Venomous Snakes of Medical Relevance in Nepal: Study on Species, Epidemiology of Snake Bite and Assessment of Risk Factors of Envenoming and Death

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Datum der Disputation:

A famous Nepali proverb

“*Bish Nabhayako Sarpa Ra Ekh Nabhayako Manis Hudaina*”

i.e., there are no snakes without venom and no humans without jealousy.

This notion defames snakes in Nepalese communities.

I would like to dedicate my dissertation

to

agonising families of deceased or maimed breadwinners due to snake bite envenomings in Nepal,

to

my parents for their tireless supports, love and motivations in my life and

to

my family Gita Subedi, Digam and Drishtanta Pandey.

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ABSTRACT

Snake bite envenoming often results in disability or death of breadwinners of poor families in the rural tropics and the subtropics of Nepal. Identification of the medically relevant snake species, circumstances of venomous snake bites, prehospital care of their bites and human responses to snakes and snake bite is, therefore, crucial to enable victims or paramedics to select the appropriate first aid measures, physicians to anticipate complications and to use appropriate treatment protocols as well as the local community to implement prevention strategies. Inadequate educational tools and educational gaps exist in Nepal and hinder identification of snakes involved in bites. To fill this gap, the aim of this dissertation is to provide an evidence-based list of medically relevant snake species. Snake specimens brought by patients bitten or their attendants to hospitals and treatment centres in the tropical and subtropical regions of the lowlands and hills in southeastern, southcentral, and southwestern Nepal over a period from January 1, 2010 through December 31, 2014, were taxonomically identified and medical records of envenoming were evaluated.

In Nepal, the epidemiology of snake bite is poorly known. Here I describe the ecological circumstances of proven krait (*Bungarus* spp.) and Russell´s Viper (*Daboia russelii*) bites to elucidate and examine, whether environmental circumstances or human behaviour contributed to envenoming. In a cross-sectional study, data about prehospital care, environmental circumstances of 46 krait and 10 Russell´s Viper bites were evaluated. Patients were interviewed using structured interview forms. Snake bite prone communities were surveyed to test people´s knowledge on snakes and their attitude towards venomous snakes in general, e.g., which non-venomous snake species they believe to be harmful, which prehospital care in case of snake bite they eventually apply, and how much they are aware of snake bite prevention.

Of 349 snakes involved in bites, 199 (57%) specimens were found to be medically relevant venomous snakes that included 11 species belonging to six genera and two families: Elapidae: *Naja naja, N. kaouthia, Ophiophagus hannah, Bungarus caeruleus, B. fasciatus, B. lividus, B. niger, B. walli;* Viperidae: *Daboia russelii, Ovophis monticola, Trimeresurus albolabris.* Among them, *Naja naja* (n = 76, 22%), *Bungarus caeruleus* (n = 65, 19%) and *Trimeresusurs albolabris* (n = 10, 3%) were the most widely distributed snakes. *Daboia russelii* (n = 10, 3%) was found to be restricted to the southwestern part of Nepal. For *B. walli*, a previously poorly known species, 13 voucher specimens represent the first country records of this species as well as the first documented cases of involvement in snake bite envenoming by this species in Nepal.

A frequently presented non-venomous snake was the colubrid *Lycodon*

aulicus (n = 40, 12%), which was often mistaken as a krait species. Submission of large numbers of killed non-venomous snakes to treatment centres corresponds to general ignorance or inability of locals regarding snake identification.

Numerous snake bites (33%) occurred at night, during the rainy season, and are mainly due to *Bungarus* species, particularly *B. caeruleus.* Bites of cobras and Russell's Vipers are a risk at daytime. Evaluation of data regarding the place where the bite happened, indicates that the snake bite risks appear to be as high in residential areas, in and around houses, as in rural areas. In cases of kraits (n = 46), 61% of the bites occurred while the victim was sleeping indoors, those of Russell´s Vipers mainly during agricultural activities in the fields. Analysis of socio-demographic data revealed that both krait and viper bites predominantly affected farmers or their family members. However, snake bites involved also people of higher socio-economic status, which suggests that it is not a health problem of poor people only living in the rural areas of Nepal.

A small number of snake bite victims (n = 7) sought help from traditional healers, but most patients went to hospitals for medical treatment using motorbikes (65%) or were transferred by ambulance cars (22%). As a first aid measure, most patients (78%) had used a tourniquet, which is of doubtful value and has often severe sequelae, instead of applying the WHO recommended pressure immobilisation bandage or local compression pad. The incidence of snake bite envenoming and death was estimated to be 1 and 0.1 per 100.000 populations, respectively. The overall case fatality rate (the chance to die due to envenoming) was calculated to be 10%, but up to 17% in cases of *Bungarus* spp. bites.

Rural community people were found to be extremely afraid of snakes, a major reason for indiscriminate killing of even non-venomous, harmless snakes, e.g., *Lycodon aulicus*, *Oligodon arnensis*, *Coelognathus* spp. and *Ptyas mucosa*, which were wrongly considered to be venomous. This is mainly due to the poor knowledge on snakes in general and on their role in providing valuable ecological services (e.g., control of rodents, etc.), which may eventually lead to a decline in snake populations and even the extinction of rare species.

The results of the present study strongly emphasize that snake bite is an important public health issue in Nepal. Since antivenoms for treating envenoming (Indian source) are scarce and exhibit unproven cross-reactivity with venoms from Nepalese snake species, there is an urgent need to improve the knowledge of people on snakes and to try changing their attitudes towards these reptiles, in addition to documenting the biodiversity and distribution of medically relevant snakes, the epidemiology and circumstances of their bites. Avoiding high-risk behaviour (e.g., killing or handling of snakes), modifying or constructing houses using screened doors and windows are some of the suggested measures preventing snake bite. Early and accurate identification of the snakes involved should help physicians to apply timely treatment, eventually referring the patient to the appropriate hospital. This also has important implications in developing public health and conservation strategies, to the benefit of the people of Nepal.

ZUSAMMENFASSUNG

Eine Vergiftung nach Schlangenbiss führt oft zu bleibenden körperlichen Schäden, wenn nicht sogar zum Tod des Ernährers einer armen Familie vor allem in den tropischen und subtropischen Gebieten Nepals. Die Identifizierung der medizinisch relevanten Schlangen, die Umstände, die zu einem Giftbiss führen, Erste-Hilfe-Maßnahmen und die Einstellung des Menschen zu Schlangen und Schlangenbissen sind entscheidend dafür, nicht nur für den Betroffenen, sondern auch für den Ersthelfer, die entsprechenden Maßnahmen zu treffen, für Ärzte, mögliche Komplikationen einzuschätzen, um die angemessene Behandlung durchzuführen, wie auch für die lokalen Gemeinden, entsprechende Präventionsmaßnahmen zu treffen. Ungeeignete Lehrmittel und generelle Unkenntnis verhindern in Nepal weitgehend eine Artbestimmung der jeweiligen Schlange, die in einem Bissunfall involviert ist.

Nepal grenzt im Norden an die Volksrepublik China, im Süden, Osten und Westen an Indien. Das Land ist geographisch in drei Hauptregionen gegliedert: die Gangestiefebene (das Terai), das hügelige Mittelland und das Hochgebirge mit der Himalaya-Bergkette. Diese Regionen weisen ausgeprägte klimatische Unterschiede auf, die eine Vielfalt an Lebensräumen hervorgebracht haben: das tropische, feucht-heiße Tiefland, das subtropische untere Mittelland, die gemäßigte Region des oberen Mittellandes sowie das kalte, trockene Hochland. Dies hat eine erstaunliche Biodiversität sowohl der Fauna als auch der Flora zur Folge. Allein die im Folgenden vor allem interessierende Herpetofauna ist in Nepal mit 147 Reptilien- und 59 Amphibienarten gut vertreten. Vor allem betrifft dies auch die Schlangenfauna mit mindestens 82 Arten, wobei Daten zu dieser Reptiliengruppe wie die Verbreitung einzelner Arten überwiegend auf älteren Untersuchungen beruhen. Neuere Studien sind selten und betreffen meist nur ausgewählte Regionen. Auch ist die Epidemiologie von Schlangenbiss-Verletzungen, ihre Morbidität und Mortalität, wie auch die Umstände und ökologischen Gegebenheiten, die zu folgenreichen Bissen führen, speziell für Nepal kaum erforscht. Im Einzelfall ist oft unklar, ob beispielsweise bestimmte Umweltbedingungen oder das Verhalten des Opfers den Bissunfall mitverursacht haben.

Ziel der vorliegenden Dissertation ist es, eine evidenzbasierte Liste der medizinisch relevanten Schlangen zu erarbeiten, was die Erstellung von geeignetem Informationsmaterial ermöglicht, das letztlich auch als Grundlage für die Behandlung von Vergiftungen nach Schlangenbiss und für den Einsatz und die Verteilung von Antiseren dienen soll. Hierzu wurden Schlangen, die von Patienten oder ihren Begleitern zu den Behandlungszentren gebracht wurden, taxonomisch bestimmt und als Belegmaterial konserviert sowie Zeit und Ort des Bissereignisses und damit

auch ihres Vorkommens registriert und, wenn vorhanden, die medizinischen Daten des Patienten evaluiert. Die Untersuchung schließt die tropischen und subtropischen Regionen des Tieflandes und der Gebirge im südöstlichen, südlich-zentralen und südwestlichen Teil Nepals ein, in denen die betreffenden Daten über den Zeitraum vom 1. Januar 2010 bis zum 31. Dezember 2014 erhoben wurden.

Kraits (*Bungarus* spp.) aus der Familie der Giftnattern (Elapidae) und Russell´s Vipern (Familie: Viperidae) zählen zu den gefährlichsten Giftschlangen. Sie standen im Mittelpunkt der Untersuchung. In einer Querschnitts-Studie wurden die Daten zu den örtlichen Wohnverhältnissen, den Vergiftungsumständen, den Erste-Hilfe-Maßnahmen und der Behandlung von 46 Krait- und 10 Russell's Viper-Bissen ausgewertet. Hierzu wurden die Patienten anhand eines speziell entworfenen Fragebogens interviewed. Darüber hinaus wurde in Gemeinden, die besonders von Schlangenbiss-Unfällen betroffen waren, Bewohner zu ihren Kenntnissen über Giftschlangen allgemein und ihrer Einstellung diesen Tieren gegenüber befragt, beispielsweise welche ungiftigen Schlangen sie für harmlos halten, welche Maßnahmen zur Ersten-Hilfe sie im Falle eines Schlangenbisses anwenden und in welchem Umfang sie über Präventions-Maßnahmen informiert sind.

Von 349 Schlangen, die in Bissunfällen involviert waren, wurden lediglich 199 (57%) als medizinisch relevante Giftschlangen identifiziert, die 11 Arten, 6 Gattungen und 2 Familien zugeordnet wurden: Elapidae: *Naja naja, N. kaouthia, Ophiophagus hannah, Bungarus caeruleus, B. fasciatus, B. lividus, B. niger, B. walli;* Viperidae: *Daboia russelii, Ovophis monticola, Trimeresurus albolabris.* Unter ihnen sind die Kobra *Naja naja* (n=76, 22%), der Krait *Bungarus caeruleus* (n=65, 19%) und die Weißlippen-Bambusotter, *Trimeresurus albolabris* (n=10, 3%) die am häufigsten involvierten Giftschlangen. Hingegen ist die Russell´s Viper, *Daboia russelii,* (n=10, 2%) vergleichsweise selten und scheint in ihrer Verbreitung offenbar auf den südwestlichen Teil Nepals beschränkt zu sein. Bissverletzungen durch diese Vipernart wurden erstmals für Nepal nachgewiesen, sie verlaufen im Allgemeinen schwer, doch wurden keine Todesfälle registriert. *Bungarus walli* ist eine bisher in Nepal kaum bekannte Art und wird leicht mit *B. caeruleus* verwechselt. Ihr Vorkommen in Nepal war lange umstritten. Doch liegen nunmehr 13 Belegexemplare vor, die erstmalig die geographische Verbreitung dieser Art und ihre Beteiligung an Vergiftungen belegen. Dieser Krait wurde im äußersten Südosten Nepals nachgewiesen, möglicherweise kommt er aber auch in der gesamten Gangestiefebene vor. Von 6 Vergiftungsfällen verliefen 2 tödlich. Für *B. niger* wurde erstmals im Rahmen dieser Untersuchung ein Fall mit tödlichem Ausgang für Nepal dokumentiert.

Die Colubride *Lycodon aulicus* (n=40) war nach *Ptyas mucosa* (n=10) die am häufigsten in den Behandlungszentren präsentierte ungiftige Schlange; sie wurde meist für einen Krait gehalten. Die hohe Zahl der eingelieferten, getöteten ungiftigen Schlangen belegt die Unkenntnis und Unfähigkeit der lokalen Bevölkerung, die Art der betreffenden Schlange zu bestimmen oder ihre Harmlosigkeit zu erkennen. Allerdings muss bei einigen aglyphen (*Rhabdophis* spp., sie besitzen keine speziellen Giftzähne) und opisthoglyphen (*Boiga* spp. sie tragen gefurchte Zähne im hinteren Teil des Rachens) Schlangen, die ebenfalls in Nepal verbreitet sind und die ein wirksames Gift in ihren Drüsen produzieren, zur Vorsicht gemahnt werden, da es in anderen asiatischen Ländern zu schweren, z.T. auch tödlichen Bissverletzungen durch diese Arten gekommen ist.

Zahlreiche Schlangenbisse (33%) erfolgten in der Nacht, besonders während der Regenzeit, und waren fast ausschließlich durch *Bungarus*-Arten verursacht, vor allem durch *B. caeruleus,* die Schlange mit dem höchsten Mortalitätsrisiko nach einem Biss. Hingegen verursachten Kobras, beispielsweise *Naja naja*, oder auch Russell´s Vipern, Bissverletzungen tagsüber. Bei der Auswertung der Daten, wo die Bisse stattgefunden hatten, zeigte es sich, dass selbst in Wohngebieten und zwar unabhängig von der Bauweise und Qualität des Hauses, ein hohes Risiko für einen Schlangenbiss besteht. In 46 Bissfällen, verursacht von Kraits, waren in 61% zur Nachtzeit Schlafende in ihren Betten betroffen. Diese nachtaktiven Schlangen werden vor allem durch Ratten und Mäuse, ihre bevorzugten Beutetiere, in die bewohnten Gebiete und in die Häuser gelockt. Hingegen ereignen sich Bissfälle mit Russell´s Vipern vorwiegend bei der Arbeit auf den Feldern. Die sozio-demographische Analyse bestätigte, dass zwar überwiegend Bauern und ihre Familienangehörigen, jedoch auch Mitglieder mit höherem sozio-ökonomischen Status betroffen sind. Dies legt den Schluss nahe, dass Schlangenbiss-Vergiftungen eine Krankheit (sie fällt unter die von der WHO definierten „neglected diseases“) nicht nur der armen Bevölkerung in den ländlichen Gebieten Nepals ist, sondern auch Bewohner größerer Gemeinden betrifft.

Eine kleine Zahl (n=7) von Opfern eines Krait-Bisses suchte Hilfe bei lokalen traditionellen Heilern, ein riskantes Unterfangen, welches eine Behandlung mit Antiserum in einem Hospital verzögert, wenn nicht gar verhindert und tödliche Folgen haben kann. Auf Grund der schlechten Infrastruktur in den ländlichen Gebieten wurde der überwiegende Anteil der Patienten mittel Motorrad (65%) zum nächsten Hospital gebracht, seltener mittels Ambulanz-Wagen. Als Erste-Hilfe-Methode hatten die meisten Patienten eine Staubinde verwendet, d.h. eine völlige Unterbrechung des Blutflusses im betroffenen Arm oder Bein, eine Methode mit zweifelhaftem Wert, oft auch mit negativen Folgen wie Gangrän, was nicht selten eine Amputation nötig macht. In wenigen Fällen nur wurde die von der WHO empfohlene „pressure immobilisation“ Bandage oder ein lokaler Druckverband angewandt.

Die Häufigkeit einer Schlangenbiss-Vergiftung wurde mit 1 pro 100.000 der Bevölkerung, eine tödliche Vergiftung mit 0,1/100.000 bestimmt. Daraus wurde die Mortalitätsrate (die Chance, an der Vergiftung zu sterben) mit 10% errechnet, sie kann im Fall eines *Bungarus*-Bisses aber auch bis zu 17% betragen. Nicht bekannt ist allerdings die Morbiditätsrate, d.h. die Folgen eines überlebten Schlangenbisses, die keinesfalls zu unterschätzen sind und die erst in den letzten Jahren, was ihr Ausmaß betrifft, wie massive Gewebsverluste oder Amputationen von Gliedmaßen, in den Fokus gerückt sind. Dies betrifft vor allem Bissverletzungen durch Vipern und den Folgen ihrer hämorrhagischen Gifteigenschaften.

Die ländliche Bevölkerung zeigte eine große Angst gegenüber Schlangen, ein wesentlicher Grund für das wahllose Töten selbst ungiftiger, harmloser Schlangen wie *Lycodon aulicus*, *Oligodon arnensis*, *Coelognathus* spp. und *Ptyas mucosa*, die man irrtümlich für giftig hielt. Dies geschieht, obwohl die Schlange (z.B. die Kobra) im Hinduismus, der vorherrschenden Religion in Nepal, als heilig gilt. Doch im Wesentlichen ist das generelle Töten der Schlangen in der geringen Kenntnis generell dieser Reptilien und deren Rolle begründet, die diese mit ihren ökologischen Dienstleistungen erbringen, beispielsweise als Vertilger von Ratten und Mäusen, wodurch auch die Ausbreitung von Zoonosen, von den Nagern übertragenen Infektionserkrankungen, verhindert wird. Letztlich führt diese Einstellung zum Rückgang der Schlangenpopulationen, mitunter sogar zur lokalen Ausrottung von Arten.

Die Ergebnisse der vorliegenden Studie bestätigen, dass Schlangenbiss ein wichtiges Gesundheitsproblem in Nepal darstellt. Antiseren, überwiegend aus indischer Produktion zur Behandlung von Vergiftungen, sind selten und in manchen Regionen nicht oder in nicht ausreichender Menge verfügbar. Zur Herstellung dieser Antiseren werden demgemäß Gifte von Schlangen verwendet, die indischer Herkunft sind. Die Kreuzreaktion der Antiseren, d.h. ihre Wirksamkeit gegenüber den Giften nepalesischer Schlangen, ist bisher ungeprüft. So ist es allein schon unter diesen schwierigen Bedingungen von essentieller Bedeutung, Schlangenbisse zu vermeiden. Dies kann erreicht werden, indem man die Kenntnisse der Bevölkerung über Schlangen generell verbessert und versucht, die Vorbehalte diesen Reptilien gegenüber abzubauen. Das Vermeiden von riskantem Verhalten (z.B. beim Töten von Schlangen und Hantieren mit ihnen), bauliche Veränderungen an Häusern wie das Anbringen von Fliegengittern an Türen und Fenstern, sind nur einige der empfohlenen Maßnahmen, Schlangenbissen vorzubeugen. Die frühe und korrekte Artbestimmung der Schlange kann Ärzten helfen, die richtigen Maßnahmen zur Behandlung der Vergiftung einzuleiten oder den Patienten gegebenenfalls an ein geeignetes Hospital zu überweisen. Eine umfassende Dokumentation von Schlangenbissen vermittelt einerseits Kenntnisse zur Symptomatik und Epidemiologie derartiger Vergiftungen, gibt aber auch wichtige Hinweise zur Biodiversität und geographischen Verbreitung medizinisch relevanter Schlangen.

Die Studie zeigt aber auch, wo noch Defizite bestehen. Es betrifft zum einen die geographische Verbreitung der medizinisch relevanten Schlangen vor allem in den bisher noch nicht untersuchten, z. T. schwer zugänglichen Gebieten, aber auch ihre Biologie, ihre Gifte und deren Eigenschaften. Dies alles hat wichtige Konsequenzen für die Entwicklung von Strategien zur Volksgesundheit, wie auch zum Naturschutz, letztlich zum Nutzen der Bevölkerung von Nepal.

LIST OF ABBREVIATIONS AND ACRONYMS

AKA	attitude, knowledge and awareness
asl	above sea level
BPKIHS	Bishweshwar Prasad Koirala Institute of Health Sciences
BZ	buffer zones
CNP	Chitwan National Park
EDCD	Epidemiology and Disease Control Division, Nepal Government
STC	snake bite treatment centre
SVL	snout vent length
TL	total lenght
T. U.	Tribhuvan University
VDC	Village Development Committee

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1. INTRODUCTION

1.1. Background of the study

Snakes, elongated limbless reptiles, are distributed on all continents except Antarctica (Vitt and Caldwell, 2014). However, snake bites mostly occur in the tropics and the subtropics especially in South and Southeast Asia, Africa and Latin America (Warrell, 1995, Kasturiratne et al., 2008). In these regions, snakes and humans frequently encounter. These confrontations often result in human envenoming and death (Warrell, 1995, Sharma et al., 2004a, Mohapatra et al., 2011, Westly, 2013). Some snakes, particularly *Bungarus caeruleus* (Common Krait), enter human habitations and bite people during sleep (Bawaskar and Bawaskar, 2004, Ariaratnam et al., 2008). Snake bite is one of the most neglected public health issues in these regions.

Snake bites particularly in residential areas are unpredictable, but preventable medical emergencies predominantly in low-income human communities (Harrison et al., 2009, Gutiérrez et al., 2013) in the rural tropical and subtropical regions. Recent studies suggest that South Asia has the highest mortality rate due to snake bites worldwide (Sharma et al., 2004a, Kasturiratne et al., 2008, Alirol et al., 2010, Rahman et al., 2010, Mohapatra et al., 2011, Westly, 2013). In India, snake bite is the sixth largest factor causing human deaths (six deaths per 100,000 population) (Westly, 2013). In southeastern Nepal, annual snake bite deaths per 100,000 population was reported to be 162, which is the highest mortality rate in Asia (Sharma et al., 2004a). But, the data have been obtained using statistics from a study in a small area with a high snake population and may not be representative for the rest of the country. The envenoming effects are curable if patients receive effective antivenom therapy timely. However, snake bite envenoming may cause morbidity or long-term disability of a family's bread-winner leading to serious socio-economic consequences.

Elapid snakes, particularly kraits, are responsible for most snake bite deaths in Nepal (Epidemiology and Disease Control Division, 2011). However, the species involved are not well defined. Most of the available information on snake bites and species involved in Nepal is based on hospital records which are poor, incomplete (Magar et al., 2013) and do not provide comprehensive information on the real snake bite situation, risk factors of envenoming and death. Ignorance of snake species involved in snake bites among rural people and clinicians as well (Silva et al., 2013a) is one of the obstacles of snake bite management in Nepal and worldwide. Because of the poor knowledge of medically relevant snakes and their distribution, the Nepal Government has not recognized the need to provide larger amounts of effective snake antivenoms yet. Therefore, there are frequent shortages of Indian polyspecific antivenom or the antivenom often is not available at all.

Local people usually kill any snake they encounter to prevent snake bite. As snakes are efficient predators of rats and mice, the decrease of snake populations leads to an increase of rodent pest that causes loss of agricultural products and increases the risk of rodent-borne diseases, such as plague, hantavirus infection, etc. (Meerburg et al., 2009). Therefore, killing of snakes has serious public health, socio-economic and conservation consequences.

Inappropriate perception and knowledge on snakes, anthropogenic habitat fragmentation or destruction (Gibbons et al., 2000) and intentional killing of snakes (Whitaker and Shine, 2000, Godley and Moler, 2013) contribute to snake bite burden as well as considerable snake population decline in some areas. In most countries, the conservation status of snakes is not defined (Boehm et al., 2013). In Nepal, snakes and measures of preventing their bites and of prehospital care are introduced to people in school and universities inadequately (Pandey and Khanal, 2013). Therefore, understanding human responses to native snakes and the life history of snakes is vital for comprehending the extent of the anthropogenic impact on declining snake populations and their conservation status. Assessment of the perception and knowledge about snakes and snake bite among locals (Akani et al., 2013), especially those living in buffer zones of protected areas, is a key component in prevention and management of snake bite.

It is, therefore, necessary to document the diversity of medically relevant snakes in snake bite prone regions, the epidemiology of bites of taxonomically identified, potentially venomous snake species and the attitudes on snakes, snake bite and treatment of community people in Nepal. This information is imperative for the development of tools for identifying snakes, preventive strategies and policies for producing better antivenoms and antivenom distribution.

1.2. Geography, physiography, climate and biogeography of Nepal

Nepal, situated in Asia bordering India and China, is located between the latitudes 26°12’ N and 30°27’ N and the longitudes 80°4’ E and 88°12’ E (Figure 1) at the crossroads of the Palaearctic, Oriental, Sino-Japanese and Saharo-Arabian zoogeographic regions (Holt et al., 2013) with an amazing variation in physiography, climate and habitat types that range from tropical forests to high alpine landscapes. Nepal supports a highly diverse snake fauna within a small area extending east to west by 885–900 km and north to the Himalaya and to its foothills in the south by 130–260 km, respectively, occupying 147,181 km^2 (Bajracharya, 1996, Practical Action Nepal, 2009). This area represents about 0.1% of the global landmass.

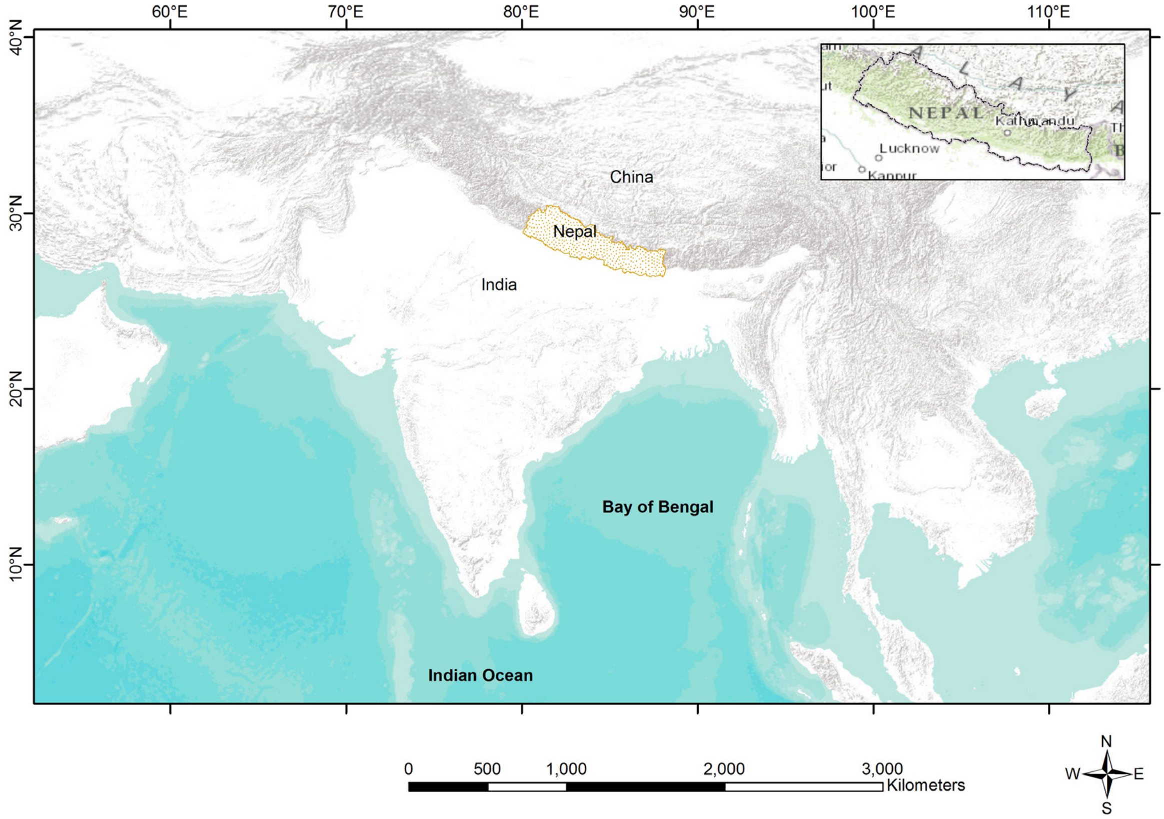


Figure 1. The location of Nepal in between China and India in South Asia.

Politically, Nepal is divided into five Development Regions (DRs) (Figure 2): Eastern, Central, Western, Mid-western and Far-western DR. Each of the DRs is further divided into Zones, Districts, Municipalities and Village Development Committees (VDCs). There are 14 Zones, 75 Districts, one metropolitan area (Kathmandu), 11 sub-metropolitan cities, 191 municipalities and 3,278 VDCs (Karobar National Economic Daily, 2014). Each VDC is further divided into – on the average – nine wards (depending on the district population). Nepal is traversed by three river systems: the Koshi in eastern, the Narayani in central and the Karnali in western Nepal. During the monsoon season large flooding occurs that may increase snake-human confrontation probability resulting in an increase of snake bites.

Nepal's topography spans from 60–8,848 m above sea level (asl) (the Mt. Everest) and is divided into lowlands, middle hills and mountains. The lowlands are further divided into: the Terai (i.e., the northernmost Ganges plains extending south to north by 30–40 km at 60–200 m asl occupying 4% of the total area of the country) and the Siwalik region (i.e., Chure hill ranges at 200–1,500 m asl occupying roughly 13% of the country area). The middle hills (i.e., Mahabharata ranges) extend east to west continuously from 1,500–4,000 m asl occupying 68% and mountains (i.e., highlands above 4,000–8,848 m asl) 15% of the total area of the country (Practical Action Nepal, 2009) (Figure 2).

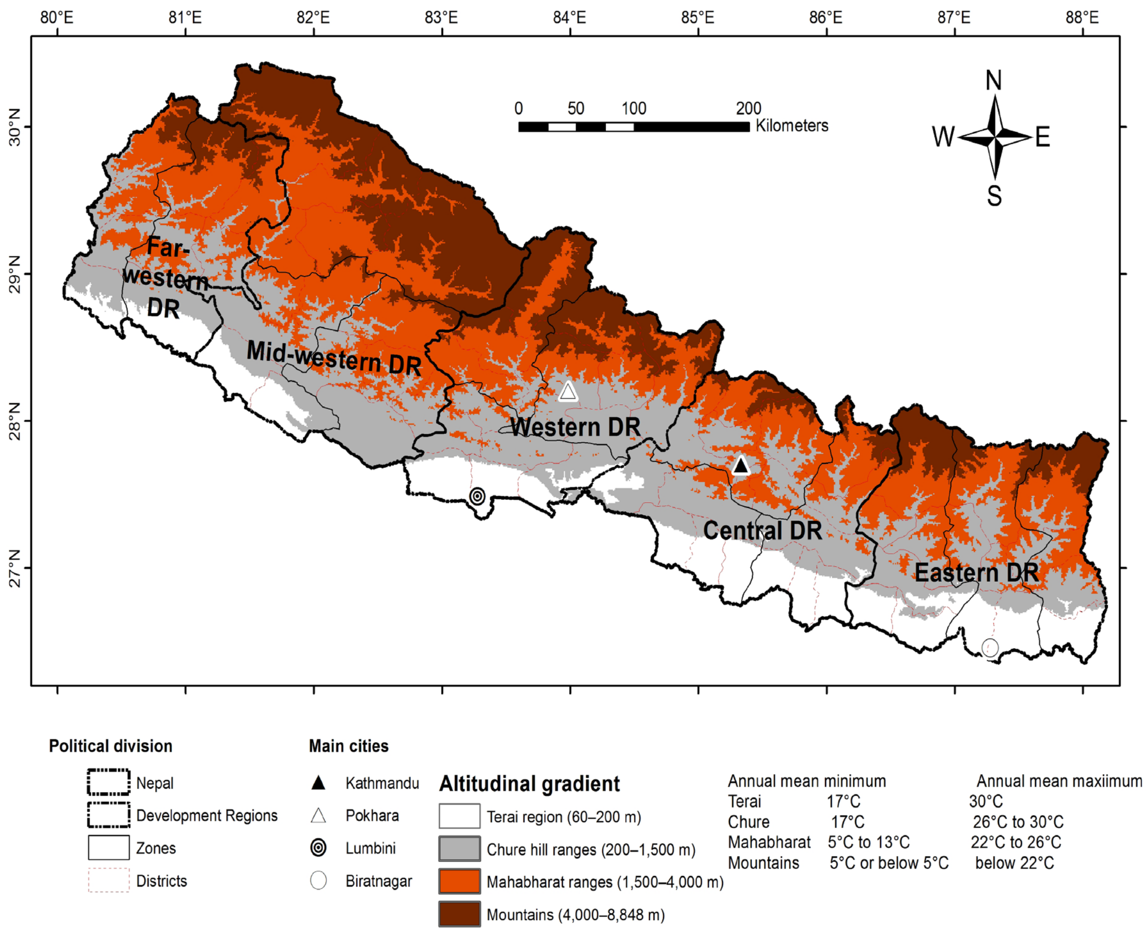


Figure 2. Development Regions (n = 5), Zones (n = 14), Districts (n = 75) and lowlands, Chure and Mahabharat hills and mountains of Nepal.

Nepal is divided into five distinct climatic ecological regions (Bajracharya, 1996) as a result of its diverse physiography. The tropical region is located in the lowlands from 60–1,000 m asl with a maximum temperature of 45 °C during summer, a minimum temperature of 0 °C during winter and with annual average rainfall of 700–1,000 mm. The subtropical region is located in the lower-midlands from 1,000–2,000 m asl with a maximum temperature of 27 °C during summer, moderately cold winter and an annual average rainfall between 1,000–2,000 mm. The temperate region extends to the upper-highlands from 2,000–3,000 m asl, with a moderately warm summer, severely cold winters, an annual average rainfall of 1,500–2,700 mm and frequent snow. Sub-alpine regions are found in the highlands from 3,000 m to about 4,000 m asl (i.e., tree-line), with a cold, windy and dry climate. The alpine region reaches the tree- and snowline (about 5,000 m asl) with extremely cold winters and short and cold summers, little rain but frequent snowfall. My study sites were situated in the tropical lowlands in the Eastern, Central and Western Development Regions (Figure 3).

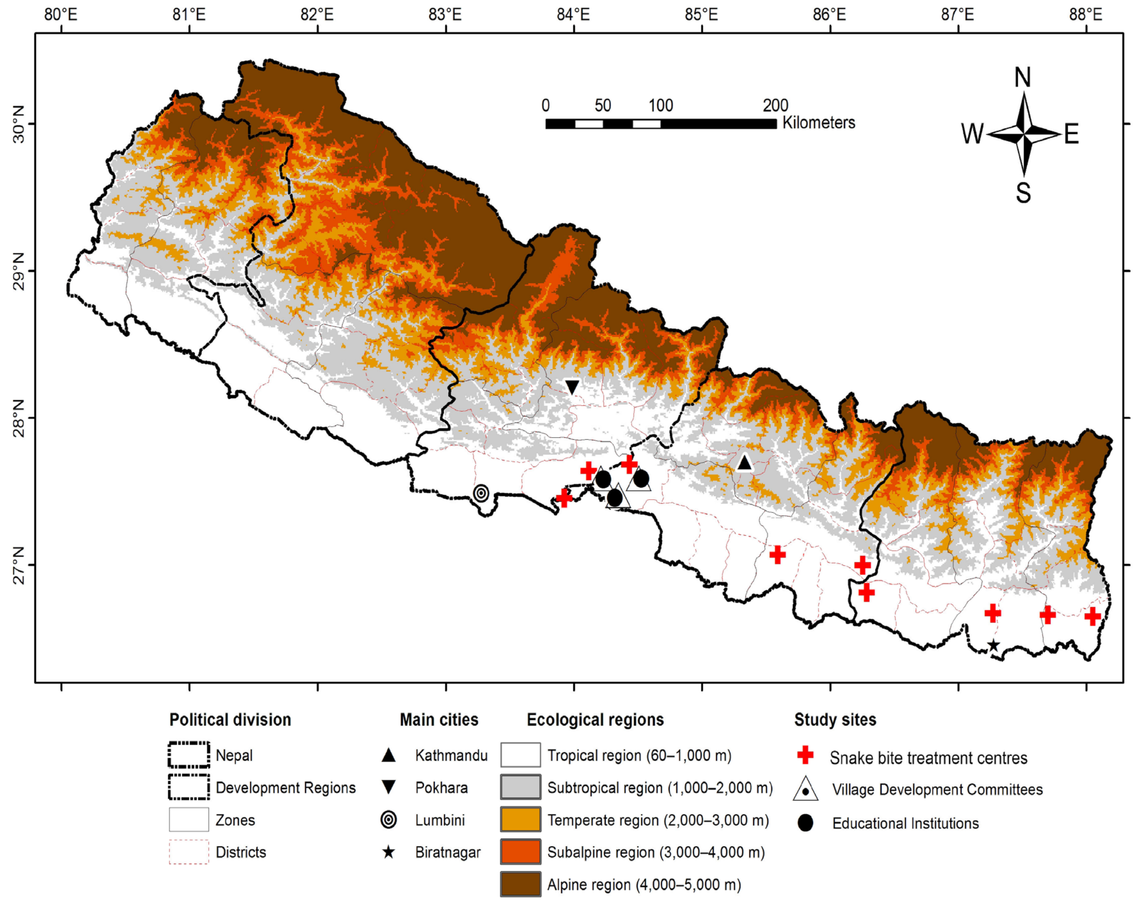


Figure 3. Topography and ecological regions of Nepal.

In Nepal, precipitation gradually decreases westwards and northwards and temperature decreases northwards. About 80% of the annual rain falls during June to September (Practical Action Nepal, 2009). The average annual rainfall is 5,400 mm in the eastern and western Nepal and approximately 144 mm in the far-western Nepal (Practical Action Nepal, 2009).

Accordingly, Nepal has four seasons: winter (December-February), summer (March-May), monsoon (June-August) and autumn (September-November). The varied landscapes with their distinct climate regimes support a distinctive flora i.e., tropical semi-evergreen monsoon forest dominated by deciduous Sal trees (*Shorea robusta*) in the lowlands to desert vegetation consisting of grass, herbs, and dwarf shrubs in the alpine region (Bajracharya, 1996).

1.2.1. Fauna diversity in Nepal

Nepal's faunal diversity is remarkable. There are 192 species of mammals (Thapa, 2014), 867 species of birds (Bird Conservation Nepal, 2014), 147 reptiles and 59 amphibians (Shrestha, 2001), 217 fish species (Shrestha, 2008), 138 terrestrial gastropods (Budha et al., 2015) and 650 species of butterflies (Prajapati et al., 2000). The Nepalese herpetofauna represents 13% of the total herpetofaunal diversity reported in South and Southeast Asia (Das and van Dijk, 2013) and about 33% of the herpetofaunal diversity reported for South Asia (Das, 1996). Nepalese reptile species alone represent 16% to those distributed in South and Southeast Asia (Das and van Dijk, 2013).

1.2.1.1. Snake diversity and distribution in Nepal

Nepal has a rich snake fauna because of its varied topography associated with ecozones and climate regions. Up to 82 snake species (Kästle et al., 2013a) belonging to 43 genera and nine families are reported to occur in Nepal (the report of family, generic and species richness in Nepal is subject to change because of ongoing taxonomic revisions). The species richness of Nepalese snakes equals about 30% of the snake fauna of India (Whitaker and Captain, 2004). Colubrid and elapid snakes dominate the lowlands of Nepal whereas viperid snakes are mostly found in the hills and mountains up to >3,657 m asl (Smith and Battersby, 1953, Shah, 1995, Kästle et al., 2013a).

Nepalese snakes are represented by Palearctic, Ethiopian and Oriental species (Kästle et al., 2002). Exact data on snake species richness in Nepal are scarce. Therefore, a checklist of the snakes of Nepal with notes on their distribution and updated nomenclature of species, genera and family is necessary to support medical and conservation strategies.

1.3. Landmarks of snake studies in Nepal

Snakes of Nepal have been known to science since 1838. Brian Hodgson, perhaps the first scientific worker on snakes including other vertebrates in Nepal and a resident at the court of Nepal for 1820–1822 and 1824–1843, collected 54 snake specimens and produced 25 drawings of snakes from Nepal and Tibet which he donated to the British Museum (Gray, 1863). Although he published collections of birds and mammals of Nepal (Cocker and Inskipp, 1988, Thapa, 2014), his snake collections were described by others (Cantor, 1839, Günther, 1861, Gray, 1863). Cantor (1839) described three species (two species with doubtful taxonomic identity), but without locality information. Günther from the British Museum catalogued Hodgson's reptilian species from Nepal's Himalayas (Günther, 1861) and decribed 23 snake species collected from central Nepal, mostly without specific locality information (five of these species with doubtful occurrence in Nepal). Later, Boulenger et al. (1907), Leviton et al. (1956), Swan and Leviton (1962), Fleming and Fleming (1973), Nanhoe and Ouboter (1987), Zug and Mitchell (1995), Shah (1995), Shrestha (2001), Schleich and Kästle (2002), Shah and Tiwari (2004), Pandey (2012) and Chhettri and Chhetry (2013) published information on the snakes of Nepal.

Until now, only small snake collections and very limited studies, inventory surveys and documentations have been carried out in certain areas of Nepal. Foreign and Nepalese investigators have concentrated their studies in the Arun Valley and its vicinity (Leviton et al., 1956, Shah and Giri, 1991), the Annapurna-Dhaulagari region (Nanhoe and Ouboter, 1987, Shah, 2001), the mid-hills including the Kathmandu Valley and its vicinity (Boulenger et al., 1907), the Chitwan National Park and its vicinity (Schleich and Maskey, 1992, Zug and Mitchell, 1995, Pandey, 2012, Pandey et al., in progress), the Bardia National Park (O'Shea, 1996), the Sukla Phanta Wildlife Reserve (Schleich and Kästle, 2002) and the Koshi Tappu Wildlife Reserve (Chhetry, 2010). Since the snake survey by Rai (2003) in the Eastern Development Region, no comprehensive snake surveys have been carried out in Nepal.

Recently, Kästle et al. (2013a) reported the distribution of 68 species. They questioned the occurrence of 14 species in Nepal and they missed to list *Trimeresurus albolabris* which is widely distributed in Nepal (Smith, 1951, Fleming and Fleming, 1973, Nanhoe and Ouboter, 1987, Rai, 2003, Pandey, 2012). During this study, I confirmed the occurrence of *Bungarus walli* and *Oligodon cyclurus* with accurate localities and voucher specimens, which were previously doubted to occur in Nepal or listed without accurate locality information. Altogether, up to 71 snake species are definitely distributed. Until now, at least 18 medically relevant venomous snakes have been reported to be distributed in Nepal (Sharma et al., 2013b). In the present study, I found only 11 of them to be medically relevant (see chapter 3.1).

1.4. Medically relevant snakes and their venom apparatus

1.4.1. Venom apparatus

The venom apparatus of venomous snakes consists of venom secreting glands in the upper jaw and of fangs. The glands (Figure 4) are located on each side of the head below and behind the eyes and contain large alveoli which store the venom that is transferred by a duct to the base of the grooved or hypodermic needle-like fangs (Figure 5) with which the snake injects the venom (Mebs, 2002, Mackessy, 2010).

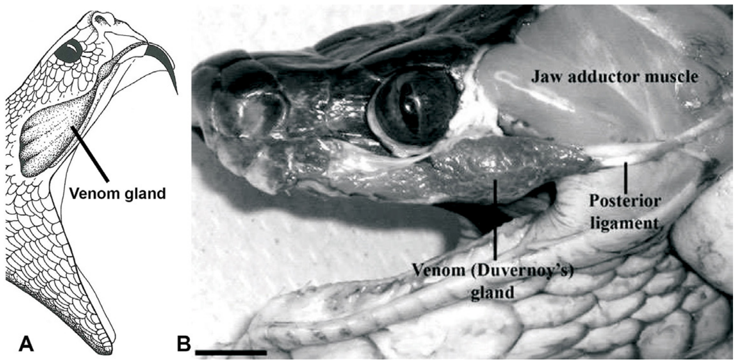


Figure 4. Snake venom glands and their location on head. **A:** the venom gland and its location in a front-fanged, solenoglyphous viper, modified from Mebs (2002), P. 244. **B:** the Duvernoy's venom gland of a back-fanged, opisthoglyphous snake, *Boiga irregularis* (Brown Treesnake, family Colubridae), common in Southeast Asia and northeastern Australia. Scale bar = ¼1 cm, reproduced from Mackessy (2010).

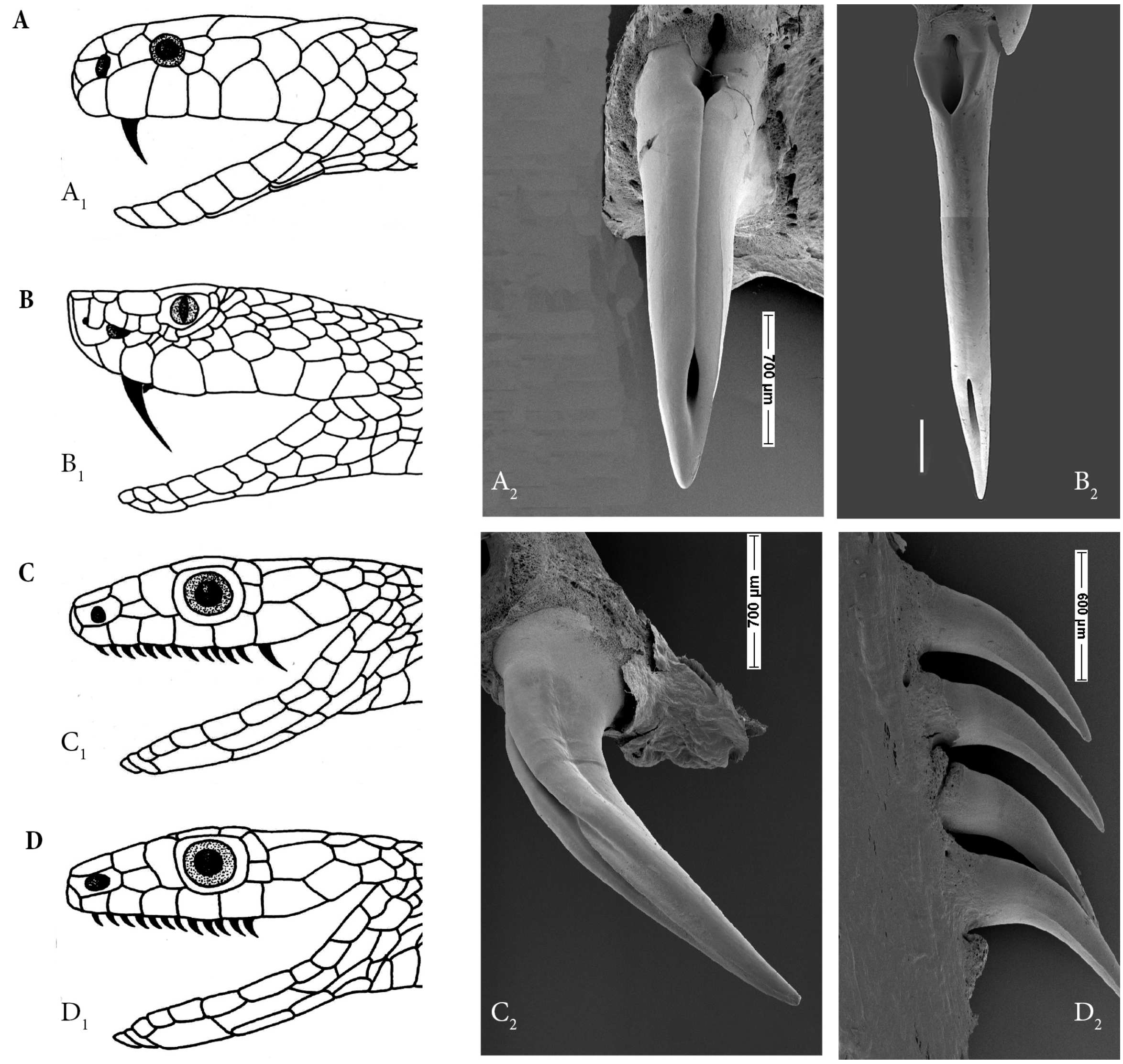


Figure 5. Types of snakes based on general morphology and location of teeth. A1, B1, C1 and D1 show the position of fangs (modified from Mebs (2002). A2, B2 and C2 show groove in the fangs and D2 solid teeth of snake (provided by Prof. Dr. D. Mebs). **A:** proteroglyphous snake with grooved front fangs: *A2* shows fangs of *Bungarus candidus* with almost closed groove. **B:** solenoglyphous snake with hollow front fangs: *B2* shows a hollow fang of *Vipera ammodytes*, white-bar = 700 µm. **C:**

opisthoglyphous snake with posterior grooved fangs: *C2* shows a fang of *Thelotornis kirtlandii* (twig snake) with groove. **D:** aglyphous snake with solid teeth: all teeth are similar (*D1* and *D2*).

1.4.2. Venom composition and mode of snake venom action

1.4.2.1. Venom composition

Snake venom is composed of toxic peptides and proteins including enzymes (Mebs, 2002). The venom composition varies intra- and interspecifically and among genera and families. Because of variable muscle pressure on the venom glands (Figure 4), different amounts of venom are injected by the snakes. Proteroglyphous and solenoglyphous snakes (Figure 5) even may not inject venom (i.e., dry bites) as they control muscle pressure (Kochva, 1987).

1.4.2.2. Mode of snake venom action

Based on the mode of action (Figure 6), snake venom toxins are classified into: pre-synaptically and post-synaptically acting neurotoxins. Pre-synaptic neurotoxins such as beta (β-) bungarotoxin from the venom of *Bungarus* species block the neuromuscular transmission by affecting the acetylcholine transmitter release. It is a phospholipase A_2 which finally causes the destruction of the nerve terminal.

Post-synaptic neurotoxins such as alpha (α-) toxins are antagonists of the acetylcholine receptor at the neuromuscular synapse where they block the transmission of nerve impulses (Chiappinelli, 1991). These neurotoxins are found only in elapids (kraits, cobras), sea snakes (Hydrophiidae) and few crotalids (e.g., *Crotalus durissus*). Patients die as a consequence of respiratory failure.

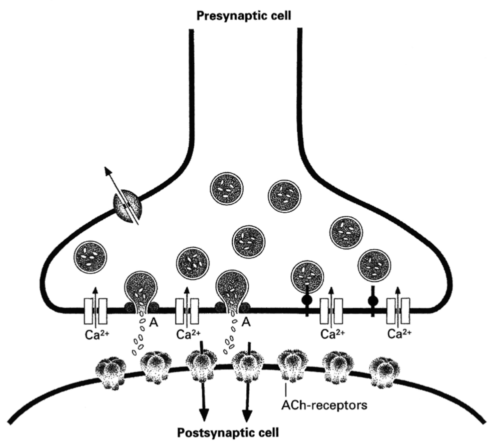


Figure 6. Neuromuscular synapse showing modes of snake venom action. Modified from Rappuoli and Montecucco (1997) and cited in Mebs (2002).

Some elapids such as cobras possess cardiotoxins and cytotoxins in their venom that damage cells (e.g., haemolysis of red blood cells) including that of the heart muscle and tissues (Dufton and Hider, 1991). Viperid venoms contain few neurotoxins only, but high amounts of haemorrhagic i.e., tissue destructing, necrotizing factors (Iwanaga and Suzuki, 1979).

In Nepal, typical examples of snake venoms interfering with blood coagulation are that of *Daboia russelii*

(Russell's Viper), *Trimeresurus* species (Green Pit Viper) and *Ovophis monticola* (Mountain Pit Viper). Their venoms contain procoagulant enzymes that activate blood clotting factors leading finally to the conversion of fibrinogen into fibrin (i.e., clot) in the blood stream. Fibrin is immediately split by the body's own fibrinolytic system causing blood incoagulability. Often within 30 minutes after the bite, the blood is incoagulable due to complete fibrinogen consumption. Other proteases cause local tissue necrosis and damage the walls of blood vessels causing haemorrhage (Mebs, 2002). This promotes bleeding into the surrounding tissues via holes in the blood vessels' walls (Mebs, 2002). Internal bleeding often causes death of the patient.

A broad spectrum of enzymes is found in snake venoms such as proteases, phospholipase A_2, cholinesterase, L-amino-oxidase, nucleases, hyaluronidase and pyrophosphatase (Iwanaga and Suzuki, 1979). Hyaluronidase accelerates the diffusion and absorption of the venom in the tissue. Some of these enzymes such as phospholipase A_2, which are present in almost all snake venoms (Rosenberg, 1990, Kini, 1997) contribute to the wide array of envenoming symptoms such as bleeding, necrosis and paralysis.

1.4.3. Signs and symptoms of snake bite envenoming and its treatment

Usually venomous snake bites leave two punctured marks with or without bleeding. *Bungarus* species often cause painless bites leaving almost invisible marks. Neurotoxicity (e.g., cobras, kraits), haemotoxicity (e.g., vipers), cytotoxicity (i.e., myotoxicity, nephrotoxicity, cardiotoxicity and local tissue damage, e.g., vipers, some cobras), swelling and oedema (e.g., viperids, some cobras and many others), haemorrhage (e.g., Russell's Viper, *Rhabdophis* species), vomiting and abdominal pain (e.g., elapid bites, particularly krait bites) may follow as typical symptoms after venomous snake bites. Viperid venoms may cause incoagulable blood, bleeding and tissue necrosis. The neurotoxic venoms paralyse muscles and cause respiratory paralysis (Warrell, 1995). Therefore, neurotoxicity due to all elapid snake bites is serious and often fatal.

1.4.4. Medically relevant snakes

Front-fanged (i.e., proteroglyphous and solenoglyphous) snakes (Figure 5) are considered medically relevant as they cause serious envenoming effects requiring medical treatment. However, there are back-fanged (i.e., opisthoglyphous) and aglyphous snakes (Figure 5) with glands (Figure 4) secreting a highly potent venom (Leviton et al., 2003, Weinstein et al., 2013). The opisthoglyphous African species *Dispholidus typus* (Boomslang) and *Thelotornis kirtlandii* (Forest Vine Snake) (Broadley, 1957, FitzSimons and Smith, 1958, Mebs et al., 1978) and the aglyphous *Rhabdophis tigrinus* (Mittleman and Goris, 1978, Ogawa and Sawai, 1986) caused human fatalities. Hence, they should also be considered as medically relevant.

Although only some reports of venomous colubrid bites causing mainly local envenoming effects are available (Mebs, 1977), all bites of snakes with a venom apparatus should receive special attention. To cure envenoming effects, medical treatment is essential. Snakes able to cause serious envenoming symptoms and/or death are medically relevant (McCue, 2013, Silva, 2013). Because of the homology of venom glands of front- and back-fanged snakes (Assakura et al., 1994) and of some fatal envenomings due to opisthoglyphous and aglyphous snakes as well, defining and documenting the medically relevant snakes is necessary.

The medically relevant venomous snakes have been found in seven families: Elapidae, Viperidae, Atractaspididae, Colubridae, Natricidae, Homalopsidae and Lamprophiidae (Vonk et al., 2008, Uetz and Hošek, 2015). There are more than 693 species of front-fanged venomous snakes worldwide; the majority of these belong to the Elapidae (71 genera, 354 species) and Viperidae (48 genera, 329 species) (Wallach et al., 2014). In Nepal, at least 10 species of proteroglyphous (Elapidae) and seven species of solenoglyphous snakes (Viperidae) are known to occur (Sharma et al., 2013b).

1.4.5. Snake bite care: first aid measures and antivenom use

Pressure immobilization bandaging (PIB) (Sutherland et al., 1979) for elapid snake bites and local compression pad immobilization (LCPI) (Tun-Pe et al., 1995a) for viperid snake bites are the most widely recommended first aid measures to delay the absorption of venom and the onset of systemic envenoming (World Health Organization, 2010). Both PIB and LCPI cause no pain and other detrimental effects. Despite their efficacy, these methods are rarely used by locals due to lack of education and training (Pandey and Khanal, 2013).

Snake antivenom, first developed by the French scientist Albert Calmette in 1895, is the drug of choice to treat snake bite envenoming. The antivenom used to treat snake bite envenoming in Nepal is produced in India using venom from *Bungarus caeruleus, Naja naja, Daboia russelii* and *Echis carinatus* collected mostly in southern India (Whitaker and Whitaker, 2012). Antivenom prepared against a particular snake venom is effective only for snake bites in a limited geographical area. Although Shrestha (2001) reported the occurrence of *Echis carinatus* in Nepal, but without voucher descriptions and defined localities, this has not been confirmed yet. Beside the four species mentioned above, *Bungarus walli*, *B. lividus*, *B. niger and Naja kaouthia* are also involved in snake bites in Nepal. Indian antivenom may be ineffective to neutralize all Nepalese snake venoms, because these snake species are not included in the Indian antivenom production. Since a frequent antivenom shortage in Nepal challenges snake bite management, finding better preventive measures will be a highly economic way to control snake bite problems.

1.5. Medically relevant snakes and snake bites in South Asia and Nepal

1.5.1. Snakes

Including snakes possessing Duvernoy’s glands (Mebs, 1977, Mebs et al., 1978, Mebs et al., 1987, Kardong, 2002, Mackessy, 2002), about 39% of the 3509 extant snake species (Wallach et al., 2014) may cause venomous bites worldwide. In Asia, at least 122 terrestrial snake species are medically relevant (Warrell, 1995). In South and Southeast Asia, at least 37 front-fanged venomous snake species occur in terrestrial ecosystems (Sawai, 1992, Whitaker and Captain, 2004). As some non-front-fanged snakes are also potentially dangerous to man (Weinstein et al., 2011), the bites of some opisthoglyphous colubrid snakes may also need medical care (Warrell, 1995). Venomous snakes pose risks of envenoming during outdoor (e.g., agricultural activities, fishing, safari, etc.) and indoor (e.g., sleeping, cooking, etc.) activities (Bawaskar and Bawaskar, 2004, Ariaratnam et al., 2008).

Although knowledge of Nepalese snakes goes back to Hodgson’s collections during the first half of the 19th century (Günther, 1860, Günther, 1861), no evidence-based documentation of medically relevant snakes is available yet. Certain known medically relevant snakes that are distributed in Nepal also occur in China, Pakistan, India, Bhutan, Bangladesh, the Maldives and Sri Lanka (Warrell, 1995, Whitaker and Captain, 2004), but only a limited number of snake studies have been carried out in Nepal. Which and how many species are involved in snake bites and envenomings has not been comprehensively studied yet. Therefore, a checklist of medically relevant snakes in Nepal is highly needed.

1.5.2. Snake bites

Snake bite envenoming causes acute morbidity, permanent disability or deaths in many developing countries including Nepal. Based on hospital records and government data, Swaroop and Grab (1954) estimated 25,000–35,000 snake bite deaths and Kasturiratne et al. (2008) 15,385–57,636 deaths annually in the Asian regions. The recent million death study in India (Westly, 2013) mentioned significantly higher numbers of snake bite deaths in India than any previous estimation. Westly (2013) reported 45,900 snake bite deaths in India annually. In Pakistan, Ali and Begum (1990) cited an estimation of 40,000 snake bites resulting in about 10,000–12,000 deaths. In Bangladesh, 623–789 snake bites occur per 100,000 population annually with estimated 6,041 deaths in rural areas (Rahman et al., 2010). In Sri Lanka, about 37,000 snake bites are reported to occur annually resulting in 194 deaths (Kasturiratne et al., 2005), in Nepal, more than 20,000 with about 1,000 deaths as concluded from hospital records (World Health Organization, 1987). This figure certainly underestimates the snake bite burden in Nepal (Sharma et al., 2003, Magar et al., 2013). In a community-based survey conducted in southeastern Nepal in 2002, the rate of annual snake bite incidence and mortality was 1,162/100,000 and 162/100,000, respectively. This is the highest figure of snake bite mortality ever reported in Asia so far (Sharma et al., 2004a).

In Nepal, India, Bangladesh and Sri Lanka, kraits, cobras and Russell's Viper are the most common venomous snakes. Their bites frequently result in serious neurotoxic envenoming, respiratory paralysis or coagulopathy, cardiovascular disorder and death. Likewise, in Nepal, these snake bites are an emergency public health problem resulting in serious socio-economic consequences. Elapid snake bite envenomings cause the majority of deaths. Their envenoming effects are time critical requiring treatment with antivenom. Few epidemiological studies in Nepal suggest snake bite case fatality ratios ranging from 3% to 58% (Sharma et al., 2003, Bista et al., 2005, Pandey, 2007, Magar et al., 2013). Snake diversity is high in the agrarian, forested/bush areas of the tropical regions where more than 50% of the Nepalese population live (Population Census 2011). Therefore, the majority of people involved in agricultural or associated activities in these regions are exposed to the risk of snake bites. Despite that, snake bite and associated studies are of low priority in Nepal (Nepal Health Research Council, 2014).

In the lowlands of Nepal, elapid snakes like the Common Krait (*Bungarus caeruleus*), the Wall's Krait (*B. walli*), the Spectacled Cobra (*Naja naja*), the Monocellate Cobra (*N. kaouthia*) and the Russell's Viper (*Daboia russelii*) cause severe envenoming and numerous deaths (Heap and Cowan, 1991, Bhetwal et al., 1998, Hansdak et al., 1998, Sharma et al., 2004a, Thapa and Pandey, 2009, Epidemiology and Disease Control Division, 2011). Epidemiological data of venomous snake bites and of the treatment seeking behaviour by rural community people in Nepal are necessary to achieve an effective snake bite management.

In South Asia, neurotoxic envenoming following the bites of kraits is a particular clinical problem, because krait venoms do not usually respond to antivenom and neostigmine (i.e., supportive anticholinesterase drugs) once paralysis has occurred (Fernando and Dias, 1982, Theakston et al., 1990, Kularatne, 2002, Anil et al., 2010). Of 16 *Bungarus* species (Abtin et al., 2014, Wallach et al., 2014), *B. caeruleus* is one of the most common species in tropical and subtropical Asia causing fatalities (Bawaskar and Bawaskar, 2004, Ariaratnam et al., 2008, Alirol et al., 2010). This species is considered to be the world's 7th dangerously venomous terrestrial snakes (Ernst and Zug, 1996), in the Indian subcontinent the 2nd after *Daboia russelii* (Wall, 1883, Theakston et al., 1990, Ernst and Zug, 1996). Studies of how often and why Common Kraits enter human residences and bite people while sleeping are necessary to prevent envenoming. Similar studies are needed to know the demographic features and socio-economic background of those bitten by *D. russelii*.

Only few people are able to identify snakes brought to the hospital despite the regular snake bite management training of medical professionals since 1999 provided by Nepal Government (Shah et al., 2003). These educational activities need evidence-based scientific information and educational tools. The problems associated with the short-supply of antivenom and doubtful compatibilities between Indian antivenom and Nepalese snake venom would be minimized by avoiding snake-human confrontation. The formulation and adoption of pragmatic preventive measures are cheaper and an effective way of addressing snake bite management problems in Nepal. Improving pre-hospital care also supports snake bite management in the hospital.

Interdisciplinary research combining the documentation of snake diversity and distribution, ecological, epidemiological and sociological determinants of venomous snake bite and understanding the attitudes, knowledge and awareness on snakes and snake bite among locals are imperative for the development and implementation of pragmatic preventive strategies and reducing ruthless killing of snakes as well.

1.6. Rationale of this study

An evidence-based, comprehensive documentation of medically relevant snakes is not available in Nepal, although it is essential for preventive strategies against snake bites and for antivenom design and distribution. Large numbers of snakes reported in Nepal still need confirmation to be listed in a national checklist of snakes. Data regarding venomous snakes of medical relevance known from hospital records are incomprehensive and unreliable as snake species involved are not identified by experts (Magar et al., 2013) and snakes known from ad hoc and cross-sectional studies in certain areas cannot represent all medically relevant snakes for other regions.

Analysis of ecological circumstances of their bite may provide more logical explanations about the entry of kraits into residences. Although *D. russelii* is considered to be distributed throughout the lowlands of Nepal (Shah, 1995, Shah and Tiwari, 2004), nothing is known about its bites in this country. Except for a few anecdotal notes, detailed ecological information on these snake species is still lacking.

Clinical and epidemiological features of some snake bites have been described in Sri Lanka (Kularatne, 2002, Ariaratnam et al., 2008) and India (Bawaskar and

Bawaskar, 2004). Similar studies from Nepal are not available (Alirol et al., 2010), but existing data clearly show that *Bungarus caeruleus* is the leading cause of snake bite mortality in Nepal (Thapa and Pandey, 2009, Epidemiology and Disease Control Division, 2011).

Several preventive strategies have been developed to cope with other public health problems, but preventive measures against krait and Russell's Viper bites are still lacking. Therefore, comprehensive ecological and epidemiological information is essential to formulate evidence based preventive measures, which may be cheaper than the hospital snake bite management. Antivenom is expensive and in limited supply. Also, crucial ventilators (respiratory support) are scarcely available when needed for the envenomed patients (especially in rural regions where the majority of bites occur). In Nepal, 83% of the total population inhabit rural areas (Central Bureau of Statistics, 2012a), where transportation and health facilities are poor or inadequate. In addition to almost exclusively nocturnal krait bites, the majority of venomous snake bites (uncategorized) occurs in the evening and at night; 27% of the bite accidents were recorded between 18:00–20:00 h, and 25% between 21:00–03:00 h by Pandey (2007). *Daboia russelii* bites usually occur while working on agricultural land which is usually not next to a road. Appropriate means of transport are not available at night. Therefore, receiving specific snake bite treatment early is extremely challenging due to poor infrastructure in rural areas.

1.7. Aim and scope of the dissertation

Aims of the dissertation are:

1. To develop a checklist of medically relevant snakes of Nepal, provide diagnostic information useful for the identification of these species, evaluate their distribution ranges as well as bite risk time and places. This comprehensive and evidence-based checklist of snake species involved in snake bites and/or envenomings is the first for Nepal. Most hospital-based epidemiological work (Shrestha, 2011, Paudel and Sharma, 2012, Magar et al., 2013) reported only group names of snakes involved. However, these reports are incomprehensive and based primarily on poor records, syndromes or history of snake bites. Since hospital data keeping is poor in Nepal (Magar et al., 2013), my voucher based reports of 11 species and their distribution patterns may support knowledge on venomous snakes, suggest risk zones for their bites and answer the question: which and how many species particularly contribute to human envenoming in Nepal.

2. To determine risk factors of envenoming due to snake bites in Nepal and to identify preventive measures against krait and Russell's Viper bites. As *Bungarus*

caeruleus is responsible for frequent deaths (Bista et al., 2005, Epidemiology and Disease Control Division, 2011), probably due to venom-antivenom incompatibilities and poor hospital facilities, adopting the best preventive measures against such fatal bites are desirable and economic. The formulation of effective measures needs the ecological and epidemiological information of their bites and socio-economic conditions of the household where bites occurred. I present the results of a thorough investigation: time of bite, monthly and seasonal variation, rainfall events at the time of bite, types of houses where bites occurred, surroundings of the snake bite locality, pre-admission histories, access to the snake bite treatment centre, geographic distribution, demography and socio-economic status of 46 proven cases of krait bites. I analysed similar data for 10 proven bite cases of *Daboia russelii* and describe several possible risk factors associated with krait and *D. russelii* bites and deaths.

3. To understand the attitude towards and knowledge of locals about native snakes and pre-hospital snake bite management supporting the development of snake bite prevention strategies and management plans as well as anthropogenic threats to snakes supporting the formulation of snake conservation strategies.

Results of the study may be useful to administrators in public health management and biodiversity conservation sectors, developers of effective antivenom, medical personnel and politicians supporting poor and rural snake bite patients.

2. MATERIALS AND METHODS

2.1. Study area and sites, study setting and population

The study area covers the eastern, central and western tropical lowlands and subtropical hills of Nepal. They are predominantly agrarian.

2.1.1. Topography, climate (temperature, rainfall) and seasons

These regions consist of the northernmost Ganges plains and the rolling Siwalik (Chure) hills extending up to 1,500 m above sea level (asl). The study area also covers the lower belts (i.e., 1,500–2,000 m asl) of the Mahabharat ranges that extend from eastern to western Nepal in 1,500–4,000 m asl. The snake bite study centres (i.e., STCs) were located in the Ganges plains (Figure 3). Snake bite cases from elevation ranges from 60–1,945 m asl receive snake bite treatment services in these STCs (Table 1). These regions are characterized by a hot tropical and mild subtropical climate.

In these regions, the temperature is high from March (about 14–31 °C) to October (about 20–31 °C). About 80% rain falls during the month of June (about 325–350 ml) to September (about 285–345 ml) (Practical Action Nepal, 2009). October and November occasionally receive post-monsoonal rainfalls. The rest of the year is almost dry. To better understand the seasonal influence on krait and other venomous snake movements towards and inside residential areas and to correlate the season of human envenomings, I defined seasons according to the rainfall pattern as:

i. the dry or summer or pre-monsoon season (March–May), characterized by the absence of rainfall, high temperature and occasional storms,

ii. the rainy or monsoon season (June–September) with frequent rainfall and high humidity and

iii. the winter season (October–February) with scanty or no rainfall, fogs and cold weather.

Accordingly, I grouped bites that had occurred in March, April and May into dry, June, July, August and September into rainy, October, November, December, January, and February into winter seasons to analyse seasonal influence on snake bite frequency.

Table 1. Snake study centres, areas and estimated population which received snake bite treatment services by the treatment centres in south of Nepal.

STC	**Study centres or** snake bite treatment centres (STCs)	**Location of STCs**		**Service area of STCs**		**Population***	**Duration of snake collection** (DD.MM.YY)	**Attended snake bite cases‡**	**Annual incidence of snake bites****	**Snake specimens**	
		Development Regions	Districts	VDCs / Municipality (N)^	Name of districts					Preserved (photos) (N)	Preserved and photos (%)
1	Nepal Red Cross Society, Sub-branch, Damak	Eastern	Jhapa	43/1	Ilam, Jhapa, Morang	679,141	01.01.10–31.12.14	5,837	172	70 (2)	1.2
2	Charaali STC, Charaali	Eastern	Jhapa	170/5	Taplejung, Panchthar, Ilam, Jhapa	1,173,507	01.01.10–31.12.14	6,983	119	28 (3)	0.4
3	Bharatpur Hospital, Bharatpur¶	Central	Chitwan	135/4	Chitwan, Nawalparasi, Tanahu, Gorkha, Makawanpur	1,221,495	01.04.11–31.10.12; 25.04–27.05.13	512	26	56 (2)	11.3
4	Kaligandaki Community Hospital, Kawaswoti	Western	Nawalparasi	31/0	Nawalparasi	252,820	15.04.04–15.09.05; 2008–2010	627	73	42 (0)	6.7
5	Bajradal Battallion STC, Tribeni	Western	Nawalparasi	27/1	Nawalparasi	241,106	15.4.12–31.12.14	887	136	67 (2)	7.8
6	Dudhauli STC, Dudhauli	Central	Sindhuli	7/0	Sindhuli	48,508	15.07.–17.10.13; 15.6.–31.10.14	220	637	18 (4)	10.0
7	Netragunj STC, Nawalpur	Central	Sarlahi	105/0	Sarlahi, Rautahat, Mahottari, Sindhuli	822,475	01.07.13–31.12.14	1,132	92	13 (0)	1.1
8	Jayakali STC, Chorva	Eastern	Siraha	122/2	Siraha, Dhanusa, Udayapur, Saptari	749,785	15.04.10–31.12.14	2,749	78	19 (5)	0.9
9	Community STC, Itahari	Eastern	Sunsari	107/3	Sunsari, Udayapur, Saptari, Morang, Dhankuta	1,260,617	15.04.12–15.12.14	3,106	92	18 (0)	0.6
	Total	**3**	**7**	**720/15**	**20**	**6,449,454**		**22,053**	13	**331 (18)**	1.6

^VDCs/Municipality were reported by medical professionals involved in snake bite treatment in the respective centre; *Nepal Population Census 2011; ‡confirmed snake bite cases only, figures in this columns represent cases for respective periods mentioned in right column; ¶for the year 2013, the snake bite cases admitted during April and May only were included; **Snake bite incidence per 100,000 populations per year. *Because of variable duration of brought snake collection and short supply of preservatives, the total number of snake species greatly varies among STCs.*

2.1.2. Structural and biotic aspects

Forests in the tropical regions are primarily dominated by the Sal (*Shorea robusta*) and in the subtropical regions by *Schima, Castanopsis* and *Alnus* species. The vegetation of the agrarian landscapes changes seasonally. The major crops in the study areas are rice, maize, wheat, mustard, banana, tea, cardamom, broom grass and bamboo. The richness and abundance of prey animals such as mice, rats, bats, birds, lizards, skinks, snakes, frogs, toads and fishes and the ambient tropical and subtropical climate favour the presence of snakes in these areas.

2.1.3. Study centres and sites, human population at risk of snake bite, incidence of snake bite and involved snake species

To evaluate the medically relevant snakes and to know the epidemiology of human envenomings due to taxonomically identified venomous snakes from a wider coverage, nine snake bite treatment centres (STCs) located in the Ganges plains of eastern, central and western Nepal were selected (Table 1, Figure 3) because of frequent reports of snake bite envenomings (Sharma et al., 2003, Sharma et al., 2004b, Pandey, 2006, Pandey, 2007, Magar et al., 2013).

The majority of people who came to these nine STCs live in rural areas dominated by agrarian environment. These STCs (Table 1, Figure 3) provide snake bite treatment services to approximately 6.5 mio inhabitants from 20 districts in the lowlands and lower hills of eastern, central and western Nepal (Figure 2, 3). The reference population numbers were extracted from the Nepal census 2011 (Central Bureau of Statistics, 2012a). I extracted data on snake bite incidents using the medical records of respective STCs.

2.1.3.1. Study sites

To understand the attitude, knowledge and awareness (AKA) about snake and snake bites of people inhabiting highly snake bite prone regions, I surveyed Chitwan National Park (CNP) buffer zone inhabitants from three distant Village Development Committees (VDCs) adjoining the CNP in Chitwan Valley. These VDCs represented diverse CNP buffer zone communities (Figure 7). I also surveyed three higher educational institutions (class 11 and above i.e., academic study units). From the selected VDCs, three wards (the smallest administrative unit of Nepal i.e., village study units) were randomly selected, and from these units, 75 household heads (25 from a current household list of each ward), 45 teachers and 30 students (15 teachers and 10 students from the daily attendance-register of each institution) representing 15 to 76% of the sampling unit population were randomly selected for interviews (Appendix 1). All respondents, however, represented agrarian villages located at about 18–45 km road distance from the referral snake bite treatment centre. Of the three village units, only the ward of Bachhayauli VDC was connected with the centre by paved road and better means of transport. I selected teachers and students as they are important to disseminate conservation and public health information and farmers who frequently encounter snakes.

The site for the AKA study has a tropical climate (temperature reaching up to 38°C during summer and dropping to a minimum of 6°C during winter) and receives about 240 cm annual rainfall mainly during the monsoons (United Nations Environment Programme, 2011).

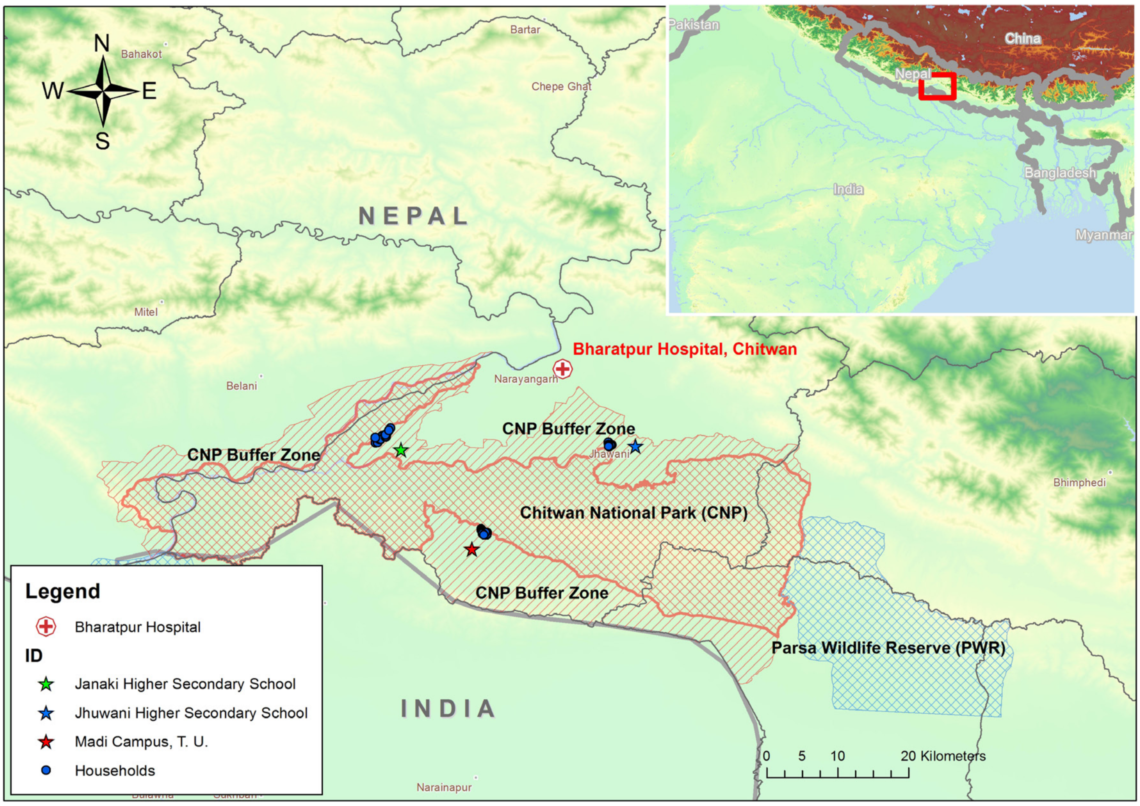


Figure 7. Locations of surveyed educational institutions (stars) and households from the selected Village Development Committees (dots) in the southcentral lowlands of Nepal for the study of attitudes, knowledge and awareness of locals on snakes and snake bites.

2.2. Field trips, survey methods and data analysis

I carried out field trips to study centres mentioned above, study sites and defined locations where krait and Russell's Viper bites occurred during three time periods: (1) 18.11.2011–07.02.2012, (2) 01.01.2013–26.02.2013 and (3) 07.01.2014–17.02.2014. I studied medically relevant snakes, epidemiology and ecological circumstances of bites and surveyed communities in snake bite prone regions during these periods. I also examined snakes brought to STCs and associated information collected during the 2014 snake bite season from February to December 2014.

2.2.1. Study of medically relevant venomous snakes in Nepal

I studied snakes brought by patients or their attendants receiving treatment during 01 April 2010 through 31 December 2014. The actual time frame studied varied for the different STCs (Table 1). I did not include snake specimens of species not involved in bites in this analysis of medically important snakes, even though these non-relevant species were present in some STCs. I excluded 10 specimens belonging to eight species which were brought by victims from India. I visited nine STCs requesting hospital staff to place dead snakes in air-tight bottles filled with 70% ethanol. These preserved specimens were labelled with patient number, initials, date of birth and date of admission. Few specimens were preserved in 10% formalin due to shortage of ethanol. I selected the centres located in seven districts (three centres in the eastern lowlands of Nepal, four in the central and two in the western lowlands of Nepal (Figure 3, Table 1) because of high snake bite admissions for which ethical approval from the Ethical Review Board of B. P. K. Institute of Health Sciences, Dharan, the Nepal National Health Research Council (NHRC) and Ministry of Forests and Soil Conservation, Nepal Government, was obtained. Written consent was obtained from all study patients or their relatives of kraits and Russell's Viper bites. In a death case, consent was obtained from patient's relative.

In total, I examined 349 snake specimens (331 specimens were preserved and 18 specimens only photographed) that had been brought to STCs (Table 1). The majority of snake specimens were collected in the Bharatpur, Charaali and Damak centres in the context of clinical and epidemiological studies of snake bite in which I was involved together with other researchers from Nepal, Switzerland and Germany (in joint projects of B. P. K. Institute of Health Sciences, Dharan, Nepal, Biodiversity and Climate Research Centre (BiK-F), Frankfurt am Main, Germany and Geneva University Hospitals, Geneva, Switzerland).

2.2.1.1. Scalation, morphometric measurements and weight of collected snakes

In addition to the photographs and measurements, I also studied basic scalation characters to confirm the species' identity. I measured snakes to the nearest 1 cm to determine the snout-vent length (SVL), cloaca to tail-tip length (CTL) and girth at mid body (GMB). I determined their weight using a digital balance. Separate spread sheets were used for the collection of morphological features of study snakes.

2.2.1.2. Snake collection and deposition of voucher specimens

Each specimen was given a voucher number (i.e., numeric or alphanumeric codes) representing the study centre and snake bite patient from the respective centre. No voucher numbers were assigned to specimens with limited patient information (Appendix 2). The specimens were deposited in the respective snake bite treatment centres (Table 1), but snakes brought by patients involved in Randomized Clinical Trials (clinicaltrials.gov number NCT01284855) were deposited in the B.P.K. Institute of Health Sciences, Dharan. If hospital staff placed multiple snakes in the same collecting jars without tag, I considered them to be found in the service area of respective centres (Table 1). Photographic specimens presented in this dissertation without acknowledgement to photographer are photographed by myself.

2.2.1.3. Identification, nomenclature and taxonomic position of snake species

I identified snakes using key morphological characters especially the scalation of head, body and tail as well as dentition and colour pattern. These features were compared with the identification keys in available published sources (Kramer, 1977, Wüster, 1998, Kabisch, 2002a, Kabisch, 2002b, Kabisch, 2002c, Schleich and Kästle, 2002, Leviton et al., 2003, Köhler, 2008, Kästle et al., 2013b) and followed the recent work for valid species, generic and family names (Pyron et al., 2013a, Hedges et al., 2014, Pyron and Wallach, 2014, Wallach et al., 2014, Uetz and Hošek, 2015).

Because of numerous recently published studies on the phylogeny and systematics of snakes (Guo et al., 2014), the taxonomic status of species, genera and family has undergone substantial changes in the recent years. This also applies to the snake fauna of Nepal. For example, in its original description (Orlov and Helfenberger, 1997) *Trimeresurus karanshahi* was considered to differ from *T. tibetanus* in aspects of scalation (i.e., 19 rather than 21 midbody scale rows) and body pattern, Tillack et al. (2003) synonymized both. Here I follow the latter authors and have excluded *T. karanshahi* from the list of Nepalese species. Similarly, there are recent changes in generic (Guo et al., 2014) and family names of Nepalese snakes. Here, I have used the most recent taxonomy except otherwise stated.

Shah and Tiwari (2004) described two subspecies of *Boiga ochracea*: *B. o. ochracea* and *B. o. stoliczkae*. Kramer (1977) did not mention *B. ochracea* but reported the subspecies *stoliczkae* from central Nepal with two localities. As 'The Reptile Database' grouped them under *B. ochracea* (Uetz and Hošek, 2015) and the recently published snake checklist by Kästle et al. (2013a) also avoided the subspecies names, only *B. ochracea* was used as species name.

2.2.1.4. Geo-referencing of identified snakes

Using available permanent addresses and phone contacts of the patients in hospital records, localities of krait and Russell's Viper bites were visited to determine the exact locality and to obtain habitat information. For other snakes, I established GPS coordinates using 'Google Earth' to locate patients' permanent addresses (Appendix 2). I also used the STCs' location for the patients without address information, assuming that the snake localities were located within the service area of the respective STC (Table 1). Similarly, I studied some snakes collected by C. L. Thapa from the Mahottari District but without specific locality information; I then used the GPS coordinates generated with Google Earth for "Mahottari".

2.2.1.5. Data analysis

2.2.1.5.1. Proportion of medically relevant and non-relevant snake species

I calculated the proportion of medically relevant venomous snakes in the present study as:

$$Medically\ relevant\ snakes\ in\ the\ present\ study\ (\%)$$
$$= \frac{11\ identified\ medically\ relevant\ snake\ species}{71\ snake\ species} X\ 100$$

2.2.1.5.2. Distribution ranges of medically relevant venomous snakes

I analysed distribution ranges of medically relevant venomous snakes that I identified during the study period using definitive distribution information in published sources. Accordingly, I suggested the maximum ranges of potentially venomous snake bite in Nepal.

2.2.1.5.3. Analysis of medically relevant snakes and their bite risk periods

I grouped the snakes registered in the STCs into three categories based on their medical relevance: a) snakes that caused systemic envenoming effects and/or extensive swelling; b) snakes with doubtful medical relevance as they caused local swelling limited to the bite site only or irritation or burning sensation that would last few hours only; c) medically non-relevant snakes.

I categorized the bite time as follows: early morning (03:00–04:59 h, Em), morning (05:00–09:59 h, M), day (10:00–16:59 h, D), evening (17:00–19:59 h, E) and night (20:00–02:59 h, N) and analysed these periods using frequency distributions.

2.2.2. Survey of confirmed krait and Russell's Viper bite envenoming

2.2.2.1. Sampling of respondents

From among the patients who brought dead snakes to STCs over the five-year period (2010–2014, Figure 3, Table 1), I selected confirmed krait and Russell's Viper bite patients with complete contact address whom I could interview (for those who survived the snake bite). When sufficient information could not be obtained from the patient or when the patient had died of snake bite, I interviewed the patient's relatives. Patients unable or unwilling to give consent were excluded. Only patients of krait and Russell's Viper bite cases with snakes that are preserved and labelled with the patient's information (patient name and address or hospital registration number) were included in this study.

2.2.2.2. Data acquisition

I investigated the ecological circumstances, pre-admission history and socio-economic conditions associated with confirmed Common Krait and Russell's Viper bites separately by structured and semi-structured interviews of the discharged patients or their relatives in the case of fatal envenoming. I used mixed research methods which combine both the quantitative and qualitative research approaches. I conducted interviews in the homes of patients 5 to 862 days after the bite and data were recorded on pre-tested standardized case record forms using an audio recording device and structured, semi-structured and standardized questionnaires (Appendix 3). Also, patients were face-to-face interviewed at the location of bite; snake bite localities were geo-referenced and ecologically characterized. The interviews were conducted from November 2011 to February 2012, January to February 2013 and January to October 2014 and data on the circumstances of the bites, the patients' demographic and socio-economic characteristics and the clinical features developed during bite to hospital admission were collected. For the complete information with minimal bias, the neighbours, first aid providers and those who were involved in carrying the patient to the STCs were also asked in case the patient was not sure of the answer. Subsequently, each patient (or relative in the case of a deceased patient) was asked for a written informed consent declaration in Nepali language to participate in the study and to be visited by myself and to provide additional personal, demographic, socio-economic and circumstantial information, including photographic and geographic data for publication in academic presentations and journals (Appendix 4). In addition, interviews regarding the case were conducted with attending healthcare personnel and other witnesses after demonstrating the patient's (or next of kin) consent and obtaining the verbal consent of the witness for clinical, laboratory and circumstantial data of study participants.

Each krait and Russell's Viper bite location was visited with the help of respondents (patients and/or relatives, i.e., eyewitnesses of the bite). Then, the exact locality where the bite had occurred were geo-referenced, habitat types were documented, surroundings of the locality and information on the weather conditions (rainfall and flooding) at the day of the bite, the day before and the day after the bite were noted. I used several memory tick questions to help the respondents recollect the exact weather conditions at the time of the bite.

I further classified road types and road-distance (in km) from snake bite location to respective STC used by the patient. Also, I evaluated the availability of transport (e.g., ambulance, motorcycle).

I categorized the risks factors such as demographics (age, gender, occupation, literacy and education status), socio-economic conditions (house types, household connected with electric lines, having electrical appliances (TV, radio, mobile, internet), sources of drinking water, type of toilet, number of sleeping rooms and number of people using these rooms), indoors, outdoors, environmental factors (surroundings of the locality with and without retreats, indoor and outdoor storage of grains and fodders, rainfall event at the day of the bite, the day before and the day after the bite, etc). I extracted demographic information such as occupation, gender ratio, age and literacy related information to analyse demographic features and to determine people who are most vulnerable to krait and Russell's Viper bites in the communities of the lowland region of Nepal.

Occupation of the patient: To define the occupation of bite patients I considered the work carried out by them within the past 12 months from the date of snake bite. If respondents were involved in two jobs, I chose the job on which they spent more time. If the same time was spent for either job, I selected his/her higher income job to define the respondent's occupation.

Gender ratio and age distribution of the patient: I calculated the gender ratio as males per 100 females (males/females x 100). To analyse age structure, I considered the age of patients at the moment of snake bite and compared it with the age structure of population in the study area as per the Nepal population census 2011.

Literacy and educational background of the patient: Patients who could read and write at least in Nepali language or in their own ethnic language or who were formally, non-formally or informally educated were considered as literate and those who could not read and write or read only as illiterate. I further asked for the highest education level that had been attained by formally literate respondents. If the respondent was studying, for example, in class 10, his or her completed educational attainment was recorded as class 9. Similarly, if respondents had passed class 10 (School Leaving Certificate) and not joined the next class at the moment of the interview (or never joined a higher class), his or her educational attainment was considered to be class 10 and so on. These definitions and categories correspond to those adopted in the population census 2001 of the Government of Nepal (Shrestha, 2002).

2.2.2.3. Data analyses and interpretation

Evaluation of potential risk factors included demographics, environmental and socio-economic variables. Socio-demographic characteristics, epidemiological features, ecological circumstances of bites and prehospital interventions adopted by patients were described using percentages for analysed categories and by calculating means (or median if the data were non-normally distributed or outliers existed), standard deviations and standard error of mean (SEM) for the continuous variables. Whenever data were normally distributed without outliers, I used mean as a central tendency value to make statistical inference. I used boxplots to detect any outliers in dataset and Shapiro-Wilk test (Razali and Wah, 2011) to examine the normality of data distribution before applying any statistical test.

The case fatality rate (CFR) was calculated as the percentage of patients who died among those bitten by identified snakes. I calculated literacy rate dividing the total number of literate krait or Russell's Viper bite patients by the total number of the species' bite patients. Continuous variables were compared using the parametric Student's t-test. For non-normal data distribution, I used non-parametric Wilcoxon test (Wilcoxon, 1945) for which median was applied. Categorical variables were compared using the X^2 test. All associations and hypothesis testing were examined at the p (level of significance) <0.05.

I assessed the general socio-economic conditions of the households where krait and Russell's Viper bites had occurred by asking the respondents, whether they had amenities and possessions like electricity, fuel, drinking water and media devices in their households. I then graded each household based on the following parameters:

(i) households using electricity (hydro-power or solar) as main sources of lighting,

(ii) households using gas as a main source of cooking,

(iii) households using a modern toilet,

(iv) households using improved drinking water and

(v) households possessing a radio, TV, computer or telephone.

To accommodate the classification of socio-economic status based on the above mentioned amenities and possessions as per the descriptions mentioned in the population census 2001 report (GC, 2002), I graded those households into five categories. For this, I developed socio-economic status index (SESI) using percentage of principal amenities and possessions available to each of households. The amenities and possessions included (i). electricity (hydro- or solar-power), (ii). gas as a main fuel of cooking, (iii). modern toilet, (iv). improved drinking water, (v). media devices (a. radio, b. Tape-recorder, c. Television (BW/colour), d. computer, e. land telephone or mobile, f. computer and g. internet. I rounded four of seven (4/7) media devices (0.57) into single score and 1–3/7 devices into 0.5 score to ease SESI calculation (GC, 2002). According to SESI, I graded economic status of households where krait and Russell's Viper bites occurred into five categories: high quality households (hereby, HQH) (having 80–100% amenities listed above), medium high quality households (MHQH) (having 60–79% facilities, medium quality households (having 40–59% facilities (MQH), low quality households (LQH) (having only 20–39%) and very low quality households (VLQH) (having below 20% or none of the above facilities).

Similarly, I categorized houses into eight types based on materials used to build up houses to know the high risk house types (Central Bureau of Statistics, 2012a).

I measured abundance of snake attractants based on observation on the exact location of bite for statistical analysis. I scored snake attractants and hiding places in and around residences: 1. Indoor grain storage, 2. Open grain storage, 3. Grain storage in sleeping room, 4. Indoor fodder storage, 5. Open fodder storage, 6. Fodder storage in sleeping room, 7. Barn adjoining house, 8. Cattle hut adjoining house, 9. Bird nests (e.g., hen, pigeon) on outskirt or indoor, 10. Wall lizards (e.g., geckos), 11. Small mammals (e.g., rodents, bats) indoor, 12. Piles of bricks/stones/logs, 13. Vegetation/grass, 14. Bushes, 15. Forest, 16. Agricultural lands, 17. Crops, 18. Streams, 19. Swamps and 20. River. Some of the changed circumstances (e.g., shift of storage) were reported by respondents and numbers of prey animals of snakes were estimated by patients themselves or their relatives. I determined any contribution of these 20 environmental factors to snake bites using X^2 test.

2.2.3. Survey of attitudes, knowledge and awareness about snakes and snake bites

I performed interview surveys of people living in the buffer zones of Chitwan National Park, the UNESCO World Heritage Site in southern Nepal. In this part of the study, I recorded the perceptions, knowledge and awareness of snakes and snake bite of 150 randomly selected community people.

2.2.3.1. Data collection

I conducted a cross-sectional survey using semi-structured and pre-tested questionnaires, mixed research methods involving quantitative and qualitative research approaches during January and February 2013. I performed personal, formal and face-to-face interviews of 150 randomly selected respondents (Appendix 1) with a mean age of 37 years (range 15 to 79 years) using voice recording, questionnaires and visual presentation (Corbett et al., 2005) such as DIN A4-sized colour photographs of adult snakes known to be distributed in the vicinity of CNP (Appendix 5) (Pandey, 2012) including photos of juveniles and various colour morphs for species with variable colour patterns.

Written informed consent (prepared in Nepali language) of all respondents was obtained to use and publish the extracted information anonymously for research and educational purposes. I explained the main objectives of the research and informed the consent clearly at the beginning of the interview and asked them whether they would participate in the survey. As for institutional informants, they were interviewed after a formal request for permission from the principal of the respective institution. I required no institutional ethical approval as I used snake photos instead of live snakes, did not involve human participants in any experiment and none would be harmed answering general attitude and aptitude test questions related to snakes and snake bite.

2.2.3.1.1. Attitudes

Fifteen questions were asked to understand their positive and 14 regarding negative attitudes towards snakes and snake conservation. I determined ambivalent attitudes if they responded ‘yes’ to both types of questions. To scrutinize and measure these attitudes, I asked questions about like, dislike or fear of snakes, intention of killing them, responses to snakes encountered in defined and undefined places, worship of snakes, realizing the need of snake conservation and snakes as farmers’ friends. I phrased the first type of question as: ‘Do you …? Why?’; I coded responses as: 1. Yes, 2. No, 3. Unknown, and noted three types of logic for Yes or No responses. I phrased a second type of question as: ‘What do you do when …?’;

I coded responses as: 1. I ignore it, 2. I kill it, 3. I call others to kill it, 4. I kill it only if I come to know it as a venomous snake, 5. I just keep it out using sticks (snake hooks, etc.). I phrased a third type of question as: 'Which of the following do you consider to be…? ' 1. All snakes around us should be killed, 2. Only venomous snakes around us should be killed, 3. All snakes around us should be conserved. Again, I coded responses as: 1. Yes, 2. No, 3. Unknown.

2.2.3.1.2. Knowledge

The knowledge test included three types of questions: the first type tested the ability of differentiating the displayed native snakes by their nature of envenoming (i.e., venomous or non-venomous) and their names (local, English and scientific); second, I tested the understanding of the need of snake conservation, and third I asked about measures of snake bite prevention. I asked the first question as: which one of the following snakes do you think are venomous or non-venomous (I considered both back- and front-fanged snakes as venomous) and which of them do you know by their local/English/scientific names?

To measure the knowledge on needs of snake conservation, I phrased questions like: do you think snakes should be conserved? If you do/don't think so, why? I asked them to give five reasons. To measure their knowledge about snake prevention, I phrased questions like: do you know how to prevent snake bite? If yes, what measures do you adopt? I asked them to give 10 practices of preventing snake bite.

I encircled the corresponding assigned snake photo numbers (i.e., 1 through 28) following their responses, and I noted names of the snakes (if they could give the names). I crosschecked encircled numbers with corresponding listed photo information (Appendix 3.3.2) and mentioned snake bite prevention with corresponding recommendations in published sources (World Health Organization, 2010) while calculating scores.

2.2.3.1.3. Awareness

To know the awareness level among buffer zone people, I asked 33 awareness test 'yes-no' questions which included deleterious, useless and useful aspects of snakes and snake bite management (Pandey and Thapa, 2010a). Of the 33 questions, 26 tested belief in popular, deep-rooted, and widely prevailing traditional beliefs or misconceptions on snakes (n = 13) and pre-hospital care of snake bites (n= 13). The next two questions tested belief in pre-hospital care of doubtful benefits in the context of Nepal (Pandey and Thapa, 2010a, Pandey and Khanal, 2013) and five more questions were on first aid measures (PIB or LCPI) recommended by

World Health Organization and the Government of Nepal (Sutherland et al., 1979, Tun-Pe et al., 1995a, Shah et al., 2003, World Health Organization, 2010).

2.2.3.1.4. Snake use in Nepal

To understand the use of snakes, I asked them whether they or their neighbour would kill snakes for food or ethno-medicine.

2.2.3.2. Data analysis

As median scores are unaffected by outliers, I used a median to analyse the entire AKA scores, using the non-parametric Wilcoxon test (Wilcoxon, 1945). I used one-sample Wilcoxon signed rank test to determine the median scores of each demographic for attitudes, knowledge and awareness, two-tailed unpaired Wilcoxon rank sum tests (also known as Mann Whitney U test) to know any differences of scores between demographics and a one-tailed unpaired Wilcoxon rank sum test to know the high score holders. I did not involve demographics with sample size below six in order to avoid measurement errors.

I analysed awareness based on the percent of median respondents after the Wilcoxon test. I determined the buffer zone people to be highly aware (herein HA) if they scored 75% and above rejecting traditional beliefs on snakes and snake bite care, refusing to seek medical help of doubtful use and accepting the suggested measures of pre-hospital care. Similarly, I concluded aware (A) respondents if they scored 50-74%, mildly aware (MA) if they scored 25-49% and unaware respondents (UA) if they scored 0-24%. I determined association of AKA scores with demographics using a Poisson Generalized Linear Regression Model. The equation was :

$$ln\mu = a + b1.x1 + b2.x2 + b3.x3 + b4.x4$$

Herein, $ln\mu$ is log meu that represents log of responses (Y-axis response variable i.e., AKA scores), a y-intercept, b1-b4 slopes for predictors (X-axis predictor variables i.e., age, gender, occupation, literacy) (herein, x1 was age, x2 gender, x3 occupation and x4 literacy). I corrected over and under dispersion of residuals using a ‘quasipoisson’ regression model wherever needed. I interpreted association of scores based on combined effects of demographic predictors.

I interpreted the data using measures of central tendency, standard deviation, figures and tables. I tested all hypotheses at 5% significance level. I rounded p-values into three digits after the decimal point; those smaller than three digit decimal numbers were represented as less than 0.001 (i.e., <0.001). I performed all analyses with the R statistical programme (R version 3.1.2 (2014-10-31).

3. RESULTS

3.1. Characterization of medically relevant snakes from the southeastern to the southwestern Nepal

Of 356 studied snake specimens involved in snake bites, I identified 349 specimens up to the species level; 331 specimens (95% of 349) were preserved and 18 (5%) were only photographed. This comprised 32 snake species. Eleven of the 32 species (34%) were found to be medically relevant (n = 199, i.e., 57% of total specimens) (Table 2, Figure 8) including *Bungarus walli* which was recorded with precise localities in Nepal for the first time. These snakes caused systemic envenoming (e.g., neurotoxic symptoms, coagulopathy) and/or swelling and tissue necrosis of the bitten parts.

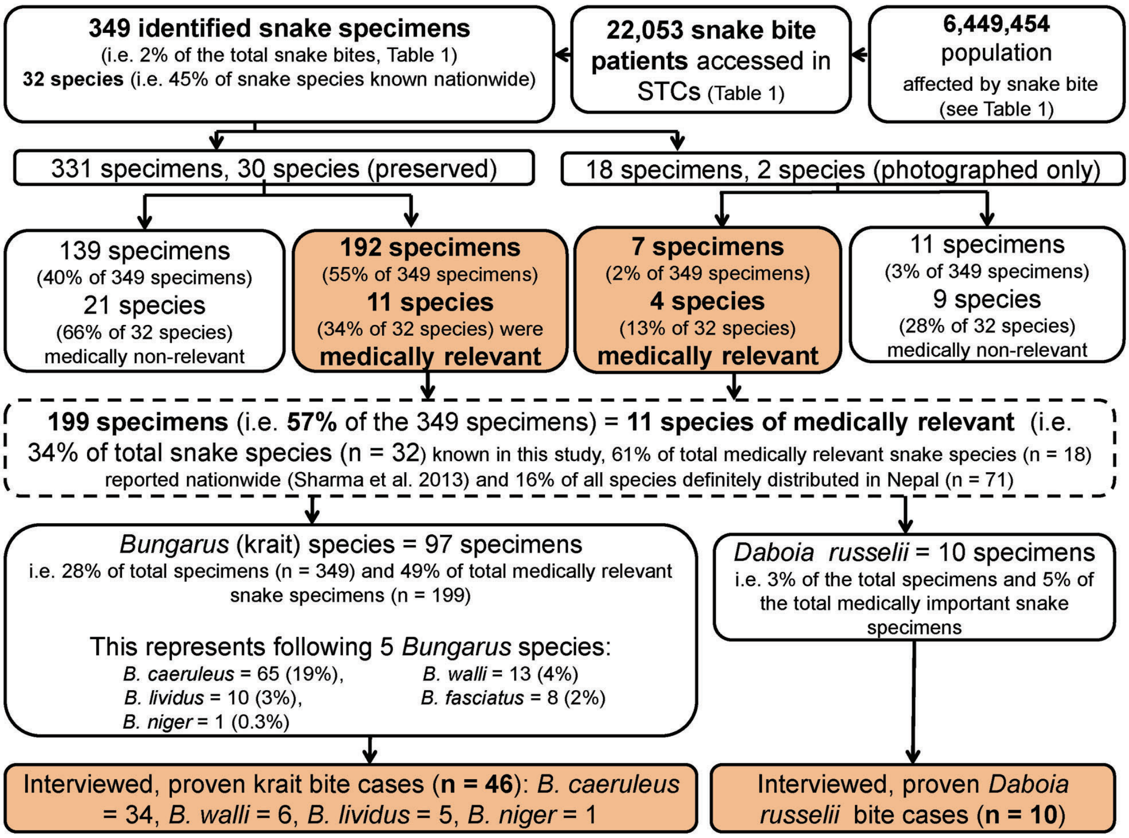


Figure 8. Flow diagram showing selected medically relevant snake specimens and confirmed krait and Russell's Viper bite cases interviewed to elucidate the circumstances of bites.

Of these 11 medically relevant snake species, eight species were proteroglyphous elapid snakes (two Asian cobras: *Naja naja* and *N. kaouthia*, five *Bungarus* species and *Ophiophagus hannah*) and three solenoglyphous viperid species (*Daboia russelii*, *Trimeresurus albolabris* and *Ovophis monticola*). The common proteroglyphous species were *Naja naja* (22%, n = 76 specimens),

Table 2. Checklist of medically relevant venomous snakes, mildly venomous snakes with uncertain medical relevance and medically non-relevant snakes involved in snake bites in Nepal.

SN	Name of snake species	Specimens (N = 349)	Relative proportion (%)	Snake bite period	Eastern Development Region											Central DR					Western DR					Altitudinal ranges (m)
					1 Jhapa	1 Morang	1 Sunsari	1	2 Ilam	2 Jhapa	2	9 Sunsari	8 Udayapur	8 Siraha	8	4 Mahottari	6 Sindhuli	7 Sarlahi	3 Chitwan	3	3 Nawalparasi	3 Gorkha	4 Nawalparasi	4	5 Nawalparasi	
2a	**Medically relevant snake species (n = 199, 57%)**																									
	A.1. Proteroglyphous snakes (Elapidae, Elapinae) causing fatal envenoming (n = 178, 51%)																									
1	*Naja naja* (Linnaeus, 1758)	76	21.8	Em(1),**M(17),**D(13),E(8),N(3)	+	+	-	+	-	+	+	+	-	+	-	+	+	+	+	+	+	-	+	-	+	88–247
2	*Bungarus caeruleus* (Schneider, 1801)	65	18.6	Em(3),M(5),D(2),E(4),**N(31)**	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+	+	+	78–262
3	*Bungarus walli* Wall 1907	13	3.7	Em(3),M(2),D(1),E(1),N(4)	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	62–171
4	*Bungarus lividus* Cantor, 1839	10	2.9	M(1),E(3),N(5)	+	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	63–147
5	*Bungarus fasciatus* (Schneider, 1801)	8	2.3	M(1)	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	+	-	-	-	-	-	93–175
6	*Naja kaouthia* Lesson, 1831	3	0.9	NA	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	+	-	-	106–185
7	*Ophiophagus hannah* (Cantor, 1799)	2	0.6	D(1)	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	90–114
8	*Bungarus niger* Wall 1908	1	0.3	E(1)	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1515
	A.2. Solenoglyphous snakes causing serious or fatal envenoming) (n = 21, 6%)																									
	Viperidae, Viperinae, causing fatal envenoming																									
9	*Daboia russelii* (Shaw and Nodder, 1797)	10	2.9	M(1),D(4),E(2),N(1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	80–118
	Viperidae, Crotalinae, causing serious envenoming																									
10	*Trimeresurus albolabris* (Gray, 1842)	10	2.9	M(1),D(1),N(2)	-	+	-	+	-	-	+	-	-	-	-	+	-	-	-	-	+	+	-	-	+	90–1223
11	*Ovophis monticola* (Günther, 1864)	1	0.3	D(1)	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1683
2b	**Species possessing venom, but additional investigation of venom effects to humans is necessary to evaluate their medical relevance (n = 71, 20%)**																									
	B.1. Opisthoglyphous (n = 29, 8%)																									
	Colubridae, Colubrinae																									
12	*Boiga trigonata* (Schneider, 1802)	13	3.7	M(2),D(1),E(2)	-	-	-	-	-	-	-	+	-	+	-	-	-	+	-	-	-	-	+	-	+	90–183
13	*Chrysopelea ornata* (Shaw, 1802)	4	1.1	M(1)	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	118–185
	Colubridae, Natricinae																									
14	*Amphiesma stolatum* (Linnaeus, 1758)	4	1.1	M(1)	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	90–199

	Homalopsidae																									
15	*Ferania sieboldi* (Schlegel, 1837)	4	1.1	NA	-	-	-	-	-	-	-	+	-	+	-	-	+	-	-	-	-	-	-	-	-	90–193
16	*Enhydris enhydris* (Schneider, 1801)	3	0.9	M(1),E(1)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	80–107
	Lamprophiidae, Psammophiinae																									
17	*Psammodynastes pulverulentus* (Boie, 1827)	1	0.3	D(1)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	312
	B.2. Aglyphous snakes (with mildly venomous toxic buccal secretions (n = 42, 12%)																									
	Colubridae, Natricinae																									
18	*Xenochrophis piscator* (Schneider, 1799)	23	6.6	D(4),E(1),M(5),N(4)	+	+	-	+	-	+	+	+	-	+	-	-	-	-	+	+	+	-	+	-	+	90–217
19	*Xenochrophis sanctijohannis* (Boulenger, 1890)	1	0.3	E(1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	189
	Colubridae, Colubrinae																									
20	*Coelognathus helena* (Daudin, 1803)	17	4.9	M(1),D(1),N(1)	-	+	-	+	-	+	-	-	-	-	-	-	-	-	+	+	+	-	+	-	+	101–214
21	*Coelognathus radiatus* (Boie, 1827)	1	0.3	D(1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	174
2c	**Aglyphous, nonvenomous and medically not relevant snakes (n = 79, 23%)**																									
	Colubridae, Colubrinae																									
22	*Lycodon aulicus* (Linnaeus, 1754)	40	11.5	M(5),D(2),E(9),N(4)	+	+	-	+	-	+	-	+	-	+	-	+	+	+	-	-	+	-	+	-	+	90–799
23	*Ptyas mucosa* (Linnaeus, 1758)	10	2.9	M(4),D(2)	-	+	-	+	-	-	+	-	-	-	-	-	+	-	-	+	-	-	+	-	+	105–199
24	*Oligodon arnensis* (Shaw, 1802)	5	1.4	M(1),E(1)	-	-	-	-	-	-	-	+	-	+	-	+	-	-	-	-	-	-	+	-	+	90–185
25	*Lycodon striatus* (Shaw, 1802)	3	0.9	M(2),E(1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	100–115
26	*Dendrelaphis tristis* (Daudin, 1803)	2	0.6	NA	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	90
27	*Lycodon jara* (Shaw, 1802)	1	0.3	NA	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	130
28	*Oligodon cyclurus* (Cantor, 1839)	1	0.3	NA	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	118
	Colubridae, Sibynophiinae																									
29	*Sibynophis sagittarius* (Cantor, 1839)	4	1.1	NA	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	+	106–185
	Boidae, Erycinae																									
30	*Eryx conicus* (Schneider, 1801)	2	0.6	E(1),D(1)	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	114–124
	Boidae, Erycinae																									
31	*Python bivittatus* Kuhl, 1820	5	1.4	D(2),N(1)	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	+	95–189
	Typhlopidae, Asiatyphlopinae																									
32	*Indotyphlops braminus* (Daudin, 1803)	6	1.7	D(1),E(1)	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	90–130

Numerals 1 through 9 in the column of Development Region (DR) are codes for the study centres (see Table 1 for the details).

Bungarus caeruleus (19%, n = 65), *B. walli* (4%, n = 13) and *B. lividus* (3%, n = 10). The common solenoglyphous species included *D. russelii* (3%, n = 10) and *T. albolabris* (3%, n = 10).

Three medically highly relevant venomous snakes were found to be widely distributed from the eastern to the western Nepal: the Common Cobra (*N. naja*), the Common Krait (*B. caeruleus*) and the Green Pit Viper (*T. albolabris*). Table 2.a shows the general geographic distribution of these species in different regions and districts where they caused bites. Patients from 12 districts brought these snakes that were found to be distributed between 62–1,683 m asl (median = 124, 95% CI = 134–144, sd = 160, mean ± SEM = 159.9 ± 8.6, p = <0.001, Table 2.a, Figure 9).

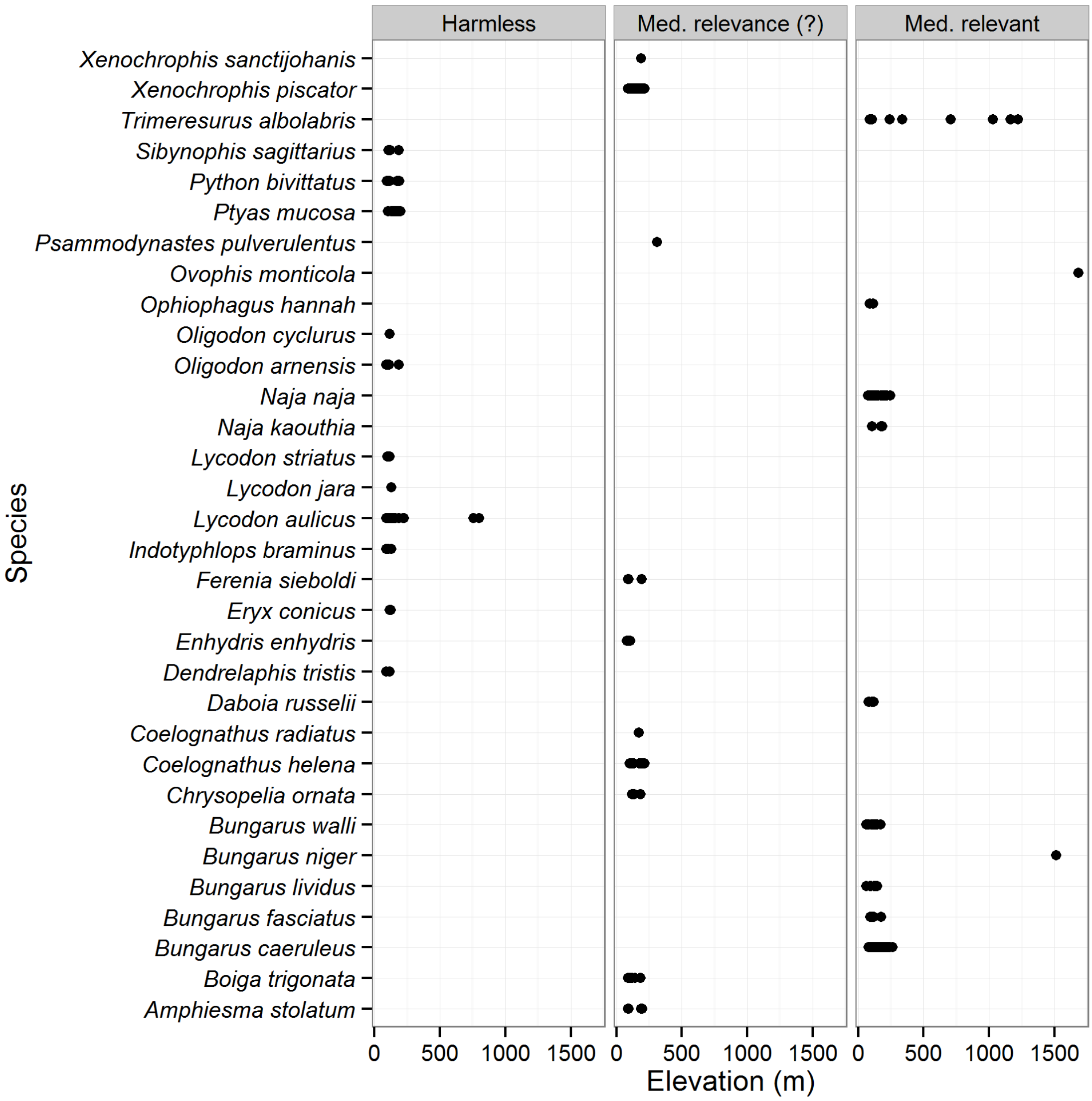


Figure 9. Altitudinal distribution profile of medically relevant snakes and those with doubtful medical relevance. Herein, Med. = medically.

3.1.1. Snakes involved in bites with doubtful medical relevance

Ten (n = 71, 20%) of the 32 snake species were not considered to be medically relevant as envenoming caused only pain at the bite site, slight bleeding from the wound, local swelling limited to bite site only and local burning sensation that lasted few hours only according to the medical personnel involved in treatment of the respective snake bites.

Six of these 10 species were opisthoglyphous and four species aglyphous snakes. The most common opisthoglyphous snake was *Boiga trigonata* (4%, n = 13) and the aglyphous snake was *Xenochrophis piscator* (7%, n = 23) (Table 2.b, Appendix 2). The other 11 species were harmless (Table 2.c, Appendix 2). All these snakes were found to occur below 1,000 m asl (Figure 9, Table 2. b, c).

3.1.2. Species accounts of medically relevant snakes in Nepal

Herein I describe distribution pattern, identification and medical significance of 18 medically relevant snake species (10 species of Elapidae family, seven of Viperidae family and one of Colubridae family, Figure 10–52) that are definitely distributed in Nepal. Only 11 species (eight of Elapidae and three Viperidae) were known to be involved in snake bites in this study.

3.1.2.1. Family Elapidae

The family Elapidae comprises nearly 355 species belonging to 55 genera worldwide (Uetz and Hošek, 2015). They are distributed in the Americas, Asia, Africa and Australia. In Nepal, 10 elapid species belong to four genera (Sharma et al., 2013b). In the present study, I identified eight elapid species of three genera to be of medical importance: *Bungarus, Naja* and *Ophiophagus*.

3.1.2.1.1. Genus *Naja* Laurenti, 1768 (cobras)

At least 26 *Naja* species (i.e., cobras) are distributed worldwide of which 15 species inhabit Africa and 11 Asia (Wallach et al., 2009). The Common Cobra (*Naja naja*) and the Monocellate Cobra (*Naja kaouthia*) are present in Nepal (Sharma et al., 2013b). Both *Naja* species have been found to be involved in snake bites during this study. Neurotoxicity is the main effect of their venom. Cobra bites are not well reported from the mid- and far-western Nepal, although cobra bites are likely to occur in those regions. *Naja* represents the medically most important snake in Nepal.

***Naja naja* (Linnaeus, 1758)**

Common/Spectacled Cobra (Goman, Nag, Dui Thople Kalo Goman in Nepali)

Coluber naja Linnaeus 1758; type locality: India orientali; holotype: BMNH 1946.1.18.50

Geographic distribution

Widely distributed in the lowlands to mid-hills of Nepal, India, Bangladesh, Sri Lanka and Pakistan (Warrell, 1995, Khan, 2004, Whitaker and Captain, 2004, Kabir, 2013, Pyron et al., 2013b, Sharma et al., 2013b, Khan, 2014). In Nepal, the snake is distributed throughout the lowlands and in some hills at an altitudinal range between <100 to 2,000 m asl (Shah, 1995, Kabisch, 2002b, Shah and Tiwari, 2004, Pandey, 2012, Sharma et al., 2013b) (Figure 10).

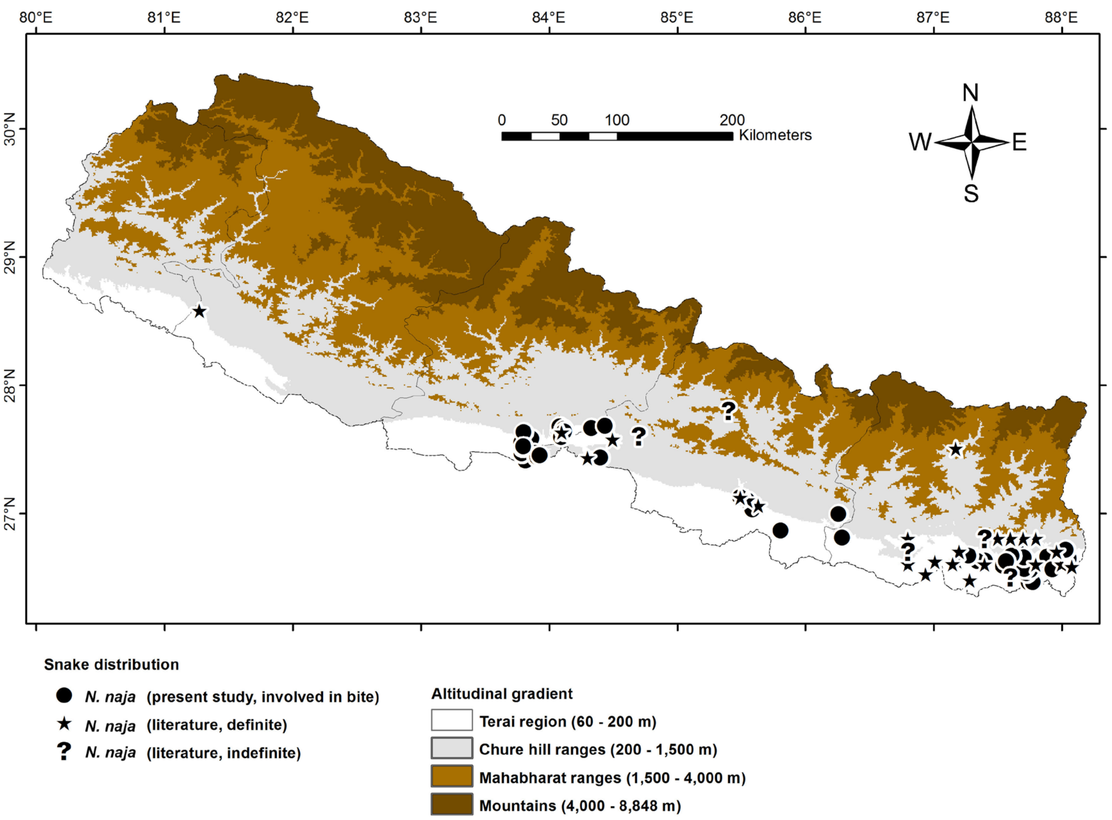


Figure 10. Distribution of *Naja naja* in Nepal.

Identification

Naja naja differs from *N. kaouthia* in having (1) a white spectacle-shaped or Y- or V-shaped marking edged with black lines on the hood (vs. white O- or oval shaped marking, i.e., monocellate, with a black centre in *N. kaouthia*), (2) 21–25 dorsal scale rows at midbody (vs. 21 in *N. kaouthia*) and (3) 176–200 ventrals and 53–68 subcaudals (vs. 164–197 and 43–61, respectively, in *N. kaouthia*). *Naja naja* differs from *Ophiophagus hannah* in having (1) small occipital scales (vs. a pair of large occipital scales in *O. hannah*) and (2) divided subcaudals (vs. anteriorly undivided and posteriorly divided in *O. hannah*). *Naja naja* differs from all species of *Bungarus* in having (1) the third supralabial in contact with the posterior nasal (vs. not in contact in all *Bungarus* species, (2) non-enlarged middorsal scales (vs. clearly enlarged in *Bungarus* species) and (3) divided subcaudals (vs. undivided in *Bungarus* species, Figure 11–14).

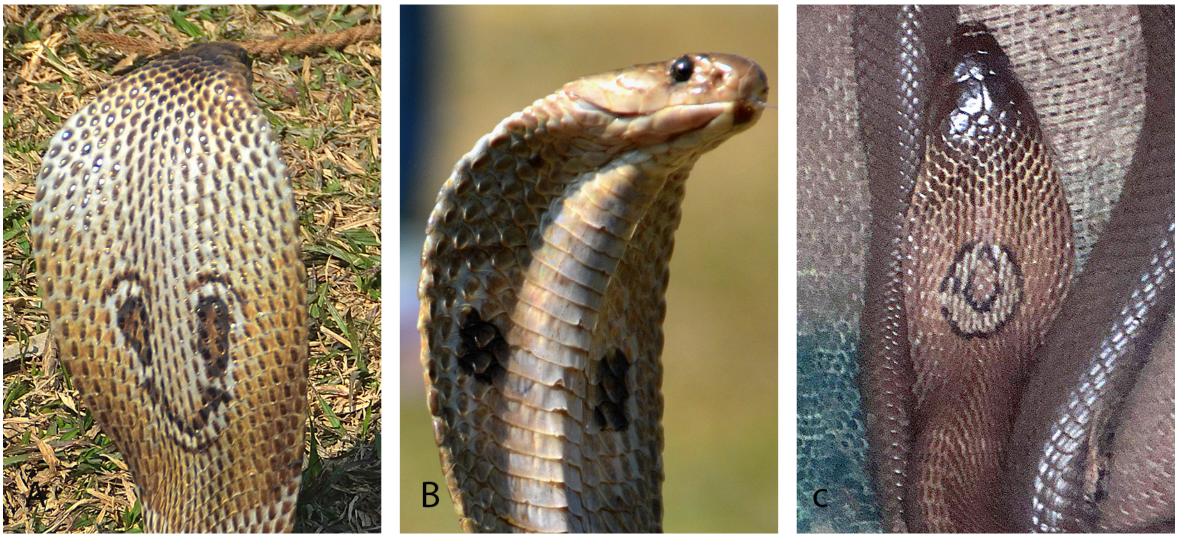


Figure 11. Hood marks of *Naja* species. **A,B:** *Naja naja* showing typical white spectacle shaped or V-shaped marking edged with black lines (A) and two black spots on either side of the throat (B) (suburbs of Biratnagar in eastern Nepal). **C:** *Naja kaouthia* showing hood possessing a dirty white annular (O-shaped) marking with a brown centre encircled by black line (indoors, western Chitwan, TL = 1.2 m, photo by S. Sapkota).

Medical importance

Naja naja is one of the most common snakes in Nepal causing numerous human envenomings, mainly during outdoor activities. Envenomings are also common in Bangaldesh (Kabir, 2013), India (Bawaskar and Bawaskar, 2004) and Sri Lanka (Kularatne et al., 2009). Up to 113 mg venom can be obtained by milking; 15 mg of the venom may kill an adult human (Kabisch, 2002b). Therefore, envenoming due to its bite is very serious and may cause death. Fang marks are often clearly seen; severe pain may begin immediately after the bite; local swelling of the bitten part may progress, blistering or even tissue necrosis may occur (Reid, 1964, Kularatne et al., 2009, Pandey et al., in progress). The envenoming effects develop as early as 15 minutes after the bite (Warrell, 1995), paralysis of the peripheral nervous system gradually leads to respiratory paralysis, asphyxia and death.

Remarks

Among the study specimens, *Naja naja* was the most common and widely distributed medically relevant snake (Table 2.a). The snake was often reported from human inhabited areas. Fleming and Fleming (1973) cited its likely distribution in the Kathmandu Valley. Bites occur at any time of the day in human activity areas in the lowlands and intermediate hills (Figure 10). A prospective study of confirmed *N. naja* bites is necessary to understand the proportion of local tissue necrosis and neurotoxicity due to bites of Nepalese cobras to suggest and to evaluate the applicability of recommended pressure immobilization first aid (Sutherland et al., 1979, World Health Organization, 2010).

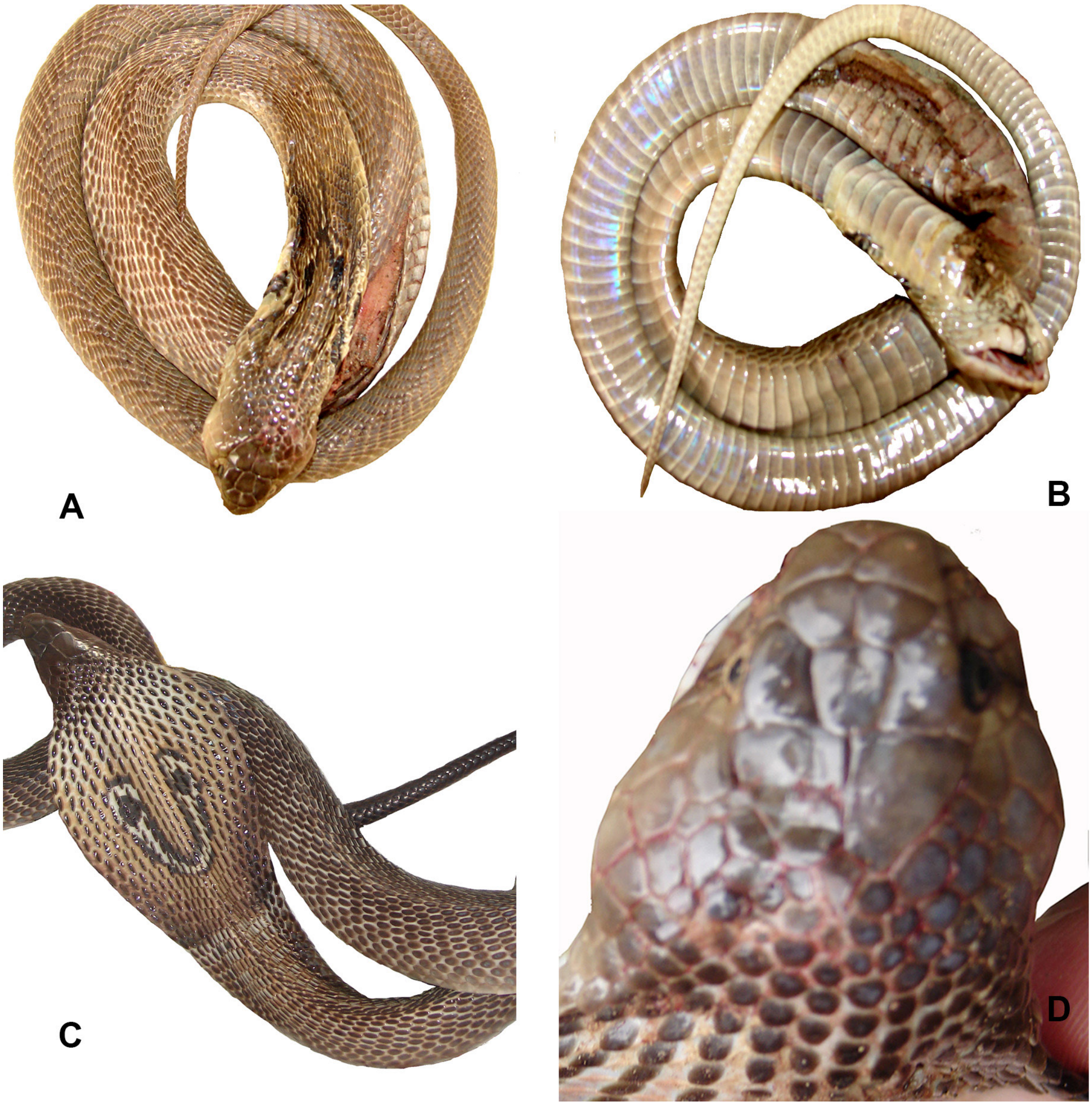


Figure 12. Dorso and ventral colouration and subcaudal pattern in *Naja naja*. **A:** dorsal view and **B:** pale grey ventrals and divided subcaudals; a dead specimen, SVL = 0.705 m, premises of an Army Camp in Sindhuli District, central Nepal; head and midbody was damaged. **C,D:** loosely arranged dorsal scales with whitish skin on the hood, neck and body. **C:** a live specimen collected from Urlabari VDC near Bargachhichowk, Morang, eastern Nepal. **D:** a dead specimen from Dudhouli, Sindhuli. The colour and subcaudal patterns are the same as *N. kaouthia*.

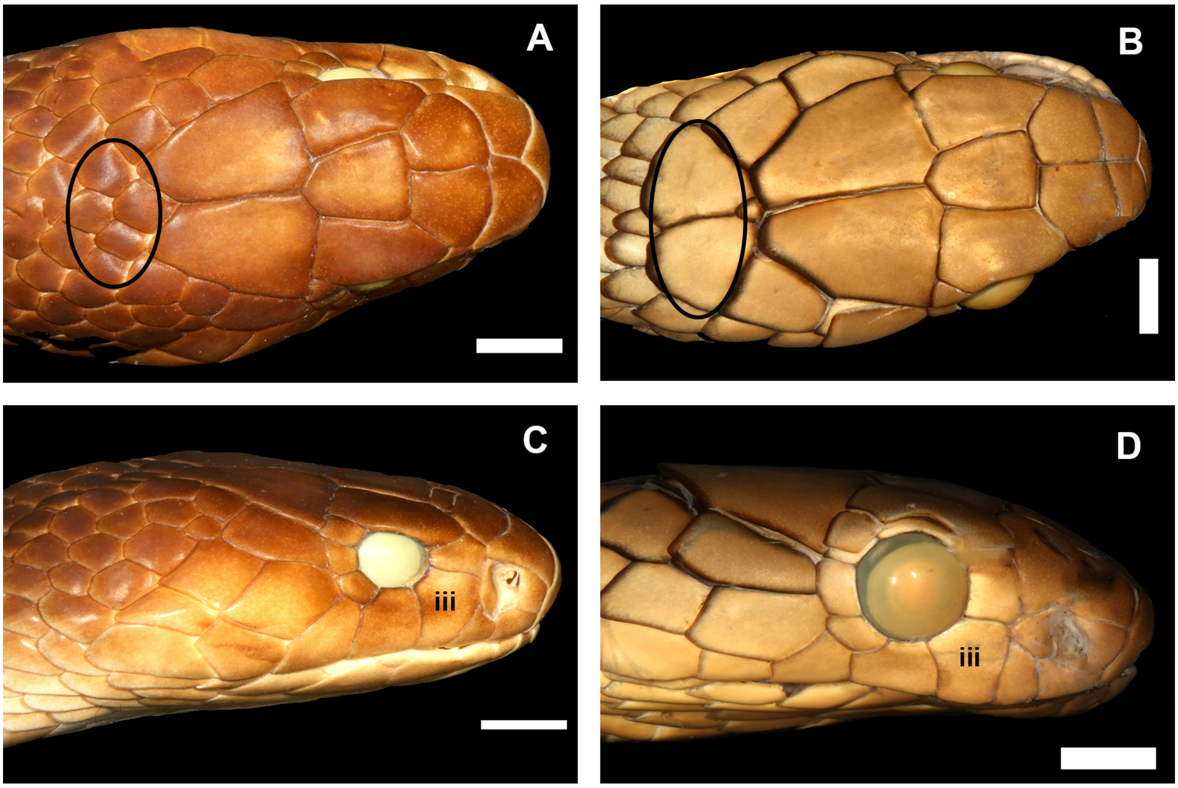


Figure 13. Occipital scales and third supralabial on head of *Naja naja* and *Ophiophagus hannah*. **B:** a pair of enlarged occipital (= parietal) scales of *O. hannah* (compare the similar scales in the part of figure **A**, the eliptical shape highlights occipital scales). **iii** in figure **C** and **D** shows third supralabial scale in contact with the posterior nasal, the preocular and the eye. **A** and **C** are *Naja naja* and **B** and **D** *Ophiophagus hannah*. Scale bar = 5 mm.

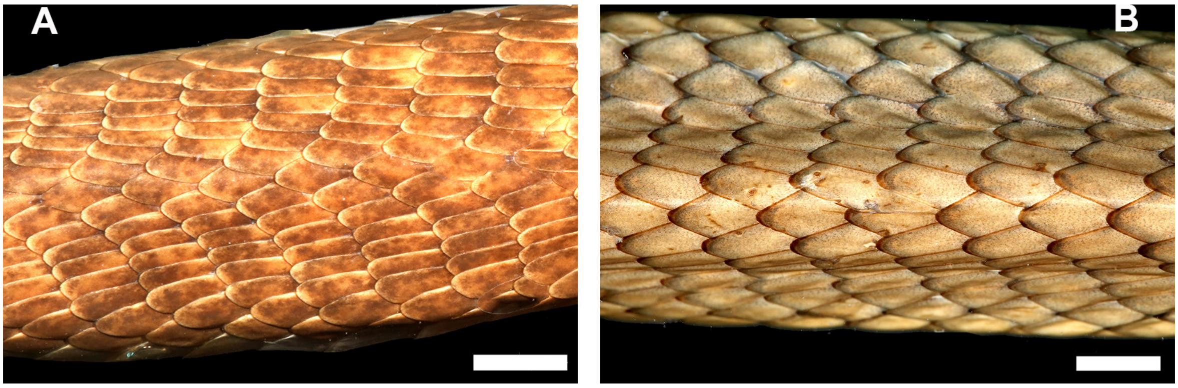


Figure 14. Non-enlarged middorsal scales of *Naja naja* (**A**) and *Ophiophagus hannah* **(B).** Scale bar = 5 mm.

***Naja kaouthia* Lesson, 1831**

Monocellate Cobra, Monocled Cobra (Goman, Paniyadarad, Ek Thople (Seto) Goman Sarpa in Nepali)

Naja kaouthia Lesson 1831; type locality: Bengal in India; holotype: formerly MNHN, illustrated in Lesson, 1832 in Bélanger (1831–1834: pl. 2)

Geographic distribution

Naja kaouthia is more widely distributed than *N. naja* in lowlands to the upper hills in northeastern India, Bangladesh, Myanmar, northern Thailand, Cambodia, Laos, southern Vietnam, northwestern Malaysia and Yunnan Province of China (Wüster and Thorpe, 1992, Warrell, 1995, Slowinski and Wuster, 2000, Gumprecht, 2009). In Nepal, the snake is distributed throughout the lowlands and upper hills in an altitudinal range between <100 to 3,200 m asl (Acharji, 1961, Kabisch, 2002b, Pandey, 2012, Sharma et al., 2013b) (Figure 15).

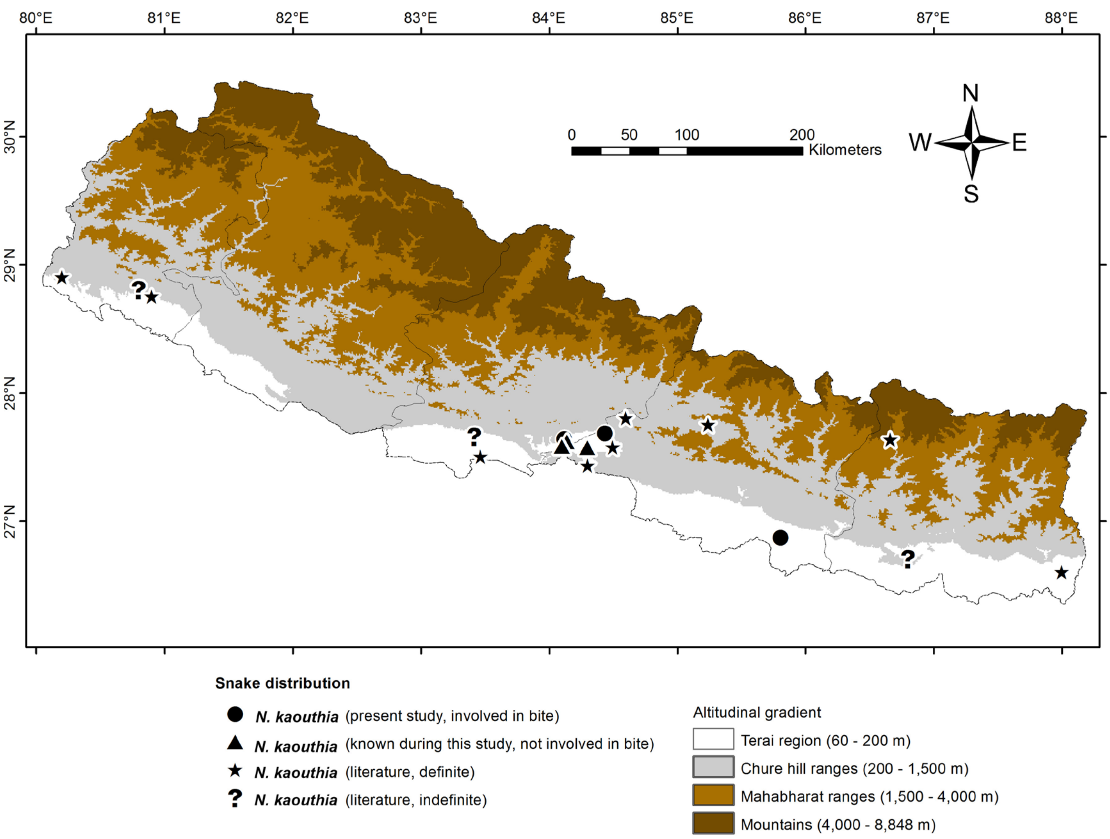


Figure 15. Distribution of *Naja kaouthia* in Nepal.

Identification

Naja kaouthia differs from *N. naja* in having (1) white O- or oval shaped marking, i.e., monocellate, with a black centre on the hood (vs. a white spectacle-shaped or Y- or V-shaped marking edged with black lines in *N. naja*,), (2) 21 dorsal scale rows at midbody (vs. 21–25 in *N. naja*) and (3) 164–197 ventrals and 43–61 subcaudals (vs. 176–200 and 53–68, respectively, in *N. naja*). *Naja kaouthia* differs from *Ophiophagus hannah* in having (1) small occipital scales (vs. a pair of large occipital scales in *O. hannah*) and (2) divided subcaudals (vs. anteriorly undivided and posteriorly divided in *O. hannah*). *Naja kaouthia* differs from all species of *Bungarus* in having (1) the third supralabial in contact with the posterior nasal (vs. not in contact in all *Bungarus* species) (2) non-enlarged middorsal scales (vs. clearly enlarged in *Bungarus* species) and (3) divided subcaudals (vs. undivided in *Bungarus* species, Figure 11–14, 16).

Medical importance

Despite its wide distribution, *Naja kaouthia* was found to be less involved in bites compared to *N. naja* in this study. Envenoming by *N. kaouthia* causes local swelling of the bitten part that may last for up to 10 days and eventually results in tissue necrosis (Reid, 1964, Warrell, 1995, Reali et al., 2003). Neurotoxic venom effects may develop within 30 minutes to 19 hours after the bite (Warrell, 1995) progressing to paralysis of the peripheral nervous system (e.g., ptosis, inability to speak or open mouth or swallow) resulting in respiratory paralysis, asphyxia and death. These effects may not be resolved by the antivenom developed against the venom of *N. naja* from India. Therefore, bites due to *N. kaouthia* should be considered seriously. A polyvalent antivenom should be produced using venoms of *N. kaouthia* as well.

Remarks

The variation of bite patterns between the similar looking *Naja naja* and *N. kaouthia* may correspond to reports on its population density, niche selection and/or behaviour. However, its records at 150 m asl in Siddharthanagar, Rupandehi, the western Nepal by Kramer (1977), at 185 m asl in Baghauda, Chitwan, the Central Nepal by Pandey (2012) and up to 3,200 m asl in Takasindu, Solukhumbu by Acharji (1961) suggest its wide distribution and risk of envenoming throughout the lowlands and lower mountains of Nepal.

Figure 16. Dorsal and ventral colouration in *Naja kaouthia*. A dead specimen brought by a patient to Bharatpur Hospital, southcentral Nepal; SVL = 0.75 m. **A:** a white annular marking with a black centre on hood. **B:** ventral view showing two dark bands on the anterior belly and paired subcaudals.

3.1.2.1.2. Genus *Ophiophagus* Günther, 1864

This genus *Ophiophagus* contains only a single species, i.e., *Ophiophagus hannah*. It is rarely involved in snake bites. Neurotoxicity is the main effect of its venom.

Ophiophagus hannah (Cantor, 1836)

Hamadryad, King Cobra (Raj Goman, Nag Raja, Kalinag, Kenwata in Nepali)

Hamadryas hannah Cantor 1836; type locality: Sundarbans, near Calcutta, India; holotype: BMNH 1996.451

Geographic distribution

Widely distributed in India, Bangladesh, Bhutan, Myanmar, Thailand, China, Cambodia, Laos, Vietnam, Hongkong, Malayan Peninsula, Indonesia and Philippines (Kabisch, 2002b, Shah and Tiwari, 2004, Pandey, 2012, Sharma et al., 2013b). In Nepal, this species is distributed throughout the lowlands (in <100 m asl) (Fleming and Fleming, 1973, Shah, 1995, Rai, 2003, Pandey, 2012, Chhettri and Chhetry, 2013) to the upper hills up to 2,460 m asl (Shah, 2000) (Figure 17).

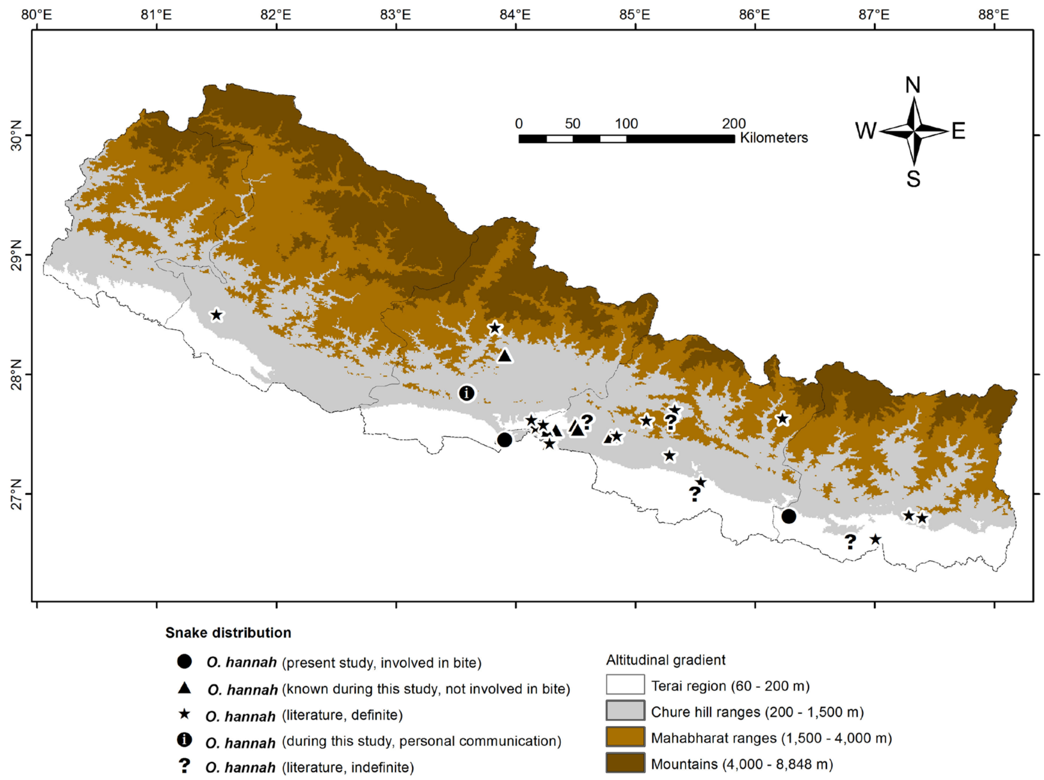


Figure 17. Distribution of *Ophiophagus hannah* in Nepal.

Identification

Ophiophagus hannah differs from *Naja* species known to be distributed in Nepal in having (1) a pair of large occipital scales in *O. hannah* (vs. corresponding occipital scales smaller in *Naja* species), (2) anteriorly undivided and posteriorly divided subcaudals (vs. all divided in *Naja* species), (3) 15 dorsal scale rows at midbody (vs. 21 in *N. kaouthia*, 21–25 in *N. naja* and (4) patternless top of the hood (vs. white O- or oval shaped marking, i.e., monocellate, with a black centre in *N. kaouthia*, a white spectacle shaped or Y- or V-shaped marking edged with black lines on the hood in *N. naja*). *Ophiophagus hannah* differs from all species of *Bungarus* in having non-enlarged middorsal scales (vs. clearly enlarged middorsal scales in *Bungarus* species). *Ophiophagus hannah* differs from all species of *Bungarus* (except *B. bungaroides*) in having (1) the third supralabial in contact with the posterior nasal (vs. not in contact in all *Bungarus* species) and (2) anteriorly undivided and posteriorly divided subcaudals (vs. undivided in *Bungarus* species). *Ophiophagus hannah* differs from *B. bungaroides* in having non-enlarged middorsal scale row (vs. clearly enlarged in *B. bungaroides*, Figure 11–14, 16, 18,19).

Figure 18. Mixed type of subcaudals (single and paired) in *Ophiophagus hannah.* Scale bar = 5 mm.

Medical importance

No confirmed case of *Ophiophagus hannah* bite has been reported in Nepal so far. Because of its diurnal habit, noticeably large in size, shy nature, preference of avoiding human encounters and emission of growling sound when cornered, snake bites in natural habitats are rare worldwide (Tin-Myint et al., 1991). However, it may bite when provoked. Most bites due to this snake occurred in people handling the snake (Tin-Myint et al., 1991). However, people working in forested areas in the tropics and subtropics are prone to being bitten by this snake.

Envenoming effects like dizziness may appear as early as 15 minutes after a bite and respiratory paralysis symptoms appear as early as 30 minutes after *Ophiophagus hannah* bite (Warrell, 1995). Envenoming symptoms include local swelling of the bite site, increasing up to the distal part of bitten body part (Tun-Pe et al., 1995b). Its venom is less necrotic than that of *Naja* species (Warrell, 1995). Like in *Naja* species bites, respiratory paralysis is apparent (Tun-Pe et al., 1995b). Death may occur due to asphyxia within 20 minutes (Noble, 1904) to 12 hours (Haile, 1963) after the bite. *Ophiophagus hannah* can inject large amounts of venom (Muthusamy and Gopalakrishnakone, 1990). Milking may yield about 420 mg venom (dry weight) (Ganthavorn, 1969); 12 mg is considered enough to kill an adult human (Kabisch, 2002b). Because of the high venom yield, its bite is believed to be highly lethal.

This venom is not included in the production of the Indian polyvalent antivenom that is used in Nepal. Therefore, large amounts of antivenom may be needed for neutralization of its venom effects. The neutralization property of Indian antivenom of Nepalese *O. hannah* venom has not been studied yet.

Remarks

I found only two *Ophiophagus hannah* specimens preserved in snake bite treatment centres in southwestern and southeastern Nepal without patient details. However, this indicates that bites to humans are rare in Nepal (Table 2.a). Similarly, rare bites have been described in Myanmar (Tun-Pe et al., 1995b) and South Asia (Tun-Pe et al., 1995b). Although the snake prefers undisturbed habitats (Whitaker and Captain, 2004), its occurrence in human settlements in Sauraha (Figure 19, Pandey et al., under internal review) suggests that it is a potentially dangerous snake posing risks of envenoming in the lowlands of Nepal. Because this species is likely to occur up to 2,500 m asl (Shah, 2000) throughout the Mahabharat ranges and it was also reported for southeastern Tibet bordering Nepal at about 4,000 m asl (Zhao and Adler, 1993), people living at these higher elevations are also exposed to snake bite risk by this species. Because of the possibility of large amount of venom injection (Muthusamy and Gopalakrishnakone, 1990) and the unproved efficacy of Indian polyvalent antivenom against Nepalese King Cobra venom, great care should be taken in cases of bites of this species.

It is considered a rare snake in Nepal (Shah, 2000). However, more field work is need to understand the actual conservation status of this species in Nepal.

Figure 19. *Ophiophagus hannah* translocated into Chitwan National Park from Sauraha village in Chitwan. Photo provided by S. Sapkota, TL = 3.75 m.

3.1.2.1.3. Genus *Bungarus* Daudin, 1803 (kraits)

The genus *Bungarus* currently represents 16 species that are distributed in Asia (Abtin et al., 2014, Wallach et al., 2014). All *Bungarus* species are medically important. The venom of kraits is of neurotoxic nature. In Nepal, of the six species recorded (Sharma et al., 2013b), five were found to be involved in snake bites.

***Bungarus caeruleus* (Schneider, 1801)**

Common Krait, Indian Krait (Gadaich, Bairi Karet, Seto-kalo Chure Sarpa, Chure Sarpa in Nepali)

Pseudoboa caerulea Schneider 1801; type locality: Vizagapatam, Andhra Pradesh, India; syntype: ZMB 2787

Geographic distribution

Widely distributed in the lowlands and intermediate elevations of Nepal, India, Sri Lanka, western Bangladesh, the upper and lower Indus valley along the Indus river of Pakistan and in some eastern valleys of Afghanistan (Khan, 2004, Whitaker and Captain, 2004, Kabir, 2013, Pyron et al., 2013b, Sharma et al., 2013b). In Nepal, the snake is distributed from less than 100 to 1,525 m asl (Schleich and Kästle, 2002, Shah and Tiwari, 2004, Pandey, 2012, Sharma et al., 2013b) (Figure 20).

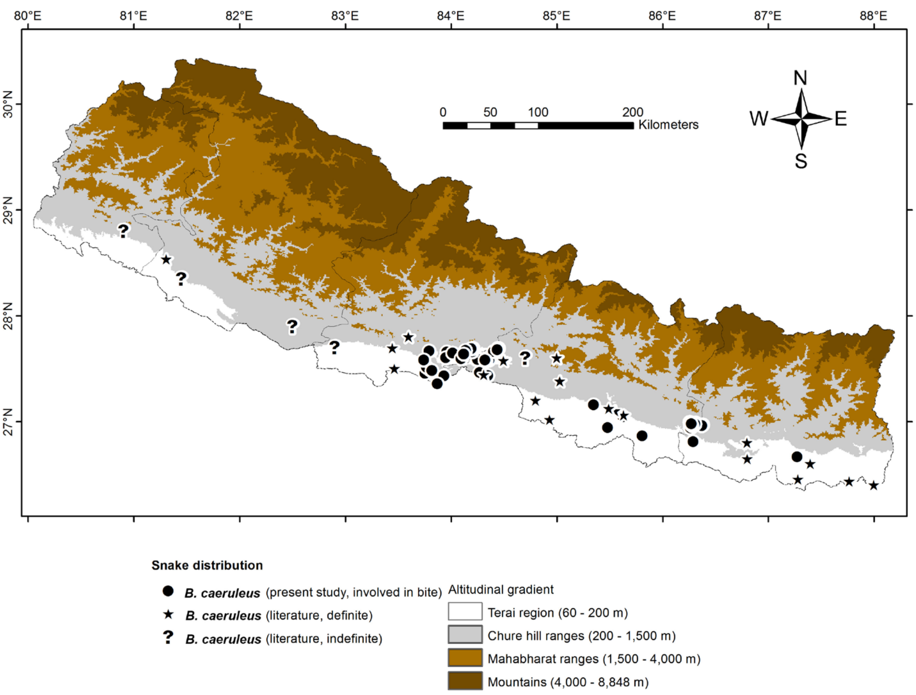


Figure 20. Distribution of *Bungarus caeruleus* in Nepal.

Identification

Bungarus caeruleus differs from all other Nepalese *Bungarus* species except *B. walli* and *B. bungaroides* in having narrow white body bands (vs. body uniform black in *B. lividus* and *B. niger* or with broad yellow bands in *B. fasciatus*). *Bungarus caeruleus* differs from *B. walli* in having (1) 15 dorsal scale rows at midbody (vs. 17–19 rows in *B. walli*) and (2) white dorsal bands at least one scale wide (vs. less than one scale wide in *B. walli*). *Bungarus caeruleus* differs from *B. bungaroides* in having (1) a pale, patternless belly (vs. dark belly with white bands in *B. bungaroides* and (2) undivided subcaudals (vs. divided in *B. bungaroides*). *Bungarus caeruleus* differs from similar looking colubrid species *Lycodon aulicus* and *L. striatus* in having (1) narrow white or pale yellowish cross-bands on shiny black, brownish black or grey body and tail (vs. white bands broader, not crossing the belly and disappearing on posterior part of body and on the tail in *L. aulicus* and *L. striatus* (2) enlarged middorsal scales (vs. non-enlarged in *L. aulicus* and *L. striatus*) and (3) no loreal scale (vs. present in *L. aulicus* and *L. striatus*). *Bungarus caeruleus* differs from *Naja naja, N. kaouthia, Ophiophagus hannah* and *Sinomicrurus macclellandi* in having the third supralabial not in contact with the posterior nasal (vs. in contact in those species, Figure 21–25).

Medical importance

Bungarus caeruleus is one of the most common venomous snakes in Nepal and is responsible for the majority of snake bite deaths (Epidemiology and Disease Control Division, 2011). Typically, sleeping people are bitten. Up to 30 mg venom can be obtained by milking (Kabisch, 2002b). About 2.5 mg venom is considered to be the fatal dose for an adult human (Kabisch, 2002b). Therefore, envenoming by this species may cause death within a short time. However, often several hours elapse between the bite and the onset of the first neurotoxic symptoms like ptosis. Its venom initially causes headache and abdominal pain (Hati et al., 1988, Theakston et al., 1990, Ariaratnam et al., 2008). Gradually, paralysis of the peripheral nervous system develops leading to respiratory arrest and death due to suffocation.

Remarks

Bungarus caeruleus was the second most common (n = 65) snake in this study causing high mortality. The majority of specimens were known from southcentral and southwestern Nepal. Although Kabisch (2002b) and Rai (2003) reported it from the eastern lowlands of Nepal, I did not find any specimens in those areas except few specimens deposited in a STC in Itahari without patient and locality details.

Bungarus caeruleus is distributed in the mid- and far-west (O'Shea, 1996,

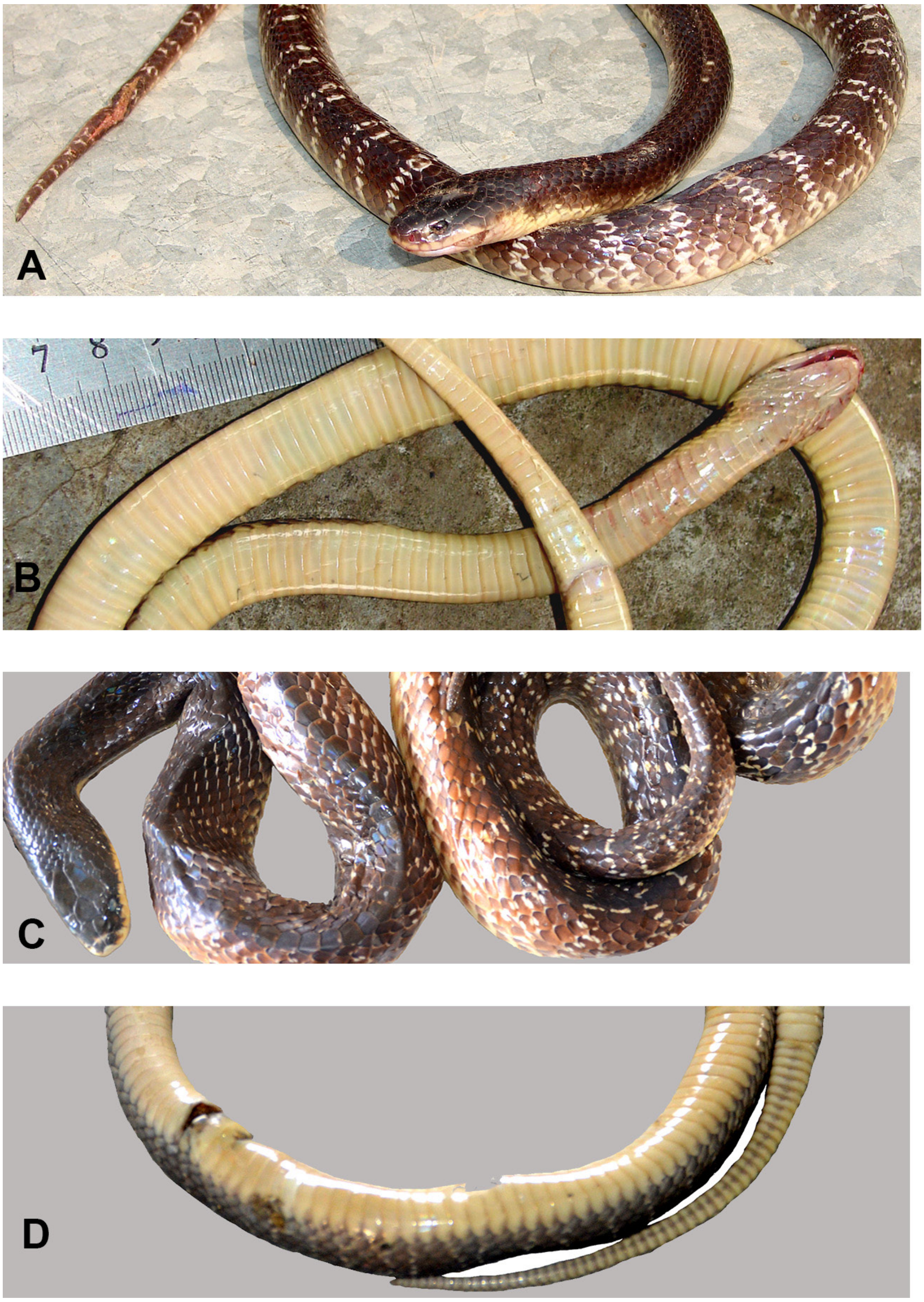


Figure 21. Dorsal and ventral colouration in *Bungarus caeruleus* and *B. walli*. **A,C:** dorsal view and **B,D:** ventral view of the respective snakes. **A,B:** *Bungarus caeruleus* (SVL = 0.738 m, Saulibas, Baghauda, Chitwan). **C:** *Bungarus walli* (Biratnagar town, Morang District, SVL = 0.137 m, dorsal scale rows at midbody = 17). **D:** *Bungarus walli* with dark pigmentation on subcaudals (Damak snake bite treatment centre).

Shah and Tiwari, 2004), in other lowland regions usually below 400 m asl (Fleming and Fleming, 1973) and in areas up to 1,400 m asl as reported by Shrestha (2001) in Nepal and up to 1,525 m asl in Almora, Utterakhand, India as reported by Kabisch (2002b) which points to risks of envenoming throughout the lowlands to lower hills of Nepal. Since they bite people while sleeping, usually bite marks are hardly seen due to its short and thin fangs and no pain of the affected body part except slight pinning sensation, the diagnosis of a krait bite is complicated. Because of the often painless bite, the sleeping person awakes by complains of abdominal pain and with first paralytic symptoms of the eyelids and other face muscles (Warrell, 1995).

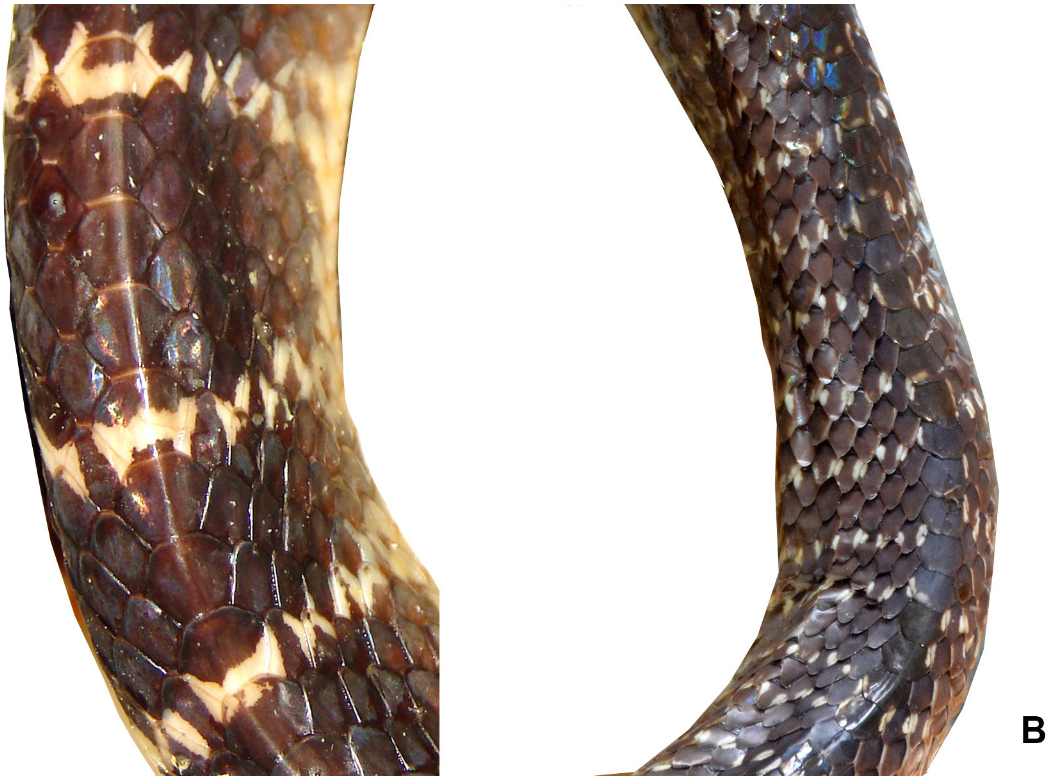


Figure 22. Clearly enlarged middorsal scales with white bands in *Bungarus caeruleus* (**A**) and *B. walli* (**B**).

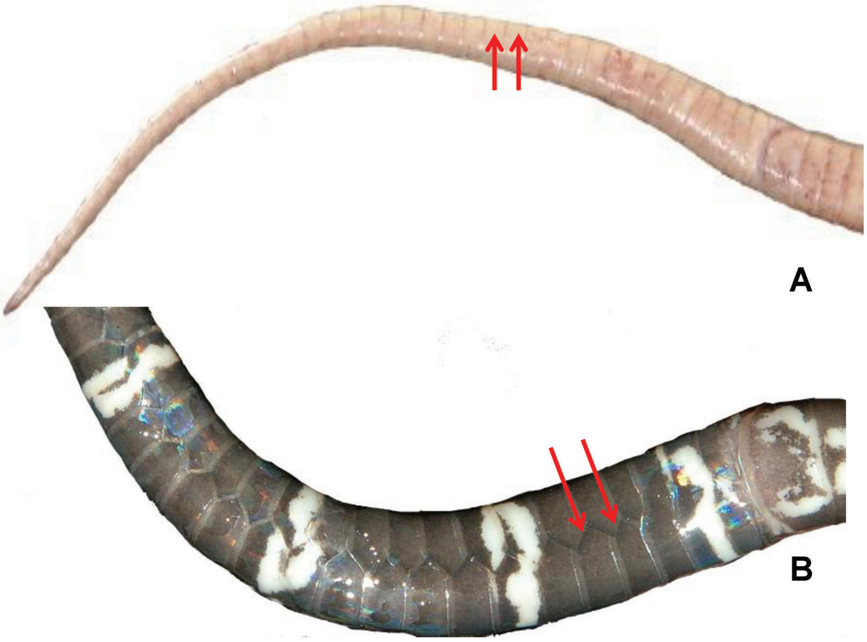


Figure 23. Subcaudal pattern in *Bungarus* species. **A:** unpaired subcaudals of *B. caeruleus* (brought to Bharatpur Hospital). The other four species (*B. walli, B. lividus, B. niger, B. fasciatus*) also have unpaired subcaudals. But, *B. bungaroides* (**B**) has paired ones (photo by S. Dalvi, from Eagle Nest, Arunachal Pradesh, India, cited in Sharma et al. 2013). Additionally, these subcaudals have white rings.

Figure 24. Absence of loreal scales in *Bungarus* species. **A:** third supralabials in *Bungarus caeruleus* without touching postnasal. **B:** *Lycodon aulicus* showing position of the loreal scale. Scale bar = 5 mm.

Figure 25. Snakes confused with kraits. **A:** *Lycodon aulicus* resembling *Bungarus caeruleus* and *B. walli* by having white bands on body (a live specimen, Damak snake bite treatment centre, Jhapa). **B:** *Oligodon arnensis* resembling *B. fasciatus* by having dark bands on brown body, near Bharatpur Airport, Chitwan.

Bungarus walli Wall, 1907

Wall's Krait (Gadaich, Bairi Karet, (Seto-kalo) Chure Sarpa in Nepali)

Bungarus walli Wall 1907; type locality: Oudh, Fyzabad, Uttar Pradesh, India; syntypes: BNHM 2169, BMNH 1946.1.18.51–53, ZSI 15727

Geographic distribution

Very little is known about its distribution. Known to be distributed in Nepal, India and Bangladesh (Wall, 1907, Khan, 1985, Azam et al., 2011). In Nepal, *Bungarus walli* is distributed in an altitudinal range of 60–170 m asl in the southeastern lowlands as shown in this study (Table 2, Figure 26).

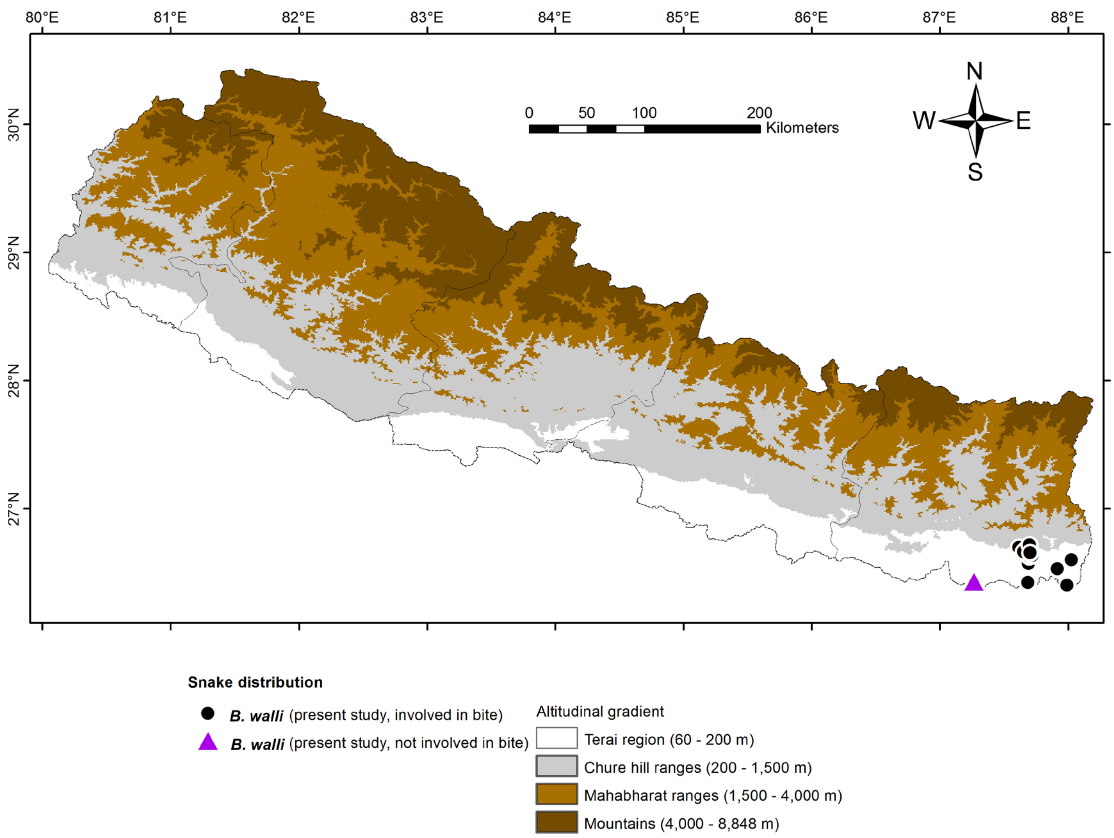


Figure 26. Distribution of *Bungarus walli* in Nepal.

Identification

Bungarus walli differs from all other Nepalese *Bungarus* species except *B. caeruleus* and *B. bungaroides* in having narrow white body bands (vs. body uniform black in *B. niger* and *B. lividus* or with broad yellow bands in *B. fasciatus*). *Bungarus walli* differs from *B. caeruleus* in having (1) 17–19 dorsal scale rows at midbody (vs.

15 in *B. caeruleus*) and (2) less than one scale wide white dorsal bands (vs. at least one scale wide in *B. caeruleus*). *Bungarus walli* differs from *B. bungaroides* in having (1) a pale belly with dark pigmentation subcaudal region (vs. belly with white bands in *B. bungaroides*) and (2) undivided subcaudals (vs. divided in *B. bungaroides*). *Bungarus walli* differs from similar looking colubrid species *Lycodon aulicus* and *L. striatus* in having (1) narrow white cross-bands on shiny black, brownish black or grey body and tail (vs. white bands broader and disappear on posterior part of body and on the tail in *L. aulicus* and *L. striatus*), (2) enlarged middorsal scales (vs. non-enlarged middorsal scales in *L. aulicus* and *L. striatus*) and (3) no loreal scale (vs. present in *L. aulicus* and *L. striatus*). *Bungarus walli* differs from *Naja naja, N. kaouthia, Ophiophagus hannah* and *Sinomicrurus macclellandi* in having the third supralabial not in contact with the posterior nasal (vs. in contact in those species, Figure Figure 21–25).

Medical importance

Recently, *Bungarus walli* was identified as a medically important snake. Although it is a common venomous snake in southeastern Nepal, very little or no epidemiological information of this species is known (Pillai et al., 2012). People in residential areas or those working in agricultural fields may have been bitten by this species, but it may have been mistaken previously as *B. caeruleus*. The bite of *B. walli* causes neurotoxic envenoming that gradually develops into paralysis of the peripheral nervous system similar to that in *B. caeruleus* envenoming and may cause death. The venom of *B. walli* has not been studied so far.

Remarks

Bungarus walli (n = 13) was the third most common snake among those causing mortality. Schleich et al. (Kabisch, 2002b, Schleich et al., 2002, Kästle et al., 2013a) doubted its occurrence in Nepal citing Mahendra (1984) who reported its distribution in Nepal without locality and voucher. All *B. walli* specimens identified in this study were found in southeastern Nepal (Table 2.a, Appendix 2). Because of its records from the Ganges floodplains of Uttar Pradesh State, India, bordering the southwestern Nepal (Wall, 1907), it is likely to be distributed throughout the lowlands of Nepal. Like in *B. caeruleus, B. walli* bites occur indoors or in the premises of houses usually without notice of bite marks and pain of bite except slight pinning sensation. This complicates the diagnosis.

***Bungarus lividus* Cantor, 1839**

Lesser Black Krait (Kalo Karet, Bairi Karait in Nepali)

Bungarus lividus Cantor 1839; type locality: Assam, India; lectotype: specimen illustrated in colored sketch of T. E. Cantor (1834–1837: no 1), designated by M. A. Smith (1943: 418)

Geographic distribution

Known to be distributed in Nepal, India and Bangladesh (Sharma et al., 2013b). Distribution records in the eastern (Kuch et al., 2011) and the central lowlands (Shah, 1999, Pandey, 2012) indicate its occurrence throughout the lowlands of Nepal usually below 250 m asl (Figure 27).

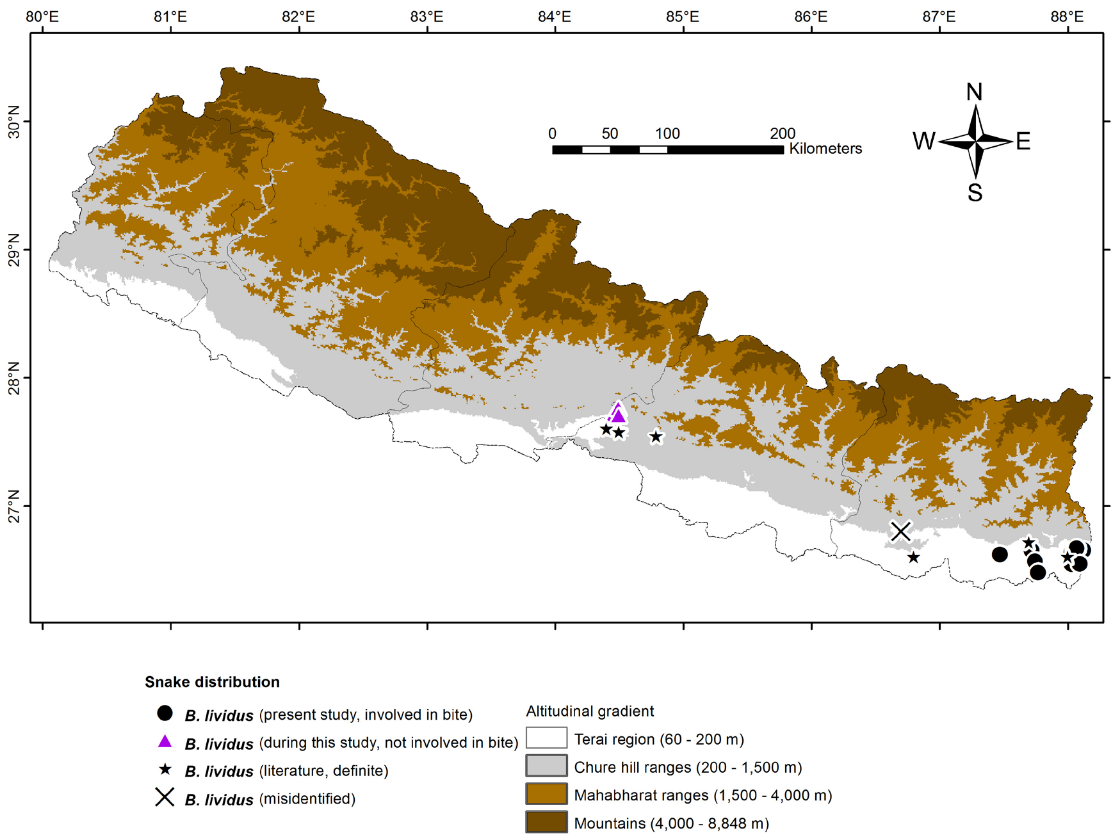


Figure 27. Distribution of *Bungarus lividus* in Nepal.

Identification

Bungarus lividus differs from all other Nepalese *Bungarus* species except *B. niger* in having (1) uniform black body (vs. narrow white body bands in *B. caeruleus*, *B. walli* and *B. bungaroides*, broad yellow bands in *B. fasciatus*). *Bungarus lividus* differs from *B. niger* in having (1) slightly enlarged middorsal scales (vs. greatly enlarged in *B. niger*) and (2) whitish undersurface of head and the anterior belly, but strongly pigmented posterior belly with brown colour and subcaudal part appearing like bands (vs. pale to yellowish ventral surface of head and anterior body, posterior belly and subcaudals slightly pigmented in *B. niger*). *Bungarus lividus* differs from *Naja naja, N. kaouthia, Ophiophagus hannah* and *Sinomicrurus macclellandi* in having the third supralabial not in contact with the posterior nasal (vs. in contact in those species, Figure 22, 28).

Medical importance

Kabisch (2002b) suggested that *Bungarus lividus* is uncommon in Nepal. But, I found it the fourth most common snake involved in bites. Based on the specimens studied, it was more common in eastern Nepal than in central and western Nepal (Table 2.a). However, very little is known about envenoming symptoms (Kuch et al., 2011). Sleeping people in residential areas or those working in agricultural fields are usually bitten by this snake.

The venom of *Bungarus lividus* has not been studied yet. However, its venom appears to be neurotoxic and may cause paralysis of the peripheral nervous system leading to death. In case of *B. lividus* bites in Nepal, burning sensation at the bite site, abdominal pain, vomiting, slurred speech, ptosis and progressive neuromuscular paralysis leading to respiratory arrest and death has been reported (Kuch et al., 2011).

Remarks

Although it is involved in snake bites particularly in the eastern lowlands of Nepal (Table 2.a), envenoming cases may occur throughout the lowlands. Indian polyspecific antivenom is produced without including *Bungarus lividus* venom. However, the efficacy of this antivenom used in Nepal has not been studied yet.

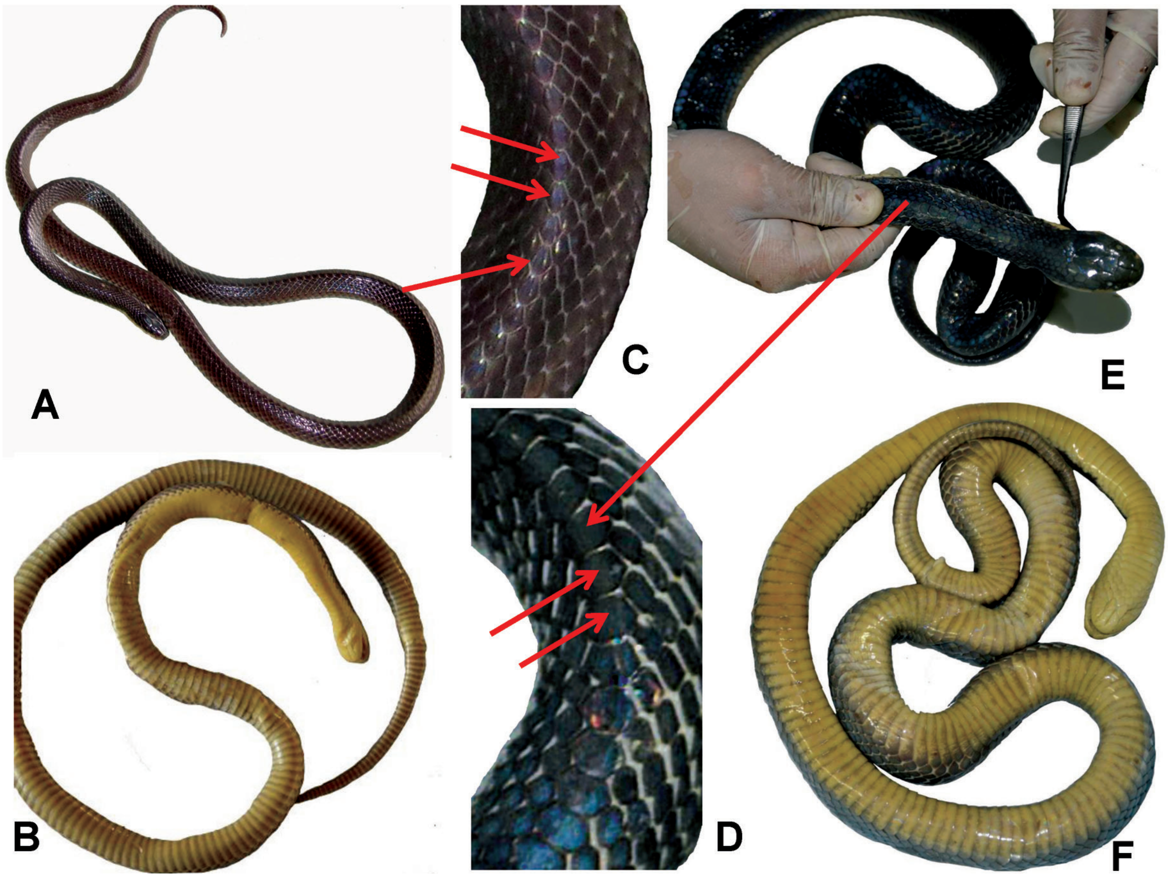


Figure 28. The entirely black dorsum and colour pattern on ventral-body surface of *Bungarus lividus* and *B. niger*. **A:** dorsal (a live specimen, Charaali, Duwagadi 04, Jhapa, SVL = 0.764 m) and **B:** ventral view (Bahuni 09, Morang, SVL = 0.612 m) of *B. lividus*. **C:** the hexagonal scales are not distinctly larger than the neighbouring scales in *B. lividus,* but distinctly larger than neighbouring scales in *B. niger* (**D**). **E,F:** dorsal (E) and ventral view (F) of *B. niger* (Golbasti, Ilam Municipality 03, Ilam; SVL = 1.187 m).

Bungarus fasciatus (Schneider, 1801)

Banded Krait (Pate Ganaguwali Sarpa, Gangawari, Laxmi Sanp, (Panhelo-kalo) Chure, Kanthamala, Raja Sanp, Maher, Gwala Sarpa, Ahiriniya Sanp in Nepali)

Pseudoboa fasciata Schneider 1801; type locality: Mansoor Cottah, Bengal, India; syntypes: ZMB 2771-2

Geographic distribution

Widely distributed in northwestern Asia (Afghanistan and Pakistan), South Asia (India, Bangladesh, Sri Lanka), east Asia (China) to Southeast Asia (Indonesia and Myanmar). Recorded from the coastal to mountain regions up to 2,300 m in Myanmar (Schleich and Kästle, 2002, Shah and Tiwari, 2004, Pandey, 2012, Sharma et al., 2013b). In Nepal, distributed throughout the Ganges plains (Pandey, 2012) to the Chure hills up to 531 m asl (Figure 29). This snake is common particularly in eastern Nepal (Rai, 2003).

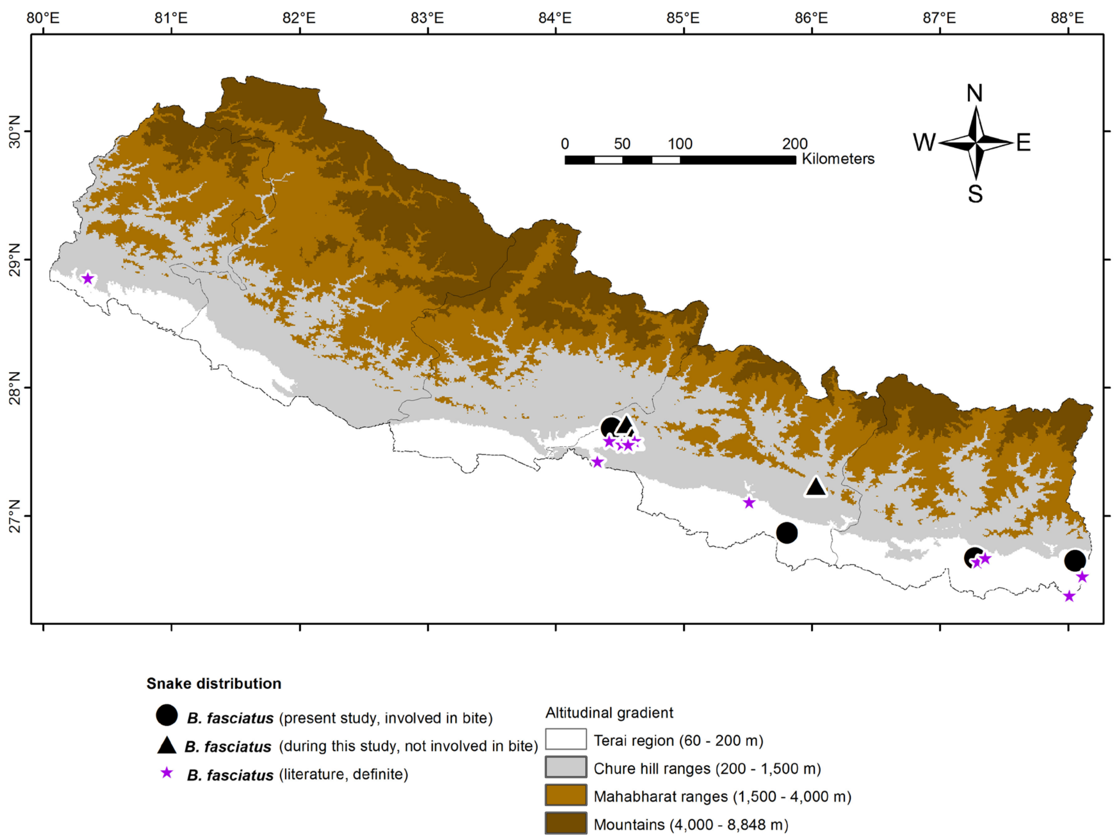


Figure 29. Distribution of *Bungarus fasciatus*.

Identification

Bungarus fasciatus differs from all kraits of Nepal in having (1) body and tail with broad and serial black and yellow rings of similar width extending across the belly (vs. entirely black, dark brown or brownish black and dorsal body without bands or lines in *B. niger* and *B. lividus*, with narrow white bands only on dorsal body in *B. caeruleus, B. walli* and *B. bungaroides*, (2) blunt tail-tip that is sometimes mistaken for a second head (vs. tapering tail-tip in all other kraits) and (3) body diameter triangular forming a distinct middorsal ridge (vs. such ridge is absent in all other kraits). *Bungarus fasciatus* differs from similar looking colubrid *Oligodon arnensis* in having (1) broad and serial black and yellow rings of similar width on body and tail extending across the belly (vs. narrower black bands only on the brown body and tail in *O. arnensis*), (2) enlarged middorsal scales (vs. non-enlarged middorsal scales in *O. arnensis*) and (3) no loreal scales (vs. present in *O. arnensis*). *Bungarus fasciatus* differs from *Naja naja, N. kaouthia, Ophiophagus hannah* and *Sinomicrurus macclellandi* in having the third supralabial not in contact with the posterior nasal (vs. in contact in those species, Figure 22, 25, 30).

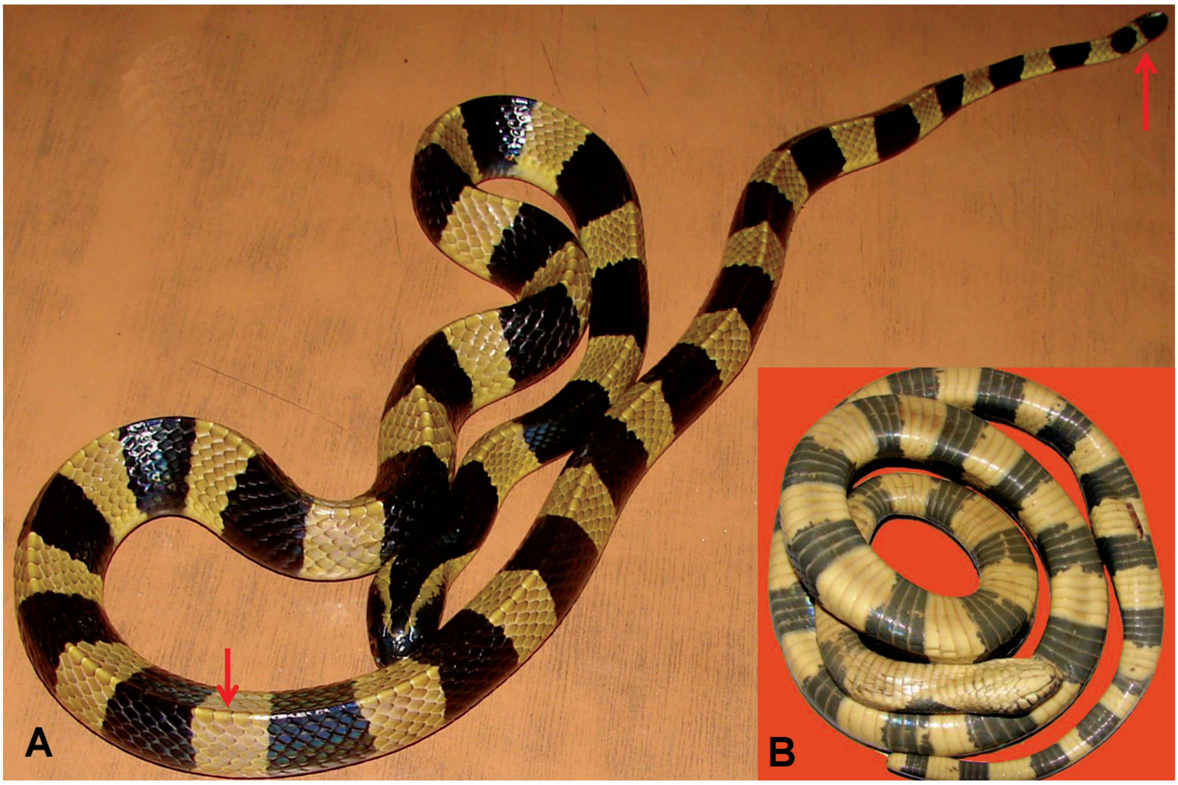


Figure 30. The banded pattern on dorsal and ventral body and a ridge across the midbody surface of *Bungarus fasciatus*. **A:** dorsal view, Damak area, Jhapa. **B:** ventral view, Bharatpur Hospital, SVL = 1.52 m.

Medical importance

Bites due to *Bungarus fasciatus* were found to be less common than those of other kraits in Nepal, probably, because of its shy behaviour. Kabisch (2002b) cited 67 *B. fasciatus* bites of a total of 640 snake bite cases admitted to a hospital in China. A maximum of 43 mg venom is obtained by milking and about 10 mg of its venom is considered to be fatal in an adult human (Kabisch, 2002b). Its venom causes progressive paralysis of the peripheral nervous system leading to death due to respiratory paralysis (Kabisch, 2002b, Sharma et al., 2013b).

Remarks

Bite appears to be rare, probably due to the shy nature of the snake (Whitaker and Captain, 2004). However, I found the snake involved in bites (Table 2.a). I found three specimens not involved in bites in Bardeutar, Kamalamai Municipality 07, Sindhuli at about 531 m asl. Its occurrence up to 2,500 m asl in Vietnam (Kabisch, 2002b) indicates the risk of bites in the lowlands to the mid-hills of Nepal. As Indian polyvalent antivenom that is used in Nepal does not include the venom of *B. fasciatus*, its bite should be considered seriously.

***Bungarus niger* Wall, 1908**

Greater Black Krait (Kalo Karet in Nepali)

Bungarus niger Wall 1908; type locality: Tindharia, Darjeeling, India; lectotype: BMNH 1946.1.18.63 (formerly BMNH 1860.3.19.1257)

Geographic distribution

Distributed in northeastern India, Bangladesh and Bhutan at 75 m to 400 m asl elevation ranges (Bauer and Gunther, 1992, Grosselet et al., 2004, Faiz et al., 2010). In Nepal, it is recorded from the Kaski District at 1,450 m asl (Tillack and Grossmann, 2001) and Ilam at 1,515 m asl in the present study. The snake is likely to be distributed throughout the hill ranges of Nepal (Figure 31). Recently, my colleagues have collected two specimens from hills of the eastern Nepal (Pandey et al., in progress).

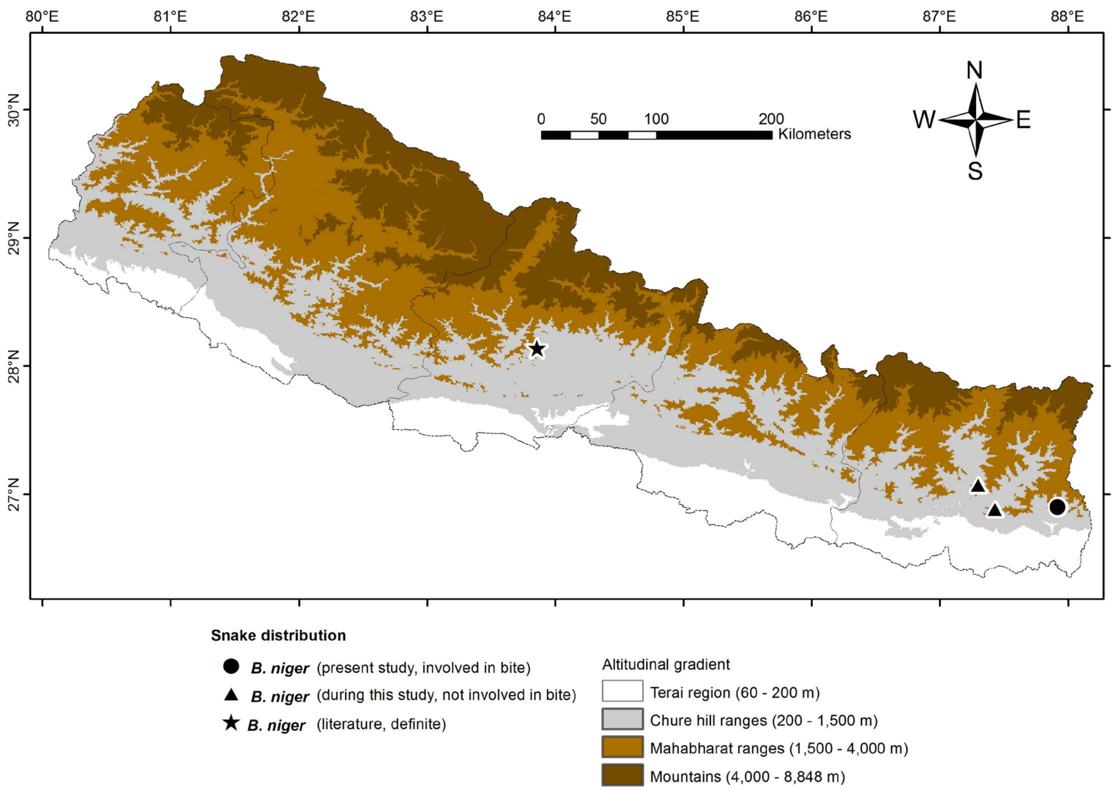


Figure 31. Distribution of *Bungarus niger* in Nepal.

Identification

Bungarus niger differs from all other Nepalese *Bungarus* species except *B. lividus* in having uniform black body (vs. narrow white body bands in *B. caeruleus*, *B. walli* and *B. bungaroides*, with broad yellow bands in *B. fasciatus*). *Bungarus niger* differs from *B. lividus* in having (1) clearly enlarged middorsal scale row (vs. slightly enlarged middorsal scales in *B. lividus*) and (2) pale to yellowish ventral surface of head and anterior body, posterior belly and subcaudals slightly pigmented (vs. whitish undersurface of head and the anterior body, but posterior belly and subcaudals strongly pigmented with brown colour appearing like bands in *B. lividus*). *Bungarus niger* differs from *Naja naja, N. kaouthia, Ophiophagus hannah* and *Sinomicrurus macclellandi* in having the third supralabial not in contact with the posterior nasal (vs. in contact in those species, Figure 22, 28).

Medical importance

Bungarus niger was recognized as a medically relevant snake by Faiz et al. (2010). I have found a single bite, the only known case involving this species in Nepal (Table 2.a). The venom of *B. niger* produces neurotoxic symptoms causing paralysis of the peripheral nervous system resulting in respiratory arrest and death. Moreover, it produces myotoxic symptoms causing systemic muscle damage with myoglobinuria, acute renal failure and hyperkalaemia (Faiz et al., 2010).

Remarks

In Nepal, more than 70% of the population is inhabiting the lowlands and hills (Central Bureau of Statistics, 2012a) and are at risks of *Bungarus niger* bites because of its wide range of distribution in the lowlands to throughout the Mahabharat ranges.

Bungarus bungaroides **(Cantor, 1839)**

Himalayan Krait, Northeastern Hill Krait (Pahadi Karet/ Himali Karet in Nepali)

Elaps bungaroides Cantor 1839; type locality: Cherrapunji, Khasi Hills, Assam, India; holotype: BMNH 1946.1.17.91

Geographic distribution

Known to be distributed in the Brahmaputra Valley of Tibet (Rao and Zhao, 2004), in Bhutan and in Darjeeling, Meghalaya, the northeastern India (Boulenger, 1896) to northern Myanmar (Sharma et al., 2013b). In Nepal, reported to be distributed in the eastern mid-mountains up to ≥1,600 m asl (Shah, 1999). However, it is likely to occur in the lowlands and lower hills (Figure 32).

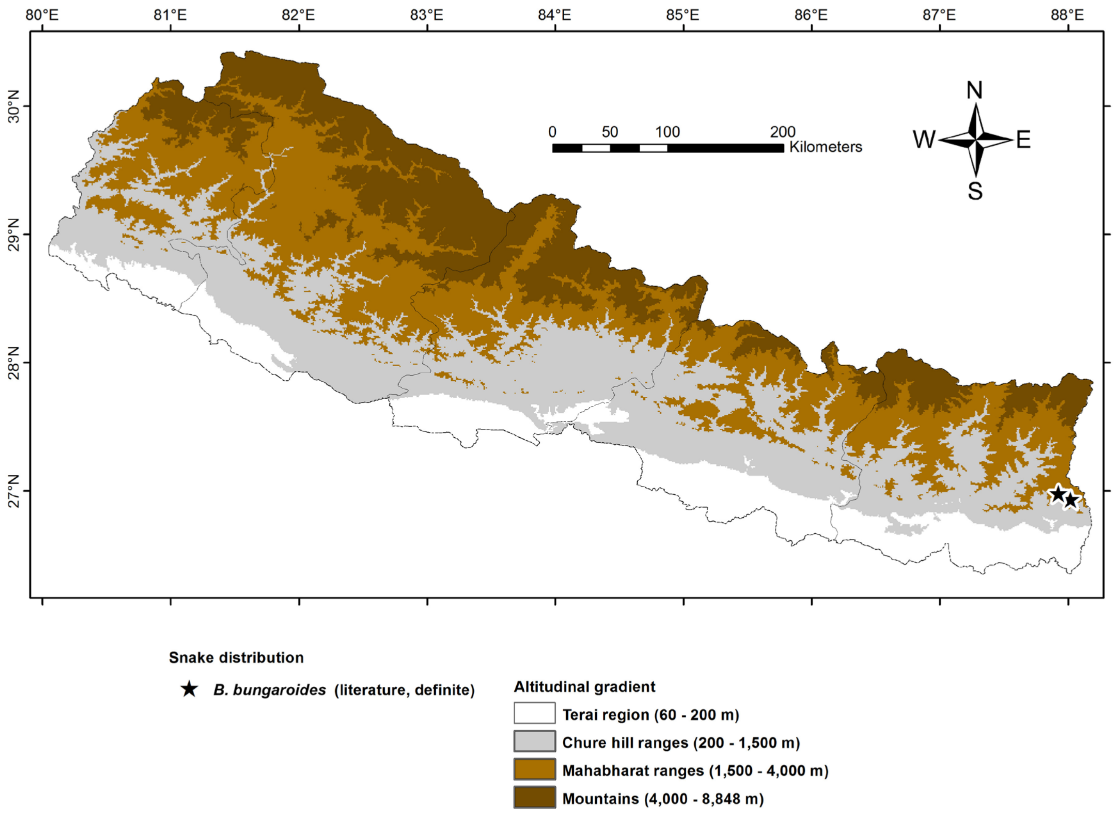


Figure 32. Distribution of *Bungarus bungaroides* in Nepal.

Identification

Bungarus bungaroides differs from all other Nepalese *Bungarus* species except *B. walli* and *B. caeruleus* in having narrow white body bands (vs. body uniform black in *B. lividus* and *B. niger* or with broad yellow bands in *B. fasciatus*). *Bungarus* *bungaroides* differs from *B. walli* in having 15 dorsal scale rows at midbody (vs. 17–19 in *B. walli*). *Bungarus bungaroides* differs from *B. caeruleus* and *B. walli* in having (1) dark belly with white bands (vs. a pale, patternless in *B. caeruleus* and *B. walli*) and (2) divided subcaudals (sometimes, few anterior subcaudals undivided) (vs. undivided subcaudals in *B. caeruleus* and *B. walli*). *Bungarus bungaroides* differs from similar looking colubrid species *Lycodon aulicus* and *L. striatus* in having (1) narrow white or pale yellowish cross-bands on shiny black, brownish black or grey body and tail (vs. white bands not crossing the belly, broader and disappearing on the posterior part of body and on the tail in *L. aulicus* and *L. striatus*), (2) enlarged middorsal scales (vs. non-enlarged in *L. aulicus* and *L. striatus*) and (3) no loreal scales (vs. present in *L. aulicus* and *L. striatus*). *Bungarus bungaroides* differs from *Naja naja, N. kaouthia, Ophiophagus hannah* and *Sinomicrurus macclellandi* in having the third supralabial not in contact with the posterior nasal (vs. in contact in those species, Figure 21–25, 33).

Figure 33. Dorsal and ventral colour pattern of *B. bungaroides* with uniformly black anterior body and white rings across body and tail. Photo by S. Dalvi, Eagle's Nest, Arunachal Pradesh, India.

Medical importance

Reports on envenoming due to *Bungarus bungaroides* and information on the venom of this species are not available. However, its venom effects may be similar to other kraits venoms.

Remarks

In the present study, this species was not collected.

3.1.2.1.4. Genus *Sinomicrurus* Slowinski, Boundy and Lawson, 2001

Five species belong to the genus *Sinomicrurus*. All are distributed in Asia (Slowinski et al., 2001, Wallach et al., 2014). They are commonly called Asian Coral Snakes. In Nepal, only *S. macclellandi* is known to be distributed.

***Sinomicrurus macclellandi* (Reinhardt, 1844)**

MacClelland's Coral Snake (Mugasanp, Karkat Nag in Nepali)

Elaps macclellandi Reinhardt 1844; type locality: Assam, India; holotype: ZMUC 65339

Geographic distribution

Distributed in northeastern India, Bhutan, Bangladesh, northern Myanmar, Thailand, Vietnam, southern China, Japan, Taiwan, Laos (Wallach et al., 2014, Uetz and Hošek, 2015).In Nepal, it is distributed in the lowlands (Schleich and Maskey, 1992) as well as in the eastern and western upper hills up to at least 1,400 m (Fleming and Fleming, 1973, Kramer, 1977, Shah, 1995) (Figure 34).

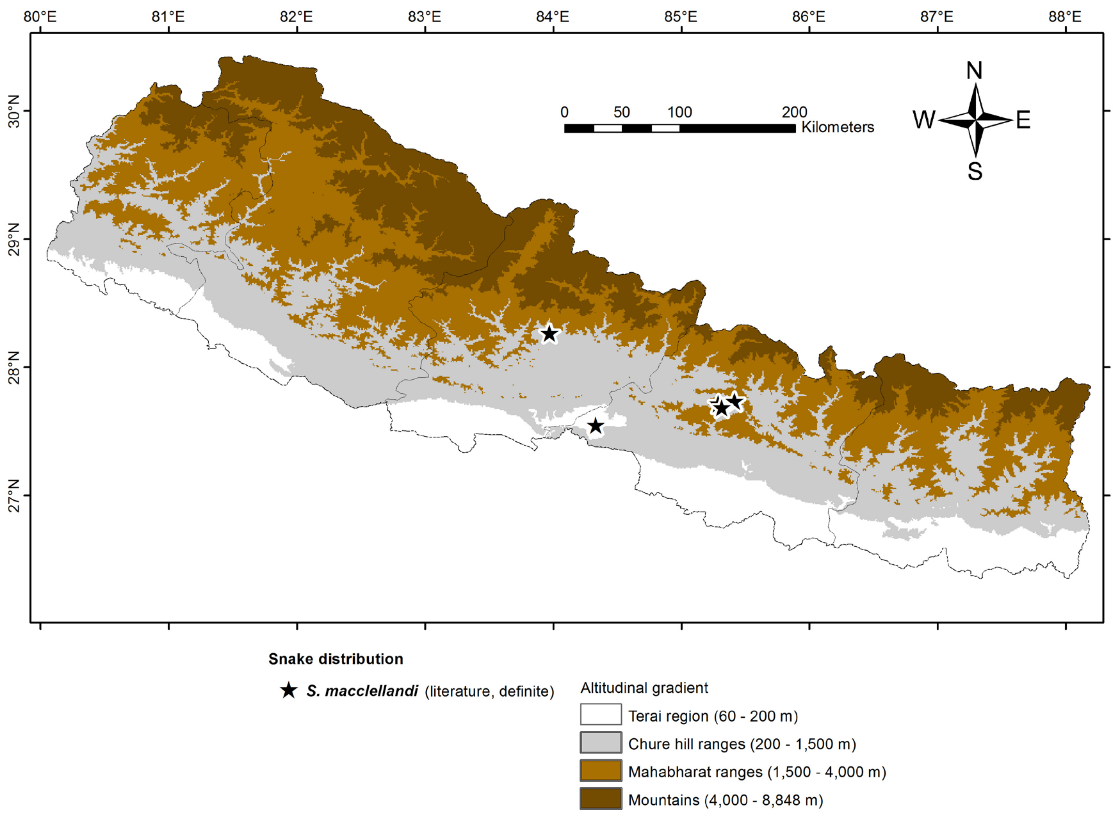


Figure 34. Distribution of *Sinumicrurus macclellandi* in Nepal.

Identification

Sinomicrurus macclellandi differs from all other Nepalese elapid snake species in having (1) 13 dorsal scale rows throughout (vs. 15 or more rows in other elapids) and (2) a combination of the following colouration characteristics: head with a wide white, yellow or cream coloured transverse band behind the eyes, dorsal body reddish brown with or without a black vertebral streak, yellowish dorsal body with black bars or quadrangular spots (vs. coloration not as described). *Sinomicrurus macclellandi* differs further from Nepalese species of *Bungarus* in having (1) the middorsal scales not larger than the adjacent scales (vs. clearly enlarged in *Bungarus* species (except in *B. lividus* which has slightly enlarged middorsal scales), (2) divided subcaudals, rarely some subcaudals are undivided (vs. undivided in *Bungarus* species except in *B. bungaroides* that possesses divided subcaudals) and (3) the third supralabial in contact with the posterior nasal (vs. not in contact with the posterior nasal in *Bungarus* species). *Sinomicrurus macclellandi* differs from similar looking colubrid snake like *Sibynophis* species in having (1) no loreal scale (vs. one loreal scale or occasionally united with prefrontal or postnasal in *Sibynophis* species) and (2) undivided anal (vs. divided in *Sibynophis* species). *Sinomicrurus macclellandi* differs from *Trachischium* species in having yellowish or yellowish-white belly with black bands or irregular blotches (vs. dark brown or coral red belly in *Trachischium* species, Figure 22–24, 35).

Figure 35. *Sinomicrurus univirgatus* from Kathmandu Valley, Nepal. Photo by H. H. Schleich.

Medical importance

Bites appear to be very rare in Nepal, but H. Schnurrenberger has died after a bite of a 0.3 m long juvenile in Pokhara, Nepal (Kramer, 1977). Because no symptoms developed within 2 hours of bite, he ignored it. Envenoming symptoms developed after six hours and he died of respiratory paralysis after 8 hours.

Remarks

In this study, this species was not collected. However, bites may occur in the lowlands to entire Mahabharat ranges where it has been reported from elevation ranges from 45 m to 2,485 m asl (Shah and Tiwari, 2004, Wallach et al., 2014).

3.1.2.2. Family Viperidae

The Viperidae family comprises nearly 329 species belonging to 35 genera worldwide (Uetz and Hošek, 2015). They are distributed in the Americas, Africa, Europe and Asia (Wallach et al., 2014). In Nepal, seven viperid species belonging to five genera have been recorded (Sharma et al., 2013b). This includes the pitless *Daboia russelii* (i.e., Russell's Viper) belonging to Viperinae and six pit vipers belonging to the Crotalinae subfamily. The pitless *Echis carinatus* has also been reported to occur in the lowlands of Nepal (Shrestha, 2001), but there exists no locality and habitat information. As it needs reconfirmation, I have not included this species in my comparisons.

3.1.2.2.1. Genus *Daboia* Gray, 1842

In Asia, *Daboia* comprises five species of which only *Daboia russelii* occurs in Nepal. Haemotoxicity is the main effect of their venom.

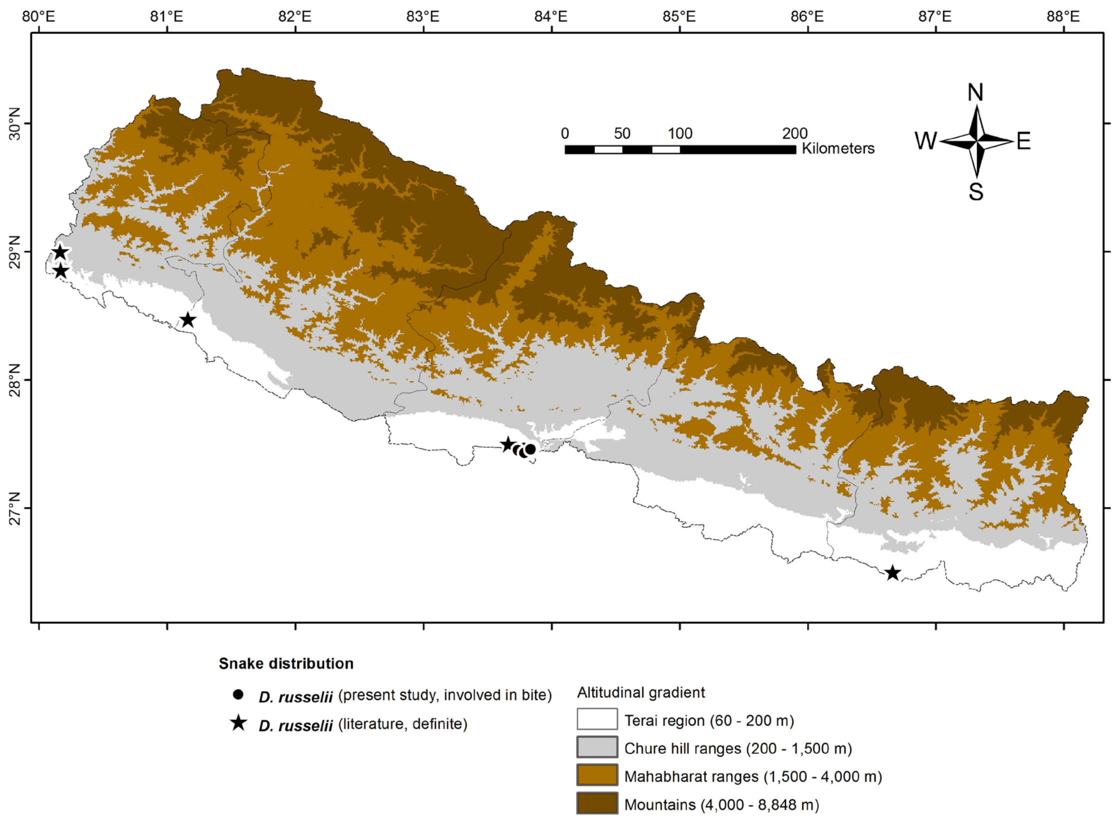


Figure 36. Distribution of *Daboia russelii* in Nepal.

***Daboia russelii* (Shaw & Nodder, 1797)**

Western Russell's Viper (Baghesarpa, Suskar, Gonus in Nepali)

Coluber russelii Shaw and Nodder 1797; type locality: Coromandel Coast in India; lectotype: BMNH II.1.1a

Geographic distribution

Patchily distributed in South Asia including Pakistan, India, Bangladesh, Sri Lanka and Nepal (Murthy, 1990a, Wüster et al., 1992, Thorpe et al., 2007, Khan, 2014). In Nepal, few authentic and irregularly distributed records of this species are known from the far-western lowlands of Nepal (O'Shea, 1996, Bhetwal et al., 1998). Shah (1995) reported this snake along an altitudinal range of 100 to 200 m asl in the eastern, western and far-western lowlands of Nepal based on the report of the Biodiversity Profile Project in 1995 and the collection in the Natural History Museum, Kathmandu, Nepal. My recent collections of this species from southwestern lowlands (Table 2.a, Appendix 2) and literature records suggest that it is widely distributed in the lowlands of Nepal (Figure 36).

Identification

Daboia russelii differs from pit viper species in having no pit organ (vs. present in pit vipers). *Daboia russelii* differs from the *Ovophis monticola* which is sometimes confused with *D. russelii* (Pandey, 2014) in having (1) three symmetrical longitudinal series of large rounded or oval spots (vs. a series of large rectangular blotches and irregularly distributed dark brown or yellowish brown spots in *O. monticola*) and (2) 27 to 33 dorsal scale rows at midbody (vs. 23–25 in *O. monticola*). *Daboia russelii* differs from *Python* species distributed in Nepal in having (1) three symmetrical longitudinal series of large rounded or oval spots with a brown centre bordered with black and yellow or white edges (rarely, these spots are fused or touching each other or occurring as chain-like patterns) (vs. asymmetrical dark brown blotches that are often bordered with black in *Python* species), (2) many small, imbricate and strongly keeled head scales (vs. smooth and larger scales of *Python* species, (3) no heat-sensitive pit organs (vs. located on the snout-tip and the first two supralabials below the nostril in pythons), not between the eye and the nostril as in pit vipers) and (4) 27–33 strongly keeled dorsal scale rows at midbody (vs. 60–75 smooth dorsal scale rows in *Python* species). *Daboia russelii* differs from *Eryx conicus* in having (1) symmetrical, round or oval or leaf-shaped blotches on the body (vs. a dissimilar, irregular pattern of dark blotches on the back in *E. conicus*), (2) longer tail (vs. shorter tail in *E. conicus*, (3) distinctly slender neck (vs. much thicker in *E. conicus*) and (4) 27–33 dorsal scale rows at midbody (vs. 40–55 in *E. conicus*, Figure 37, 38).

Medical importance

Although *Daboia russelii* is of high medical importance, no confirmed bites are known from Nepal. Envenoming initially causes painful local swelling. Coagulopathy with non-clotting blood leads to internal bleeding and cardiovascular shock. Additionally, myotoxicity with myoglobinuria occurs leading to renal failure. Local envenoming may result in tissue necrosis (Warrell, 1995, Gawarammana et al., 2009, Jeevagan et al., 2013). Like in case of krait bites, *D. russelii* bites also cause vomiting and abdominal pain (Warrell, 1995).

In this study, envenoming occurred in the lowlands of Nepal. Reports of *D. russelii* distribution in 2,134 m (Palni Hills, southern India) (Smith, 1943) to 3,000 m (India) (Murthy, 1990b) indicate the risk of envenoming in hillys of Nepal as well.

Remarks

Daboia russelii is a medically highly important snake, although no confirmed bites were known from Nepal before. It is likely to be distributed throughout the lowlands (Shah, 1995, Kabisch, 2002c) posing risks of envenomation. It is rare and patchily distributed in Nepal. This is supported by similar distribution patterns in India bordering southern Nepal (Murthy, 1990a).

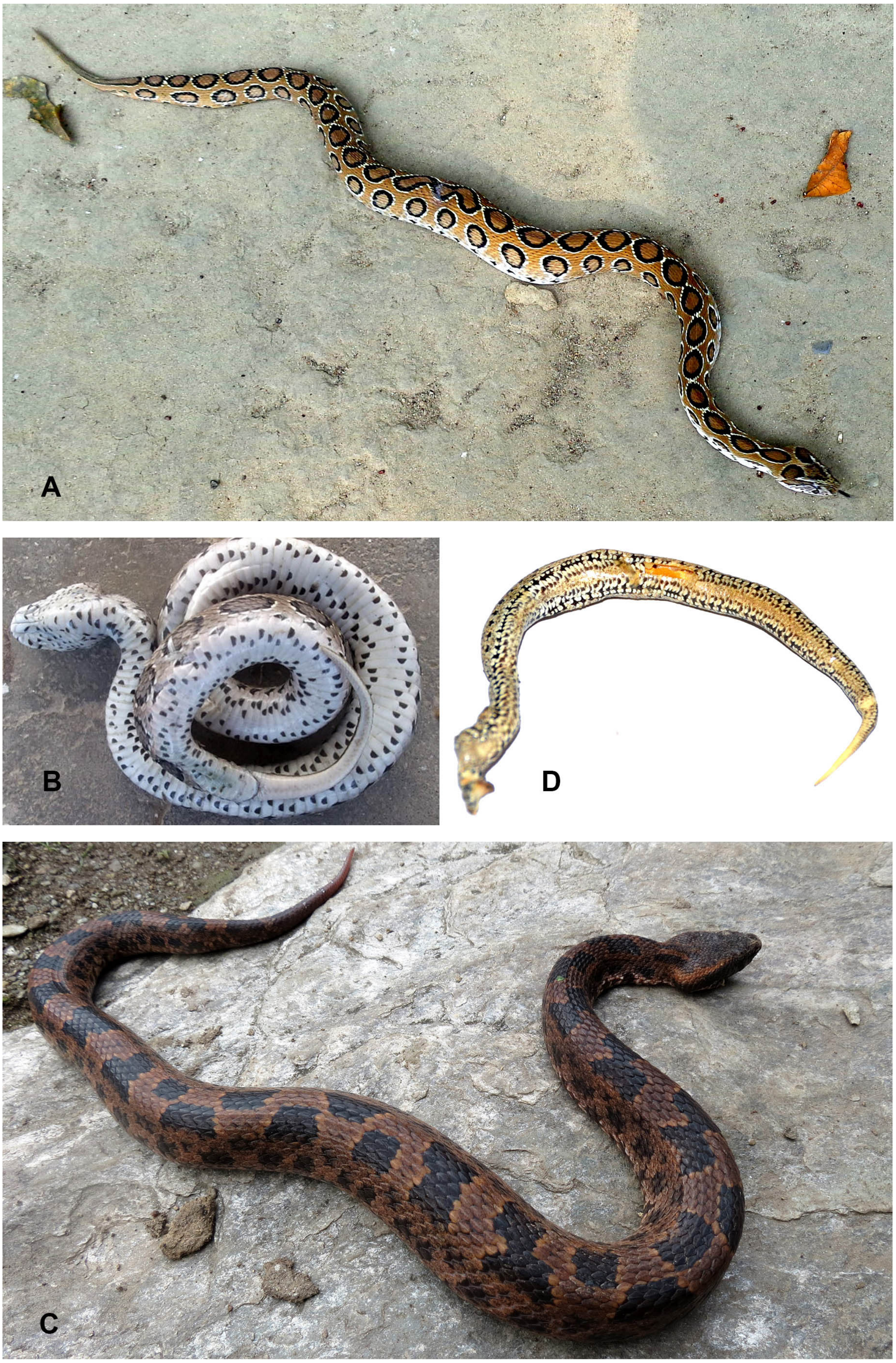


Figure 37. Body pattern in *Daboia russelii* and *Ovophis monticola*. **A,B:** *Daboia russelii*, A from Pratappur 06, Nawalparasi, SVL = 0.550 m, photo by C. M. Sharma and B **from** Tribeni area, SVL = 0.530 m. **C,D:** *Ovophis monticola,* C from Ghandruk, Kaski, photo by N. Sapkota. and D from Fikkal Bazaar, Ilam, SVL = 0.201 m.

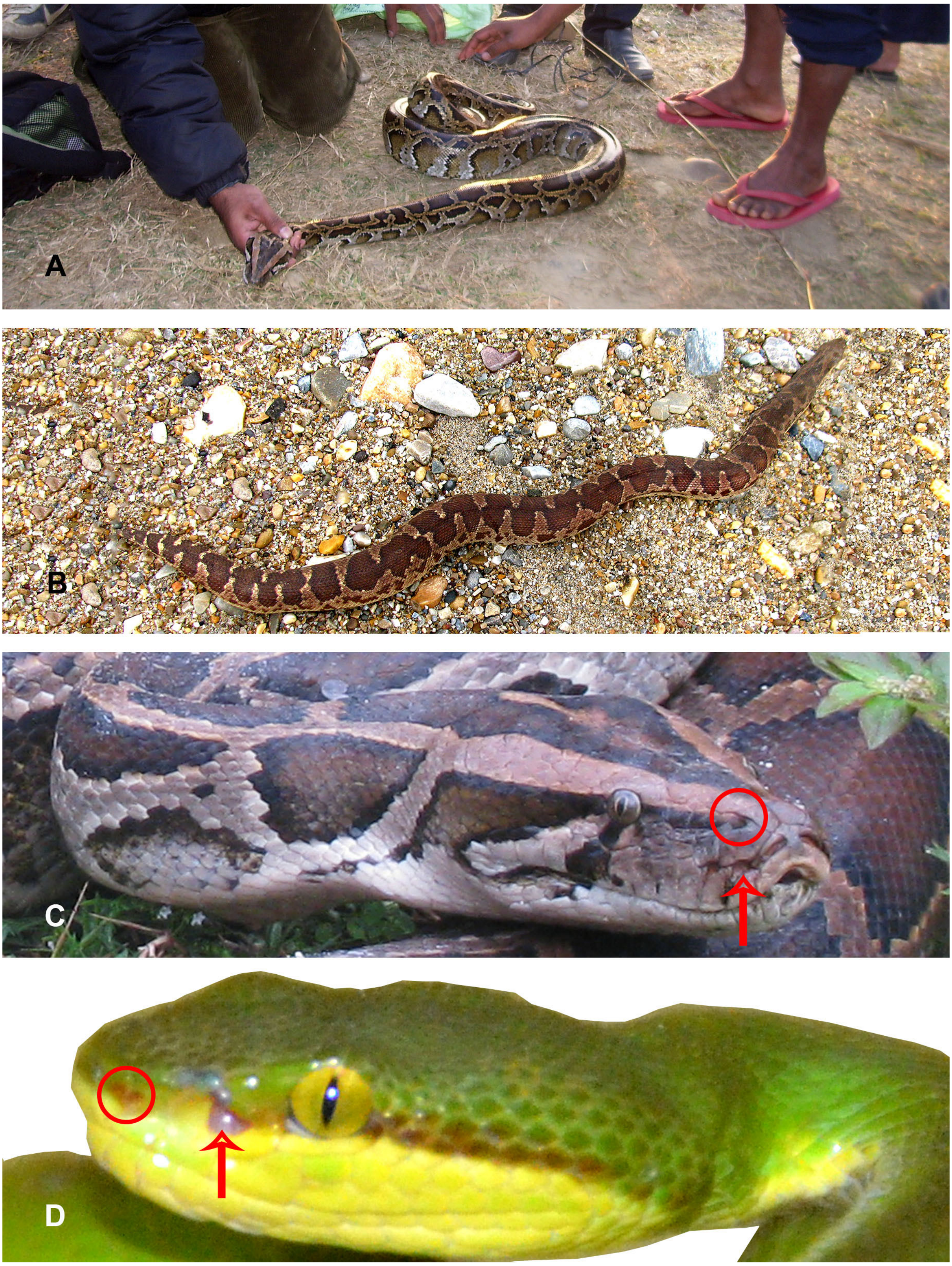


Figure 38. Body blotch pattern in *Python bivittatus* and *Eryx conicus* and heat sensitive organs. **A:** asymmetrical dark brown blotches that are often bordered with black in *P. bivittatus.* **B:** dissimilar, irregular pattern of dark blotches on the dorsal body, distinctly slender neck and shorter tail in *E. conicus* (Amlekhgunj area, Parsa, photo by K. Pokharel). **C,D:** position of the heat sensitive pit organ in *P. bivittatus* (C) and *Trimeresurus albolabris*, Ilam District, the southeastern Nepal (D). Pit organ shown by red arrow between the eye and the nostril that is indicated by the red circle.

3.1.2.2.2. Genus *Trimeresurus* Lacépède, 1804

The genus *Trimeresurus* includes 50 species (Uetz and Hošek, 2015) that are widely distributed in Asia (Wallach et al., 2014). In Nepal, the distribution of three species is well documented. I found only one species involved in snake bites during this study. Haemotoxicity is the main effect of their venom.

Trimeresurus albolabris **(Gray, 1842)**

White-lipped Tree Viper, White-lipped Pit Viper (Hareu, Haryou Sarpa, Pattar in Nepali)

Trimesurus albolabris Gray 1842; type locality: China; holotype: BMNH 1946.1.19.85

Geographic distribution

Distributed in India, Bhutan, China, Laos, Myanmar, Thailand and Vietnam (Wallach et al., 2014). In Nepal it is common throughout the lowlands up to the middle hills (Smith, 1951, Fleming and Fleming, 1973, Nanhoe and Ouboter, 1987, Rai, 2003, Pandey, 2012) (Figure 39).

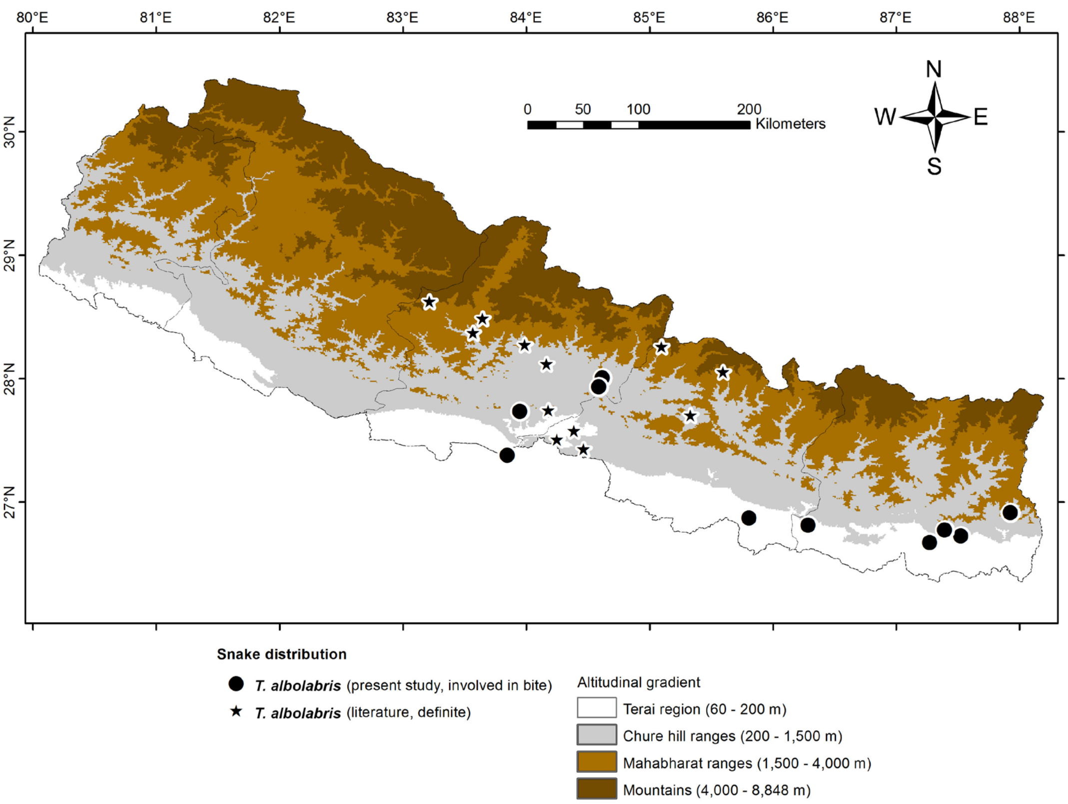


Figure 39. Distribution of *Trimeresurus albolabris* in Nepal.

Identification

Trimeresurus albolabris differs from similar looking green colubrid snakes in having pit organ and small, smooth, numerous head scales (vs. large head scales without pit organs in *Orthriophis hodgsonii*, *Boiga cyanea* and *Ahaetulla nasuta*). The *T. albolabris* differs from similar looking *A. nasuta* in having triangular head with vertical pupil (vs. neck not distinct from head and body, head with horizontal pupil and very long and pointed snout in *A. nasuta*). *Trimeresurus albolabris* differs from Nepalese Green Pit Vipers except *T. erythrus* in having (1) supralabials below eyes pale green, yellow or white (vs. green in *T. septentrionalis*) and (2) irregularly arranged, small and smooth head scales (vs. feebly imbricate, small and smooth or weakly keeled head scales in *T. septentrionalis*). *Trimeresurus albolabris* differs from *T. erythrus* in having (1) smooth head scales (vs. strongly keeled head scales in *T. erythrus*) and (2) 21 (rarely 19 or 23) dorsal scale rows (vs. 23–25, rarely 21, in *T. erythrus*. *Trimeresurus albolabris* differs from *T. gramineus* in having dark green body (vs. light green body in *T. gramineus*). *Trimeresurus albolabris* differs from *T. tibetanus* in having (1) green body surface (vs. green to yellowish-olive and reddish-brown dorsal body with scattered short brown bands or irregular reddish-brown spots), (2) dorsal part of the tail brightly red tail (vs. green with red to brown spots), (3) yellowish-white or whitish belly (vs. light green, yellowish or light brown belly with spots or patternless in *T. tibetanus*) and (4) weekly keeled 21 rows (rarely 19 or 23) (strongly keeled dorsal scales arranged in 19–21 rows at midbody in *T. tibetanus*, Figures 40,41).

Medical importance

In Nepal, this snake is mostly encountered by people during outdoor activities while cutting grass or working in bush areas. Envenoming by this species is likely to occur throughout lowlands to the intermediate hills of Nepal and causes painful local swelling that may spread distally from the bitten part, blood coagulopathy, blister formation and necrosis (Warrell, 1995, Yang et al., 2007, Isbister et al., 2014). Although fatal cases are known from Hong Kong (Warrell, 1995), fatalities are not confirmed for Nepal.

Remarks

A local newspaper in Nepal reported a death following a Green Pit Viper bite, but without evidence of the correctly identified snake (Maden, 2014).

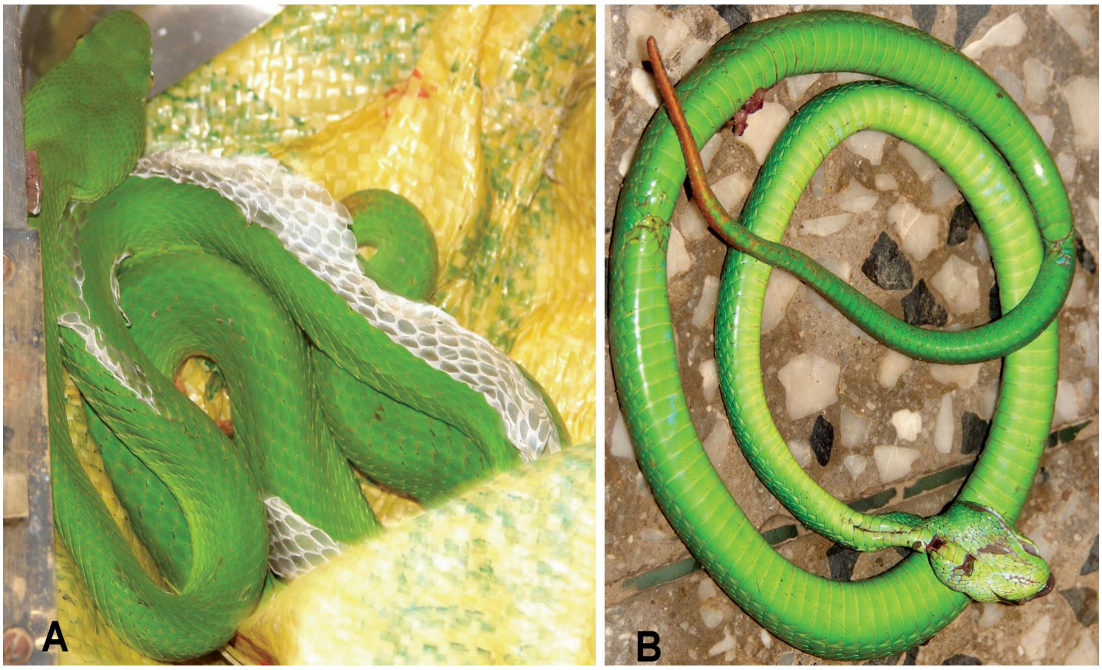


Figure 40. Green body possessing small, smooth and many head scales and bright red tail in *Trimeresurus albolabris.* **A:** dorsal view of a specimen, Gorkha District. **B:** a ventral view of a dead specimen, the Bharatpur Hospital (SVL = 1.11 m).

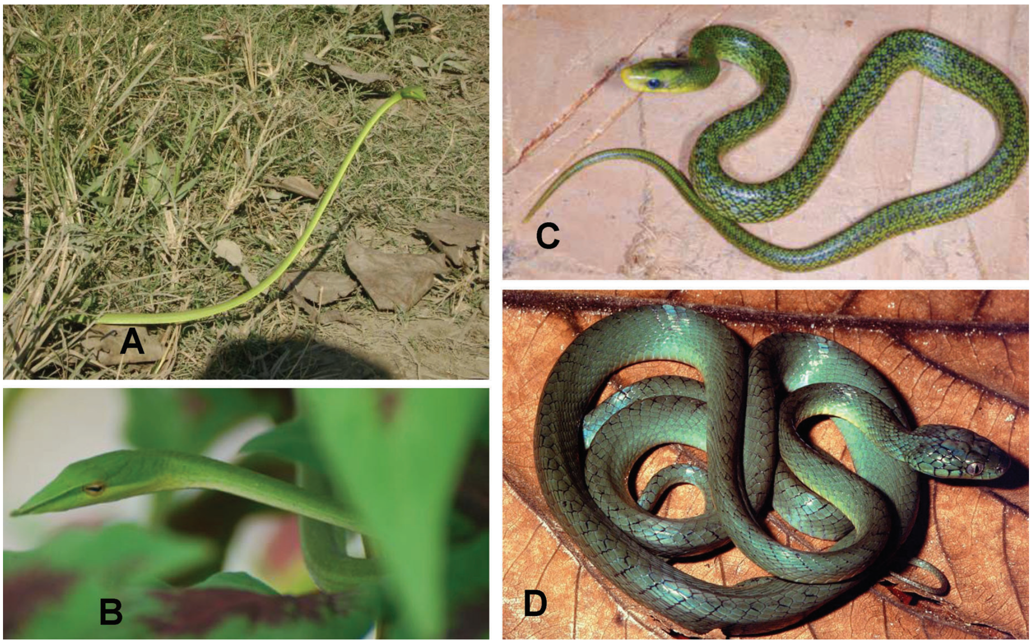


Figure 41. Some green colubrid snakes confused with venomous Green Pit Vipers. **A:** green dorsum of mildly venomous *Ahaetulla nasuta* (a specimen from Chitwan National Park, photo by B. Lama). **B:** *Ahaetulla nasuta* possessing long pointed snout and horizontal pupil (Sauraha village, photo by Y. Paudel). **C:** non-venomous *Orthriophis hodgsonii* with few very large scales on top of the head and the round pupil that distinguish it from Green Pit Vipers (central Nepal, photo by F. Tillack). **D:** the mildly venomous *Boiga cyanea* having a vertical pupil and greenish dorsum confuse with Green Pit Vipers, but very large scales on top of the head and lacking pit organs and front-fangs differ it from Green Pit Vipers (Thailand, photo by F. Tillack).

***Trimeresurus septentrionalis* Kramer, 1977**

Kramer's Pit Viper (Haryou Sarpa, Pattar in Nepali)

Trimeresurus albolabris septentrionalis Kramer 1977; type locality: near Hemja, Kaski, Nepal; holotype: MHNG 1404.31

Geographic distribution

Known from Nepal, northwestern India (Uttarakhand) and Bangladesh. In Nepal, common in the mid-hills in Myagdi, Kaski, Lamjung and Rasuwa Districts between 900 to 3,050 m asl (Kramer, 1977). Kramer (1977) described its type locality from Kaski, Nepal (Figure 42). Shah (2001) guessed its distribution in Annapurna-Dhaulagiri region by interviewing locals.

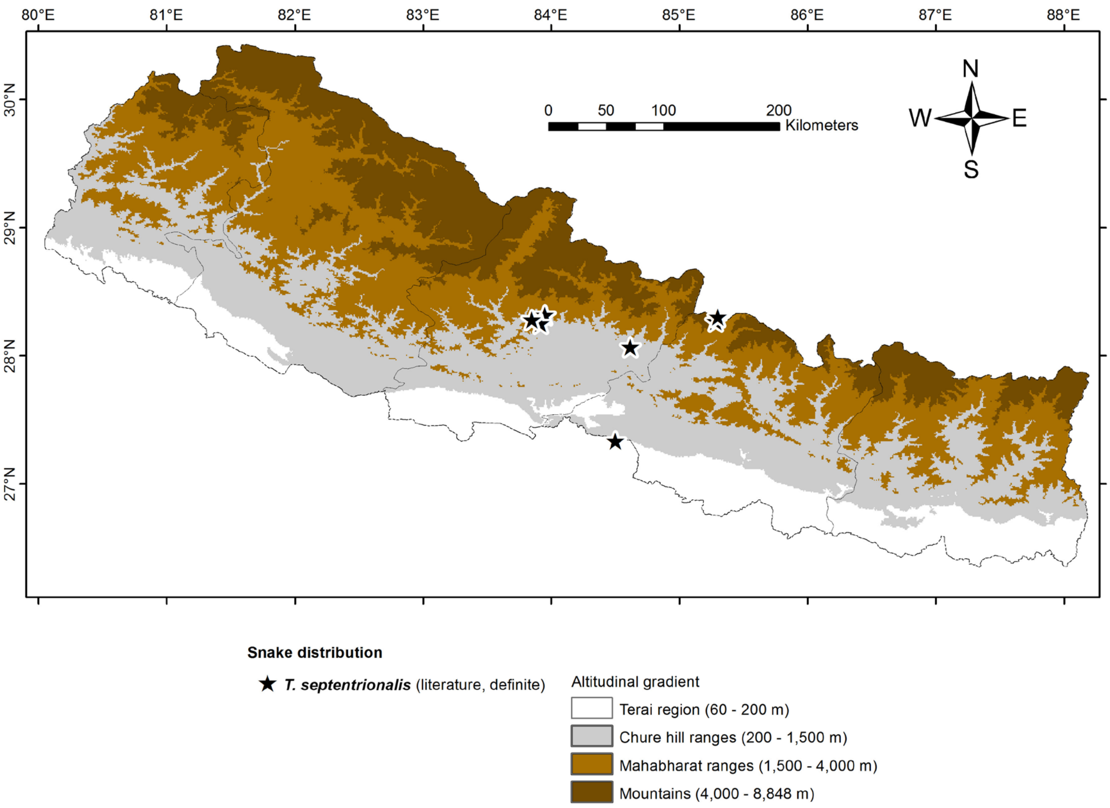


Figure 42. Distribution of *Trimeresurus septentrionalis* in Nepal.

Identification

Trimeresurus septentrionalis differs from similar looking green colubrid snakes in having pit organ and small, many smooth head scales (vs. large head scales without pit organs in *Orthriophis hodgsonii*, *Boiga cyanea* and *Ahaetulla nasuta*).

Trimeresurus septentrionalis differs also from similar looking *A. nasuta* in having triangular head with vertical pupil (vs. non-triangular head as neck not distinct from head and body, head with horizontal pupil and very long and pointed snout in *A. nasuta*). *Trimeresurus septentrionalis* differs from Nepalese Green Pit Vipers except *T. erythrus* in having (1) supralabials below eyes green (vs. pale green, yellow or white in *T. albolabris*) and (2) feebly imbricate and smooth or weakly keeled head scales (vs. irregularly arranged and smooth in *T. albolabris*). *Trimeresurus septentrionalis* differs from *T. albolabris* in having strongly keeled dorsal body scales arranged in 21 rows at midbody (vs. weekly keeled 21 dorsal scale rows (rarely 19 or 23) in *T. albolabris*). *Trimeresurus septentrionalis* differs from *T. erythrus* and *T. tibetanus* in having dorsal body scales arranged in 21 rows at midbody (vs. 23–25 (rarely 21) in *T. erythrus*, 19–21 rows in *T. tibetanus*, Figures 40, 41, 43).

Figure 43. Dorsal view of *Trimeresurus septentrionalis*. An adult female from Pyaudi, Kaski District in Gandaki Zone of Nepal, at 1050 m asl. Photo by F. Tillack.

Medical importance

Clinical and epidemiological information on proven *Trimeresurus septentrionalis* bite is rare. In Nepal, no proven bite due to this species is known. However, it can be assumed that bites may be common in the hills. Although the venom of this species and its effects on humans have not been studied so far, envenoming due to its bite may cause similar envenoming symptoms as in the case of *T. albolabris* bites described above.

Trimeresurus tibetanus Huang, 1982

Tibetan Pit Viper (Hareu, Haryou Sarpa, Pattar, Karanko Haryou Sap in Nepali). Previously, it was known as *Himalayophis tibetanus*

Trimeresurus tibetanus Huang 1982; type locality: Phulchoki, Godavari village, Nepal (Orlov and Helfenberger, 1997); holotype: FU 80001

Geographic distribution

Information of its distribution exists for Nepal and China. In Nepal, it is widely distributed in the hills and mountains in altitudinal ranges from 2,000 to 2,700 m asl in the Phulchoki and Helambu area in the Kathmandu Valley and in Tibet of China up to 3,200 m asl (Orlov and Helfenberger, 1997, Tillack et al., 2003) (Figure 44).

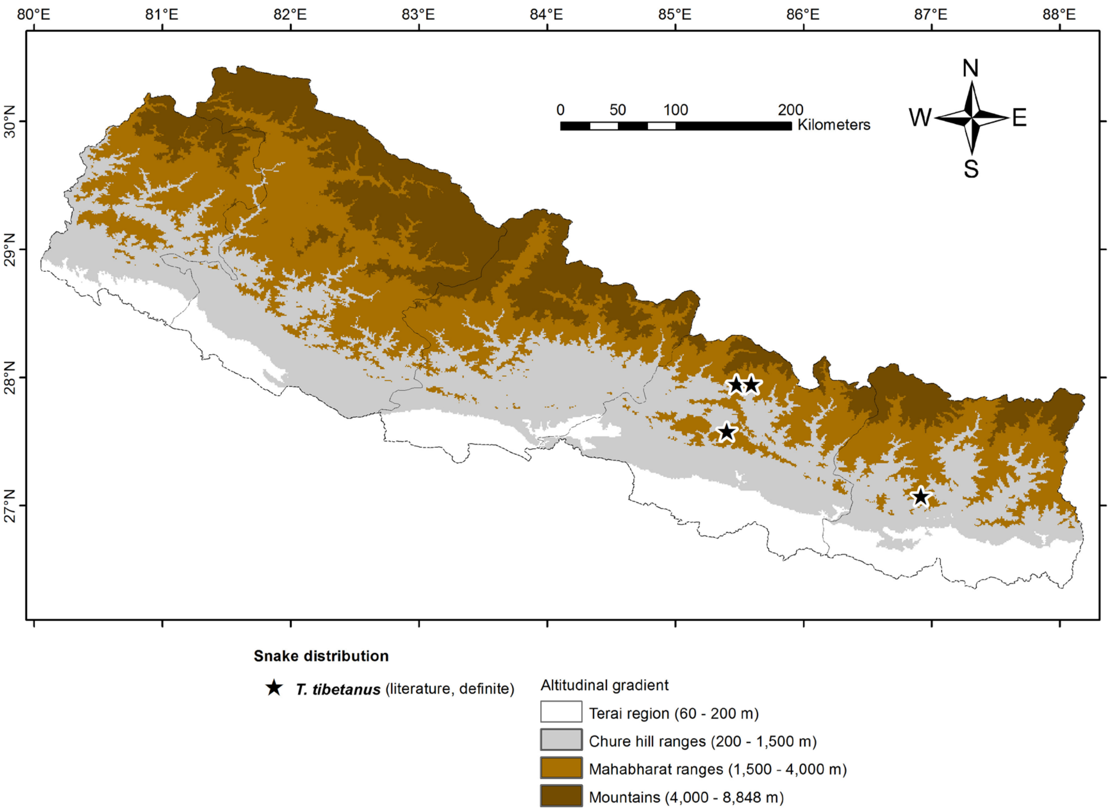


Figure 44. Distribution of *Trimeresurus tibetanus* in Nepal.

Identification

Trimeresurus tibetanus differs from similar looking green colubrid snakes in having pit organ located and small, many smooth head scales (vs. large without pit organs in *Orthriophis hodgsonii*, *Boiga cyanea* and *Ahaetulla nasuta*). *Trimeresurus* *tibetanus* differs from similar looking *A. nasuta* in having a triangular head with vertical pupil (vs. non-triangular head as neck not distinct from head and body, head with horizontal pupil and very long and pointed snout in *A. nasuta*). *Trimeresurus tibetanus* differs from other similar looking Geen Pit Vipers in having (1) green to yellowish-olive and reddish-brown dorsal body with scattered short brown bands or irregular reddish-brown spots (vs. such patterns are absent in Green Pit Vipers: *Trimeresurus septentrionalis* and *T. albolabris*), (2) dorsal part of the tail green with red to brown spots (vs. brightly red in *T. septentrionalis* and *T. albolabris* and (3) light green, yellowish or light brown belly with spots or patternless in *T. tibetanus* (vs. light yellowish-green in T. septentrionalis, yellowish-white or whitish in *T. albolabris*). *Trimeresurus tibetanus* differs from *T. albolabris* in having strongly keeled dorsal scales arranged in 19–21 rows at midbody (vs. weekly keeled 21 rows (rarely 19 or 23) in *T. albolabris*). *Trimeresurus tibetanus* differs from *T. erythrus* in having 19–21 dorsal scale rows at midbody (vs. 23–25 (rarely 21) in *T. erythrus*). *Trimeresurus tibetanus* differs from *T. septentrionalis* in having usually 19–21 dorsal scale rows at midbody (vs. 21 rows in *T. septentrionalis,* Figure 40, 41, 43, 45).

Medical importance

No clinical and epidemiological data on bites and envenoming by this snake are available. Although *Trimeresurus tibetanus* venom and venom effects have not been studied so far, envenoming by this pit viper may cause similar effects like those of the other pit vipers described above. Therefore, *T. tibetanus* should be considered as a medically relevant species.

Remarks

During this study, *Trimeresurus tibetanus* was not involved in snake bites.

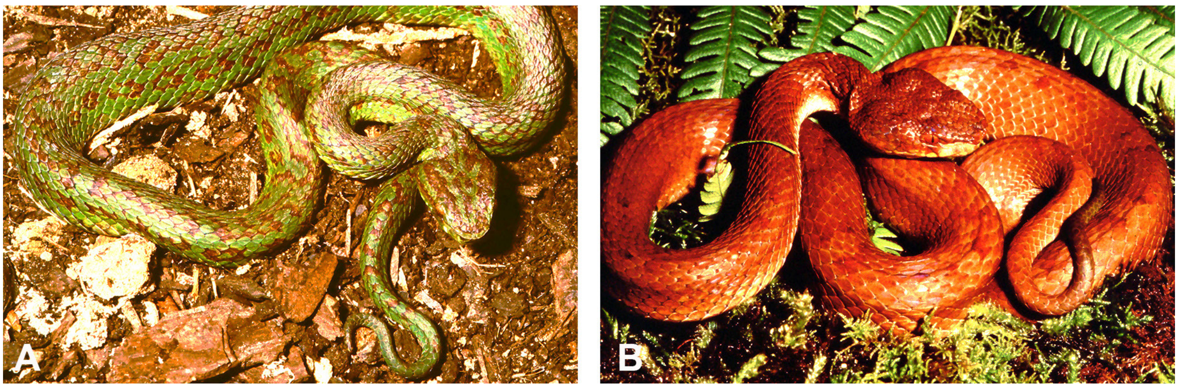


Figure 45. Dorsal body colour pattern with scattered short brown bands or irregular reddish-brown spots in *Trimeresurus tibetanus*. **A:** an adult male from Phulchoki, Godavari, 2,525 m asl and **B:** an adult female of the brown variety from Tark Ghyang, Helambu, 2,560 m asl; photos by F. Tillack.

3.1.2.2.3. Genus *Ovophis* Burger in Hoge and Romano-Hoge, 1981

To this genus seven species belong that are distributed in southeastern Asia (Wallach et al., 2014). In Nepal, the distribution of one species is defined that was involved in snake bites. Haemotoxicity is the main effect of their venom.

***Ovophis monticola* (Günther, 1864)**

Mountain Pit Viper (Andho Sarpa, Gurube, Chhirbire Sarpa, Gurbhe Sarpa; Bakchama in Nepali)

Trimeresurus monticola Günther 1864; type locality: Sikkim, India; syntypes: BMNH 1946.1.18.76 and 1946.1.19.91

Geographic distribution

Distributed in Nepal, India (Arunachal Pradesh, Assam, Darjeeling of West Bengal and Sikkim), China (Xizang, Sichuan, Guizhou and Yunnan Province), Bhutan, Bangladesh, Myanmar (Orlov et al., 2002, Wallach et al., 2014). In Nepal, this snake is widely distributed in the lowlands (Pandey, 2014), the entire hill ranges in 900 to 2,700 m asl. (Fleming and Fleming, 1973, Shah, 2001) (Figure 46).

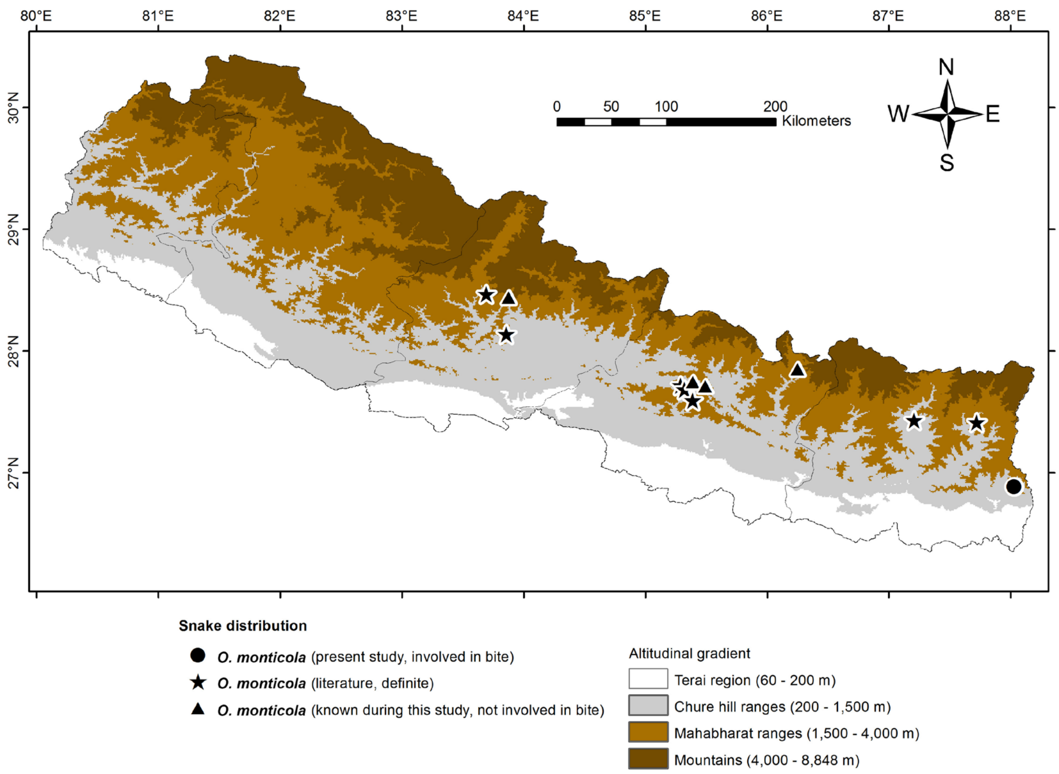


Figure 46. Distribution of *Ovophis monticola* in Nepal.

Identification

Ovophis monticola differs from similar looking *Python* species and *Eryx conicus* in having triangular head with pit organ (vs. these features are absent in *Python* species and *Eryx conicus*). *Ovophis monticola* differs from all Green Pit Vipers of Nepal in having light or dark brown dorsal body (vs. green in *Trimeresurus albolabris, T. septentrionalis, T. erythrus* and *T. graminieus*). *Ovophis monticola* differs from *Gloydius himalayanus* in having (1) small, many head scales (vs. with large head scales in the front and small in the back of head in *G. himalayanus*), (2) body with a series of large rectangular blotches and irregularly distributed dark brown or yellowish brown spots (vs. with dark brown or blackish brown spots (males slightly lighter than females), zig-zag bands or horse-shoe shaped blotches in *G. himalayanus*), (3) belly with smaller dark brown or black blotches (vs. brown, speckled black and white in *G. himalayanus*) and (3) smooth or weakly keeled 23–27 dorsal scale rows at midbody (rarely 21, 28 or 29) (vs. 21 rows of strongly keeled dorsal scales (rarely 23) in *G. himalayanus*). *Ovophis monticola* differs from *Protobothrops jerdoni* in having (1) body with a series of large rectangular blotches and irregularly distributed dark brown or yellowish brown spots (vs. with a series of 42 to 50 irregularly shaped reddish brown bands (sometimes broken at the sides) with black and yellow borders in *P. jerdoni*), (2) smooth head-top scales (vs. keeled head-top scales in *P. jerdoni*), (3) dorsal surface of head brown with or without dark blotches (vs. black with symmetrical yellow marks in *P. jerdoni*), (4) smooth or weakly keeled 23–27 dorsal scale rows at midbody (rarely 21, 28 or 29) (vs. strongly keeled 21 (rarely 19 or 23) (except outer 2–3 rows) in *P. jerdoni*) and (5) belly with smaller dark brown or black blotches (vs. cream or yellowish-grey belly with numerous dark brown spots in chessboard-like pattern in *P. jerdoni*, Figure 37, 38).

Medical importance

Ovophis monticola is a medically important snake in the hill areas of Nepal (Bhattarai et al., 2008). Envenoming by this species causes severe burning pain, local swelling lasting for more than two weeks and damages muscles (Bhattarai et al., 2008). Local envenoming may result in blistering and necrosis. Blood incoagulability, bleeding and associated symptoms may develop. There exists a fatal case report (Warrell, 1995).

Remarks

During this study, I noted four specimens not involved in bites originating from Pulchowk in Kathmandu Valley, near Temple of Suryavinayek, Bhaktapur, Bulung VDC in Dolakha and Ghandruk, Kaski as shown in photos made by colleagues.

3.1.2.2.4. Genus *Gloydius* Hoge and Romano Hoge, 1981

This genus includes 13 species that are distributed in Asia (Orlov et al., 2002, Uetz and Hošek, 2015). Only one of them occurs in Nepal. I did not find it being involved in snake bites during this study. Haemotoxicity is the main effect of its venom.

***Gloydius himalayanus* (Günther, 1864)**

Himalayan Pit Viper (Bhyagute Sarpa, Gurbhe Sarpa, Bagchama in Nepali). This species is also known as *Agkistrodon himalayanus*.

Halys himalayanus Günther 1864; type locality: Garhwal, Uttaranchal, India; syntypes: BMNH 1946.1.18.75 (formerly BMNH 1860.3.19.1189) and BMNH 1946.1.19.64 (formerly BMNH 1860.3.19.1358)

Geographic distribution

Distributed in Nepal, Pakistan and northwestern India up to 4,880 m (Smith, 1943, Khan, 2014). In Nepal, found in the hill ranges between 1,640 to 3,050 m asl (Smith and Battersby, 1953, Kramer, 1977, Nanhoe and Ouboter, 1987, Rai, 2003) (Figure 47).

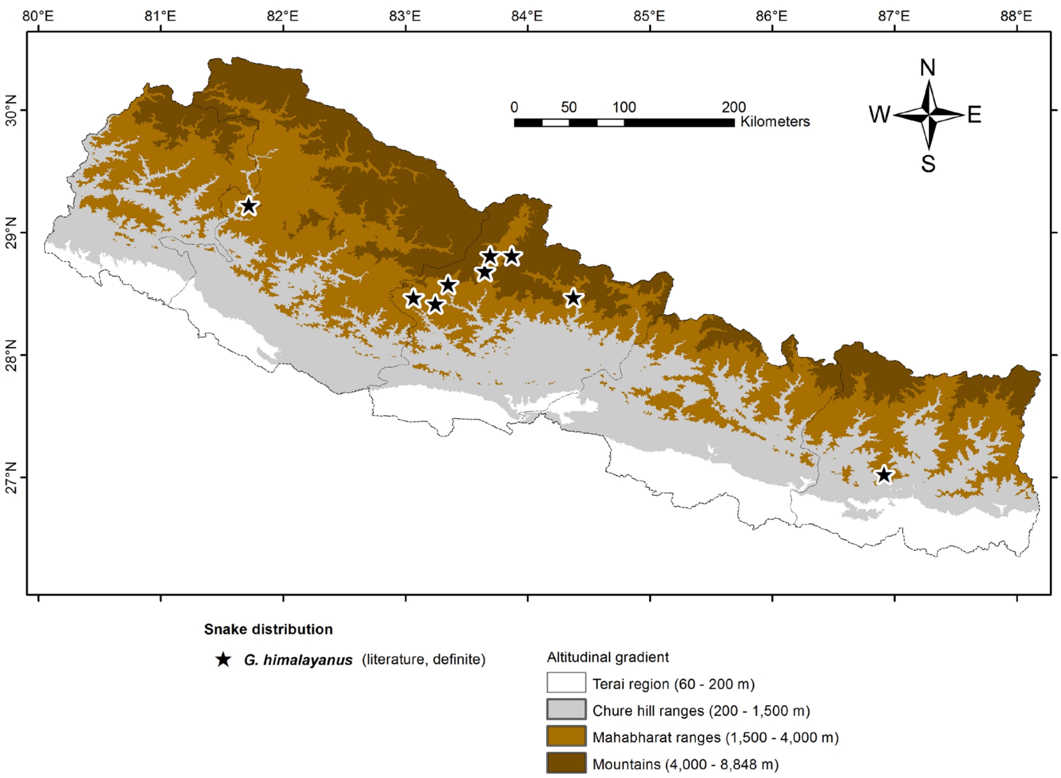


Figure 47. Distribution of *Gloydius himalayanus* in Nepal.

Identification

Gloydius himalayanus differs from *Python* species and *Eryx conicus* in having triangular head with pit organ (vs. these features are absent in *Python* species and *Eryx conicus*). *Gloydius himalayanus* differs from all Green Pit Vipers of Nepal in having brown or grey dorsal body with dark brown or blackish brown spots (vs. green dorsal body in *Trimeresurus albolabris, T. septentrionalis, T. erythrus* and *T. graminieus*). *Gloydius himalayanus* differs from *Ovophis monticola* and *Protobothrops jerdoni* in having (1) with large scales in the front and small scales in the back of head (small, many head scales in *O. monticola* and numerous, small and keeled head-top scales in *P. jerdoni*), (2) dorsal body brown or grey with dark brown or blackish brown spots (males slightly lighter than females), zig-zag bands or horse-shoe shaped blotches (vs. light or dark brown dorsal body with a series of large rectangular blotches and irregularly distributed dark brown or yellowish brown spots in *O. monticola* and yellowish-olive or olive brown dorsal body with a series of 42 to 50 irregularly shaped reddish brown bands (sometimes broken at the sides) with black and yellow borders in *P. jerdoni*), (3) belly brown, speckled black and white (vs. with smaller dark brown or black blotches in *O. monticola* and cream or yellowish-grey with numerous dark brown spots in chessboard-like pattern in *P. jerdoni*) and (4) body scales strongly keeled, arranged in 21 (rarely 23) rows (vs. smooth or weakly keeled 23–27 rows (rarely 21, 28 or 29) in *O. monticola*) (Figure 37, 38, 48).

Medical importance

No clinical and epidemiological information on envenoming due to *Gloydius himalayanus* bites is available for Nepal. Envenoming effects due to its bites are almost similar to those of other Pit Viper bites (Warrell, 1995). These included burning pain, local swelling that may extend up to the groin, blistering and local necrosis (Warrell, 1995). In some cases, pain and swelling disappears within two to three days without tissue damage.

Remarks

I did not find *Gloydius himalayanus* involved in snake bites during this study.

Figure 48. Brown or grey dorsal body with dark brown or blackish brown spots in *Gloydius himalayanus*. **A:** an adult female from Syang, Mustang District, western hills of Nepal, 2,700 m asl and **B:** a juvenile with striped pattern from same locality; photo by F. Tillack.

Smith (1943) reported that Wall collected a specimen at the foot of the Dharmsala Glacier in 4,877 m asl in northeastern India. Probably, Shah 1995 and Shah et al. 2003 generalized its distribution up to 4,800 m asl based on this information.

3.1.2.2.5. Genus *Protobothrops* Hoge and Romano-Hoge, 1983

This genus comprises 14 species that are distributed in south and Southeast Asia (Wallach et al., 2014, Uetz and Hošek, 2015). Only single species is known to be distributed in Nepal. I did not find it involved in snake bites during this study. Haemotoxicity is the main effect of their venom.

Protobothrops jerdonii (Günther, 1875)

Jerdon's Pit Viper

Trimeresurus jerdonii Günther 1875; type locality: Khasi Hills, India; syntypes: BMNH 196.1.18.66–68

Geographic distribution

Known to be distributed in Nepal, northeastern India, Bhutan, northwestern Myanmar, south China, Laos and north Vietnam (Kramer, 1977, Wallach et al., 2014). In Nepal, poorly known; so far only found in Dolakha District at 2,800 m asl (Kramer, 1977) (Figure 49). Likely to be distributed in elevation ranges between 1,200 m and 3,250 m asl (Kramer, 1977, Wallach et al., 2014).

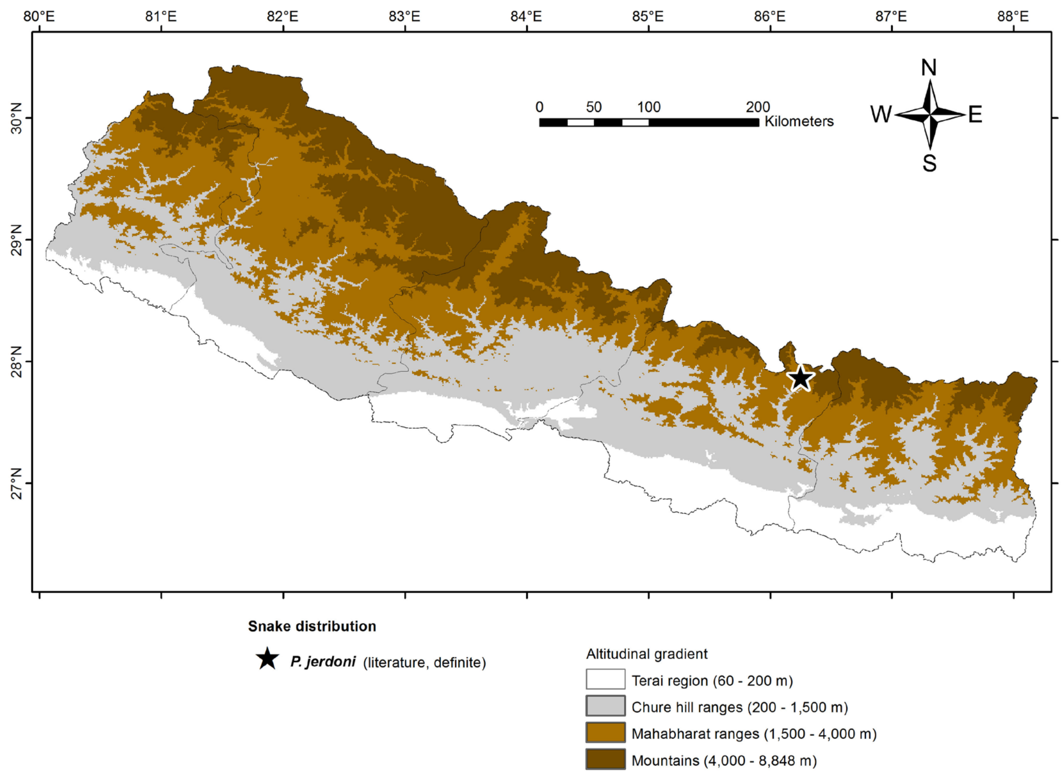


Figure 49. Distribution map of *Protobothrops jerdoni*.

Identification

Protobothrops jerdoni differs from all colubrids in having a triangular head with a pit organ (vs. these features are absent in those snakes). *Protobothrops jerdoni* differs from all Green Pit Vipers of Nepal in having yellowish-olive or olive brown dorsal body (vs. green dorsal body in *Trimeresurus albolabris, T. septentrionalis, T. erythrus* and *T. graminieus. Protobothrops jerdoni* differs from *Ovophis monticola* in having (1) yellowish-olive or olive brown dorsal body with a series of 42 to 50 irregularly shaped reddish brown bands (sometimes broken at the sides) with black and yellow borders (vs. light or dark brown dorsal body with a series of large rectangular blotches and irregularly distributed dark brown or yellowish brown spots in *O. monticola*, (2) keeled head-top scales (vs. smooth in *O. monticola*), (3) dorsal head surface black with symmetrical yellow marks (vs. brown with or without dark blotches in *O. monticola*) and (5) cream or yellowish-grey belly with numerous dark brown spots in chessboard-like pattern (vs. with smaller dark brown or black blotches *O. monticola,* Figure 37, 38, 40, 41, 50).

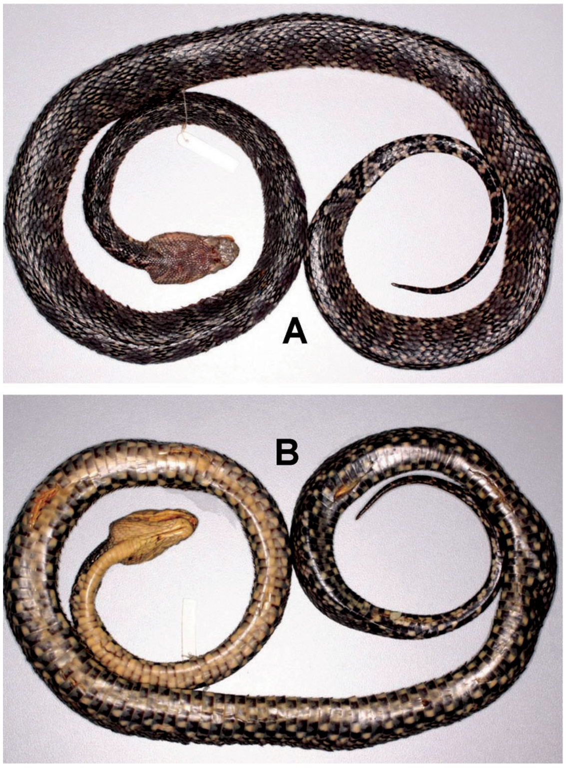


Figure 50. Colour pattern of *Protobothrops jerdoni*. **A:** olive brown dorsal body with symmetrical yellow marks on head and **B:** cream or yellowish-grey belly with numerous dark brown spots in chessboard-like pattern (Dolakha District, central hills of Nepal, 2,600 m asl, photo by F. Tillack).

Medical importance

No clinical and epidemiological information on envenoming due to *Protobothrops jerdoni* bite is available for Nepal. Envenoming effects due to its bites may be similar to other Pit Viper bites (Warrell, 1995).

Remarks

I did not find *Protobothrops jerdoni* involved in snake bites during this study.

Pit vipers requiring further studies

In Nepal, *Trimeresurus erythrus* has been listed to occur (National Trust for Nature Conservation, 1994, Rai, 2003, Shah and Tiwari, 2004) without reliable locality and specimen details (Kabisch, 2002c, Kästle et al., 2013a), the distribution of *T. graminieus* is questionable (Shah and Tiwari, 2004) and *T. insularis* does not occur in Nepal (Kramer, 1977). Thus, I did not describe their characteristics, although *T. albolabris* is similar to these pit vipers. Since *T. albolabris* and *T. sepentrionalis* are highly similar, their distribution pattern, phylogeny and degree of medical significance should be thoroughly revised.

3.1.2.3. Family Colubridae

The Natricinae subfamily of the Colubridae family includes at least 227 species belonging to 35 genera (Uetz and Hošek, 2015). Some aglyphous snakes (e.g., *Rhabdophis* species) possess buccal glands secreting toxic saliva (Leviton et al., 2003). Venoms poured into the wound during the bite (or chewing) may cause local to serious systemic envenoming effects and death of the victim. They are also distributed in Nepal (Gruber, 2002).

3.1.2.3.1. *Rhabdophis* Fitzinger, 1843

In Asia, 21 *Rhabdophis* species are distributed (Wallach et al., 2014, Uetz and Hošek, 2015), two in Nepal (Swan and Leviton, 1962, Pandey, 2012). So far only *R. subminiatus* and *R. tigrinus* (Ogawa and Sawai, 1986) have been involved in human envenoming. *Rhabdophis subminiatus* and *R. himalayanus* are distributed in Nepal and may be medically important, although no information about confirmed bites is available. I did not find any *Rhabdophis* species involved in snake bites during this study. Herein, I describe only species that caused severe human envenoming.

***Rhabdophis subminiatus* (Schlegel, 1837)**

Red-necked Keelback

Tropidonotus subminiatus Schlegel 1837; type locality: Java, Indonesia; holotype: RMNH

Geographic distribution

Distributed in northeastern India, Bangladesh, China, Thailand, Vietnam, Cambodia, Laos, Myanmar, west Malaysia, Singapore and Indonesia (Warrell, 1995, Wallach et al., 2014, Zhu et al., 2014). In Nepal, the snake is recorded only from the Chitwan Valley, the southcentral lowlands (Pandey, 2012). This Chitwan specimen was submitted to the Central Department of Zoology, Tribhuvan University (T. U.), Kritipur, Nepal in 2002 (Pandey, 2012). Probably, two other sources mention its distribution in Chitwan based on specimen submitted to T. U. (Gruber, 2002, Shah and Tiwari, 2004) (Figure 51).

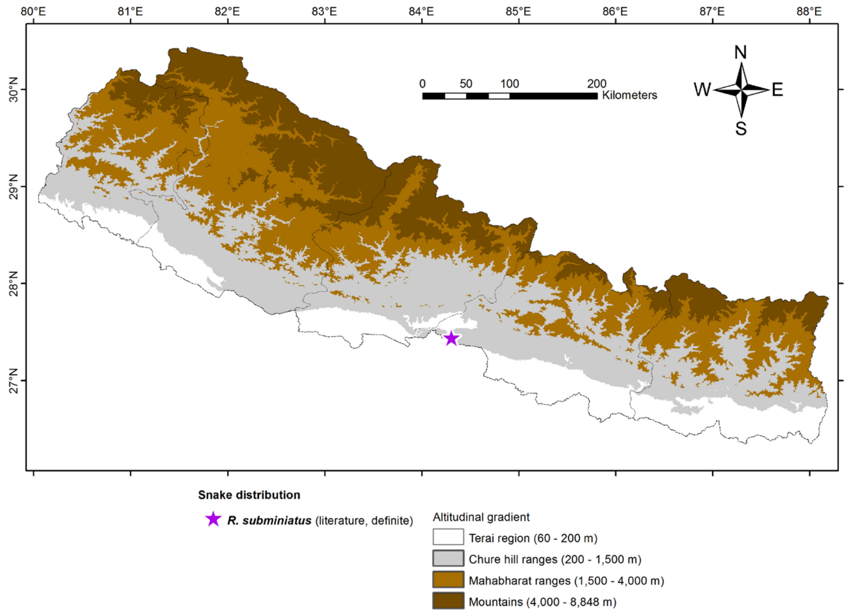


Figure 51. Distribution of *Rhabdophis subminiatus* in Nepal.

Identification

Rhabdophis subminiatus differs from closely related *Amphiesma* and *Xenochrophis* species in having a groove on dorsal surface of the neck (vs. the groove is absent in those species). *Rhabdophis subminiatus* differs from *R. himalayanus* in having (1) scales of the groove on the neck are larger than the neighbouring scales (vs. clearly narrower in *R. himalayanus*) and the reddish colour on the forebody present on the interstitial skin only (vs. present on the interstitial skin and on the scales in *R. himalayanus*, Figure 52, 53).

Medical importance

Venoms of this snake species are potentially lethal to humans (130 microgram venom is the lethal dose for a 20 gm mouse) (Warrell, 1995). There is no report of confirmed bites by this species in Nepal. But, in other countries, it has caused life-threatening envenoming such as headache, nausea, vomiting, thrombocytopenia, coagulopathy and bleeding (Mather et al., 1978, Mebs et al., 1987, Smeets et al., 1991, Zotz et al., 1991, Warrell, 1995, Seow et al., 2000). This species has no venom apparatus to inject venom into human (or animal) body as in proteroglyphous and solenoglyphous snakes. The snake has an aglyphous dentition (Mebs et al., 1987). Duvernoy's glands secretions containing coagulating enzymes are carried into the saliva that is poured into the wound during the bite. Since there are reports of death due to the bites of similar species *R. tigrinus* (Mittleman and Goris, 1978, Ogawa and Sawai, 1986), *R. subminiatus* should be considered as a medically relevant species for Nepal as well. Although *R. subminiatus* was previously considered a nonvenomous colubrid snake, preventive measures of snake bites should be adopted while handling any colubrid snake and medical advice should be sought after bite.

Although venom effects of *Rhabdophis himalyanus* have not been reported yet, similar symptoms may be anticipated after its bites.

Remarks

I did not find *Rhabdophis subminiatus* involved in snake bites during this study although it is distributed in Chitwan Valley (Pandey, 2012). The risk of envenoming is high in Chitwan Valley in the southcentral lowlands as it has been recorded from only this valley in Nepal. But, this may also include the entire lowlands. Recently, I have confirmed *Rhabdophis himalyanus* to be distributed in Ghandruk, Kaski District, mid-western hills of Nepal supported by photo vouchers (Figure 53).

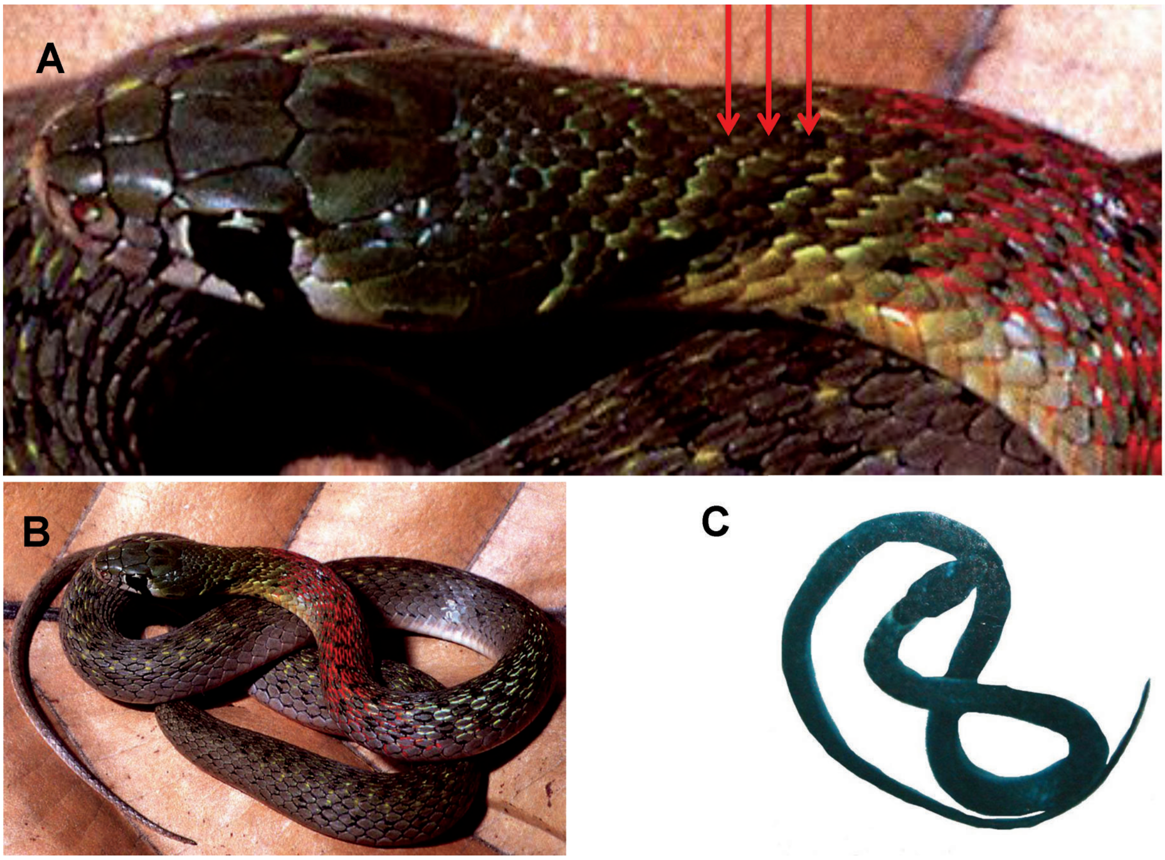


Figure 52. *Rhabdophis subminiatus* having larger scales of the groove on dorsal surface of neck than the neighbouring scales and the reddish colour occurring on the interstitial skin on the forebody. A,B: an adult female *R. subminiatus* from Khao Lak, Phang Nga, Thailand; photo by F. Tillack; C: dorsal view of *R. subminiatus* specimen from Chitwan Valley, cited in Pandey (2012).

Figure 53. *Rhabdophis himalayanus* from Ghandruk, Kaski District, mid-western hills of Nepal.

3.1.2.3.2. Opisthoglyphous or aglyphous snakes in the present study with doubtful medical relevance

Numerous species of snakes belonging to the Colubridae family have rear-fangs i.e., opisthoglyphous dentition. Bites have been reported in various countries (Weinstein et al., 2011). Bites occurred when people handled the snakes.

In this section, these mildly venomous opisthoglyphous and aglyphous snake species listed in Table 2.b are not described. Some opisthoglyphous genera e.g., *Ahaetulla*, *Boiga*, etc. possess a venom and are involved in human envenoming in other countries (Weinstein et al., 2011). They are distributed in Nepal, but no case reports of envenoming by these species are available.

Because of limited or no clinical and epidemiological information of envenoming by these snakes, their medical relevance is still questionable. Although they are generally regarded as mildly venomous, they may cause serious envenoming in humans depending on the frequency of bites, the size of snake and health condition and age of the victim. Therefore, further, comprehensive studies including their venom properties are necessary to declare their medical relevance.

3.1.3. Time, season and place of medically relevant snake bites

Of the total 199 medically relevant snake specimens collected, the time of bite was known for 121 snakes, date for 139 snakes and place of bite for 93 snakes. Envenoming due to these snakes occurred mainly at night (n = 46, 23% of the total medically relevant specimens), in the morning (n = 29, 15%), during day time hours (n = 21, 10%) and in the very early morning (n = 5, 3%). Likewise, among these 121 specimens, most envenoming episodes occurred during the rainy season (June to September, n = 99, 50%) followed by the dry (March to May, n = 26, 13%) and winter season (October to February, n = 14, 7%) (Table 3, Figure 54).

Seven of 11 medically relevant snake species (n = 71 specimens) were involved in snake bites in residential areas during this study (7 species bit people in the premises of house (n = 15 specimens) and 5 species indoors (n = 56 specimens, Figure 55). Proteroglyphous snakes prevailed over other species. Of micro-level localities known for 70 specimens (35% of medically relevant specimens), 27 snakes (i.e., 14%) were involved in bites to sleeping people (Table 3).

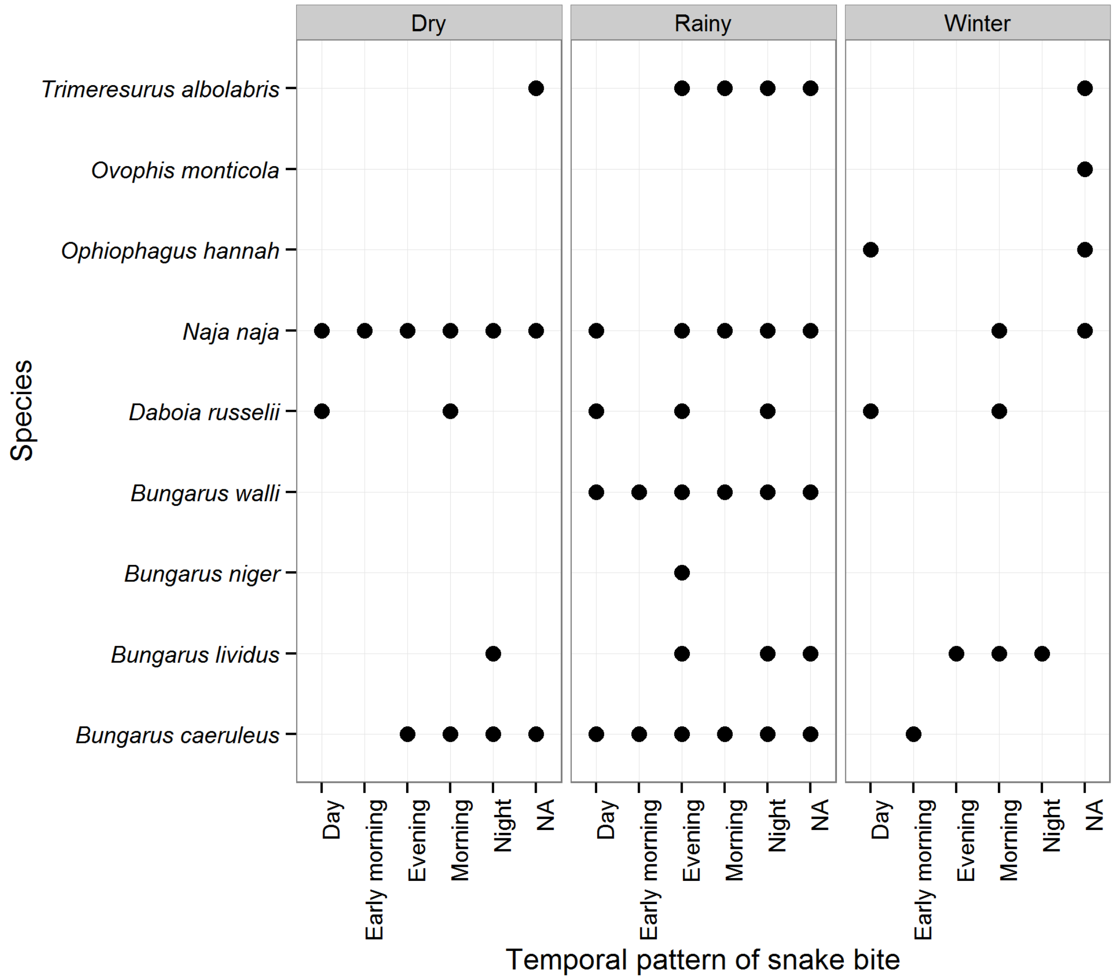


Figure 54. Medically relevant snakes with known period and season of bites. Period and month of bite was not known for 78 and 60 cases, respectively. The dry season includes March–May, the rainy June–September and the winter October–February.

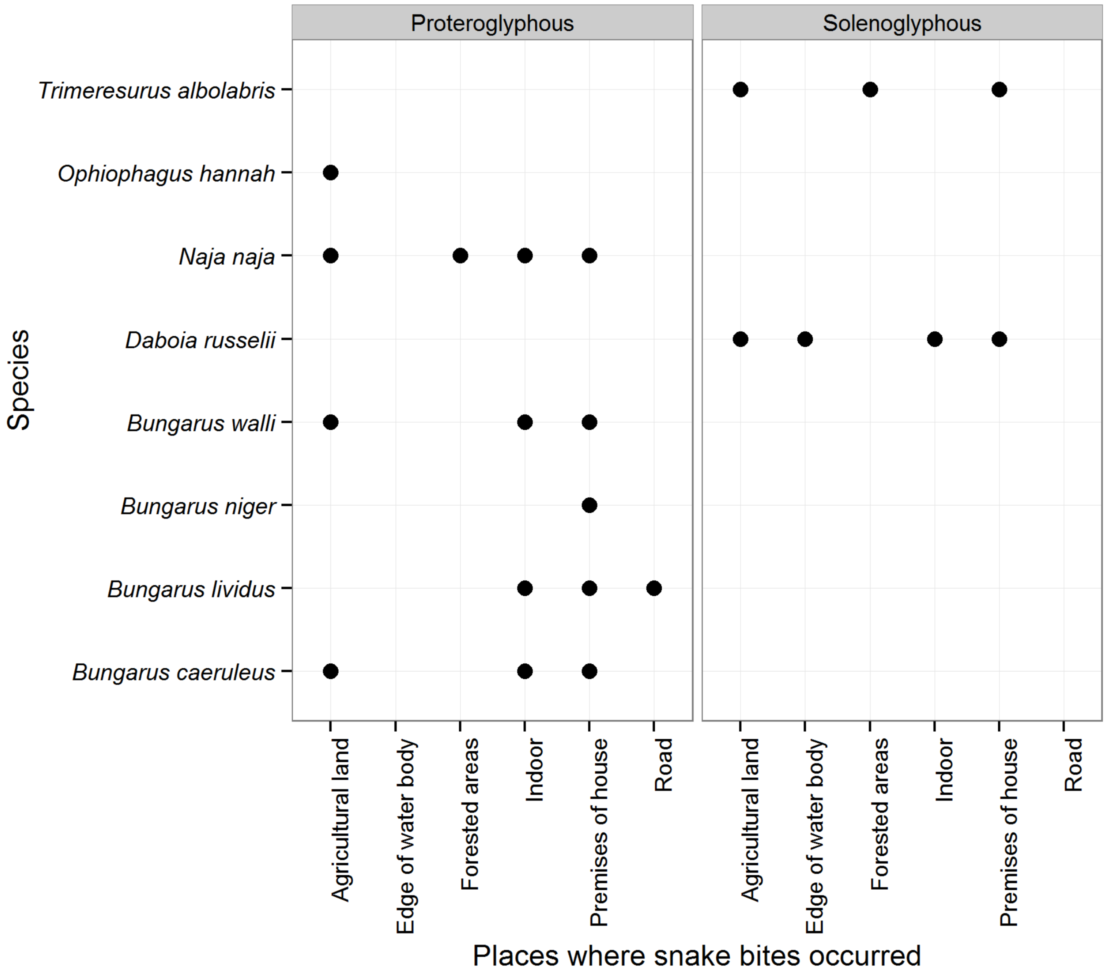


Figure 55. Places risk for medically relevant snake bite in Nepal.

3.1.4. Snakes brought alive to the hospital in the course of snake bite treatment

Eleven patients or their attendants brought live snakes involved in bites representing 10 species. Of these 10 species, seven were snakes potentially causing lethal envenoming. *Bungarus lividus*, *B. fasciatus, N. naja* and *T. albolabris* were collected in the Charaali snake bite treatment centre (STC), *B. walli*, *Python bivittatus* and *Lycodon aulicus* in Damak STC, *Amphiesma stolatum* and *B. caeruleus* in Dudhouli and two *Daboia russelii* specimens were collected in Tribeni STC.

Table 3. Risk factors of snake bite envenomings in Nepal based on evidence of involved medically relevant snakes.

Risk factors	Risk of medically relevant snake bites (N = 199) N (%)	Statistics ($\chi 2$ = chisquare test value, df = degree of freedom, p = level of significance at 5%)
A. Snake species (n = 11)	**199 (100)**	
A.1. Proteroglyphous snakes	***178 (89)***	*$\chi 2$ = 287.08, df = 7, p = < 0.001*
Naja naja	76 (38)	
Bungarus caeruleus	65 (33)	
Bungarus walli	13 (7)	
Bungarus lividus	10 (5)	
Bungarus fasciatus	8 (4)	
Naja kaouthia	3 (2)	
Ophiophagus hannah	2 (1)	
Bungarus niger	1 (1)	
A.2. Solenoglyphous snakes	***21 (11)***	*$\chi 2$ = 7.71, df = 2, p = 0.021*
Daboia russelii	10 (5)	
Trimeresurus albolabris	10 (5)	
Ovophis monticola	1 (1)	
B. Periods of the day	**121 (61)**	$\chi 2$ = 36.98, df = 4, p = <0.001
Night (20:00–02:59 h)	46 (23)	
Morning (05:00–09:59 h)	29 (15)	
Day (10:00–16:59 h)	21 (11)	
Evening (17:00–19:59 h)	20 (10)	
Early morning (03:00–04:59 h)	5 (3)	
Not available	78 (39)	
C. Months	**139 (70)**	$\chi 2$ = 107.65, df = 11, p = <0.001
July	28 (14)	
June	25 (13)	
August	23 (12)	
September	23 (12)	
May	15 (8)	
April	10 (5)	
November	6 (3)	
October	5 (3)	
January	1 (1)	
February	1 (1)	
March	1 (1)	
December	1 (1)	
Not available	60 (30)	
D. Seasons	**139 (70)**	$\chi 2$ = 91.35, df = 2, p = <0.001
Rainy season (June–September)	99 (50)	
Dry or Pre-monsoon season (March–May)	26 (13)	
Winter season (October–February)	14 (7)	

E. Places i.e. localities (where bite occurred)		
E.1. Macrolevel localities	***93 (47)***	$\chi 2$ = 143.19, df = 5, p = <0.001
Indoor	56 (28)	
Agricultural lands	17 (9)	
Premises of houses	15 (8)	
Forested areas	3 (2)	
Edge of water body	1 (1)	
Road	1 (1)	
Not available	106 (53)	
E.2. Microlevel localities	***70 (35)***	*$\chi 2$ = 86.34, df = 23, p = <0.001*
Bed on furniture	15 (8)	
Agricultural lands (crops not defined)	9 (5)	
Bed (on furniture or floor not defined)	7 (4)	
Bed on floor	5 (3)	
Yard or Backyard	4 (2)	
Door or near door	4 (2)	
Floor	3 (2)	
Cowshed	2 (1)	
Culvert	2 (1)	
Outskirts of the house	2 (1)	
Paddy field*	2 (1)	
Pile of straw used as fodder	2 (1)	
Sugarcane*	2 (1)	
Corner of house	1 (1)	
Corridor of house	1 (1)	
Fishing area	1 (1)	
Grass (Bamboo)*	1 (1)	
Ground	1 (1)	
Muddled agricultural field	1 (1)	
Piles of paddy	1 (1)	
Roof	1 (1)	
Sack of grain	1 (1)	
Stump of a tree	1 (1)	
Toilet	1 (1)	
Not available	129 (65)	

*vegetation areas

3.2. Epidemiology, circumstances and pre-admission histories of confirmed venomous snake bites in southern Nepal

3.2.1. Incidence of snake bites, envenoming and case fatalities

At least 43 envenomings among 808 snake bites occurred annually in southern Nepal. This resulted in at least four deaths per year and 10% case fatality rate (Table 4).

During this study, I confirmed 96 kraits and 10 Russell's Vipers among 199 snake specimens involved in snake bites (Table 2.a). Of the confirmed krait (*Bungarus* species) bite cases (n = 65, 19%), I characterized the socio-demographic and socio-economic background, the circumstances of bites and pre-admission interventions used in 34 Common Kraits (*Bungarus caeruleus*), in six Wall's Kraits (*B. walli*), in five Lesser Black Kraits (*B. lividus*), in one Greater Black Krait (*B. niger*) and in 10 Russell's Viper (*Daboia russelii*) bites.

Among these cases, krait bites caused eight deaths (case fatality rate = 17%) and five dry bites (11%), Russell's Viper caused no death and no dry bites. Among the eight deaths, *Bungarus caeruleus* alone caused five, *B. walli* two and *B. niger* one death. All dry bites were due to *Bungarus caeruleus*.

3.2.2. Socio-demographic and socio-economic features

Socio-demographic background as shown in appendix 6**:** The mean age of the krait bite patients was 30.3 ± 2.1 years (95% CI = 26–35). Of 46 proven krait bites, envenomings due to kraits occurred according to age group ($\chi 2 = 36.174$, df = 2, p = <0.001) with 74% (n = 34) envenoming in 18–52 years old adults, 22% (n = 10) in children below 18 years (the patient with minimum age was five years old) and 4% (n = 2) in 60–65 years old elders. 57% (n = 26) were males, 43% (n = 20) females, 43% (n = 20) farmers, 35% (n = 16) students (22% belonged to farmer families) and 33% (n = 15) patients were illiterate (Figure 56).

Adults were affected by envenomings due to Russell's Viper bites ($\chi 2 = 6.2$, df = 2, p = 0.045) as well. Among these viper bite cases, the mean age of patients was 39.4 ± 6.9 years (95% CI = 23.79–55.01); 70% (n = 7) were adults aged 18–44 years, 10% (n = 1) a 4-years old child, 20% (n = 2) 70–82 years old elders; 60% (n = 6) were males, 40% (n = 4) females, 70% (n = 7) farmers, 20% (n = 2) students (one student belonged to a farmer family) and 40% (n = 4) patients were illiterate (Figure 56). Both Common Kraits ($\chi^2 = 0.783$, df = 1, p = 0.376) and Russell's Viper bites ($\chi^2 = 0.4$, df = 1, p = 0.527) did not occur according to gender (Figure 56).

Table 4. Annual incidence of venomous snake bites and associated deaths in southern Nepal.

STC code	Study centres (i.e. Snake bite treatment centres (STCs))	Population getting snake bite treatment service*	Years	Snake bite cases‡	Envenomed cases	Death cases	Case fatality rate (%)	Snake bites per year	Envenoming per year	Deaths per year	Annual snake bite incidence per 100,000 population		
											Bites	Envenomings	Deaths
1	Nepal Red Cross Society, Sub-branch, Damak, Jhapa, Eastern DR	679,141	5	5,837	300	54	18	1,167	60	11	172	9	2
2	Charaali STC, Jhapa, Eastern DR	1,173,507	5	6,983	243	13	5	1,397	49	3	119	4	0
3	Bharatpur Hospital, Chitwan, Central DR	1,221,495	1.6	512	99	7	7	322	62	4	26	5	0
4	Kaligandaki Community Hospital, Kawaswoti, Nawalparasi, Western DR	252,820	3.4	627	33	7	21	184	10	2	73	4	1
5	Bajradal Battallion STC, Tribeni, Nawalparasi, Western DR	241,106	2.7	887	74	9	12	328	27	3	136	11	1
6	Dudhauli STC, Dudhauli, Sindhuli, Central DR	48,508	0.7	220	40	2	5	309	56	3	637	116	6
7	Netragunj STC, Nawalpur, Sarlahi, Central DR	822,475	1.5	1,132	30	3	10	755	20	2	92	2	0
8	Jayakali Snakebite Treatment Center, Chorva, Siraha (JSTC), Eastern DR	749,785	4.7	2,749	134	14	10	584	28	3	78	4	0
9	Community STC, Itahari, Sunsari, Eastern DR	1,260,617	2.7	3,106	219	12	5	1,165	82	5	92	7	0
	Total	**6,449,454**	**27**	**22,053**	**1,172**	**121**	**10**	**808**	**43**	**4**	**13**	**1**	**0.1**

*numbers of population affected by snake bites was obtained from ´Population Census 2011´ according to the service areas of the respective snake bite treatment centre reported by health professionals involved in that centre; ‡confirmed snake bite cases only.

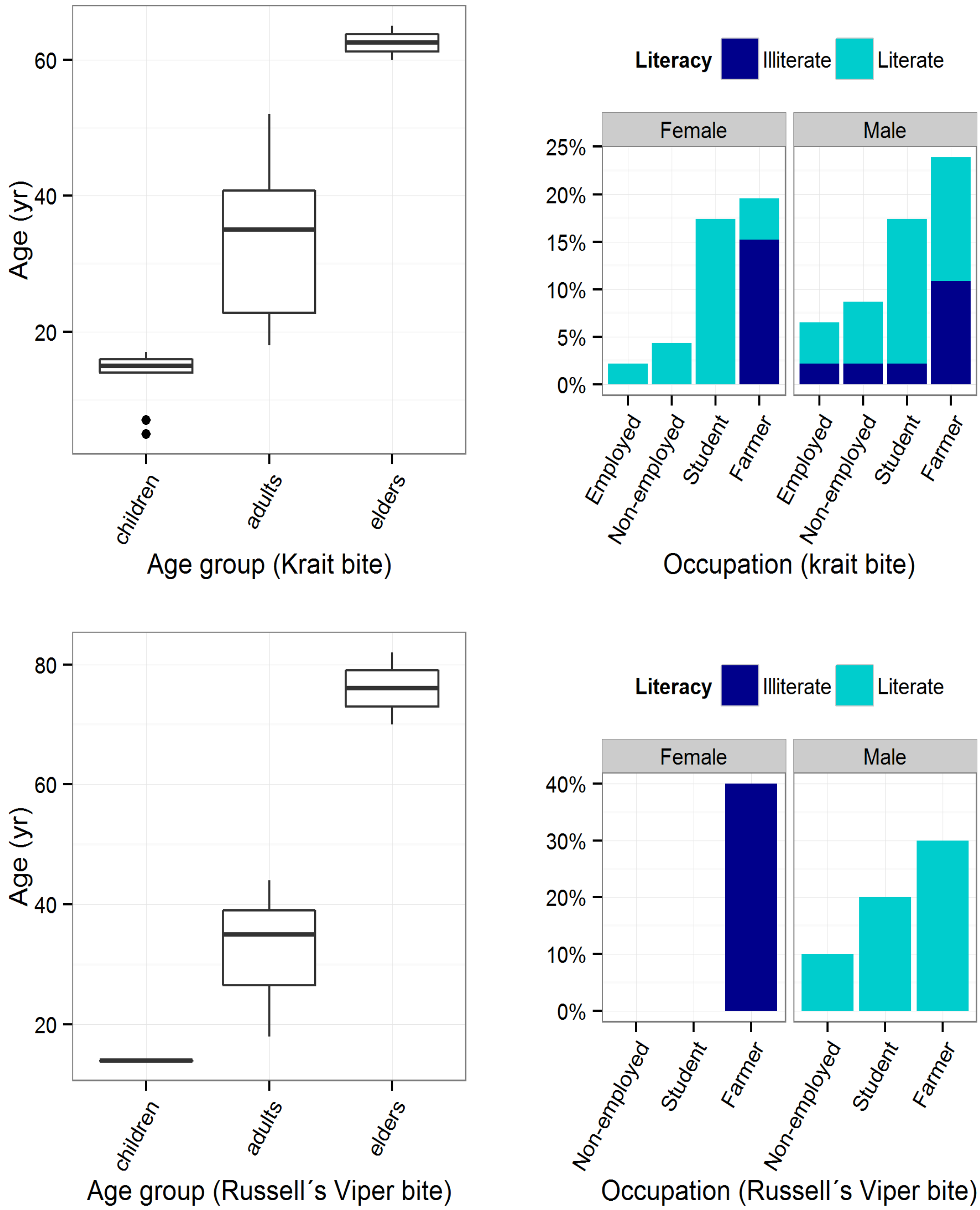
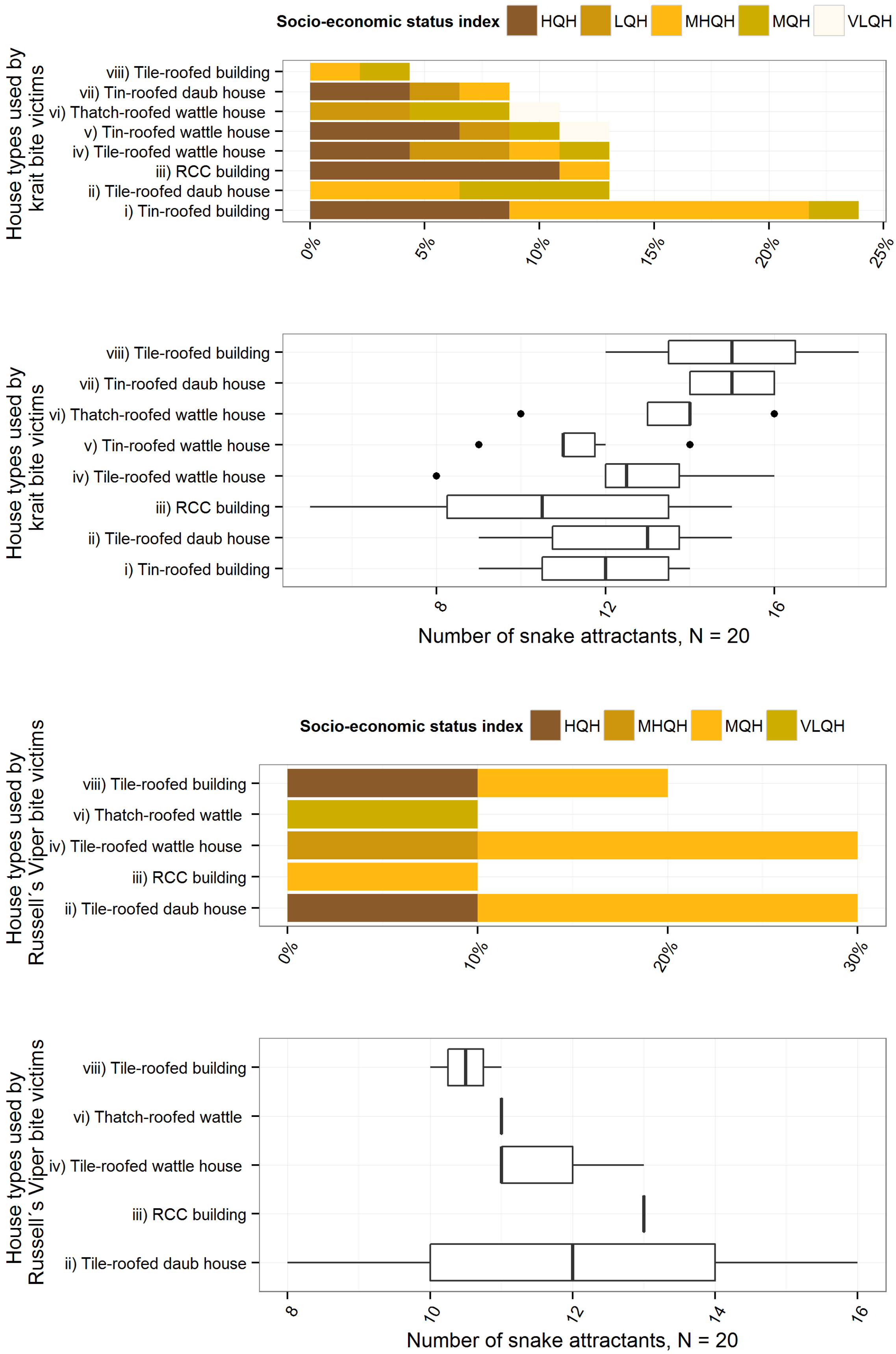


Figure 56. Demographic distribution (i.e., age structure, gender, occupation and literacy) of patients bitten by krait and Russell's Vipers. Detailed demographics are mentioned in the appendix 6.

Socio-economic status as shown in appendix 6: Kraits mostly affected households with medium (n = 12, 26%) to high socio-economic status (n = 15, 33%) and entered all types of houses (χ^2 = 7. 913, df = 7, p = 0.34) causing bites, which mostly occurred in brick/block/bamboo-cement houses with galvanized-tin roofs (n = 11, 24%). Russell's Vipers mostly affected households with medium socio-economic status (n = 6, 60%) and entered only a single house. It caused bites mostly in agriculatural areas (Figure 57, Figure 58).


Socio-economic status index
HQH
LQH
MHQH
MQH
VLQH
House types used by krait bite victims
viii) Tile-roofed building
vii) Tin-roofed daub house
vi) Thatch-roofed wattle house
v) Tin-roofed wattle house
iv) Tile-roofed wattle house
iii) RCC building
ii) Tile-roofed daub house
i) Tin-roofed building
0%
5%
10%
15%
20%
25%
House types used by krait bite victims
viii) Tile-roofed building
vii) Tin-roofed daub house
vi) Thatch-roofed wattle house
v) Tin-roofed wattle house
iv) Tile-roofed wattle house
iii) RCC building
ii) Tile-roofed daub house
i) Tin-roofed building
8
12
16
Number of snake attractants, N = 20
Socio-economic status index
HQH
MHQH
MQH
VLQH
House types used by Russell´s Viper bite victims
viii) Tile-roofed building
vi) Thatch-roofed wattle
iv) Tile-roofed wattle house
iii) RCC building
ii) Tile-roofed daub house
0%
10%
20%
30%
House types used by Russell´s Viper bite victims
viii) Tile-roofed building
vi) Thatch-roofed wattle
iv) Tile-roofed wattle house
iii) RCC building
ii) Tile-roofed daub house
8
10
12
14
16
Number of snake attractants, N = 20

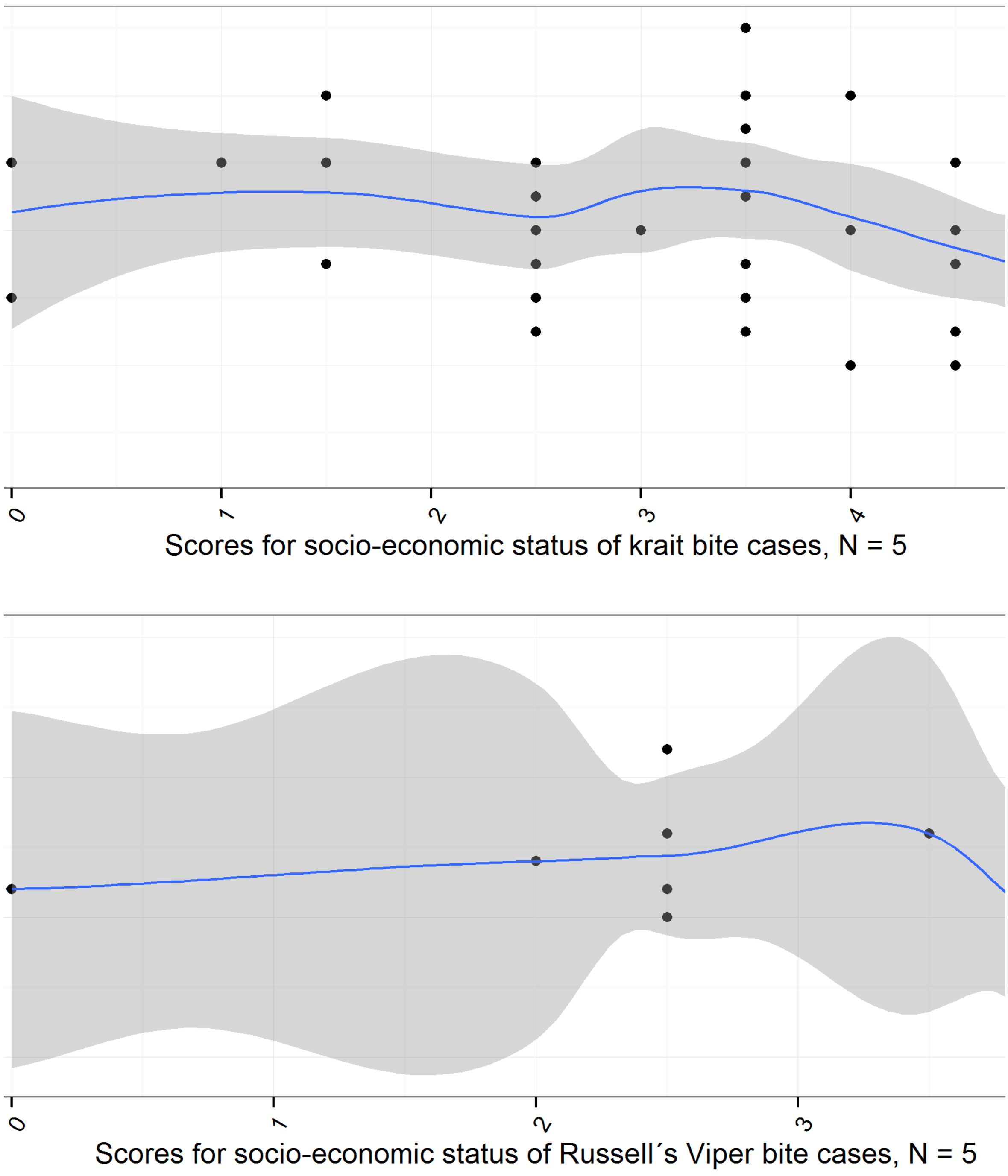


Figure 57. Socio-economic status (SES) index, house types and snake attractants in and around the houses used by krait (n = 46) and Russell's Viper bite patients (n = 10). Linear regression line and 95% confidence intervals for the distribution of snake attractants (response variable) against scores for socioeconomic status of krait and Russell's Viper bite cases is shown in the last two figures. **HQH** = high quality households; **MQH** = medium quality households; **MHQH** = medium high quality households; **LQH** = low quality households; **VLQH** = very low quality households. Detailed statistical information is mentioned in the appendix 6. The legend for house types used is elaborated in the legends for figure 58 and snake attractants in appendix 6.

Figure 58. Types of houses where krait bites occurred. The houses are ordered according to

frequency krait bites occurred in the particular houses. The types of houses shown in this figure also apply for Russell's Viper bites.

(i) = Brick/block/bamboo-cement or brick-wood-cement houses with galvanized-tin roofs,

(ii) = Brick/stone-wood-daub houses with tiled roofs,

(iii) = Rod-concrete-cement buildings,

(iv) = Wattle and daub (wood, bamboo) houses with tile/slate roofs,

(v) = Wattle and daub (wood, bamboo) houses with galvanized-tin roofs,

(vi) = Wattle and daub (wood, bamboo) houses with thatched roofs,

(vii) = Brick/stone-daub houses with galvanized-tin roofs,

(viii) = Brick-wood-cement houses with tiled roofs.

3.2.3. Circumstances and risk factors of envenoming

3.2.3.1. Localities and sites where bites occurred, accessibility to health centres and transport facilities, body parts affected and activities of victims

Locality where bite occurred: Krait bites occurred mostly in rural areas (n = 29, 63%, p = < 0.001) in average 24.1 ± 3 km road distance (95% CI = 16–31) from snake bite treatment centre (Table 1, Figure 3). Of the total krait bite patients, 61% used black and gravel road (p = < 0.001). After about one km of soil road travel, they had access to gravel or paved roads. Russell's Viper bites also occurred mostly in rural areas (n = 8, 80%, p = 0.007) in average 15.7 ± 1.6 km road distance (95% CI = 12.16–19.30) from snake bite treatment centre (Table 1, Figure 3). Patients often used paved roads (60%, p = 0.044). After less than one km soil road travel, they accessed paved road (Appendix 6).

Accessibility to health and transport facilities: Krait bite cases needed 0.3–16 hours to reach the snake bite treatment centre (mean ± SEM = 2.46 ± 0.43, median = 1.4, sd = 2.94, 95% CI = 1.3–2.55, p = 0.09) and Russell's Viper bite 0.3–1.5 hours (mean ± SEM = 0.53 ± 0.12, median = 0.33, sd = 0.37, 95% CI = 0.33–0.67, p = 0.011, Appendix 6). 35% (n = 16) krait bite and 90% (n = 9) Russell's Viper bite victims were admitted to STCs (Table 1, Figure 3) within 1 hour (Appendix 6, Figure 59). 45 of 46 krait bites occurred in areas accessible by four-wheel vehicles only, one area could only be accessed by motorcycle. Regarding ambulance availability when needed, 29 (63%) krait bite respondents replied that an ambulance could be available within 30 minutes after an emergency call (Appendix 6). Emergency transport could be available within 30 minutes of call also for all Russell's Viper bite victims (Appendix 6).

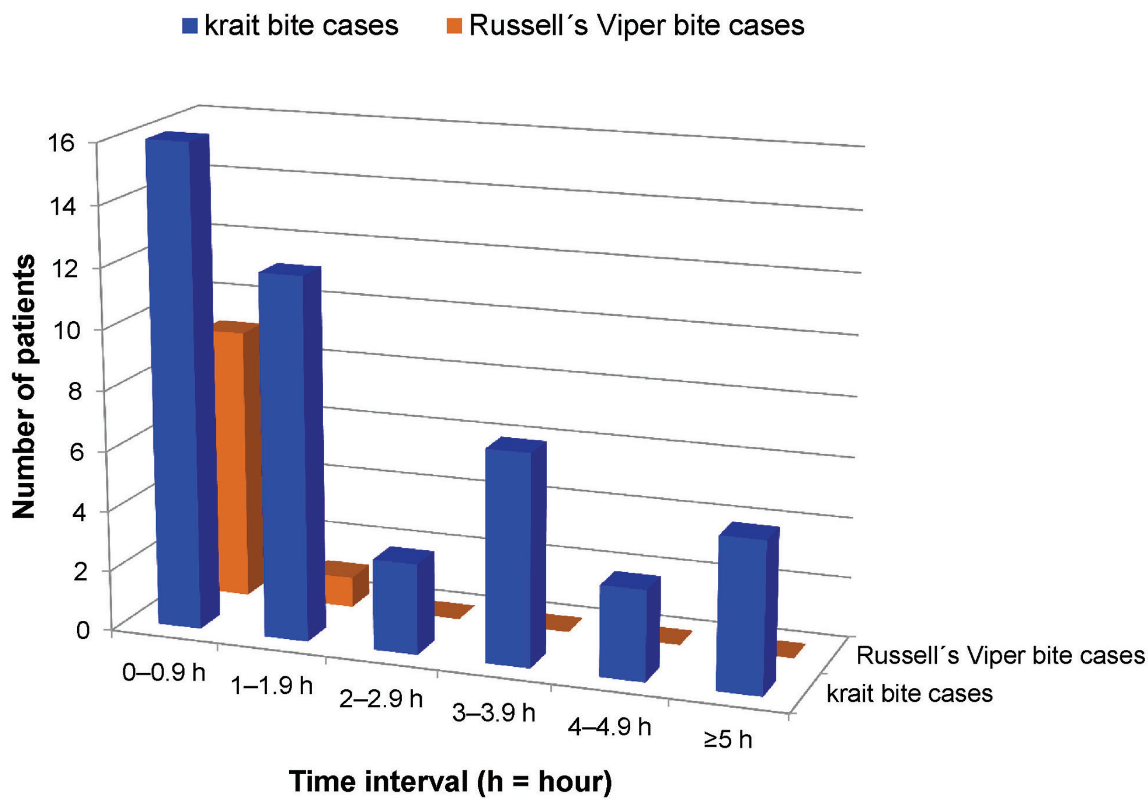
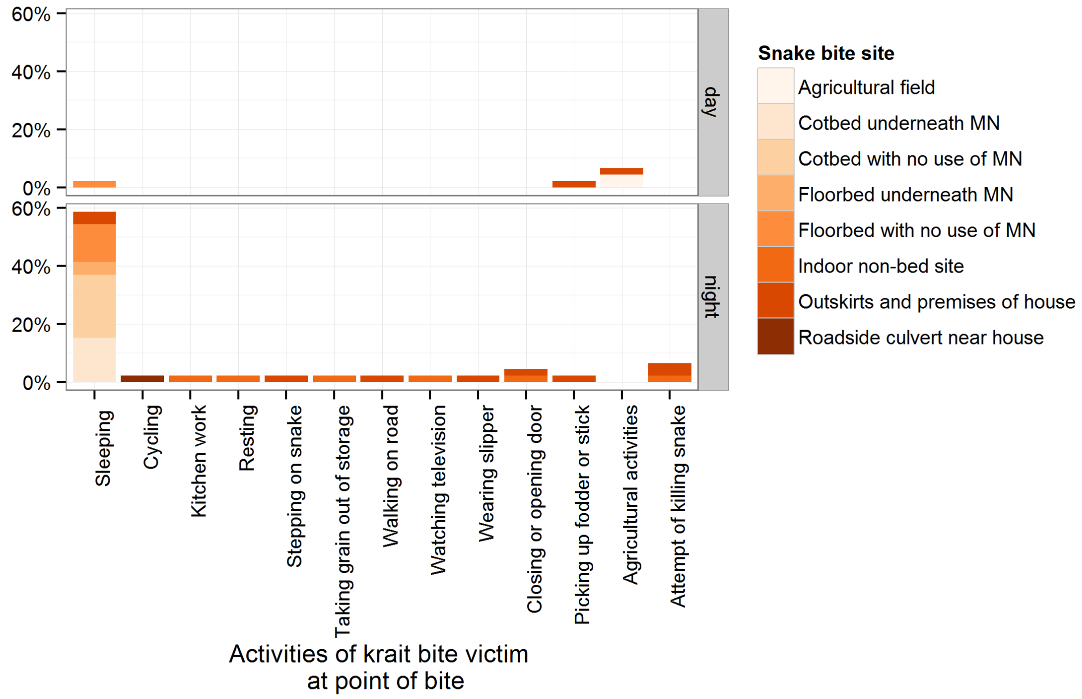


Figure 59. Time interval between snake bite and hospital access.

Specific site where bite occurred and activities of victims during the bite: 70% (n = 32) krait bites occurred indoors while the patient was sleeping (61%, n = 28) in bed. Most of them used a furniture bed (65%, n = 17) and a mosquito net (35%, n = 9). The rest of the bites occurred while sleeping on the floor (35%, n = 9), in attempts to kill the snake (7%, n = 3) or opening/closing a door (4%, n = 2). 30% (n = 14) of the bites occurred outdoors (either in the outer corridor, yard or premises of house except in three case where the bite occurred in the agricultural field while digging, ploughing and cutting grass) (Appendix 6, Figure 60).

Contrarily, Russell's Viper bites occurred mainly outdoors (90%, n = 9) while the patient was involved in agricultural activities (70%, n = 7). Only a single bite (10%) occurred indoors while picking up the mattress and two (20%) in the premises of the house (Appendix 6, Figure 60).



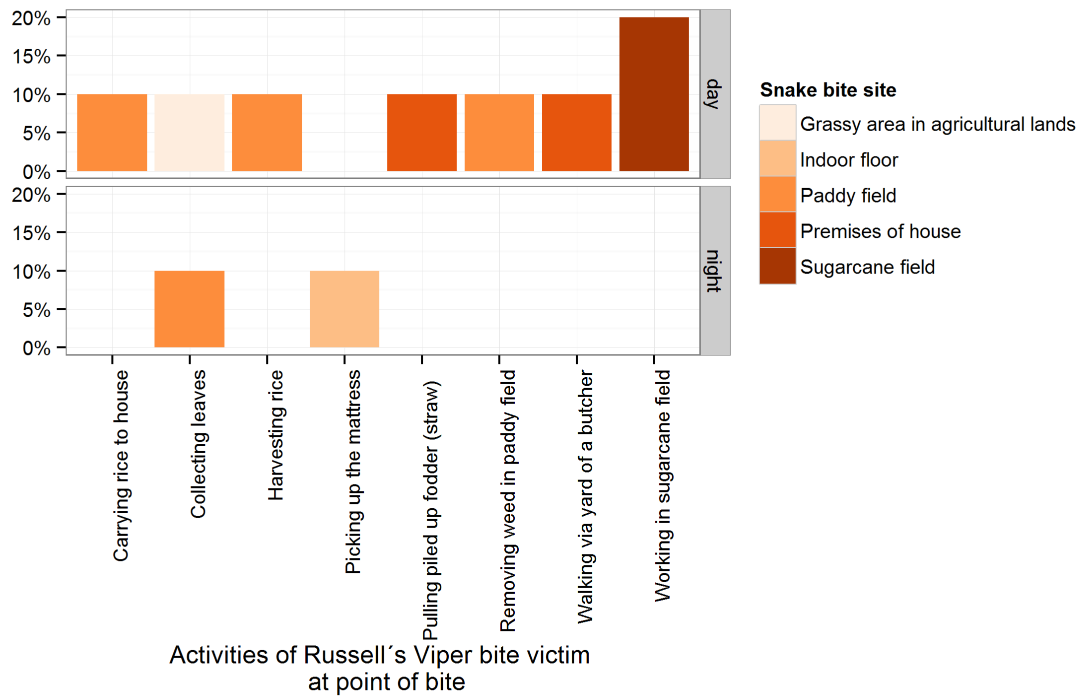
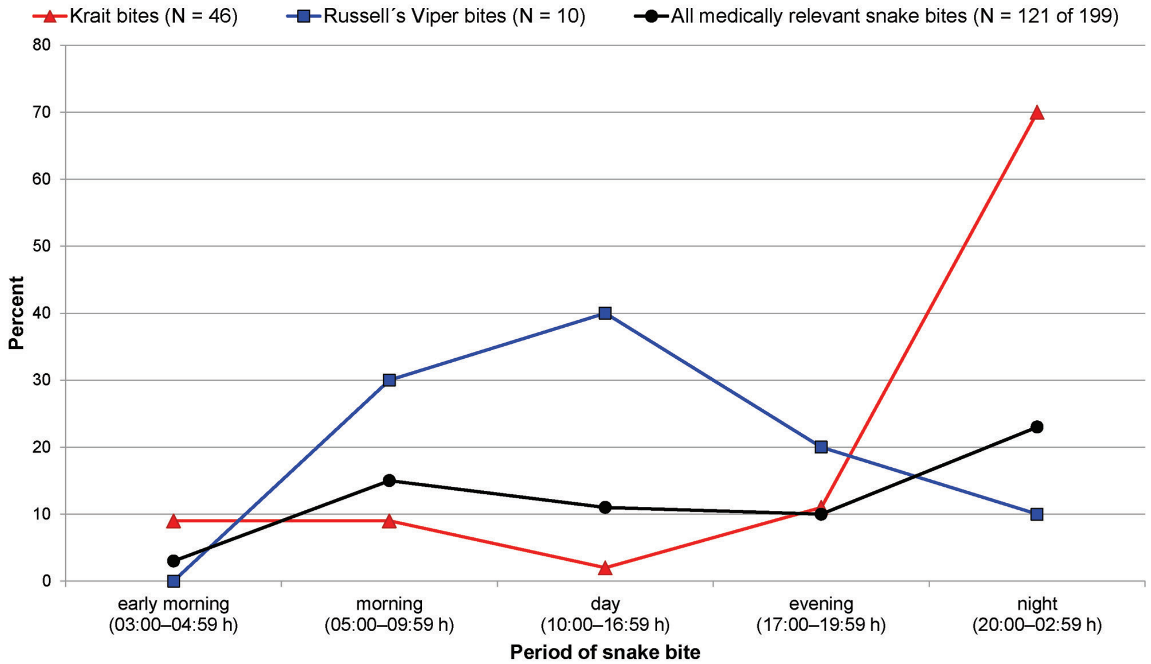


Figure 60. Places, time and activities of the victims bitten by kraits and Russell's Vipers. MN = mosquito net.

Body parts affected in snake bite: With both kraits and Russell's Viper mainly upper extremities were bitten. Patients received bites in the hands, 41% (n = 19) by kraits and 80% (n = 8) by Russell's Viper bite. The bites due to kraits were especially common in fingers or toes (49%, n = 22, Appendix 6).

3.2.3.2. Time, month and season of bites

Among the 46 krait bites, 89% (n = 41) occurred during dark hours between 18:00–05:59 h; the peak bite time was 20:00–02:59 h at night (70%, n = 32). The maximum frequency of these bites occurred in August and September (24%, n = 11 each), 80% (n = 37) during the rainy season. In contrast, Russell's Viper bites occurred mostly during the day (80%, n = 8), the maximum frequency of these bites in July (30%, n = 3) and November (20%, n = 3), 40% (n = 4) during the rainy season (Appendix 6, Figure 61).



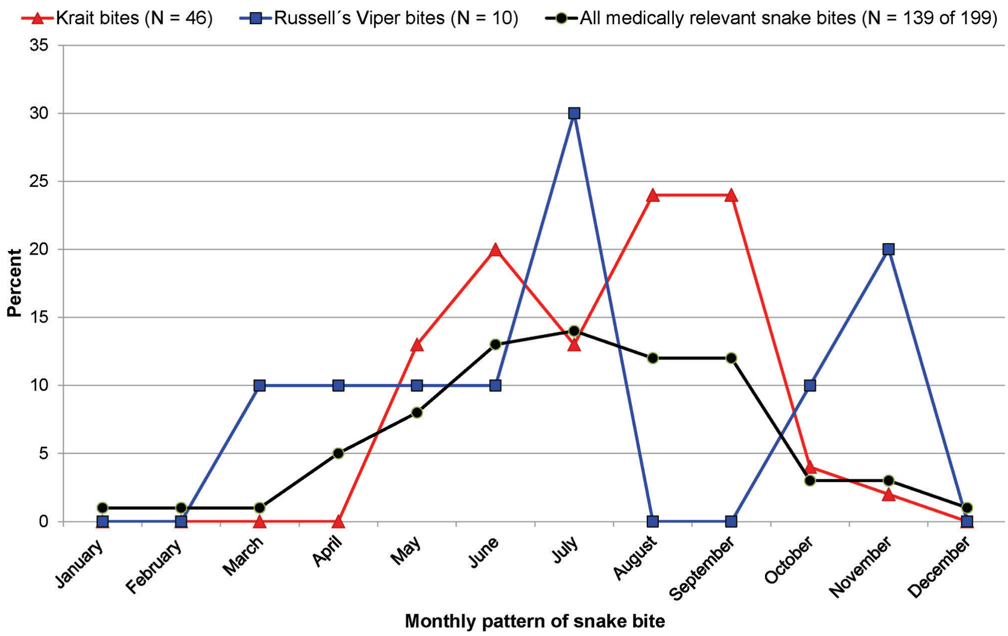


Figure 61. Periods and monthly pattern of krait and Russell's Viper bites. June–September represents rainy or monsoon season, March–May dry or pre-monsoon and October–February winter season.

3.2.3.3. Ecological circumstances of bites

Snake attractants: I identified 20 snake attractants in and around houses where krait bites occurred, of which each of respondents reported 5–18 attractants (mean ± SEM = 12.35 ± 0.38, median = 12.5, sd = 2.58, 95% CI = 11.58–13.11). In 59–96% households prey animals of snakes were present, such as rodents (*Bandicota sp.*, *Mus* sp., *Rattus* sp.), birds (pigeons, hen, sparrow) and lizards (e.g., gekkonids, agamids and scincids). The most common snake shelters were vegetation and crops (paddy, maize, wheat, sugarcane and vegetables), piled rubbish, rubble and bushes. 41% (n = 19) of the respondents reported indoor grain storage even in bedroom and 35% (n = 16) used to keep the storage open. These environmental factors provided ample shelter and prey animals for kraits (χ^2 = 98. 21, df = 19, p = <0.001 Appendix 6, Figure 57).

I identified 19 snake attractants in and around houses belonging to Russell's Viper bite patients of which each of respondents reported 8–16 attractants (mean ± SEM = 11.6 ± 0.67, median = 11, sd = 2.11, 95% CI = 10–14.5). The proportions of prey animals and retreat sites of snakes were similar to those reported for kraits (Appendix 6, Figure 57).

Rainfall events: Often krait bites occurred during a rainy season, but not always following rainfalls (χ^2 = 15.897, df = 5, p = 0.007). However, 30% (n = 14) of the patients reported rainfall on the day of the bite. Also, Russell's Viper bites did not occur during rainfall (χ^2 = 30, df = 5, p = <0.001, Appendix 6, Figure 62).

I excluded the analysis of moon-light and flooding effects on snake bites because respondents could not memorize moonlight and flooding when the bite occurred.

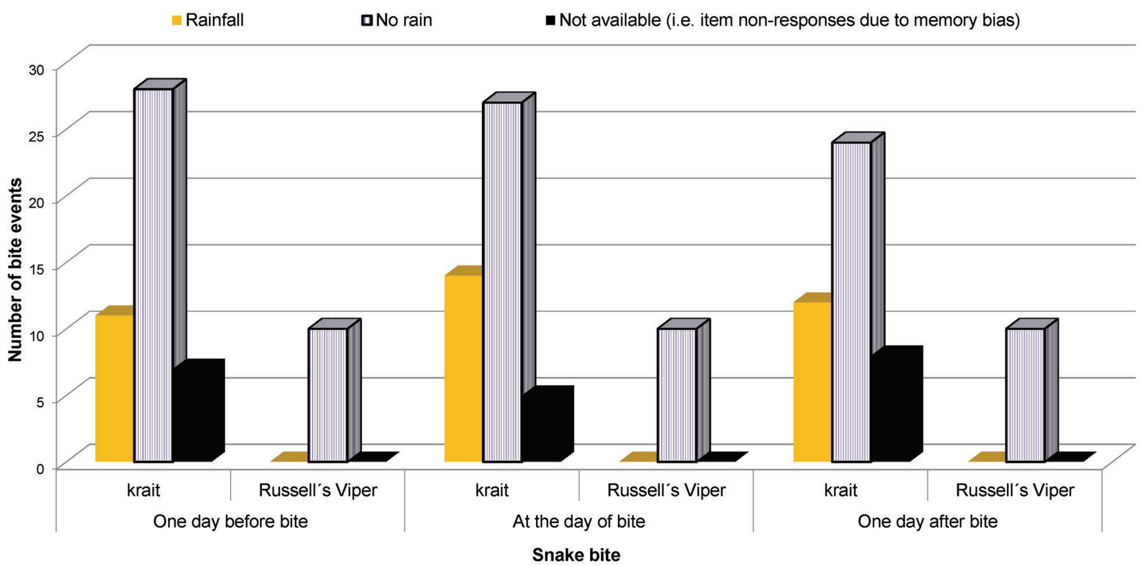


Figure 62. Rainfall events and snake bites.

3.2.4. Prehospital interventions of snake bite victims

Up to 26% krait and 40% Russell's Viper bite victims sought pre-hospital treatment with non-medical persons or clinicians without antivenom supply.

Seeking traditional healers*:* Only 7 (15%) krait bite victims sought help from traditional healers after the bite (Appendix 6). In one case, three ghost experts were called in for exorcism which lasted two hours before the bite was considered to be serious at the suggestion of the victim's grandmother. One of the patients who had visited a healer died due to delayed admission to medical care. None of the Russell's Viper bite victims contacted traditional healers.

Seeking help of medical personnel at local healthcare centres:

Twelve (26%) of the krait bite victims were initially transferred to a local healthcare centre where no treatment facilities for snake bite envenoming was available. These patients were not aware of the nearby snake bite treatment centre where treatment with antivenom was possible. The majority of the cases (n = 27, 59%) were brought directly to the healthcare centres (Appendix 6). Only 40% (n = 4) of the Russell's Viper bite victims shought medical care in inappropriate healthcare centre. Others (60%, n = 6) directly visited STCs (Table 1, Figure 3, Appendix 6).

Adopting first aid measures: Interestingly, none of the krait and Russell's Viper bite victims applied the widely used WHO recommended first aid measures i.e., the pressure-immobilization bandage, PIB, for krait bites and local compression pad immobilization, LCPI, for Russell's Viper bite victims. Instead, 78% (n = 36) krait bite and all Russell's Viper bite victims used tourniquets in an attempt to prevent venom entry into circulation (Appendix 6).

Mode of transportation used by victims: The majority of patients in this series used fast means of transport to access STCs (Table 1, Figure 3). 65% (n = 30) krait and all Russell's Viper bite victims used a motorcycle as means of transport to access treatment facilities (Appendix 6).

3.2.5. Knowledge about snake bite prevention

41% (n = 19) krait bite patients or their relatives replied that they had no idea about snake bite prevention. Among those (54%, n = 25) who replied knowing preventive measures, they knew only two. Similar knowledge was found among Russell's Viper bite cases (Appendix 6).

3.3. Attitudes, knowledge and awareness on snakes and snake bite among people inhabiting snake bite prone areas in southcentral Nepal

Demographic characteristics of the respondents: Informants comprised 33% farmers (n = 50), 30% teachers (n = 45), 23% students (n = 34) and 14% others (n = 21). Respondents were illiterate (20%) to highly literate (32%). Three respondents refused to declare their education status. The literate respondents (80%, n = 120) attained up to class 10 (21%, n = 31), class 11 to 12 or equivalent intermediate degree (21%, n = 31), Bachelor's and Master's degree (32%, n = 48). Sixty-eight percent (n = 102, sex ratio 213) were males, 98% (n= 147) belonged to the Hindu religion and three adopted Buddhism, Christianity and Eshai.

3.3.1. Attitudes of CNP buffer zone people to snakes and their conservation

3.3.1.1. Positive attitudes

Chitwan National Park (CNP) buffer zone people gained higher positivity scores when comparing negative and ambivalent attitudes towards snakes. More than 47% of respondents (n = 70) were positive to snakes and their conservation (median = 99, p = 0.047, Table 5). They scored >53% (n = >8/15) for the positivity test (median = 9, p = <0.001, Table 6.a). Students, teachers and literate respondents were more positive to snakes (Table 7). Although positive attitudes were not significantly different between males and females (p = 0.213), both gender and occupation influenced their positive attitudes towards snakes (b = 0.397, p = 0.047).

Table 5. Chitwan National Park buffer zone population with positive, negative and ambivalent attitudes to snakes.

Hypothesis tests (for all respondents with different responses to attitude test questions, please, see Table 8)	**Median, range**	**Mean±SEM**	**sd**	**W (res)**	**p-value**	**95% CI**
a. With positive attitudes (n = 15, see Table 8.a); H0: M = M0(70), Ha: M > M0(70)	99, 12–148	91.6±11.08	42.92	90	0.047	70.5–Inf
b. With negative attitudes (n = 14, Table 8.b); H0: M = M0(9), Ha: M > M0(9)	13, 0–129	28.86±9.84	36.82	81.5	0.037	8.5–Inf
c. With ambivalent attitudes (n = 9, see Table 8.c); H0: M = M0(14), Ha: M > M0(14)	22, 7–62	28.11±6.78	20.33	31	0.040	14.5–Inf

Abbreviations: **n** = sample size i.e. total number of attitude test questions, **SEM** = standard error of mean, **sd** = standard deviation, **W(res)** = value for one-tailed one-sample Wilcoxon signed rank test of respondents with attitudes (Table 8) to snake and their conservation, **CI** = confidence interval, **H0** = null hypothesis, **Ha** = alternative hypothesis, **M** = population median, **M0** = hypothesized median.

Positive response to snakes being encountered at specified and unspecified localities was different. 78% of respondents (n = 117) ignored snakes encountered while walking on the path and 77% (n = 115) remained tolerant to snakes at unspecified localities (Table 8.a, Figure 63). Of all respondents, 43% /n = 64) prefered and 41% (n = 62) disliked snakes giving certain reasons (Table 9).

Table 6. Scores for attitudes of Chitwan National Park buffer zone people to snakes and their conservation.

Demographics		**a. Score for positive attitudes** (n = 15, see Table 8.a) (null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 8 of 15); alternative hypothesis (Ha): M > M0)			**b. Scores for negative attitudes** (n = 14, see Table 8.b) (null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 2 of 14), alternative hypothesis (Ha): M > M0)			**c. Scores for ambivalent attitudes** (n = 9, see Table 8.c) (null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 1 of 9); alternative hypothesis (Ha): M > M0)		
		Median, range	**W (pos)**	**p-value**	**Median, range**	**W (neg)**	**p-value**	**Median, range**	**W (amb)**	**p-value**
	Age (150)	**9,4–14**	**67885.5**	**<0.001**	**2,0–7**	**5058**	**<0.001**	**2,0–7**	**4618**	**<0.001**
Age (years)	15–24 (42)	10,4–14	639.5	<0.001	2,0–6	332.5	0.044	2,0–5	337	0.001
	25–34 (22)	9,4–14	115	0.102	2,0–6	125	0.226	1,0–4	60	0.048
	35–44 (40)	9,5–13	478.5	0.001	2.5,0–7	336	0.037	2,0–7	357	0.004
	45–54 (21)	10,5–13	156	0.007	2,0–7	80	0.442	1,0–6	92.5	0.030
	55–64 (17)	9,6–13	107.5	0.021	3,1–6	104	0.006	2,1–5	120	<0.001
	65+above (8)	6,5–12	7	*0.901*	3,1–7	25.5	0.029	1,0–5	12	0.412
Gender	Male (102)	9,4–14	3317.5	<0.001	2,0–7	2130	0.055	2,0–7	2475.5	<0.001
	Female (48)	9,4–13	620	0.017	3,1–7	604	<0.001	1,0–5	335	0.012
Occupation	Farmer (50)	8,4–13	538.5	0.214	3,1–7	736	<0.001	1.5,0–6	490	0.001
	Teacher (45)	9,6–13	718.5	<0.001	2,0–6	401.5	0.321	2,0–7	451	<0.001
	Student (34)	10,4–14	414.5	0.001	2,0–6	185	0.269	1.5,0–5	197	0.002
	Other * (21)	10,6–14	158	0.001	2,0–6	91	0.411	2,0–4	129	0.025
Educational status	*Illiterate (27)*	8,5–13	143.5	0.439	3,1–7	211	0.003	1,0–5	115.5	0.026
	Literate (120)	9,4–14	4671	<0.001	2,0–7	3055.5	0.006	2,0–7	3212	<0.001
	≤ Class 10 (31)	8,4–14	195	0.193	3,0–7	329	<0.001	2,0–6	275	0.001
	Class 11–12 (31)	11,5–14	465.5	<0.001	1,0–6	136	0.918	2,0–4	190	0.012
	Master´s D (22)	9,6–13	238.5	0.006	2.5,0–6	153	0.186	2,0–7	170	0.001
	Bachelor´s D (26)	9.5,4–13	117	0.028	2,1–6	67	0.067	2,0–5	95	0.003
	Lit. inf. † (10)	11,5–13	49	0.015	1.5,0–6	17	0.584	0.5,0–3	18.5	0.5

Symbols and abbreviations: *hotel owner (3), miller (3), fisherman (2), boat-man (1), mason (1), labourer (1), housewife (7), nature guide (3); **†**respondents able to read and write by informal education but never attained school, < less than, > greater than, **n** = sample size i.e. total number of attitude test questions, **D** = degree, **W** = value for one-tailed one-sample Wilcoxon signed rank test, **pos** = positive, **neg** = negative, **amb** = ambivalent; parentheses in column demographics show number of respondents involved in statistical analysis.

Table 7. Attitudes to and awareness of native snakes in Chitwan National Park buffer zone people.

Demographics	a. Scores gained for attitude test						b. Scores gained for awareness test			
	i. Positive attitude		ii. Negative attitude		iii. Ambivalent attitude		i. Awareness		ii. Unawareness	
	W	p-value	W	p-value	W	p-value	W	p-value	W	p-value
Younger & older* (Ha.1)	1168.5	0.743	1137.5	0.581	954.5	0.061	948	0.064	1390	0.229
Male & female (Ha.1)	2755	0.213	1836.5	**0.012**	2929	**0.045**	3447	**<0.001**	1876.5	**0.021**
Female > male (Ha.2)	x	x	3059.5	0.006	x	x	x	x	3019.5	**0.011**
Male > female (Ha.2)	x	x	x	x	2929	**0.022**	3447	**<0.001**	x	x
Farmer & student (Ha.1)	582.5	**0.014**	1182	**0.002**	824	0.808	623.5	**0.039**	795	0.618
Student > farmer (Ha.2)	1117.5	0.007	518	0.002	x	x	1076.5	**0.020**	x	x
Farmer & teacher (Ha.1)	793.5	**0.013**	1557.5	**0.001**	1019.5	0.418	412	**<0.001**	1410	**0.033**
Teacher > farmer (Ha.2)	1456.5	0.006	x	x	x	x	1838	**<0.001**	x	x
Farmer > teacher (Ha.2)	x	x	1557.5	**0.001**	x	x	x	x	1410	0.017
Teacher & student (Ha.1)	711.5	0.595	777.5	0.902	711.5	0.585	289.5	**<0.001**	1098.5	**0.001**
Teacher > student (Ha.2)	x	x	x	x	x	x	1240.5	<0.001	x	x
Student > teacher (Ha.2)	x	x	x	x	x	x	x	x	1098.5	<0.001
Literate & illiterate (Ha.1)	2128	**0.011**	1244	**0.055**	1798.5	0.356	2550	**<0.001**	1276	0.085
Literate > illiterate (Ha.2)	2128	0.005	x	x	x	x	2550	<0.001	x	x
Illiterate > literate (Ha.2)	x	x	1996	**0.028**	x	x	x	x	x	x

Symbols and abbreviations: *15–34 years old people are considered young and 45–64 year respondents as older; null hypothesis (**H0**): population median score (**M**) = hypothesised population score (**M0 = 0**), alternative hypothesis.1 (**Ha.1**) = population median score (**M**) ≠ hypothesised population score (**M0**), alternative hypothesis.2 (**Ha.2**) = population median score (**M**) > hypothesised population score (**M0**), **W** = value for one- and two-tailed unpaired Wilcoxon rank sum test.

Table 8. Responses of Chitwan National Park buffer zone people to attitude test questions (n = 38) about snakes and their conservation.

SN	**a. Responses to positive attitude test questions** (n = 15); ***note 1***: number of respondents with ***unknown*** reply to like or dislike of snakes were 4(3%), worship of snakes 1(1%), respond snakes that they encountered wherever and whenever 4(3%), **friendly association between snakes and farmers 21(14%), need of conservation of all snakes 41(27%)**, all surrounding snakes should be killed 6(4%) and only venomous snakes should be killed were 4(3%).	**Respondents**	
		N	%
1	Yes, I like snakes	82	55
2	No, I do not fear snakes	21	14
3	Yes, I ignore whatever snakes that I observe in the crop-field while working	79	53
4	Yes, I ignore whatever snakes that I observe on the path while walking	117	78
5	Yes, I ignore whatever snakes that I observe in premises of house or barn	55	37
6	Yes, I ignore whatever snakes that I observe indoors	12	8
7	Yes, I rescue whatever snakes that I observe indoors	39	26
8	Yes, I worship snakes	126	84
9	No, I do not prefer to kill whatever snakes that I encounter anywhere	115	77
10	No, I do not eat snake meat	148	99
11	No, my neighbours do not eat snake-meat	139	93
12	No, my neighbours do not kill snakes even for medicinal purposes	129	86
13	Yes, all snakes around us should be conserved	99	66
14	Yes, I consider snakes as friends of farmers	92	61
15	Yes, I think snakes need to be conserved	122	81
	b. Responses to negative attitude test questions (n = 14); ***note 2***: number of respondents having **item non-responses** for killing snakes wherever and whenever that they encounter were 2(1%), all surrounding snakes should be killed 77(51%) and only venomous snakes should be killed were 39(26%).		
1	No, I do not like snakes	64	43
2	Yes, I fear snakes	129	86
3	Yes, I kill whatever snakes that I observe in crop-field while working	10	7
4	Yes, I call others to kill whatever snakes that I observe in crop field while working	12	8
5	Yes, I kill whatever snakes that I observe on the path while walking	0	0
6	Yes, I call others to kill whatever snakes that I observe on the path while walking	6	4
7	Yes, I prefer to kill whatever snakes that I encounter anywhere	29	19
8	Yes, I eat snake meat	2	1
9	Yes, my neighbours eat snake meat	7	5
10	Yes, my neighbours kill snakes for medicinal purposes	14	9
11	Yes, all snakes around us should be killed	2	1
12	Yes, only venomous snakes around us should be killed	74	49
13	No, I do not consider snakes as friends of farmers	37	25
14	No, I do not think snakes need to be conserved	18	12
	c. Responses to ambivalent attitude test questions (n = 9) (i.e. ´Yes´ responses to two or more questions that signify ambivalence)		
1	I like snakes in general/ I fear snakes in general	62	41
2	I fear snake/ I ignore snakes observed at premises of house and indoors	47	31
3	I worship snakes/ I kill or call others to kill snakes while I observed them in the crop field while working or on the path while walking	22	15
4	I worship snakes/ I prefer to kill whatever snakes that I encounter anywhere	25	17
5	I like snakes in general/ I kill whatever snakes that I encounter anywhere	9	6
6	I prefer to kill snakes/ all snakes should be conserved	7	5
7	All snakes should be killed/ only all venomous snakes should be killed/ all snakes should be conserved/ I think snakes should be conserved	52	35
8	I prefer to kill whatever snakes that I encounter anywhere/ I consider snakes as farmers´ friends	15	10
9	I kill or call others to kill snakes that I observe in the crop fields/ I consider snakes as farmers´ friends	14	9

Abbreviation and symbol: **N** = number of respondents, **%** = percent of respondents

Table 9. Reasons for certain attitudes to snakes.

SN	a. **Major reasons of ´I like snakes´** (frequency of respondents (**f**) = 64)	f	%
1	Snakes have attractive appearance and movement patterns (Attract), some snakes are non-poisonous (NP), prevent environmental pollution absorbing poison from environment (**PEP**), snakes do not bite until teasing (SUT)	22	34
2	Snake balances natural ecosystem and contribute to food-web (Ecosyst), snakes are farmer´s friends and important component of human beings (SFH), snakes are important component of biodiversity (Biod), snake venoms have medicinal value (Med), snakes are important for education (SIE), **PEP**	15	23
3	**PEP**	12	19
4	Pleasing God ("*Nag Devata*"), revering garland of Cobra worn by God Shiva as a God (God)	4	6
5	Biod, snakes attract tourist (AT)	3	5
6	Imitation (tradition) of worshipping snakes as a God by their predecessors or guardians (IP), ´PEP´, God, snakes eat prey animals (rats, frogs, insects, etc.) (EP), Biod	3	5
7	**PEP**, Attract, NP	3	5
8	All snakes are not harmful (ASNH), snakes attract tourist (AT)	2	3
	b. Major reasons of ´I dislike snakes´ (**f** = 62)		
1	I fear snakes´ shape, size, movement, dreams related to snakes, etc. (Fear)	27	44
2	Snake may bite any time, fear bite, it bites (Bite)	10	16
3	Snakes are poisonous (P)	9	15
4	Death after snake bite (DAB)	8	13
5	DAB, snakes are poisonous (P)	2	3
6	Snakes are dangerous animals (Danger)	2	3
7	Some snakes are venomous (SSV)	2	3
8	All snakes are dangerous (or harmful, venomous) (ASD), P	2	3
	c. Major reasons of ´I worship snakes´ (**f** = 96) (note: respondents worshipping snakes without reasons (**f** = 30, 20%)		
1	Imitated the practice of worshipping snakes by predecessors/parents (IP)	47	49
2	IP, God, prevention from witchcraft, witch and the Devil (PW), protection (Prot)	18	19
3	God	16	17
4	Prevention from snakebite or worshippig snakes might keep their trouble away (PB)	11	11
5	IP, wishing flourishment in the future (Wf)	4	4
	d. Major reasons of ´I do not worship snakes´ (**f** = 11)		
1	No tradition of worshipping snake "*Nag*" in "*Nagpanchami*" (e.g., some Tharus) (NT)	7	64
2	Snakes do not lose natural potentiality of envenoming despite worshipping it ("Gadha dhoyara gai hudaina" i.e. black stone never turns white) (DNP)	2	18
3	It is duty of pandit ("Brahman" who is invited to worship serpent god) (DP)	2	18
	e. Major reasons of snake killing attitudes (**f** = 29)		
1	Kill venomous snakes only (KVO) because they are dangerous	9	31
2	Snake may bite any time, I fear from bite, it bites (Bite)	8	28
3	I fear from snakes´ shape, size, movement, dreams related to snakes, etc. (Fear)	7	24
4	Snakes are poisonous (P)	2	7
5	Snakes encountered might harm or disturb people (SEH)	2	7
6	Death after bite (DAB)	1	3
	f. Major reasons of ´I do not kill any snakes´ (**f** = 81)		
1	I fear to kill/see snake, snake can chase (run) man (FK)	38	47
2	Neglecting encountered snakes without reasons (Ignore)	17	21
3	All snakes are not harmful (ASNH)	14	17
4	Snakes are symbol or representative of God (God)	4	5
5	Snakes do not bite until teasing them (SUT)	4	5
6	Snake does not attack (I do not kill snake until it attacks) (DA)	2	2
7	Snakes balance natural ecosystem and contribute to food-webs (Ecosyst)	2	2
	g. Major reasons of regarding snakes as friends of farmers (**f** = 60)		
1	Eats prey animals (e.g., rodents, insects, etc.) (EP)	50	83
2	EP, prevent environmental pollution absorbing poisonous gases (PEP)	6	10
3	EP, Snakes balance natural ecosystem and contribute to food-webs (Ecosyst)	4	7

Note: Respondents´ responses for why questions are grouped, coded and quantified in this table.

3.3.1.2. Negative attitudes

Although they liked snakes (>55%, Table 8.a), 86% (n = 129) respondents feared snakes; 43% (n = 64) were disgusted by snakes primarily due to preconceptions about snakes' shape, size, movement and related nightmares (44%, n = 27, Table 8.b, 9.b). Proportionately, males, literate persons, farmers and teachers feared snakes (Figure 64). A higher degree of negative attitudes, aggression or antagonism to snakes would encounter indoors and around human activity areas (e.g., homes, residential premises, crop-fields) (47%, n = 70 showed aggressive attitude of killing). The snake killing attitude among people varied from place to place (Figure 63). Only 1% (n = 2) of the respondents intended to kill all snakes and 49% (n = 74) wanted to kill all venomous snakes (Table 8.b).

However, overall evaluation indicated that they were less negative towards snakes. More than 6% of the respondents (n = 9) were negative to snakes (median = 13, p = 0.037, Table 5.b). They received >14% scores (>2/14) for the negativity test (median = 2, p = <0.001, Table 6.b). Farmers, females, students and illiterate people were the most negative towards snakes (Table 7.a.ii).

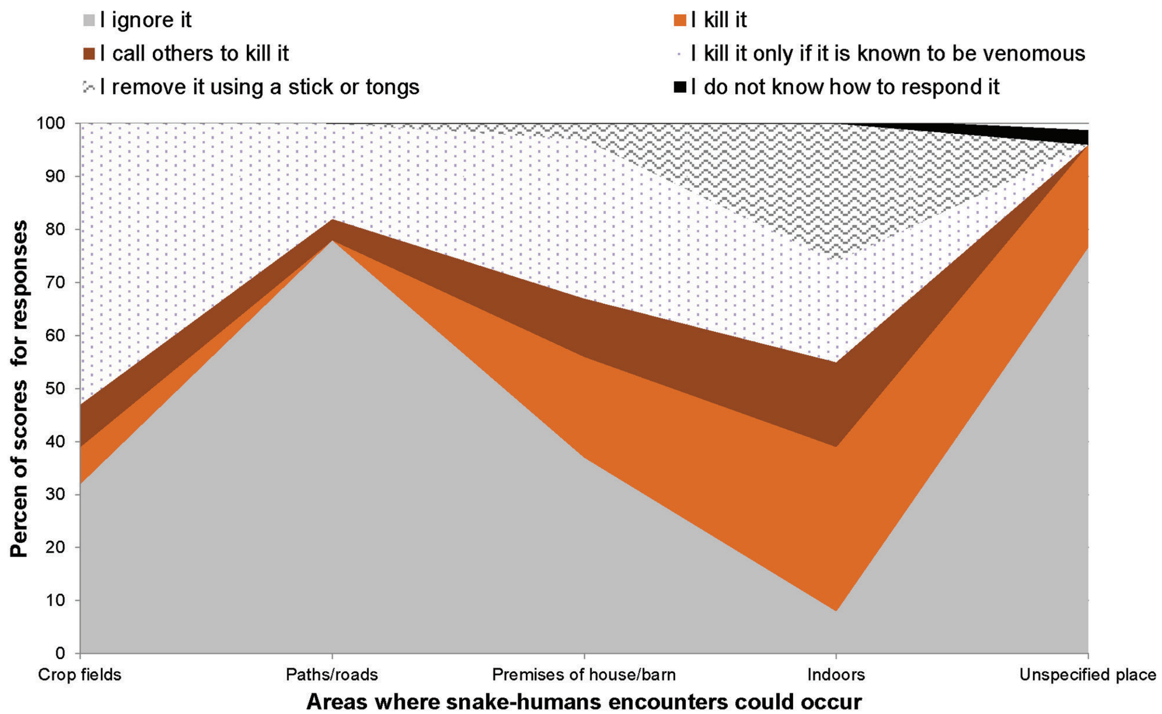


Figure 63. Human responses to snakes encountered in specified and unspecified locations in the buffer zones of Chitwan National Park.

Figure 64.
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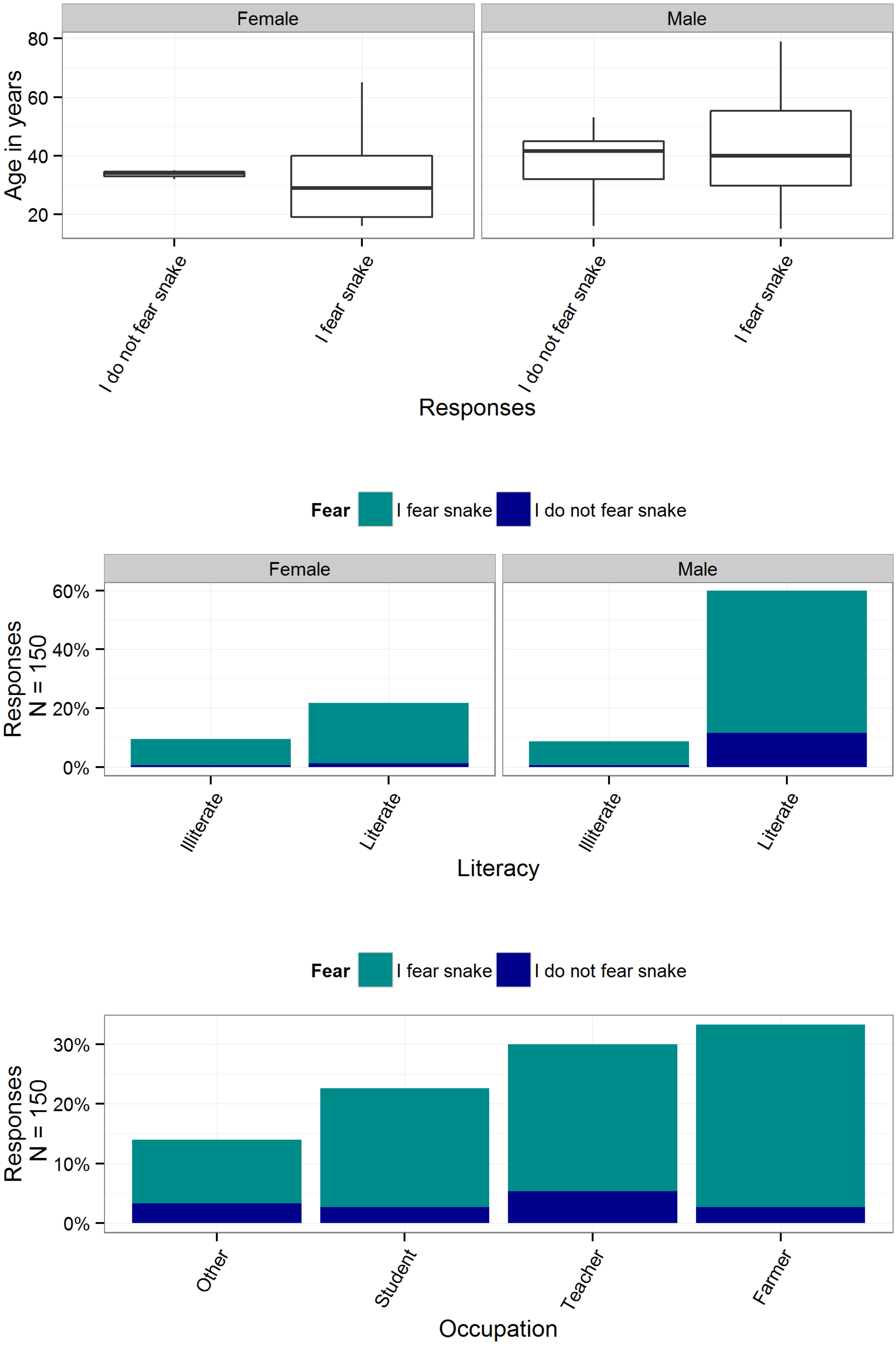

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Figure 64. Attitude towards snakes with respect to gender, literacy and occupation. NA indicates no response by respondents.

3.3.1.3. Ambivalent attitudes

More than 9% of respondents (n = 14) were found to be ambivalent towards snakes (median = 22, p = 0.04, Table 5.c) and each scored >11% (>1/9) in the ambivalent test (median = 2, p = <0.001, Table 6.c). Particularly, males exhibited a more ambivalent attitudes than females (Table 7.a.iii).

There were no differences in ambivalence between ‘teachers and farmers’ and ‘teachers and students’ (Table 7.a.iii). However, teachers showed the highest scores for ambivalence (median = 2, p = <0.001, Table 6.c).

3.3.2. Knowledge of CNP buffer zone people about snake identification, snake conservation and snake bite prevention

3.3.2.1. Snake identification

Buffer zone people identified venomous snakes (Table 10.a) more often than non-venomous ones (Table 11.a), but with noticeable confusion (Table 10.b, 11.b, 12.b,d). They identified more than 63% (>10 of 16) venomous (median = 11, p = <0.001, Table 10.a) and more than 25% (>3/12) non-venomous snake species correctly (median = 3, p = 0.001, Table 11.a). Their claim of more than 50% (>6/12) non-venomous snakes to be venomous (median = 7, p = <0.001, Table 10.b) and 19% (>3/16) venomous snakes to be non-venomous (median = 4, p = <0.001, Table 11.b) proved their confusion in snake identification by the nature of envenoming. Of all, 0.67% (n = 1) of respondents considered all snakes to be venomous and 5% (n = 7) could not identify any non-venomous snake.

Females more than males identified more venomous snakes (median = 12, p = <0.001, Table 10.a), but males more than females identified more non-venomous snakes (Table 11.a). Farmers identified more venomous snakes (median = 12, p = <0.001) than teachers (median = 9, p = 0.812) (Table 10.a). Students had the best aptitude of identifying venomous snakes among all occupational groups (Table 12.a). Illiterate people identified more venomous snakes, but literate respondents identified more non-venomous species (Table 12.a,c).

Of all respondents, 24% identified Common Kraits (*Bungarus caeruleus*), 5% Common Cobra (*Naja naja*) and 12% Green Pit Viper (*Trimeresurus albolabris*) as non-venomous. Of the total, 91% wrongly thought Common Wolf Snakes (*Lycodon aulicus*) to be venomous and 66% to be kraits (*Bungarus* species); 33% claimed Rat Snake (*Ptyas mucosa*) to be venomous and 2% identified them as Cobra (*Naja* species); 59% knew Pythons (*Python bivittatus*) as non-venomous, 37% as a venomous snake (Figure 65).

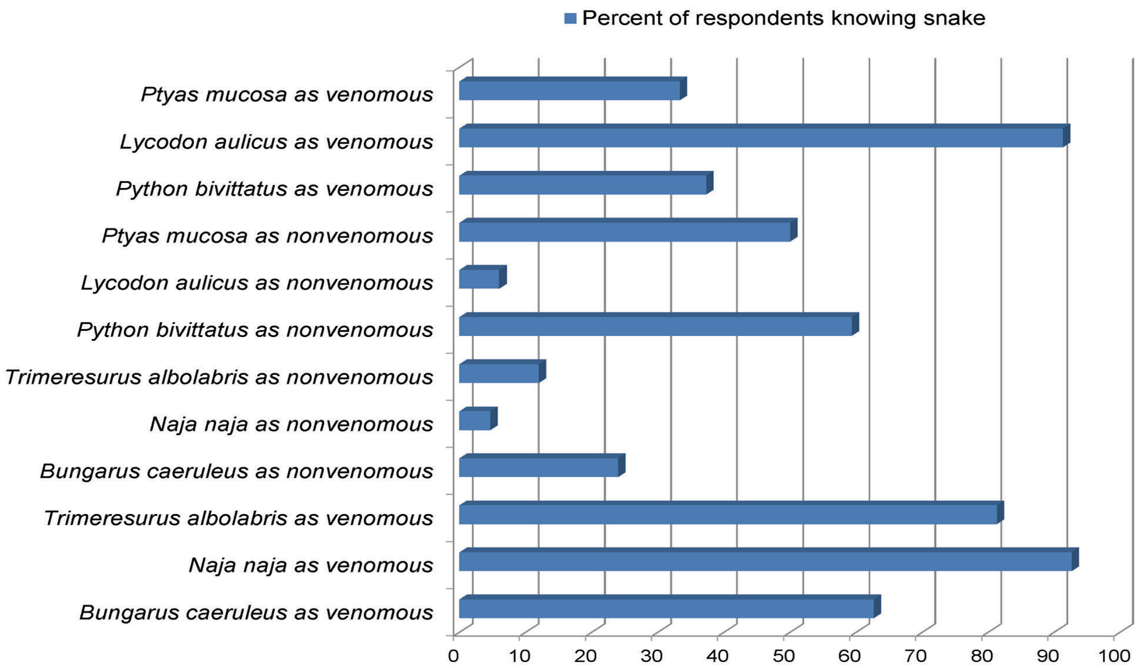

Figure 65. Knowledge on local snake species regarding assessment of venomousness by Chitwan National Park buffer zone people.

Furthermore, CNP buffer zone people were almost ignorant to snake identification regarding scientific and English names, but were slightly aware of the local names (median = 6). Older people more than younger, students and teachers more than farmers, teachers more than students and literate more than illiterate people provided English names to displayed snakes (Table 12.e, 13.a). Conversely, farmers more than students and teachers knew the snakes' local names (Table 12.f, 13.b). Of 28 displayed snake species, they named 24 species (Figure 66). They commonly recalled the local rather than the English name. Nobody knew the name of the Saw-scaled Viper (*Echis carinatus*) and only 1% of the respondents knew the local and English name for *D. russelii*. Of all, 83% gave the local name for the Monocellate Cobra (*Naja kaouthia*), 72% for the Common Cobra (*N. naja*) and 23% for the Green Pit Viper (*T. albolabris*), 73% for the Striped Keelback (*Amphiesma stolatum*) and 60% for the Python (*P. bivittatus*).

3.3.2.2. Snake conservation and snake bite prevention

81% (n = 122) of CNP buffer zone people considered the need for snake conservation (Table 8.a), but only respondents aged below 35 years, such as teachers, students and literate people explained a reason for snake conservation (Table 14.a). The people believed in snake conservation because they thought snakes contribute to food-web of ecosystem and agricultural yield and snake venom could have medicinal value (n = 15, 23%), they considered snakes as symbols of god (n = 16, 17%) and they would worship snakes (n = 47, 49%).

Although 85% (n = 127) replied that they know preventive measures against snake bite, their reasoning was poor. Respondents aged 15–24 years, teachers, students and literate respondents mentioned on the average only slightly more than two appropriate preventive measures (Table 14.b).

The knowledge about snake conservation and preventive measures against snake bite were significantly better among students and teachers than among farmers, also more among literate than among illiterate people (Table 12.g, h). Snake conservation knowledge was better among males than females (Table 12.g), knowledge about snake bite prevention was better among younger respondents (Table 12.h).

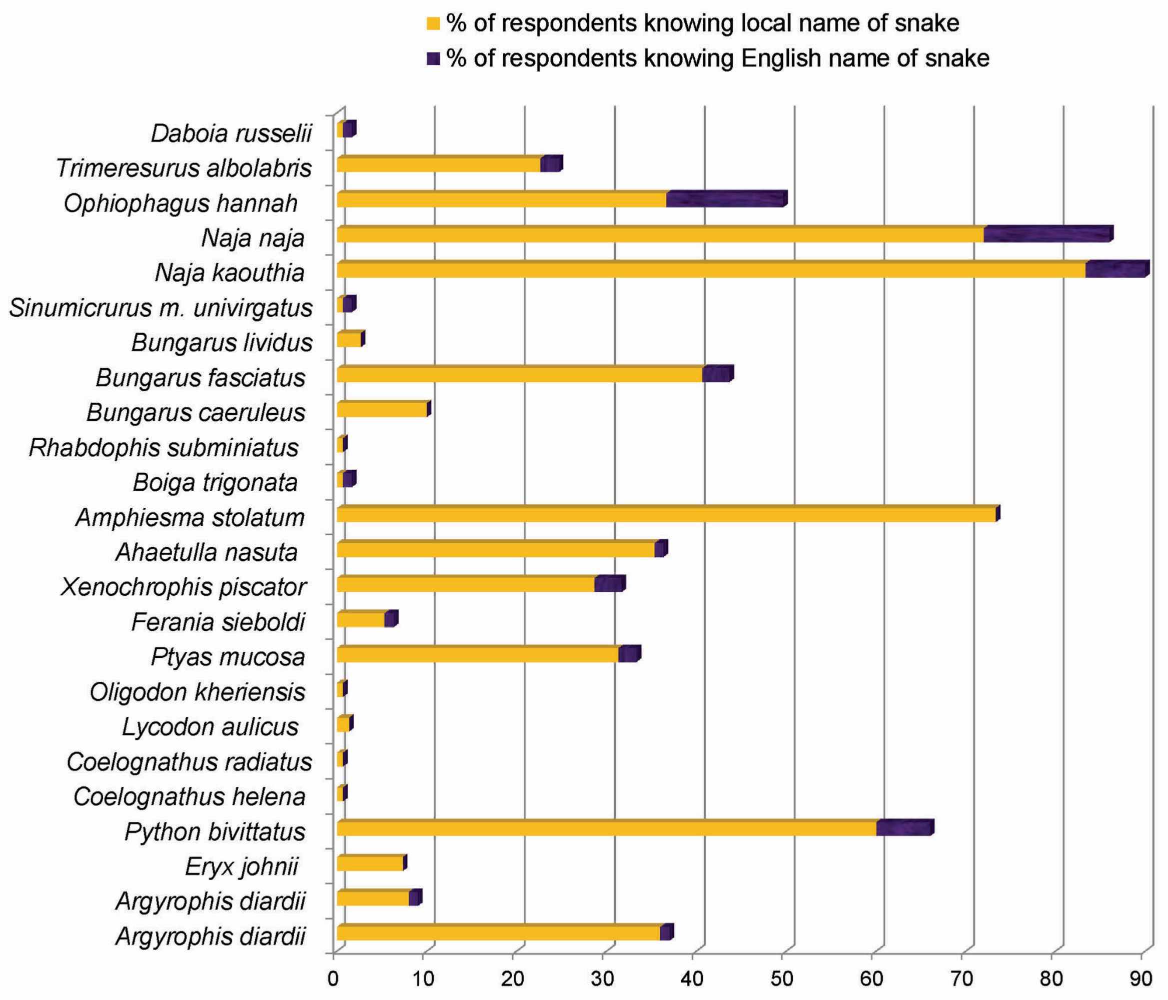

Figure 66. Knowledge on snake identification by Chitwan National Park buffer zone people.

3.3.3. Awareness of snakes and pre-hospital care of snake bite among CNP buffer zone people

Their awareness level was below 50% (i.e., average) except for the recommended pre-hospital care of snake bite. More than 48% respondents were found to be aware (n = 72, p 0.045, Table 15) and each scored >48% (n = >16) in the awareness test by rejecting the traditional beliefs and medical help of doubtful use and accepting the modern measures of pre-hospital care of snake bite (median = 19, p = 0.001, Table 16.a). Likewise, >21% (n = >32) of respondents were unaware (p = 0.033, Table 15) and each of the respondents scored 24% (n = 8) for unawareness by accepting traditional beliefs and medical help of doubtful use and rejecting modern measures of pre-hospital care (median = 9, p = <0.001,Table 16.b). More than 11% (n = >17) of respondents were unfamiliar (p = 0.034) with awareness test questions, i.e., they did not know >3 awareness test questions (median = 3.5, p = <0.001, Table 16).

Buffer zone people were highly aware of particular practices of snake bite care and belief. The analysis of 33 awareness test questions (Table 17), showed them to be highly aware of the need to visit a treatment centre equipped with antivenom (95%) to cure envenoming (88%, n = 132). They also had information on the nearest snake bite treatment centre (83%, n = 125). A total of 95% respondents rejected the belief that all snakes are venomous and 85% refused to visit traditional healers (Table 17). More than half of the buffer zone people accepted widely recommended first aid measures. A total of 61% responded that they would apply pressure immobilization bandaging (PIB) and 51% agreed to local compression pad immobilization (LCPI) (Table 17). Overall, only more than 51% of respondents (n = >76) agreed to apply suggested first aid measures (median = 125, p = 0.031, Table 15.c). The level of awareness was greater among males than females, among students and teachers than farmers, among teachers than students and among literate than illiterate people (Table 7.b.i).

3.3.4. Use of snakes

A total of 86 to 99% of respondents answered that they would not use snakes and snake products at all (Table 8.a). Only 2/150 respondents, who had tried snake meat in Malaysia during their oversea job, consumed *Python* meat after their return to Nepal and 7/150 respondents knew of some ethnic neighbours (Tharu, Mushahar, Kusunda and Newar) eating snake-meat. Only 9% (n = 14) of respondents knew about killing *Python* for gallbladder and fat, cobras for fat and intestines used to cure backache, burn wounds or other wounds, piles, mastitis, and rheumatism.

Table 10. Familiarity of Chitwan National Park buffer zone people with native venomous snakes.

Demographics		a. Correct scores for knowing venomous snakes (CSV, n = 16); null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 10); alternative hypothesis (Ha): M > M0			b. Incorrect scores for claiming non-venomous (ISV, n = 12) snakes to be venomous; null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 6), alternative hypothesis (Ha): M > M0)		
		Median, range	W (CSV)	p-value	Median, range	W (ISV)	p-value
All respondents		**11,4–16**	**6237.5**	**<0.001**	**7,1–12**	**5756.5**	**<0.001**
Age (years)	15–24	11,7–15	612.5	<0.001	7,2–12	449.5	0.013
	25–34	10,4–16	86	0.181	5,2–11	121	0.431
	35–44	10.5,4–16	422.5	0.142	7,2–11	386.5	0.011
	45–54	12,6–14	136.5	0.048	7,1–10	115	0.214
	55–64	12,4–15	95	0.084	7,1–10	80	0.132
	65+above	11.5	22.5	0.285	9,3–11	30.5	0.045
Gender	Male	11,4–16	2567.5	0.070	6,1–11	2134.5	0.174
	Female	12,4–16	754.5	<0.001	8,3–12	843.5	<0.001
Occupation	Farmer	12,6–16	878.5	<0.001	8,1–11	815.5	<0.001
	Teacher	9,4–16	310.5	0.812	6,2–11	370.5	0.611
	Student	7,7–15	349	0.008	6,2–11	231.5	0.259
	Other†	12, 7–14	172	0.001	8,1–12	143	0.027
Educational status	*Illiterate*	12,6–16	256	0.006	9,3–11	369	<0.001
	Literate	11,4–16	3667.5	0.004	6,1–12	3144	0.062
	Class 10	12,4–15	301.5	0.012	7,1–12	245	0.039
	Class 11–12	11,7–16	253.5	0.059	5,2–11	169.5	0.687
	Master´s degree	10,4–16	98.5	0.730	6.5,2–11	157.5	0.280
	Bachelor´s degree	10.5,7–15	137	0.117	6.5,3–10	106.5	0.177
	Literate informally‡	12,7–14	42	0.074	7,1–11	28	0.276

Symbols and abbreviation: †hotel owner, miller, fisherman, boat-man, mason, labourer, housewife, nature guide; **‡**respondents able to read and write by informal education and never attained school; **n** = number of snake species displayed, **W** = value of one-tailed one-sample Wilcoxon signed rank test

Table 11. Familiarity of Chitwan National Park buffer zone people with native non-venomous snakes.

Demographics		a. Correct scores for knowing non-venomous snakes (CSN, n = 12); null hypothesis (H0): median scores (M) = hypothesized median scores (M0 = 3), alternative hypothesis (Ha): M > M0			b. Incorrect scores of claiming venomous snakes (n = 16) to be non-venomous (ISN); null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 3); alternative hypothesis (Ha): M > M0		
		Median, range	W (CSN)	p-value	Median, range	W (ISN)	p-value
All respondents		**3,0–11**	**5303.5**	**0.001**	**4,0–11**	**5354**	**0.001**
Age	15–24	2,1–7	172	0.998	4,1–9	580	0.001
	25–34	3.5,0–10	132	0.022	4,0–9	121	0.018
	35–44	2.5,0–10	314	0.510	3,0–10	318.5	0.038
	45–54	4,1–11	130	0.006	4,2–8	128	0.001
	55–64	4,1–9	76.5	0.177	3,1–11	52.5	0.151
	65+above	1.5,0–5	8	0.932	2,1–3	0	0.994
Gender	Male	4,0–11	3148	<0.001	4,0 –11	3045	<0.001
	Female	2,0–7	172	0.998	3,0–9	284.5	0.698
Occupation	Farmer	2,0–7	230	0.996	2.5,0–7	235.5	0.964
	Teacher	5,1–10	773	<0.001	5,0–11	679	<0.001
	Student	4,1–9	300	<0.001	4,1–9	469	<0.001
	Other**†**	2,0–11	80	0.604	3,2–8	62	0.036
Educational status	*Illiterate*	2,0–5	26	1.000	2,0–6	78.5	0.946
	Literate	4,0–11	4071.5	<0.001	4,0–11	3817.5	<0.001
	Class 10	3,0–9	170	0.424	3,1–11	131	0.296
	Class 11–12	4,1–9	250.5	<0.001	4,0–8	344.5	0.001
	Master´s degree	5,1–10	237	0.006	5,0–10	449.5	<0.001
	Bachelor´s degree	5,1–7	188	0.001	4,1–9	159.5	0.005
	Literate informally**‡**	4,1–11	35	0.234	3,2–5	55	0.003

Symbols and abbreviation: **†**hotel owner, miller, fisherman, boat-man, mason, labourer, housewife, nature guide; **‡**respondents able to read and write by informal education and never attained school; **n** = number of snake species displayed, **W** = value of one-tailed one-sample Wilcoxon signed rank test

Table 12. Familiarity of Chitwan National Park buffer zone people with native snakes, their knowledge about snake conservation and prevention of their bites.

Group of people	a. Knowing VS		b. Claim of NVSasVS		c. Knowing NVS		d. Claim of VSasNVS		e. Knowing English name		f. Knowing local name		g. Snake conservation		h. Snake bite prevention	
	W	p-value	W	p-value	W	p-value	W	p-value	W	p-value	W	p-value	W	p-value	W	p-value
Younger and older† (two tailed)	1214.5	0.994	1200	0.914	428.5	0.877	1199.5	0.911	1284.5	**0.035**	1107	0.450	1461	0.076	1533	**0.026**
Older† > younger (one-tailed)	x	x	x	x	x	x	x	x	1831.5	**0.018**	x	x	x	x	x	x
Younger > older† (one-tailed)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	1533	0.013
Male and female (two tailed)	1620	**0.001**	1568	**<0.001**	3679	**<0.001**	3343.5	**<0.001**	1152	1	2358	0.716	3171.5	**0.002**	2861	0.091
Female > male (one-tailed)	3276	<0.001	3328	<0.001	x	x	x	x	x	x	x	x	x	x	x	x
Male > female (one-tailed)	x	x	x	x	3679	<0.001	3343.5	<0.001	x	x	x	x	3171.5	0.001	x	x
Farmer and student (two tailed)	1022.5	0.114	1145	**0.007**	328	**<0.001**	412	**<0.001**	720	**0.014**	1086.5	**0.030**	346	**<0.001**	324	**<0.001**
Farmer > student (one-tailed)	x	x	1145	0.003	x	x	x	x	x	x	1086.5	0.015	x	x	x	x
Student > farmer (one-tailed)	x	x	x	x	1372	<0.001	1288	<0.001	980	0.007	x	x	1354	<0.001	1376	<0.001
Farmer and teacher (two tailed)	1543.5	**0.002**	1551.5	**0.001**	483.5	**<0.001**	457	**<0.001**	649.5	**<0.001**	1632.5	**<0.001**	380	**<0.001**	483.5	**<0.001**
Farmer > teacher (one-tailed)	1543.5	0.001	1551.5	0.001	x	x	x	x	x	x	1632.5	<0.001	x	x	x	x
Teacher > farmer (one-tailed)	x	x	x	x	1766.5	<0.001	1793	<0.001	1600.5	<0.001	x	x	1870	<0.001	1766.5	<0.001
Teacher and student (two tailed)	1000.5	**0.019**	836	0.482	696.5	0.496	641	0.217	520	**0.004**	912.5	0.143	787	0.819	673	0.353
Students > teacher (one-tailed)	1000.5	0.009	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Teacher > student (one-tailed)	x	**x**	x	x	x	x	x	x	1010	0.002	x	x	x	x	x	x
Literate and illiterate (two tailed)	2039.5	**0.035**	2420	**<0.001**	660	**<0.001**	887.5	**<0.001**	1118	**0.003**	1883.5	0.185	610.5	**<0.001**	750.5	**<0.001**
Illiterate > literate (one-tailed)	2039.5	0.017	2420	<0.001	x	x	x	x	x	x	x	x	x	x	x	x
Literate > illiterate (one-tailed)	x	x	x	x	2580	<0.001	2352.5	<0.001	2052	0.001	x	x	2629.5	<0.001	2489.5	<0.001

Symbols and abbreviation: **†**15–34 years old people are considered younger and 45–64 years as older people; **VS** = venomous snakes (including mildly and highly venomous ones), **NVS** = non-venomous snakes, null hypothesis (**H0**): population median score (**M**) = hypothesised population score (**M0 = 0**) (**i.e. H0: M = M0**), alternative hypothesis.1 (**Ha.1**) = population median score (**M**) ≠ hypothesised population score (**M0**), alternative hypothesis.2 (**Ha.2**) = population median score (**M**) > hypothesised population score (**M0**), **W** = value for two-tailed and one-tailed unpaired Wilcoxon rank sum test

Table 13. Familiarity of Chitwan National Park buffer zone people with names of native snakes (n = 28).

Demographics		**a. Knowing snakes by their English name** (KEN); null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 1); alternative hypothesis (Ha): M > M0			**b. Knowing snakes by their local name** (KLN); null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 5), alternative hypothesis (Ha): M > M0		
		Median, range	**W (KEN)**	**p-value**	**Median, range**	**W (KLN)**	**p-value**
	All respondents	**0,0–12**	**2888**	**1**	**6,0–14**	**5625**	**0.004**
Age (years)	15–24	0,0–2	82	1	5,1–11	414.5	0.171
	25–34	0,0–7	91.5	0.891	5,0–11	91.5	0.405
	35–44	0,0–8	236	0.990	6,2–11	508.5	0.009
	45–54	0,0–12	93	0.376	7,1–14	150	0.003
	55–64	0,0–4	42.5	0.965	5,1–7	39	0.892
	65+ above	0	0	0	5,3–7	16	0.641
Gender	Male	0,0–12	1780.5	0.985	7,5–11	2582	0.026
	Female	0,0–3	0	0	6,0–11	597.5	0.033
Occupation	Farmer	0,0–3	0	0	6,0–11	824	<0.001
	Teacher	0,0–6	558.5	0.142	4,1–9	253.5	0.974
	Student	0,0–2	66	1	5,1–11	239.5	0.319
	Other†	0,0–12	0	0	7,1–14	203	0.001
Educational status	*Illiterate*	0	0	0	6,0–11	257.5	0.005
	Literate	0,0–12	2243	0.999	5,1–14	3277.5	0.056
	Up to class 10	0,0–12	0	0	6,1–14	298.5	0.001
	Class 11 to 12	0,0–2	56	1	4,1–9	174	0.751
	Master´s degree	1,0–6	240.5	0.046	4,1–9	90.5	0.930
	Bachelor´s degree	0,0–3	83	0.939	5,1–11	116	0.203
	Literate informally‡	0,0–8	0	0	7.5,3–10	42	0.012

Symbols and abbreviation: †hotel owner, miller, fisherman, boat-man, mason labourer, housewife, nature guide; ‡respondents able to read and write by informal education but never attained school; **n** = number of snake species displayed, **W** = value of one-tailed one-sample Wilcoxon signed rank test. I zeroed **W** and **p** values for confidence interval (**CI**) below 95%.

Table 14. Knowledge of Chitwan National Park buffer zone people about the need of snake conservation and preventive measures against snake bites.

Demographics		a. Scores for logics explaining the need of snake conservation (cons., n = 5); null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 1), alternative hypothesis (Ha): M > M0			b. Scores for appropriate preventive measures mentioned (prev., n = 10); null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 2), alternative hypothesis (Ha): M > M0		
		Median, range	**W (cons.)**	**p-value**	**Median, range**	**W (prev.)**	**p-value**
	All respondents	**1,0–4**	**2064**	**0.626**	**2,0–9**	**3678.5**	**0.210**
Age (years)	15–24	1,0–4	251.5	0.055	2.5,0–7	398	0.005
	25–34	1.5,0–4	103.5	0.028	2.5,0–6	107.5	0.170
	35–44	1,0–3	66.5	0.904	2,0–9	225	0.568
	45–54	1,0–3	24	0.909	1,0–7	51	0.824
	55–64	1,0–4	27.5	0.720	2,0–4	49	0.602
	65+above	0,0–2	3.5	0.960	0,0–2	0	0
Gender	Male	1,0–4	1042	0.099	2,0–9	1935	0.062
	Female	0,0–3	158	0.992	2,0–4	264	0.872
Occupation	Farmer	0,0–2	80	1	1,0–6	169	1
	Teacher	1,0–4	199	0.001	2,0–9	338.5	0.004
	Student	1,0–4	162	0.013	3,0–7	317.5	0.001
	Other†	1,0–2	0	0	2,0–7	78	0.481
Education status	*Illiterate*	0,0–2	0	0	0,0–6	55	0.999
	Literate	1,0–4	1423	0.028	2,0–9	2675	0.002
	Class 10	0,0–4	0	0	1,0–5	144.5	0.797
	Class 11 or 12	1,0–4	150.5	0.037	3,1–7	295	<0.001
	Master´s degree	1,0–4	69	0.008	2,0–9	89.5	0.009
	Bachelor´s degree	1,0–4	57	0.015	2,0–6	77.5	0.317
	Literate informally‡	1,0–2	0	0	1,0–7	14.5	0.717

Symbols and abbreviation: †hotel owner, miller, fisherman, boat-man, mason, labourer, housewife, nature guide; **‡**respondents able to read and write by informal education and never attained school; **n** = number of logical statements to support their "Yes" reply to the need of snake conservation and preventive measures of snake bite, **W** = value for one-tailed one-sample Wilcoxon signed rank test. I zeroed **W** and **p** values for confidence interval below 95%.

Table 15. Chitwan National Park buffer zone people responding to misbeliefs on snakes, traditional and modern care of snake bites.

		General responses	Median, range	W (resp)	p-value	Median *	Median %	LA†
a. All respondents´ responses (n = 33, see Table 17)		Aware (not believing on misbelief but believing on recommended care), H0(A): M = M0(72), Ha (A): M>M0(72)	82,4–142	335	0.045	72	48	MA
		Unaware (believing on misbelief but not believing on recommended care), H0(UA): M = M0(32), Ha (UA): M>M0(32)	40,2–141	362.5	0.033	32	21	
		Unknown to both traditional and modern information, H0(Uk): M = M0(17), Ha (Uk): M>M0(17)	24,1–61	362	0.034	17	11	
		Not answered to both traditional and modern information **(i.e. item nonresponses**), H0(NA): M = M0(1), Ha (NA): M>M0(1)	2,0–11	417.5	0.002	1	1	
b. Categorical responses	n = 28, see Table 17.a–c	Aware (not believing misbelief on snakes and snake bite care), H0(A28): M = M0(67), Ha (A28): M>M0(67)	75,4–142	280.5	0.040	67	45	MA
		Unaware (believing on misbelief on snakes and snake bite care), H0(UA28): M = M0(35), Ha (UA28): M>M0(35)	43,2–141	278	0.045	35	23	
	n = 13, see Table 17.a	Aware (not believing misbelief on snakes), H0(A13): M = M0(62), Ha (A13): M>M0(62)	72,39–142	62.5	0.036	62	41	MA
		Unaware (believing misbelief on snakes), H0(UA13): M = M0(28), Ha (UA13): M>M0(28);	43,2–82	71.5	0.037	28	19	
	n = 15, see Table 17. b,c	Aware (not believing on traditional and doubtful pre–hospital care of snake bite), H0(A15): M = M0(60), Ha (A15): M>M0(60)	76,4–128	90.5	0.044	60	40	MA
		Unaware (believing on traditional and doubtful pre-hospital care of snake bite), H0(UA15): M = M0(33), Ha (UA15): M>M0(33)	43,18–141	91.5	0.039	33	22	
	pre–hospital care (n = 5, see Table 17.d)	Aware (believing the recommended pre-hospital care of snake bite), H0(A5): M = M0(76), Ha (A5): M>M0(76)	125,77–142	15	0.031	76	51	A
		Unaware (not believing on recommended pre-hospital care of snake bite), H0(UA5): M = M0(1), Ha (UA5): M>M0(1)	22,2–47	15	0.031	1	1	

Symbols and abbreviations: *median significantly greater than (after hypothesis test), †level of awareness, % = percent; **W(resp)** = one-tailed one-sampled Wilcoxon value of respondents who responded particular belief on snakes and/or care of snake bites, **H0** = null hypothesis, **Ha** = alternative hypothesis, **M** = population median, **M0** = hypothesized median (parenthesis contains figure of hypothesised median); **UA** = unaware (0–24%), **MA** = slightly aware (25–49%), **A** = aware (50–74%), **Uk** = Unknown, **NA** = Not answered, **resp** = respondents

Table 16. Awareness of Chitwan National Park buffer zone people concerning belief on snakes and snake bite care.

Demographics		a. Scores for awareness (rejecting traditional belief and medical help of doubtful use and accepting modern measures of pre-hospital care, n = 33); null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 16), alternative hypothesis (Ha): M > M0(16)			b. Scores for unawareness (accepting traditional belief and medical help of doubtful use and rejecting modern measures of pre-hospital care, n = 33); null hypothesis (H0): population median scores (M) = hypothesized median scores (M0 = 8), alternative hypothesis (Ha): M > M0(8)		
		Median, range	**W (Aware)**	**p-value**	**Median, range**	**W (Unaware)**	**p-value**
	All respondents	**19,3–31**	**6564.5**	**0.001**	**9,0–24**	**6628**	**<0.001**
Age (years)	15–24	16,7–28	433.5	0.182	11,2–18	628	<0.001
	25–34	20.5,3–31	178	0.049	8,2–23	98.5	0.452
	35–44	19,4–30	394.5	0.260	8.5,2–12	470.5	0.132
	45–54	21,6–29	193.5	0.004	8,2–14	94	0.667
	55–64	21,9–27	111	0.014	10,3–24	114.5	0.037
	65 and above	9,3–25	8	0.930	9,0–17	19	0.223
Gender	Male	20,3–31	3769.5	<0.001	8,0–24	2698.5	0.039
	Female	13.5,3–27	335.5	0.952	10,2–23	855.5	<0.001
Occupation	Farmer	12,3–28	435.5	0.975	9.5,0–24	873.5	0.005
	Teacher	22,14–30	898	<0.001	8,2–17	382	0.650
	Student	16,7–28	271	0.329	11,2–18	426.5	<0.001
	Other*	21,5–31	142.5	0.029	9,2–22	126.5	0.216
Educational status	*Illiterate*	10,3–28	75	0.997	10,0–23	227.5	0.005
	Literate	20,5–31	4954	<0.001	9,2–24	3982	0.005
	Up to class 10	22,5–31	388	0.001	7,2–21	165.5	0.918
	Class 11 or 12	17,7–29	734	0.068	12,3–18	376.5	<0.001
	Master´s degree	22,16–30	325	<0.001	7,3–17	123	0.682
	Bachelor´s degree	21,13–28	220	<0.001	9,2–15	135.5	0.129
	Literate informally†	12.5,7–26	25	0.620	12.5,4–24	48.5	0.018

Symbols and abbreviations: *hotel owner, miller, fisherman, boat–man, mason, labourer, housewife, nature guide; †respondents able to read and write by informal education but never attained school, **n** = total number of awareness test questions, **W** = value of one-tailed one-sample Wilcoxon signed rank test. **Note: 1.** Scores for unknown (to traditional belief, medical help of doubtful use and modern measures of pre-hospital care (median = 3.5, range = 0–30); **2.** Scores for not answered (any questions regarding traditional belief, medical help of doubtful use and modern measures of pre-hospital care (item non–responses) (median = 0, range = 0–16)

Table 17. Responses of Chitwan National Park buffer zone people to awareness test questions.

SN	**a. Traditional belief on snakes** (those which are potentially cause snake bites are Italicized)	**Responses** (% percent, N number of respondents)						**Level of awareness**
		I believe (N)	I believe (%)	I don´t believe (N)	I don´t believe (%)	I don´t know (N)	Item non–responses (N)	
1	All snakes surrounding us are venomous	2	1	142	95	6	0	HA
2	Snakes can have rebirth	22	15	98	65	30	0	A
3	Snakes can hypnotize	15	10	96	64	39	0	A
4	*View of snake on the way/journey bode good future*	**34**	23	92	61	24	0	A
5	After bites, snakes go to tree-top to view victim´s funeral	7	5	91	61	52	0	A
6	Snakes eyes can photograph to take revenge	43	29	86	57	21	0	A
7	*Kill partner of snake to avoid revenge of survived ones*	**59**	39	72	48	19	0	MA
8	*Snakes possess invaluable stone ´Mani´*	**53**	35	63	42	34	0	MA
9	Snakes can suckle milk from cows, goats, or sheep	57	38	62	41	30	1	MA
10	*Some snakes guard the property of people*	**59**	39	61	41	30	0	MA
11	Vine snakes bite only on eye or forehead	55	37	58	39	37	0	MA
12	There are two-mouthed snakes	40	27	49	33	61	0	MA
13	Snakes (e.g., cobras) can dance in tune of music	82	55	39	26	29	0	MA
	b. Traditional belief on pre-hospital care							
1	Visiting traditional healers	18	12	128	85	2	2	HA
2	Sucking wound	34	23	108	72	5	3	A
3	Applying other traditional concoction topically	25	17	90	60	31	4	A
4	Squeezing the wound	47	31	88	59	13	2	A
5	Ingesting other traditional concoction	32	21	85	57	27	6	A
6	Applying the cloaca of chickens	28	19	82	55	34	6	A
7	Ingesting chillies	45	30	82	55	19	4	A
8	Applying honey on the site of bite	20	13	76	51	49	5	A
9	Incising bite site	62	41	74	49	12	2	MA
10	Ingesting herbal medicine	40	27	74	49	31	5	MA
11	Applying herbal medicine topically	43	29	72	48	31	4	MA
12	Using snake stone	47	31	63	42	36	4	MA
13	Applying (tight) tourniquet	95	**63**	48	32	4	3	MA
	c. Seeking medical help of doubtful use							
1	Visiting medical person	133	**89**	5	3	1	11	UA
2	Visiting any hospital or healthcare centre	141	**94**	4	3	1	4	UA
	d. Recommended measures of pre-hospital care							
1	Visiting healthcare facilities supplied with antivenom	142	95	2	1	3	3	HA
2	Envenomation can be cured by antivenom	132	88	8	5	7	3	HA
3	Availability of nearby snake bite treatment centre	125	83	22	15	3	0	HA
4	Pressure immobilization bandaging (PIB)	92	61	40	27	12	6	A
5	Local compression pad immobilization (LCPI)	77	51	47	31	17	9	A

Awareness level: **UA** = unaware (0–24%), **MA** = slightly aware (25–49%), **A** = aware (50–74%), **HA** = highly aware (75–100%)

4. DISCUSSION

4.1. Characterization of medically relevant snakes causing envenoming in Nepal

This dissertation provides an example of the biodiversity of medically relevant snakes in Nepal as revealed by preserved specimens brought by victims to snake bite treatment centers which enabled the accurate species identification. It highlights the diversity of venomous snakes causing potentially fatal envenoming in humans. It also increases the number of species involved in snake bites as compared to what has been reported previously in Nepal (Joshi, 1983, Heap and Cowan, 1991, Bhetwal et al., 1998, Hansdak et al., 1998, Shah et al., 2003, Sharma et al., 2003, Sharma et al., 2004a, Sharma et al., 2004b, Bista et al., 2005, Bhattarai et al., 2008, Joshi, 2010, Kuch et al., 2011, Paudel and Sharma, 2012, Timsinha et al., 2014). This also reveals the relative proportion (i.e., 57%) of medically relevant snakes involved in human envenoming in Nepal for the first time (Table 2). This information can be used as an important source for community education and research on snake bite prevention and management.

Because no diagnostic tools for identifying the species involved in snake bites (Chandler and Hurrell, 1982, Selvanayagam et al., 1999, Pathmeswaran et al., 2006, Ariaratnam et al., 2009) are currently available for Nepal, this morphology-based identification will enable clinicians to anticipate envenoming effects (Ariaratnam et al., 2009) and to adopt an appropriate treatment (Shah et al., 2003), lay people to apply first aid measures (Sutherland et al., 1979, Tun-Pe et al., 1995a) and locals to develop preventive strategies.

4.1.1. Species richness, diversity, distribution ranges of medically relevant snakes and risk zones for snake bites in Nepal

The study results confirm that the diversity of snake species causing envenoming in southern Nepal is higher than previously reported and that there are distinct geographical differences not only by altitudinal zonation, but also between different regions of the Terai lowlands.

4.1.1.1. Species richness

Eleven medically highly relevant snake species are involved in envenoming in Nepal (Table 2.a), representing 61% of the species potentially causing severe envenoming (Sharma et al., 2013b). Eight species are proteroglyphous elapid snakes (Table 2.a) representing 80% of all elapids distributed in Nepal (Sharma et al., 2013b) (Table 18).

Table 18. Representation of medically relevant snake species in Nepal.

Family	Subfamily	Nepal*		Current study area			
		Genera	Species	Genera		Species	
		N	N	N	%	N	%
Exclusively medically relevant species		**9**	**20**	**5**	**56**	**11**	**55**
Elapidae	Elapinae	4	10	3	75	8	80
Viperidae	Crotalinae	4	6	2	50	2	33
Viperidae	Viperinae	1	1	1	100	1	100

*I listed only species with definite distribution information available in published sources; I did not include subspecies.

The most diverse medically relevant snake genus is *Bungarus*. I identified five *Bungarus* species reported to occur in Nepal (Sharma et al., 2013b). This represents 31% of *Bungarus* species known to be distributed in Asia (Abtin et al., 2014, Wallach et al., 2014) including new localities for *B. walli* and *B. niger*.

The solenoglyphous viperid snakes known to be involved in snake bites during this study represented 43% of viperids reported to be distributed in Nepal (Sharma et al., 2013b) (Table 18). This richness in venomous snakes and suitable habitats in Nepal has important medical consequences.

4.1.1.2. Contribution to the knowledge of venomous snake species diversity

The records of 13 distribution localities of *Bungarus walli* from southeastern Nepal (Figure 29, Table 2.a, Appendix 2) represent the first country reports for this species in Nepal. Previously, *B. walli* was doubted to occur in Nepal (Kabisch, 2002b, Schleich et al., 2002, Kästle et al., 2013a) or was reported without locality details (Mahendra, 1984, Sharma et al., 2013b). During this study, I interviewed six proven *B. walli* bite cases to understand the circumstances of bites (described in chapters 3.2 and 4.2).

Likewise, *Bungarus niger*, which is poorly known in Nepal, brought by a patient from Ilam (at 1515 m asl) is the second record for this country. This extends its distribution range by 423 km eastwards from its first described locality near Naudanda, Kaski District, in the midwestern hills of Nepal (Tillack and Grossmann, 2001) (Figure 31, Appendix 2).

Daboia russelii is a poorly known snake with poorly defined localities in Nepal, although it is said to occur throughout the lowlands in nine districts (Shah and Tiwari, 2004). So far, the identification of this species with 10 localities in southwestern Nepal is the fourth report with confirmed locality (Table 2.a., Figure 36, Appendix 2). This species was known from two localities in the far-western lowlands (O'Shea, 1996, Schleich and Kästle, 2002). Probably, Bhetwal et al. (1998) described this species for these localities as already recorded by O'Shea (1996). Shah (1995) reported its distribution along altitudinal ranges of 100 to 200 m asl with one locality in the southeastern, one in the southwestern and one in the far-western lowlands of Nepal referring to the collections of the Natural History Museum in Kathmandu and to a report of the Biodiversity Profile Project (Biodiversity Profile Project, 1995). Other sources (Schleich et al., 2002, Kästle et al., 2013a) provided the same locality information. Schleich and Kästle (2002) noted four imprecise distribution localities in southwestern and southeastern Nepal. Recently, Chhettri and Chhetry (2013) erroneously reported its occurrence at Karmaya in the Sarlahi District (Pandey, 2014).

4.1.1.3. Distribution patterns, ranges and risk zones for snake bite envenoming

The distribution pattern of venomous snakes and their respective contribution to snake bite varies greatly throughout Nepal. Snake bite data from eastern, central and western Nepal as described in this study are, therefore, important for snake bite management and prevention. The checklist in Table 2 may become an educational tool that enables the identification of snakes, which in turn helps patients to select first aid measures (Sutherland et al., 1979, Tun-Pe et al., 1995a, World Health Organization, 2010) and clinicians to prognose envenoming effects and to be prepared for timely treatment (Silva et al., 2013a).

The western and central lowlands of Nepal are dominated by kraits and the eastern lowlands by cobras (Table 2.a, Figure 10, 15, 20, 26, 29, 27, 31). In western Nepal, 29–40% of all bites were found to be caused by kraits, 1–14% by vipers and 6–10% by cobras (Shrestha, 2011, Paudel and Sharma, 2012, Magar et al., 2013). In eastern Nepal, Sharma et al. (2004b) mentioned that cobras (n = 17) envenomed people more often than kraits (n = 4) and Green Pit Vipers (n = 3). Particularly, *Naja naja* and *Bungarus caeruleus* were predominant in causing human envenoming (Table 2.a).

Although these snakes are mostly known from areas below 1,600 m asl (Table 2.a), they occur in the lowlands and highlands of Nepal posing there risks of envenoming. These snakes occur in different climatic and ecological zones even above their altitudinal distribution ranges (Table 2.a). However, a literature review indicated no risks of envenoming above 5,000 m asl (Smith, 1943).

4.1.1.3.1. Distribution ranges and risk zones for proteroglyphous snake bites

The general geographical distribution ranges of venomous snakes (see chapter 3.1.2., Appendix 2) indicate risk of envenoming in areas beyond the high risk zones for snake bites as suggested by the Nepal Government (Bista et al., 2005, Epidemiology and Disease Control Division, 2011). The medically relevant proteroglyphous venomous snakes are mainly distributed in the lowlands, but also in some valleys of the middle hills with tropical climate and even in the Himalayan regions up to 3,200 m asl (Acharji, 1961) where they pose risks of envenoming. Since snake population and diversity is highest in the agrarian, forested or bushy areas of the tropical lowlands where more than 50% of people live (Nepal Population Census 2011), people involved in agricultural or forested activities are at risk for proteroglyphous snake bites.

Although I found most of the species at lower elevation ranges (Table 2.a), *Naja kaouthia* was present up to 3,200 m asl (Acharji, 1961), *Ophiophagus hannah* up to 2,460 m (Shah, 2000), *Bungarus niger* up to 1,515 m (as shown in the present study), *B. caeruleus* up to 1,400 m (Shrestha, 2001) and to 1,525 m (Kabisch, 2002b) and *N. naja* up to 1,300 m asl (Shah and Giri, 1991). The distribution range *of B. niger* was found to be extended to the eastern hills. The checklist of medically relevant snakes (Table 2.a) and maps (see chapter 3.1.2) also report the ranges of their distribution.

Particularly, *Bungarus* species are of highest medical relevance in Nepal. They are distributed between 62 m and 1,515 m asl (Table 2.a). Literature records of *Bungarus* distribution in 1,730 m asl in Dingari, Ilam, eastern Nepal (Kabisch, 2002b) to 2,072 m asl in Darjeeling, West Bengal State, India bordering southeastern Nepal (Boulenger, 1896) suggest risks of envenoming from the lowlands to the middle hills of Nepal.

Bungarus caeruleus and *B. walli* have a similar morphological appearance (Figure 19, 25), but they are distributed unevenly in Nepal (Table 2.a, Figure 21, 22). *Bungarus caeruleus* was the second most common snake occurring throughout the lowlands (usually below 400 m asl) (Fleming and Fleming, 1973) and intermediate hills, possibly up to 1,525 m asl (Kabisch, 2002b). However, only six of 65 *B. caeruleus* specimens were known from eastern Nepal. The easternmost *B. caeruleus* specimen was deposited in a snake bite treatment centre in Itahari (Figure 20) without patient and locality details. Although *B. caeruleus* was found to be common in the central and the western lowlands of Nepal, its distribution ranges point to risks of bites throughout the lowlands and the lower hills.

In contrast, none of the *Bungarus walli* specimens (n = 13) were known from central and western Nepal. All specimens were known from eastern Nepal only. The most western *B. walli* specimen (which was not involved in a bite) was collected in a kitchen of a house in Biratnagar (Figure 26). Previously, this species had been often mistaken for *B. caeruleus*. Therefore, *B. walli* is likely to be distributed throughout the lowlands of Nepal (Wallach et al., 2014). However, this raises the question, why these similar looking kraits concentrate in two different areas in the lowlands. Further studies are needed to answer the question and reveal whether these species are sympatric or allopatric.

Bungarus niger, which is recently reported to be a medically relevant snake (Faiz et al., 2010), caused death of a patient from the hills in eastern Nepal. Similar risks may occur up to 1,450 m asl of the western hills (Tillack and Grossmann, 2001). The similar looking *B. lividus* (Figure 28) was also found to be involved in human envenoming (Kuch et al., 2011). Although Kabisch (2002b) suggested *B. lividus* as an uncommon species in Nepal, I observed it to be the fourth common snake among the medically relevant species (Table 2.a). It is also known from Chitwan Valley, the central lowlands of Nepal (Pandey, 2012) usually below 250 m asl (Sharma et al., 2013b). Since more than 70% of the population inhabit the lowlands and lower hills (Central Bureau of Statistics, 2012a), they are at risk of *B. niger* and *B. lividus* bites.

Educational and medical interventions are urgent, because even motivated scholars are confused when identifying snakes. Misidentification of the snake brought to the hospital caused delayed treatment of a *Bungarus caeruleus* bite case in Sri Lanka that led to the death of the patient (Silva et al., 2013a). Rai (2003) misidentified *B. caeruleus* for *B. lividus* because he noted brown body with dark bands on the anterior and head region and the rest of the body having white bands up to the tip of the tail which is rather typical for *B. caeruleus*. He noted also a yellow belly, but I found it creamy white with dark pigments across the posterior part of the belly and tail and without any white bands on the dorsal body (Figure 21, 28). People inhabiting the ranges of *Bungarus* species should be able to distinguish those venomous snakes from non-venomous specimens, their behaviour and distribution patterns.

Bungarus fasciatus was less involved in snake bites in Nepal. I could not find patient details for specimens that are deposited in snake bite treatment centres (STCs) (Table 2.a, Figure 30) because of poor or no tags. Paramedics involved in snake bite treatment in the respective STCs informed me that all snakes were brought to the centre by patients or their attendants. Rai (2003) reported that *B. fasciatus* is the most common krait in eastern Nepal. I found it in the Chitwan Valley, southcentral Nepal (Pandey, 2012). Kabisch (2002b) reported the species in Kanchanpur, the far-western Nepal. My recent records of the *B. fasciatus* distribution in 531 m asl in the hills of Sindhuli District, central Nepal (but not involved in snake bites) and distribution reports up to 2,500 m asl in Vietnam (Kabisch, 2002b) suggest its possible distribution in the entire lowlands and hill ranges of Nepal. Because of its shy nature and considering it as a holy snake, people tolerate it if the snake appears in residential areas. Therefore, people should be informed about the potentially fatal bite of this snake.

Among all examined specimens, *Naja naja* was the most common snake, more in southeastern than in southwestern Nepal. Different rainfall patterns along the eastern to the western Nepal might be responsible for this variation (Practical Action Nepal, 2009). Only a small number of *N. kaouthia*, which looks similar to *N. naja* (Figure 11–13), was found to be involved in bites (Table 2.a). The variations of sample size of these similar looking snakes may correspond to their population density or niche preference. However, definitive distribution records of N. *kaouthia* from about 150 m asl by Kramer (1977) to 3,200 m asl in Solukhumbu by Acharji (1961) indicate that it is likely to occur throughout the lowlands to the upper hills (Figure 10, 21). Fleming and Fleming (1973) cited the likely distribution of *N. naja* in the Kathmandu Valley and Pokhrel et al. (2011) reported *N. kaouthia* from the Nagarjun forest near the Kathmandu Valley. Therefore, great care is necessary while working in forested areas in hilly regions. As I have collected anecdotal records of cobra bites in the upper hills of Nepal, people should be aware of that snake.

Because of the significant geographical variations among cobras (Wüster, 1998), there might also be variations in the venom composition of specimens from India and Nepal. Therefore, antivenom developed against the venom of *N. naja* from India may not be effective to neutralize *N. kaouthia* bites in Nepal. The findings of high dosage (up to 980 ml) of antivenom used to treat snake bite envenoming in a hospital in southcentral Nepal (Pandey et al., submitted) may indicate the poor efficacy of Indian polyvalent antivenom.

The few reported cases of the King Cobra (*Ophiophagus hannah*) envenoming support the observation of its rare bites to humans, which has also been reported in Myanmar (Tun-Pe et al., 1995b) and in other Asian countries (Veto et al., 2007). The literature of its distribution in Nepal points to potential risks of envenoming in the lowlands (Pandey, 2012) and up to 3,500 m asl in the upper hills (Shah, 2000). Therefore, great care should be taken while working in plantation or forested areas in the lowlands to the upper hills of Nepal.

Although *Naja naja* was the most common venomous snake involved in human envenoming (Table 2), *B. caeruleus* is responsible for more snake bite deaths in Nepal (Epidemiology and Disease Control Division, 2011). This is due to the fact that patients often arrive late at the hospitals (Pandey et al., submitted). Krait venoms cause non-reversible paralysis that poorly responses to the delayed antivenom therapy (Theakston et al., 1990, White et al., 2003, White, 2004). These venoms can also cause long-term neurological damage (Bell et al., 2010). Likewise, other hospital-based epidemiological studies (Heap and Cowan, 1991, Hansdak et al., 1998, Bista et al., 2005, Thapa and Pandey, 2009, Epidemiology and Disease Control Division, 2011) reported kraits to be the major cause of snake bite deaths in Nepal.

4.1.1.3.2. Distribution ranges and risk zones for solenoglyphous snake bites

The solenoglyphous viperine snakes are mostly distributed in hill regions except for the Russell's Viper (*Daboia russelii*) that is mainly distributed in the lowlands of Nepal. In this study, bites by *D. russelii* are confirmed for the first time in Nepal (Table 2.a). This emphasizes its medical relevance including the circumstances of its bites (described in chapter 3.2). The snake's distribution range was extended by about 242 km to 381 km, respectively, to the east from the Bardia National Park (O'Shea, 1996, Bhetwal et al., 1998) and Suklaphanta Wildlife Reserve (Schleich and Kästle, 2002). Its occurrence at elevations between 80 and 118 m asl as shown in the present study (Table 2.a) and up to 3,000 m asl in India as reported by Murthy (1990b) indicates a high risks of envenoming in the upper hills as well. However, knowing its precise distribution nationwide needs well-organized surveys.

Two of the seven solenoglyphous pit viper species reported to be distributed in Nepal (Sharma et al., 2013b) were found to be involved in bites during this study period: *Trimeresurus albolabris* and *Ovophis monticola.* They caused severe pain, local swelling (Warrell, 1995, Bhattarai et al., 2008) and coagulopathy as in the case of other pit viper bites (Warrell, 1995, Sarmin et al., 2013, Isbister et al., 2014), but requiring no treatment with antivenom. Depending on the circumstances, the venom effects of these snakes may also cause severe envenoming (Warrell, 1995, Isbister et al., 2014) or death of the patient (Warrell, 1995, Maden, 2014). These snakes are distributed in the tropical (Pandey, 2012, Pandey, 2014), subtropical (Table 2.a) and temperate regions up to 2,743 m asl (Smith, 1951, Fleming and Fleming, 1973, Kramer, 1977). *Trimeresurus albolabris* occurs up to 3,200 m asl (Smith, 1951, Nanhoe and Ouboter, 1987) and *Ovophis monticola* up to 2,250 m (Fleming and Fleming, 1973). Published information of pit viper distribution up to 4,877 m asl in India (Smith, 1943) indicate that viperid snakes may occur beyond the high risk zones for snake bite envenoming as suggested by the Epidemiology and Disease

Control Division, Nepal Government (Shah et al., 2003, Bista et al., 2005).

Although treatment of most pit viper envenomings is not particularly time critical (Bhattarai et al., 2008) like in elapid bites, people living in sub-alpine regions in the highlands at the level of tree-line should be educated about the need of medication to cure local and systemic effects of pit viper bites. *Daboia russelii* should also be included in educational and research programmes to support antivenom design, distribution and snake bite management.

In conclusion, elapid and viper bites need great attention and special care because of their envenoming effects. The high risk zones of snake bite in Nepal should be updated because of the effects of global climate warming (Deutsch et al., 2008) which may cause uphill movement of the venomous snakes. This further supports increased risks of venomous snake bites in wider ranges than those suggested in Government documents (Shah et al., 2003, Bista et al., 2005, Epidemiology and Disease Control Division, 2011). Therefore, knowledge about medically relevant snakes, their altitudinal and geographic distribution patterns can be a bench mark of further studies and of snake bite management in Nepal.

In Nepal, at least six crotalid species are distributed (Sharma et al., 2013b), but there is no specific antivenom to treat crotalid snake bites. Also, effectiveness of the polyvalent snake antivenoms from India to treat these snakes have not been proved yet. Pit viper antivenoms produced in other countries have not been tested regarding their effectiveness against the venoms of the pit viper species in Nepal.

4.1.2. Distribution of medically non-relevant snakes in Nepal

Twenty-one of 32 snake species involved in snake bites were found to be harmless or of doubtful medical relevance. The snakes involved in snake bites without symptoms of systemic envenoming (Harris et al., 2010) should be documented comprehensively by multicentre studies nationwide. This may help to understand and minimize the snake bite burden at hospitals and to highlight the snake diversity associated with public health.

4.1.2.1. Species involved in snake bites with doubtful medical relevance

Ten of 21 species were mildly venomous (20%, n = 71 of the total specimens). They caused doubtful medical effects as paramedics involved in treatment reported minor envenoming effects, patients were recovering without medical treatment (except anti-tetanus injection). Six of the 10 species were opisthoglyphous snake species possessing mild venom (Table 2.b, Appendix 2) and representing 55% of the back-fanged snake species distributed nationwide (Gruber, 2002). *Boiga* *ceylonensis* bites in Khandala, India, caused moderate envenoming symptoms with slight bleeding and itching that lasted for 30 minutes and swelling for 2 hours (Whitaker, 1970). Bites of the Nepalese *Boiga* species may cause similar mild envenoming. However, because Weinstein et al. (1991) reported the lethal potency of *Boiga irregularis* in infants and small children, *Boiga* bites need to be monitored and treated with care.

Weinstein et al. (2011) also mentioned that *Enhydris enhydris* bite caused slight bleeding and throbbing pain that subsided within an hour. In my study, *E. enhydris* and members of the same group i.e., *Ferania sieboldii*, were involved in snake bites (Table 2.b) that caused mild envenoming. Additionally, in my study, no reports of medically significant envenoming effects due to *Chryopelea* species bites were recorded (Ismail et al., 2010, Tan et al., 2012, Silva et al., 2013b).

I identified four aglyphous snake species which may possess toxic buccal secretions (Table 2.b, Appendix 2). Although Fry et al. (2003) reported that venoms of *Coelognathus helena* and *C. radiatus* are similar to elapid snake venoms, Harris et al. (2010) described four *C. radiatus* bites causing only local pain and slight bleeding at the bite site. Therefore, venom effects of these species to humans and their medical relevance (Table 2.b) still need further investigation.

Although two aglyphous *Rhabdophis* species that are reported to have the potential to produce potentially fatal bites are distributed in the lowlands to the upper hills of Nepal (Swan and Leviton, 1962, Pandey, 2012), I did not find any specimen belonging to this genus involved in snake bites I studied. The only representative of this genus, a specimen of *R. himalayanus* from Ghandruk, Kaski District in the mid-western hills of Nepal (Figure 53) was found in July 2014. Unlike *R. subminiatus* (Mittleman and Goris, 1978, Ogawa and Sawai, 1986), fatal bites of *R. himalayanus* have not been observed yet (Weinstein et al., 2011). This snake is distributed from 1,100 m asl in the lower hills (Kramer, 1977) to 2,350 m asl in the upper hills of Nepal (Nanhoe and Ouboter, 1987). However, fatal envenoming due to *Rhabdophis* species bites may occur throughout the lowlands and the hill ranges.

Aglyphous *Xenochrophis* and opisthoglyphous *Amphiesma* species that are supposed to be nonvenomous, have been shown to possess toxic saliva (Leviton et al., 2003). The effect of their venom in humans is still questionable. In the present study, none of these snake bites required medical care because of their mild or absent of envenoming effects. Medically relevant bites by these species have not been described yet (Weinstein et al., 2011). Because of phosphodiesterase activity in the *Amphiesma stolatum* venom (Hill and Mackessy, 2000), its bite confuses people who assume that the snake is venomous. Therefore, bites due to mildly venomous snakes shown in this study (Table 2.b) are attributed to species with doubtful medical relevance. However, special care should be taken in case envenoming symptoms appear. Based on comprehensive prospective studies, these snakes may eventually either be grouped into medically relevant or not relevant species. Since only few data on the effects of Duvernoy's gland secretions exist (Weinstein and Kardong, 1994, Weinstein et al., 2013), in Nepal, the number of medically relevant snakes may increase.

4.1.2.2. Medically non-relevant snake species involved in snake bites

A total of 32 snake species were involved in snake bites during this study. They belonged to eight families and 22 genera, representing 46% of snake species distributed in Nepal (Kästle et al., 2013a). Among 32 snake species, 11 species (23% of total study specimens) were medically non-relevant. The most common nonvenomous species presented to the study centres were *Lycodon aulicus* (12%, n = 40) (Figure 25) and *Ptyas mucosa* (3%, n = 10) (Table 2.c). Because of the poor knowledge (see chapter 3.3.2) and inadequate education about snakes (Pandey and Khanal, 2013), people ask for treatment in case of even harmless snake bites. As snake bite patients are recommended for 24 hours hospital observation (World Health Organization, 2010), it burdens the hospital and public health sectors.

I identified the non-venomous snake *Oligodon cyclurus* with a photo voucher for the first time in Nepal (Figure 67). A specimen was also brought by a patient from India bordering eastern Nepal. This species was previously questioned to occur in Nepal (Kästle et al., 2013a) or was listed without locality information (Shrestha, 2001). This report is a contribution to the knowledge on the snake diversity in Nepal.

Figure 67. *Oligodon cyclurus* brought to Charaali snake bite treatment centre, southeastern Nepal.

Interestingly, I discovered two *Lycodon aulicus* bite cases evidenced with snake voucher treated with 16 and 17 antivenom vials, respectively (Figure 68). Locals claimed it to be a Common Krait and requested clinician to use antivenom. This misuse of antivenom also has the potential of hazardous effects of the antivenom for the patients.

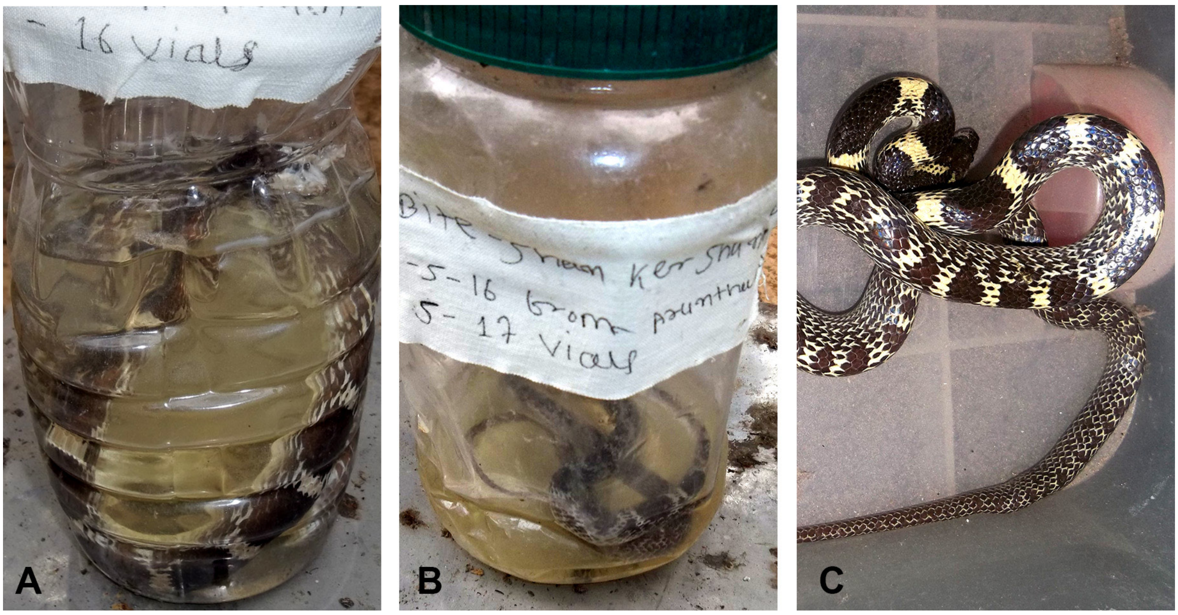

Figure 68. Use of antivenom to treat a harmless *Lycodon aulicus* being confused with *Bungarus caeruleus*. Specimens A and B were brought by patients to Dudhauli snake bite treatment centre (STC) and specimen C (*L. aulicus*) to Damak STC.

The misidentification by clinicians of brought snakes is also common in other parts of Nepal (Shah et al., 2003). This demonstrates enormous educational deficits among medical professionals, who are involved in snake bite management, although they get regular training in snake bite management since 1999 (Shah et al., 2003). This problem is also commonplace in the Indian subcontinent (Silva et al., 2013a). Therefore, existing educational training should be equipped with medically relevant snake identification tools including illustrative keys; school and university curricula should be improved (Pandey and Khanal, 2013). In future, in order to help building of a reference collection and database for the molecular diagnosis of snake bite, generating molecular genetic information ('DNA barcodes') of the snakes involved in snake bites is necessary.

The occurrence of *Lycodon aulicus* and *Oligodon arnensis* (Table 2.c) in human residential areas might attract ophiophagous krait species in these areas. Therefore, snake attractants should be identified and removed from the residences and its premises.

4.1.3. Use of the checklist of snakes involved in snake bites

The evidence-based documentation of medically relevant snakes (Table 2.a) should be useful to design, produce and distribute effective antivenoms (i.e., mono- or polyvalent antivenom). This reduces the effects of antivenom incompatibilities and supports improvement of distribution of limited antivenom sources to snake bite prone areas. Until reliable diagnostic tools are available, the morphology based species identification (see chapter 3.1.2) and the checklist (Table 2) should be useful in this context. This may help clinicians to understand also symptoms of venomous snake bites (Pathmeswaran et al., 2006) and locals to distinguish venomous from nonvenomous snakes (Figure 69).

4.1.4. Risk factors for the medically relevant venomous snake bites in Nepal

4.1.4.1. Periods, seasons and places

The analysis of localities where bites of medically relevant snakes occurred shows that risks of snake bite envenoming in Nepal are high at night and during the rainy season in residential areas (Table 3, Figure 54). Furthermore, records of the majority of bites at night and indoors indicate the involvement of mainly kraits. The majority of nocturnal elapid snake bites (72%) during 7 pm to 4 am in the Chitwan Valley (Pandey et al., submitted) is based mainly on the history and symptoms of bites and only partly on identified snakes. However, previous studies have confirmed that Common Kraits are usually involved in snake bites at night (Theakston et al., 1990, Kularatne, 2002, Bawaskar and Bawaskar, 2004, Ariaratnam et al., 2008). It has also been reported that nearly half of all snake bite envenomings in Nepal are due to kraits (Epidemiology and Disease Control Division, 2011). Therefore, kraits are the prime risk factor of snake bite envenoming in Nepal. Although I have found that Common Krait bites occurred also inside anti-mosquito bed-nets, the use of bed-nets at night (Chappuis et al., 2007) may prevent these nocturnal krait bites to some extent only.

Figure 69. *Ptyas mucosa* (**A**) and *Indotyphlops braminus* (**B**), the harmless snake species, were considered venomous snakes by locals.

In this study, seasonal activities of medically highly relevant snakes like *Bungarus caeruleus* and *Naja naja* correspond to reports of their involvement in snake bites in July, September and October in India and Sri Lanka (Bawaskar and Bawaskar, 2004, Ariaratnam et al., 2008). Although *Bungarus* species are exclusively nocturnal (often docile during the day), the risks of *B. caeruleus* and *B walli* envenoming may occur any time of the day (Figure 54). The bite patterns shown in the present study are congruent with the results of studies in India and Sri Lanka (Kularatne, 2002, Bawaskar and Bawaskar, 2004, Ariaratnam et al., 2008), although *B. walli* envenoming cases are rare and had not been described before.

The majority of snakes brought to hospitals bit people in the premises of their house or indoors and on agricultural land (Figure 55), where the snakes might hide in rodent burrows, cracked walls, piles of bricks, or under stones, rubble and in crevices of wattle and daub houses (Table 3) (Wall, 1921, de Silva, 1990, de Silva, 2004, Sharma et al., 2013b). They might have entered human dwellings probably in search for prey. This eventually leads to snake-human-encounters and envenoming. Similar bite patterns have been reported in India and Sri Lanka (Bawaskar and Bawaskar, 2004, Ariaratnam et al., 2008).

Because of their diurnal living style, large body size and producing a growling sound before attack, encounters or bites due to *Ophiophagus hannah* are rare (Purananda, 1957). Since *O. hannah* feeds mainly on snakes and prefers tranquil and undisturbed forested areas in the vicinity of water and in bamboo, tea and coffee plantation areas when there are no human activities, residences should be built far from such places and great care is needed in these areas.

4.1.4.2. Misconception of people on snakes

Prevalent misconception of people on snakes and poor knowledge about their general behaviour and biology put them at risk of envenoming. In the present study, 11 live snakes involved in bites were brought to snake bite treatment centres (STCs) due to the wrong perception that snakes could suck venom from the bitten wound, treatment would be effective with live snakes at STC or killing of snake would cause revenge to the patient or family members. A family of a deceased patient from Dudhouli, Sindhuli denied giving the live *B. caeruleus* to me because they planned to extract venom for a traditional healer. This ingrained misbelief in Nepalese communities may put them at risk of multiple snake bites.

4.2. Epidemiology, circumstances and pre-admission histories of venomous snake bite cases and analysis of risk factors of envenoming in southern Nepal

4.2.1. Incidence of snake bite envenoming and deaths in Nepal

The overall case fatality rate (CFR, chances of death in a venomous snake bite case) was found to be 10 in the present study area (Table 4) which is also lower than rates reported (i.e., 12–28 CFR) in studies performed in small geographical regions in the southern Nepal (Heap and Cowan, 1991, Hansdak et al., 1998, Shah et al., 2003, Sharma et al., 2004a, Bista et al., 2005, Pandey, 2006, Chappuis et al., 2007, Pandey, 2007, Thapa and Pandey, 2009, Joshi, 2010, Pandey et al., 2010b, Paudel and Sharma, 2012, Magar et al., 2013, Pandey et al., submitted). From a single-centre study carried out in 2007, Pandey et al. (submitted) recorded a 21% CFR for southcentral Nepal. Recently, a similar study based on 10 centres in western Nepal reports 13% CFR (Magar et al., 2013). This indicates that the CFR due to venomous snake bites is greatly reduced in Nepal. However, it is higher than recorded in most studies covering rural tropical populations of Asia (0.4 to 54%) and Africa (0.1 to 28%) (Chippaux, 1998).

Incidence of krait and Russell's Viper bites in the southern Nepal: This study reveals the actual incidence and relative proportions of confirmed krait (n = 46) and Russell's Viper (n = 10) bites resulting in case fatality rate, CFR, 17% (n = 8) and 0%, respectively, for the first time in Nepal. A retrospective hospital based study estimated the proportion of neurotoxic envenoming due to bites of unidentified kraits to be 29–38% (Thapa and Pandey, 2009) and 30–40% (Shrestha, 2011, Paudel and Sharma, 2012). In India, the rate of krait bite envenoming and associated death is higher. In rural districts of Maharastra, India, there are more krait bites (26%) than cobra bites (23%) (Bawaskar et al., 2008). In a recent retrospective study on snake bite patients admitted to a tertiary healthcare centre in northern India, kraits were reported to be the most common snake (54%) responsible for envenoming (Ahmed et al., 2012). Other studies recorded between 33–50% fatalities after krait bites (Hati et al., 1988, Bawaskar and Bawaskar, 1992, Bawaskar and Bawaskar, 2000).

In Nepal, the Common Krait (*Bungarus caeruleus*) is considered to cause the majority of snake bite morbidity and mortality (Sharma et al., 2004a, Epidemiology and Disease Control Division, 2011). Although the existing data clearly show that *B. caeruleus* is the leading cause of snake bite mortality (up to 50% case fatality rate, CFR) in Nepal (Thapa and Pandey, 2009, Epidemiology and Disease Control Division, 2011), I found only 15% CFR among the confirmed *B. caeruleus* bites (n = 34) and 17% among all krait bites (n = 46). The incidence and proportion of envenoming and death rates does not correspond to the episodes reported nationwide (Bista et al., 2005, Epidemiology and Disease Control Division, 2011). It is, because a previous estimation was based on the history of bites and on non-expert identification of brought snakes. The present study is the first report of identified krait bites and associated deaths in southern Nepal.

Previously Schleich et al. (Kabisch, 2002b, Schleich et al., 2002, Kästle et al., 2013a) doubted on occurrence of Wall's Krait (*B. walli*) in Nepal citing Mahendra (1984), who reported its distribution in Nepal without locality data or vouchers. The similar appearance of this species (Figure 21) may have caused its confusion with *B. caeruleus*. Although *B. walli* is reported to occur in Bangladesh, West Bengal, Bihar and Uttar Pradesh States of India bordering Nepal (Wallach et al., 2014), no envenoming reports have been published yet. Probably, the present study represents the first six confirmed cases of envenoming due to this species from eastern Nepal which led to two deaths (CFR for this species = 33%). Similarly, in eastern Nepal, I reported a single Greater Black Krait (*B. niger*) bite causing death for the first time for this country (Figure 28, 31, Table 2).

Considering all krait species bites, this study shows a lower case fatality rate (CFR) than in other southeast Asian countries, i.e., 6–33% CFR (Shah and Hati, 1983, Hati et al., 1988, Bawaskar and Bawaskar, 2004, Ariaratnam et al., 2008, Alirol et al., 2010). However, the CFR of krait bites is comparable to those in a recent report from Sri Lanka i.e., 6–18% (Kularatne, 2002, Ariaratnam et al., 2008). But, the krait bite mortaliy rate known in this study is lower than in various parts of India: 33% in West Bengal (Shah and Hati, 1983, Hati et al., 1988), 30% in Maharastra, 30% (Bawaskar and Bawaskar, 2004). Occasionally, kraits do not inject venom, so called dry bites. I recorded only five (11%) dry bites due to Common Kraits. In Sri Lanka, Ariaratnam et al. (2008) noted 4.5%, Kularatne (2002) 10% and Theakston et al. (1990) one (20%) among 88, 210 and five Common Krait bite envenomings, respectively. In India, Bawaskar and Bawaskar (2004) reported one dry bite (4%) among 23 Common Krait bites, Hati et al. (1988) two (12%) among 17 Common Krait bites. Occasional dry bites of kraits indicate unintentional bites or their ability of controlling the injection of venom when they bite to deter potential predators.

Bites of Western Russell's Viper (*Daboia russelii*) in southwestern Nepal is the first proven case series for the country. Although *D. russelii* bites cause envenoming and deaths in Southeast Asia, there exists no authentic report of its bite in Nepal yet. I identified 10 *D. russelii* bites with definite localities, habitat information and voucher specimens in the southwestern lowlands of Nepal (Table 2, Figure 36). Like krait and other elapid bites, those of *D. russelii* occur in other parts of Asia (Alirol et al., 2010, World Health Organization, 2010). I found no deaths and no dry bites due to its envenomation. However, this species caused 0–4% CFR in Sri Lanka (Kularatne, 2003, Kularatne et al., 2011). Therefore, in Nepal its envenoming should be considered as one of the serious public health problems requiring early care.

Because of long-term research beginning in 2010 in Damak and Charaali and its extensions into other centres later on, different snake bite treatment centres provided different numbers of patients and preserved snake specimens (see Table 1). Accordingly, enrolled patients for the interview at the location of bite and socio-demographic and epidemiological features of krait and Russell's Viper bite envenoming varied.

4.2.2. Demography and socio-economic conditions of krait and Russell's Viper bite patients

Confirmed krait (n = 46) and Russell's Viper (n = 10) bite cases represent only a small portion of the total number of 349 snake specimens presented to STCs in my study area. Appendix 6 presents the burden, circumstances and risk of bites due to kraits and Russell's Viper. Although cobra bites were more prevalent than krait bites among the identified snake specimens (Table 2), I particularly summarized krait bites. This is because kraits, mainly the Common Krait (*Bungarus caeruleus*), often cause a painless bites to sleeping people, even under a mosquito net at night in high quality houses. In South Asia, particularly in Nepal, Bangladesh, India and Sri Lanka, krait bites result in severe neurotoxic envenoming, paralysis and death, which is a particular clinical problem, because the symptoms do not respond to antivenom and neostigmine treatment once paralysis has occurred (Fernando and Dias, 1982, Theakston et al., 1990, Kularatne, 2002, Anil et al., 2010). This study supports results of epidemiological and ecological studies on kraits and Russell's Viper bites in Sri Lanka (Kularatne, 2002, Kularatne, 2003, Ariaratnam et al., 2008) and India (Bawaskar and Bawaskar, 2004, Whitaker and Whitaker, 2012).

Envenomings due to both kraits and Russell's Viper bites affected mainly 18–57 years old adults. A study of envenomings based on both voucher and history of bites in a single study centre in Nepal in 2007 indicated that envenomings are not related to a certain age groups (Pandey et al., submitted). However, in this study three of eight deaths (i.e., 38% of all deaths and 7% of all krait bites) occurred in children (n = 10, 22%). This finding is consistent with a recent report showing a close to double mortality rate among victims 1–14 years old (Paudel and Sharma, 2012) and a high case fatality rate, i.e., 50% of all deaths among patients 20 years old and below in Bharatpur Hospital (Pandey et al. submitted). Although the age structure of the patients (Figure 56) represents that of the corresponding population (Population Census 2011), the majority of productive members of the population are at risk of krait and Russell's Viper bite. A similar age structure of snake bites has been reported for other parts of Nepal (Magar et al., 2013).

The socio-demographic data analysis suggests that both krait and Russell's Viper bites are affecting mainly farmers or associated family members (Appendix 6). Similar results had been obtained by Sharma et al. (2004a, b) in southeastern Nepal where 44% of the patients were farmers followed by students (21–25%) and housewives (23–32%). In southcentral Nepal, Pandey (2007) reported that 59% farmers, students (27%) and housewives (6%) were affected by snake bites. In Sri Lanka, De Silva (2004) found that in 85% of snake bites agricultural workers were involved. Like krait bites, farmers were mostly bitten by Russell's Vipers (Kularatne, 2003, Kularatne et al., 2011). The results indicate that snake bites affect active human resources contributing to the agro-economy of Nepal (Harrison et al., 2009).

In both Common Kraits and Russell's Viper, gender did not play a significant role. Males were slightly more affected than females. Studies in India and Sri Lanka also showed more krait bites in males, i.e., 67%, (Anil et al., 2010) and 61% (Ariaratnam et al., 2008). In contrary, Bawaskar and Bawaskar (2004) reported a slightly higher rate involving females (52%) in India. The gender ratio of snake bite patients in this study (Appendix 6) did not correspond to that of the population in the respective communities (Central Bureau of Statistics, 2012b, Central Bureau of Statistics, 2012a) and to that reported by Magar et al. (2013) for similar populations in the Western Development Region of Nepal. But, it corresponds to some studies in Nepal that reported snake bite (species unidentified) mainly affected 57% (Paudel and Sharma, 2012) or 55% males (Shrestha, 2011). Since more than 60% of krait and Russell's Viper bites occurred in literate persons (Appendix 6), the literacy has no positive role in snake bites. However, there is a need of educating people living in the snake bite prone regions.

Although the majority of krait and Russell's Viper bites occurred in rural areas where urban households are normally considered as wealthy and rural ones as poor (United States Agency for International Development, 2011), the study shows a different scenario in Nepal. The risks of krait bites are likely to occur in households representing a higher socio-economic status in the southern lowlands of Nepal (Appendix 6). This indicates that envenoming is no longer a health problem of the poor (Harrison et al., 2009). Understanding these conditions provides better clues for mitigating the effects of venomous snake bites especially at night in the rural tropics and subtropics.

I found that krait bites occurred often in well-structured and permanent types of houses (Appendix 6, Figure 57, 58). This differs from previous findings. In Sri Lanka, kraits were found particularly in wattle and daub dwellings with thatched roofs (de Silva, 2004). Ariaratnam et al. (2008) and Kularatne (2002) reported that 96–100% of krait bites had occurred inside thatched, wattle and daub houses. In India, Bawaskar and Bawaskar (2004) recorded 96% of all krait bites in such houses. Although based on a small sample size (n = 46) and not corrected for the proportion of house types in this area, my records of a larger number of bites in well-structured houses (Appendix 6) indicate that all types of houses are at risk of krait bites. The surroundings of the houses, the availability of indoor and outdoor shelters and an abundance of prey animals for snakes may attract kraits to residences (Figure 57, Appendix 6).

Since some of their bites also occurred in people sleeping even on furniture beds in buildings (Figure 57, Appendix 6), this characterisation of the socio-economic status may be important to address that krait bites are not exclusively a disease of the poor (Harrison et al., 2009). Since indoor bites due to Russell's Viper is small (Appendix 6) and krait bites are not associated to poverty (Figure 57, 58), the development of effective preventive measures against these nocturnal snakes is essential. These efforts minimize personal and public funds for the treatment.

4.2.3. Circumstances and risk factors of envenoming

The majority of krait and Russell's Viper bites that occurred in people living in rural areas (Appendix 6) is proportional to the rural population of Nepal where 83% of the total population inhabit rural areas (Central Bureau of Statistics, 2012a). In these areas, transportation and health facilities are inadequate. Krait bites occurred in 63% (n = 29) rural people while sleeping (61%, n = 28) and Russell's Viper bites in 80% (n = 8) during agricultural activities (70%, n = 7, Appendix 6) like in other Asian countries (Theakston et al., 1990, Kularatne, 2002, Bawaskar and Bawaskar, 2004, Ariaratnam et al., 2008). There was up to 81% snake bites in rural areas in India (Halesha et al., 2013) and up to 99% in Sri Lanka (Ariaratnam et al., 2008). Mohapatra et al. (2011) reported that 97% of snake bite deaths in India occurred in rural areas. However, victims accessed snake bite treatment centres earlier (median = 1.4 h, krait bite, 0.33 h, Russell's Viper bite; Appendix 6) than victims of the same species in other countries (Kularatne, 2002, Ariaratnam et al., 2008). Kularatne (2002) reported admission of 81% of Common Krait bite patients in Sri Lankan hospitals within seven hours of the bite (range: 1–24 hours).

This early admission is the result of public awareness campaigns that had been conducted in the communities particularly in Chitwan, Nawalparasi and Jhapa Districts informing people about dangers of snake bite and the need for transporting victims in a vehicle quickly to receive timely medical treatment. However, this interval, in some cases, was longer, because they sought treatment when they had abdominal cramps or blood seen on their body parts at night. All sites in this study were connected by roads except in one case, where only motorcycle could be used. The analysis of the road facilities in localities where krait and Russell's Viper bites occurred (Appendix 6) suggests that victims could be easily carried to the nearest snake bite treatment centre (STC) if transport was available. Since the majority of patients used private motorcycles, improvement of public or emergency transport using a network of motorbike volunteers (Sharma et al., 2013a) is necessary.

Like in this study (Appendix 6), the majority of krait bites occurred indoors i.e., in 98.5% (Kularatne, 2002) or 100% (Ariaratnam et al., 2008) of the cases in Sri Lanka, 96% (Bawaskar and Bawaskar, 2004) in India. I found that the majority of the patients (65%, n = 17) had slept on a furniture bed when they were bitten. Although a previous study in Nepal reported that sleeping under a mosquito net (Chappuis et al., 2007) may prevent nocturnal snake bites, I noticed cases of krait bites in people sleeping under a mosquito net (35%, n = 9, Appendix 6). There was no difference of krait bites while sleeping under a mosquito net or without using it. Hence, the use of mosquito nets alone cannot prevent krait bites if the net is improperly applied. However, sleeping on cot, bunk or furniture bed or hammock using mosquito net is more safe.

I reported two victims who deliberately did not use a mosquito net to get fanned well. Rather, they used a net while there was load shedding to be safe from mosquito bite. Some people slept on floor in summer to get coolness from soil or concrete floor on hot summer days. It indicates the need of education improving sleeping behaviour of people. Recently, several communities in the study area of Chitwan and Nawalparasi Districts received long-lasting insecticide impregnated-mosquito nets as a part of the campaign to eliminate malaria in Nepal by 2026. Whether the use of these impregnated-nets has any additional protective effect against krait bites needs to be investigated.

Since krait bites are not associated with a certain house type (Appendix 6, Figure 57), people living in any house type are at risk of krait bites. The construction of houses using netted windows and doors and avoiding any snake attractants indoors and in the premises is necessary to prevent nocturnal snakes entering human dwellings.

However, because of limited climbing abilities of kraits (Shrestha, 2001, Schleich and Kästle, 2002, Shah and Tiwari, 2004, Whitaker and Captain, 2004), general improvement of the quality of housing alone might not be sufficient to prevent krait bites. In the present study, I noted that some Common Kraits had climbed on the walls of houses or reached the roof. One Common Krait climbed on a wall and then moved down through a tiled roof after it had bitten a girl sleeping on a furniture bed in the second floor of a house. Kularatne also reported a single bite episode of a Common Krait in a hut on a tree top in Sri Lanka (Kularatne, 2002).

Kraits may be attracted to houses at night in search of prey animals. At that time, moving body parts could stimulate the kraits to bite for predation or in defense (e.g., when touched or rolled over by a sleeping person).

Occurrence of three of 10 (30%) Russell's Viper bites in and around the premises of the house (two in the premises and one indoors) indicates that Russell's Viper also lives in and around houses posing risk of bites. As similar risk (21%) regarding this species was reported in Sri Lanka (Kularatne et al., 2011). Unlike kraits, Russell's Viper bites occurred in agricultural land during farming activities (Appendix 6) which is reported elsewhere (Kularatne, 2003, Kularatne et al., 2011). The farmers who are at high risk should know the general biology of Russell's Viper to prevent its bite.

There are clear monthly and seasonal patterns of krait bites (Appendix 6). Kraits entered the house (Figure 57, 58) during the rainy season (80%) particularly in August and September (Figure 61). Similar monthly and seasonal patterns of krait bites are reported from Sri Lanka and India (Theakston et al., 1990, Kularatne, 2002, Bawaskar and Bawaskar, 2004, Ariaratnam et al., 2008).

An uneven distribution of Russell's Viper bites (i.e., 30% in July and 20% November, Figure 61, Appendix 6) reflects that bites are typically related to various agricultural activities. Similar seasonal patterns of bites due to Russell's Viper are reported in Sri Lanka (Kularatne, 2003, Kularatne et al., 2011).

The ecological circumstances of the species responsible for the majority of snake bites may be used to formulate standard preventive measures against indoor or outdoor snake bites because antivenoms are expensive and in short supply. Potential prey animals and snake shelters in and surrounding houses favoured krait bites. The majority of victim families stored grains and fodder improperly. This way of storing and the availability of prey animals (Appendix 6) are primary causes of indoor krait envenoming.

Like in this study, snake attractants were similar in and around wattle and daub houses in villages of Maharashtra, India, and Anuradhapura, Sri Lanka (Bawaskar and Bawaskar, 2002, Kularatne, 2002). Only three of 10 Russell's Viper bite envenomings occurred in (n = 1) and around houses (n = 2) where snake attractants were similar to those houses where krait bites occurred (Figure 57, Appendix 6). Other envenomings occurred while harvesting sugarcane and activities in paddy fields (i.e., weed removing, harvesting, etc.) that are high risk activities.

Rainfall events did not affect the prevalence of krait and Russell's Viper bites in this study (Appendix 6). Patterns of their bites did not correspond to the trend of shifting rainfall in pre-monsoon. Less numbers of krait bites in July (13%, n = 6), which is the highest rainfall month in Nepal (Practical Action Nepal, 2009) also indicates that krait bites might not occur according to rainfall events only. A higher percentage of krait and Russell's Viper bites during day without rain confirms that rather, the extent of rainfall and overflooding episodes may influence bite events. De Silva (2004) also reported a similar experience in Sri Lanka. Therefore, to understand the influence of rainfall on krait bites more precisely, larger numbers of confirmed krait bite cases from wider areas in the lowlands are still necessary. Although all Russell's Viper bites occurred during hot days (Appendix 6), similar prospective studies involving larger samples are necessary to understand the influence of rainfall on snake bite events.

Although *Bungarus caeruleus* and *Daboia russelii* are widely distributed species in Asia, very little is known about the ecological circumstances of their bites. However, the epidemiological characteristics of cases including krait and Russell's Viper bites are similar to those reported for other parts of Nepal and Asia (Kularatne, 2003, Sharma et al., 2003, Bawaskar and Bawaskar, 2004, Sharma et al., 2004a, Sharma et al., 2004b, Pandey, 2007, Ariaratnam et al., 2008, Alirol et al., 2010, Kularatne et al., 2011, Paudel and Sharma, 2012, Magar et al., 2013).

4.2.4. Prehospital interventions and risk factors for morbidity and mortality due to snake bites

Delayed hospital access with fully developed ptosis and coma or limited or no ventilator support were risks of death because two krait bite victims who accessed treatment centres with these symptoms died. Although most snake bites occurred in places which may be reached by four-wheel vehicles, sometimes up to 16 hours are needed to reach the nearest snake bite treatment centre. Therefore, people should know the availability of the nearest snake bite treatment centres.

Consulting a traditional healer before getting antivenom treatment is a behavior that places victims at the risk of death. However, it is significantly less common than in Bangladesh i.e., 86% (Rahman et al., 2010), in India i.e., 61% to 74% (Hati et al., 1992, Inamdar et al., 2010) and in Pakistan i.e., 75% (Chandio et al., 2000). I found that 15% (n = 7) krait and no Russell's viper bite victims had visited traditional healers before receiving medical care (Appendix 6). It is supported by similar practices reported in other parts of Nepal. In eastern Nepal, Sharma et al. (2004a) reported 22% and in central Nepal, Pandey (2007) and Pandey et al. (2010b) respectively reported 56% and 26% of snake bite victims who visited traditional healers before seeking professional medical treatment after snake bite. This tendency is also common in Afrian countries, i.e., 81% in Nigeria (Michael et al., 2011) and 68% in Kenya (Snow et al., 1994). This malpractices prolonge the time needed to reach medical care and could be deleterious because krait bites cause neurotoxicity which is time critical. Russell's Viper bites cause haemotoxicity which is fatal if untimely treated. Therefore, information on the practices of pre-hospital care of snake bite is important for survival of the patient.

Ignorance of or limited information on the existing snake bite treatment facility in the nearby healthcare centre diverted 26% (n = 12) krait and 40% (n = 4) Russell's Viper bite patient to local clinicians who had no antivenom available (Appendix 6). This delayed definitive medical care and put the patient at risk of death as krait bite would result in irreversible paralysis and Russell's Viper bite in haemorrhage. Therefore, people need to be informed about the nearest snake bite treatment centre and the best way to get there.

Applying traditional snake bite first aid methods is still common in Nepal. 78% (n = 36) of krait and 100% (n = 10) of Russell's Viper bite victims used tourniquets (Appendix 6) and none used the widely used WHO recommended first aid measures (World Health Organization, 2010). The observed absence of pressure immobilisation bandaging (PIB) and local compression pad immobilization (LCPI) and dominance of tourniquet use in the present study is corresponding with the fact that the tourniquet use is recommended in teaching materials in Nepal (Pandey and Khanal, 2013) although the tourniquet is potentially dangerous and its effectiveness is not proven. In Nepal, most snake bite victims apply tourniquets as a primary first aid measure, i.e., 95% (Magar et al., 2013) in southwestern Nepal, 93% (Heap and Cowan, 1991), 88% (Sharma et al., 2004a) and 90% (Sharma et al., 2004b) in southeastern and 69% (Pandey et al., 2010a) in southcentral Nepal.

Additionally, the use of various deleterious and useless first aid measures as noted in this study (Appendix 6) is respectively less than those practiced in the past in Nepal (eating of chilies, i.e., 44 to 57%, washing the wound, i.e., 22 to 50%, burning the wound, i.e., 26%, incisions of the wound and trying to suck out the venom, i.e., 16 to 18%, applying topical concoctions, i.e., 16% or using a snake stone, i.e., 4% (Heap and Cowan, 1991, Bhetwal et al., 1998, Sharma et al., 2004a, Sharma et al., 2004b). A recent study reported that more than 95% of snake bite patients in Bangladesh applied ligatures proximal to the bite site and 13% incised the bite site (Harris et al., 2010). These practices prolong the time needed to have actual treatment and many of these practices are deleterious. Since krait and Russell's Viper bites cause time critical health problems, understanding the existing practices of pre-hospital care of snake bite patients is also important for increasing the survival of the patients.

Carrying the snake bite victims to a snake bite treatment centre in quick and comfortable means of transport is vital to ensure effective treatment. In this study, the most common mode of transport was motorcycle, followed by ambulance, bicycle or combinations of these modalities (Appendix 6). Although often four-wheel motor roads (Appendix 6) and ambulance transport were available, people prioritized motor-bike over calling ambulance. However, in a referral hospital in the southcentral Nepal, victims used ambulance primarily (Pandey et al., submitted). By comparison, in a study of snake bite management in Madi Valley, the most rural region of Chitwan District, bicycle (51%) was the most used mode of transport, followed by ambulance (28%) and motorbike (11%) (Pandey et al., 2010b). In eastern Nepal, several people (42%) used motorbike to transport the victims (Sharma et al., 2004a). Although the majority of respondents replied that ambulance could be available within half an hour of call, if it was not busy at the time of call, only 10 (22%) krait bite and none of Russell's Viper bite victims used an ambulance. These data on the modes of transport highlight the urgent need for emergency medical services and pre-hospital care system development within Nepal. The development of a nationwide net work of motorcycle volunteers (Sharma et al., 2013a) for the emergency transport of venomous snake bite victims to treatment centres could be life saving. Simple solutions for the problems of transporting the snake-bitten victim are feasible, and prior work in Nepal by Sharma et al. (2013a) demonstrated that effective and rapid transport to a healthcare facility makes a difference in the outcome of snake bite envenoming. Since appropriate means of public transport are often not available at night in rural regions, receiving snake bite treatment is extremely challenging in rural Nepal. Because the vast majority of krait bites occur in the rural human dwellings at night (Theakston et al., 1990, Kularatne, 2002, Bawaskar and Bawaskar, 2004, Ariaratnam et al., 2008), promotion of the motorbike ambulance approach (Sharma et al., 2013a) including improved public transportation is essential.

4.2.5. Knowledge about snake bite prevention

Lack of knowledge regarding preventive measures against snake bite was evident among 41% of krait and Russell's Viper bite patients or their relatives (Appendix 6). This may reflect poor formal education regarding snake bite prevention and snake bite care in Nepal (Pandey and Khanal, 2013). Therefore, preventive strategies and nationwide training of health professionals using pragmatic educational tools is essential to reduce snake bite burden and fatalities. Free of cost supply of antivenom by the Nepal Government (Shah et al., 2003) has not been used properly. An educational approach should be extended to farmer communities and schools in snake bite risk areas. This approach should use updated information about snake identification (see chapter 3.1.2), prehospital care and recommended preventive measures (Pandey and Khanal, 2013). Further, I recommend a model describing the potential demographic, socio-economic and environmental markers (Figure 70) to examine and analyse it thoroughly, so that local aspects of the issue could be understood. This model may help to pinpoint the major risks and possible solutions for krait and Russell's Viper bites, associated morbidity and death in Nepal and in other regions with similar geo-climate and socio-economic conditions.

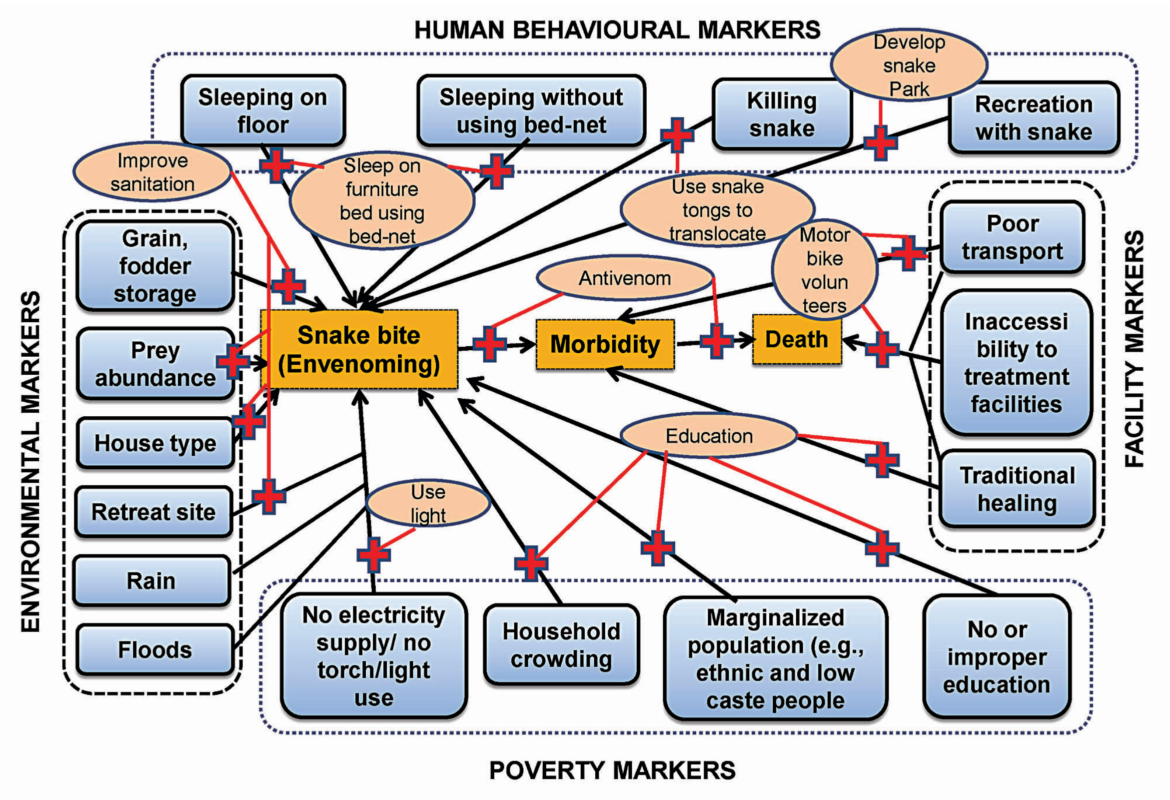

Figure 70. A model showing potential environmental and socio-economic markers indicating risks for krait and Russell's Viper bites and associated morbidity and death. Potential interventions to reduce the risk factors of bite, morbidity and deaths are illustrated with red plus sign and oval shapes.

4.3. Attitudes, knowledge and awareness of snakes and snake bite among Chitwan National Park buffer zone people: implications for biodiversity conservation and public health in southern Nepal

Although the buffer zone people showed a positive attitude toward snakes in certain localities with low human activities, the ignorance on snake behaviour, on venomous snake species and unavailability of enough antivenom when required led to an increased negative attitude towards snakes, which may lead to mass killing of snakes in Nepal. These problems are also present in communities of the Indian subcontinent.

4.3.1. Threats to snake communities in Nepal

Ignorance for the need of snake conservation, extreme disgust and fear of snakes, snake killing and noticeable confusion while differentiating venomous from non-venomous snakes are challenges for snake conservation in Nepal. Analysis of interview data indicate that 55% (n = 82) people liked snakes, 43% (n = 64) disgusted and 41% (n = 62) were ambivalent (Table 8). Similar problems apparently exist in Brazil (Alves et al., 2014), Kenya (Wojnowski, 2009) and in Australia (Whitaker and Shine, 2000). Alteration of snake populations modifies the trophic cascade with possible deteriorating effects on the ecosystem. Consequently, these threats contribute to a global biodiversity conservation crisis (Chapin III et al., 2000) and species extinction that is already triggered by climate change (Thomas et al., 2004). Therefore, authorities should consider human-snake conflicts as an important driver of declining snake population.

4.3.1.1. Fear, negative attitudes and ignorance of snakes' ecological services

Snake killing is the result of a negative attitude mainly due to fear. Unawareness about essential ecological services of snakes facilitates snake killing. 95% of the respondents interviewed were aware that all snakes are not venomous, but more than two-thirds of all respondents feared snakes. Responses opposing snake conservation (12% respondents, Table 8.b), absolute ignorance about snake conservation (3%, n = 5) and extreme fear of snakes (especially among farmers, Figure 64) lead to massive snake killing, which is common place in Sarlahi, southcentral Nepal (Chhettri and Chhetry, 2013).

This imposes threats of snake conservation in the lowlands of Nepal. Farmers, females and teachers were found to be more responsible for snake killing (Table 7.a.ii), since farmers and females encounter snakes during agricultural and household work. Likewise, being conveyers of formal and informal education in communities, ambivalent teachers also contribute indirectly to the snake population decline. Overall, Nepalese snakes are in verge of a rapid population decline.

Mild temperament of people to any snake they encounter (Table 8.b) and more tolerance to snakes in less human activity areas (Figure 63) suggest that fear is triggering anthropogenic mortality of snakes in Nepal (Table 9.b, e). This fear of snake originated at divine times (Nepal Bible Society, 2003) and was introduced to the scientific community during the Linnean time (Linnaeus, 1758). Perceptions of Nepalese communities on snakes still support Linnaeus's perception of snakes as a foul and loathsome animal. Believing in snake fictions (Table 17.a) propagates a negative attitudes towards snakes in Nepalese communities and elsewhere (Dodd Jr, 1987, Burghardt et al., 2009). This is accompanied by unawareness of snake bite prevention (Table 14.b), believing in snakes and snake bite fictions (Table 17.a, b) and bad consequences owing to inappropriate care of snake bites (Table 17.b,c) induce fear of snakes in the human community.

Furthermore, poor transport, poorly equipped or inaccessible medical facilities and high snake bite mortality (Sharma et al., 2004a, Pandey, 2007) intensify fear. Moreover, a famous Nepali proverb "*Bish Nabhayako Sarpa Ra Ekh Nabhayako Sapra Hudaina* i.e., "there are no snakes without venom and no humans without jealousy" fortifies fear and contributes to negative attitudes towards snakes. Finally, poor knowledge about ecological services of snakes (Table 9) leads people to kill them. Like teachers in Kenyan (Wojnowski, 2009) and students in Brazilian communities (Alves et al., 2014), a fear of snakes is common in Nepal (86%), which is preserved over generations (Murray and Foote, 1979) and people continue to kill snakes. However, 55% (n = 82, Table 8.a) still like snakes mainly because of their attractive appearance and behaviour (34%, n = 22, Table 9.a). Therefore, apathy, antipathy and propensity for snake killing are challenges to snake conservation.

4.3.1.2. Reasons for massive snake killing

In Nepal, the combination of fear with poor aptitude of distinguishing venomous and nonvenomous snakes (Table 10, 11) leads to mass killing of snakes. This is common even in and around biodiversity hotspots (Zug and Mitchell, 1995, Shah, 2001). Similar ruthless killing of snakes reported from other parts of Nepal (Shah, 2002) and intentional killing of snakes encountered elsewhere (19%, Table 8), suggest educational deficits. However, the problems to differentiate venomous from non-venomous snakes (Table 10.b, 11.b) and the intention of nearly half of the respondents to kill all venomous snakes has the potential to contribute to the local decline in the snake populations and threatens the existence of rare and endangered snake species.

About 37% respondents considered pythons to be venomous snakes (Figure 65), a reason for its human-caused high mortality. Less familiarity of teachers and students (Table 10, 11) indicate educational deficits. The fact that even teachers and students fail to recognize the snake species impede conservation and public health in Nepal. Since snake venoms are a source of several biomedicines, the loss of even a single venomous snake species may prevent new discovery in science.

4.3.1.3. Predisposed positive attitudes towards snakes

Several factors predispose positive attitudes in the buffer zone population. The belief in a snake's ability to absorb poisonous atmospheric gases and its contribution to controlling environmental pollution (Table 9.a) and the fact that 98% respondents from the Hindu culture (a total of 84% (n = 126) epitomize snakes (Table 8.a) as gods (Miller, 1970)), influenced scores for positive attitudes (Table 6.a). However, an in-depth interview clarified that the majority were not real devotees of the serpent-god because 69% replied with improper logic for why they would worship snakes (Table 8.c). These people may be influenced by negative connotations of these animals (Nepal Bible Society, 2003), which often cause grief to people (Harrison et al., 2009), although snakes are awesome, venerated or deified and have captivated humans since ancient times (Gordon, 1905, Boulenger, 1913, Encyclopaedia of Religion and Ethics, 1922, Miller, 1970, Sasaki et al., 2010). Therefore, harmonious snake-human co-existence is dubious and arguable in Nepal and elsewhere, despite positive connotations of the snake's association with humans in Asclepian times and Hindu mythologies.

66% of the respondents (n = 99) agreed to conserve all snakes, but with irrelevant logic behind this preference. Also, 61% (n = 92) accepted snakes to be farmers' friends considering their role of controlling rodents (83%, n = 50), but farmers who frequently encounter snakes were more negative to snakes (Table 6.b, 7.a.ii). On the other hand, inclusion of enthnological issues (Table 8.b) reduced the degree of negativity, because most Hindus denied killing snakes for food and only a few people reported exploiting snakes for medicinal purposes. Also, maximum non-responses for 'all surrounding snakes should be killed' (n = 77, 51%) and 'only venomous snakes should be killed' (n = 39, 26%, Table 8.b) minimized negativity. Hence, I expected higher negative attitudes towards snakes than what I found in this survey. So, the in-depth interviews showed that snake populations in the lowlands of Nepal and areas with similar geo-sociological dynamics are at risk of decline.

4.3.2. Consequence of rodent-borne epidemic diseases due to snake population decline

Alteration of snake population dynamics disrupts the prey-predator relationships (e.g., snakes control rodent population efficiently) that alters the trophic cascade of ecosystems, modifies structure and function of the ecosystem and diminishes productivity of the agricultural and grassland ecosystem. Subsequently, snake killing contributes to famine and disseminating fatal epidemic rodent-borne diseases (plague, Hantavirus infection, etc.) (Meerburg et al., 2009). Subsequently, improper human perceptions on snakes degrade ecosystem health and threaten not only a single populations, but the entire ecosystem.

4.3.3. Average awareness and aptitude of knowing snakes

The average awareness of Chitwan National Park buffer zone people (Table 15, 16) concerning their attitude and knowledge of snakes is low. Furthermore, familiarity with snakes among people attaining formal education and illiterate people, together with a noticeably lower aptitude of snake-related knowledge among teachers and students (Table 9, 10), urge educational interventions to enhance their awareness level, thus supporting snake conservation. Exposing people regularly to live snakes in zoos (Whitaker, 1985) or in nature (Wojnowski, 2009) increases the awareness of people with snakes. A similar, educational intervention increased awareness of Kenyan teachers (Wojnowski, 2009).

4.3.4. Use of snakes

Use of snakes for food or medicine, however, is not a snake-conservation threat in Chitwan Valley unlike in China, Vietnam or Brazil (Zhou and Jiang, 2004, Alves et al., 2007, Somaweera and Somaweera, 2010) and in other parts of Nepal (Zug and Mitchell, 1995, Maskey et al., 2002). Snake killing for human use was insignificant in Nepal compared to past reports (Shah, 1997, Shah, 2002). Similar to some Indian communities (Joshi and Joshi, 2010), only locals from small ethnic communities used pythons and cobras as food and/or medicine. The majority of Tharu respondents in this study denied eating snake meat, although Zug and Mitchell (1995) mentioned that Tharu people from Chitwan eat snake meat. Therefore, human use of snakes does not pose a threat to snake populations in this region.

4.3.5. Risk factors of snake bite, envenoming and health hazards

Fear, bias, negativity, ignorance and wrong beliefs are human behavioural risk factors of snake bite in Nepal and elsewhere with a similar geo-socio-economic and cultural background. Ignorant, negative or scared people who mostly encourage killing snakes put themselves at risk of envenoming. Lack of basic skills about preventive measures against snake bite (Table 14.b), intention of killing all venomous snakes and confusion of knowing snakes (Table 10, 11) among buffer zone people suggest that inhabitants of agrarian lowlands of Nepal are at risk of snake bite. Therefore, public health authorities should consider human-snake conflicts as one of the causes of snake bites.

Findings of small scores for appropriate measures of snake bite prevention (although 85%, n = 127, claimed to know of preventive measures against snake bite and 15%, n = 23 of informants had no idea how to prevent snake bite) indicate ignorance of preventive measures. Score analysis shows (Table 14.b) farmers and illiterate persons to be at high risk of snake bite. The low scores of even better educational profile people are indicative of risks of snake bite to all sectors of communities. This reflects poor or no education about snakes and snake bite prevention at schools, universities (Pandey and Khanal, 2013) and communities.

Snake killing attitudes followed by the inability to distinguish venomous from nonvenomous snake species (Table 10.b, 11.b) enhances risks of snake bite. Of all respondents, 91% considered *Lycodon aulicus* (a nonvenomous snake which dwells in residential areas) as a venomous snake and 66% thought it to be the Krait. Moreover, 61% of respondents claimed *Daboia russelii* to be a *Python* (Figure 65). Confusion in differentiating venomous from non-venomous snakes even among teachers and students (Table 10.b, 11.b) in Nepal, teachers in Kenya (Wojnowski, 2009) and medical personnel in Sri Lankan communities (Silva et al., 2013a) confirm the urgent need of educational intervention in Nepal and elsewhere.

Handling of venomous snakes with bare hands can cause envenoming. Misidentification of a snake brought in the hospital complicates treatment (Silva et al., 2013a). Snake identification supports diagnosis of snake bite and treatment, enhances snake bite prevention and avoids multiple bites to a patient or a bite to the first-aid provider. Snake identification can prevent snake bites during the attempt to kill the snake to bring it to the treatment centre. If snakes are mishandled, envenoming is possible even by recently killed and decapitated or inadequately killed (Suchard and LoVecchio, 1999) snakes.

This study shows some myths involving snakes (Table 17.a) as they are still persisting in Nepalese communities (Pandey and Thapa, 2010a, Pandey and Thapa, 2010b, Pandey and Khanal, 2013). This exacerbates antagonism or the prejudice of people against snakes. Developing familiarity of people with native snakes is the only way to reduce confusion when it comes to recognizing snakes. Knowing the snakes also reduces the risk of snake bite. This educational gap is an opportunity for educating people nationwide.

4.3.6. Challenges of snake bite management in Nepal

Dependency on traditional healers for snake bite treatment has been greatly reduced in Chitwan Valley from 56% (Pandey, 2007) to 26% (Pandey et al., 2010b). In fact, the survey indicates that 85% of the people are rejecting the idea of seeking traditional healers as an alternative treatment of snake bite (Table 17.b). Hence, traditional healing is not a major challenge to snake bite management in this valley. But, the situation is different in other countries. About 86% of snake bite patients still visit traditional healers in Bangladesh (Rahman et al., 2010), 75% in Pakistan (Chandio et al., 2000), and 61% in India (Inamdar et al., 2010). Belief in other traditional snake bite treatment methods (Table 17.b) is still indicative of challenges to hospital management of snake bites.

Slightly more than average scores for the recommended first aid measures (Pressure Immobilization Bandaging, 61% or Local Compression Pad Immobilization, 51%) to snake bite (Table 17.d) in the present study are the result of snake bite management trainings, books, poster and pamphlet distribution in 2007, 2008, 2009, and 2011 (Pandey et al., 2010b). However, a recent hospital-based snake bite report from southwestern Nepal (Magar et al., 2013) reported the use of inappropriate snake bite first aid as common practice. This indicates inadequate education related to the pre-hospital care of snake bite (Pandey and Khanal, 2013).

The knowledge of snakes concerning the symptoms of envenoming and their names is crucial. This has both conservation and public health implications. Because of the scarcity of expert identification of snakes involved in envenoming, the unavailability of snake identification kits in Nepal and other developing countries, educating people about snakes is the most economical way to ensure snake conservation and better envenoming treatment.

4.3.7. Urgent needs

A pragmatic educational approach is an important tool to develop knowledge and a positive attitude towards snakes. The ability of first aiders and locals from snake bite prone zones to identify offending snakes assists in developing preventive and therapeutic strategies. These strategies make people feel secure and contribute to develop positive attitudes toward snakes. I found that knowing non-venomous snakes correlated to scores for positivity ($r = 0.15$, $p = 0.01$), but the same did not apply for venomous snakes ($r = -0.06$, $p = 0.82$). Probably, a greater fear of snakes influenced the latter. However, an increased ability to identify snakes contributes toward preserving at least the non-venomous snake population, as is the case in

Japan (Sasaki et al., 2010).

Education of people about venomous and non-venomous snakes, realistic measures of prevention and rationalized pre- and hospital care of snake bite is an important step. Snake parks (Seshadri, 1984, Whitaker, 1985) and regional museums, related courses in schools and universities (Pandey and Khanal, 2013) increase positive attitudes to all snakes (Wojnowski, 2009). Issuing Nepalese postal stamps (Nemésio et al., 2013) containing colour pictures of common venomous snakes, familiarises with snakes. Furthermore, developing a nationwide citizen-scientist network (Balakrishnan, 2010) and snake release centres can minimize the unnecessary killing of snakes. Consequently, positive attitudes, good knowledge and thorough awareness of native snakes and snake bite among buffer zone community people will support biodiversity conservation and human health.

Therefore, like in Kenya (Wojnowski, 2009), in-depth educational training of school and university teachers together with farmers, females and people from all age groups about native snake behaviour and ecological services is essential in Nepal. The use of slides and videos showing native snakes (Morgan and Gramann, 1989), along with morphology-based snake identification tools (Trinca, 1963) will be helpful in this respect. Inclusion of information about the general biology and the ecological role of snakes in school and university curricula (Pandey and Khanal, 2013) may rectify the ambivalence of educators.

5. CONCLUSIONS

Although *Bungarus caeruleus* and *Naja naja* predominantly cause snake bite envenoming and deaths in Nepal, it must also be considered that other elapids, viperids and venomous colubrids also cause health problems. The confirmed human casualties due to bites of *B. niger, B. walli* and *Daboia russelii* reported for the first time in Nepal underlines the value of preserving snakes responsible for bites that are brought to health facilities. This also shows the great need of educating local people and health professionals to increase their knowledge and familiarity on medically relevant snakes of Nepal, change their attitude towards snakes, involve them in biodiversity conservation and promote a better public health status of the community. Tools like the book on the medically relevant snakes of Nepal, booklets, posters and pamphlets, snake parks and snake museums may aid community people to identify common venomous snakes, prevent snake bites and select appropriate first aid measures when required.

Comparison of venom composition of Indian snake venom used in antivenom production with corresponding Nepalese snake is essential. Also, ED50 (effective neutralizing dose of antivenom) of Indian antivenom against medically relevant snakes of Nepal is crucial to decide on the inclusion of venoms from *Bungarus niger, B. walli, B. lividus, Naja kaouthia, Trimeresurus albolabris* and *Ovophis monticola* in the antivenom production for Nepal. Until more effective antivenom is available, the available antivenom should be provided to qualified health facilities in affected areas. Because of possible Indian antivenom incompatibilities against *B. lividus, B. niger* and *N. kaouthia* bites and poor health facilities in Nepal, adopting the best preventive measures of snake bite would be desirable and economic. Therefore, educational tools should be developed and regular trainings should be organized.

This dissertation provides an example of the biodiversity of medically relevant snakes in Nepal as revealed by preserved snakes brought by victims to snake bite treatment centers which enabled accurate species identification. This documentation of medically relevant snakes of Nepal is a first attempt and worth of future investigation. Prospective preservation of voucher specimens and tissue collection for molecular studies will be key challenges for future work. Financial and time constraints limited my work in the nine selected snake bite treatment centres located in the Eastern, Central, and Western Development Regions of Nepal. For the complete list of medically relevant snakes, I recommend documenting medically relevant snakes from the mid- and far-western Nepal using preserved snakes brought to the snake bite treatment centres. However, the present checklist of medically relevant snakes of Nepal may be used as a tool for education and snake identification nationwide. *Daboia russelii* has a larger distribution than previously known across the lowlands of Nepal. Concerned authorities should understand the actual distribution patterns of this species and educate people about prevention and first aid measures. The variation of krait and cobra bite patterns and the distribution of *B. walli* and *B. caeruleus* in the eastern and the central and western lowlands of Nepal needs further study to better understand the behavioural and movement patterns of these snakes.

The results of this study indicate that kraits represent a risk of fatal envenoming to people from all sectors of the society living in urban and rural areas of Nepal. The fact that nightly bites occur on sleeping people even on furntiture beds under mosquito nets and even inside concrete houses is a new finding and poses a great challenge to snake bite prevention in this region. All types of houses at night hours in rainy seasons are at high risk for *B. caeruleus* bite. While analyzing the habitats and distribution of *B. niger* in middle hill of the eastern and western Nepal, I realized that most hill people do not have an idea about the distribution of kraits in their areas.

The cumulative effect of fear, antipathy, negativity, ignorance and ambivalence to native snakes among community people are potential threats to local snake population decline or even to the extinction of rare or endangered snake species in the lowlands of Nepal. Because population decline or extinction has multiple negative impacts on biodiversity and ecosystem health, one should consider the responsible factors when developing conservation and public health improvement strategies.

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8. APPENDICES

Appendix 1. Selected study sites, sampling units, sampling unit population and sample size.

Study sites	Sampling units (classes of listed educational institutions below, wards of Village Development Committee (VDC*))	Sampling unit population	Sample size (i.e. number of respondents)	Sample size (%)
Bachhayauli	Class 12, Jhuwani Higher Secondary School, Bachhayauli 09, Chitwan	33 (10 students, 23 teachers)†	25 (10 students, 15 teachers)	76
	Ward number 3, Bachhayauli VDC*, Chitwan	148 household heads‡	25 (household heads)	17
Baghauda	Bachelor´s degree of Business Studies, 1st year, Madi Multiple Campus, Tribhuvan University, Baghauda 03, Chitwan	44 (24 students, 20 teachers)†	25 (10 students, 15 teachers)	57
	Ward number 5, Baghauda VDC*, Chitwan	87 household heads‡	25 (household heads)	29
Meghauli	Class 11 and 12, Janaki Higher Secondary School, Telauli, Meghauli 05, Chitwan	60 (28 students, 32 teachers)†	25 (10 students, 15 teachers)	42
	Ward number 6, Meghauli VDC*, Chitwan	43 household heads‡	25 (household heads)	58
	Total	**415**	**150** (30 students, 45 teachers, 75 villagers)	**36**

Symbols: *each VDC consists of nine wards which are the smallest administrative units of Nepal, †obtained from daily attendance register, ‡obtained from community forest register and social workers of respective wards, **%** (percent) = sample size / unit sample population x 100

Appendix 2. Voucher specimens and co-ordinates of study snakes.

Abbreviations: STC = Snake Bite Treatment Centre; **NRCSSbDa** = Nepal Red Cross Society, Sub-branch, Damak; **CSTCChar** = Charaali STC, Charaali; **BHBha** = Bharatpur Hospital, Bharatpur; **KCHKa** = Kaligandaki Community Hospital, Kawaswoti; **BBSTCTri** = Bajradal Battallion STC, Tribeni; **DSTCDu** = Dudhauli STC, Dudhauli; **NSTCNa** = Netragunj STC, Nawalpur; **JSTCCho** = Jayakali STC, Chorva; **CSTCIta** = Community STC, Itahari, **DPSC** = Deb Pandey Snake Collection. Name of study centre (in bold) is followed by voucher number and co-ordinate.

***Amphiesma stolatum*—DSTCDu**: Du2014.2, 26.99544° N, 86.25838° E, 188 m; DSC05696.DPP, 26.99464° N, 86.25904° E, 199 m; **JSTCCho:** not catalogued, 26.8110° N, 86.28807° E, 90 m; **CSTCIta**: not catalogued, 26.66956° N, 87.2736° E, 93 m

***Boiga trigonata*—BBSTCTri**: CMS2014.23, 27.47133° N, 83.88367° E, 111 m; Tri8.1, 27.43417° N, 83.92633° E, 118 m; Tri8.2, 27.41° N, 83.82° E, 105 m; Tri58, 27.37838° N, 83.85229° E, 106 m; Tri61, 27.45136° N, 83.91890° E, 121 m; **CSTCIta**: not catalogued, 26.66956° N, 87.2736° E, 93 m (three specimens); **JSTCCho**: not catalogued, 26.81101° N, 86.28807° E, 90 m (three specimens); KGHKa: KG22, 27.63746° N, 84.11509° E, 183 m; **NSTCNa**: Nawalpur5, 27.10831° N, 85.51442° E, 142 m

***Bungarus caeruleus*—BHBha**: 3409, 27.46435° N, 84.26933° E, 172 m; 28607, 27.65962° N, 83.95855° E, 262 m; 28807, 27.60535° N, 83.95047° E, 147 m; 3.005, 27.65502° N, 84.40140° E, 199 m; 3.009, 27.59925° N, 84.25587° E, 154 m; 3.011, 27.58772° N, 84.24983° E, 146 m; 3.022, 27.69298° N, 84.44857° E, 208 m; 3.028, 27.69283° N, 84.44162° E, 210 m; 3.030, 27.66158° N, 84.20038° E, 164 m; 3.035, 27.58328° N, 84.35868° E, 166 m; 3.039, 27.67790° N, 84.44007° E, 201 m; 3.041, 27.66325° N, 84.40195° E, 188 m; 3.044, 27.69340° N, 84.20696° E, 190 m; 3.047, 27.64935° N, 84.01596° E, 172 m; 3.060, 27.57692° N, 84.32916° E, 172 m; NBT1.CK28, 27.66804° N, 83.79339° E, 191 m; NBT3.CK29, 27.69159° N, 84.19043° E, 218 m; Madi01SaulibasCK37, 27.43598° N, 84.34783° E, 228 m; NBT4.CK30, 27.58509° N, 84.32087° E, 124 m; BH011.3, 27.59602° N, 84.09648° E, 152 m; 2014BH2,4?6, BH011.11,13, NBT5, 27.68192°, 84.43639°, 175 m (seven specimens); **KCHKa**: KGH03,18?20,36, 26.86720° N, 85.80687° E, 106 m (five specimens); KGH21, 27.67246° N, 84.13581° E, 235 m; KGH28,46,47, 27.63904° N, 84.11883° E, 185 m (four specimens); **BBSTCTri**: Tri43, 27.45873° N, 83.75447° E, 107 m; Tri 48, 27.48910° N, 83.80485° E, 116 m; Tri 10, 27.43472° N, 83.93278° E, 120 m; Tri 21, 27.51577° N, 83.76814° E, 111 m; Tri 29, 27.35990° N, 83.87082° E, 85 m; Tri06, 27.48455° N, 83.81909° E, 78 m; Tri60 27.58293° N, 83.74149° E, 132 m; **DSTCDu**: Du2014.1, 26.94838° N, 86.26261° E, 188 m; Du2014.3, 26.94315° N, 86.26543° E, 180 m; Du2014.4, 26.98802° N, 86.31363° E, 205 m; Du2014.5, 26.97119° N, 86.2849° E, 184 m; Du6.36, 26.96745° N, 86.28514° E, 181 m; Du6.69, 26.96511° N, 86.29227° E, 190 m; DrCLT, 26.99367° N, 86.26249° E, 194 m; Du01, 26.97874° N, 86.30766° E, 169 m; Du02, 26.96592° N, 86.27782° E, 166 m; Du09, 26.99544° N, 86.25838° E, 188 m; Du3, 26.99261° N, 86.2601° E, 185 m; Du4, 26.98021° N, 86.27328° E, 179 m; **NSTCNa**: Ne01?3, 27.16046° N, 85.34855° E, 159 m; 26.94444° N, 85.48150° E, 88 m; 27.04864° N, 85.62703° E, 128 m; **JSTCCho**: not catalogued, 26.96422°, 86.37192°, 219 m; 26.97228°, 86.38047°, 242 m; 26.81127° N, 86.29004° E, 137 m; 26.81101° N, 86.28807° E, 90 m (two specimens); **CSTCIta**: DSCN0251, 26.66956° N, 87.2736° E, 93 m

***Bungarus fasciatus*—CSTChar:** not catalogued, 26.64795° N, 88.05465° E, 118 m (two specimens); **BHBha**: 2014. BH7, BH.011.1, 27.68192° N, 84.43639° E, 175 m (two specimens); **KCHKa**: KGH01,02, 26.86720° N, 85.80687° E, 106 m (two specimens); **CSTCIta**: DSCN0248,49, 26.66956° N, 87.2736° E, 93 m (two specimens)

***Bungarus lividus*—NRCSSbDa**: 269-01(440), 26.62066° N, 87.47229° E, 124 m; 455, 26.65145° N, 87.71992° E, 95 m; 857, 26.47879° N, 87.77055° E, 63 m; 920, 26.56701° N, 87.74485° E, 98 m; **CSTCChar**: 110-02(210), 26.63811° N, 88.03052° E, 147 m; 2-025(2312), 26.54411° N, 88.03045° E, 128 m; not catalogued (four specimens), 26.65518° N, 88.12472° E, 126 m; 26.66850° N, 88.07089° E, 137 m; 26.54715° N, 88.09456° E, 92 m; 26.64783° N, 88.05346° E, 145 m

***Bungarus niger*—**2.023, 26.89874° N, 87.91900° E, 1,515 m

***Bungarus walli*—NRCSSbDa**: 31.01, 26.42364° N, 87.68823° E, 73 m; 46, 26.57245° N, 87.69182° E, 102 m; 233, 26.69752° N, 87.61655° E, 143 m; 962, 26.60065° N, 88.02698° E, 110 m; MVEM.BW3, 26.67586° N, 87.66519° E, 133 m; MVEM.BW4, 26.66417° N, 87.65444° E, 128 m; MVEM.BW5, 26.62639° N, 87.69725° E, 100 m; not catalogued (four specimens), 26.63428° N, 87.72141° E, 116 m; 26.71724° N, 87.69970° E, 171 m; 26.42638° N, 87.26693° E, 70 m; 26.65659° N, 87.70363° E, 130 m; **CSTCChar**: MVEM.BW6, 26.40206° N, 87.99326° E, 62 m; MVEM.BW7, 26.53147° N, 87.91759° E, 79 m

***Chrysopelea ornata*—NRCSSbDa**: not catalogued, 26.65659° N, 87.70363° E, 130 m; **CSTCChar**: not catalogued:

26.65160° N, 88.05282° E, 139 m; 26.64795° N, 88.05465° E, 118 m; **KCHKa**: KGH29, 27.63904° N, 84.11883° E, 185 m

***Coelognathus helena*—NRCSSbDa**: 315-01(522), 26.58005° N, 87.60425° E, 101 m; not catalogued, 26.65659° N, 87.70363° E, 130 m (two specimens); **CSTCChar**: not catalogued, 26.66650° N, 88.11674° E, 131 m; **BHBha**: BH.011.6, 27.68192° N, 84.43639° E, 175 m; NBT08, 27.67811° N, 84.43628° E, 214 m; NBT07,14?16, 27.68192° N, 84.43639° E, 175 m (four specimens); NBT11, 27.69501° N, 84.31119° E, 185 m; NBT12, 27.70712° N, 84.41740° E, 196 m; **KCHKa**: KGH40,41,44, 27.63904° N, 84.11883° E, 185 m (three specimens); **BBSTCTri**: Tri26, 27.50250° N, 83.74167° E, 115 m; Tri 59, 27.44883° N, 83.85937° E, 111 m

***Coelognathus radiatus*—BHBha**: DSC01990, 27.58228°, 84.49004°, 174 m

***Daboia russelii*—BBSTCTri**: Tri08, 27.43751° N, 83.82568° E, 84 m; Tri17, 27.44293° N, 83.82912° E, 110 m; Tri22, 27.43216° N, 83.78925° E, 105 m; Tri24, 27.46296° N, 83.84714° E, 80 m; Tri33, 27.45988° N, 83.83887° E, 82 m; Tri 35, 27.43427° N, 83.82396° E, 106 m; Tri39, 27.45300° N, 83.79000° E, 106 m; Tri47, 27.46867° N, 83.78583° E, 108 m; Tri68, 27.46617° N, 83.77482° E, 106 m; Tri69, 27.47787° N, 83.85918° E, 118 m

***Dendrelaphis tristis*—CSTCChar**: 240, 26.64795° N, 88.05465° E, 118 m; **JSTCCho**: not catalogued, 26.81101° N, 86.28807° E, 90 m

***Enhydris enhydris*—NRCSSbDa**: 1286, 26.49131° N, 87.56214° E, 80 m; **BBSTCTri**: Tri54, 27.45533° N, 83.83367° E, 107 m; **CSTCIta**: DSCN0252, 26.66956° N, 87.27360° E, 93 m

***Eryx conicus*—BBSTCTri**: Tri01, 27.46389° N, 83.90917° E, 114 m; **JSTCCho**: not catalogued, 26.82914° N, 86.24571° E, 124 m

***Ferania sieboldii*—DSTCDu**: Dudhauli07, 26.98160° N, 86.31298° E, 193 m; **JSTCCho**: not catalogued, 26.81101° N, 86.28807° E, 90 m (two specimens); **CSTCIta**: not catalogued, 26.66956° N, 87.27360° E, 93 m

***Indotyphlops braminus*—**”**NRCSSbDa**: not catalogued, 26.65659° N, 87.70363° E, 130 m; **BBSTCTri**: Tri53, 27.48367° N, 83.78500° E, 108 m; Tri11.1,2, 27.45256° N, 83.92796° E, 100 m (two specimens); **JSTCCho**: not catalogued (two specimens), 26.71869° N, 86.23150° E, 92 m; 26.81101° N, 86.28807° E, 90 m “

***Lycodon aulicus*—NRCSSbDa**: 716, 26.62658° N, 87.58036° E, 118 m; 735, 26.65324° N, 87.45772° E, 143 m; 758, 26.62504° N, 87.43026° E, 117 m; 884, 26.53777° N, 87.67439° E, 95 m; 008.01, 26.70796° N, 87.68494° E, 159 m; 147.01(297), 26.62385° N, 87.43539° E, 118 m; 259.01(425), 26.55151° N, 87.80876° E, 95 m; 273.01(445), 26.55042° N, 87.62014° E, 93 m; 293.01(467), 26.66277° N, 87.62845° E, 123 m; not catalogued, 26.65659°, 87.70363°, 130 m (two specimens); 26.66956°, 87.27360°, 93 m; **CSTCChar**: 128, 26.73448° N, 88.14068° E, 224 m; not catalogued, 26.64795° N, 88.05465° E, 118 m; **BHBha**: NBT10, 27.74425° N, 84.42564° E, 220 m; **DSTCDu**: Dudhauli05, 27.06501° E, 86.28496° N, 799 m; Dudhauli06, 27.06598° N, 86.28118° E, 758 m; coordinate was not available for a single case; **KCHKa**: KGH23,32,38,49, 27.63904° N, 84.11883° E, 185 m (four specimens); KGH37, 26.86720° N, 85.80687° E, 106 m; **BBSTCTri**: Tri23, 27.42467° N, 83.81890° E, 104 m; Tri28, 27.47995° N, 83.86000° E, 121 m; Tri50, 27.45083° N, 83.81833° E, 106 m; Tri55, 27.41396° N, 83.80835° E, 107 m; Tri57, 27.35784° N, 83.86889° E, 102 m; Tri62, 27.41242° N, 83.83239° E, 110 m; Tri63, 27.38143° N, 83.84706° E, 105 m; Tri65, 27.52978° N, 83.66859° E, 116 m; **NSTCNa**: DPP.8.13.03, 27.05711°, 85.63194°, 153 m; DPP.8.13.04, 27.08106° N, 85.49846° E, 125 m; DPP.8.13.09, 27.12526° N, 85.48987° E, 140 m; DPP.8.13.10, 27.03079° N, 85.57970° E, 123 m; **JSTCCho**: not catalogued, 26.81101° N, 86.28807° E, 90 m (three specimens); **CSTCIta**: not catalogued, 26.66956° N, 87.27360° E, 93 m (three specimens)

***Lycodon jara*—NRCSSbDa**: not catalogued, 26.65659° N, 87.70363° E, 130 m

***Lycodon striatus*—BBSTCTri**: Tri12.1, 27.46333° N, 83.90083° E, 115 m; Tri12.2,18, 27.45256° N, 83.92796° E, 100 m (two specimens)

***Naja kaouthia*—BHBha**: BH.011.12, 27.68192° N, 84.43639° E, 175 m; **KCHKa**: KGH07, 26.86720° N, 85.80687° E, 106 m; KGH12, 27.63904° N, 84.11883° E, 185 m

***Naja naja* —NRCSSbDa**: 1.004(575), 26.58985° N, 87.54176° E, 100 m; 1.006(844), 26.46122° N, 87.74384° E, 75 m; 01.010(983), 26.69472° N, 87.64469° E, 138 m; 01.011(1014), 26.63515° N, 87.84763° E, 143 m; 01.015(34), 26.46441° N, 87.77382° E, 75 m; 01.022(213), 26.53211° N, 87.72561° E, 95 m; 01.025(459), 26.61093° N, 87.81428 E, 117 m; 960, 26.65659° N, 87.70363° E, 130 m; 91, 26.55821° N, 87.77520° E, 95 m; 147, 26.50964° N, 87.72709° E, 88 m; 793, 26.65659° N, 87.70363° E, 130 m; 834, 26.75432° N, 87.67159° E, 214 m; not catalogued, 26.65659° N, 87.70363° E, 130 m; 1029, 26.63224° N, 87.40112° E, 115 m; 1219, 26.69320° N, 87.67032° E; 146 m; 01.028(579), 26.61010° N, 87.62976° E, 106 m; 01.035(1065), 26.63208° N, 87.58012° E, 120 m; 01.039(1206), 26.63002° N, 87.34001° E, 111 m; 01.041(1257), 26.66264° N, 87.67738° E, 130 m; 01.046(094), 26.61093° N, 87.81428° E, 117 m; 01.048(107), 26.56212° N; 87.75787° E, 99 m; 01.052(263), 26.70463° N, 87.65011° E, 145 m; 1.066, 26.65659° N, 87.70363° E, 130 m; 177.01(334), 26.56521° N, 87.70996 E, 104 m; not catalogued, 26.66951°, 87.61066°, 122 m; **CSTCChar**: 128, 26.65160° N, 88.05282° E, 139 m; not catalogued, 26.56312° N, 87.92746° E, 97 m; 2.026(2398), 26.66314° N, 87.88933° E, 119 m; not catalogued, 26.64686° N, 88.05046° E, 138 m; 2.046, 26.64795° N, 88.05465° E, 118 m; not catalogued (three specimens), 26.62623° N, 87.56651° E, 119 m; 26.64795° N, 88.05465° E, 118 m; 26.71698° N, 88.03134° E, 190 m; **BHBha**: 3.014, 27.63856° N, 84.12606° E, 184 m; 3.045, 27.58408° N, 83.86198° E, 183 m; 3.054, 27.67864° N, 84.08454° E, 247 m; BH.011.02, 27.59602° N, 84.09648° E, 152 m; BH.011.04, 27.66660° N, 84.33070° E, 176 m; BH.011.08,27.68192°, 84.43639°, 175 m; BH.011.10, 27.43574° N, 84.40004° E, 217 m; NBT06, 27.65936°, 84.11427°, 208 m; **KCHKa**: KGH08,10?12,22,31,52,53, 27.63904° N, 84.11883° E, 185 m (eight specimens); KGH13, 26.86720° N, 85.80687° E, 106 m; **BBSTCTri**: Tri03, 27.44222° N, 83.90083° E, 114 m; Tri04, 27.44111° N, 83.90861° E, 114 m; Tri11, 27.45139° N, 83.90917° E, 114 m; Tri15, 27.51221° N, 83.79584° E, 121 m; Tri20, 27.55217° N, 83.78583° E, 127 m; Tri30, 27.44543° E, 83.90801° N, 116 m; Tri31, 27.63500° N, 83.80333° E, 124 m; Tri36, 27.47083° N, 83.88667° E, 116 m; Tri37, 27.44831° N, 83.91783° E, 116 m; Tri38, 27.45800° N, 83.90600° E, 114 m; Tri44, 27.41034° N, 83.81825° E, 107 m; Tri46, 27.46767° N, 83.78783° E, 108 m; not catalogued, 27.52167° N, 83.79972° E, 118 m; Tri04.DPP, 27.45256° N, 83.92796° E, 100 m; **DSTCDu**: Du10, 26.99424° N, 86.25784° E, 199 m; not catalogued, 26.99442° N, 86.25755° E, 201 m; **NSTCNa**: DPP.8.13.06, 27.12467° N, 85.49245° E, 140 m; DPP.8.13.07, 27.09850° N, 85.55199° E, 154 m; DPP.8.13.08, 27.12574° N, 85.49212° E, 141 m; DPP.8.12.13, 27.03011° N, 85.58860° E, 124 m; DPP.8.13.13, 27.02327° N, 85.57712° E, 120 m; **JSTCCho**: not catalogued, 26.81101° N, 86.28807° E, 90 m (two specimens); **CSTCIta**: not catalogued, 26.66956° N, 87.27360° E, 93 m (three specimens)

***Oligodon arnensis*—BBSTCTri**: Tri18, 27.48467° N, 83.84317° E, 110 m; **KCHKa**: KGH35, 26.86720° N, 85.80687° E, 106 m; KGH45, 27.63904° N, 84.11883° E, 185 m; **JSTCCho**: not catalogued, 26.81101° N, 86.28807° E, 90 m; **CSTCIta**: not catalogued, 26.66956° N, 87.27360° E, 93 m”

***Oligodon cyclurus*—CSTCChar**: not catalogued, 26.64795° N, 88.05465° E, 118 m

***Ophiophagus hannah*—BBSTCTri**: Tri107, 27.45111° N, 83.91056° E, 114 m; **JSTCCho**: not catalogued, 26.81101° N, 86.28807° E, 90 m

***Ovophis monticola*—CSTCChar**: 340.02, 26.88336° N, 88.02974° E, 1683 m

***Psammodynastes pulverulentus*—NRCSSbDa**: 352, 26.78290° N, 87.31567° E, 312 m

***Ptyas mucosa*—NRCSSbDa**: 712, 26.71192° N, 87.61656° E, 159 m; 215.01(377), 26.65324° N, 87.45772° E, 143 m; **BHBha**: BH.011.07, 27.68192° N, 84.43639° E, 175 m; **KCHKa**: KGH16,17, 27.63904° N, 84.11883° E, 185 m (two specimens); **BBSTCTri**: Tri13, 27.509722° N, 83.79056° E, 127 m; Tri14, 27.49028° N, 83.73639° E, 105 m; Tri67, 27.46969° N, 83.77813° E, 106 m; **DSTCDu**: DSC05727, 26.99424° N, 86.25784° E, 199 m; Du08, 26.99472° N, 86.25968° E, 176 m

***Python bivittatus*—NRCSSbDa**: 109, 26.71748° N, 87.68390° E, 171 m; **CSTCChar**: not catalogued (two specimens), 26.51208° N, 88.00585° E, 95 m; 26.64795° N, 88.05465° E, 118 m, **BHBha**: not catalogued, 27.62234° N, 84.35660° E, 189 m; **BBSTCTri**: 27.39007° N, 83.82282° E, 104 m

***Sibynophis sagittarius*—KCHKa**: KGH01, 27.63904° N, 84.11883° E, 185 m; KGH50, 26.86720° N, 85.80687° E, 106 m; not catalogued, 27.63904°, 84.11883°, 185 m; **BBSTCTri**: Tri02, 27.43472° N, 83.93278° E, 120 m

***Trimeresurus albolabris*—NRCSSbDa**: 15.01(150), 26.72312° N, 87.52562° E, 243 m; 24.01(161), 26.77168° N, 87.39366° E, 335 m; **CSTCChar**: 26.91090° N, 87.92635° E, 1223 m; **BHBha**: 642, 28.00376° N, 84.61938° E, 1163 m; NBT02, 27.73333° N, 83.95499° E, 708 m; **DPSC**, 27.93251° N, 84.58964° E, 1031 m; **KCHKa**: KGH09, 26.86720° N, 85.80687° E, 106 m; **BBSTCTri**: Tri40, 27.37609° N, 83.84814° E, 104 m; **JSTCCho**: not catalogued, 26.81101° N, 86.28807° E, 90 m; **CSTCIta**: 26.66956°, 87.27360°, 93 m

***Xenochrophis piscator*—NRCSSbDa**: 218.01(380), 26.59961° N, 87.75004° E, 109 m; 136.01(283), 26.61680° N, 87.50210° E, 119 m; 721, 26.58635° N, 87.72236° E, 107 m; 726, 26.63726° N, 87.69768° E, 120 m; 251.01(417), 26.62038° N, 87.93363° E, 112 m; 255.01(421), 26.70796° N, 87.68494° E, 159 m; 92.01(235), 26.67161° N, 87.38837° E, 143 m; not catalogued, 26.65659° N, 87.70363° E, 130 m; **CSTCChar**: not catalogued, 26.64795° N, 88.05465° E, 118 m; **BHBha**: BH.011.5, 27.66660° N, 84.33070° E, 176 m; BH.011.9, 27.43574° N, 84.40004° E, 217 m; NBT13, 27.43913° N, 84.31896° E, 201 m; NBT17, 27.68192 N°, 84.43639° E, 175 m; **KCHKa**: KGH30,33,51, 27.63904° N, 84.11883° E, 185 m (three specimens); **BBSTCTri**: Tri16, 27.50833° N, 83.80500° E, 122 m; Tri34, 27.50833° N, 83.80500° E, 122 m; Tri45, 27.49222°

N, 83.80889° E, 114 m; Tri49, 27.44092° N, 83.83168° E, 107 m; Tri51, 27.55217° N, 83.78533° E, 124 m; **JSTCCho**: not catalogued, 26.81101° N, 86.28807° E, 90 m; **CSTCIta**: not catalogued, 26.66956° N, 87.27360° E, 93 m“

***Xenochrophis sanctijohanis*—BHBha**: NBT09, 27.62234° N, 84.35660° E, 189 m

Appendix 3. Questionnaire used in interviews concerning kraits and Russell´s Viper envenomings.

Centres:	Bharatpur General Hospital		Damak Red Cross Sub-centre	
	Charali Nepal Army STC		Other: …… ……	

Read aloud in front of respondents: I am going to ask you about snake which bit you, your experiences and history of the bite until you accessed the snake bite treatment centre. Some questions are just ´yes´ and ´no´ questions. For these questions, reply ´yes´, if you believe or agree and ´no´ if you do not. Some questions are open questions. For open questions, share or write down your experience of each question. At last, I will ask your informed consent (signature) to allow the publication of information shared herein. For this, I will provide you an informed consent letter prepared in your own Nepali language, please, read (or listen) and sign if you agree with it. Abbreviations used: PA = Permanent address; STC = Snake bite treatment centre; SLC = School Leaving Certificate.

Time & date of interview … : … hr. (24:00hr), … . … .2013 (DD.MM.YYYY)

Demography of snake bite victim (respondent). Cross (X) to indicate ´yes´ or ´present´; Wherever no box cross over the selected option.

Name				Male	Female	Religion	
Age (yrs)		**Occupation**				Ward no.	
Permanent address	**District**	Chitwan	Jhapa	Nawalparasi	**VDC**		
	Morang	Sunsari	Sindhuli	Name of **tole**			

Note: ***If bite occurred in address different from permanent addres***, mention it on the back of this paper or on separate paper.

Education status	Illiterate:	a. Unable to read and write		b. Read only	
	Literate:	a. Able to read and write		if literate,	

Educational attainment:		
a. Literate by informal education	never attended school	
b. Literate by formal education	studied up to SLC (class **10**) in school,	
	studied class **11 &/or 12** in Higher Secondary School or equivalent Intermediate Degree in University	
	studied **Bachelor´s Degree** in university,	
	studied **Master´s Degree** or above in university,	

Note: If confirmed snake bite victims are absent or dead, mention the demography of his or her relatives or any eyewitness of the event (e.g., neighbour).

Eyewitness Name			Male	Female	Relationship with victim Cross [X] for appropriate option below:	
Age (yrs)		**Occupation**			father/mother/son/daughter/brother/ sister/uncle/aunty/neighbour/ ………	
Address (if different to PA of patient)	**District**	Chitwan	Jhapa	Nawalparasi	VDC: ………………………,ward:…	
	Morang	Sunsari	Sindhuli	Name of tole		

A. Description of exact locality where snake bite occurred

1 **Which is the place where bite occurred?**

Full administrative name of the place (***if different to PA***):	
Case Identification (Hospital registration) no. of victim:	
Photo number/s of the exact location of bite:	

GPS data of snake location:		N:	
Altitude:		E:	

B. Description of exact surroundings of the snake locality

2 Now, I will ask you **´yes´ or ´no´ questions about exact surroundings of the locality where bite occurred** (within 500 metres from the bite location) (e.g., do you have grain storage? Please, reply ´yes´ if you have it and ´no´ if you don´t have it.) *Just **cross (X)** for replied options below.*

2.1. Grain storage [e.g., Bhakari]	Yes	No	If yes,
Indoors	Yes	No	
Outdoors	Yes	No	
Open-mouthed storage	Yes	No	
Closed-mouthed storage	Yes	No	
Storage in sleeping room	Yes	No	
Storage in store room	Yes	No	
2.2. Fodder storage [e.g., Tauwa]	Yes	No	If yes,
Indoors	Yes	No	
Outdoors	Yes	No	
Open-mouthed storage	Yes	No	
Closed-mouthed storage	Yes	No	
Storage in sleeping room	Yes	No	
Storage in store room	Yes	No	
2.3. Barn [i.e. *Dhansar*]	Yes	No	If yes,
adjoining to house	Yes	No	
≤20 metres from house	Yes	No	
≥20 metres from house	Yes	No	

2.4. Cattle hut [i.e. *Goth*]	Yes	No	If yes,
adjoining to house	Yes	No	
≤20 metres from house	Yes	No	
≥20 metres from house	Yes	No	
2.4. Animals in and aside house	Yes	No	If yes,
2.4.a. Birds (e.g., hen, pigeon, sparrow) or small mammal (e.g., bat) nest	Yes	No	If yes,
2.4.a.1. Are they free to forage around house?	Yes	No	If 4.a. is yes,
2.4.a.2. How many each of those birds or small mammals are in your house? Mention number in the parenthesis. Hen (n = …….), Pigeon (……), Peafowl (……), Sparrow (……), Swallow (……), Others ……..(……)			
2.4.b. Pigs, Cats, Dogs (farmed or pet)	Yes	No	If yes,
2.4.b.1. Do they freely move around house?	Yes	No	If 4.b. is yes,
2.4.b.2. How many animals do you have? Mention number in the parenthesis. Pigs (n = ……..), Cats (……..), Dogs (…….), others ………(…….)			
2.4.c. Lizards, Skinks	Yes	No	If yes,
2.4.c.1. How many lizards move/stay inside or aside your house? Mention number in the parenthesis. Lizards (n = ……..), Skinks (………..), others …………(………)			
2.4.d. Rodents	Yes	No	If yes,
2.4.d.1. How many rodents do you estimate in your house? Cross the range of estimated numbers given in the parentheses: Rat (n = <5 [….]/ 5-10 [….]/ >10 [….]), Mole (<5 [….]/ 5-10 [….]/ >10 [….]), Dukuri Rat (small type of mice) (<5 [….]/ 5-10 [….]/ >10 [….]); 2.4.e. Bat (……)			
2.5. Piles of bricks/ stones/ rubble/logs near to house	Yes	No	
2.7. Vegetation/grass aside or near to house	Yes	No	
2.7. Bushes aside or near to house	Yes	No	
2.9. Forest aside or near to house	Yes	No	
2.10. Agricultural lands aside or near to house	Yes	No	
2.11. Crops aside or near to house	Yes	No	
2.12. Streams aside or near to house	Yes	No	
2.13. Swamps aside or near to house	Yes	No	
2.14. River aside or near to house	Yes	No	

C. Description of types of house where snake bite occurred

3 Here, we discuss the **type of house you used and the housing units (i.e. building materials)** used to build this house. Please, just mention or cross (X) the appropriate options for type of housing units and house listed below:

3.a	Foundation	3.a.i. RCC with pillar (HT1)	3.a.ii. Cement bonded bricks/stones (HT1)	3.a.iii. Mud bonded bricks/ stones (HT2)	3.a.iv.Wooden pillar (HT3)	3.a.v. Others (HT4)
Cross (X) here						
3.b	Outer wall of house	3.b.i. Cement bonded bricks/ stones (HT1)	3.b.ii. Mud bonded bricks/stones (HT2)	3.b.iii. Wood/planks (HT3)	3.b.iv. Unbaked bricks (HT3)	3.b.v. Bamboo (HT4)
Cross (X) here						

3.c	Roof of house	3.c.i. RCC (HT1)	3.c.ii. Galvanized iron (HT1)	3.c.iii. Tile/slate (HT2)	3.c.iv. Wood/planks (HT3)	3.c.v.Thatch/straw (HT4)	3.c.vi. Mud (HT4)
Cross (X) here							

D. Bite history

4 **How, where and in which situations did the snake bite you (or your relative/neighbour)?** Please, remember the day of the bite and try to share your entire experience of how the bite occurred.

4.1. Time and date of bite: … : ...hr (24:00)	………/..……/ 20….(DD.MM.YYYY)
4.2. Weather conditions before, during and after the bite	………/..……/ 20….(BS)

Note 1 for ´yes´, 0 for ´no´, Uk for ´unknown´ in the table below
M = morning, D = Day, E = evening, N = night

Weather conditions	Day of bite	One day before bite	One day after bite
Uniform hot day			

Rainfall			

4.3. Indoor and outdoor bites; activity of victim during bite, bitten body part; Symbols used: + = with, - = without

[Cross (X) at appropriate options below]

4.3.1. Indoor bite	Yes	No	Unknown	If yes,
4.3.1.a. Bed	Yes	No	Unknown	If yes,
4.3.1.a.i. Bed on furniture	Yes	No	Unknown	If yes,
Furniture bed + mosquito net	Yes	No	Unknown	
Furniture bed - mosquito net	Yes	No	Unknown	
4.3.1.a.ii. Bed on floor	Yes	No	Unknown	If yes,
Floorbed + mosquito net	Yes	No	Unknown	
Floorbed - mosquito net	Yes	No	Unknown	
4.3.1.b. Other indoor locations:	…………………………………………………………			
Door	Yes	No	Unknown	
Inner corridor of house	Yes	No	Unknown	
4.3.2. Outdoor bite	Yes	No	Unknown	
4.3.2.a. Outskirts of house	Yes	No	Unknown	If yes,
4.3.2.a.i. Outer corridor	Yes	No	Unknown	
4.3.2.a.ii. Yard	Yes	No	Unknown	If yes,
4.3.2.a.iii. Yard (sleeping bed)	Yes	No	Unknown	
Other outskirt locations:	………………………………………………………………………………..			
4.3.2.b. ≤5 m far from from house	Yes	No	Unknown	
4.3.2.c. ≥5 m far from house	Yes	No	Unknown	
4.3.3. Activities carried at the moment of bite				
Sleeping	Yes	No	Unknown	
Opening door	Yes	No	Unknown	
Killing snake	Yes	No	Unknown	
Playing	Yes	No	Unknown	
Walking barefoot at dark	Yes	No	Unknown	
Sweeping house floor	Yes	No	Unknown	
Other activities performed:	…………………………………………………………………….			
4.3.4. Bitten body part	Yes	No	Unknown	
4.3.3.a. Extremities	Yes	No	Unknown	
4.3.3.a.i. Hand	Yes	No	Unknown	
4.3.3.a.ii. Leg	Yes	No	Unknown	
4.3.3.a.iii. Digits*	Yes	No	Unknown	* finger or toe
4.3.3.b. Trunk	Yes	No	Unknown	
4.3.3.c. Neck	Yes	No	Unknown	
4.3.4.d. Head	Yes	No	Unknown	
4.3.4.e. Bite site unknown	Yes	No		

E. Pre-hospital care of victim

5 What did you or your families or friends or neighbours do immediately after the bite until you accessed or were carried to the Bharatpur/Damak/Charali snake bite treatment centre?*(Note: use back side of the paper or extra paper if more space is needed)*

5.1. Pre-hospital care/ management sought. Cross (X) at appropriate options below

5.1.1. Seeking traditional healers		Yes	No	Unknown	
5.1.2. Seeking medical persons or health care facilities		Yes	No	Unknown	
5.1.3. First-aid measures adopted		Yes	No	Unknown	If yes,
5.1.3.1. PIB		Yes	No	Unknown	
5.1.3.2. LCPI		Yes	No	Unknown	
5.1.3.3. Tourniquet	5.1.3.3.i. Single	Yes	No	Unknown	
	5.1.3.3.ii. Multiple	Yes	No	Unknown	

5.1.3.4. Bite site incision	Yes	No	Unknown	
5.1.3.4. Suction of wound	Yes	No	Unknown	
5.1.3.5. Squeezing the wound	Yes	No	Unknown	
5.1.3.7. Ingestion of chillies*	Yes	No	Unknown	If yes,
5.1.3.7.i. Why do you eat chillies? Please, give your reasons:				
5.1.3.7. Washing wound	Yes	No	Unknown	
5.1.3.9. Topical application herbals medicine	Yes	No	Unknown	
5.1.3.10. Topical application of traditional concoctions	Yes	No	Unknown	
5.1.3.11. Ingestion of herbals medicine	Yes	No	Unknown	
5.1.3.12. Ingestion of traditional concoctions	Yes	No	Unknown	
5.1.3.13. Application of black stone (snake stone)	Yes	No	Unknown	
5.1.3.14. Combination of any two or more treatment methods adopted before reaching to STC (e.g., 5.1.3.3+5.1.3.1)				
5.1.4. Means of transportation used				
5.1.4.1. Motorbike	Yes	No	Unknown	If yes,
5.1.4.1.i. Who was the driver? a. Normal driver	b. Self	c. Driver of motocycle ambulance		
5.1.4.2. Ambulance	Yes	No	Unknown	
5.1.4.3. Cycle+motorbike	Yes	No	Unknown	
5.1.4.4. Motorbike + Jeep	Yes	No	Unknown	
5.1.4.4. Stretcher (Doli) + Jeep	Yes	No	Unknown	
5.1.4.5. Carried in back+bull-cart+ambulance	Yes	No	Unknown	
5.1.4.7. Bus	Yes	No	Unknown	
5.1.4.7. Cycle	Yes	No	Unknown	
5.1.4.9. Stretcher	Yes	No	Unknown	
5.2.10. Other combination (e.g., 5.1.4.9+5.1.4.2):				
6 **Do you know how to prevent snake bite?**	Yes	No	Unknown	If yes,

6.1. What preventive measures against snake bite do you adopt? Measures:	
1.	6.
2.	7.
3.	8.
4.	9.
5.	10.
6.1. Score of correct measures [CS]	

F. Accessibility of snake bite victims to STC, Area (i.e. rurality) where bite episode occurred, and time to start antivenom

7 In how many minutes did you access the snake bite treatment centre at Bharatpur/Damak/Charali from your home? Please, specify the date if it is different to date of bite. ………..(in minutes) or ………(in hours)

Krait bite time	... : ... Hr	Hospital accessed time and date	… : … ; …………..	7.1. Time needed (hrs.)	

7.2.1. Area			7.2.2. Types of road used by victims to reach hospital			
Place	Yes	No	Types of road	Yes	No	Estimated distance (km.)
Rural			Black road			
Suburb			Gravelled road			
Urban			Soil or dirt road			
			7.2.2.i. Total road distance travelled from home to hospital/STC (km)			

7.3. Do you have a motor (four wheel vehicle) road within 5 minutes walking distance from your home?	Yes	No	If no,
7.4. Do you have a motor cycle road within 5 minutes walking distance from your home?	Yes	No	
7.5. After how many minutes did a motorbike or ambulance reach at the site of emergency when you looked or called for it?			……..min.

7.6. In how many hours did you receive antivenom treatment therapy first time at Bharatpur/Damak/Charali ? ………..(in minutes) or ………(in hours)

7.7.i. duration of observation in hospital	……….hr/s	7.7.ii. Time and date of starting first dosage of antivenom: ….:…hour; …./…./201…	7.7.iii. Interval of bite time & start of first dosage of antivenom (hrs.) [i.e., 7.1+7.7.i]	

8 **Remarks:** survived (S) [ ]; death (D) [ ]; permanently disabled (PD) [ ]

G. Assessment of socio-economic conditions of households where snake bites occurred

In this section, I will ask you some of your living conditions or styles.

9 Do you have or use following facilities in your household? *Mention or cross (x) over appropriate options below.*

9.1. Electricity	Yes	No	
9.2. Fuel			
9.2.1. Cooking fuel	Yes	No	If yes,
9.2.1.a. Solid fuel	Yes	No	
9.2.1.a. i. Firewood	Yes	No	

9.2.1.a. ii. Cow dung	Yes	No	
9.2.1.a. iii. Thatch	Yes	No	
9.2.1.a. iv. Straw	Yes	No	
9.2.1.a. v. Leaves	Yes	No	
9.2.1.b. Gas fuel	Yes	No	If yes,
9.2.1.b.i. LP gas	Yes	No	
9.2.1.b.ii. Bio-gas	Yes	No	
9.2.1.c. Liquid fuel	Yes	No	If yes,
9.2.1.c.i. Kerosene	Yes	No	
9.2.1.d. Electricity	Yes	No	If yes,
9.2.1.d.i. Hydro-electricity	Yes	No	
9.2.1.d.ii. Solar-electricity	Yes	No	
9.2.2. Lighting fuel	Yes	No	If yes,
9.2.2.a. Gas fuel	Yes	No	If yes,
9.2.2.a.i. Bio-gas	Yes	No	
9.2.2.b. Liquid fuel	Yes	No	If yes,
9.2.2.b.i. Kerosene	Yes	No	
9.2.2.c. Electricity	Yes	No	If yes,
9.2.2.c.i. Hydro-electricity	Yes	No	
9.2.2.c.ii. Solar-electricity	Yes	No	

9.3. Toilet: Please, reply me the different types of toilet facilities you use.			
9.3.a. Household having toilet facility: Do you have toilet?	Yes	No	if yes,
9.3.a.i. Do you have own indoor toilet?	Yes	No	if no,
9.3.a.ii. Do you have own outdoor toilet?	Yes	No	
9.3.b. Household having no toilet facility: if you don´t you have own toilet?			
9.3.b.i. Do you use public toilet?	Yes	No	
9.3.b.ii. Do you use open toilet?	Yes	No	
9.3.c. Modern toilet: Do you have toilet with flushing system, connected to drainage or septic tank or sewage?	Yes	No	
9.3.d. Ordinary toilet: Do you have toilet without flushing system and connection to drainage or septic tank or sewage?	Yes	No	
9.4. Sources of improved drinking water (place from where household members fetch water for drinking/cooking purposes). What type of drinking water sources do you use often?			
9.4.a. Private source of drinking water	Yes	No	
9.4.b. Public source of drinking water	Yes	No	
9.4.c. Improved source of drinking water	Yes	No	if yes,
9.4.c.i. Pipe (tap) (water collected from metal or polythene pipe)	Yes	No	
9.4.c.ii. Tube-well (Borehole, Jet pump)	Yes	No	
9.4.d. Unimproved source of drinking water	Yes	No	if yes,
9.4.d.i. Dug-well (Well, spring i.e. Kuwa)	Yes	No	
9.4.d.ii. River/stream (Khola/Kulo/Nahar)	Yes	No	
9.4.d.iii. Spout (Stone tap i.e. Pandhero)	Yes	No	
9.4.d.iv. Others (excluding sources listed above): ……………	Yes	No	

9.5. Do you have following media and electronic devices? Cross for appropriate options:

Media	Powered by a. battery	b. solar-electricity	c. hydro-electricity	Score of b. & c. ´Yes´	Score of b. & c. ´No´
9.5.1. Radio					
9.5.2. Tape recorder					
9.5.3. Television (B/W)					
9.5.4. Television (Colour)					
9.5.5. Mobile phone					
9.5.6. Land phone					
9.5.7. Computer					
9.5.8. Internet					
Total score:					

Appendix 4. Informed consent form used during interview survey of kraits and Russell´s Viper envenomings.

Informed consent form

Nepali date: ……../……. 20…. BS

English date: ……./……. 20…. AD

I am …………………………………………………………. (full name of snake bite victim/ his or her family member) (……… years). I live in ……………………………….(village, tole), ……………………………(VDC-ward no), ………………..(District) . Hereby, I provide my consent to use and publication of geographical position data, name of village, photos of the localities of snakes which bit me or my …………………(relation of respondent), information of weather and bite history unless reaching hospital for the research and teaching purpose only. Also, I give consent to publish all those data related to my illness due to snake bite in print or electronics media without disclosing my name, road address, and telephone numbers.

………………………………………….. (name and signature of snake bite victim)

…………………………………………….. (name and signature of witness)

Appendix 5. Checklist of snakes (displayed while interview) in vicinity of the Chitwan National Park, Nepal.

PN	Scientific Name	Common name	Vernacular name	Toxicity
	Typhlopidae			
1	*Indotyphlops braminus*	Brahminy Worm Snake/ Common Blind Snake/ Brahminy Blind Snake	Andha Sarpa or Sanp/ Ganeule Sanp/ Teliya Sarpa/ Nelia Sarp/ Matti Sanp/ Dhudh Sanp/ Andhara Sanp	Nv
2	*Argyrophis diardii*	Diard's Worm/ Diard´s Blind Snake/ Large Worm/ Western Large Worm Snake/ Indochinese Blind Snake	Phusre Telia/ Andha Sap/ Matti Sanp/ Dhudh Sanp/ Andhara Sanp/ Ganeule Sanp/ Teliya Sanp or Sarpa	Nv
	Erycidae (Boidae)			
3	*Eryx johnii*	Red Sand Boa/ Brown Earth Boa/ John´s Sand Boa	Domukhe or Lide or Laxmi or Mate Sanp/ Lal Dhusar/ Duitauke Sarpa/ Jhataha	Nv
	Pythonidae			
4	*Python bivittatus*	Burmese Rock Python	Ajingar/ Ajgar/ Thulo Pate Ajinger/ Sonakatar	Nv
	Colubridae			
5	*Coelognathus helena*	Common Trinket Snake	Singare Sarpa (long-striped snake)/ Gahane Sap/ Male Sap	Nv*
6	*Coelognathus radiatus*	Copper-headed Trinket Snake/ Copperhead Trinket Snake/ Copperhead Racer	Singare Sarpa/ Ratothauke Gahane Sap	Nv*
7	*Dendrelaphis tritis*	Common Bronzeback Tree Snake	Sirish or Sirise (tree living)/ Siris Rukh Sanp/ Shipu/ Laudanga	Nv
8	*Lycodon aulicus*	Common Wolf Snake	Chichinde (gourd-shaped snake)/ Dhamiloo Sanp/ Buwase Sarp/ Sikhaphyancha/ Sikham Phyancha/ Sikhphyancha	Nv
9	*Lycodon jara*	Yellow-speckled Wolf Snake/ Twin-spotted Wolf Snake	Jor Thople Sikhaphyancha	Nv
10	*Oligodon arnensis*	Common/Banded Kukri Snake/ Russet Kukri Snake	Pate Khukuri Sap/ Gurbay/ Pate Sikhan Pyancha/ Sankhad Sanp	Nv
11	*Oligodon kheriensis*	Coral Red Kukri Snake/ Coral Kukri Snake	Puwale Khukuri Sap/ Harrama (Rai community)	Nv
12	*Ptyas mucosa*	Asiatic Rat Snake/ Indian Rat Snake/ Indian Wolf Snake	Dhamin or Dhaman (big garlands), Dhamila or Dhamala/ Muse Sarpa/ Lambaiya (lanky snake)/ Bichhar (nipple sucking snake)	Nv
14	*Xenochrophis piscator*	Checkered Keelback	Pani Sarpa or Pani Sanp or Pani Syap (water snake)/ Kothe Dhodiya Sap/ Dhodiya Sanp/ Pankhadar/ Gareha Sarpa/ Dom	Mv, Vs
15	*Ahaetulla nasuta*	Common Vine Snake/ Common Green Whip Snake/ Green Vine Snake	Sugia or Suga Sarpa (parrot like or parrot snake)/ Hario Chabuke Sarpa/ Udne Hareu/ Harahara	Mv, Bf
16	*Amphiesma stolatum*	Striped Keelback/ Buff-striped Keelback	Bagale/ Nauri/ Nauria/ Ashare/ Harara/ Harihara/ Bahune Sarpa/ Harhare Sarpa/ Hurra/ Chyarra/ Dirisarp/ Deri/ Dondaha	Mv, Bf
17	*Boiga trigonata*	Common Cat Snake/ Indian Cat Snake/ Indian Gamma Snake	Sanbe or Sabhe (cylindrical snake, in Kirat or Limbu)/ Adhoo Sarpa/ Tirish/ Batashe Sarpa (windy or gliding snake)/ Bharati Birale Sap/ Basara (nesting snake)/ Lohagin (irony)/ Birale Sarpa (catlike snake)/ Batyoudesyaap (gliding snake)/ Chittar (cupid)/ Chudeu (crested)/ Katakhor (cutter of pen)	Mv, Bf
18	*Rhabdophis subminiatus*	Red-necked Keelback	Lal Kanthe Daline Sap	V, Vs
	Homalopsidae			
13	*Ferania sieboldi*	Siebold's Smooth-scale Water Snake/ Siebold´s Smooth Water Snake	Dhod or Dhodia Sarpa/ Machhagidhi/ Chile Pani Sap/ Pani Sarpa	Mv, Bf

	Elapidae			
19	*Bungarus caeruleus*	Common Krait/ Common Indian Krait	Bairi Karet/ Kret Sarpa (file snake)/ Chure Karet/ Seto-kalo-chure Krait/ Ganaich/ Gadainch/ Ghod Gadainch (horse like krait)/ Kalaich (killing monster)/ Karkat nag (cancer snake)	V
20	*Bungarus fasciatus*	Banded Krait	Panhelo-kalo-chure Sarpa/ Kanthmala Sap (snake with necklace or garland)/ Laxmi Sarpa (money making snake)/ Ganguwali or Pate Ganguwali Sarpa/ Gangwari (cowshed living)/ Gun Gawari/ Gangwar/ Ganguri Sarpa/ Maher/ Gwala Sarpa (cow-herd snake)/ Rajasarp (king snake)/ Ahiriniyasarp (not looking snake)	V
21	*Bungarus lividus*	Lesser Black Krait	Kalo Krait (black krait)	V
22	*Sinumicrurus m. univirgatus*	MaClelland's Coral Snake	Setofetawal Nag/ Muga Sanp/ Rato Sarpa/ Karkat Nag (cancer cobra)/ Nag/ Naag (semi-divine serpent)	V
23	*Naja kaouthia*	Monocled Cobra/ Monocellate Cobra	Goman/ Nag/ Ek Thople Goman/ Seto Goman/ Paniadarad (water burning pain)/ Supailyasyaap/ Tilakdom (with black hood marking)/ Dom/ Dumini	V
24	*Naja naja*	Spectacled/ Common Cobra	Goman (cobra, aggresive snake)/ Nag/ Dui Thople Goman/ Kalo Goman/ Dudhiya Goman (milky cobra)/ Dumini (female sweeper)/ Supailyasyap/ Supailesyap/ Supya Sarpa/ Phetara (expanded hood)/ Kopre (hooded or bent ahead)	V
25	*Ophiophagus hannah*	King Cobra	Queta or Kenwata/ Raj Goman/ Darad (much poisonous or paining)/ Nagraja (snake king)/ Alhaad (Sanskrit: fireband)/ Kalinag (black cobra)/ Bhainsedom (buffalo sweeper)	V
	Viperidae			
26	*Trimeresurus albolabris*	White-lipped Green Pit-viper/ White-lipped Bamboo Viper	Harau/ Harau Sanp/ Haryousarpa/ Setojibre Hareu Sap/ Pattar	V
27	*Daboia russelii*	Russel´s Viper	Baghe Sarpa, Suskar	V
28	*Echis carinatus*	Saw-scaled Viper	Karaute Sarpa	V

Abbreviations: **PN** = photo number (PN 27 and 28 are presumed to be distributed in Chitwan valley and lowlands of Nepal (Shah and Tiwari 2004, Shrestha 2001). So, we included them despite these were not reported from Chitwan valley (Pandey 2012)), **Nv** = Non-venomous, **Mv** = Mildly venomous, **Bf** = Back-fanged, **Vs** = Venomous secretion, **V** = Venomous; This checklist was adopted from: Pandey 2012, Shah and Tiwari 2004, Schleich and Kästle 2002, Shrestha 2001, Zug and Mitschel 1995). Althgouh *Coelognathus radiatus* possesses postsynaptic neurotoxin in its Duvernoy´s gland (Fry et al. 2003), Harris et al. (2010) reported four *Coelognathus radiatus* bites on the feet causing pain and bleeding at the bite site. Therefore, I considered both nonvenomous snakes while analysing knowledge of locals on surrounding venomous snakes.

Appendix 6. Circumstances and risk factors for krait (*Bungarus* species) and Russell´s Viper (*Daboia russelii*) bites including baseline characteristics of patients in southern Nepal. Abbreviations: **STC** = Snake Bite Treatment Centre, **NA** = not available or not applicable, **sd** = standard deviation, **SEM** = standard error of the mean, **CI** = 95% confidence interval, **t** = one sample Student´s t-test, **V** = Wilcoxon signed rank test, **χ2** = One-way Chi-Square test, p = p-value at 5% significance level. Note: when not indicated, the hypothesis test values were analysed for two-tailed condition.

	I. Socio-demographic and socio-economic characteristics of patients envenomed due to krait (*Bungarus* species) bites in south Nepal			**I. Socio-demographic and socio-economic characteristics of patients envenomed due to bites of Russell´s Viper (*Daboia russelii*) bites in southwestern Nepal**		
Circumstances/risk factors of bites	***Bungarus* species bites (N = 46:** Bharapur Hospital = 21 cases, Bajradal Battallion STC = 7, Damak STC = 7, Charaali STC = 5, Dudhauli STC = 4, Netragunj STC = 2)			***Daboia russelii*** bites (all cases from Bajradal Battallion STC, Nawalparasi)		
	Risk [N (%)]	**Statistics**	**CI**	**Risk** [N (%)]	**Statistics**	**CI**
A. Demographic factors						
1. Age (in years)		range = 5–65, mean±SEM = 30.28±2.11, median = 29, mode = 40, sd = 14.31, t = 0.03, df = 45, p = 0.977	26.03–34.53		range = 14–82, mean±SEM = 39.4±6.9, median = 35, mode = 40, sd = 21.82, t = 0, df = 9, p = 1	23.79–55.01
Adults: children: elders		$\chi2 = 36.174$, df = 2, p = <0.001			$\chi2 = 6.2$, df = 2, p = 0.045	
Adults (18–57 yrs.)	34 (74)	range = 18–52, mean±SEM = 33.32±1.85, median = 35, mode = 40, sd = 10.8, V = 201, p = 0.362	29–38	7 (70)	range = 18–44, mean±SEM = 32.57±3.66, median = 35, mode = 35, sd = 9.68, t = 0.0004, df = 6, p = 1	23.62–41.52
Children (5–17 yrs.)	10 (22)	range = 5–17, mean±SEM = 13.5±1.29, median = 15, mode = 16, sd = 4.1, V = 15, p = 0.72	9.5–16.5	1 (10)	14	NA
Elders (58–65 yrs.)	2 (4)	range = 60–65, mean±SEM = 62.5±2.5, median = 62.5, sd = 3.5 (test statistics NA)	NA	2 (20)	range = 70–82, mean±SEM = 76.5±6, median = 76, sd = 8.49 (test statistics NA)	NA
2. Occupation		$\chi2 = 15.565$, df = 3, p = 0.001			$\chi2 = 6.2$, df = 2, p = 0.045	
Farmer (including 3 labourers*)	20 (43)			7 (70)		
Student**†**	16 (35)			2 (20)		
Unemployed**‡**	6 (13)			1 (10)		
Employed**	4 (9)			NA		

3. Gender (male : female)		$\chi2 = 0.783$, df = 1, $p = 0.376$, sex ratio = 130		$\chi2 = 0.4$, df = 1, $p = 0.527$, sex ratio = 150
Male	26 (57)	age: range 5–65, mean = 32, sd = 14.31	6 (60)	
Female	20 (43)	age: range 7–60, mean = 28, sd = 14.29	4 (40)	
4. Literacy		$\chi2 = 5.57$, df = 1, $p = 0.018$		$\chi2 = 0.4$, df = 1, $p = 0.527$
Literate	31 (67)		6 (60)	
Illiterate	15 (33)		4 (40)	
B. Socio-economic status index (SESI) and house types used				
1. Household quality		$\chi2 = 10.957$, df = 4, $p = 0.027$		$\chi2 = 6.8$, df = 3, $p = 0.079$
High quality households (HQH)	15 (33)		2 (20)	
Medium quality households (MQH)	12 (26)		6 (60)	
Medium high quality households (MHQH)	11 (24)		1 (10)	
Low quality households (LQH)	5 (11)		NA	
Very low quality households (VLQH)	3 (7)		1 (10)	
2. Types of houses		$\chi2 = 7.913$, df = 7, $p = 0.34$		$\chi2 = 2$, df = 4, $p = 0.736$
i) Brick/block/bamboo-cement or brick-wood-cement houses with galvanized-tin roofs	11 (24)		NA	
ii) Brick/stone-wood-daub houses with tiled roofs	6 (13)		3 (30)	
iii) Rod-concrete-cement buildings	6 (13)		1 (10)	
iv) Wattle and daub (wood, bamboo) houses with tile/slate roofs	6 (13)		3 (30)	
v) Wattle and daub (wood, bamboo) houses with galvanized-tin roofs	6 (13)		NA	
vi) Wattle and daub (wood, bamboo) houses with thatched roofs	5 (11)		1 (10)	
vii) Brick/stone-daub houses with galvanized-tin roofs	4 (9)		NA	
viii) Brick-wood-cement houses with tiled roofs	2 (4)		2 (20)	

		II. Circumstances of *Bungarus* species bites			II. Circumstances of *Daboia russelii* bites	
A. Localities and sites where bites occurred, body parts involved and activities carried by victims during the bite						
1. Localities						
a. rurality		χ2 = 18.565, df = 2, p = <0.001			χ2 = 9.8, df = 2, p = 0.007	
Rural	29 (63)			8 (80)		
Suburb	10 (22)			1 (10)		
Urban	7 (15)			1 (10)		
b. Accessibility to health and transport facilities						
b.i. Types of roads connecting STC and snake bite localities		χ2 = 66.435, df = 5, p = < 0.001			χ2 = 6.25, df = 2, p = 0.044	
Paved and gravel road	28 (61)			NA		
Paved, gravel and soil road	6 (13)			NA		
Paved road	5 (11)			6 (60)		
Paved and soil road	3 (7)			3 (30)		
Gravel road	2 (4)			1 (30)		
Gravel and soil road	2 (4)			NA		
b.ii. Total road-distance* (km) *from localities to treatment centre *(NA = 1)*	45	range = 1.2–80, mean±SEM = 24.12±3.04, median = 20, sd = 20.39, V = 529, p = 0.503	16–28.75	10	range = 8–25, mean±SEM = 15.73±1.57, median = 14.5, sd = 4.99, t = 0, df = 9, p = 1	12.16–19.30
Paved road		range = 0–74, mean±SEM = 18.27±2.75, median = 14, sd = 18.45, V = 539, p = 0.612	10.5–22		range = 0–20, mean±SEM = 11.03±1.63, median = 11, sd = 5.2, t = 0, df = 9, p = 1	7.34–14.72
Gravelled road		range = 0–45, mean±SEM = 5±1.34, median = 2, sd = 8.96, V = 520, p = 0.069	1.99–5.5		range = 0–20, mean±SEM = 4.42±2.15, median = 0.10, sd = 6.79, V = 37.5, p = 0.322	0–9.5
Soil road		range = 0–15, mean±SEM = 1.03±0.42, median = 0, sd = 2.82, V = 105, p = 0.001	0.75–5.5		range = 0–2, mean±SEM = 0.28±0.2, median = 0, sd = 0.63, V = 6, p = 0.181	0.2–1.9
b.iii. Motor-road availability at bite site		χ2 = 42.087, df = 1, p = <0.001			All sites connected to motorable road from STCs	
Four-wheel motor road	45 (98)			10 (100%)		
Motorcycle road only	1 (2)			0		
c. Time interval (hours, h) from the bite to access in STCs		range = 0.3–16, mean±SEM = 2.46±0.43, median = 1.4, sd = 2.94, V = 696, p = 0.09	1.3–2.55		range = 0.3–1.5, mean±SEM = 0.53±0.12, median = 0.33, sd = 0.37, V = 55, p = 0.005	0.33–0.67
hours (h) needed to access STCs		χ2 = 18.174, df = 5, p = 0.003			χ2 = 6.4, df = 1, p = 0.011	
0–0.9 h	16 (35)			9 (90)		
1–1.9 h	12 (26)			1 (10)		
2–2.9 h	3 (7)			NA		
3–3.9 h	7 (15)			NA		
4–4.9 h	3 (7)			NA		
≥5 h	5 (11)			NA		

d. Ambulance availability				
within 30 minutes	29 (63)		10 (100)	
within 30–60 minutes	12 (26)		NA	
within >60 minutes	3 (7)		NA	
Not available	2 (4)		NA	
e. Specific sites where bite occurred				
Indoor vs outdoor location		$\chi 2 = 7.044$, df = 1, p = 0.008		$\chi 2 = 6.4$, df = 1, p = 0.011
Indoor	32 (70)		1 (10)	
Outdoor	14 (30)		9 (90)	
Indoor sites				
Beds vs non-beds		$\chi 2 = 12.5$, df = 1, p = <0.001	NA	NA
Beds	26 (81)			
Non-bed sites	6 (19)			
Bed types	24	$\chi 2 = 2.462$, df = 1, p = 0.117	NA	NA
Furniture bed	17 (65)			
Mattress bed on floor	9 (35)			
Use or no use of mosquito net	24	$\chi 2 = 2.462$, df = 1, p = 0.117	NA	NA
Bed with no use of mosquito net	17 (65)			
Bed underneath mosquito net	9 (35)			
f. Bite sites in general		$\chi 2 = 17.3043$, df = 1, p = 0.016		$\chi 2 = 6.2$, df = 2, p = 0.045
Outskirts and premises of house	11 (24)		2 (20)	
Bed on cot without using mosquito net	10 (22)		NA	
Bed on cot using mosquito net	7 (15)		NA	
Bed on floor without using mosquito net	7 (15)		NA	
Indoor non-bed sites (e.g. grain store)	6 (13)		1 (20)	
Bed on floor using mosquito net	2 (4)		NA	
Agricultural field	2 (4)		7 (70)	
Roadside culvert near house	1 (2)		NA	

III. Prehospital interventions (practices and/or treatment seeking behaviour) adopted by patients for snake bite care		
1. Seeking traditional healers	*7 (15)*	0
2. Seeking healthcare at local healthcare centres	*12 (26)*	4 (40)
3. First aid measures		
Pressure immobilization bandaging (PIB)	0	0
Local compression pad immobilization (LCPI)	0	0
Single tourniquet	24 (52)	4 (40)
Multiple tourniquets	12 (26)	6 (60)
Ingestion of chillies to test envenoming	10 (22)	1 (10)
Washing the wound	7 (15)	0
Bite site incision	5 (11)	0
Squeezing the wound	3 (7)	1 (10)
Topical application or ingestion of traditional concoctions	2 (4)	0
Topical application or ingestion of herbal medicine	1 (2)	0
Application of snake stone	1 (1)	2 (20)
4. Mode of transportation used		
Motorbike (all normal driver)	30 (65)	10 (100)
Ambulance	10 (22)	0
Bicycle	2 (4)	0
Bicycle and motorbike	1 (2)	0
Motorbike and Jeep	1 (2)	0
Stretcher (Doli) and Jeep	1 (2)	0
Carried on back, bull-cart and ambulance	1 (2)	0

IV. Knowledge of patients (or their relatives if victim was killed) about snake bite prevention (number of test questions = 10)						
I know about prevention of snake bite	25 (54)	range = 1–6, mean±SEM = 2.5±0.32, median = 2, mode = 1, sd = 1.49, V = 97.5, p = 0.123	2–3.75	6 (60)	range = 1–5, mean±SEM = 2.4±0.61, median = 2.3, mode = 1, sd = 1.49, V = 10, p = 1	1.5–3.5
I do not know about prevention of snake bite	19 (41)			4 (40)		
I am unknown	1 (2)			NA		
Not available	1 (2)			NA		

*labourers would relied on non-agricultural activities as well for the subsistence; †10 of krait bitten students and one of *Daboia russelii* bitten students were belonged to farmer family; ‡non-employed occupation of krait bite patients represented three business (one shopkeeper, one tailor and one clinician), one priest, one housemaid and one housewife and *Daboia russelii* bitten patient was mason; **employed occupation included two teacher, one driver and one tea-farm supervisor

AFFIDAVIT

I herewith declare in lieu of an oath that I have produced the present dissertation **“Venomous Snakes of Medical Relevance in Nepal: Study on Species, Epidemiology of Snake Bite and Assessment of Risk Factors of Envenoming and Death”** autonomously and in doing so did not avail myself of resources which are not specified therein. In particular, all borrowings taken from other writings are marked with references to the respective writings.

I assure that I have adhered to the principles of good scientific practice and did not make use of the services of any commercial doctorate agencies or consultants.

EIDESSTATTLICHE ERKLÄRUNG

Ich erkläre hiermit an Eides statt, dass ich die vorgelegte Dissertation **“Venomous Snakes of Medical Relevance in Nepal: Study on Species, Epidemiology of Snake Bite and Assessment of Risk Factors of Envenoming and Death”** selbständig angefertigt und mich anderer Hilfsmittel als der in ihr angegebenen nicht bedient habe, insbesondere, dass alle Entlehnungen aus anderen Schriften mit Angabe der betreffenden Schrift gekennzeichnet sind.

Ich versichere, die Grundsätze der guten wissenschaftlichen Praxis beachtet, und nicht die Hilfe einer kommerziellen Promotionsvermittlung in Anspruch genommen zu haben.

Frankfurt am Main, den ....

Deb Prasad Pandey

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