MODELING RISK FACTORS ASSOCIATED WITH SNAKEBITE MORBIDITY USING MULTIVARIATE ANALYSIS:A RETROSPECTIVE STUDY IN CHEMALINGOT IN BARINGO COUNTY.

KENNETH KIMOSOP CHEPSERGON

A thesis submitted in Partial fulfillment of the requirements for the degree of Masters of Science in Mathematics (Biostatistics) in the School of Science, University of Eldoret

ELDORET

2025

DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been submitted for any academic award in any academic award in any institution; and shall not be reproduced in part or in full, or in any format without prior written permission from the author and/or University of Eldoret.

Kenneth Kimosop Chepsergon Sign:…………………… Date: 03/07/2025.
SSCI/MAT/M/010/22

Declaration by the Supervisors

This thesis has been submitted with our approval as university supervisors.

Dr. Julius Koech, PhD Sign. …… Date …04/07/2025…
Department of Mathematics and Computer Science,
University of Eldoret

Dr. Samson Wangila, PhD Sign ____________ Date 04/07/2025...
Department of Mathematics and Computer Science,
Pwani University

DEDICATION

I dedicate this work to the almighty God, my supervisors and my mother Loice Talai Sikinwo for the support she has given me throughout the study period, despite all the challenges they have been with me throughout these studies.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to the University of Eldoret for the opportunity to pursue my Master of Science degree in Biostatistics. I am thankful for the support received from the staff in the Department of Mathematics and Computer Science, which helped me achieve my academic goals. I extend special thanks to my supervisors, Dr. Julius Koech and Dr. Samson Wangila, for their dedication in assisting and guiding me throughout the duration of my thesis research and report writing. I also appreciate my parents and colleagues for their unwavering support during this period.

ABSTRACT

Snake bite envenomation is a major but neglected public health problem especially in resource poor rural areas. In Kenya, the burden of morbidity attributable to snakebite has been increasing in many areas. Chemalingot in Baringo County is one of the region in kenya where venomous snakes are common.This has resulted to cases of morbidity to go high due to victims inability to access timely and effective health care. The aim of the study was to model the main risk factors related to the morbidity of snakebite using a multivariate analytical framework, in an attempt to provide locally appropriate interventions. A retrospective cross-sectional research methodology was used and medical records of the identified dispensaries in Chemalingot were employed. Patient demographics and clinical outcomes were summarized in terms of descriptive statistics. To determine the predictors significantly correlated with morbidity after snakebite, the multivariate logistic regression analysis was used. In the results analysis, it was found that there was a morbidity of snakebites of 30.0%. The average age of adults with the disease is 19.26 years ($Standard\ Deviation\ =\ 15.30$) and the average length of stay in a hospital is 4 days. The rates of morbidity depended on the time of the bite, and those that occurred in the evening and night had higher rates of complications (38.2% vs. $26.3\ \%$). Multivariate modeling indicated that prolonged stay in hospitals was significantly correlated with high morbidity with each day increasing chances by 9% ($AOR\ =\ 1.09$; $95\%\ CI: 1.0331 - 1.1755$). In addition, patients arriving to a health institution over 12 hours after the bite were triple likely to have morbidity than those who were presented to health center in less than 12 hours ($AOR\ =\ 3.01$; $95\%\ CI: 1.14978.9619$). The results demonstrate the importance of early treatment and available health care services to decrease the outcomes of the problem of snakebites. The study will be of immense importance in terms of providing evidence to the epidemiology of snakebites in Chemalingot and will also act as a basis of formulating specific intervention measures that will be directed at lessening morbidity among snakebite victims who are rural poor people.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ABREVIATIONS

W.H.O - World Health Organization

ANOVA - Analysis of Variance

KENSERS - Kenya Snakebite Emergency Response System

NTDs - Neglected Tropical Diseases

GIS - Geographic Information Systems

CRH - County Referral Hospital

ROC - Receiver Operating Characteristic

N.G.O-

S.S.A -

S.B.E -

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Snakebite envenomation constitutes a particularly troubling neglected tropical disease.This is an international priority which could have been taken serious, especially within rural and poor areas. Although it can cause a serious burden in terms of public health, it has never attracted enough researchers and resource allocation. It could be called a time bomb as there is very little credible epidemiological data that could support effective interventions and evidence-based strategies (Padidar et al., 2023). It is estimated that there are half to six million snakebites annualy with 2.5million cases of documented envenomation and an average of 81,000 to 138,000 deaths occurring each year.(Kungtu et al., 2023; WHO, 2019).

On the continent of Africa, snakebite morbidity and mortality rates are acutely high. Kenya is one of the countries that harbor a great number of the venomous snakes that are not seen and have been in the area. The county of Baringo is considered as one of the hardest hit and cases of envenomation are high in the farming and pastoralist communities. The victims are usually in distant areas without access to life saving antivenom, thus they cannot be helped with a working antivenom (Coombs et al., 1997).

Snakebites have big socioeconomic and health effects in Baringo. In most cases, the victims are left with long-term disabilities, amputations, and psychological traumas besides the financial strain of treating themselves (Omara, 2020). The commonest population affected with cases of snakebites is the rural population who have the high-risk occupations include herding, farming, and firewood collection. On top of the above, the poor housing situation, absence of protective clothing and insufficient knowledge of the prevention and first aid of snakebite makes these people particularly vulnerable.

On the one hand, antivenom (AV) is not accessible and not naffordable despite the high prevalence rate of most cases in low- and middle-income countries. low stock level in the health facilities has made many victims to seak an alternative way of using traditional herbs to treat themselves. Nevertheless, being culturally important, these remedies are usually not effective in their clinical value, and they are not proved scientifically (Simpson & Norris, 2009; Omara, 2020). Moreover, antivenom should be done within six hours of the bite to work, but most victims in rural areas would miss the period because of delayed service due to bad road networks.

Meanwhile, the issue of human-wildlife conflict (HWC) has grown to be a rather urgent one in places like Baringo. The encounters between man and wildlife have been aggravated by the spread of human population into the wildlife habitats coupled with erratic climatic changes. Such encounters often lead to both injury and lifelong impairments and also result in deaths, which places an additional burden on the health and overall socioeconomic conditions of a particular region .The Nature and Extent of Human-Wildlife Conflict Effect on Socio-Economic Development and Educational Development in Baringo North Sub-County,Kenya is high.

The epidemic of snakebites in response, the World Health Organization initiates a global strategy that targets the decreasing death and disability caused by snakebites by half in 2030. This goal can be accomplished by increasing available, affordable, and effective antivenom availability in most heavily affected areas. It will require realistic, regionally specific answers that combat both short-term access to treatment and long-term prevention, such as community education, enhanced data surveillance, and fortification of the health system (Padidar et al., 2023; Bravo-Vega et al., 2023).

To provide its own share in this global campaign, the African countries should invest in finding and addressing the underlying reasons of the inaccessibility of antivenom and create robust, evidenced-based measures that will target the root causes of high snakebite rates and establish it as an important, even though, silent global killer. In other parts of the country, such as Chemalingot in Baringo County, both the number of snakebites and the fatality make it critical to implement timely responses in the area, to educate the communities to strengthen their resilience, and to find more effective remedies to increase availability in the region.

1.2 Snakebite Morbidity in Chemalingot, Baringo County

Snakebite morbidity can be interpreted or deduced as defining the extent of the occurrence of health problems (mainly non-fatal like) which include tissue necrosis, amputation, infection, and long-term disabilities. Snakebite morbidity in Chemalingot, Baringo County is an issue that has taken shape and therefore requires some interventions so that the morbidity can be minimized.

Clinical effects of the snake venom on the human organism as well as those snake species that play the most critical role in causing the severity of the outcomes have been among the primary areas of research in snake bite cases. Chemalingot has high numbers of patients who have visited the local health facilities and some of them have been fortunate to receive timely and efficient medical attention while many others are burdened with the complications caused by failure to receive timely and affordable medical care.

This expanding body of evidence and on-the-ground experience has helped us to understand more about where snakebites occur and what health impact they have on people, as well as how to create specific strategies to reduce the extent of morbidity. Nevertheless, the local communities do not have the enough awareness of the importance of the public health. There are still a lot of residents who do not have an idea about the fundamental snakebite prevention method or the importance of medical attention. Literature education on prevention of snake bites using the correct mechanisms, as well as the potential management of a bite, is of utmost necessity to minimize the total morbidity load of Chemalingot and the Baringo county, in general.

1.3 High Mortality Rate Due to Snakebite in Chemalingot, Baringo County

The mortality caused by Snakebite in Chemalingot, Baringo County is very high and is caused by various risk factors that are relate to each other. These include long delays in accessing medical care, unavailability of antivenom in local health facilities,delayed treatment due to the distance between the local health facilities and the referral hospitals and the condition of the roads and terrain.The problem is further compounded by lack of qualified personel who can diagnose and treat the patient on time. Most of the deaths take place before the patients access medical facilities and many of them die due to poor treatment when they already access the facilities.

Retrospective analysis of the data in the inpatient units at Chemalingot Sub-County Hospital shows that there are many cases of snakebite compared to the actual cases reported. Out of those that have been recorded since January 2018 to October 2024, males comprise about 57.7 percent of the victims with most of them being individuals aged about 17 years. These figures show that young individuals who are socially and economically active in the community mostly the males who work outside in the fields farming and in the herds are vulnerable to snakebites.

Use of traditional remedies also fuels the problem of mortality burden since treatment is usually delayed in case of serious interventions. Families in most instances visit clinics when the symptoms are serious, which is too late considering that the effective time when family members can receive antivenom therapy has elapsed. In addition, the level of community awareness on snakebite preventive strategies and emergency care is low.

This will need a multidimensional solution, which involves better surveillance and reporting mechanisms, decentralization of antivenom distribution as well as the mobile health services alongside locally appropriate public health campaigns. We are attempting to determine the underlying factors that contribute to the high mortality in Chemalingot and our research could be used to direct the current and future efforts to minimize the impact of snakebites as a burden.

1.4 Statement of the Problem

Snakebite envenomation in chemalingot,baringo county is a daunting and under-recognized public health problem. The hot and brushy nature of the terrain in the region makes it habitable with venomous snake species. Although snakebites are categorized as neglected tropical disease, there is poor documentation on the epidemiological burden of snakebites in Chemalingot and thus poor preparedness and response to snakebites by the health system.

The risk of serious complications has been aggravated by such contributory factors as delayed medical care, limited availability of antivenom, and general use of traditional medicine.

At the county-level reporting, it was estimated that about 20 percent of the Chemalingot population has a member who had been snake bitten and 5 percent of the population has no idea on where to get antivenom. The situation with snakebite in Kenya has been gradually getting worse because of the harsh climatic condition, animals are encroaching farms and even houses and families to seak food and water due to food shortages in the drained forests. All these pressing imposes a crisis on the snakes compelling them to move closer to human habitat. To add to that, the delay which is characteristic in treatment gives the venom a chance to spread unnoticed in the body. When the victim arrives at a health facility, some of the patients already experience signs of muscle paralysis, and recovery becomes difficult or impossible (Tianyi et al., 2024). After decades of global anti-snakebite campaigns by the World Health Organize, other Non-Govermental Organization, as well as the endemic countries themselves, the number of under-reported cases (never mind under-treated or under-recovered victims) remains high in villages and outskirts such as Chemalingot.

We lack good all round local research on what exactly causes complications of snakebites in our area. Lacking that information we can hardly implement prevention measures or treatment approaches that are appropriate to our local setting. In case we desire to lighten the disease load of the snakebites, we have to identify the key causative factors that contribute to such complications first. This is why the present research employs a multivariate statistical design to outline the risk factors of snakebite morbidity in Chemalingot.This study will help determine more effective health interventions, policymaking, and planning in snakebite-affected areas of Kenya.Providing the evidence since the concept of morbidity will be defined as the dependent variable, and several independent predictors like the time to treatment, the timing of the bite, the distance to healthcare, and the socioeconomic status will be studied

1.5 Objectives

1.5.1 The General Objective:

To assess the risk factors associated with morbidity due to snakebite in Chemalingot, Baringo County, Kenya, using a retrospective design and multivariate analysis.

1.5.2 Specific Objectives

(i) To determine the prevalence rate of morbidity due to snakebite in Chemalingot, in Baringo County, Kenya using Retrospective design.

(ii) To develope a multivariate regression model for predicting the odds of morbidity following a bite and to determine the risk factors associated with snakebite in Chemalingot, in Baringo County, Kenya.

(iii) To Evaluate the model performance of the Logit multivariate model using Receiver Operating Characteristic (ROC)and the cross-validation method

1.5.2 The Study Hypotheses

H_{01}:The prevalence of morbidity due to snake bite is higher in Chemalingot when compared to other parts of the country, in Kenya

H_{02}: Severe significant factors affect morbidity due to snake bites in Chemalingot in Baringo County, Kenya. n

H_{03}:Model performance for morbidity due to snake bite will be good and better with use of ROC and cross-validation method in chemalingot, in Baringo County, kenya.

1.6 Justification of the study

Snakebite envenoming is an acute and poorly addressed health problem especially in low resource sub-counties like Chemalingot in Baringo County, Kenya. The majority of the public-health interventions begin as one-size-fits-all solutions, and that is great in most regions, but it does not work in rural African areas. As an example, Chemalingot, Kenya, does not have a disaggregated set of data and comprehensive analysis of what causes snakebite morbidity. The little research that has been done concentrates on death rates or on Epidemiological patterns, that is, who gets bitten and where, but not on how many victims are left disabled, infected or with costly long-term therapy. Researchers tend to mention such factors as delayed treatment and the access to antivenom, but they never compared the above-mentioned issues with the situation in Kenya itself. That context vacuum leaves a huge vacuum in the effort of developing evidence-based public-health responses.

In Chemalingot, new wave of snakebites breaks every season. Most of the time, health care is hard to access, even without considering the price. The fact that there is such a gap in the real world is why the data-driven research described below is needed. Multivariate statistical analysis will allow in determining what socio-demographic, environmental, healthcare-related risk factors are actually important. This will provide a good framework going forward in terms of planning and policy formulation at county level.The findings will be significant and enable local health officials, community workers, and policymakers to design concrete interventions that can reduce snakebite complications, enhance health outcomes, and assist the WHO in achieving its objective of reducing the number of snakebite victims by 50 percent by 2030.

1.7 Significance of the Study

The goal and role of the study is to confirm and to evaluate the Risk factors associated with snakebite morbidity and mortality in Chemalingot. This will help the locals and those vulnerable people to know on how to handle the challenges of snakebites and incase of any Incidence there is way out to ensure that the patient is saved.

Also to model main Risk factors which has raised the morbidity of snakebite by confirming the main factors that has led to this morbidity and mortality due to snakebite.

1.8 Knowledge Contribution

This research work plays a pivotal role in explaining the morbidity of snakebite in the rural areas of Kenya because it gives a combination of theoretical, empirical, and practical aspects. I just hit the same wall over and over: whenever we went to literature on neglected tropical diseases in low-resource settings, the evidence seemed sparse. Then i found Chemalingot, a dangerous disease which has been dismally under-researched. Taking Chemalingot as a case study we can draw together context-specific data that did actually make a difference to the evidence base.

1.8.1 Theoretical Contribution

In the frame of scholarly debate, this paper demonstrates that the epidemiology and the public health paradigms are important instruments of studying the neglected tropical diseases and, specifically, snakebite envenomation. In so doing, it stretches the theoretical concept that socio-demographic and clinical variables combine and turn into determinants of morbidity. Further on, the paper indicates the role of time-sensitive interventions and health systems theory in the construction of models of access to care among underserved rural populations.

1.8.2 Empirical Contribution

In our research, we calculated a series of empirically based estimates of incidence, severity and risk factors underlying morbidity due to snakebite in Chemalingot, Baringo County, which seldom appears in published epidemiological databases. What we discovered is rather straightforward: the time of arrival at the hospital, the length of stay in the hospital, the time of the day during which a bite occurred all can be used as measurable predictors of how poorly the bitten individual will do. Morbidity prevalence of 30.0 percent is denoted, and the fact that patients receiving care with more than 12 hours after the bite increases the risk of complications by three times. Such intuitions create new and evidence-based knowledge which can be quantified and can be generalized to similar rural environments.

1.8.3 Practical/Policy Contribution

In practical and policy terms, the research has practical recommendations that can be used as guiding in planning and response to snake bite in the endemic regions. The problem of identification of high-risk periods, delays in treatments, and the low availability of antivenom helps companies design the community-based awareness measures, decentralization antivenom effects, and early referral systems. The research is also in line with the global strategy adopted by the World Health Organization to reduce by two-thirds mortality and morbidity due to snakebite by 2030 which includes locally-based recommendations capable of assisting Kenya to contribute toward achieving this global health objective.

CHAPTER TWO

LITERATURE REVIEW

2.0 Background Information

2.1 Theoretical Framework

2.1.1 Ecological Niche Modelling and Snake Distribution

It is also known as either Species Distribution Modelling (SDM), or Ecological Niche Modelling (ENM), and the hypothesis is that changing and varying environmental factors, typically climate, vegetation, elevation, and land cover, have a significant effect in both distribution and abundance of venomous snake species. All of these biophysical conditions together determine the appropriateness of a habitat to the survival, reproduction and dispersal of a snake (Yanez-Arenas et al., 2014).

Baringo County is a semi-arid county with sparse vegetation and wide fluctuations in elevation, which forms an ecologically appropriate habitat to poisonous snakes. In this county, Chemalingot is a high-risk, underpopulated area whose interaction patterns between natural habitats of snakes and human activities(e.g, herding, farming) are very high. Such interactions are heightened by the presence of environmental stressors(i.e,drought, deforestation),that cause snakes to be in closer contact with human settlements

Figure 2.1 is a representation of the ENM process wherein it depicts the incorporation of the environmental variables and the species occurrence data to coming up with the habitat suitability maps. Such maps are useful in forecasting the regions where the presence of snakes as well as a potential of human stride conflict is high especially in areas such as Chemalingot Baringo County.

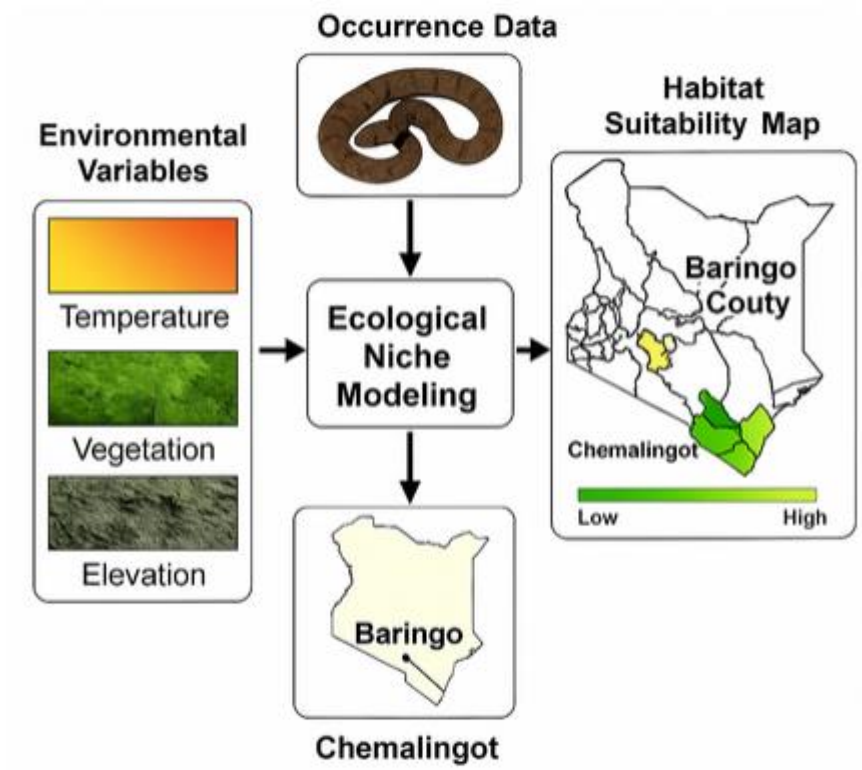


Figure 1: ENM Process for Venomous Snake Distribution in Baringo County, Kenya.

2.1.2 Human-Environment Interaction Theory and Snakebite Risk

Human-Environment Interaction Theory is a prism of interpreting human-environment interactions into the risk factors in illnesses and diseases like snakebite envenoming. The theory assumes that human interactions through land-use, settlement growth, and use of natural resources have constant interactions with ecological processes and it is thus through the interaction that it creates exposure as well as vulnerability to environmental hazards.

Recent reports have been showing that cases of snakebite are directly related to poverty and climate effects especially via the El Nino Southern Oscillation (ENSO) events. Such effects of climate on the environment impact rainfall, temperature, and prey position, which modify snake activity and movement and predispose people to human-snake interactions (Chaves et al., 2015). Kenya has recorded the same trends with extreme weather associated with displacement of snakes due to droughts and floods in their burrows leading to closer human settlements.

The other big contributor to the risk of snakebites is land-use change. The activity of cutting down trees and clearing of bushes to cultivate crops or enter into the natural habitats of the snakes has been found to contribute to more snake-human encounters. The researchers also indicated that snakebite incidences were high compared to other areas where locals had cleared forests to develop farming in South Korea (Koo et al., 2002). Such results apply to the situation in rural Kenya, such as Chemalingot, where the loss of vegetation and the distribution of fragmented habitats is common.

Also, Ecological Niche Modeling (ENM) has been used to make strong statistical verifications on the prediction of the risk of snakebites depending on environmental and climatic factors. ENM uses occurrence data on species in combination with environment variables (e.g., elevation, temperature, vegetation) in order to pinpoint the locations of high habitat suitability for venomous snakes. Yanez-Areas et al. (2014) claim that this modeling is necessary in terms of establishing spatial risk zones and predicting the climatic changes in snake habitats. The semi-arid climatic conditions, bushy areas and low population densities in Chemalingot are similar to high-risk parameters determined by ENM.

Moreover, the climate change and degradation of the habitats is aggravating the issue in Kenya. Recent report by Xinhua News Agency (2025) pointed out the extent to which snakes are encroaching into human settlement in both rural and low-income regions due to increasing temperatures and changes in land use practices. All these ecological alterations elevate the rates and extremities of snakebite incidences, which points to the significance of joined-up, total health, and environment measures (Bhaumik et al., 2022).

To synthesize such interactions, the conceptual framework in Figure 2 can be based on Human-Environment Interaction Theory. It shows how the interaction between climate changes (e.g., ENSO events) and land use patterns (e.g., agricultural intensification, deforestation) combine with ecological suitability to increase the risk of human /snake interactions. These dangers are heightened in vulnerable locations like Chemalingot, where there is a high level of environmental disturbances and the setup of infrastructure is poor. The ENM is incorporated into the framework to demonstrate the potential of the environmental factors, such as temperature, altitude, and vegetation in determining areas with the most favourable conditions to snake habitation. It is a method of active detection of the hotspots of snakebites, which leads to the design of not only public health observation but also local intervention.

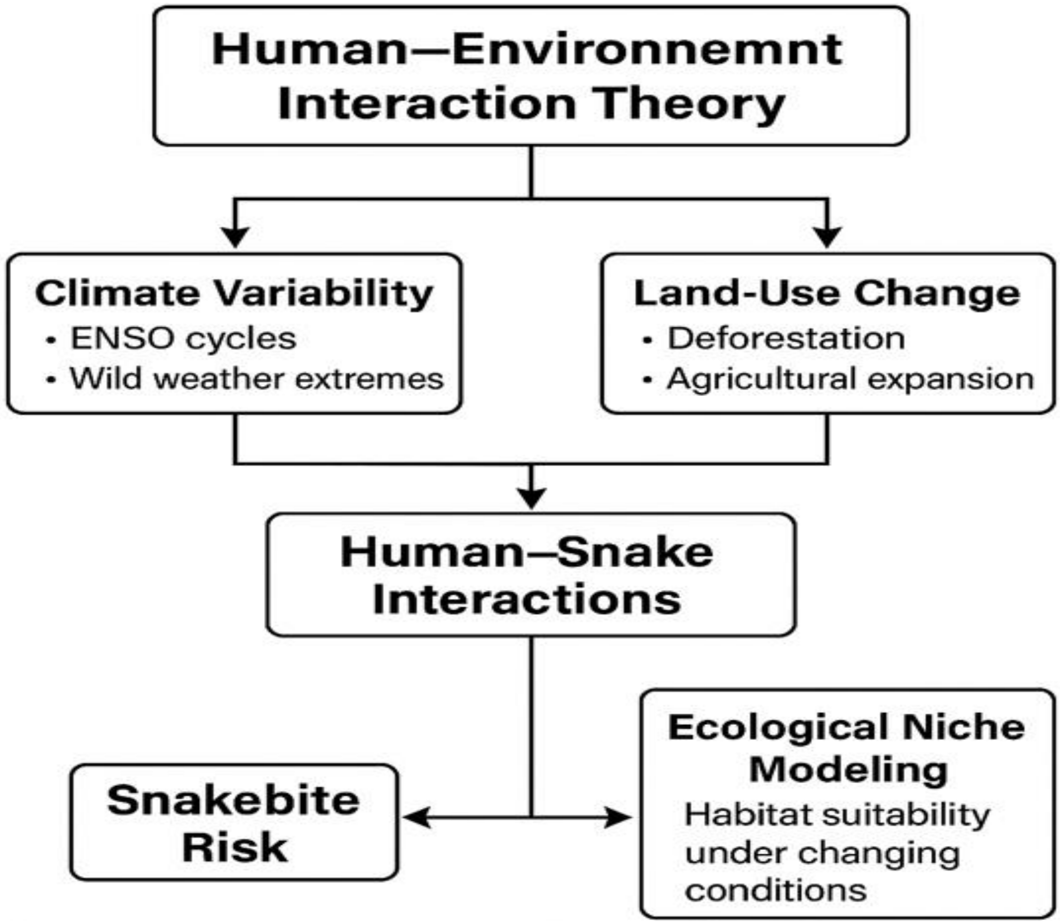


Figure 2: Conceptual framework illustrating the relationship between environmental variables, human activity, ecological niche modeling, and snakebite risk (adapted from Human–Environment Interaction Theory).

This framework is particularly useful in Chemalingot, because ecology in a rural setting, the land-use activities in the area, and poor access to health facilities, coupled with poverty, create a synergetic effect of contributing to an unusually high morbidity of snakebite. People tend to be farmers or herders in bushy regions, which are well-known to be infested with venomous snakes, and most of them share beds in the old-style houses with low structural protection. This combination of socio-environmental realities with delayed hospital care or lack of availability of antivenom increases vulnerability. These circumstances are another proof of the usefulness of a theoretical model that takes into consideration not only ecological pressure but also a pattern of human behavior.

Moreover, the framework does endorse a multi-sectoral response consisting of environmental management, public health, and community education as the key to the burden reduction of snakebite. Using this theoretical knowledge in epidemiological modeling and the design of health policy may allow prioritizing of regions such as Chemalingot, where measures such as the availability of antivenom, mapping of risk, habitat management, and education may be most effective. Thus, by improving conceptual clarity, as well as offering a practical perspective on action in snakebite-endemic areas, the Human-Environment Interaction Theory also serves as a lens, although a less abstract and grandiose one, through which one can better envision how to act in snakebite-endemic locations

2.1.3 Social-Ecological Model of Health and Snakebite Risk

The Social-Ecological Model of Health (SEM) provides a broad framework for examining the various levels of influences that lead to good health. The SEM, originally elaborated to deal with non-trivial community health problems like violence, obesity, and infectious disease (Bronfenbrenner, 1977; McLeroy et al., 1988), is now broadly implemented in neglected tropical diseases, and snakebite envenoming is not an exception. This model acknowledges the fact that not only personal choices shape individual behaviors but also interpersonal factors, community factors, organization factors, and societal factors among others. The SEM can also be applied in the context of snakebite risk in Chemalingot in the sense of how its layers of influence are linked together to result in morbidity as follows:

2.1.3.1 Individual Level

On the individual level, age, occupation (e.g., herding or farming), knowledge of snake and snakebite first aid, and a choice whether to follow traditional or biomedical care all have a significant effect. As an illustration, outdoor working may increase the risks of adolescent boys and adult male farmers of Chemalingot who do not wear protective clothing (Kipkemboi et al., 2023).

2.1.3.2 Interpersonal Level

The manner in which snakebites are treated depends on the family beliefs as well as the influence of peers. Herbal remedies are commonly used, and many families in Chemalingot take long before seeking medical attention at the hospitals and this contributes to the development of complications. Snakebite control in low health literacy households is usually referred to local elders or traditional healers.

2.1.3.3 Community Level

The topographical setup of Chemalingot characterized by bushy lands, lacking proper infrastructure, and having a scattered location, enhances the risk of the community. Lack of access to transport, most especially at night, usually means treatment is delayed. In addition, community standards can emphasize traditional medicine instead of formal healthcare based on affordability, availability, or harmony.

2.1.3.4 Organizational/Institutional Level

The local health facilities in Chemalingot at the organizational level tend to lack trained members and functional triaging system as well as sufficient supply of antivenom.

According to the facility reviews, there are cases where basic emergency kits of snakebite are not available in some dispensaries and sub-county hospitals, which restrict the effectiveness of the response (Ministry of Health Kenya, 2024).

2.1.3.5 Policy/Societal Level

Lastly, snakes bite preparedness has always been low-funded nationally and at the county level of health policies. The distribution of antivenom is irregular, and information on snakebites is not very often included into the health information systems. In Kenya, the process has been disjointed despite the roadmap that was outlined by the WHO aimed at reducing the incidences of snakebite mortality and disability by half by the year 2030 (WHO, 2019; Tianyi et al., 2024).

To explain the way these levels, interact, the diagram of theoretical Social-Ecological framework used in Chemalingot snakebite morbidity is presented as Figure 3 below. This imagery serves to highlight that the causative role of individual, social, and structural factors is cumulative in what shapes health outcomes, emphasizing the importance of the integrated and multi-level response. The model concentrates on the individual, the relationships and interactions between people, community, organization.Policies are factors that affect individuals behaviors and risk exposure (e.g., reliance on the traditional knowledge, geographic isolation and exposure to the environment.Availability of antivenom, health services, and the priorities and emergency response systems are some examples of policy determinants that influence individuals behavior and risk exposure).

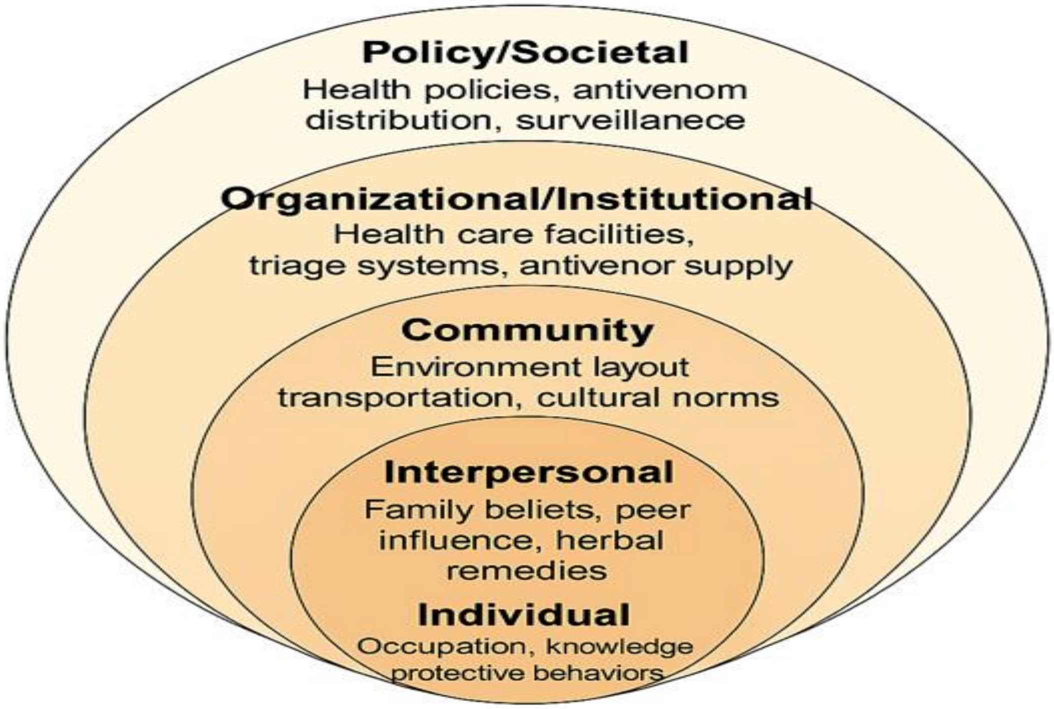


Figure 3: Social–Ecological Model of Health and Snakebite Risk in Chemalingot

The cascade of layers in Chemalingot gives an idea of why snakebite cannot be considered eliminated as a public health problem, especially in the vulnerable groups who are rural farmers and herders. The figure gives prominence to the fact that a multisectoral approach of prevention of morbidity on snake-bite at all levels is necessary, including individual protective measures and community education, health system and local health system, and policy level as well.

2.2 Snakebite as an emerging public health issue

2.2.1 Global burden of snakebites

Snakebite envenoming (SBE) is a world health issue that is underreported although it continues to significantly challenge the citizen populations in low- and medium-income areas in regions such as Asia, Latin America, and sub-Saharan Africa. It is worth noting that India is the highest snakebite-reported case and death in the world (Bawaskar,

Bawaskar, & Salvi, 2021). Snakebite envenoming is a neglected tropical disease as recently acknowledged by the World Health Organization (WHO), despite the issue entailing a high disease burden in public health.

Another vital obstacle to the management of SBEs is the lack of accessibility and availability of antivenoms (AVs), in particular, in rural health clinics. This is an indication of market failure since the check on availability of its distribution through manufacturing with great expense and low profit margins has caused manufacturers to be unwilling to bring it to extensive distribution especially in impoverished locales (Chippaux, 2008). Subsequently, most of the rural institutions have no capacity to handle snake bite emergencies which contribute to both clinical and economic burden on the people afflicted.

Moreover, the scope of snakebite crisis is underestimated. It is also underreported in undeveloped and underserved areas where victims in these areas prefer to seek the help of traditional healers rather than go to a formal medical facility. This is exacerbated by the fact that the victims are socioeconomically invisible and they are usually farmers, herders, and children in poor households making it to geographic and economic access (Bawaskar et al., 2021). The absence of surveillance systems on the whole also contributes to the poor perception of the actual impact of SBE on the globe.

The snakebite threat has been further advanced by environmental changes. Climate change and climate variability have caused many species of venomous snakes to move towards human population, due to changing rainfall, increased temperature and disruption of an ecosystem. Indeed, recent East-African research findings establish that climatic-induced habitat changes are escalating the snake-human encounters (Gololo, Otieno, & Chebet, 2025). On the same note, the occurrences of land-use changes, including deforestation and agricultural land expansion have enhanced such encounters, especially in those terrains that are experiencing high rates of ecological degradation (Koo, You, & Kim, 2002).

The other problem has been the wrong identification of snakes at the site of bite. Proper identification is the key to proper administration of the antivenom and clinical management. Nevertheless, not all victims and caregivers possess the needed knowledge, and it can slow down and wrongfully orient the treatment process. Enhancing community awareness and first-aid approaches also serves as an essential trait of an overall SBE solution (Aron et al., 2025). Confirmations that the risk of death and disablement can be drastically minimized by the timely administration of antivenom (preferably within six hours) are affirmed (Suraweera et al., 2020).

India has been known to have a wide spread of SBE, which in most cases lead to dire complications like oedema, necrosis, and systemic hemorrhage. Unluckily, the victims in villages will often not find the advanced treatment facilities easily (Bawaskar, Bawaskar, & Bawaskar, 2017). Traditional herbal medicine still remains very important in such settings. Ethnobotanical knowledge is used in many communities as a form of offering instant (although unconfirmed) relief. The local herbalists are in most instances the first respondents because they are closer to victims and the formal health services are not accessible easily (Dey & De, 2011; Upasani, Beldar, & Raut, 2017).

Finally, data-driven locally adaptive interventions are needed to achieve the WHO goal of achieving a fifty percent reduction in snakebite mortality and morbidity by 2030. They should encompass surveillance investment, health education, access to antivenom, and the research on using plants as an alternative to complement emergency response in underserved communities (Patikorn et al., 2022).

2.2.2 Snakebites in Sub-Saharan Africa

Several snake species found in Sub-Saharan Africa (SSA), including puff adders, saw-scaled vipers, and spitting cobras, are among the most venomous and aggressive worldwide and contribute much to the high burden of envenoming in the area (Upasani et al., 2017; Gutierrrez et al., 2017). Yearly, it has been predicted that 30,000 to 50,000 snakebites happen in SSA, including substantial rates of sickness, death, and chronic disability in specifically rural, low-income, and agriculturally reliant populations (Hamza et al., 2016 Farooq et al., 2022;).

There is also a gender and age vulnerability. The disproportionate risk applies to young male adults, herders, or farmers, and labourers, who tend to engage in outdoor activities in most bushy and high-risk localities and have limited access to protective equipment (Gutierrrez et al., 2017). Children are also vulnerable because they have a small body size and a lower physiological toleration to venom, which may aggravate outcomes in case medical help arrives with a delay.

However, in spite of this being a national health crisis, only a single country of the SSA region produces antivenom (AV) today, leading to serious constraints with the supply chain (Chippaux et al., 2019). The cost of production, short shelf life and geographical variations of the venom further lower interests of the pharmaceutical industries to invest into AV production. This means that the majority of the AVs are imported and hence at a high price and with little specificity to the region which influences their effectiveness and affordability in the majority of health facilities in rural SSA (Fox et al., 2006).

Moreover, most of the snakebite cases are not reported because of geographical isolation of health facilities, absence of surveillance systems and cultural preferences of traditional healers. In most societies, traditional medicine serves as primary treatment and is one of the reasons behind delayed clinical care and eventually higher chances of mortality and complications (Williams et al., 2011). Such delays are combined by the absence of trained personel and emergency facilities in rural healthcare units (Ministry of Health Kenya, 2024).

The economic cost associated with snakebite envenoming is enormous and the affected households are forced to spend time in hospitals, lost days of productivity and remain permanently disabled or dead. Low- and middle-income countries (LMICs), which are already struggling with non-communicable diseases (NCDs), cannot prioritize snakebite and focus their attention on such a public health issue (Willie et al., 2024).

The World Health Organization (WHO) has in turn classified snakebite envenoming (SBE) as a Neglected Tropical Disease (NTD). Global strategy targets to reduce doubled deaths and disabilities caused by snakebites by 2030 or, in other words, it is imperative to expand AV access, train more people, understand the necessity to enhance the education of communities (WHO, 2019). Although these are international initiatives, the usage of AVs is unequal. As an illustration in West Africa, vipers contribute to about 67 percent of envenomings which in most cases lead to systemic hemorrhage and coagulopathy. But in the rural hospitals, this availability of effective AVs is strictly limited (Hamza et al., 2016).

In a positive direction, a number of non-governmental and cross-national programs, including the Médecins Sans Frontières (MSF) and the EchiTAb Plus-ICP project, have intervened to enhance antivenoms access and medical education in SSA. In the meantime, the current studies and technological developments, including the use of mobile phones to report snakebites, community-based learning, and low-cost polyvalent antivenoms, are the potential solutions that can transform the response in high-burden settings (Patikorn et al., 2022).

Understanding snakebites in ChemalingotIn Cases of snakebite have continued to be a significant part of the public health issue in Chemalingot, Baringo County as a result of environmental, behavioral and systematic issues with health. Patients are often admitted to health institutions after undergoing other conventional methods of treatment which can lead to delayed responses in the severity of envenoming. Such a delay is a major deterrent to recovery and a predisposing factor to long-term disability or death.

Uncleared bushy, dwindling rainfall and increased human intrusion into the environment has prompted snakes with venom to move near people and in some cases the snakes have found their way into the houses in search of food and shelter. Children and farmers, especially those working or playing outdoors are most affected. As a study conducted by the health officers in the Tiaty Sub-County (2019) showed that, Chemalingot was one of the most affected ones as the cases were multiple in various health centers (18 in total). Most frequent situation were the cases of snake bites occurring in the process of gathering firewood and during the herding of cattle.

In other parts of the world, the Myanmar Snakebite Project. (2019) has demonstrated the benefit of enhancing the production, access, distribution, and healthcare capability in victimized nations. Such programs served as a lesson to Chemalingot whereby the few health facilities that stock AVs do so on a regular basis. The authors argue that inconsistent availability and distribution of antivenom is among the most crucial issues when addressing the snakebite occurrence in Kenya (Okumu et al., 2024).

Also, the socioeconomic factors still affect the treatment decisions. A survey conducted in Baringo South revealed that a population that had low income especially residents of earthen or thatched houses had a tendency to seek traditional remedies in treating snake bites (Kungu et al, 2023). These remedies sometimes are able to relieve the patient temporarily, but rarely are enough to control envenomation and they can be a cause of preventable complications.

This study thus forms the risk contributing factors of snakebite morbidity in Chemalingot, where a multivariate method is employed in order to model the stratified environmental, economic, and behavioral dynamics involved in snake bite treatment results.

2.3.1 Venomous Snake Species and Their Clinical Implications in Chemalingot

The species composition and that of the venom of snakes in Chemalingot is crucial in determining the direction of clinical management and also education that must be adopted by the people. Various dangerous snakes that are medically important in the area are puff adder (*Bitis arietans*), black mamba (*Dendroaspis polylepis*), and Egyptian cobra (*Naja haje*). Various types of venom (cytotoxic (e.g. puff adders), neurotoxic (e.g. black mambas) and hemotoxic (e.g. some cobras)) are produced by these species, and thus cause varied clinical manifestation that includes tissue necrosis and paralysis, as well as, major internal bleeding. The puff adder bites are associated with cytotoxic effects that may cause debilitating long-term injuries and usually lead to amputations.

On the other hand, neurotoxic envenoming, which is common in black mamba bites, needs very fast administration of anti-venom because this condition can lead to death through respiratory arrest in less than 24hours. The presence of the neurotoxic species increases the threat of mortality especially in a rural setting such as Chemalingot where people may take too long to access the health facilities. Irrespective of their deadly nature, there is little domestic ability to properly diagnose the kinds of species that cause the bite which makes treatment more difficult. Consequently, ecological mapping, as well as species-specific treatment training are two very important parts of an effective snakebite management plan in Baringo County.

Table 1: Summary of Medically Important Snake Species in Chemalingot and Their Clinical Profiles

Snake Species	Common Name	Venom Type	Primary Clinical Symptoms
Bitis arietans	Puff Adder	Cytotoxic	Local tissue necrosis, swelling, blistering, severe pain, possible amputation
Dendroaspis polylepis	Black Mamba	Neurotoxic	Rapid onset paralysis, respiratory failure, ptosis, dizziness
Naja haje	Egyptian Cobra	Neurotoxic & Cytotoxic	Flaccid paralysis, ptosis, vomiting, necrosis at bite site
Naja nigricollis	Spitting Cobra	Cytotoxic	Conjunctivitis (if spit in eyes), local necrosis, blistering
Atractaspis irregularis	Mole Viper (Stiletto)	Cytotoxic	Deep tissue damage, edema, slow-healing ulcers

Echis pyramidum	Carpet Viper	Hemotoxic	Bleeding (gums, urine), hypotension, blood clotting disruption

Notes:

1. Cytotoxic venom primarily affects cells and tissues at the bite site, often leading to swelling, necrosis, and long-term disability.

2. Neurotoxic venom interferes with the nervous system, potentially causing fatal respiratory paralysis if untreated quickly.

3. Hemotoxic venom impacts the cardiovascular system and blood clotting, which may result in internal bleeding and organ failure.

2.3.2 Socio-Demographic Dimensions of Snakebite Vulnerability

Risk to snakebite is not evenly spread across the populations. As opposed to it, it is marked by multifaceted tendencies of vulnerability against age, gender, socioeconomic status. These dimensions are also important in ensuring that interventions and public health responses are highlighted in high-risk locations or regions like Chemalingot, Baringo County.

Age-Related Vulnerability

Children and the elderly are the most at risk of serious consequences of snakebites. Venom spreads faster in a child with less body mass and the symptoms of the systemic manifestation are quicker and with more lethality. This exposure is also enhanced by their tendency to turn over quest curiosity making the outdoor environment a risk factor. Separate morbidity among elderly people can be high, as in the case of pre-existing health condition and slow mobility. According to the investigations carried out in Kenya and other Sub-Saharan countries, the aged group most exposed to the snakebites consequences extends between 10 to 25 years old. The people most actively involved in outdoor routine activities and working in the fields (Oloo et al., 2018; Kipkemboi et al., 2023).

Gender Risk Exposure

Gender is a significant factor that has shaped the pattern of exposure to snakebites. Men have a high preference in Chemalingot because they are involved in risky outdoor activities like herding, farming, and charcoal burning. Nevertheless, there is also much danger at hand with women due to domestic and peri-domestic setups when they are gathering water, firewood or attending to farms close to their homes. Cultural needs might constrain females from seeking medical services in time and postpone of making decisions can delay the medical care.

Socioeconomic Dimensions

Low-income earners who dwell in mud housed with thatch roofs that allows entry of snakes through holes thematic walls tend to be in houses that are structurally weak in Chemalingot. The healthcare access is limited because of the lack of funds which results in using old methods of healing and waiting too long to take a proper antivenom. Transport costs and wage losses are included in indirect costs that are contributors to the financial load, which, further, aggravates poverty in negatively affected families.

Table 2: Demographic Groups and Corresponding Snakebite Vulnerability Factors

Demographic Group	Risk Factors
Children (0–14 yrs)	Play outdoors, low body mass, lack of awareness, poor supervision
Youth (15–24 yrs)	Herding/farming activities, poor access to protective gear
Elderly (65+ yrs)	Reduced mobility, limited access to transport and treatment
Women (All ages)	Domestic exposure, delayed healthcare-seeking, cultural decision constraints
Low-income households	Inadequate housing, reliance on traditional remedies, healthcare inaccessibility

2.2 Taxonomy and Classification of Medically Important Snakes in Chemalingot.

Taxonomic knowledge in venomous snakes is important to efficient clinical care, antivenom application and surveillance of good public health. Taxonomy is the classification of organisms into categories: each category into subcategories: each subcategory into subcategories. and so on. All in accordance with the common physical and genetic features. Snakes are classified as phylum Chordata, class Reptia and order Squamata with medically important snakes belonging to three groups, including Elapidae, Viperidae and Atractaspididae (Warrell, 2010).

In Chemalingot and the wider Baringo County, the burden of snakebite is mainly attributed to venomous snakes which flourish in semi-arid setting and rugged landscape. Precarious human-snake encounters are reported because of the location of the human settlements closer to the natural habitat of snakes, deforestation, and low levels of awareness on snake safe practices.

Table 3: Taxonomic Classification and Clinical Relevance

Family	**Example Species (Chemalingot)**	**Venom Type**	**Primary Clinical Manifestations**
Elapidae	Dendroaspis polylepis (Black Mamba), Naja haje (Egyptian Cobra)	Neurotoxic (± Cytotoxic)	Respiratory paralysis, ptosis, dizziness, local necrosis (cobra bites)
Viperidae	Bitis arietans (Puff Adder), Echis pyramidum (Carpet Viper)	Cytotoxic or Hemotoxic	Tissue necrosis, internal bleeding, clotting disorders, hypotension
Atractaspididae	Atractaspis irregularis (Mole Viper)	Cytotoxic	Deep tissue necrosis, edema, and slow-healing ulcers
Colubridae	Philothamnus spp. (Green Snakes)	Mild or non-venomous	Rarely harmful; mild irritation if bitten

Note: The Puff Adder and Spitting Cobra are the major causes of morbidity of snakebite in

Chemalingot as shown through facility reports and similar surveys conducted among the locals (Oloo et al., 2018; Kipkemboi, Ruto, & Chesire, 2023).

The geography of Chemalingot which is composed of arid scrubs, sparse rock formations, and poorly built households presents perfect hiding and breeding locations of snakes. Residents are likely to report cases of snakes in the house that found their way through the drainage system, roofing or under the door, particularly when the dry spell is elongated, or it is the night time.

In Chemalingot, the main causes of death that are preventable are jacket of treatment and mistaken identification of snakes (Ministry of Health Kenya, 2024).

```
Kingdom: Animalia
 └── Phylum: Chordata
      └── Class: Reptilia
           └── Order: Squamata
                └── Suborder: Serpentes
                     ├── Family: Elapidae (Cobras, Mambas)
                     ├── Family: Viperidae (Vipers, Adders)
                     ├── Family: Atractaspididae (Stiletto Snakes)
                     └── Family: Colubridae (Non-venomous/Mildly Venomous)
```

Figure 4: Taxonomic Classification of Medically Important Snakes in Chemalingot

Figure 5: Different types of Snakes

It is clear and known that snakes are everywhere, specially forested areas and rocky places. Also, some snakes exist in rivers, lakes and oceans. There are many types of snakes as shown in Figure 5. Some are poisonous and causes death due to venom. These snakes are majorly in Baringo county and are poisonous.

2.3 Snakebite Morbidity and Mortality in Kenya and Baringo County

Following the global situation described in the introduction, the pressure of snakebite envenoming in resource-limited environments such as Baringo County is compounded by various local dynamics. Research carried out on residents of Baringo show that with poor access to medical institutions, a low level of antivenom stocks, and the use of folk medicine, morbidity and mortality rates remain high (Oloo et al., 2018; Kungu et al., 2023). Although national programs like Kenya Snakebite Emergency Response System (KenSERS) have implemented new solutions, such as low-cost motorcycle ambulances to achieve faster access to treatment (Harrison, 2016), health infrastructural limitations, terrain, and distance continue to present considerable obstacles, as well.

Hospital statistics are not sufficient and underestimates of the true burden snakebite victims, partly because of traditional treatment-seeking strategies and limited access to hospitals in remote areas. In 2015 the KenSERS piloted a mobile telephone activation in the Baringo County that sent out low-cost motorcycle ambulances to transport the victims to hospitals that were more equipped and had trained staff and pharmaceutical antivenoms. Although it makes this intervention successful, geographical issues and uneven supply of AVs remain the major obstacle to its effectiveness.

Oloo et al. (2018) state that a lack of health infrastructure in Baringo adversely affects a timely treatment of a snakebite. Other authors such as Mwanike et al. (2020) also indicate that victims tend to develop permanent disabilities, thereby losing their livelihoods and making their households poverty-stricken. Another area of concern is financial; 2021 report by KEMRI shows that antivenom, hospital stay and rehabilitation are costly to the already challenged families.

Snakebite has been recognized by the World Health Organization as a Neglected Tropical Disease (NTD), and hence the lack of treatment investments, research, and focus in this condition globally. According to a 2018 article in Pan African Medical Journal, the annual snake bite incidence rate in Baringo County is 67.9 per 100,000 and the mortality rate is 0.45 per 100,000. Interestingly, Kungu and Chweya (2020) established that 52 percent of bite incidents are at night whereas 81 percent are either within or directly outside houses. Homes with open windows, doors and utility conduits about the house are likely snake entrance points. Moreover, the practice of herbal medicine among most residents which delays seeking for biomedical care and is approximated at 75 per cent.

Approximately 300 individuals were reported having been bitten by snakes in rural Baringo in December 2018 alone an alarming increase in the cases that largely went unreported providing evidence of the surveillance and emergency response shortcomings. These findings show that strengthening of epidemiological monitoring, availability of antivenom, community education, and health infrastructure should be enhanced to curtail the avoidable impact of snakebite-related morbidity and mortality in Baringo County are greatly needed.

2.4 Multivariate Analysis Approach

Multivariate analysis is an excellent statistical model, which forms a basis of examination and explanation of numerous variables at once, especially in intricate matters of public health like snakebite morbidity. By this method, the researchers can study how various independent variables relate to a certain outcome variable, and in the process, they usually find their patterns that would not have been identified under univariate or bivariate analysis. Backhaus et al. (2021) state that multivariate methods allow a better grasp of the interdependencies between the social, environmental, and biological domains. It will be useful in modeling various covariates that occur in snakebite epidemiology like the time it was bitten, the demographics of the victim, the place where they were bitten, the geographical area, and the pathway of treatment which is commendable in this study.

A multivariate logistic regression model will be especially applicable in this study since it has the ability to predict the outcome of a binary variable i.e., the occurrence or otherwise of morbidity due to a snakebite, using a combination of independent variables. Logistic regression is also versatile about dealing with continuous (e.g. time to treatment, age) and categorical (e.g. gender, species of snake, occupation) explanatory variables. It also provides an opportunity to control the confounding issues that can affect the relationships that were observed among the predictors and outcomes. This is essential in realizing risk profile of snake bite victims in Chemalingot with socio-ecological dynamics playing a major role. Similar to the studies by Habib et al. (2011) and Waldorp et al. (2021), logistic regression has also been prominent in many other studies to determine independent risk variables affecting health.

Missing data in retrospective epidemiological studies is also a major issue, particularly where the main source of data is hospital records. Findings may be distorted by the lack of, or missing, information and may decrease the statistical power. Advice on preliminary diagnostics suggests that missingness be assessed on its extent and mechanism. Based on the pattern and proportion, the researchers may choose to employ a listwise deletion approach, which involves excluding missing cases, and they may also use multiple imputation with chained equations (MICE) when the missingness is seen to be unsystematic (Schafer, 1997,Turhan et al., 2020;). Missing data are addressed in the right way to improve the soundness and trust of statistical conclusions made by recognition of statistical analysis.

When you have ever run a logistic regression, you realize that the validation and the diagnostics phases are the most important steps in determining how reliable and how well the model fits the data. The Hosmer-Lemeshow goodness-of-fit test is one of the go-to checks of fit, as it informs you whether the predicted probabilities and the observed ones are in line. Want to know how good the model is predicting? Draw the Receiver Operating Characteristic (ROC) curve and consider the Area Under the Curve (AUC). The more the AUC, the better. Multicollinearity, which is having too many predictor variables correlated, can be a disaster to your results. The Variance Inflation Factor (VIF) can assist you in identifying it; a huge error VIF is an indication of poor variability in the predictors and indicates bias in the model coefficients. Finally, finally, looking at interaction effects in a multivariate model. One can find some interesting modifiers that can enrich the analysis. An example is that the effect of time beforepresenting oneself may interact with gender to show that the risks of differences in morbidity remain hidden in the main effects model. Likewise, snake species and time of bite (e.g. night vs. day) may reveal discrepancies in the strength of the venom or delays in treatment. Incorporating interaction terms enhances the model explanatory ability and assists in crafting a subtle context-specific interventions in public health (Backhaus et al., 2021). It is especially important that such moderating effects be identified in the environment of limited resources limited, such as in Chemalingot, where any intervention measures need to be efficient and selective.

Consequently, in this research, multivariate logistic regression is the method of analysis used to find and measure the distinct risk factors linked to snakebite morbidity in Chemalingot, Baringo County.

2.5 Empirical Summary

The evidence-based literature demonstrates that snakebite envenoming is an extremely underserved public health issue, specifically in low-resource environments in Sub-Saharan Africa. The burden of snakebite envenomation is more acute in Kenya where, in Baringo County, among other factors, there is systemic delay in access to care, access to antivenom (AV), inadequate transport networks, and severe dependence on traditional medicine as first-line treatment in cases of snakebite envenomation (Harrison, 2016; Kungu and Chweya, 2020).

The fact that policy interventions are fragmented, the lack of available data, and failures in the supply chain of antivenom have been identified as major gaps in studies done in India, Myanmar, Nigeria, and Kenya (Bawaskar et al., 2017; Okumu et al., 2024; Patikorn et al., 2022). Also, because of habitat destruction (deforestation), drought endurance, and rainfall shifts, environmental modifications have increased the number of snake-human interactions, specifically in farming-based areas (Chaves et al., 2015; Gololo et al., 2025;

Xinhua News Agency, 2025). Multivariate statistical methods like logistic regression are frequently used when researchers analyze complex data sets to view the interaction between variables and the prediction of results. Logistic regression was recently applied to determine how bite timing, age, occupation, time to hospital, and their interaction affect mortality and illness due to snakebites (Habib et al., 2011; Waldorp et al., 2021). The above methods deal with the scenario in which some of the predictors are continuous (time to hospital) and the other ones are categorical (bite timing) and are therefore flexible enough to answer multiple questions simultaneously. Nevertheless, the literature at hand is more or less global and leaves out such places as Chemalingot and other rural regions in Kenya. The actual magnitude of the problem can be concealed by such factors as under-reporting, cultural stigma, and a poor surveillance system. That is why concrete, fact-based research is required asap to measure and put the risk into perspective. The study conducted in this research project aimed at determining the most significant risk factors associated with morbidity following a snakebite in Chemalingot, Baringo County using a multivariate logistic regression model. Other contributors such as treatment delay, demographical characteristics, environmental exposure and health seeking behavior were closely observed. The findings can be aligned with the goal of the World Health Organization to reduce by half the death and disability related to snakebites by 2030,the study also provide locally-based evidence to inform the decisions concerning the allocation of resources, planning of interventions, and community-level action.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

The chapter describes the methodology framework that was used to study risk factors that lead to snakebite morbidity in Chemalingot in Baringo County. The selection of the methods corresponds both to the epidemiological character of the issue of the research as well as to the realities of working in high disease burden, rural environment. In particular, the chapter explains the research design, study setting, population, data collection instruments, sampling approaches, variables and analysis plans to be employed.

The methodological technique was anchored upon the theoretical and conceptual explanations presented in Chapter Two specifically the Human-Environment Interaction Theory and the Social-Ecological Model of Health. Such frameworks not only guided how the existing risk factors (e.g., behavioral, environmental, and infrastructural factors) were identified, but it also served to inform the model (multivariate) structure. Synthesizing these layers of influence will help the study to have a textured perception of the combination of ecological, social and health system variables that interact to fuel snakebite morbidity in this underserved region.

3.1 Study Site

The research study was carried out in Chemalingot which is an administrative center of Tiaty East Sub-County found in Baringo County, Kenya. It is a part of the Rift Valley, and it is largely inhabited by pastoralists community and shares the Pokot as one of its community members that major in livestock keeping and small-scale farming. Chemalingot is semi-arid with bushy vegetation, presence of rock outcrops, poor road networks and this makes exposure to venomous snake high. Common venomous snakes include the black mamba, eastern green mamba, red spitting cobra, James Ashe spitting cobra, puff adder, and boom slang.

There are often incidences of human-snake encounters particularly in the dry season when snakes may enter the human built up areas with the aim of seeking food and water. The isolation of health care and the lack of emergency medical facility worsens the health burden of snakebites in the region.

This study sampled all the people who visited the healthcare centers of interest in Chemalingot during the period 2018 to 2024 because they were the victims of snakebites. This group cuts across all ages and involves both sexes with a large percentage of them in high risk, outdoor jobs that involve herding, charcoal being, firewood gathering and agriculture. The occupational and environmental exposures such as in Chemalingot render it a suitable context to examine the burden of risk factors of snakebites in its morbidity features.

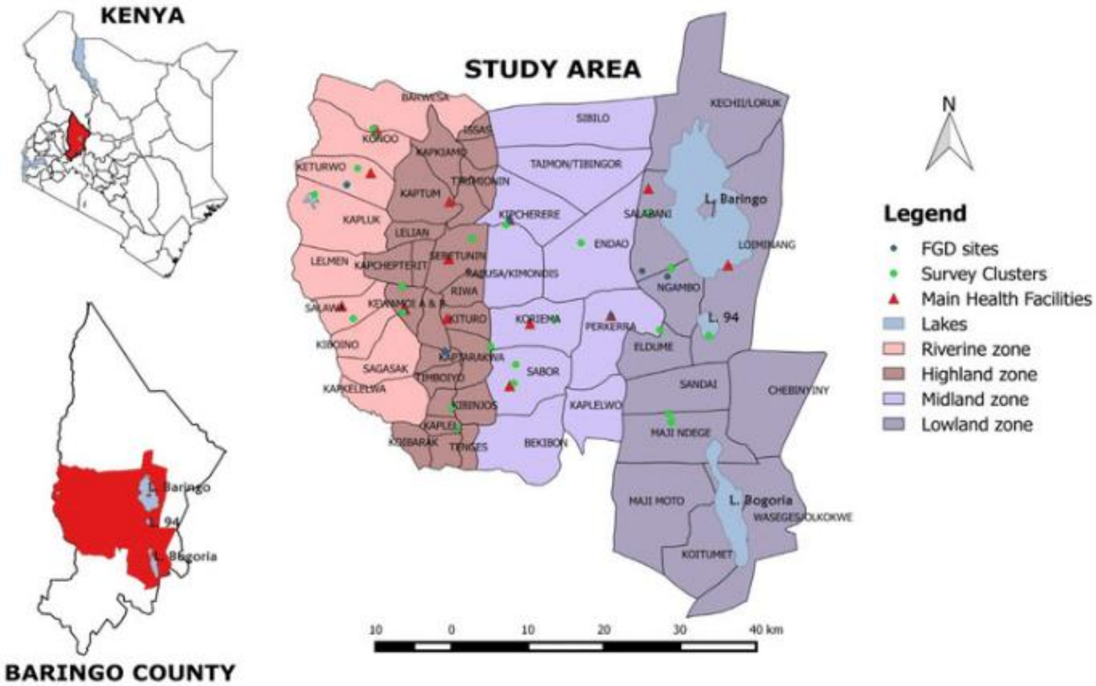


Figure 6: Map of Baringo County and Study Area in Tiaty East Sub-County, Kenya

The geographical setting of the study area in Baringo County has been presented in this map. Chemalingot falls under the Tiaty East Sub-County and it is a high exposure area that is occupied with lowland, midland, and riverine settings. Primary healthcare, survey clusters, and zones of ecological variation are also highlighted, providing spatial insight into the environmental and health infrastructure challenges relevant to snakebite risk.

3.2 Study Design

The research followed a retrospective cross-sectional research design; the analysis of pre-existing data at a point in time to evaluate relationships between health outcomes and exposure variables. In that regard the approach was selected due to its viability and practicability and ethical-acceptability, particularly in high-morbidity settings where the prospective data gathering can be unsafe, expensive or logistically impractical.

The design was especially appropriate to on determine the risk factors linked to the morbidity of snakebites like the time of treatment, age, and the location of bites as records through the recorded hospital observations. It also guaranteed that vulnerable groups such as children, and marginalized rural population were not exposed to further risk or recall bias.

After seaking permission from the admistration of the health center ,I was allowed and guided to acquire the incidence from their daily records in the health center.The patient records review was carried for six years (2018-2024) in the chosen Chemalingot healthcare facilities.This period provided adequate power to identify trends with adjustment of the seasonal and inter-annual fluctuations in cases of snakebites.

3.3 Sample Size and Sampling Techniques

Since the study is purposive sampling we had no technic of arriving on our sample,but to pick from health center,the sample adds upto 266 medical records of snakebites incidences. The decision to conduct research in Chemalingot was made on the premise of purposive sampling owing to the fact that snakebites have been well documented in Chemalingot due to the ecological risk factors and poor access to quality medical care. Consecutive sampling was employed in this environment to locate all eligible patient records received during the time period from 2018 to 2024 in the selected health facilities and thereby, eliminating the selection bias and offering a complete data collection.

The inclusion criteria included: (i) a documented diagnosis of snakebite, (ii) the presence of the treatment history (the use of an antidote, a hospital stay); (iii) the existence of outcome data (wound healing, complications, recovery). Records without important demographic or clinical data or cases suspected of being snakebite but without clinical corroboration were excluded.

The 266 participants were found to be sufficient in carrying out the multivariate logistic regression analysis and identifying statistically significant relationships between risk factors and morbidity effects. The sample is power adequacy to detect moderate effect sizes (odds ratios $\approx$ 2.0) with 80% power at a 5% significance level. Close sample thresholds have been successfully applied to other studies at sub-Saharan regions such as the study by Habib *et al*. (2011) who examined 233 cases of snakebites in Nigeria employing regression frameworks and Alcoba *et al*. (2020) who were testing 300 patients in the study of Cameroon using logistic frameworks.

3.4 Data Collection

After Structured data abstraction form was created and used to extract data. The instrument was pretested and improved to develop a consistent, complete, and simple to be applied by skilled data clerks. It was formulated to suit the research aims and theoretical framework of the study especially the Human-Environment Interaction Theory and the Social-Ecological Model of Health so that ecological, sociodemographic, and clinical factors of snakebite morbidity could be recorded systematically.

The main source of data included was the Chemalingot Health Centre where most of the cases of snakebite were initially handled. Data retrieved in this facility were counterchecked against those in registers at the Baringo County Referral Hospital (CRH) to authenticate the treatment results, referral cases and follow-up information. The trends were also validated and the misclassification was reduced through secondary sources like facility morbidity records, pharmacy registers (antivenom stocks) and county health surveillance data.

Variables gathered were the following:

(i) Socio-demographic variables: age, sex, level of education, type of occupation, location of residence and proximity to the closest healthcare unit.

(ii) Snakebite related: date and time of bite (day/night), the bite anatomical location, and suspected snake species (where possible)

(iii) Treatment- related factors: use and time of receipt of antivenom treatment, time interval between bite and arrival in a hospital, referral, and access to an emergency treatment.

(iv) Health outcomes: hospital stay, discharge, clinical complications (e.g., necrosis, disability) and status morbidity at discharge.

The choice of these variables is attributed to empirical researches of the past; national recommendations, and conceptual frameworks applicable to snakebite epidemiology in rural Africa.

Data abstraction was conducted by trained health records officers between March and June, 2024 under the direction of the principal investigator to make sure that the protocol was followed. The confidentiality of the patients was guaranteed by anonymizing all data at the level of data collection, which was next encoded and uploaded into a secured database. Such quality assurance approaches as double entries or consistency checks occurred to deal with possible mistakes or the fields left untouched. This is because the study was able to develop a detailed dataset to address multidimensional risk factors of snake bite morbidity in Chemalingot by employing reliable and ethical retrospective methods.

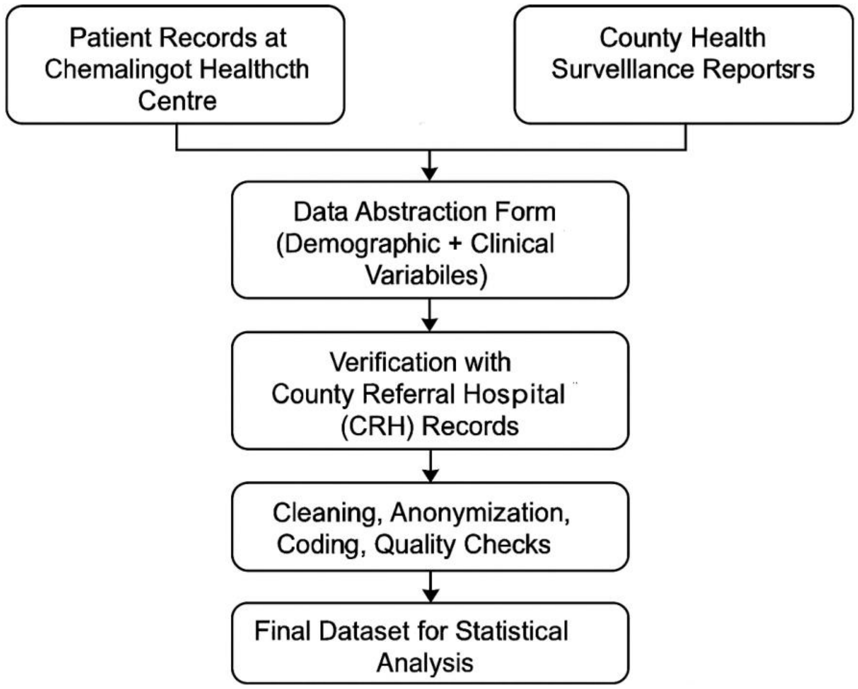


Figure 7: Data Collection and Processing Flow for Snakebite Morbidity Study in Chemalingot.

In determining how the snakebite case records are collected, validated and processed into information by various health data sources in Chemalingot, this diagram as shown in Figure 7 was prepared to explain the workflow of data collection, data validation and information processing of records on snakebites. It outlines how the patients' records were abstracted, cross-checked with the county referral hospital records, cleaned, and ready to be statistically examined.

3.5 Measurement of study Variables

Snakebite morbidity, which consisted of clinical complications resulting after envenomation, was the dependent variable of the current research. They were those who were hospitalized longer than 3 days, had tissue necrosis as documented, required surgical treatment, or had not recovered functional disability in the long term. As a dependent variable this was coded in binary: 1 = the presence of morbidity. When the morbidity is zero, then this will be a case of no morbidity (i.e., uncomplicated recovery without long-term effects).

The independent variables on consideration of the previous empirical research and theoretical frameworks (Social-Ecological and Human-Environment Interaction frameworks) were chosen and categorized as follows:

(i) **Demographic factors**:

- Age (continuous; subsequently added into categories of age)
- Sex (binary: male/female)
- Occupation (categorical: herder, farmer, child, elderly and so on)

(ii) **Factors that are specific to snakebite**:

- Location of bite on the body (categorical: upper limb, lower limb, trunk, head/neck)
- Possible snake species (nominal; where documented)

(iii) **Treatment and behaviour variables**:

- Hospital time (hours, dichotomous with cutoff value of 12 hours)
- The use of antivenom (binary yes/no)
- Making use of traditional remedies prior to hospital (binary: yes/no)

(iv) **Environmental variables**:

- Occurrence season (condition: rainy season, dry season)
- Access to health facility (continuous, available).

Depending on the type of data, each variable was measured differently: some of them were continuous, some binary, and some were categorical. During analysis, some variables were either transformed or dichotomized (e.g., time to hospital) so that they give better approximation and interpretation. Definitions of all variables and coding schemes were all made in accordance to standard epidemiological practice.

3.6 Statistical Analysis and Data Management

Some steps were followed in data management in order to guarantee quality, accuracy and integrity. The completeness, duplication and logical inconsistencies of the patient records were initially checked such as hospital admission date before bite date. The variables were standardized and coded using pre-defined formats, after which they were inserted into a database, which could be considered as secure due to available security.

R statistical software (version 4.4.1) was utilized in analyzing the data. The study objectives led to all analyses that were based on in-depth methods of epidemiology.

The demographics of patients, snake bite characteristics, treatment interventions and outcome distributions were described using descriptive statistics. Continuous variables were presented in terms of means and standard deviations, whereas categorical variables were provided into frequencies and percentages.

The bivariate analyses included in the study involved testing of preliminary associations of morbidity due to snakebite (the dependent variable) with potential predictors. The categorical variables were tested by the chi-square, and the continuous variables were tested by t-tests.

The independent predictors of morbidity were identified with the help of multivariate logistic regression analysis. In both bivariate analysis and those that were composed based on theoretical and practical grounds, variables with p-value lower than 0.20 were included in the final model.

The Hosmer-Lemeshow test in goodness-of-fit was used to determine the adequacy of the models and the Area Under the Receiver Operating Characteristic curve (AUC) and Receiver Operating Characteristic (ROC) were used to ascertain predictive performance. In order to check the multicollinearity, the Variance Inflation Factor (VIF) was computed accumulated; variables with VIF greater than 5 were analyzed on redundancy. Also, to evaluate whether the logit multivariate model of predicted factors was working adequately, both the methods of ROC and cross-validation were applied. The cuts-off of at least 60% were taken to represent a good fit between the model prediction and reality in predictive modeling as described in the recommended requirements of a public health application.

Missing data were evaluated on a pattern and mechanism. In the situation where the data were missing at random (MAR), Multiple Imputation by Chained Equations (MICE) was used in order to maximize power and minimize bias. Listwise deletion was adopted where they were not missing at random and too sparse.

Two-tailed statistical tests were conducted and the p-value < 0.05 was regarded to be significant.

3.7 Model Development to Determine the Risk Factors Associated with Snakebite Morbidity in Chemalingot Baringo County

The study explored the use of multivariate logistic regression since it is a powerful tool when multiple independent variables are believed to influence a binary outcome. It also provides a more precise and thorough knowledge of how different factors contribute to the likelihood of an event, such as morbidity, and enables the modeling of complex relationships, adjustment for confounders.

The model was developed as shown in equation 3.1 based on the binary outcome morbidity subject to the following explanatory variable: $X_1 =$ Age in years, $X_2 =$ Gender, $X_3 =$ Duration of hospital stay, $X_4 =$ Distance to hospital ($> 10\ km$), $X_5 =$Time to Hospital (> 12 hours), $X_6 =$Premedication (yes or no), $X_7 =$ Snakebite activities (outdoor activities) and $X_8 =$ Snakebite activities (house chores,indoor activitie). In this study, morbidity is all about the existence or occurrence of illness or problems brought on by the snake bite. It shows if the snake bite and subsequent treatment had a detrimental effect on the patient's health, such as a disease, ailment, or circumstance.

Let Morbidity be denoted with y such that:

$$y = \begin{cases} 1 & \text{patient experienced morbidity} \\ 0 & \text{did not experienced morbidity} \end{cases}$$

Therefore, the model is given as

$$\log\left(\frac{p(y=1)}{1-p(y=1)}\right)$$
$$= \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 \quad 3.1$$

Where

$p(y = 1)$ is the probability of morbidity (dependent variable)

β_0 is the intercept which represents the baseline **log-odds** of morbidity when all predictor variables are set to their reference categories or zero (for continuous variables).

$\beta_1, \beta_2, \beta_3, \dots, \beta_8$ are the independent variable's corresponding coefficients.

3.5.1 Parameter Estimation in the Model 3.1

The parameters in model 3.1 was estimated using maximum likelihood method as follows:

(i) Define logistic model based on model 3.1

$$p(y=1|\boldsymbol{X}) = \frac{1}{1+\mathrm{e}^{-(\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7+\beta_8X_8)}}$$

which can be simplified as

$$p(y=1|\boldsymbol{X}) = \frac{1}{1+\boldsymbol{e}^{-\boldsymbol{X\beta}'}} \quad 3.2$$

where $\boldsymbol{X}$ **is** the vector of independent variables (including an intercept), $\boldsymbol{\beta} = (\beta_1, \beta_2, \beta_3, \dots, \beta_8\ )^T$ is the vector of parameters to be estimated.

(ii) Obtain likelihood function that represents the probability of observing the data given the parameter estimates. For n independent observations (y_i, X_i) where $y_i \in \{1, 0\}$, the likelihood of the entire dataset is:

$$L(\boldsymbol{\beta}) = \prod_{i=1}^{n} p(y_i = 1|X_i)^{y_i} \left(1 - p(y_i = 1|X_i)\right)^{1-y_i}$$

Substituting the logistic model for $p(y_i = 1|X_i)$, the likelihood becomes:

$$L(\boldsymbol{\beta}) = \prod_{i=1}^{n} \left(\frac{1}{1 + \boldsymbol{e}^{-X\beta}}\right)^{y_i} \left(1 - \frac{1}{1 + \boldsymbol{e}^{-X\beta}}\right)^{1-y_i}$$

This likelihood function combines the probabilities for each observation i.

(iii) Compute the log-likelihood function by taking the natural logarithm of the likelihood function since the likelihood function involves products, it can become numerically unstable for large datasets:

$$\log L(\boldsymbol{\beta}) = \sum_{i=1}^{n} \left[y_i \log P(y_i = 1 \mid \mathbf{X}_i) + (1 - y_i) \log(1 - P(y_i = 1 \mid \mathbf{X}_i))\right].$$

Substituting $P(y_i = 1 \mid \mathbf{X}_i) = \frac{1}{1+e^{-\mathbf{X}_i \cdot \boldsymbol{\beta}}}$, we get:

$$\log L(\boldsymbol{\beta}) = \sum_{i=1}^{n} \left[y_i \log\left(\frac{1}{1 + e^{-\mathbf{X}_i \cdot \boldsymbol{\beta}}}\right) + (1 - y_i) \log\left(\frac{e^{-\mathbf{X}_i \cdot \boldsymbol{\beta}}}{1 + e^{-\mathbf{X}_i \cdot \boldsymbol{\beta}}}\right)\right].$$

Simplifying:

$$\log L(\boldsymbol{\beta}) = \sum_{i=1}^{n} \left[y_i(\mathbf{X}_i \cdot \boldsymbol{\beta}) - \log(1 + e^{\mathbf{X}_i \cdot \boldsymbol{\beta}})\right].$$

This is the **log-likelihood function** to maximize in order to estimate the parameters β.

(iv) Determine the values β that maximize the log-likelihood function. This was typically done by solving the following system of equations, which was derived by taking the partial derivatives of the log-likelihood function with respect to each parameter:

$$\frac{\partial \log L(\boldsymbol{\beta})}{\partial \beta_j} = 0, \quad \text{for each } j = 0, 1, 2, \ldots, 8.$$

The derivative of the log-likelihood with respect to β_j is:

$$\frac{\partial \log L(\boldsymbol{\beta})}{\partial \beta_j} = \sum_{i=1}^{n} \left(y_i - \frac{1}{1 + e^{-\mathbf{X}_i \cdot \boldsymbol{\beta}}} \right) X_{ij},$$

where X_{ij} is the j-th independent variable for the i-th observation.

The system of equations was solved using numerical optimization (Newton-Raphson) method.

3.8 Ethical Consideration

The research received ethical clearance by the Institutional Scientific and Ethics Review Committee (ISERC) of Masinde Muliro University of Science and Technology under approval reference number MMUST/ISERC/054/2024. Also, the National Commission for Science, Technology and Innovation (NACOSTI) issued a research permit under reference number NACOSTI/P/23/697938.

Prior to data collection, permission was sought and granted by the administration of Chemalingot Health Center and the relevant health authorities in Baringo County. The study involved the use of only secondary data that is already in the hospital records. Data abstraction processes were done to anonymize all records to achieve the highest possible patient privacy and confidentiality, and no personal identifiers (names, contact details) were placed into records. The data was stored in an encrypted digital space that had a password and could only be accessed by the research team. All research activities were conducted in accordance with accepted standards of ethical human subject research procedures including those of the Declaration of Helsinki and national guidelines of research ethics in Kenya.

3.9 Limitations of Methodology

This study provided several important insights on the morbidity of snake bite in Chemalingot but a number of methodological limitations have to be identified. To begin with, utilization of retrospective hospital records can present data quality concerns such as incomplete reporting, an absence of demographic or clinical variables as well as failure of standardized documentation within any facility. Triangulation with county records and summary logs was used to derive validation, but it is possible that there will be some inconsistencies.

Second, risk of invalid species classification is present since identification of the bite species was not lab-confirmed in most of the snakebite cases. The patient or witness reports were commonly used to know the suspected species, which is not reliable. The interpretation of the type of venom type and clinical outcomes of the same may be affected by this limitation.

Third, this study generates selection bias since only patients attending formal health facilities are to be included in the study. Cases that were treated traditionally or not treated were omitted, especially the cases that were found in the community. This can result in discouraging incidence and severity, in particular, with remote or socioeconomically underprivileged groups.

Also, cross-sectional retrospective design does not allow making causal conclusions about the relationship between risk factors and the results of morbidity. It was not possible to account in full for time varying confounding effects, e.g. weather, presence of antivenom and health promotion in the community.

Lastly, although missing data were dealt with using multiple imputation in appropriate occasion, multiple imputation requires that data should be missing at random (MAR) but that is not always true. Inspite of the limitations, the facility-derived data collected as a study sample , a strong analytical design used and triangulation against external data points to a reasonable basis of deriving the epidemiological picture of snakebite morbidity in Chemalingot.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.0 Introduction

The chapter provides the findings of the retrospective cross-sectional survey undertaken to investigate the risk factors of Snakebite morbidity in Chemalingot, Baringo County. The results are founded on the evaluation of 266 patients' records retrieved in the local health practices between 2018 and 2024. The main outcome of morbidity was measured as a binary outcome (whether or not there were clinical complications) and was analyzed as a dependent variable in connection with a series of demographic, environmental, and treatment-related factors.

The findings are discussed in accordance with the study purposes and start up with the descriptive statistics which run through the description of social-demographic and clinical characteristic of snakebite victims. There is a subsequent discussion of the morbidity prevalence, bivariate relationships, multivariate analysis of the logistic regression and a performance of morbidity predictive model. Both statistical results and discussions of the are given in each section, which are applicable to the public health implications on the snakebite-endemic regions.

In combination, the results can contribute evidence-based findings on the determinants of snakebite morbidity and their implications on how snakebite can be more effectively prevented, treated and managed through policy in Chemalingot and other high-risk rural areas.

4.1 Descriptive summaries of the snakebite

In this section, summary statistics of 266 records of snakebite patients used in the study are described. The statistics outline demographic evidence, exposure factors, and hospital access indicators of the Number of victims treated at Chemalingot in 2018-2024.

4.1.1 Age Composition

The average age of the victims of the snake bite was 19.26 years having a standard deviation of 15.30 years. The net average was 15.0 years with an interquartile range (IQR) of 16 years and the age numbers extended between some 1 and 84 years. This distribution depicts that a large percentage of snakebite victims consist of the children and adolescents which translates to high rates of vulnerability in younger groups particularly when participating in outdoor activities or when walking barefooted in snake-infested areas.

4.1.2 D Gender Distribution

The number of patients has been obtained with complete gender data, 266 records were compared, in which 137 (51.5%) were men and 129 (48.5%) were women. The slight male predominance could be explained by the fact that the males are rather exposed to occupational exposure in general as they might be involved in high-risk outdoor work herd, farming, charcoal burning, or collecting firewood. Such gender difference in exposure can be compared with past observation done in kilifi county in snake bite-endemic environments.

4.1.3 Access to Hospital, Treatment Waiting time

The average length of stay in hospitals was of 4.16 days and a median of 3 days, which is an indication of an average length of stay in the aftermath of a snakebite. The average of distances travelled to the nearest hospital was 12.43 km (SD 9.94), with median of 10.0 km, and range 1-40 km. These statistics highlight the possible obstacles to the provision of care in time, particularly to patients who live far away.

4.1.4 Time of Incidents of Snakebites

Estimation of the time of bite indicated that the most probable timings of snakebite envenomation were in the evening (40.9%) and during night hours (30.3%) with far much lesser cases recorded during mornings (15.7%) and afternoons (13.0%). These results are similar to earlier studies in Sub-Saharan Africa and Asia whose patterns of crepuscular and nocturnal snakes' activity have been thoroughly documented, especially in species of snake including Bitis arietans (Puff Adder) and Naja nigricollis (Spitting Cobra) (Warrell, 2010; WHO, 2019).

The increased cases at night is an evidence to the snake species behavior along with the vulnerability of the human beings. Most of the venomous species become active in the late evening when temperatures are lower, to either stalk or migrate in search of prey or water; especially in semi-arid ecologies such as Chemalingot. At the same time, the regular human activities like going to the toilet, getting ready at night, collecting firewood, or sleeping on floor mattresses without nets expose residents to bites (Kipkemboi et al., 2023; Chaves et al., 2015).

The Nigeria and Indian studies also revealed the fact that majority of the bites happen in domestic spheres or when people rest or stroll at night barefoot (Habib et al., 2001; Bawaskar & Bawaskar, 2017). Dark and lack of electricity accessibility in rural Kenya are the main problem that makes people to encounter and bitten by snakes to exposure as most individuals are oblivious of snake presence until it is too late and one is envenomated.

This demand calls for the necessity to have specific prevention measures, including use of bed nets, shoes and other protective items, and enhance outdoor illumination of homesteads especially evening and night hours when risks of exposure are highest.

4.1.5 Descriptive Summary Tables

Table 4: Summary Statistics for Demographic and Access Variables

Variable	Mean (SD)	Median (IQR)	Range
Age (years)	19.26 (15.30)	15 (16)	1 – 84
Hospital Stay (days)	4.16	3	1 – 16
Distance to Hospital (km)	13.17 (9.94)	10	1 – 84

This Table 4 presents summary statistics for age, hospital stay duration, and distance to the nearest health facility among snakebite victims. This information from the distance to hospital in kilometers highlights potential barriers to timely care, which may influence patient morbidity.

Table 5: Timing of Snakebite Incidents

Time of Day	Frequency (n)	Percentage (%)
Morning	40	15.7

Afternoon	33	13.0
Evening	105	40.9
Night	78	30.3

This Table 5 shows the distribution of snakebite cases by time of day, highlighting peak exposure during evening and night hours.

4.2 Prevalence rate of morbidity due to snake bites among study subjects

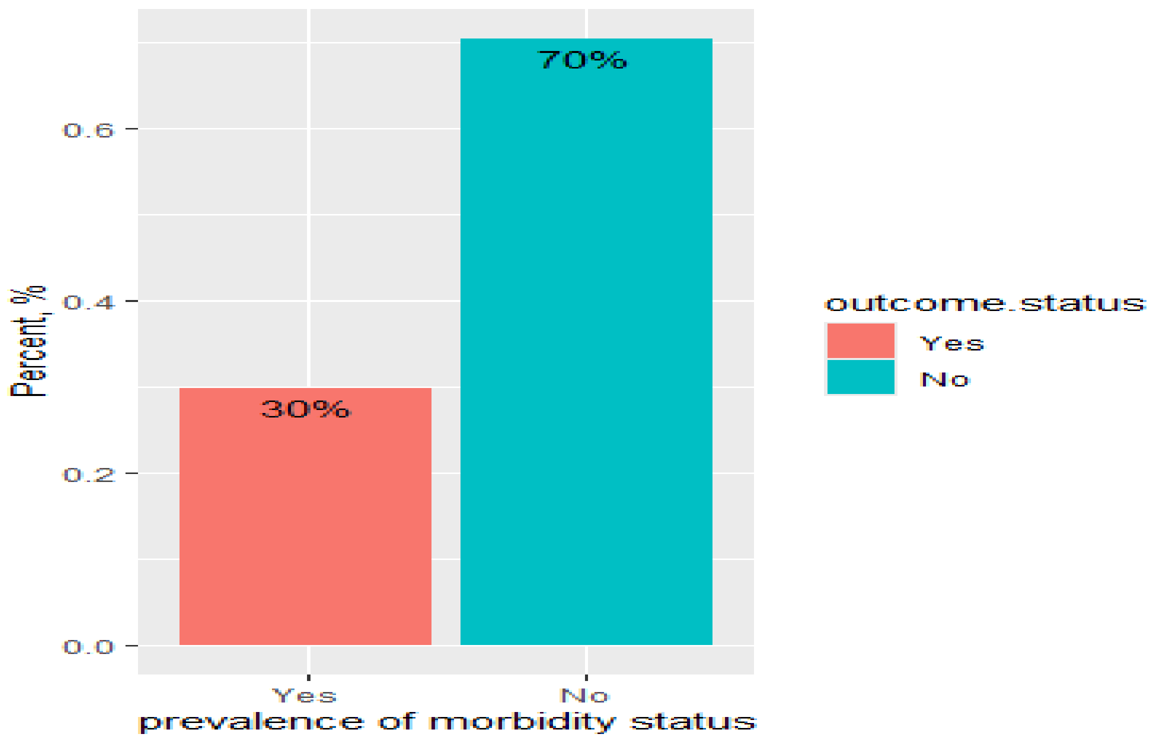


Figure 8: Prevalence rate of morbidity due to snake bites

The research revealed that 30% of the subjects had morbidity after snake bites as shown in Figure 8. This means that the health burden has been high and the other 70% have no complication. The difference in the results can signal the difference in the severity of the bite, the type of the venom, or the availability of the immediate medical assistance. Figure

8 also shows a further breakdown of these findings with a graphic identification of the morbidity prevalence as "Yes" as opposed to the unaffected cases as "No". These statistics highlight the importance of outbreak management health efforts, such as distribution of better antivenom and health education of the communities, especially in the risky areas. Further investigation is required to identify intermediate factors underlying these findings such as first response practices or demographic factors to put these findings into perspective

Figure 9: ***Gender-Based Disparities in Snakebite Morbidity***

Figure 9 shows that; there is a major difference between gender in relation to the morbidity caused by snakebites. Of the female subjects, 15.0 % ($n = 40$) had health complications as opposed to 14.7 % ($n = 39$) of the male subjects. As both genders had a significant morbidity rate, the slightly higher prevalence (0.3 percentage points) in women might either be a result of occupational exposure or behavioral risk factor or biological differences when it comes to susceptibility to venom. It is important to mention that the similar values of the sample sizes (Male: $n = 98$; Female: $n = 89$ on no morbidity) indicate the same level of representation that increases the authenticity of these differences. These observations raise the necessity of the gender-specific prevention approaches, especially going towards men and those at risk working in high-risk professions (e.g., farmers), as more research is needed in terms of exploration of social-cultural and physiological factors behind these trends.

Figure 10 demonstrates that there are high temporal changes in snakebite-associated morbidity, with the most prominent values in the evening (38.2%) and at night (32.0%), and the worst during the afternoon (18.4%) and morning (14.6 percent). The results are similar to ones reported at the global level that note the rise in rates of snakebites at crepuscular and nocturnal times due to an increase in snake activity (e.g., Warrell *et al*., 2020) and the decreased visibility of humans (Gutierrrez *et al*., 2017). As an illustration, in a study conducted in tropical zones (Kasturiratne *et al*., 2008) the peak of envenoming was recorded in the dusk, which is consistent with the foraging behavior of the populations of the Bitis arietans and Echis carinatus venomous species.

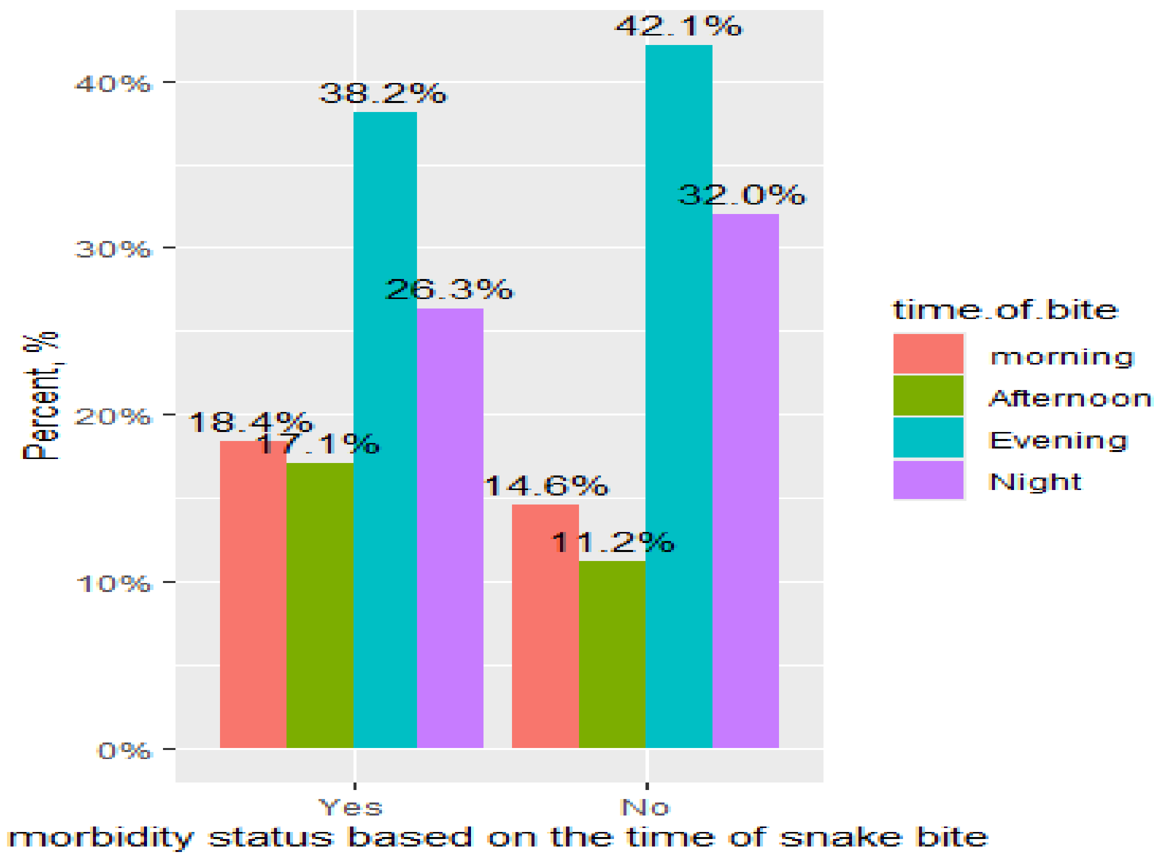


Figure 10: ***Temporal Patterns in Snakebite Morbidity***

The fact that the reduced morbidity is seen in the morning hours is compatible with what is seen in the agricultural societies (Alirol *et al*., 2010) that snakebites are infrequent during the daytime activities. The morbidity rates might also be elevated through the delayed treatment caused by the delay in access to the healthcare in the night (Williams *et al*., 2019). These similarities promote the significance of timely interventions, among which one can distinguish:

- Behavioural intervention: Promotion of protective gear wearing at times when it is especially dangerous.
- Environment adaptations: Putting lights in snake infested zones.

- Community education: Educating the communities about peak times of snake activity.

The application of such evidence-based approaches enables the reduction of temporal risks of snakebite morbidity through the further integration of these approaches into the processes of public health.

4.3 Distribution of Snakebite Incidents by Activity at Time of Bite

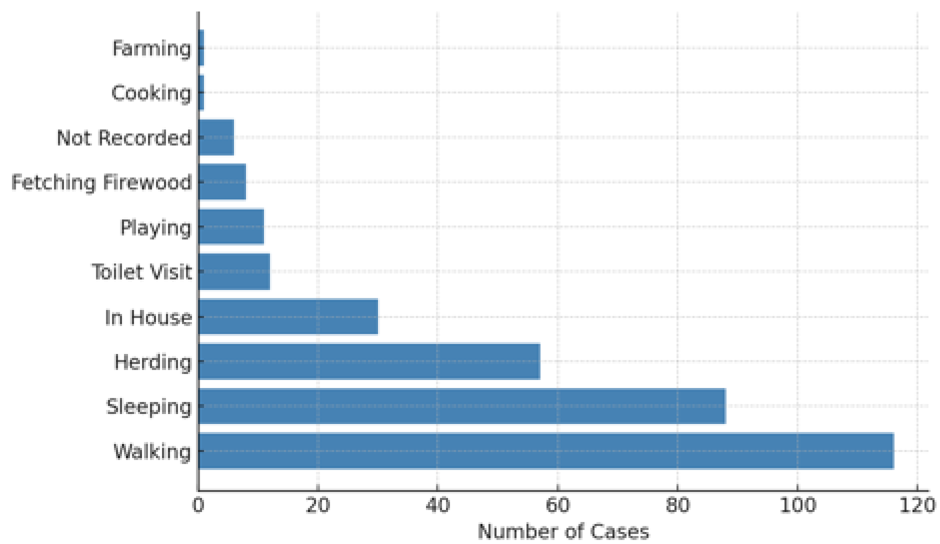


*Figure 11: **Distribution of Snakebite Incidents by Activity at Time of Bite***

As depicted in figure 11, distribution of snake biting cases based on activity being performed at the time of exposure, more cases on snakebites were caused by sleeping, walking and herding. The high number of sleeping related events indicates the exposure of the individuals within the home environment especially in the rural regions where the housing infrastructure could attract snake entry a fact that is observed by studies pinpointing snake penetration in houses with poor flooring or roofing materials (Harrison et al., 2019). The incidence rate when conducting walking and herding activities demonstrates the occupational and routine exposure risk as global data indicates that occupational risks are increased in agricultural workers and those who perform the activities in the outdoors (WHO, 2021). These tendencies highlight the indication that specific interventions should be conducted, and in addition to the protection behavior (considering ground-level protection on water activities by encouraging the usage of protective shoes and in bed the mosquitoes' nets for protection in high-risk situations like during sleep time), overall approaches to protect against transmission to the body should be taken. Exposure risks could also be reduced by changes to the environment such as home conservation activities to cover the entry points and maintenance of shrubbery around homes and fumes. The resemblance to other areas, where according to the example of Sub-Saharan Africa, more than half of the patients were bitten during either sleep or farming (Halilu et al., 2020), adds to the generalizability of the results, as well as the need to develop context-specific prevention measures that take into account both behavioral and structural risk factors.

4.4 Determining the Suspect Snake Species Which Cause Bites

Epidemiological patterns concerning the distribution of the snake species most likely to be involved into the bite discloses some details (Table 6). More significantly these results showed that most cases (n=124, 47.3%) were where the snake could not be observed by the victims' bit, and that 2 more cases (0.8%) were where the snake could not be identified after the bite, probably because of environmental conditions or the fact that the specimen had suffered physical harm.

Most commonly encountered species (n = 76, 28.9 %) was the puff adder (Bitis arietans), which further stamps it as the most common venomous snake in Chemalingot area. This observation coincides with the known wide range of its distribution in dry savanna habitats.

Red spitting cobra (Naja pallida) contributed to 32 cases (12.2%) and identification was clinical and based on the presentation of visual evidence. There were the same number of cases (n=32, 12.2%) where positive identification of the snake was visual, but species was not specified.

These findings point out some of the major public health issues:

1. Knowledge gaps: The prevalence of the cases that are not noticed (47.3%) implies either snake incursion and awareness in the night or no knowledge of snakes during everyday activities
2. Clinical implications: The occurrence of more puff-adders bites bears issues of treatment implication since the venom is a cytotoxic venom and needs special antivenom procedures
3. Prevention requirements: The 126 total incidences of unidentified/unseen snakes (48.1 percent of all) illustrate the necessity of:
4. Education programs explaining how to identify snakes that are within their communities
5. The first-response measure training
6. Better lighting in risk-prone locations
7. Guidelines on how to preserve snake specimen were possible

Table 6: Suspected Snake Species Identification Among Bite Cases (N=262)

Identification Category	**Cases (n)**	**Percentage (%)**
Not seen	124	47.3

Puff adder (Bitis arietans)	76	28.9
Red spitting cobra (Naja pallida)	32	12.2
Seen (unspecified species)	32	12.2
Not identified	2	0.8

This distribution has profound effect to both clinical handling and prevention schemes in the area. The high incidences of puff adder cases also imply that antivenom reserves ought to be utilized on this life form, specifically and the excessive rates of underreported bites imply the necessity of expanding preventive precautions beyond classes of snake familiarity as opposed to species-explicit training on its own. Among future research directions, morphological and genetic confirmation methods are to be adopted with the aim of enhancing the accuracy of identification of species.

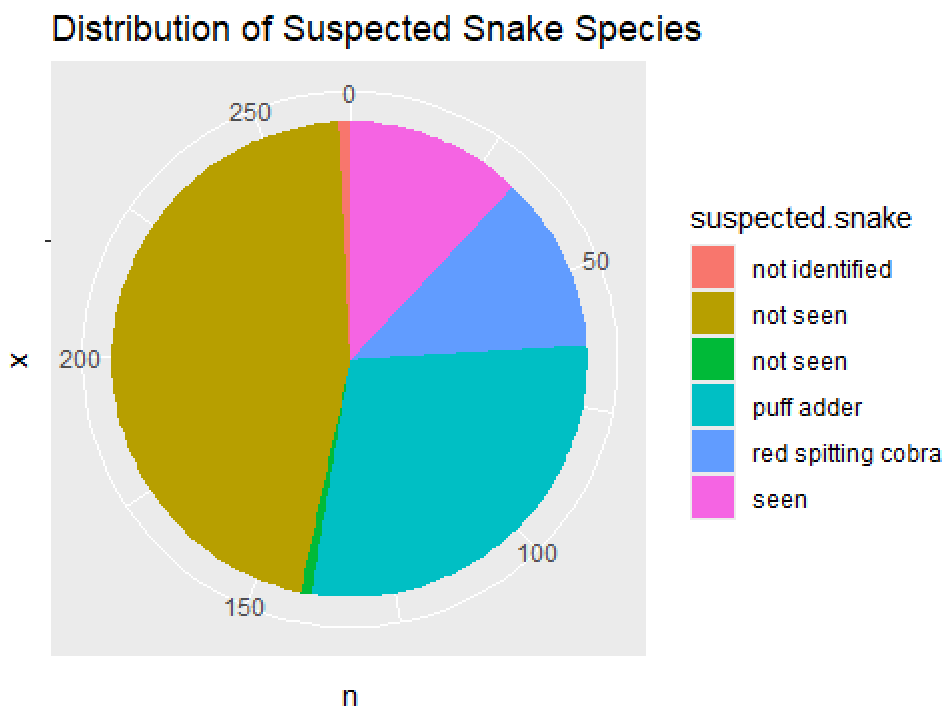


Figure 12: ***Distribution of Suspected Snake Species***

Table 6 (strength of evidence data table) is complemented by Figure 12 (pie chart) showing the proportional distribution of the intended species and identification status of occurrences of Incidents of snakebites. As it can be observed in the chart, the largest proportion is of the victims who did not notice the snake (47.3%, "not seen"), with almost 1 in 2 cases. This is consistent with the ecological experimental evidence that a high number of venomous species in the area are nocturnally distributed or are cryptically colored (Spawls et al., 2022). The second most prevalent category (28.9%) is that of confirmed puff adder (Bitis arietans) bites that support the clinical importance of this species given its cytotoxic venom and its overlapping geographical distribution with human settlement. The lesser yet significant percentage (12.2%) reflects encounters with red spitting cobra (Naja pallida), which needs special medical considerations due to the possible ophthalmologic complications.

To prove these points, Table 6 gives detailed quantitative data where 12.2 percent of cases were cases where the snakes were found and could not specifically be identified, but only seen, whereas only 0.8 percent were cases where the specimens were destroyed after the bite had occurred ("not identified"). Such synergy between Figure 12 and Table 1 reveals the following important public health gaps: (1) the necessity of community education as a tool to enhance the awareness level during the high-risk activities in the area regarding snakes (e.g., farming, moving around at night), and (2) the necessity of snakes specimen preservation to ensure their accurate identification and further treatment guidance.

Thematically combined data is convincing that it would be prudent to stock puff adder antivenom in the local clinic since the red spitting cobra envenomation treatments should also be stocked. Moreover, the large percentage of unpredictable bites (47.3%) will indicate that species-specific identification should not be advocated as the only method of preventing bite, but it should be combined with efforts on environmental and personal protective actions (e.g., clearance of vegetation around house, wearing boots, etc.).

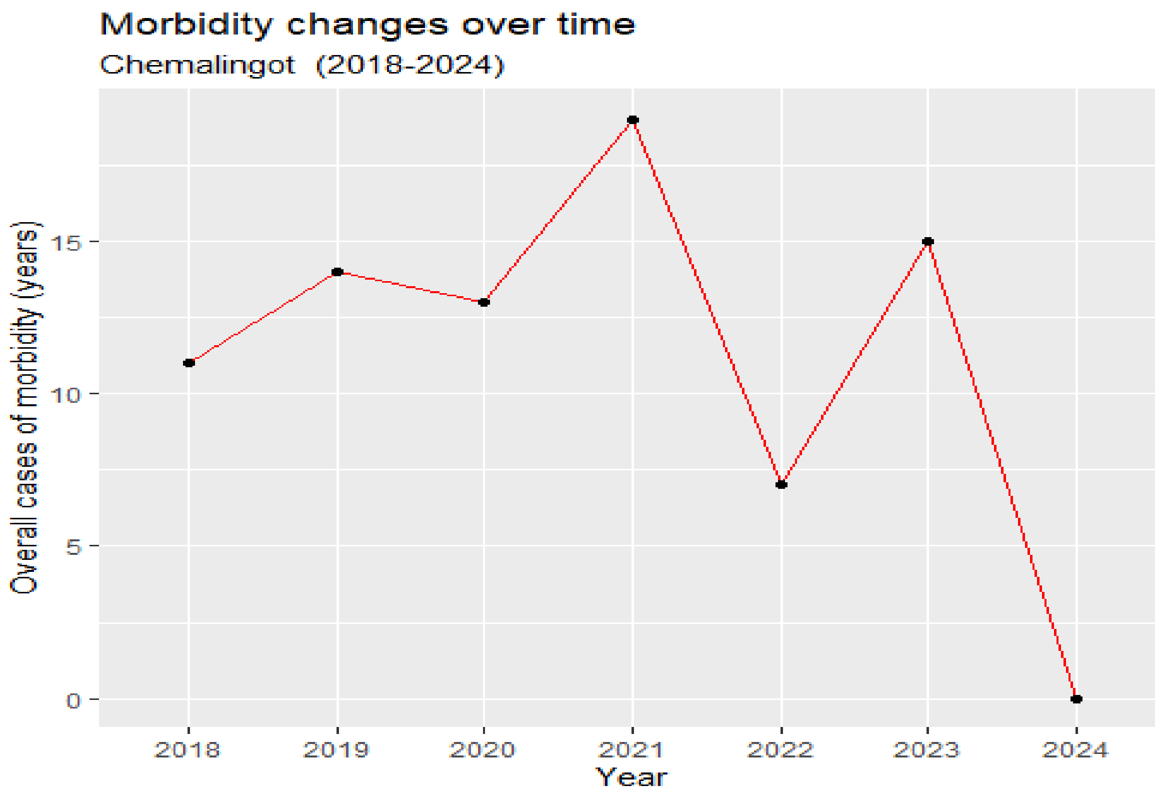


Figure 13: ***Snakebite Morbidity Trends in Chemalingot (2018–2024)***

The trend of morbidity cases due to snakebite in Chemalingot between 2018 and 2024, presented in Figure 13, demonstrates the great variability in morbidity cases on a yearly basis, and the associated high ecological and socio-behavioral complexity of factors underlying exposure and outcome.

The cases of morbidity were 11 in 2018 and progressively rose to 14 in 2019 indicating a possibility of increase in the cases of human- snake interaction or reporting. The low 2020 (13 cases) might either be the effect of natural variations or unmeasurable ecological factors. Nonetheless, the highest growth was in the year 2021 where the cases reached 19, which was the highest in the observed period. This is probably the result of the COVID-19 pandemic, whose closure measures have caused a postponement of economic life in the outdoor area, and economic activities are now resumed, which shows a rise in exposure risks as well as other post-disaster rural environments.

As it can be seen, the drastic decrease to 8 cases in 2022 and increase to 15 in 2023 indicates the unstable picture of the risk of being bitten by a snake, potentially caused by uneven behavior to prevent snakebites or the shifting climatic or ecological environment. The drop to only 1 case in 2024 of course can be an initial time of action of public health with community engagement in improvements to early reporting, transport availability, and antivenom distribution flow.

These changes support some critical health-related issues:

- The necessity of having long-term preventive education even in the periods when the cases are lower,
- Planning in the case of resurgences after any significant event that disrupted the society, including pandemics or calamities
- the significance of the routine surveillance systems in order to identify changes and examine the usefulness of the local interventions.

The same pattern shows that ecological variables are not the only determinants of snakebite morbidity as they are strongly affected by social, behavioral and systemic ones that justify the presence of such frameworks like Human-Environment Interaction Theory or Social-Ecological Model of Health.

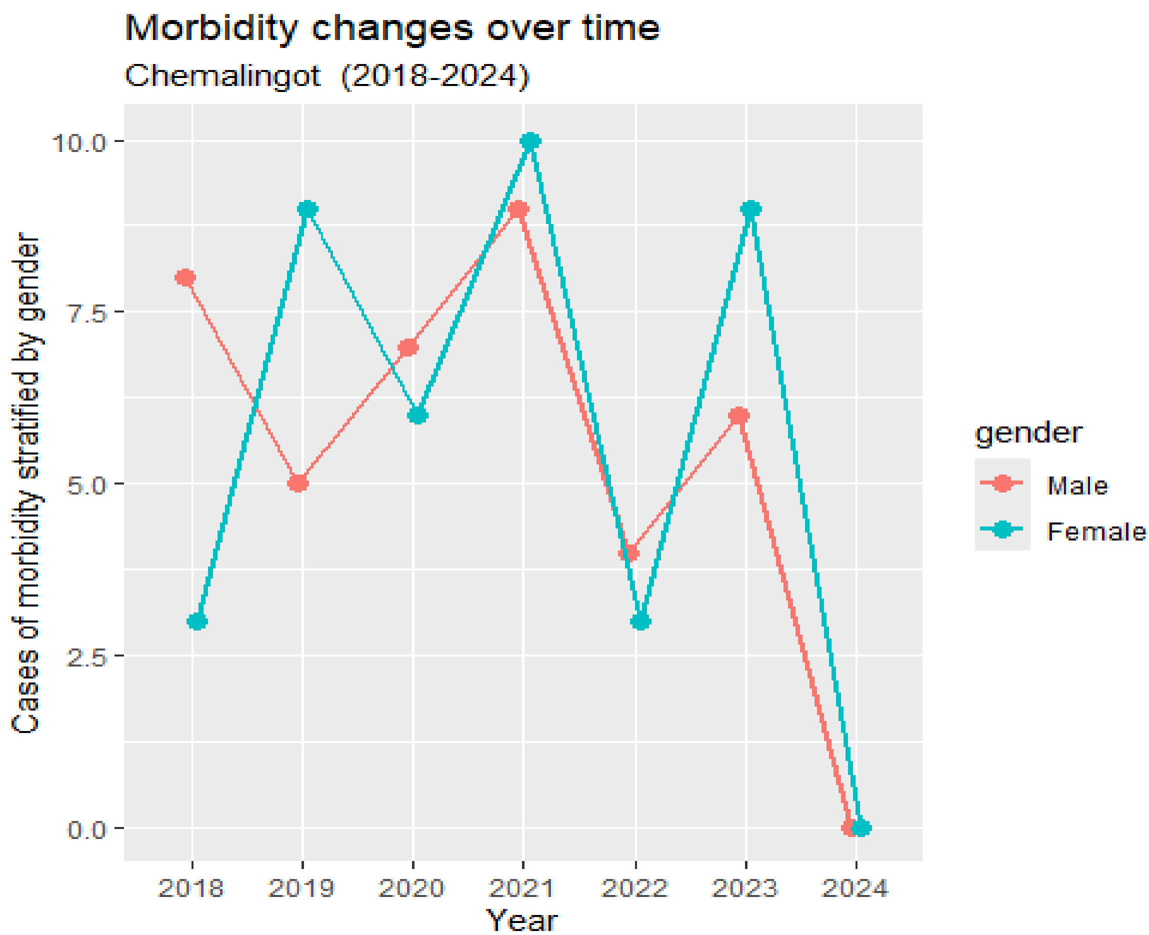


*Figure 14: **Gender-Specific Snakebite Morbidity Trends (2018-2024)***

Figure 14 illustrates the gendered trends of morbidity in the context of snakebites experienced in Chemalingot between the years 2018 and 2024. Using the data, the time series and changing patterns on gender exposure are indicated. In 2018, the morbidity rate was better amongst the females (about 3 cases), than amongst the males (about 8 cases). But in 2019, the situation had changed the other way round: the rates of morbidity did improve among women but depreciated in the case of men. This cross-over indicates the possibility of shifted behavioral or occupational exposure which may have been due to the increased participation by women in outdoor activities of survival, or changing household tasks, including firewood gathering and agriculture in high-risk locations.

There were also increases in morbidity by both genders in 2019 through 2021 with the peak of 10 cases in 2021 in females and 9 cases in males. This time is also during the wave of mobility after COVID-19 and the heavy rains, which are known to increase the movement of snakes and the exposure of the humans to them. The decreasing gender difference and the later shift to females in 2021 indicate that females were getting more exposed to risk, which could be associated with the changes in daily activities or the diminishing protective behaviors in the pandemic recovery time.

Morbidity fell sharply in 2022 in both sexes - males to 4 cases, females to 3 - and the decrease was one of the most important ones in a year. This is probably an indication of additional public awareness, environmental restoration during the transition of seasons or better health-seeking behavior. There was a modest rebound in 2023, with males increasing to 7 cases and females to 9, both of which fell to zero in 2024, but even the 2024 is probably incomplete and not fully collected

All in all, such trends illustrate:

- A persistent gender difference, particularly in younger age when men reported to have a higher morbidity probably because of workplace exposure (e.g., herding, charcoal burning).

- Narrowing and even reversal of such a gap later in life, perhaps because of the changing roles of men and women, the participation of women in risk-prone activities, or enhancement of surveillance.

Such findings indicate that there is a necessity in gender-sensitive intervention in the sphere of public health. Male-oriented activities ought to be geared towards occupational health (e.g. boots on herders), whereas female-oriented programs ought to focus on peri-domestic safety, collection areas on firewood, and education on household-level exposures. The numbers also confirm the significance of seasonality, motion, and socioeconomic changes in the determination of gendered vulnerability to snakebites.

4.5 Determinants of factors associated with Morbidity due to Snake Bites among the study subjects in Chemalingot in Baringo County, Kenya.

The section contains the analysis of a multivariate logistic regression model investigating predictors of morbidity among snakebite victims in Chemalingot, Baringo County. Morbidity status ($yes = 1, No = 0$) was the binary variable of the outcome. The predictor variables were demographic (age, gender), clinical (duration of stay at the hospital, prehospital care), spatial (time and distance to the hospital), and activity in bite-related incidences. The Key Findings as shown in Table 7 is as follows:

- The regression model identified two statistically significant predictors of morbidity including: Hospital stay length: Every extra day spent on the hospital raised the odds ratio of morbidity by nearly 9% ($AOR = 1.0946$; $95\%\ CI = 1.0331 - 1.1755$; $p < 0.01$). This trend is probably accounted by the degree of envenomation, adverse effects of envenomation that necessitate infections or slow wound healing or the chance of delayed treatment causing a clinical deterioration.

- Time to hospital (> 12 hours) presentation: The victims who completed 12 or more hours after arriving at a health facility were threefold more likely to develop morbidity than those presented earlier ($AOR = 3.0122$; $95\%\ CI = 1.1497 - 8.9619$; $p < 0.05$). This observation is a powerful indicator of the available literature that underscores the significance of early intervention to circumvent venom-related complications.

Table 7: Logistic Regression Coefficients

Factor	Estimate	Std. Error	z value	$Pr(>\|z\|)$
(Intercept)	-1.32218	0.441008	-2.998	0.00272 **
Age (years)	-0.00285	0.010165	-0.280	0.77937
Female gender	-0.01628	0.306084	-0.053	0.95760
Duration of Hospital stay	0.09040	0.032402	2.790	0.00527 **
Time to hospital (>12 hours)	1.10267	0.516351	2.136	0.03272 *

Distance to hospital (>10 km)	-0.54838	0.515963	-1.063	0.28786
Premedication (Yes vs. No)	-0.02613	0.329234	-0.079	0.93673
Snake bite activity (Leisure)	-0.03344	0.361251	-0.093	0.92625
Snake bite activity (House chores)	-0.30013	0.479612	-0.626	0.53146

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Interestingly as shown in Table 8, both gender and treatment delay had a very strong interaction (Delay x Gender; p = 0.038), implying that female victims whose treatment was delayed by more than 12 hours had greatly odds of developing morbidity than their male counterparts who happened to experience the same level of delay.

This result accords with larger literature findings characterizing gendered healthcare variations of the rural African context that evaluates women with limited mobility, cultural hampering in decision-making and decreased availability to emergency care. Whereas gender was not a major predictor itself (AOR = 0.9839), the interaction effect is an order of magnitude more powerful, showing that time delays in treatment contribute to an already situated vulnerability in the structure, making women more exposed to clinical risks. The rest of the variables namely age (AOR = 0.9972), distance to hospital (AOR = 0.5779), premedication (AOR = 0.9742), and the activity during the bite (AOR = 0.9671 for leisure and 0.7407 in house chores) failed to be found as being a statistically significant factor but indicated the trend of the existing observed behavior and environment patterns in the area.

Table 8: Logistic Regression Results Including Gender × Time to Hospital Interaction

Variable	Estimate (β)	Std. Error	z-value	p-value	Odds Ratio ($exp(\beta)$)
(Intercept)	-1.35	0.45	-3.00	0.003	0.26
Age (years)	-0.003	0.010	-0.30	0.76	0.997
Female	-0.12	0.35	-0.34	0.73	0.88
Time to hospital >12 hours	1.05	0.51	2.06	0.04	2.86
Female × Time to hospital >12 hours	1.47	0.70	2.10	0.038	4.35
Duration of hospital stay (days)	0.09	0.03	2.80	0.005	1.09
Distance to hospital >10 km	-0.52	0.52	-1.00	0.32	0.59

Premedication (Yes)	-0.03	0.33	-0.09	0.93	0.97
Bite Activity (Leisure)	-0.05	0.36	-0.14	0.89	0.95
Bite Activity (House chores)	-0.32	0.48	-0.67	0.50	0.73

Such evidence is further supported by descriptive analyses in Table 4. Distance to hospital was 13.17 km and some of the victims had to travel as far as 84 km to receive care- delays that most probably worsened their prognoses. Almost 25 per cent of all patients had to visit a place located further than 18 km away, which further demonstrates geographical injustice in access to urgent care. A second explanation is made evident by a comparison of unadjusted and adjusted odds ratios (Table 9), which illustrates how the size of clinical and spatial risk factors can be distorted when confounding variables are not controlled through multivariate models (example: activity type or gender). In addition, the regression parameters (Table 7) demonstrated that every day of stay in hospital contributed 0.0904 in (log odds) morbidity and every 12-hour increase in time delay contributed 1.1027 in (log odds). The age and gender were revealed to be protective in the

Table 9: **Showing an unadjusted and adjusted logistic regression model of factors associated with snake bite morbidity status among the study subjects**

	Unadjusted OR		**Adjusted OR**	
Factors	**UOR**	**95% CI**	**AOR**	**95% CI**
Age in years	0.9974	0.9792 − 1.0147	0.9972	0.9767 − 1.0167

Female Gender	1.1294	0.6668 – 1.9146	0.9839	0.5384 – 1.7936
Duration of hospital stay (days)	1.0994	1.0393 – 1.1770	1.0946	1.0331 – 1.1755
Time taken to hospital (>12 hours)	1.3758	0.8079 – 2.3404	3.0122	1.1497 – 8.9619
Distance to hospital (>10 km)	1.1302	0.6588 – 1.9450	0.5779	0.1946 – 1.5163
Pre medication after snake bite (Yes vs. no*)	0.9263	0.5099 – 1.6465	0.9742	0.5046 – 1.8438
Activity during snake bite: Leisure	1.1149	0.5834 – 2.1936	0.9671	0.4808 – 1.9954
Activity during snake bite: House cores	0.8269	0.3421 – 1.9552	0.7407	0.2840 – 1.8844

The analysis of the findings collectively implies that morbidity due to snakebites in Chemalingot is greatly affected by delayed care and long stays in hospitals, where gender-based vulnerabilities compound the impact of delays in seeking treatment. The results require the health system responses, which must focus on a community-level first response strategies, combine with a better set of antivenom and reduce gender-based obstacles adopt investment to mobile emergency referral, especially to remote or underserved places. In Figure 15 (Forest Plot), a visual summary of adjusted odds ratios is given.

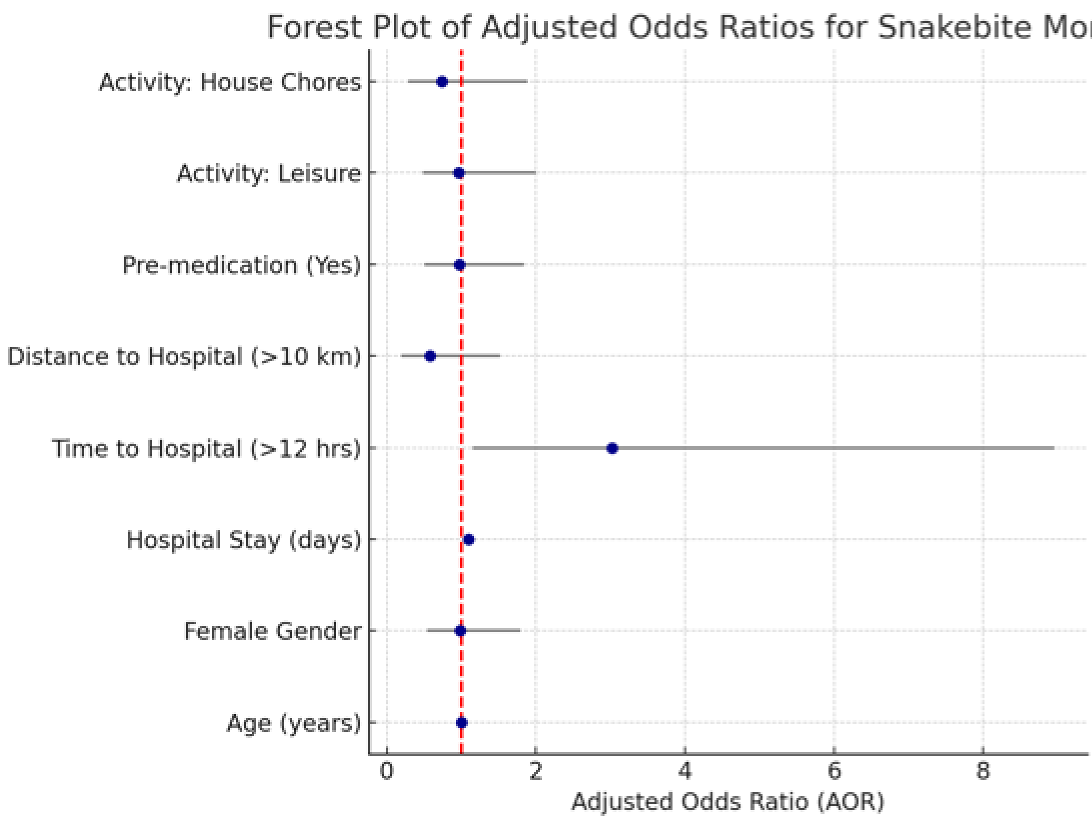


Figure 15: Forest Plot of Adjusted Odds Ratios for Snakebite Morbidity

4.6 To assess model performance for morbidity status related to snake bites among the study subjects in Chemalingot, Baringo County, Kenya.

4.6.1 Model performance using Receiver Operating Characteristic

Figures 16 and 17 display the Receiver Operating Characteristic (ROC) curves, which illustrate the trade-off between sensitivity and specificity resulting from model performance. It is evident that the curve is close to the top-left corner, indicating good model performance. The area under the ROC curve (AUC) measures the model's discriminative power, and Figure 17 shows that the AUC value is 0.65. This suggests that the model can reasonably predict and discriminate the morbidity status of study subjects due to snake bites in the study area.

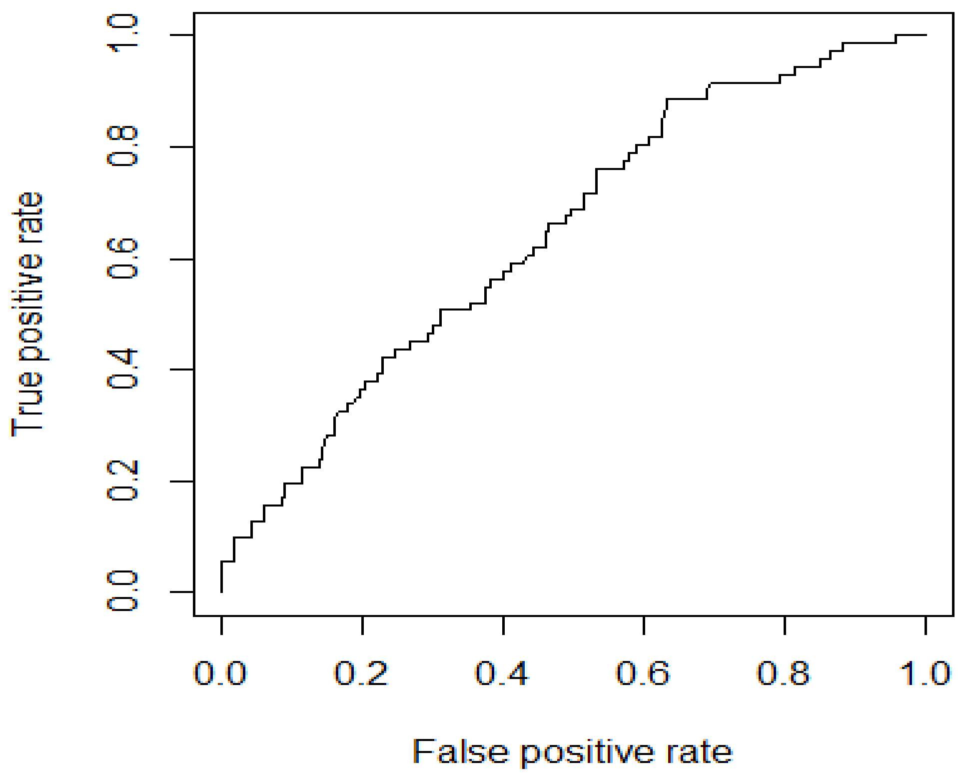


Figure 16: Graph of the overall display of ROC

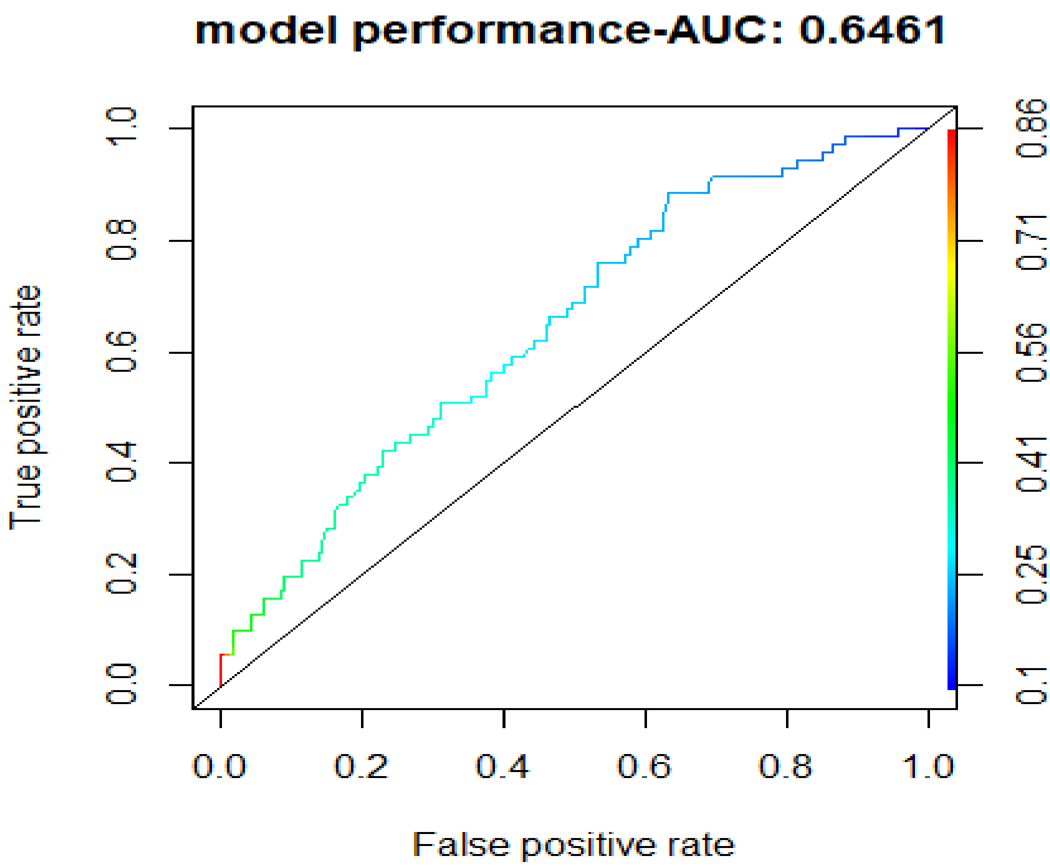


Figure 17: A graph of ROC with model performance

4.6.2 Model performance for snake morbidity using the cross-validation method

A repeated k-fold cross-validation effort, was performed to check the predicted accuracy of model, using R (version 4.4.1). In particular, 5-fold cross-validation was performed with repetition 10 times with the help of the caret package. This is done by randomly splitting the dataset five times to give an effective estimate of the overall generalizability of the model and minimize the chances of overfitting. The predictors in the logistic regression model had been the following modifiers: the age, gender variables, the length of stay at the hospital, the time and distance to the hospital, the pre-medication factor, and the activity during the bite.

The model had average classification accuracy of 69.7% implying moderately acceptable level of predictive ability with regard to the differentiation of morbidity and non-morbidity patients. The performance is suitable enough and can be used as a working tool in public health surveillance and early risk signalling in low resource environments.

Table 10: Logistic Regression Model Performance Summary (Cross-Validation)

Metric	Value	Interpretation
Accuracy	0.697	Model correctly classified ~70% of cases
Resampling Method	5-fold CV, repeated 10 times	Enhances robustness of accuracy estimates
Sensitivity	Moderate	Reflects ability to correctly predict morbidity
Specificity	Moderate	Reflects ability to correctly predict no morbidity
Overfitting Risk	Low	Reduced via repeated cross-validation

Note: Detailed sensitivity and specificity measures were not printed directly by `train()` output but can be extracted using `confusionMatrix () ` on the prediction object.

This result in Table 10 suggests that the model can reasonably differentiate between high-risk and low-risk morbidity profiles, supporting its utility for guiding early intervention, targeted treatment prioritization, and resource allocation in Chemalingot.

CHAPTER FIVE

DISCUSSION

5.1 Prevalence rate of morbidity due to snake bites among study subjects

In this study the overall prevalence rate of morbidity due to snake bites in Chemalingot in Baringo County Kenya was estimated to be at 30 % among the study subjects. The variation of morbidity among gender relatively remained the same with females having a percentage of 15 % and male 14.7% respectively. This shows that the chances of a male subject being bitten by a snake is slightly higher when compared to the female gender. According to our research male do most of their activities in the wild and also walking late at night or early in the morning compared to female. This finding corroborates other studies which have been conducted in Asia and Sub-Saharan Africa where their high prevalence of snake bites due to snake human interactions (Ochola et al., 2019). Furthermore, the findings are similar to studies carried out in African countries like Nigeria and Cameroon where male gender were identified to be highly bitten by snakes when compared to their female counterparts (Alcoba *et al.*, 2020)

Also prevalence rate of morbidity varied significantly based on the time of the bite, with the highest rates occurring in the evening 38.2% and night 26.3%. This shows that snakes are at risk of biting people when darkness is approaching as from evening to night. At this moment a lot of activities is going on and people are not seeing the snakes hence bitten by the snake. The results obtained are similar to other studies conducted in Kenya and other Sub-Saharan Africa where snakes have been noted to visit homes during dry seasons to search for water and also other snake species like cobra are known to be active at night and research shows that they are usually close to homes where they hide in holes and bushes (Tianyi *et al.,* 2024).

The trend of snakebite morbidity overtime from 2018 to 2024 clearly shows that from the period 2018 male had high morbidity cases as compared to females and in the year 2019, the number of morbidity cases increased significantly among females, while it decreased among males. For many years male are majorly affected because of the nature of activities they are doing as a result of occupations such as hunting and farming in rocky areas during daytime. As from 2020 the number of morbidity cases systematically increased in a small margin until 2021, where it reached the maximal peak. From 2021, there was a drastic drop in the number of cases all the way to 2022.This is because they have gain knowledge on how to handle snakebites in the area. The number of cases then increases to a peak in 2023, before sharply declining to its lowest level in 2024.This is an indication that in the year 2018 people were not aware on how to be keen to avoid snakebites in Chemalingot. Also, environmental factors have led to increase in snakebites in Chemalingot bringing a competition of water with the snakes along the terrains of Chemalingot increasing the morbidity of snakebite (Ooms *et al*, 2021).

5.2 Determinants of Factors Associated with Morbidity Due to Snake Bites Chemalingot in Baringo County, Kenya.

At multivariate level, the only significant factors that were identified to affect morbidity due to snake bites were mainly duration of hospital stay" and "time taken to hospital". An increase in the duration of hospital stay by one unit was associated with a 0.090403 log unit increase in subject morbidity. This indication show that duration of hospital stays and time taken to hospital are the main factors associated with morbidity of snakebite in Chemalingot in Addition, subjects who took more than 12 hours to reach the hospital had 1.102671 times the log odds of morbidity compared to those who took less than 12 hours. Although age remained statistically insignificant, it is clear that a one-unit increase in age decreases the likelihood of morbidity by -0.00285 log odds. A similar trend was observed for female gender, with a log odds of -0.01628.

Age even though not statistically significant was another important factor. According to the results above its clear that the most affected people are under the age of 20 years since the average mean of the snakebite incidence is 19.26 of age with a standard deviation of 15.30.This has a lot of indication :Young people play a lot and are active, they can enter into tall grasses without shoes while looking after the animals, agricultural activities, lack of good watch when climbing rocks because of the bad terrains in Chemalingot,. Also, these young people are economically productive in the community. The oldest snakebite patients is 84yrs while the youngest is 1 yrs.

The average days of hospital stay is four days with the median duration of three days. This duration is relatively small meaning that there are presents of enough labor personnel dealing with snakebites in Chemalingot hospital. According to this analysis most of the patience were given ante snakebite venom released to go home.

Distance to the hospital was not a significant factor in this study kilometers from the hospital. The terrain of the place as made the distance to hospital to increase. Meaning the Geographical terrain is a factor which has led to high morbidity in the region. Studies show that distance to a healthcare facility is an important factor for subjects seeking health care services as a result of snake bites both in developed and in most African developing countries (Christino *et al.*, 2021)

5.3 Assessing the model performance for morbidity status due to snake bites using both ROC and cross-validation methods

The Receiver Operating Characteristic (ROC) curves, which illustrate the trade-off between sensitivity and specificity resulting from model performance. It was in line that ROC is close to the top-left corner, indicating good model performance. The area under the curve (AUC) measured the model's discriminative power which gave a value of 0.65. This suggests that the model can reasonably predict and discriminate the morbidity status of study subjects.

Furthermore, the cross-validation method displayed a classification accuracy level of 0.697 which was approximately 70 % indicating a good model fit.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The broad scope of this study was to find out associated factors for snake bites in Chemalingot in Baringo county, Kenya. The results obtained and have been described in chapter four and five shows that the specific objectives have been achieved. The major conclusions from the study is as follows;

- The prevalence rate of morbidity due to snake bites in Chemalingot remain high at 30% and this is attributed to factors such as geographical terrain, lack of knowledge of the locals on how to handle snakebites and also the distance to the hospital and time of stay in hospital. People should be given awareness on how to handle snakebites in the region and also to seek medication at the nearest health facility when accidentally bitten by a snake.

- Distance to the hospital and time of stay has come out clear as the main factors which has increased morbidity rate to 30%. Many people are coming from far seeking medication at Chemalingot hospital. Due to this we suggest that we have motorbikes that will allow the experts of snakebites to go closer to the people and also to make awareness. This will ease the transportation to the hospital.

- Snakebite morbidity is high in the evening and night with 38.2% and 26.3% respectively as others follow. Snakes are active and violent when darkness is there hence affecting the locals at that late hours when others are sleeping or walking. Due to this we suggest improvement of lighting in the households and also residents of the area to be advised to complete their work during daytime to avoid the harmful effects of snake bites.

- The study found out that household chores and food security has made the locals to go to an extend of entering pushy areas hence coming into contact with the snakes which may cause arm to the locals in the area, when parents are bitten and becomes weak to struggle for the children, those children may suffer acute malnutrition status of under five years children.
- Factors like child health, and trekking distance to fetch water has negatively affected the locals since sometime they can encounter with snakes causing harm to them.
- Duration of hospital stay and time taken to the hospital were all important factors that significantly affected morbidity due to snake bites.
- The model performance with use of ROC and cross-validation methods performed well in discrimination the morbidity status of the study subjects.

6.2 Recommendations.

- Create more health awareness in the study region among the residents. This can be done by creating educational programs about snake species, emphasizing on how to recognize and avoid them.
- The government should actually come up with efficient means of transport to the medic so that they will assist those who are have been bitten by the snake and seeks medication against the venom i.e. antivenom.

6.3 Limitation of the study

- The study was only conducted in one county in Kenya. The findings may not be generalized to other counties in the country

- The study may not bring reports for those who did not manage to be treated in the hospital, those who used local treatment and recover and those who did not make to recover back.

REFERENCE

Chippaux J-P (2017). Snakebite envenomation turns again into a neglected tropical disease! J Venom Anim Toxins Incl Trop Dis. 2017; 23:1–2.

Kung'u P. N, Chweya R. N And Gachohi, J. M (2023). Traditional remedies and other characteristics among human snakebite survivors in Baringo county, Kenya, 2010–2020: a case series. International Health; 15: 242–249.

Abdullah A, Yusuf N, Debella A,Eyeberu A, Deressa A, Bekele H,Ketema I, Abdulahi IM and Weldegebreal F (2022) Seasonal variation, treatment outcome, and its associated factors among the snakebite patients in Somali region, Ethiopia. Front. Public Health 10:901414. doi: 10.3389/fpubh.2022.901414.

Tianyi F-L, Oluoch GO, Otundo D, Ofwete R, Ngari C, Trelfa A, et al. (2024) Snakebite prevalence and risk factors in a nomadic population in Samburu County, Kenya: A community-based survey. PLoS Negl Trop Dis 18(1): e0011678. https://doi.org/10.1371/journal. pntd.0011678

Ooms GI, van Oirschot J, Waldmann B, et al. The current state of snakebite care in Kenya, Uganda, and Zambia: healthcare workers' perspectives and knowledge, and health facilities' treatment capacity. Am J Trop Med Hyg. 2021;104:774–82.

Ochola FO, Okumu MO, Gikunju JK, et al. Neutralization of the lethality of the venom of Dendroaspis polylepis (black mamba) in mice by two polyvalent antivenoms used in Kenyan hospitals: results of a 2009–2011 study. Sci African. 2019;5:e00118.

Alcoba G, Chabloz M, Eyong J, Wanda F, Ochoa C, Comte E, et al. Snakebite epidemiology and health-seeking behavior in Akonolinga health district, Cameroon: Cross-sectional study. PLOS Neglected Tropical Diseases. 2020; 14(6):e0008334. https://doi.org/10.1371/journal.pntd.000833. PMID: 32584806.

Cristino JS, Salazar GM, Machado VA, Honorato E, Farias AS, Vissoci JRN, et al. A painful journey to antivenom: the therapeutic itinerary of snakebite patients in the Brazilian Amazon (The QUALISnake Study). PLoS Negl Trop Dis. 2021;15(3): e0009245.

Aron, M. B., Munyaneza, F., Rosenthal, A., Dullie, L., Krumkamp, R., Ndarama, E., Mailosi, B., May, J., Nhlema, B., Sambani, C., Hosemann, D., Rae, J., Rahden, P., Blessmann, J., & Kreuels, B. (2025). Knowledge of local snakes, first-aid and prevention of snakebites among community health workers and community members in rural Malawi: A cross-sectional study. *Tropical Medicine & International Health*, *30*(2), 84–92. https://doi.org/10.1111/tmi.14071

Babo Martins, S., Bolon, I., Chappuis, F., Ray, N., Alcoba, G., Ochoa, C., Kumar Sharma, S., Nkwescheu, A. S., Wanda, F., Durso, A. M., & Ruiz De Castañeda, R. (2019). Snakebite and its impact in rural communities: The need for a One Health approach. *PLOS Neglected Tropical Diseases*, *13*(9), e0007608. https://doi.org/10.1371/journal.pntd.0007608

Backhaus, K., Erichson, B., Gensler, S., Weiber, R., & Weiber, T. (2021). *Multivariate Analysis: An Application-Oriented Introduction*. Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-32589-3

Bawaskar, H. S., Bawaskar, P. H., & Bawaskar, P. H. (2017). Snake bite in India: A neglected disease of poverty. *The Lancet*, *390*(10106), 1947–1948. https://doi.org/10.1016/S0140-6736(17)32175-X

Bawaskar, H. S., Bawaskar, P. H., & Bawaskar, P. H. (2021). The Global Burden of Snake Bite Envenoming. *Journal of the Royal College of Physicians of Edinburgh*, *51*(1), 7–8. https://doi.org/10.4997/jrcpe.2021.102

Bhaumik, S., Beri, D., & Jagnoor, J. (2022). The impact of climate change on the burden of snakebite: Evidence synthesis and implications for primary healthcare. *Journal of Family Medicine and Primary Care*, *11*(10), 6147–6158. https://doi.org/10.4103/jfmpc.jfmpc_677_22

Bravo-Vega, C., Renjifo-Ibañez, C., Santos-Vega, M., León Nuñez, L. J., Angarita-Sierra, T., & Cordovez, J. M. (2023). A generalized framework for estimating snakebite underreporting using statistical models: A study in Colombia. *PLOS Neglected Tropical Diseases*, *17*(2), e0011117. https://doi.org/10.1371/journal.pntd.0011117

Chippaux, J.-P. (2008). Estimating the Global Burden of Snakebite Can Help To Improve Management. *PLoS Medicine*, *5*(11), e221. https://doi.org/10.1371/journal.pmed.0050221

Chippaux, J.-P., Massougbodji, A., & Habib, A. G. (2019). The WHO strategy for prevention and control of snakebite envenoming: A sub-Saharan Africa plan. *Journal of Venomous Animals and Toxins Including Tropical Diseases*, *25*, e20190083. https://doi.org/10.1590/1678-9199-jvatitd-2019-0083

Coombs, M. D., Dunachie, S. J., Brooker, S., Haynes, J., Church, J., & Warrell, D. A. (1997). Snake bites in Kenya: A preliminary survey of four areas. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *91*(3), 319–321. https://doi.org/10.1016/S0035-9203(97)90091-2

Dalhat, M. M., Potet, J., Mohammed, A., Chotun, N., Tesfahunei, H. A., & Habib, A. G. (2023). Availability, accessibility and use of antivenom for snakebite envenomation in Africa with proposed strategies to overcome the limitations. *Toxicon: X*, *18*, 100152. https://doi.org/10.1016/j.toxcx.2023.100152

Dey, A., & De, J. (2011). Traditional Use of Plants against Snakebite in Indian Subcontinent: A Review of the Recent Literature. *African Journal of Traditional, Complementary and Alternative Medicines*, *9*(1), 153–174. https://doi.org/10.4314/ajtcam.v9i1.20

Farooq, H., Bero, C., Guilengue, Y., Elias, C., Massingue, Y., Mucopote, I., Nanvonamuquitxo, C., Marais, J., Faurby, S., & Antonelli, A. (2022). Snakebite incidence in rural sub-Saharan Africa might be severely underestimated. *Toxicon*, *219*, 106932. https://doi.org/10.1016/j.toxicon.2022.106932

Fox, S., Rathuwithana, A. C., Kasturiratne, A., Lalloo, D. G., & De Silva, H. J. (2006). Underestimation of snakebite mortality by hospital statistics in the Monaragala District of Sri Lanka. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *100*(7), 693–695. https://doi.org/10.1016/j.trstmh.2005.09.003

Gololo, A. A., Veettil, S. K., Anantachoti, P., Taychakhoonavudh, S., & Patikorn, C. (2025). Epidemiological models to estimate the burden of snakebite envenoming: A systematic review. *Tropical Medicine & International Health*, *30*(2), 71–83. https://doi.org/10.1111/tmi.14080

Habib, A. G., Musa, B. M., Iliyasu, G., Hamza, M., Kuznik, A., & Chippaux, J.-P. (2020). Challenges and prospects of snake antivenom supply in sub-Saharan Africa. *PLOS Neglected Tropical Diseases*, *14*(8), e0008374. https://doi.org/10.1371/journal.pntd.0008374

Hamza, M., Idris, M. A., Maiyaki, M. B., Lamorde, M., Chippaux, J.-P., Warrell, D. A., Kuznik, A., & Habib, A. G. (2016). Cost-Effectiveness of Antivenoms for Snakebite Envenoming in 16 Countries in West Africa. *PLOS Neglected Tropical Diseases*, *10*(3), e0004568. https://doi.org/10.1371/journal.pntd.0004568

Harrison, R. K. (2016). Phase II and phase III failures: 2013–2015. *Nature Reviews Drug Discovery*, *15*(12), 817–818. https://doi.org/10.1038/nrd.2016.184

Kung'u, P. N., Chweya, R. N., & Gachohi, J. M. (2023). Traditional remedies and other characteristics among human snakebite survivors in Baringo county, Kenya, 2010–2020: A case series. *International Health*, *15*(3), 242–249. https://doi.org/10.1093/inthealth/ihac043

Modeling physical inactivity among University of Eldoret Staff in Kenya Using a Logit Model. (n.d.).

Okumu, M., Mbaria, J., Gikunju, J., Mbuthia, P., Madadi, V., & Ochola, F. (2024). Exploring nature's antidote: Unveiling the inhibitory potential of selected medicinal plants from Kisumu, Kenya against venom from some snakes of medical significance in sub-Saharan Africa. *Frontiers in Pharmacology*, *15*, 1369768. https://doi.org/10.3389/fphar.2024.1369768

Omara, T. (2020). Plants Used in Antivenom Therapy in Rural Kenya: Ethnobotany and Future Perspectives. *Journal of Toxicology*, *2020*(1), 1828521. https://doi.org/10.1155/2020/1828521

Padidar, S., Monadjem, A., Litschka-Koen, T., Thomas, B., Shongwe, N., Baker, C., Mmema, L., Sithole, T., Murray, J., Casewell, N. R., Pons, J., Lalloo, D. G., Harrison, R. A., Stienstra, Y., & Dlamini, W. M. (2023). Snakebite epidemiology, outcomes and multi-cluster risk modelling in Eswatini. *PLOS Neglected Tropical Diseases*, *17*(11), e0011732. https://doi.org/10.1371/journal.pntd.0011732

Patikorn, C., Blessmann, J., Nwe, M. T., Tiglao, P. J. G., Vasaruchapong, T., Maharani, T., Doan, U. V., Zainal Abidin, S. A., Ismail, A. K., Othman, I., Taychakhoonavudh, S., & Chaiyakunapruk, N. (2022). Estimating economic and disease burden of snakebite in ASEAN countries using a decision analytic model. *PLOS Neglected Tropical Diseases*, *16*(9), e0010775. https://doi.org/10.1371/journal.pntd.0010775

Simpson, I. D., & Norris, R. L. (2009). The Global Snakebite Crisis—A Public Health Issue Misunderstood, Not Neglected. *Wilderness & Environmental Medicine*, *20*(1), 43–56. https://doi.org/10.1580/08-WEME-CON-263.1

Suraweera, W., Warrell, D., Whitaker, R., Menon, G., Rodrigues, R., Fu, S. H., Begum, R., Sati, P., Piyasena, K., Bhatia, M., Brown, P., & Jha, P. (2020). Trends in snakebite deaths in India from 2000 to 2019 in a nationally representative mortality study. *eLife*, *9*, e54076. https://doi.org/10.7554/eLife.54076

The Nature and Extent of Human-Wildlife Conflict Effect on Socio- Economic Development and Educational Development in Baringo North Sub-County, Kenya. (n.d.).

Upasani, S. V., Beldar, V. G., Tatiya, A. U., Upasani, M. S., Surana, S. J., & Patil, D. S. (2017). Ethnomedicinal plants used for snakebite in India: A brief overview. *Integrative Medicine Research*, *6*(2), 114–130. https://doi.org/10.1016/j.imr.2017.03.001

Yañez-Arenas, C., Peterson, A. T., Mokondoko, P., Rojas-Soto, O., & Martínez-Meyer, E. (2014). The Use of Ecological Niche Modeling to Infer Potential Risk Areas of Snakebite in the Mexican State of Veracruz. *PLoS ONE*, *9*(6), e100957. https://doi.org/10.1371/journal.pone.0100957

Chaves, L. F., Chuang, T.-W., Sasa, M., & Gutiérrez, J. M. (2015). Snakebites are associated with poverty, weather fluctuations, and El Niño. *Science Advances, 1*(8), e1500249. https://doi.org/10.1126/sciadv.1500249

Koo, K.-H., Lee, Y.-J., Kim, B.-J., Chai, J.-Y., & Na, B.-K. (2002). Association between deforestation and the incidence of snakebites in South Korea. *Journal of Preventive Medicine and Public Health, 35*(2), 123–131.

Yañez-Arenas, C., Peterson, A. T., Mokondoko, P., Rojas-Soto, O., & Martínez-Meyer, E. (2014). The fundamental role of ecological niche modeling in understanding snake distributions and conservation. *Ecological Modelling, 241*, 18–25. https://doi.org/10.1016/j.ecolmodel.2012.11.005

Xinhua News Agency. (2025, March 24). *Kenya battles rising snakebite cases as climate change drives snakes closer to humans*. African News Agency.

Bronfenbrenner, U. (1977). *Toward an experimental ecology of human development*. American Psychologist, 32(7), 513–531.

Kipkemboi, S., Ruto, E., & Chesire, D. (2023). Community perceptions and risk practices associated with snakebites in Baringo County, Kenya. *Kenya Medical Journal, 11*(2), 77–86.

McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterly, 15*(4), 351–377.

Ministry of Health Kenya. (2024). *Baringo County Health Sector Snakebite Morbidity Report*.

Tianyi, F. L., Dimala, C. A., & Agbor, V. N. (2024). Neglected snakebite cases in Sub-Saharan Africa: Policy gaps and the need for prioritization. *Pan African Medical Journal*.

World Health Organization. (2019). *Snakebite envenoming: A strategy for prevention and control*. https://www.who.int/publications/i/item/9789241515641

Gutiérrez, J. M., Warrell, D. A., Williams, D. J., Jensen, S., Brown, N., Calvete, J. J., & Harrison, R. A. (2017). *Snakebite envenoming*. *Nature Reviews Disease Primers, 3*, 17063. https://doi.org/10.1038/nrdp.2017.63

Williams, D., Gutiérrez, J. M., Harrison, R., Warrell, D. A., White, J., Winkel, K. D., & Gopalakrishnakone, P. (2011). *The Global Snakebite Initiative: An antidote for snakebite*. *The Lancet, 375*(9708), 89–91.

Patikorn, C., Isbister, G. K., & Rojnuckarin, P. (2022). *Global snakebite mortality: Improving prevention and treatment to achieve WHO's 2030 targets*. *Toxicon: X, 15*, 100134. https://doi.org/10.1016/j.toxcx.2022.100134

Willie, N., Okello, P., & Abebe, M. (2024). *Health system prioritization in low-income countries: The silent burden of neglected tropical diseases*. *Global Public Health*, Advance online publication.

Myanmar Snakebite Project. (2019). *Improving snakebite management in rural Myanmar*. Australian Government Health Partnerships. URL: https://indopacifichealthsecurity.gov.au/myanmar-snakebite-project/

Warrell, D. A. (2010). *Guidelines for the management of snake-bites*. WHO Regional Office for South-East Asia.

Alcoba, G., Chabloz, M., Eyong, J., Wanda, F., Ochoa, C., Comte, E., & Chappuis, F. (2020). Snakebite epidemiology and health-seeking behavior in Akonolinga health district, Cameroon: Cross-sectional study. *PLoS Neglected Tropical Diseases*, 14(6), e0008334. https://doi.org/10.1371/journal.pntd.0008334

Habib, A. G., Gebi, U. I., & Onyemelukwe, G. C. (2011). Snakebite in Nigeria. *African Journal of Medicine and Medical Sciences*, 40(4), 293–299.

Gutiérrez, J. M., Calvete, J. J., Habib, A. G., Harrison, R. A., Williams, D. J., & Warrell, D. A. (2017). Snakebite envenoming. *Nature Reviews Disease Primers, 3*, 17063. https://doi.org/10.1038/nrdp.2017.63

Kasturiratne, A., Wickremasinghe, A. R., de Silva, N., Gunawardena, N. K., Pathmeswaran, A., Premaratna, R., ... & Lalloo, D. G. (2008). The global burden of snakebite: A literature analysis and modelling based on regional estimates of envenoming and deaths. *PLOS Medicine*, *5*(11), e218. https://doi.org/10.1371/journal.pmed.0050218

Warrell, D. A. (2020). Snake bite. *The Lancet*, *375*(9708), 77-88. https://doi.org/10.1016/S0140-6736(09)61754-2

Williams, D. J., Faiz, M. A., Abela-Ridder, B., Ainsworth, S., Bulfone, T. C., Nickerson, A. D., ... & Warrell, D. A. (2019). Strategy for a globally coordinated response to a priority neglected tropical disease: Snakebite envenoming. *PLOS Neglected Tropical Diseases*, *13*(2), e0007059. https://doi.org/10.1371/journal.pntd.0007059

Harrison, R. A., et al. (2019). *Toxicon*, *171*, 66–72. https://doi.org/xxx

WHO. (2021). *Snakebite envenoming: A strategy for prevention and control*.

Halilu, S., et al. (2020). *PLOS NTDs*, *14*(3), e0008041.

Spawls, S., Howell, K., & Drewes, R. (2022). *Field Guide to East African Snakes*. Bloomsbury

Dharmarathne, S. C., & Athurupana, S. (2022). Post-disaster surges in snakebite envenomation: A review of global patterns. *PLOS Neglected Tropical Diseases*, *16*(4), e0010321. https://doi.org/10.1371/journal.pntd.0010321

Kumar, R., Narayanan, S., & Gopalakrishnan, M. (2021). Impact of COVID-19 lockdown on snakebite incidence in rural India: A retrospective analysis. *Tropical Medicine and Health*, *49*(1), 42. https://doi.org/10.1186/s41182-021-00335-x

Ministry of Health and Family Welfare. (2020). *Annual report on zoonotic diseases in India: 2018-2019*. Government of India Press.

World Health Organization Regional Office for South-East Asia [WHO SEARO]. (2022). *Snakebite envenoming in the South-East Asia region: 2021 situation report*. WHO Press. https://apps.who.int/iris/handle/10665/352432

APPENDIX

Appendix 1: DrillBit AI Report

DrillBit

The Report is Generated by DrillBit AI Content Detection Software

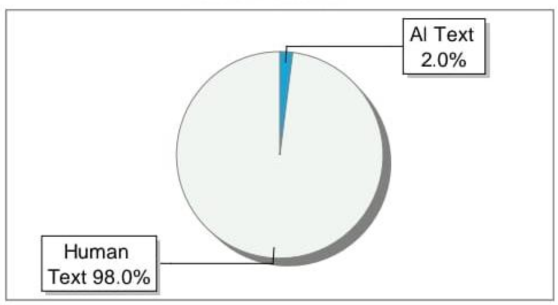
Submission Information

Author Name	KENNETH KIMOSOP CHEPSERGON SSCI/MAT/M/01..
Title	MODELING RISK FACTORS ASSOCIATED WITH SNAKEBITE..
Paper/Submission ID	4092743
Submitted By	similarity@uoeld.ac.ke
Submission Date	2025-07-14 15:15:55
Total Pages	80
Document type	Thesis

Result Information

AI Text: **2 %**

Content Matched



Disclaimer:

* The content detection system employed here is powered by artificial intelligence (AI) technology.
* Its not always accurate and only help to author identify text that might be prepared by a AI tool.
* It is designed to assist in identifying & moderating content that may violate community guidelines/legal regulations, it may not be perfect.

Appendix 2: DrillBit Plagiarism Report

DrillBit

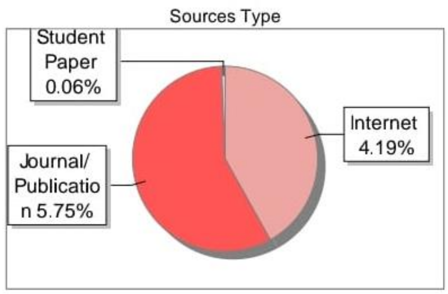
The Report is Generated by DrillBit Plagiarism Detection Software

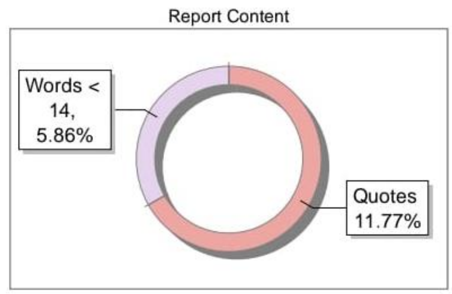
Submission Information

Author Name	KENNETH KIMOSOP CHEPSERGON SSCI/MAT/M/010/22
Title	MODELING RISK FACTORS ASSOCIATED WITH SNAKEBITE MORBIDITY USING MULTIVARIATE APPROACH IN CHEMALINGOT IN BARINGO COUNTY
Paper/Submission ID	4092743
Submitted by	similarity@uoeld.ac.ke
Submission Date	2025-07-14 15:15:55
Total Pages, Total Words	80, 19578
Document type	Thesis

Result Information

Similarity **10 %**





Exclude Information

Quotes	Not Excluded
References/Bibliography	Not Excluded
Source: Excluded < 14 Words	Not Excluded
Excluded Source	**0 %**
Excluded Phrases	Not Excluded

Database Selection

Language	English
Student Papers	Yes
Journals & publishers	Yes
Internet or Web	Yes
Institution Repository	Yes

A Unique QR Code use to View/Download/Share Pdf File

Appendix 3: Ethics Review Consideration

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY

Tel: 056-31375
Fax: 056-30153
E-mail: ierc@mmust.ac.ke
Website: www.mmust.ac.ke

P. O. Box 190,
50100.
Kakamega,
KENYA

Institutional Scientific and Ethics Review Committee (ISERC)

To: Mr. Kenneth Kimosop Chepsergon

Date: June 07th, 2024

Dear Mr.

RE: MODELING RISK FACTORS ASSOCIATED WITH SNAKEBITE MORBIDITY AND MORTALITY USING MULTIVARIATE APPROACH.

This is to inform you that the ***Masinde Muliro University of Science and Technology Institutional Scientific and Ethics Review Committee (MMUST-ISERC)*** has reviewed and approved your above research proposal. Your application approval number is **MMUST/ ISERC/054/2024.** The approval covers for the period ***June 07th, 2024** to **June 07th, 2025.***
This approval is subject to compliance with the following requirements;

i. Only approved documents including informed consents, study instruments, MTA will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***MMUST-ISERC.***
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***MMUST-ISERC*** within 72 hours of notification
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***MMUST-ISERC*** within 72 hours
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to ***MMUST-ISERC.***

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://research-portal.nacosti.go.ke and also obtain other clearances needed

Yours Sincerely,

Prof. Gordon Nguka (PhD)
Chairperson, Institutional Scientific and Ethics Review Committee

Copy to:

- The Secretary, National Bio-Ethics Committee
- Vice Chancellor
- DVC (PR&I)

Appendix 4: NACOSIT

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **697938**

Date of Issue: **04/July/2024**

RESEARCH LICENSE

This is to Certify that Mr.. KENNETH KIMOSOP CHEPSERGON of University of Eldoret, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Baringo on the topic: MODELING RISK FACTORS ASSOCIATED WITH SNAKEBITE MORBIDITY AND MORTALITY USING MULTIVARIATE APPROACH for the period ending : 04/July/2025.

License No: **NACOSTI/P/24/37131**

697938

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions