation		Rescue, translocation, relocation		Need for more community outreach/ intervention		Need for training doctors/first responders/ investing in medical infrastructure		Sustainable co-existence	
India	Global	India	Global	India	Global	India	Global	India	Global
1.Snakes	4	6	3	4	14	25	8	16	4
2. Wildlife (incl. snakes)		4				3			

While many studies focussed on snakebite management (Michael et al., 2019), few included the concept of promoting sustainable coexistence (Narayanan and Bindumadhav, 2019) or snake conservation (Parkin et al., 2020). Although 10 papers in total touched upon working and theoretical models of mitigation, it is significant that not a single study addressed the long-term impact or efficacy of those methods.

In India, where there are a combination of different issues contributing to mortality in different regions, and a number of not-for-profit organizations running snakebite mitigation projects in different regions over a significant number of years (Whitaker, 2018; Togridou et al., 2019), there is still no published data to assess the efficacy of any of these methods (Ralph et al., 2019). Many papers discuss the need for community awareness and outreach, without going as far as recommending working solutions for these, or repeated the global guidelines, without adapting them to the regional circumstances. The most common problems in designing mitigation tactics and assessing impact were identified as the lack of funding and/or the paucity of time to either expand the project region or follow up on the retention and implementation of outreach programmes (Samuel et al., 2020). Rescue, relocation and translocation are some of the most common methods of short-term conflict resolution (Harvey et al., 2014; Keener-Eck, Morzillo

and Christoffel, 2020a); however, there are increasing numbers of studies pointing to the futility of such exercises (also see Box A), especially when undertaken without a thorough understanding of snake ecology, population density, and behaviour (Ramesh and Nehru, 2019; Blackwell et al., 2016). Similarly, papers reviewed could not demonstrate the efficacy of rescues with the given data (Low, 2018; Harvey et al., 2014). Only 7 papers discussed partnering with the Forest Department or other relevant authorities to extricate snakes out of situations which could prove harmful to the snakes as well as humans, as short-term solutions (Bhattarai et al., 2017; Togridou et al., 2019; Low, 2018). No study provided data on the number of snakes killed in retaliation in the project area (which can be collected as demonstrated in Whitaker and Shine [2000]), showed the impact of rescues on reducing snakebites or retaliatory killings, mentioned a centralised database of snake species encountered during rescues (see Boxes B and C) or gave an idea of the number of rescuers involved. These data are relevant to understanding the scale of rescue methods being applied and to monitor the impact on both humans and snakes, since snakes are a protected group in India (Wild Life (Protection), 2016). The survival and return rates of snakes that have undergone long-distance translocation, a common practice among snake rescuers in India, has only been monitored for a few select species from other countries and is not necessarily applicable to the Indian scenario (Ramesh and Nehru, 2019).

Only three papers analysed mass livestock mortality and morbidity due to snakebites, with one article (Herrera et al., 2017) suggesting the annual figures to be as high as 10,000 for cows in Costa Rica, while discussing the use of active immunisation of cattle to increase survival of envenomation. The recent, and first, global scoping review of snakebite in domestic animals (Bolon et al., 2019) highlighted lack of data, especially from developing countries. These data are needed to fully understand the extent of livestock mortalities, particularly in agrarian economies, and therefore analyse the true societal cost. No data is available for India, nor has any compensation been discussed even though various compensation schemes for domestic animals lost to predation by large carnivores is a high priority (Karanth et al., 2018). Compensation is available for human deaths due to snakebite in several States in India, and this was discussed in a few papers; however, there has been no impact study to show awareness of,

and the feasibility of claiming, such compensation in the cases of snakebite deaths (Roshnath et al., 2018).

There is a lack of studies on perceptions of extrinsic and intrinsic value of snakes by the public, and lack of data from agricultural systems regarding the effectiveness of snakes as rodent control agents (Ramesh and Nehru, 2019). Snakes were classified as problem animals by respondents in locally based studies in other regions (Western et al., 2019; Keener-Eck, Morzillo and Christoffel, 2020b), which showed a correlation between occupation (farming) and negative perception. A few studies also looked at fear and disgust of snakes as evolutionary or taught responses, hypothesising that those who feared snakes the most also had trouble correctly identifying them (Henke et al., 2019) and were less likely to absorb corrective information (Castillo-Huitrón et al., 2020). One study concluded that using audio-visual aids can be effective in changing the perception of people about snakes (Quesada-Acuña and Pérez-Gómez, 2020), though the sample size was limited. These studies are highly pertinent since snakes occupy a unique position among dangerous wildlife of being present in both urban and rural human-dominated landscapes and have one of the highest mortality rates of humans caused by any dangerous wildlife species (Tumram et al., 2017; Conover, 2019). A one-size-fits-all approach cannot be taken, and projects that evaluate responses pre, during and post-intervention over a longer period of time need to be designed after taking stock of the issues in the area (Johansson et al., 2016). Few studies have addressed the socio-economic, gender and literacy-related complexities (Vaiyapuri et al., 2013; Kasturiratne et al., 2017; Dandona et al., 2018) that need to be understood for every region before implementing mitigation methods. This applies even if they seem simple, like the recommendation to wear boots (Ralph et al., 2019), which risks ignoring differences between the feet of habitual barefoot walkers and habitual shoe-wearers even within the same population (D'Août et al., 2009), suitability of available boots to resist bites by the most dangerous local species (Pe et al., 1998), and likelihood of long-term behavioural change (Box D). A multidisciplinary approach is required, especially in countries like India, which have varied cultures, traditions and beliefs in different geographical regions, as well as diverse socio-economic conditions wherein it may seem more economically effective to eliminate problem animals (Soto-Shoender and Giuliano, 2011), particularly within economically challenged communities (St John et al., 2012). Until we have a clear understanding

of where, how, why and to what extent the conflict is occurring, successful mitigation models cannot be fully designed, executed or replicated in other areas (Box E).

The need for understanding HSC is especially pressing in the context of climate change, since several recent studies suggest possible increases in HSC as humans and snakes respond via shifting distributions and behaviours (Yousefi et al., 2020). Where range extensions occur in areas where existing levels of conflict is low, the necessary medical infrastructure may be lacking [Zacarias and Loyola, 2019]) and will require increased training for doctors, scaling up of medical infrastructure and instigation of outreach programmes, concurrent with collecting more precise data for monitoring and mapping predicted and current areas of human-snake conflict (Heathcote et al., 2019; Longbottom et al., 2018; Rifaie et al., 2017).

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Supplementary Sheet – S2

I. DHS data for snakebite case in Goa, India for 2019-2021

Table S2.1: Breakdown of the State Department provided data for number of snakebite cases and deaths between 2019-2021, in Goa India

North Goa District									
Taluka	Health Facility	2019		2020		2021		Total Cases	Total death
		Cases	Deaths	Cases	Deaths	Cases	Deaths		
Bardez	Hospital, Mapusa (Asilo)	181	0	156	0	151	0	488	0
	PHC Aldona	6	0	1	0	6	1	13	1
	PHC Candolim	4	0	0	0	9	0	13	0
	PHC Colvale	0	0	0	0	1	0	1	0
	PHC Siolim	14	0	17	0	13	0	44	0
	PHC Saligao							0	0
	UHC Mapusa	0	0	0	0	0	0	0	0
Pernem	CHC Pernem	16	0	35	0	27	0	78	0
	PHC Cansarvanem	9	0	13	0	14	0	36	0
Bicholim	CHC Bicholim	35	0	25	0	28	0	88	0
	PHC Mayem	0	0	0	0	0	0	0	0
Tiswadi	UHC Panaji	1	0	0	0	0	0	1	0
	PHC Chimbel	0	0	0	0	0	0	0	0
	PHC Corlim	0	0	0	1	0	0	0	1
	PHC Porvorim	0	0	2	0	0	0	2	0
	UHTC St. Cruz							0	0
	RHTC Mandur							0	0
Sattari	CHC Valpoi	28	0	58	0	34	0	120	0
	CHC Sanquelim (Sankhali)	43	0	58	0	14	0	115	0
Ponda	Sub District Hospital, Ponda	38	0	45	0	36	0	119	0
	PHC Betki	20	0	14	0	11	0	45	0
	PHC Marcaim	16	0	13	0	22	0	51	0
	PHC Shiroda	9	0	3	0	12	0	24	0
	Total	420	0	440	1	378	1	1238	2

South Goa District									
Taluka	Health Facility								
Salcete	South Goa District Hospital, Margao (Hospicio)	203	0	176	1	175	2	554	3
	PHC Curtorim	0	0	0	0	5	0	5	0
	PHC Loutolim	1	0	0	0	0	0	1	0
	PHC Navelim	0	0	0	0	0	0	0	0
	UHC Margao	0	0	0	0	0	0	0	0
	PHC Chinchinim	4	0	0	3	6	0	10	3
	PHC Colva							0	0
Mormugao	Cottage Hospital, Chicalim	77	0	50	0	43	0	170	0
	PHC Cortalim	4	0	0	2	0	0	4	2
	PHC Cansaulim	1	0	1	0	7	0	9	0
	UHC Vasco							0	0
Quepem	PHC Quepem	21	0	26	0	15	0	62	0
	PHC Balli	18	0	5	0	9	0	32	0
Sanguem	CHC Curchorem	30	0	27	0	28	0	85	0
	PHC Sanguem	20	0	37	0	24	0	81	0
Dharbandora	PHC Pillem, Dharbandora	10	0	28	0	16	0	54	0
Canacona	CHC Canacona	39	0	26	0	36	0	101	0
	Total	428	0	376	6	364	2	1168	8
Tertiary	Goa Medical College	329	6	307	5	304	5	940	16
All state totals		1177	12	1123	12	1046	8	3346	26

II. CBHI vs State DHS data for 2019-2022

Table S2.2: CBHI data vs State DHS provided data for 2019-2022 for snakebite cases and deaths for Goa, India (source: publicly available data taken from the annual National Health Profile reports on the CBHI website)

Year	State-Reported Cases	CBHI Cases	State-Reported Deaths	CBHI Deaths
2019	1177	1048	6	3
2020	1123	1018	13	6
2021	1046	481	8	1
2022	1187	790	2	0
Total	4533	3337	29	10

Supplementary Sheet – S3

I. Alternative Models Considered to Poisson GAM

1) Quasi-Poisson GAM

The quasi-Poisson GAM introduces a dispersion parameter to correct for overdispersion while maintaining the Poisson structure. However, this approach resulted in over-smoothing of the seasonal pattern, reducing the model's ability to detect biologically meaningful trends. Given the importance of seasonality in snake ecology, this model was rejected.

2) Negative Binomial GAM (NB GAM)

A Negative Binomial GAM was tested, as it introduces an additional variance parameter to better handle overdispersion. However, it flattened seasonal effects, causing the month effect, which was significant in Poisson GAM, to become non-significant ($p = 0.202$, $EDF = 1.001$). The deviance explained dropped from 51.1% (Poisson) to 37.5% (NB GAM), suggesting that the model failed to capture key rescue variations.

3) Observational-Level Random Effects (OLRE) GAM

To further explore whether unmeasured variability could be accounted for, an Observational-Level Random Effect (OLRE) model was tested. OLRE is typically used in hierarchical models to account for excess variability at the individual level. However, in this case, it unexpectedly increased overdispersion (from 4.44 to 11.17) rather than reducing it. This suggests that excess variability in the data was likely due to reporting bias or unmodeled external environmental factors rather than unaccounted-for random effects. Given this, OLRE was deemed inappropriate for modelling overdispersion in this dataset (Eskew and Todd, 2017).

Since none of these alternative models improved model fit while preserving seasonal and climatic trends, the Poisson GAM ($k=6$) was retained, with robust standard errors applied to

account for overdispersion while maintaining biologically meaningful trends (Murase et al., 2009).

II. Species rescue counts for April 2016-March 2022, from Goa India

Table S3.1: List of all the species rescued in North Goa and South Goa from April 2016 to March 2022 by the Goa Forest Department

Sr. No.	Common Name	Scientific Name	North Goa Rescues	South Goa Rescues	Total Rescues	% of Total Rescues
18.	Rat snake	<i>Ptyas mucosa</i>	3773	4620	8393	27.5
19.	Spectacled cobra	<i>Naja naja</i>	2725	5584	8309	27.2
20.	Russell's viper	<i>Daboia russelii</i>	1145	1068	2213	7.2
21.	Whitaker's boa	<i>Eryx whitakeri</i>	1528	834	2362	7.7
22.	Indian rock python	<i>Python molurus</i>	2300	2113	4413	14.4
23.	Bronzeback tree snake	<i>Dendrelaphis tristis</i>	727	237	964	3.2
24.	Checkered keelback	<i>Fowlea piscator</i>	619	535	1154	3.8
25.	Kukri	<i>Oligodon spp.</i>	32	36	68	0.2
26.	Wolf snake	<i>Lycodon spp.</i>	370	613	983	3.2
27.	Common krait	<i>Bungarus caeruleus</i>	204	98	302	1.0
28.	King cobra	<i>Ophiophagus hannah</i>	57	58	115	0.4
29.	Saw scaled viper	<i>Echis carinatus</i>	24	11	35	0.1
30.	Bamboo pit viper	<i>Trimeresurus gramineus</i>	39	1	40	0.1

31.	Green vine snake	<i>Ahaetulla nasuta</i>	35	21	56	0.2
32.	Trinket snake	<i>Coelognathus helena</i>	95	95	190	0.6
33.	Forsten cat snake	<i>Boiga forsteni</i>	57	126	183	0.6
34.	Striped keelback	<i>Amphiesma stolatum</i>	38	50	88	0.3
35.	Other snakes	(Varied species)	571	59	630	2.1
36.	Banded racer	<i>Argyrogena fasciolata</i>	5	1	6	0.0
37.	Ornate flying snake	<i>Chrysopelea ornata</i>	3	21	24	0.1
38.	Coral snake	<i>Calliophis spp.</i>	6	2	8	0.0
39.	Hump-nosed pit viper	<i>Hypnale hypnale</i>	4	4	8	0.0
40.	Malabar pit viper	<i>Craspedocephalus malabaricus</i>	4	0	4	0.0
41.	Dumeril's black headed snake	<i>Sibynophis subpunctatus</i>	3	0	3	0.0
42.	Dog-faced water snake	<i>Cerberus rynchops</i>	0	8	8	0.0
43.	Green keelback	<i>Rhabdophis plumbicolor</i>	1	1	2	0.0
44.	Beddome's cat snake	<i>Boiga beddomei</i>	1	5	6	0.0
	Total		14366	16201	30567	100

III. GAM data

A. AIC selection for GAMs

Table S3.2: Akaike Information Criterion (AIC) comparison across all Poisson GAM models tested for the eight most frequently rescued snake species in Goa. The lowest AIC value for each species is highlighted and was used to select the final model included in the GAM analysis.

Sr No.	Species	Model	AIC
1.	Rat Snake	Month + Rainfall	2698.65
		Month + Humidity	2700.238
		Month + Temperature	2678.065
		Month + Temperature + Humidity	2639.038
		Month + Temperature + Rainfall (Final Model)	2553.762
2.	Russell's Viper	Month + Rainfall	1248.858
		Month + Temperature	1258.152
		Month + Humidity	1232.21
		Month + Humidity + Temperature (Final Model)	1227.431
3.	Spectacled Cobra	Month + Rainfall	2796.624
		Month + Temperature	2618.161
		Month + Humidity	2702.452
		Month + Temperature + Humidity	2557.904
		Month + Temperature + Rainfall (Final Model)	2546.296
4.	Indian Rock Python	Month + Rainfall	1670.373
		Month + Temperature	1623.70
		Month + Humidity	1689.047

		Month + Temperature + Rainfall	1577.611
		Month + Temperature + Humidity (Final Model)	1557.858
5.	Whitaker's Boa	Month + Rainfall	1345.201
		Month + Temperature	1335.872
		Month + Humidity	1299.519
		Month + Temperature + Humidity (Final Model)	1227.431
6.	Checkered Keelback	Month + Rainfall	957.8586
		Month + Temperature	972.6476
		Month + Humidity	950.9822
		Month + Temperature + Humidity (Final Model)	936.6318
7.	Bronzeback Tree Snake	Month + Rainfall	1082.389
		Month + Temperature	1018.457
		Month + Humidity	1047.842
		Month + Temperature + Humidity	1000.4452
		Month + Temperature + Rainfall (Final Model)	991.0702
8.	Common Krait	Month + Rainfall	589.8634
		Month + Temperature	593.281
		Month + Humidity	599.5798
		Month + Rainfall + Temperature (Final Model)	586.431

B. Monthly rescue count graphs for the final selected eight species for GAMs

The following are monthly rescue counts of the selected eight snakes in North Goa and South Goa from April 2016 to March 2022. Linear trendlines are included to provide a general visual

indication of overall trends across districts. These have not been statistically tested. These plots reflect only Forest Department-documented rescues and do not include removals conducted independently by private rescuers.

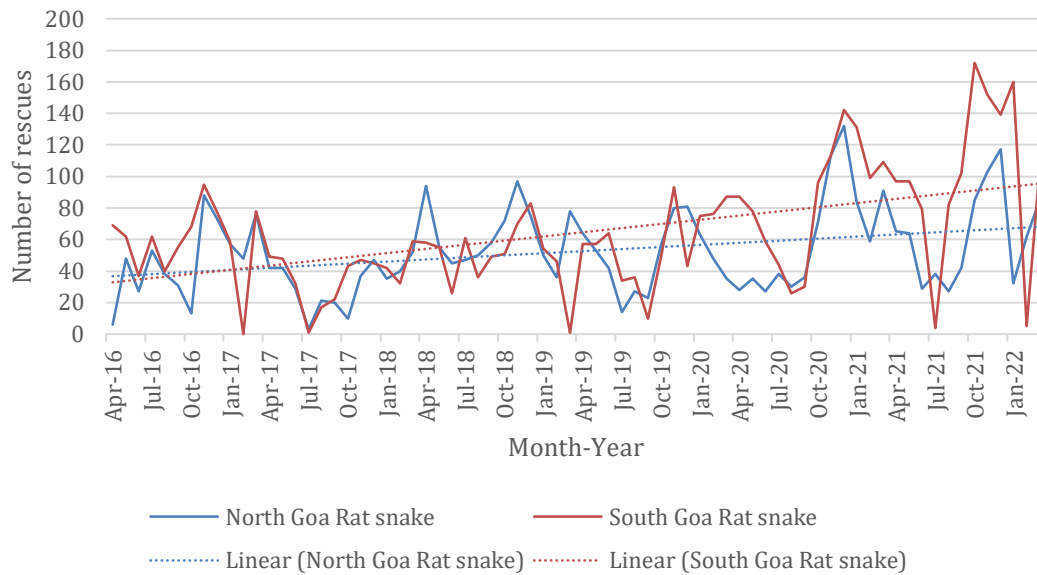


Figure S3.1: *Monthly rescue counts of rat snakes in North Goa and South Goa from April 2016 to March 2022.*

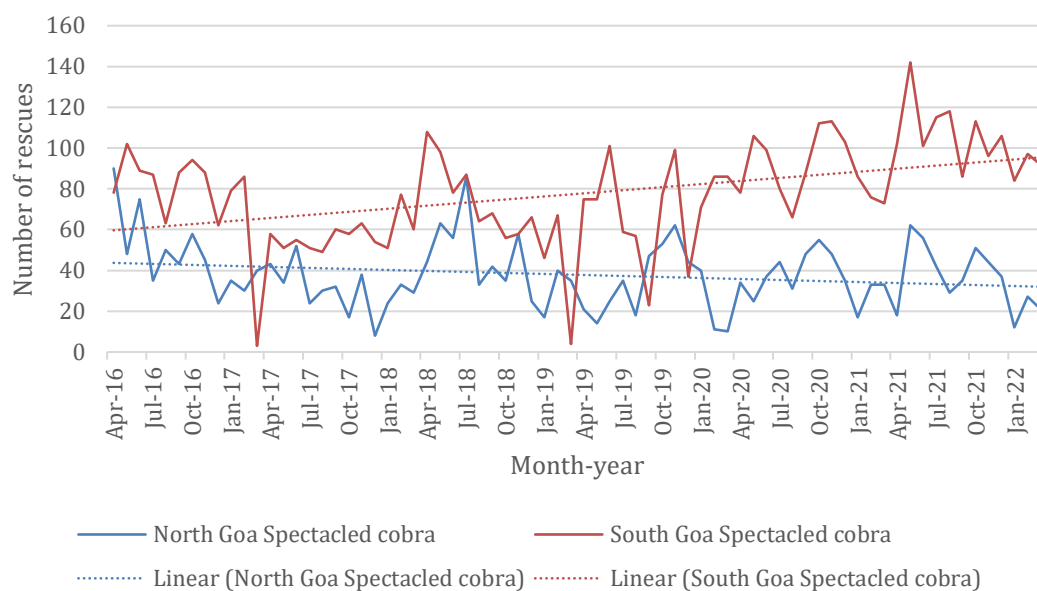


Figure S3.2: Monthly rescue counts of spectacled cobras in North Goa and South Goa from April 2016 to March 2022.

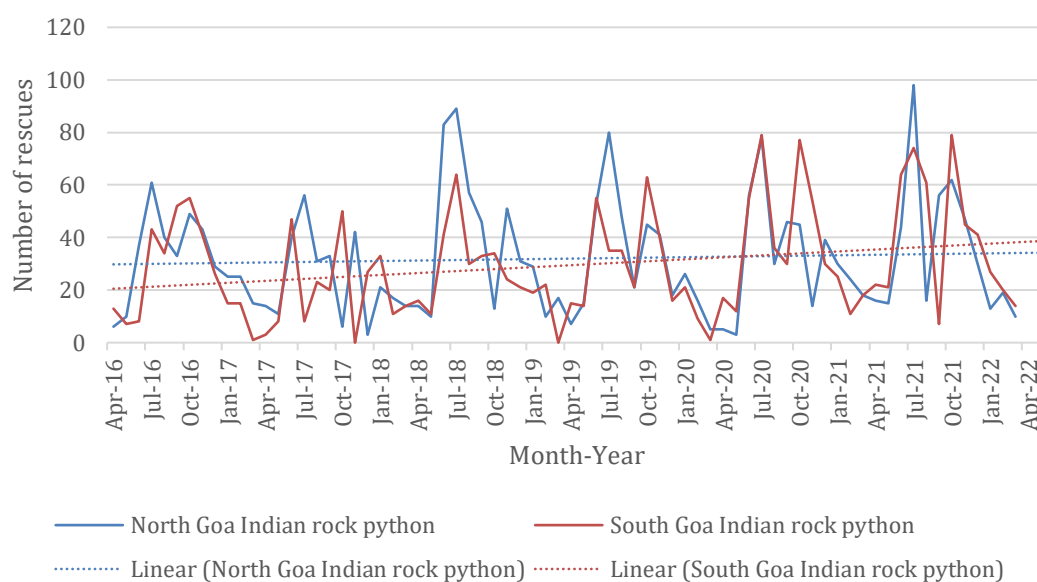


Figure S3.3: Monthly rescue counts of Indian rock python in North Goa and South Goa from April 2016 to March 2022.

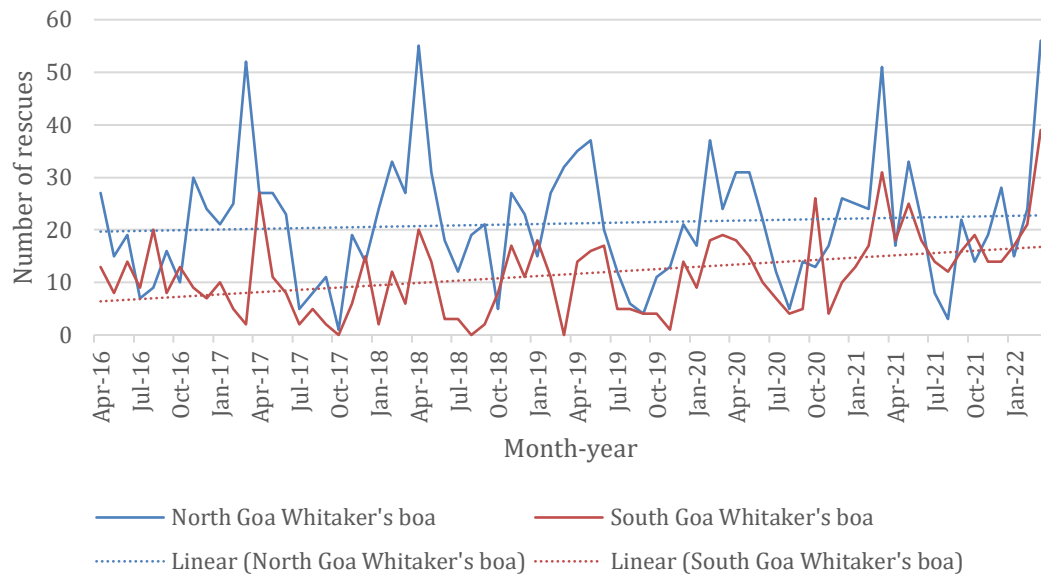


Figure S3.4: Monthly rescue counts of Whitaker's boas in North Goa and South Goa from April 2016 to March 2022.

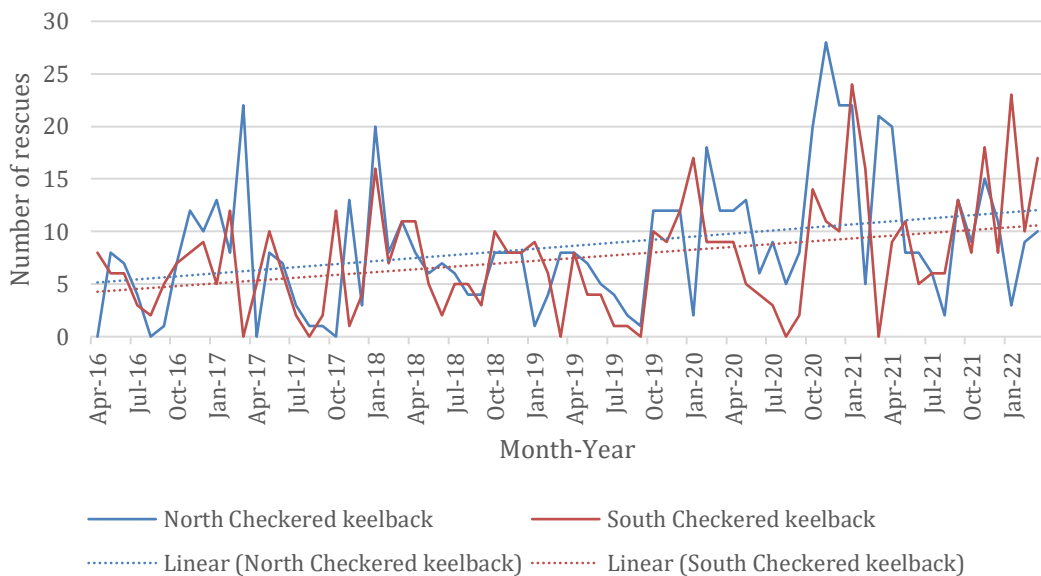


Figure S3.5: Monthly rescue counts of checkered keelbacks in North Goa and South Goa from April 2016 to March 2022.

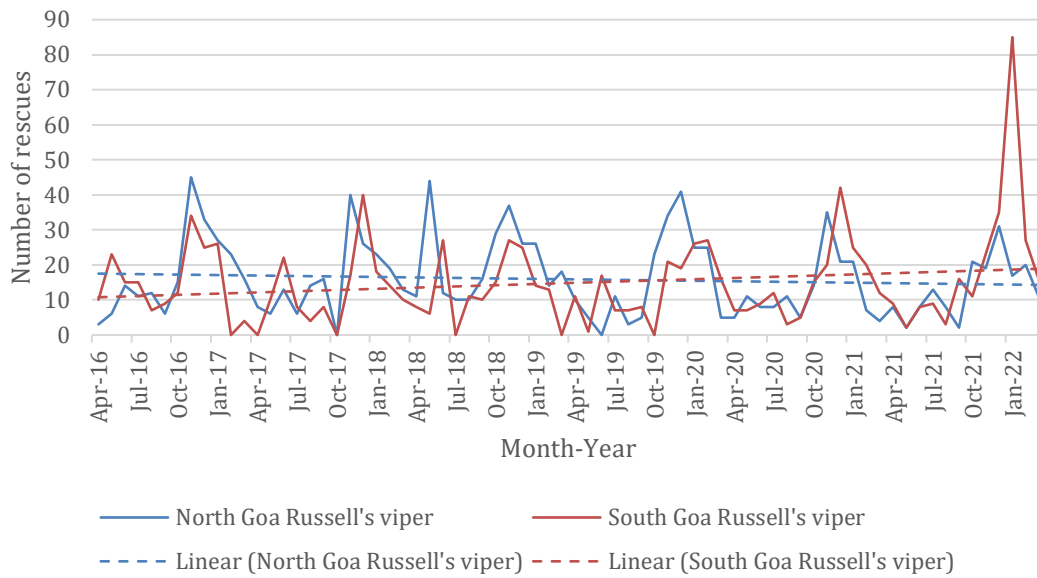


Figure S3.6: Monthly rescue counts of checkered keelbacks in North Goa and South Goa from April 2016 to March 2022.

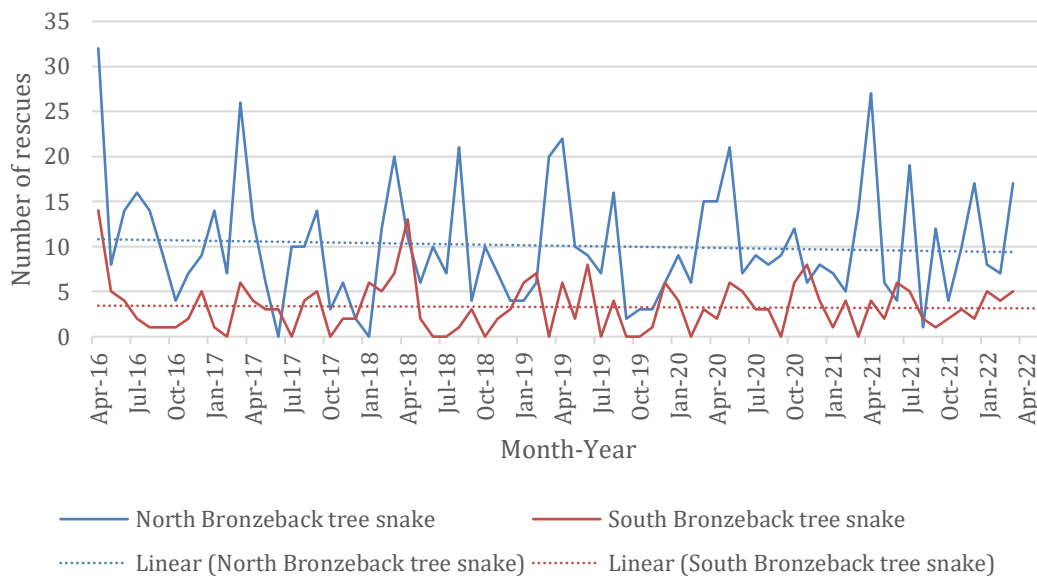


Figure S3.7: Monthly rescue counts of bronzeback tree snakes in North Goa and South Goa from April 2016 to March 2022.

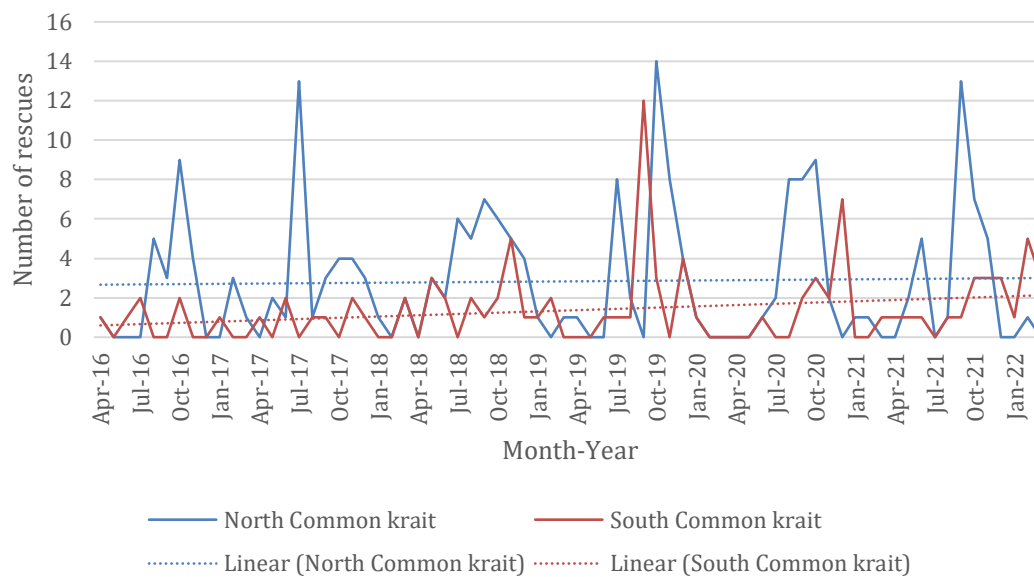


Figure S3.8: *Monthly rescue counts of common kraits in North Goa and South Goa from April 2016 to March 2022.*