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EDITED BY

Deb Prasad Pandey,
Agriculture and Forestry University, Nepal

REVIEWED BY

Priyanka Kadam,
Snakebite Healing and Education Society, India
Mahmood Sasa,
University of Costa Rica, Costa Rica

*CORRESPONDENCE

Ganeswar Chandrasekharuni
✉ snakebite@madrascrocodilebank.org

RECEIVED 13 October 2025

REVISED 28 December 2025

ACCEPTED 29 December 2025

PUBLISHED 28 January 2026

CITATION

Chandrasekharuni G, Vasquez C and
Whitaker R (2026) Mitigating the snakebite
crisis in India: a narrative review of efforts by
the madras crocodile bank trust.
Front. Amphib. Reptile Sci. 3:1723953.
doi: 10.3389/famrs.2025.1723953

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Mitigating the snakebite crisis in India: a narrative review of efforts by the madras crocodile bank trust

Ganeswar Chandrasekharuni^{1*}, Chloe Vasquez²
and Romulus Whitaker¹

¹Snake Conservation and Snakebite Mitigation Project, Madras Crocodile Bank Trust, Chennai, India,

²Department of Global Health, University of Washington, Seattle, WA, United States

Snakebite is a deadly yet severely neglected public health crisis. Each year, venomous snakebites kill up to 140,000 people per year and leave another 400,000 permanently disabled. About half of the world's snakebite deaths occur in India, and an unknown number of snakes are killed out of fear and retaliation. This article examines the multifaceted efforts of the Madras Crocodile Bank Trust (MCBT), a leading grassroots organization tackling SBE through education, advocacy, research, and venom production. MCBT's initiatives revolve mostly around education and outreach. These include the creation of educational films and posters in regional languages, which are distributed directly to communities. MCBT coordinates a network of so-called "snake rescuers" who remove snakes from houses and relocate them away from human dwellings, while delivering important snakebite prevention and first aid information to communities. MCBT coordinates training programs for rescuers and clinicians, sharing herpetological, first aid, and technical snake handling knowledge through a train-the-trainers model. Besides education, MCBT collaborates with state and national governments, including India's first National Action Plan for Snakebite Envenoming (NAPSE). The organization also supports the Irular Snake Catchers' Industrial Cooperative Society (ISCICS), India's largest venom supplier, through technical and administrative support. Through this work, MCBT works to address sustainability and quality control challenges within the current venom extraction model. By detailing MCBT's activities, key insights, and future directions, this article aims to shed light on the ongoing challenges of snakebite envenoming in India and the concrete steps being taken toward more effective, sustainable solutions.

KEYWORDS

education, prevention, snake, snake rescue, snakebite

1 Introduction

Snakebite envenoming is a neglected public health crisis, occurring most frequently in tropical and subtropical regions. Each year, approximately 5.4 million snakebites occur across the globe, leading to 2.7 million cases of envenoming and between 81,000 and 138,000 annual deaths (Kasturiratne et al., 2008; Gutiérrez et al., 2017). Hundreds of thousands of survivors suffer lifelong disabilities, including amputations, chronic pain, and psychological trauma, underscoring the substantial social and economic burden of snakebites worldwide (Gutiérrez et al., 2017). Recognizing its severe impact, the World Health Organization (WHO) declared snakebite envenoming a Category A Neglected Tropical Disease in 2017 (Chippaux, 2017). India bears the unfortunate title of “snakebite capital” of the world, with the heaviest burden of snakebite-related morbidity and mortality of any country. India alone accounts for nearly 50% of global deaths due to snakebite envenoming (SBE). An estimated 1.11–1.77 million bites and 58,000 fatalities occur in the country annually (Suraweera et al., 2020). Not all snakebites cause envenoming; 330,000 to 530,000 cases are ‘dry bites’ or bites by non-venomous species in India (Suraweera et al., 2020).

India is home to over 350 species of snakes, of which 60 have venoms which can cause medically significant illness (Whitaker and Ashok, 2004). Snakes evoke fear and superstition in the country, fueling human-snake conflicts (Chaaithanya et al., 2021; Pandey, 2023). Rural areas bear the brunt of this crisis, where ancestral beliefs often overshadow scientific knowledge on snakebites, leading to reliance on ineffective traditional remedies (Chaaithanya et al., 2021; Pandey, 2023; Vaiyapuri et al., 2023; Munshi et al., 2024). In hospitals, inadequate antivenom availability compounds treatment challenges, worsened by delays and poor infrastructure, hindering timely medical care. Complicating matters, caste, and religious biases impede access to treatment, particularly affecting economically disadvantaged communities (Ten Have et al., 2023; Vaiyapuri et al., 2023). Additionally, unavailable or under-resourced ambulance services contribute to delays, often resulting in fatal outcomes (Vaiyapuri et al., 2023).

The scarcity of region-specific antivenom aggravates the problem, with Northeast India facing heightened risks due to limited neutralization effects (Laxme et al., 2019; Chakma et al., 2020). Furthermore, inconsistent data collection exacerbates underreporting and misrepresentation of snakebite epidemiology, hindering effective policy formulation. Primarily affecting agricultural workers and low-income individuals, snakebites perpetuate cycles of poverty, burdening families with prolonged debt and trauma. Snakebite envenoming (SBE), often termed a “poor man’s disease” disproportionately affects agricultural workers and low-income individuals, leading to fatalities and lifelong disabilities (Harrison et al., 2009).

Victims, often breadwinners in rural households, endure immense financial strain due to treatment costs, taking over two

years to repay loans (Pandey et al., 2025). This highlights the urgent need for policymakers to overhaul compensation schemes. Despite constituting a significant portion of fatalities, snakebite victims receive inadequate support compared to encounters with larger wildlife. Varying compensation policies among states compound the issue, leaving victims unaware or uncertain of their entitlements (Vaiyapuri et al., 2013; Roshnath et al., 2018; Kadam et al., 2024).

Retaliatory killings of snakes proliferate due to fear and anger, exacerbating human-snake conflicts. To address these challenges, policymakers must prioritize standardizing compensation policies nationwide and conducting comprehensive awareness campaigns to educate communities about available schemes and mitigate retaliatory killings, fostering harmonious coexistence between humans and snakes.

Grassroots organizations in India, such as the Madras Crocodile Bank Trust (MCBT), have emerged as pivotal players in mitigating the snakebite crisis. Established in 1976 by Romulus Whitaker, Zai Whitaker, and conservationists, the Madras Crocodile Bank Trust and Centre for Herpetology (MCBT) aimed to save India’s crocodilian population. In 1978, MCBT established the Irula Snake Catcher’s Industrial Cooperative Society (ISCICS), now India’s largest venom producer, supplying 80–90% of the nation’s venom required for antivenom manufacturing (Whitaker and Whitaker, 2012; Chakma et al., 2020).

In order to alleviate the immense socioeconomic impact of snakebites on rural communities, MCBT established the Snake Conservation & Snakebite Mitigation Project in 2016. Since its foundation, the snakebite project has developed a multifaceted approach to address the complex challenges posed by snakebite envenoming. This includes public education campaigns, workshops for healthcare workers and snake rescuers, contributions to national policies, and research into antivenom quality and snakebite prevention strategies (Litschka-Koen et al., 2019). These activities aim to bridge critical gaps in awareness, policy, and healthcare delivery while promoting coexistence between humans and snakes.

This narrative review of MCBT’s snakebite-related activities and experiences over the past decade aims to highlight successes, challenges, and key lessons from MCBT’s initiatives. By sharing insights from MCBT’s extensive experience, this paper seeks to inform the global snakebite mitigation community and contribute to the development of sustainable, scalable solutions to this neglected health crisis.

2 Materials and methods

This narrative review was constructed based on annual reports by MCBT from 2014 to 2025. Two authors of his study, GC and RW, have directed MCBT’s snakebite initiatives during the period of study. The authors have compiled publicly available documents, educational materials, and academic articles referencing MCBT’s activities. Most materials on MCBT’s work are available through the MCBT website and YouTube Channel.

3 Results

3.1 Educational materials

The MCBT Snakebite Mitigation project's educational component demonstrates a priority in prevention-focused outreach, growing from 60 programs in 2017 to over 1,000 programs by 2025, reaching 1,600,000 people across 18 states. MCBT's multimedia approach, consisting of films in eight languages, comic books, games & puzzles, 'street-plays', and music videos reflect an understanding that effective prevention education must be culturally relevant and engaging (see Figure 1).

MCBT has partnered with EvaneScence and Kucing Pvt. Ltd. to develop a collection of short films exploring diverse topics (Madras Crocodile Bank Trust, 2010; Evanesence Studios Science communication & wildlife filmmakers. Evanesence Studios official website, 2025). The investigative documentary on 'Snakebites in Northeast India' shed light on victims' struggles and treatment challenges (Snakes and snakebite in the northeast [Film]. Director: grant davis and tiara aurora; producer: gnaneswar ch. India, 2022). The documentary featured in high level meetings between government, grassroots and non-profit stakeholders and advocacy groups. These meetings culminated in the publication of the National Action Plan for Snakebite Envenoming (NAPSE) (Bijlwan and Pandey, 2024; Shewale et al., 2025).

To engage young audiences, MCBT partnered with an influential YouTuber to produce a catchy music video - *Paambu Goes Hissu* - about medically important snakes and snakebite first aid (Sargunraj, 2019). The music video, available in Tamil and English, visually demonstrates inappropriate snakebite care in a comedic manner.

In 2019, artist and author Rohan Chakravarty partnered with MCBT to create an original comic book, "Making friends with

Snakes but from a distance". This comic was intended to go beyond the usual poster, depicting snakes and co-existence in a comic way (A comic book on snakes by Rohan Chakravarty, the man behind Green Humour - The Hindu). This was one of MCBT's first approaches to destigmatize the perception of snakes. MCBT uses these music videos, original comics, and interactive activities to captivate children during outreach, making learning fun.

'Snake Rescue the Right Way' is a film available in English, Hindi, and Kannada (Snake rescue the expert way hindi, 2023). The film teaches scientifically-backed rescue techniques. Educators screen this film during rescue workshops to visually demonstrate safe and ethical procedures for responding to snake calls, removing snakes from houses, and releasing them into the wild. 'The Beauty of Snakes' informs the audience about snake ecology while encouraging a respectful appreciation of snakes as a key part of the natural environment (The beauty of snakes - telugu, 2025). The film, available in five languages, aims to show snakes in a more informative, less dramatic way, to spark awe and curiosity about snakes way of life.

'4 Deadliest Snakes of India,' introduces the so-called 'Big 4' snakes of India, which are responsible for over 90% of envenoming in India (Laxme et al., 2019): Russell's Viper (*Daboia russelii*), Saw-Scaled Viper (*Echis carinatus*), Common Krait (*Bungarus caeruleus*) and Spectacled Cobra (*Naja naja*). The film, available in English, Hindi, Tamil, Gujarati, Talugu, Malayalam, Kannada, and Odiya, walks the viewers through basic snake behavior, various snakebite prevention methods and the logic behind each (4 deadliest snakes of India kannada, 2023). In its first year online, '4 Deadliest Snakes of India,' garnered over 500,000 views on youtube and 5000 shares on Facebook (Annual report- 2018-19).

'Snakebite' & 'RIGHT - Northeast' are two films that focused on promoting the proper first aid for snakebites through an enactment of a skit. 'Snakebite,' explains proper first aid following an accident,



FIGURE 1
Community awareness program.

and has been translated into English, Hindi, Tamil, Odiya, Gujarati, Kannada, and Telugu (*Snakebite - english*, 2023). ‘RIGHT’ is catered toward India’s Northeastern snakes and cultural context, and is available in English with efforts underway to translate the film to Assamese and Bengali.

MCBT has also made posters on snakebite first-aid and prevention, available in 6 and 7 languages respectively. These are distributed during awareness programs, training workshops, and other engagement activities. Over 4,500 posters are given as printed leaflets or stickers that can be installed in community centres, spreading snakebite knowledge to subsequent visitors (*Annual report 2021–2022; The madras crocodile bank trust & Centre for herpetology*). MCBT partnered with University of Reading and the National Health Mission Tamil Nadu to publish a Tamil poster for snakebite prevention and first-aid. This was released by the Minister of Health and Family Welfare and later circulated to all the Primary Health Centres of the State. In a similar initiative, MCBT collaborated with ‘Aviratha’, an NGO based out of Karnataka, in designing back covers for notebooks that were distributed to students of rural communities. This back cover has preventive measures and first-aid on snakebite. 200,000 notebooks were donated to 30,000 students (*Annual report- 2019–2020*).

Similarly, MCBT partnered with the Global Snakebite Initiative and various other funders to paint school walls with snakebite-related information. A certain set of schools from rural parts of Tamil Nadu were identified and their road-facing walls were painted. This initiative was celebrated by the schools themselves (*Annual report 2022–2023*). In one case, a community member suffered a snakebite, and reported that the wall painting helped him respond appropriately in the moment of the accident (*Personal communication to MCBT, 2023*).

To address communities with poor internet connection and spark interest in outreach programs, MCBT worked with a collective of actors in staging ‘street-plays’ which are often seen in fairs and gatherings. About 10 street plays were performed in the

district of Tirunelveli of Tamil Nadu to promote right first-aid and co-existence with snakes (*Annual report- 2019–2020*).

3.2 Workshops & outreach

MCBT conducts broad snakebite awareness programs for various stakeholder groups, reaching an estimated 1.6 million people across 15 Indian states through both online and in-person activities (*Litschka-Koen et al., 2019; Vaiyapuri et al., 2023*).

Workshops generally cater to two groups: snakebite prevention and first aid education for schoolchildren, and so-called “snake rescuer” workshops (*Figure 2*). Beyond formal programming, MCBT engages with a wide range of national and international media and academic platforms, discussing snakes and snakebite in India.

Each community outreach session is designed to address common misconceptions about snakes, promote ecological awareness, and reduce fear-driven reactions that often lead to unnecessary killings. Depending on the context, MCBT employs educational films, quizzes, and games to engage the audience. Programs are held in community centers, lasting 60–90 minutes (*Litschka-Koen et al., 2019*).

In order to expand our reach, Madras Crocodile Bank also partners with local NGOs through a program called “train the trainers” (*Figure 3*). These programs have a learning schedule of 6 hours, with a focus on ecology, myth-busting, right practices, documentation and standardized reporting.

Partner organizations are selected through a systematic assessment of their capacity, reach, and alignment with project goals (see *Table 1*). Each partnership is formalized through Memorandums of Understanding (MoUs), clearly defining roles and responsibilities. When required, training and capacity-building support are extended to partner organizations to ensure effective program delivery. Once fully capacitated and onboarded, these



FIGURE 2
Snake rescuer training workshop.



FIGURE 3
Train the trainer workshop.

community partners conduct awareness programs on snakebite prevention and first aid in schools and high-burden communities.

While many of these programs have focused on schoolchildren, MCBT also conducts teacher training workshops on Snakebite Mitigation and First Aid, reaching hundreds of primary school teachers. This program aims to create a more sustainable knowledge source for communities. These teachers, who are community leaders, will continue to share snakebite knowledge to future student cohorts (Annual report- 2017–18).

All outreach programs include two rounds of assessments, with pre- and post-program surveys administered to at least two participants per session. Until October 2025, these assessments have demonstrated a significant improvement in knowledge across

23 of the 26 questions asked right after the program. However, further evaluations revealed that there is a loss of knowledge in the participants, months after the activity was conducted.

MCBT provides specialized training for local “snake rescuers,” individuals who respond to local calls to remove a snake from human dwellings or their surroundings. Attendees include informal rescue networks, registered NGOs, and Forest Department officials. Training sessions usually span two days, beginning with powerpoint presentations and film screenings on snakes and snake identification, snakebite first aid, and proper rescue techniques. While programs aim to fulfil core competencies, each workshop is tailored to the needs of the audience. Powerpoints are tailored to local language, snake biodiversity, and audience background. The theoretical session is followed by hands-on rescue practice using a rope, and (if permission is obtained from local authorities), live snakes. MCBT trainers make a point to keep workshops small and allocate individual attention to each participant. We aim to eliminate certain common malpractices among snake handlers and rescuers across India.

MCBT contributes to snakebite management workshops for healthcare practitioners organized by the National Centre for Disease Control (Microsoft Word - achievement during 2024–25). In 2024, MCBT participated in 12 state-level doctor training workshops, supporting state health departments in fulfilling mandates under the National Action Plan for Snakebite Envenoming (NAPSE) (Figure 4). These workshops targeted medical officers, epidemiologists, and department heads involved in snakebite treatment and surveillance. Licensed doctors give training on clinical snakebite management, while MCBT herpetologists provide information on snakes and snake identification, dispelling common snake and treatment myths.

MCBT works to raise awareness about snakebite by engaging in television, radio, documentaries, news articles, magazines, blogs,

TABLE 1 Implementational partners (2016 – 2025).

Indiansnakes.org	Into the wild	Reptiles conservancy alliance
World Wide Fund for Nature - India	Agastya International Foundation	Adavi Trust
Wild Bihar	Eastern Ghats Wildlife Society	Wildlife Conservation Through Research & Education
Ashoka Trust for Research in Ecology and Environment	Hope & Beyond	Rural Youth Development Education Society
People for Animals – Angul unit	Kenneth Anderson Nature Society	Organisation for Wildlife Studies
Simultala Conservationists	Haavu Mattu Avu	Animal Rescue and Protection Force
Help Earth	PinkPulp	



FIGURE 4
Healthcare training workshop.

and others (A comic book on snakes by Rohan Chakravarty, the man behind Green Humour - *The Hindu*; Srimathi, 2023; Thiagarajan, 2023; Maadan, 2024). The MCBT Snakebite team consistently participates in national and international conferences and symposiums, presenting on Snakes and Snakebite in India (*Annual report 2021–2022*; *Annual report 2022–2023*; Thiagarajan, 2023). Through workshops and educational materials, such as posters and short films, translated into regional languages, MCBT has reached over 1,600,000 individuals. Considering the reach of media and conference presence, that statistic is much higher.

3.3 Policy

MCBT's policy work includes core membership in the National Action Plan for Prevention and Control of Snakebite Envenoming (NAPSE) as an NGO representative, instrumental support to local governments, establishment of India's first snakebite registry in partnership with National Health Mission Tamil Nadu, and drafting the inaugural White Paper for ICMR. These achievements reflect MCBT's commitment and understanding that for sustainable solutions to endure, deeper government interventions are required. MCBT strategically supports policy development with its expertise across multiple intervention needs for systematic snakebite mitigation.

MCBT's advocacy efforts are focused on standardizing treatment protocols and ensuring adequate antivenom supply, especially for rural areas. MCBT works closely with government bodies, including the National Centre for Disease Control and the Indian Council for Medical Research, Ministry of Health & Family Welfare. Additionally, MCBT advocates for incorporating snakebite management into medical education curricula and setting up a national snakebite registry to improve data collection.

The National Action Plan for Snakebite Envenoming (NAPSE), initiated by the Ministry of Health and Family Welfare, Government of India, presents a comprehensive roadmap to curb snakebite-related fatalities and disabilities by 2030. Encompassing key strategies such as ensuring sustained anti-venom availability, enhancing capacity building, establishing robust referral mechanisms, and fostering public awareness (*National Action Plan for Prevention and Control of Snakebite Envenoming in India –An Initiative to halve the Snakebite deaths by 2030 through “One Health” Approach, 2024*) NAPSE was officially unveiled on March 12, 2024 (*National Action Plan for Prevention and Control of Snakebite Envenoming in India –An Initiative to halve the Snakebite deaths by 2030 through “One Health” Approach, 2024*). MCBT's extensive collaboration with the Ministry played a pivotal role in shaping the National Action Plan initiative. Through relentless advocacy efforts and policy contributions, including the drafting of the inaugural White Paper for the ICMR (Chakma et al., 2020), MCBT secured a prominent position as the sole non-clinical member on the Core Committee tasked with formulating the Action Plan. This milestone underscores our commitment to advancing preventative measures and underscores the significance of multi-sectoral partnerships in addressing this critical public health issue.

MCBT has also been working with multiple state governments, especially the Tamil Nadu government, in state-level interventions. Since 2019, series of meetings and policy advice have led to a greater sense of awareness on snakebites, resulting in actions such as the Tamil Nadu State Government declaring 'Snakebite Envenoming' as a notifiable disease. A notifiable disease is any illness that must be reported to government authorities by law. This reporting enables health departments to track cases, detect outbreaks early, and intervene to mitigate health crises. All hospitals and clinics must report such cases, and failing to do so can result in legal action (Saxena, 2019). States that have declared snakebite as notifiable as of the writing of this article are Karnataka, Tamil Nadu, Kerala, Meghalaya and Nagaland (NDTV, 2024).

Through its advocacy and partnerships, MCBT has helped bring snakebite envenoming to the forefront of India's public health agenda, integrating field expertise into the public health policy discussion. MCBT's work illustrates a “One Health” approach, with collaboration between conservationists, researchers, and policymakers. Continued joint action will be crucial to achieving the goal of ending snakebite deaths and disabilities by 2030.

3.4 Attempts to improve quality venom sourcing

Presently, the Irular Snake Catchers' Industrial Cooperative (ISCICS) is the only major licensed venom supplier in India for antivenom production, and produces an estimated 80-90% of the venom used for national antivenom production (Whitaker and Whitaker, 2012; Chakma et al., 2020; Srimathi, 2023) (Figure 5).

The Irular are a community of "forest scientists," with a vast traditional knowledge of local wildlife and ecology. They are best known for their snake and rat-catching skills, with about 330 community members from the Chengalpet area forming part of the ISCICS (*The irular snake catcher's co-operative - by chloe vasquez*). Irular Co-op members hold licenses from the Wildlife Department for snake catching in certain areas, and bring the specimens to the co-operative (hosted within the Madras Crocodile Bank Trust). Here, the snakes are kept for 21 days, and "milked" for their venom four times during the period of captivity (Whitaker and Whitaker, 2012). Among the license holders, around 10 work full time in the "pit," where they demonstrate 'Big 4' snake behavior and perform venom extraction for park visitors.

Before each extraction, the pit workers clip the underbelly scales to keep track of which snakes have been milked already. After extraction, the venom is kept on ice while subsequent snakes are milked. The venom is freeze-dried and sold to all major antivenom producing laboratories in India (Whitaker and Whitaker, 2012).

Unfortunately, the present venom extraction methods do not meet World Health Organization's Good Manufacturing Practice (WHO-GMP) standards. MCBT works closely with the ISCICS to implement venom quality enhancements. Over the years, MCBT has facilitated visits from the WHO and Ministry of Health & Family Welfare to ISCICS to discuss venom quality regulations. Our focus is on refining existing antivenom, a vital step to reduce snakebite deaths. In August, 2024, the MCBT's Snakebite Mitigation Project coordinated a trip with some of the Irular snake handlers to visit state-of-the-art serpentariums and labs across India, in hope of exposing Irular to modern venom extraction techniques.

Furthermore, MCBT is working to establish a state-of-the-art serpentarium in Tamil Nadu, facilitating venom extraction and research. While permission for the project has been initially granted by the Tamil Nadu state government, many steps remain to construct a functioning and GMP-compliant serpentarium.

The Irular Cooperative remains central to India's antivenom supply, linking traditional expertise with modern public health needs. Through its partnership with ISCICS, MCBT is working to modernize venom extraction and establish GMP-compliant facilities, ensuring that the Irular's knowledge continues to support safer, more effective antivenom production in the years ahead.

3.5 Research

The Madras Crocodile Bank Trust (MCBT) works to bridge the gap in research on snakebite envenoming and human-snake coexistence. Working with a range of partners, we study snakebite trends, prevention methods, regional venom differences, venom quality, and the safety of snake rescuers. MCBT's work generates critical insights that inform policy, strengthen antivenom production, and guide evidence-based interventions to reduce snakebite deaths across India.

Accidental deaths from snakebite envenoming (SBE) are common yet preventable. In 2019, MCBT conducted a study on the acceptability of common prevention materials and practices. This study was conducted in the Thiruvavur district of Southern India, given the region's high agricultural dependence, widespread poverty, and the presence of medically significant venomous snakes. Despite distributing 150 preventive kits with essentials like gumboots, mosquito nets, and torch lights, subsequent surveys showed low kit usage rates, prompting further investigation. Collaborating with an international team of researchers, the MCBT Snakebite Mitigation team explored societal barriers hindering kit utilization, uncovering factors like financial constraints, cultural beliefs, and social pressures (Malhotra et al., 2021). A subsequent study in the Tirunelveli district reinforced these findings, highlighting the need for tailored interventions informed by community-specific insights (Annual report 2021–2022). These studies underscore the importance of understanding local contexts to effectively combat snakebite fatalities and promote the adoption of preventive measures.



FIGURE 5
Stockboard of the irular snake catchers' cooperative society.

Understanding regional venom variation is crucial for effective antivenom production. MCBT collaborated with Dr. Kartik Sunagar at the Indian Institute of Science to map geographical venom differences and assess antivenom efficacy (Senji Laxme et al., 2021; Laxme et al., 2019; Laxme et al., 2021; Sunagar et al., 2021). (Laxme et al., 2019; Laxme et al., 2021) and (Sunagar et al., 2021) found that current antivenoms exhibit poor dose efficacy and fail to treat bites from across the country, where local venoms and venomous species are different from Tamil Nadu's 'big four'. In the Northeast alone, there are over 20 venomous snakes for which antivenom is not manufactured (Snakes and snakebite in the northeast [Film]. Director: grant davis and tiara aurora; producer: gnaneswar ch. India, 2022). This research informs India's efforts to upgrade antivenom quality, ensuring it meets WHO standards and India's needs.

Snakebite data is notoriously patchy, with hospitals systemically underreporting cases of envenoming. MCBT has spent the past decade integrating technology to streamline snakebite data collection and provide widespread access to this data. In 2019, MCBT's Snakebite Mitigation Project partnered with Open Data Kit (ODK) and the Tamil Nadu state Health Department to streamline data collection processes for several key variables of interest. This project created a snakebite registry for hospitals and data on hospitals which reliably stock antivenom, geotagged snakebite registries, and snake habitats. In parallel with standard healthcare reporting systems, MCBT has conducted community level surveys in multiple districts of Tamil Nadu using ODK mechanisms. These can be compared to the hospital datasets to estimate underreporting and fill in the gaps. The ODK surveys later encouraged MCBT to dwell deeper into more advanced reporting initiatives like the Big4Mapper and SERPENT app. These apps, developed by Indiansnakes.org and Leopard Tech Lab with inputs from MCBT, used citizen science to drive data collection and real-time snakebite tracking.

In 2022, MCBT partnered with Tamil Nadu Forest Department, indiansnakes.org and University of Reading to develop a variation on Kerala's SARPA App for Tamil Nadu. 'SARPA TN', a mobile app that helps to call a snake rescuer, identify snakes, locate the nearest hospital and learn more about snakes through watching its educational films (Annual report 2022–2023). Later in 2025, the Tamil Nadu Forest Department formally signed an Memorandum of Understanding (MoU) with MCBT to formally rename the app as 'NAAGAM' (The Hindu, 2024).

MCBT has two principal field stations: the Agumbe Rainforest Research Station (founded to study King Cobra behavior and ecology) and the Gharial Ecology Project in Chambal. In Agumbe, research includes radio-tracking and breeding program (Barve et al., 2013; Lang, 2018).

Recently, in 2025, the Snakebite Mitigation team initiated two major research projects on the impact and effectiveness of interventions in Tripura, a state in Northeast India. One investigates snake rescuer training workshops to enhance the technical skills and safety practices of snake rescuers. The other

addresses school-based outreach programs to cultivate greater snakebite awareness and preparedness among young communities through meticulously tailored educational sessions. Structured knowledge-based surveys were administered to participants both before and after each activity. The outcomes of these research projects will inform future snakebite education efforts while internally assessing the effectiveness of the programs.

Additionally, MCBT publishes "Hamadryad," an open-access journal dedicated to the herpetofauna of the Indian subcontinent, featuring articles on reptile and amphibian ecology, Human-Snake coexistence, taxonomy, and conservation efforts (Hamadryad). Together, these diverse research initiatives reflect MCBT's commitment to generating practical, evidence-based solutions that advance snakebite prevention, treatment, and coexistence efforts across India.

4 Discussion

Despite being largely preventable, snakebite envenoming represents one of India's most devastating yet neglected public health crises. While it is excellent that much research and funding is going toward improving antivenom and other treatments, the key problems remain that most rural people in India are unaware that antivenom is the only effective treatment for severe envenomation, that it is often only available at district level hospitals, that snakebite does not occur during 'doctor's hours', and getting to hospital in time, from a remote rural area, is often impossible. It is abundantly clear that the long list of challenges detailed above, facing the successful outcome of snakebite cases, demonstrates the strongest possible focus on prevention by education and outreach (Ten Have et al., 2023). If we are to reach the goal of reducing snakebite mortality in India by 50% by 2030 (Snakebite envenoming – A strategy for prevention and control; National Action Plan for Prevention and Control of Snakebite Envenoming in India –An Initiative to halve the Snakebite deaths by 2030 through "One Health" Approach, 2024), the government and funding agencies need to be educated on this integral point. Historical efforts have been concentrated almost exclusively on clinical treatment and antivenom development rather than community-based prevention strategies that could prevent bites from occurring (Chapman and Borri, 2019; Lv et al., 2023). Against this backdrop, MCBT's Snake Conservation and Snakebite Mitigation Project represents a comprehensive, holistic intervention.

Beginning in 2016, MCBT has worked with a wide array of stakeholders (see Table 2: Institutional Collaborators & Advisors) to address community awareness gaps, inadequate emergency response systems, poor data repositories, substandard antivenom quality, and the absence of evidence-based policy frameworks. This multifaceted approach successfully reached over 1,600,000 individuals across multiple states, establishing unprecedented integration of prevention expertise within national health policy frameworks. The organization's focus on educating communities

about snakes' ecological importance distinguishes its approach from traditional fear-based messaging to a model that promotes co-existence. However, many challenges complexify MCBT's work.

Translating educational materials into multiple Indian languages faces challenges such as dialectal variations and differing regional names for the same snake species. Many translations are only partly accurate due to slang, local dialects, and inconsistent terminology. Some medically important snakes have multiple local names, while others lack established regional names, causing confusion. Beyond language, cultural and occupational contexts deeply shape how messages are understood. The process of translation involves not just two languages but also two cultures (Ninganna, 2021). These variations create barriers to accurate translation.

Research findings reveal the challenge of translating education outcomes into sustained behavioral change. Prevention kit distribution studies in Tamil Nadu demonstrated lower than the anticipated rates of acceptability, despite free provision of essential protective equipment including torches, gumboots, and mosquito nets. MCBT's ongoing evaluations of outreach programs have exposed the challenging reality of knowledge retention following educational interventions. These findings show that complex socioeconomic barriers, including financial constraints, cultural beliefs, and social pressures, cannot be addressed through simple equipment provision alone. One-time interventions prove insufficient to fully eradicate deeply entrenched misconceptions surrounding snakebite envenoming (Carter et al., 2024). Similarly, for snake rescuer workshops, follow-up trainings prove resource-intensive, particularly given the dispersed nature of rescue operations conducted by individual practitioners across vast geographic areas.

MCBT's experience demonstrates that effective prevention requires sustained, multi-touchpoint engagement rather than sporadic educational events, to achieve maximum retention of snakebite mitigation knowledge. The authors advocate for integrated, long-term community partnerships to achieving meaningful behavioral transformation in snakebite prevention (Pandey et al., 2025).

TABLE 2 Institutional collaborators & advisors (2016 – 2025).

National centre for disease control	Indian council for medical research	Government of Tamil Nadu
Evolutionary Venomics Lab	Indian Snakebite Initiative	The Liana Trust
Humane World for Animals	Snakebite Healing & Education Society	Nature Works
Little Flower Hospital	Christian Medical College, Vellore	Centre for Wilderness Medicine, Manipal
University of Reading	Avoidable Deaths Network	Viper Specialist Group - IUCN
Snake Specialist Group - IUCN	University of Melbourne	Leopard Tech Labs

MCBT continues to systematically integrate and document rescue activities by workshop participants, but data collection remains largely voluntary, creating significant gaps in operational monitoring and impact assessment. The absence of mandatory reporting protocols mirrors broader challenges in community-based intervention evaluation, where individual behavioral changes are difficult to track and quantify over extended periods.

Community based education and subsequent behavior change are difficult to quantify, as is common in community education and complex interventions. In public health literature, MCBT's multi-faceted approach is a "complex intervention" due to its multiple interacting parts (materials, trainings, community meetings, media, networks), making it difficult to isolate the impact of outreach and advocacy efforts on beneficiary behavior and subsequent reductions in human-snake conflict or snakebite-related deaths (Moore et al., 2015; Skivington et al., 2021). Even if randomized control trials were achievable (which, with inter-community communication and spillover effects, they are not), measurements of community effects are not generalizable. Local aspects such as snake density and biodiversity, human population density, cultural factors, and climate patterns could all affect the local epidemiology and impact of an outreach program.

Funding flows (see Table 3: Funding institutions) are often structured for one-time, quantifiable projects which are easier to standardize and report. While the evidence suggests that knowledge gained from educational programs should be renewed and reinforced, funding priorities encourage grassroots implementation groups to reach larger populations and conduct more one-time trainings. Presently, MCBT has been unable to track the average number of snakes the network rescues/relocates per year. Similarly, it is difficult to estimate changes in beneficiary behavior such as retaliatory snake killings at the local level. These data would be useful to inform future interventions and garner support for outreach, and MCBT hopes to continue expanding meaningful evaluation of program impact over the coming years.

Costs per educational workshop vary significantly, depending on multiple factors including resources offered by collaborating partners, geographic accessibility, and participant recruitment capacity. Unpredictable operational expenses complicate large-scale program planning and execution, as budget projections cannot rely on standardized cost models. The resulting uncertainties complicate grant-seeking, fundraising and budgeting, ultimately impacting MCBT's ability to scale up.

TABLE 3 Funding institutions (2016 – 2025).

USV private limited	Oracle foundation	Infosys foundation
Deshpande Foundation	HCLFoundation	Global Snakebite Initiative
Google Giving	United Way Chennai	Mr Venu Srinivasan
Save the Snakes Society	King Cobra Conservancy	Ophirex Inc
Srinivasan Services Trust	Hamish Ogston Foundation	Fidelity



FIGURE 6
Meeting with stakeholders.

A more sustainable and efficient national approach would place greater emphasis on snakebite training in medical and primary school curricula. Officially integrated educational programs would have greatly magnified impact while simultaneously providing robust frameworks for effectiveness assessment through longitudinal educational cohort studies. While MCBT advocates for these more ambitious goals, the Snakebite Mitigation project continues to support and conduct workshops to bridge the knowledge gap.

The Wildlife Protection Act, 1972, categorizes snake handling as unlawful outside official channels. Unlike protocols established for larger wildlife management (National Tiger Conservation Authority, [[NoYear]]), however, most Forest Departments have not mandated standardized rescue procedures for snakes. The majority of actual snake rescues are performed by non-departmental personnel, leaving these activities in a regulatory grey zone. This legal ambiguity creates several cascading challenges: participants operate without clear legal frameworks, training programs lack consistent institutional support, and quality assurance mechanisms remain underdeveloped. Thus, current wildlife protection regulation creates barriers to recruiting and training the very individuals who provide essential community services. Efforts such as Snake Awareness Rescue Protection App (SARPA), a digital platform used in Kerala, India, to prevent snakebites. SARPA connects users with local snake rescuers who are on hand to safely bag and translocate snakes that enter homes

(Kirkham, 2023). As many as 26,420 snakes had been reported from human-habitated areas until July 2023, according to the data recorded by SARPA (The Hindu, 2023).

Significant problems remain with the Irular Snake Catcher Cooperative's present setup and procedure. For one, the pit is exposed to open air, exposing the venom extraction center to dust and other potential contaminants. In addition, the WHO recommends that liquid venom be "snap frozen" to at least -20°C , and lyophilized (freeze-dried) using state-of-the-art equipment (World Health Organization, 2013). If temperature requirements are not met within minutes of extraction, then enzymes and proteins within the venom can begin to degrade, with impacts for antivenom quality.

There are also concerns about the sustainability of the current model. Snakes are collected in specific areas around the Chengalpattu district, where this Irular community is based. After 21 days, the snakes are released in specific areas (which are far away from the collecting sites), which the Tamil Nadu Forest department designates (Whitaker and Whitaker, 2012). However, research has shown that displaced snakes have low survival rates (Reinert and Rupert, 1999; Barve et al., 2013). ISCICS members already mention that the snake populations, especially the saw-scaled vipers, are dwindling in the permitted zone (*personal communication*).

WHO-GMPs recommend extracting venom at a maximum of one time per 2–3 weeks to 3 months (World Health Organization, 2013). ISCICS procedures surpass this limit (Whitaker and Whitaker, 2012), extracting venom at a rate which does not allow for the full regeneration of all venom toxins. Besides clinical problems with the current methods, there are ethical issues with such frequent venom extraction and the high mortality rate associated with the current catch-and-release model.

As a result of these quality and quantity issues, the cooperative is facing pressure to pivot from the current "catch-and-release" model to a serpentarium model (Whitaker and Whitaker, 2012; Subramanian, 2022). However, this change would come with serious ramifications. For one, it requires a large sum of upfront investment for the construction of a new WHO-GMP standard facility. Such a facility would require:

1. Ventilation, humidity and construction standards.
2. Special cages that meet animal husbandry necessities and protect snake handlers (who's job places them at a high risk for bites and exposes them to aerosolized venom particles).
3. Specialized personnel training.
4. Detailed "standard operating procedures" (SOPs) and records of each snake and extraction, ensuring traceability of each venom batch.

On top of the costs for opening such a facility, there would be an immense impact on the livelihoods of the Irular community. Under a serpentarium model, there would be no need for constant influx of new snakes. So, it is likely that many of the 334 license holders would no longer play a role in snake catching. In any case, antivenom producers have decried the low quality of Irular Co-

Op venom, and, unless the current situation improves, ISCICS members are likely to lose income as other venom producers enter the market.

Moving forward, achieving the National Action Plan's goal of reducing snakebite deaths by 50% by 2030 requires unprecedented commitment to prevention-focused interventions (Figure 6). Forest Departments must establish dedicated protocols for rescue and release operations. The snakebite mitigation community should invest in interactive educational approaches including films, games, and multimedia platforms that transcend traditional awareness methodologies. MCBT's holistic model provides compelling evidence that comprehensive, community-centered approaches can achieve transformative impact in addressing complex public health challenges affecting vulnerable populations.

4.1 Limitations

Until this point, published academic literature on MCBT's work is limited, necessitating references to non-traditional sources such as YouTube and the MCBT webpage. Similarly, the dearth in literature motivated the narrative nature of this review, which was not structured based on a systematic PRISMA approach. This review reflects the experience of the authors in implementing MCBT's snakebite mitigation activities from 2016 onwards.

5 Conclusion

MCBT's comprehensive snakebite mitigation strategy includes diverse educational materials, training workshops, policy engagement, research initiatives, and venom quality improvement programs. However, MCBT's experiences highlight the challenges of national community-based work. The organization's difficulties with knowledge retention, behavioral change, and funding demonstrate that future investments must prioritize sustainable, integrated grassroots prevention and awareness strategies.

Author contributions

GC: Project administration, Methodology, Data curation, Conceptualization, Writing – original draft, Visualization, Writing – review & editing, Resources, Funding acquisition. CV: Formal Analysis, Conceptualization, Visualization, Methodology, Resources, Writing – review & editing. RW: Supervision, Conceptualization, Visualization, Writing – original draft, Resources, Funding acquisition.

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Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Acknowledgments

The authors gratefully acknowledge the invaluable support of implementational partners, advisors, contributors, and funding organizations, whose commitment made this pan-Indian effort possible. Their guidance and assistance were essential to the successful completion of this research and are deeply appreciated.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

A systematic literature review was conducted utilizing major electronic databases, including PubMed, Web of Science, ResearchGate, and Google Scholar, as well as relevant organizational websites and grey literature. For survey implementation and data collection, Google Forms and KOBO survey platforms were used, while statistical analyses were performed using 'R'. Reference management and manuscript formatting were supported by Mendeley and Jenni AI, with language correction facilitated through Grammarly. The author(s) declared that generative AI was used in the creation of this manuscript.

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