GHANA COLLEGE OF PHYSICIANS AND SURGEONS

FACULTY OF PUBLIC HEALTH

SPATIOTEMPORAL RELATIONSHIPS BETWEEN DOG BITES, DOG VACCINATION COVERAGES, DOG AND HUMAN RABIES IN GHANA: IMPLICATIONS FOR ONE HEALTH COLLABORATION

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Dr. ERIC ODEI

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Dr. Eric Odei

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DECLARATION

The research report is my own work, and it has not been used for other degrees or diplomas in the past.

DR. ERIC ODEI

Signature..... Date.....17/10/2024.....

CERTIFICATION (SUPERVISORS' SIGNATURES)

Prof. Irene A. Agyepong MBChB DrPH MWACP FGCPS
Ghana College of Physicians and Surgeons,
P.O.BOX M429, Ministries, Accra, Ghana
Telephone: +233-(0)244-862665
Email: iagyepong@gcps.edu.gh

Signature..... Date 17/10/2024

Dr. Bashiru Boi Kikimoto PhD
Veterinary Services Directorate, P.O. Box M161, Accra, Ghana
Telephone: +233 244-289782; Office: +233 200 474719
E-mail: boikikimoto@gmail.com

Signature..... Date 18/10/2024

Dr. Simon Sovoe PhD
Environmental Protection Agency (EPA)
P.O.Box MB326, Ministries Post Office, Accra, Ghana
Telephone: +233-(0)246-099870
Email: Simon.Sovoe@epa.gov.gh

Signature..... Date 17/10/2024

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ABSTRACT

Introduction

Rabies is preventable, yet globally, about 59,000 people die from the disease annually. About forty percent (40%) of these deaths occur in Sub-Saharan Africa (SSA). Rabies remains an important public health concern to human and veterinary health professionals in SSA. In line with the global strategic framework to eliminate dog-mediated human rabies by 2030, Ghana has committed to eliminating human rabies by improving dog vaccination coverages, creating awareness and providing prompt post-exposure treatment using the One Health approach. The study aimed to investigate the spatiotemporal relationships between dog bites, dog vaccination coverages, dog and human rabies cases in Ghana for the period 2015-2021 and to identify existing mechanisms, barriers and enablers of One Health collaboration for elimination of dog-mediated human rabies.

Methods

A mixed-methods approach was employed. Rabies surveillance data from the Disease Surveillance Department (DSD) of Ghana Health Service (GHS) and Veterinary Services Directorate (VSD) were abstracted for all 260 districts in Ghana and modelled using Besag-Yorke-Mollie model in R-INLA and SaTScan for spatial, temporal and spatiotemporal mapping and cluster analysis. Key informant interviews (KIIs) were conducted with 35 purposively selected officers in GHS and VSD at the national, regional and district levels to determine extent of data-sharing and collaboration between the two sectors. Concurrently, a cross-sectional survey was conducted among 468 frontline staff of the animal health and human health sectors in the same 12 purposively selected districts where KIIs were being conducted to assess their knowledge, perception and practices with respect to One Health collaboration for rabies elimination. A desk review of national policy documents on dog and human rabies elimination in Ghana was conducted to understand the policy environment.

Results

In the period 2015-2021, average annual reported dog bites, human rabies cases, dog rabies cases, and dogs vaccinated were 16,675, 19, 86, and 60,952 respectively translating into average annual dog bite incidence of 58.9 per 100,000 population, average annual human rabies incidence of 0.07 per 100,000 population, average annual dog rabies incidence of 8 per 100,000 dogs and vaccination coverage of 5.7%. Dog bites were spatiotemporally associated with dog vaccination coverage (RR:1.77; 95% Credible Interval (CI):1.26-2.46) but much less significantly so with dog rabies (RR:1.03; 95% CI:1.01-1.06) and human rabies cases (RR: 1.03; 95% CI: 1.00-1.06). Key Informant Interviews revealed that the approach to dog vaccinations were more reactionary than proactive with vaccinations being carried out in response to suspected rabies cases or dog bites. There was poor collaboration for routine data-sharing between the human health and veterinary services due to lack of a clear policy. Unwillingness and inability of pet owners to bear cost of vaccination and inadequate law enforcement regarding responsible pet ownership contributed to the low dog vaccination coverage.

Conclusion and Recommendations

Lack of One Health policy accounts for the poor collaboration for routine data sharing between the two sectors. Weak legislation and inadequate law enforcement are major drivers of the low dog vaccination coverages. Finalizing and implementing the One Health policy alongside stronger legislation with law enforcement on dog vaccinations are urgently required to ensure the achievement of ‘zero by 30’ target.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

AU-IBAR	African Union-Inter-African Bureau for Animal Resources
CHAG	Christian Health Association of Ghana
CHIM	Centre for Health Information Management
DHIMS	District Health Information Management
DSD	Disease Surveillance Department
FAO	Food and Agriculture Organization
FPH	Faculty of Public Health
GARC	Global Alliance for Rabies
GCPS	Ghana College of Physicians and Surgeons
GHS	Ghana Health Service
GSS	Ghana Statistical Service
HDR	Human-to-dog ratio
IDSR	Integrated Disease Surveillance and Response
INLA	Integrated Nested Laplace Approximation
GARC	Global Alliance for Rabies Control
KCCR	Kumasi Collaborative Centre for Research in Tropical Medicine
MDAs	Ministries, Departments and Agencies
MMDAs	Metropolitan/Municipal/District Assemblies
MoFA	Ministry of Food and Agriculture
MeSH	Medical Subject Headings
NMIMR	Noguchi Memorial Institute for Medical Research
OIE	World Organization for Animal Health

SARS	Severe Acute Respiratory Syndrome
SARE	Stepwise Approach to Rabies Elimination
VSD	Veterinary Services Directorate
WHO	World Health Organization

1.0 INTRODUCTION

1.1 BACKGROUND

1.1.1 DEFINITION

Rabies is an acute viral infection caused by the rabies virus of the genus Lyssavirus.[1,2] It is characterized by progressive viral encephalitis that is almost always fatal. It is transmitted through the saliva of an infected animal, mostly dogs, who are the main transmitter to humans.[3]

1.1.2 EPIDEMIOLOGY

Globally rabies kills about 59,000 people every year with about 95% of the deaths occurring in Africa and Asia.[4] About 95 % of these deaths are due to dog-mediated rabies.[5] In contrast, in the developed world where rabies accounts for an insignificant proportion of mortalities, most cases of human rabies are due to exposure to infected wild animals such as racoons, bats, foxes, and skunks.[6,7] In Ghana, rabies virus has been identified in dogs, cats, monkeys, bats, cattle, sheep and goats. Dogs predominantly contributed 94% of rabies cases reported within the period from 2013 to 2017 by the Veterinary Services Directorate of the Ministry of Food and Agriculture (MoFA).[8,9]

The most common mode of rabies virus transmission is through the bite of an infected host. Incubation period ranges from 2 weeks to 2 years or more. In Africa, most victims of human rabies are children below 15 years of age. [10] Clinically, rabies is characterised by an acute neurological stage with signs of hyperactivity (furious rabies) or paralysis (dumb rabies) predominating. In both furious and dumb rabies, complete paralysis eventually occurs followed by coma and death from respiratory failure. Without intensive care, death occurs during the first seven days of illness. [11]

Although both human and canine rabies have no cure they can be prevented.[11,12] This can be done through a combination of dog vaccination, control of stray and unvaccinated dog population, administration of prompt and adequate post-exposure treatment of exposed victims and pre-exposure prophylaxis to potentially vulnerable groups such as people living in remote, highly rabies-endemic areas with limited local access to rabies biologicals.[11-13]

In Ghana rabies prevention activities have been erratic, hardly sustained and mostly reactive, often following reports of death from rabies at a particular locality. Such reports are often received with heightened but short-lived active surveillance, increased public awareness creation and sometimes mass dog vaccination in the affected community.[14,15] To a limited extent however, routine dog vaccinations are being carried out on an ongoing basis at public outlets of the Veterinary Services Directorate of Ministry of Food and Agriculture across the country as well as private outlets for which monthly reports are routinely sent from the District to the National level through the Regional

Veterinary offices.[14] Vaccination coverages from these reports are generally low due to low patronage resulting from inadequate law enforcement to compel dog owners to vaccinate their dogs, high cost of vaccinating a dog, inadequately resourced Veterinary Service, low public awareness and lack of an integrated surveillance system to track the disease in both humans and animals.[14,15]

The lack of an efficient surveillance system has resulted in gross underreporting and hence inadequate attention from governments in spite of the high potential to cause preventable deaths.[14-16]

1.1.3 THE ONE HEALTH APPROACH TO RABIES ELIMINATION

1.1.3.1 THE HISTORICAL PERSPECTIVE AND CONCEPT

The recognition that human health and animal health are inseparably linked to each other dates back to the ancient priest healers who used to heal both human and animal ailments together.[17] Then in the 18th century, Rudolph Virchow, the founder of comparative medicine and cellular pathology, coined the term zoonoses and declared that "between animal and human medicine there are no dividing lines nor should there be—the object is different but the experience obtained constitutes the basics of all medicine." Sir William Osler, the founder of modern human medicine and veterinary pathology, coined the term One medicine" in the late 1800s.[17] From the 19th through the 20th to the 21st century, the concept of "One Health" has evolved to reflect the interconnectedness between human health, animal health and the environment in the wake of emerging infectious diseases such as Avian influenza, Ebola, and SARS. This concept calls for the working together and closer collaboration among veterinarians, ecologists, conservation scientists, and the medical community in the control of emerging infectious diseases.[18]

In line with this concept, in December 2015, the World Health Organization (WHO) and the World Organization for Animal Health (OIE), in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and supported by the Global Alliance for Rabies Control (GARC), organized the Global Conference with the theme "Global elimination of dog-mediated human rabies: the time is now," in Geneva Switzerland where member countries agreed on a global strategic framework for the elimination of the public health threat of rabies by 2030. A goal of zero human dog-mediated deaths dubbed 'zero by 30' is to be achieved by participating countries worldwide.[19,20] Emphasis on the One Health approach in the implementation of this framework is strongly being advocated in order for member countries to achieve the desired results.[20]

1.2 STATEMENT OF THE PROBLEM

Rabies is endemic in all regions of Ghana and dogs are the main source of transmission. According to Veterinary Services Division (VSD) reports, an average of twenty-two (22) human rabies deaths was reported annually during the period 2006-2012. In the period 2008-2012, a total of seventy thousand, nine hundred and fifty-three (70,953) dog bite cases were reported. Dog vaccination coverages, however, remained low at 5%-30% nationwide due largely to high cost of dog vaccination, low

awareness creation, unwillingness of pet owners to vaccinate their animals given the high costs, continuous presence of stray dogs in the communities, and lack of law enforcement regarding responsible pet ownership. [8]

In line with the global strategic framework to eliminate human rabies deaths from dog-mediated rabies by 2030, Ghana has committed to achieving 'the zero by 30 goal' using the Stepwise Approach towards Rabies Elimination (SARE) by improving dog vaccination coverages as one key elimination strategy. This is based on the fact that over 95% of human rabies cases are from dog bites.[20,5] This offers an opportunity for veterinarians and human health workers to work closely with each other to attain universal dog vaccination, manage dog bite victims appropriately and institute the required community interventions to prevent deaths from rabies. This requires coordination, collaboration and communication (the 3C's) between the medical and veterinary fields of practice to which data sharing and harmonisation are central.[19-22]

However, the extent to which data sharing, harmonization and collaboration take place across the medical and veterinary fields of practice in Ghana is scantily documented in scientific literature and linkages between human and animal health data within the context of rabies elimination in Ghana have not been well established. [9,14-16] Also, very few studies in Ghana have attempted to relate rabies surveillance data from the human health sector to those from the animal health sector such as human rabies incidence to animal rabies incidence, dog vaccinations to dog bite cases, as well as their spatial and temporal relationships. [9,23-24] Knowledge about areas of high or low vaccination coverages, high incidence of dog bites, dog rabies and human rabies, their spatial and temporal relationships including peak periods will be useful for planning, resource allocation and targeted interventions by both sectors.[9,23] The purpose of this study was therefore to investigate the linkages between rabies-related data reported by the human and animal health sectors, and the extent of collaboration between human health workers and animal health workers for the elimination of human rabies deaths from dog-mediated rabies within the context of One Health approach in Ghana.

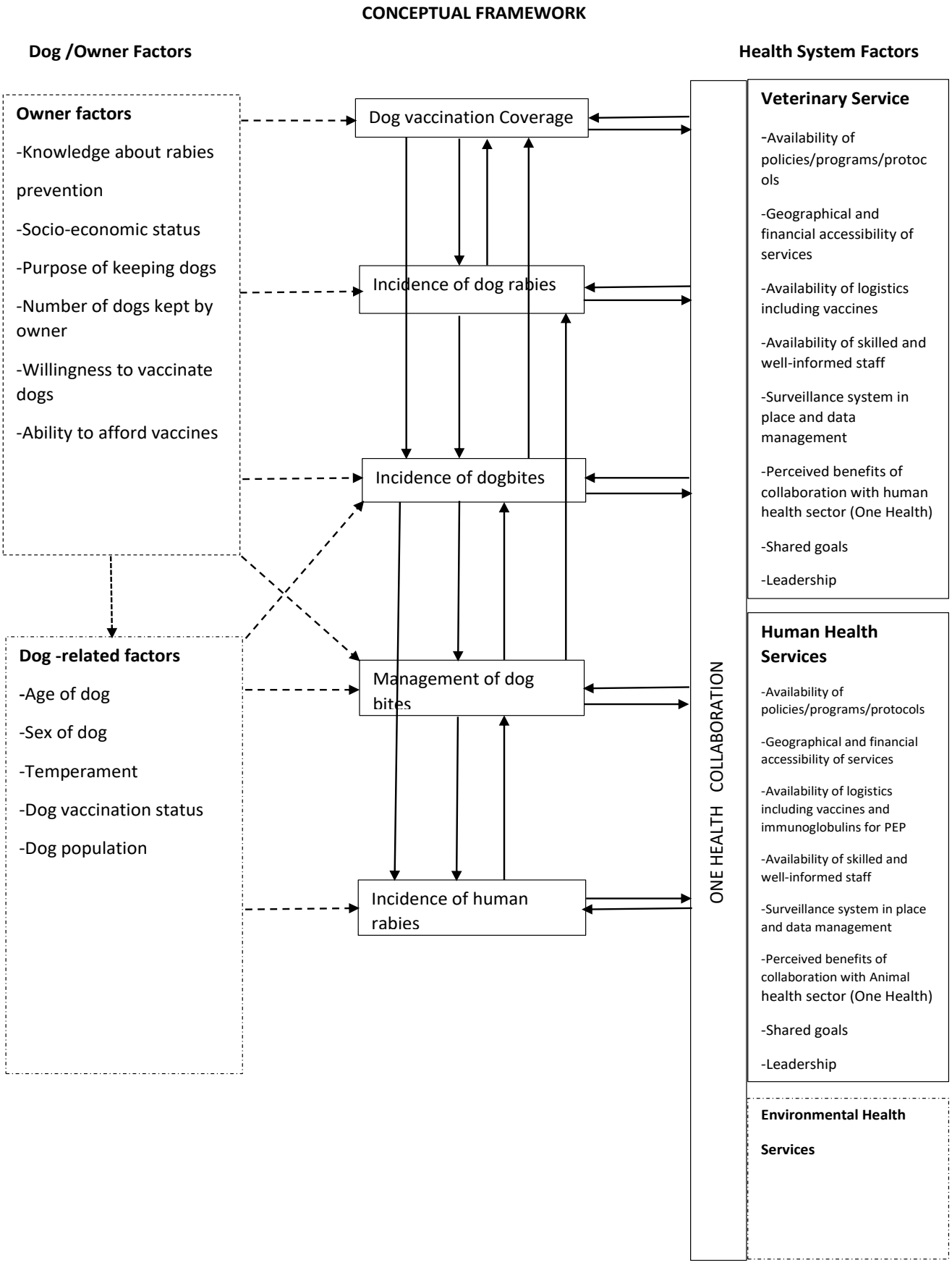

Figure 1: The Conceptual Framework (Adapted from Ghana Rabies Strategic Programme for Elimination, 2015-2030 (unpublished document from VSD)[8]

The conceptual framework used for exploring human rabies deaths from dog-mediated rabies for the study is as presented in figure 1 in which the factors influencing dog vaccination coverages, incidence of dog rabies, and ultimately human rabies are categorized as follows:

- Health system factors
- Dog- Owner factors
- Dog- related factors

1. Health system factors:

These have to do mainly with the preventive services and interventions put in place by the Veterinary, and Human Health Services with the support of the Environmental Health Department to reduce human and dog rabies in the communities and the nation as a whole.[8] The outcome of such interventions will largely be determined by the extent of collaboration among these sectors particularly between the Veterinary and Human Health Services which is the focus of this study. Such collaboration will be engendered by shared goals, perceived benefits of pooling resources from both sectors, including human and material resources, in a resource-poor setting.[20] The importance of legislation, policies and guidelines spelling out roles and responsibilities, governance structures and leadership cannot be over-emphasized. Established reporting structures with defined linkages between departments will ensure continuity and progress of elimination activities in the context of changing political environments and personnel. When these are clearly spelt out, it helps to reduce doubt and mistrust between the collaborating agencies or sectors involved and paves way for smooth and unhindered collaboration.[20,21,53] It also helps to reduce duplication of work and saves cost. For example, an intervention such as mass dog vaccination often spearheaded by the Veterinary Services Directorate can receive a tremendous boost if the elaborate cold-chain system being operated by the EPI under the Ghana Health Service, together with its extensive transport facilities, is shared with the former. The resulting increase in dog vaccination coverages will ultimately impact positively on the control of dog and human rabies. In the same vein, through collaboration, an Integrated Case Bite Management and Rabies Surveillance put in place will help early detection and response to suspected human and dog rabies outbreaks. Management of dog bites will thus be comprehensive ensuring that all unreported cases are investigated and the necessary interventions put in place to reduce deaths from rabies.[25]

2. Dog Owner factors

Although not the focus of the proposed study, these are factors that can affect the incidence of rabies by determining the choices and decisions made by the dog owner regarding dog vaccination, number of dogs kept and purpose of keeping dogs. The owner's knowledge, cultural beliefs about rabies and its

prevention will also influence such decisions.[26-28] Their socioeconomic status will partly determine whether or not they can afford dog vaccination or post-exposure prophylaxis in case there is an incident of dog bite that warrants this.[29]

These choices and decisions will influence dog vaccination coverages, management of dog bites and ultimately, the control of dog and human rabies in the community.

3. Dog-related factors

These are the characteristics of the dog that determine its tendency to bite persons or other animals and the resulting consequences. These include the age of the dog, its sex, the vaccination status, its innate temperament, and the dog population in its vicinity and how they are kept. In Ghana and many African countries, studies have shown that most bites reported by victims are from stray dogs who are unvaccinated and pose substantial risk of rabies transmission to humans and other dogs in the vicinity. [30-31] Such dogs are usually killed and the carcass disposed of without consulting the veterinary services directorate. A few such dogs who escape being killed continue roaming on the streets, inflicting bites on unsuspecting victims and are often not available for observation under quarantine till they die naturally from the disease. Victims are likely to receive post-exposure prophylaxis presumptively thereby increasing cost of treatment. In the absence of appropriate medical care, fatalities often result. [24,30, 32-33] Though not the main focus of the proposed study, these factors tend to influence the incidence and management of dog bites and ultimately incidence of human rabies to a large extent.

1.3 RESEARCH QUESTIONS

The research questions posed in this study are:

1. Are dog bites and incidence of dog and human rabies clustered in space or space and time?

2. What is the spatiotemporal relationship between dog bites, dog vaccination coverages, and incidence of dog and human rabies in Ghana?

3. What is the extent of collaboration, data sharing and harmonization across medical and veterinary fields of practice in relation to human and dog rabies prevention and control; and what can be done to improve the situation?

4. What is the knowledge, perception and practices of frontline health workers in the Human Health and the Animal Health sectors on One Health collaboration.

5. What are the barriers and enablers of One Health collaboration for policy decisions and implementation for the successful elimination of human and dog rabies as a public health problem in Ghana.

1.4 JUSTIFICATION/RELEVANCE OF THE STUDY

As has already been demonstrated in Brazil, Thailand and Indonesia, which have made significant progress in rabies elimination, public awareness creation and adequate post-exposure management of dog bites must go hand in hand with dog vaccination if elimination targets are to be achieved and sustained.[7-9] This obviously requires an integrated surveillance system that links rabies-related data from both human health and veterinary fields of practice for the purpose of estimating disease burden, detecting outbreaks, forecasting resource requirements and monitoring progress to show attainment of sustainable maintenance of disease elimination. By mapping rabies-related data from the two sources to show their spatial and temporal relationships, human health and animal health professionals can work together more effectively. This fosters stronger partnerships and coordinated efforts to eliminate human and dog rabies under One Health. [34] Obviously, such a system requires that rabies-related data from both fields of practice are well harmonized and shared freely across both sectors in a state and manner that guarantees their usefulness in policy decisions and actions.[9]

However, the perspectives of key personnel from both sectors who are responsible for the implementation of such a programme need to be examined so as to identify the gaps and have them addressed. This study, by seeking to examine these factors in-depth and to document the recent and current state will also establish a baseline to which subsequent progress could be compared given that it is being conducted at a time that Ghana is transitioning into a new era in its fight against rabies.

It is envisaged that findings from the study will help guide policy makers and implementers to make informed decisions about resource allocation, timing and periodicity of interventions as well as options for monitoring and evaluation. By attempting to establish linkages between human health and animal health data, this study will help prepare the ground for closer collaboration between human health workers and veterinary professionals as Ghana sets out to eliminate rabies by 2030 using the One Health approach.

2.0 OBJECTIVES

2.1 GENERAL OBJECTIVE

To investigate the spatiotemporal relationships between dog bites, dog vaccination coverages and dog and human rabies in Ghana for the period 2015-2021 and to identify existing mechanisms, potential barriers and enablers of One Health collaboration between human and animal health professionals for the elimination of dog-mediated human rabies.

2.2 SPECIFIC OBJECTIVES

1. To describe temporal, spatial and spatiotemporal distribution of incidence of dog bites, dog vaccination coverages and incidence of dog and human rabies.
2. To analyze the spatiotemporal relationships between dog bites, dog vaccination coverages and dog and human rabies.
3. To assess existing mechanism for collaboration, data sharing and harmonisation across medical and veterinary fields of practice in relation to human and dog rabies control.
4. To assess knowledge, perception and practices of key personnel in both medical and veterinary sectors on collaboration.
5. To identify the barriers and enablers of One Health collaboration for policy decisions and implementation for rabies elimination in Ghana.

3.0 LITERATURE REVIEW

3.1 INTRODUCTION

This chapter discusses the importance of spatial and temporal analysis, forming data linkages and joint surveillance between animal health and human health fields of practice under One Health collaboration. It examines the human resource implications as well as the factors that promote or militate against data sharing, collaboration and harmonization in both fields of practice and their influence on policy decisions in the context of the implementation of the One Health Initiative for rabies elimination.

To conduct this literature review, a comprehensive search strategy was adopted. Electronic databases used included MEDLINE, PubMed Central, Scopus and Web of Science. These databases were accessed through search engines like Google Scholar and PubMed. Keywords included "One Health" "rabies elimination" "dog bites", "dog rabies", "human rabies", "dog vaccination coverage", "spatiotemporal", "Spatial Analysis", "One Health collaboration" "veterinary-medical collaboration" with their Medical Subject Headings (MesH) terms. Boolean operators were used to refine the search results.

3.1.1 SPATIAL AND TEMPORAL RELATIONSHIPS AMONG HUMAN AND DOG RABIES, DOG VACCINATION COVERAGE AND DOGBITES

Spatial analysis helps to understand the behavior of diseases from a geographical perspective to identify significant clusters and associated factors. These analytical tools can be used to monitor epidemiological indicators over time, to identify risk factors and clusters of high endemicity where additional resources should be targeted.[35] Spatiotemporal patterns have been shown to be exhibited by a number of diseases among human and animal populations. These include hand-foot-and-mouth disease, diarrheal diseases, vector borne diseases, scrub typhus transmission, Dengue fever, hemorrhagic fever with renal syndrome, cutaneous anthrax, human and dog rabies. [36-44] However, very few studies have looked at the spatial, temporal and spatiotemporal relationships between human rabies and dog bites sourced from Human Health surveillance (HH) data on one hand, and dog vaccination coverages and dog rabies cases from Animal Health (AH) data on the other hand in the context of One Health. [9] A study in Tunisia by Bouslama et al. to describe and analyse the epidemiological situation of dog rabies in Tunisia during the period 2011–2016, revealed spatial clustering of cases mainly in the densely populated areas (Northern and Central-Eastern). How these clusters are related to vaccination coverages or dog bites was however not explored. [45]

According to epidemiological theory dog vaccination coverage of 70% is sufficient to prevent rabies outbreaks. [46] Estimates of R_0, the basic reproductive number, have been obtained for dog rabies using data from high-density urban and rural environments under epidemic conditions. Such estimates have

been found to support the theoretical vaccination threshold of 70% coverage required for interruption of transmission of the rabies virus. However, it has been observed that in rural communities such as found in Africa, where dog density might be relatively low, transmission could still be interrupted at coverages lower than 70% since R_0 depends on the density of the susceptible host among other factors. [47] This underscores the importance of spatial analyses in studying the relationship between vaccination coverages and rabies incidence. Moreover, because other factors such as vaccine potency, frequency of vaccination campaigns, genetic variation among dog populations, dog population growth rate (birth and death rates) come into play in determining outcomes of dog vaccination programmes, conflicting results have been obtained in the very few studies that have attempted to correlate vaccination coverages and rabies incidence. For example, whereas Cleaveland et al.[47] found in Tanzania that vaccination coverages of 64.5, 61.1, 70.6 and 73.7% in four successive campaigns resulted in more than 70% decline in the incidence of dog rabies in the Serengeti District, Eng et al. [48] found in Mexico that vaccination coverages as high as 56-86% could not prevent rabies outbreak in the city of Hermosillo. In stark contrast to this is the finding by Lee et al.[49] in Korea where vaccination coverage as low as 30–50% resulted in the apparent elimination of dog rabies. The need for temporal and spatiotemporal analyses in such studies is thus indicated.

Turkson in 2023 conducted a spatiotemporal investigation of reported cases of animal rabies in Ghana and found a positive but weak correlation between human and animal rabies cases.[9] He found more rabies cases in the wet than dry season. However, a Poisson regression model fitted to the data revealed no statistically significant relationship between animal rabies cases and predictor variables such as month, year, season and animal species. Although the study used data mainly from the Animal Health sector, some attempt was made to relate animal rabies cases to human rabies cases. The author attributed the weak correlation between human rabies cases and animal rabies cases to lack of collaboration in reporting between Human Health and Animal Health institutions.[9]

3.1.2 ONE HEALTH COLLABORATION, DATA SHARING AND HARMONIZATION ACROSS THE MEDICAL AND VETERINARY FIELDS

Collaboration is any action which is intended to benefit others regardless of whether the actor also benefits in the process.[50] The need for collaboration between human health workforce and the veterinary services workforce is a long-held concept that derives from the recognition that human and animal diseases are closely interrelated. The interrelatedness between canine and human rabies adds more credence to this concept thereby making rabies elimination a test case for One Health implementation.[51]Rabies elimination is hinged primarily on closer collaboration between human

health workers and veterinarians at all levels particularly in the area of surveillance where there is the critical need for data sharing and harmonization across both sectors.[51,52] However, available studies suggest that the level of collaboration between health workers and veterinarians in terms of data-sharing and harmonization has not been adequate.[14,53] This could be due to a number of reasons. According to Lange et al, collaboration presents a social dilemma to the two groups of professionals.[50] The two professionals often feel more responsible towards their clients or patients than to each other. As a result, they see collaboration with each other as less important compared to their responsibility towards their clients at least for the short term. By so doing, they fail to recognize that if everyone pursues a non-cooperative course of action, then everyone will ultimately be worse off (often in the longer term) than would have been the case if everyone had collaborated.[54] Even though collaboration is highly desirable both for the sector itself and for society as a whole, the professionals involved often do not have a well-defined idea of the benefits offered by increased contact and collaboration in the long term. By creating this awareness among the professionals, collaboration can be improved.[54]

Although lack of time has often been cited as another reason for this observed non-collaboration, one important but often concealed reason is insufficient awareness or understanding among the groups of the benefits to be derived therefrom.[55-56] The two groups do not well appreciate the added value to be derived from their collaboration. [55] Thus, awareness creation about the complementary nature of their service is necessary to improve collaboration between the two groups.

The third reason has to do with mutual prejudices and psychological barriers between the two professions.[57]Having a common goal is needed to cause a reduction in prejudice and resistance between the two groups.[58]

The fourth reason has to do with lack of clear local policies and structures to guide the extent and level of collaboration with regard to data sharing, case management and institution of preventive measures including dog vaccination and post-exposure prophylaxis. According to Axelsson and Axelsson, the biggest barriers to achieving integration in health programmes are differences in values, interests and commitments among principal actors.[59] The medical and veterinary perspectives on One Health issues and their solutions may differ widely.[60] However, very few studies have examined the extent of these variations within the context of prevention and control of zoonosis such as rabies in Ghana so as to inform policy decisions on how best to foster collaboration in identified areas. This is one of the gaps that the study sought to address.

3.1.3 KNOWLEDGE, PERCEPTION AND PRACTICES ON COLLABORATION ACROSS THE HUMAN HEALTH AND VETERINARY SECTORS

According to the Ottawa Charter for health promotion (1986) there is a great need for intersectoral collaboration in public health. More specifically, with human rabies mediated by dogs claiming the lives of thousands of people globally year after year, coordinated and integrated surveillance for priority diseases in the animal and human health sectors underpin the successful implementation of global strategic framework for rabies elimination adopted at the global conference on rabies in December 2015 through the collaborative efforts of WHO, OIE, FAO and the Global Alliance for Rabies Control (GARC).[19,61] Integrated zoonotic disease surveillance will facilitate joint planning, effective monitoring of disease trends, prompt and early detection and management of outbreaks, and more importantly, joint monitoring of programme indicators to assess effectiveness of programme interventions. With respect to rabies, programme indicators that may require joint monitoring include incidence of dog bites in the community, uptake of post-exposure prophylaxis, deaths from human rabies, proportion of dog bites attributable to rabid dogs among others. [20]

The need for collaboration is even more pressing if dog bites were to be managed more effectively in most health facilities in Ghana. Events leading to a victim showing up at a health facility after being bitten by a dog, and whether or not they receive appropriate care therefrom with or without rabies immunoglobulin and vaccination (depending on risk assessment) will all require the working together and close collaboration between the animal and human health personnel. More specifically, critical aspects of the management that require close collaboration between both sectors include confinement of the dog for observation by the veterinarians, post-mortem or antemortem tests for rabies in the biting dog, and active case search for other exposed victims in the affected communities, both human and animals alike. However, most studies conducted elsewhere and the few ones done in some districts in Ghana suggest that this collaboration is either completely non-existent or rarely optimum.[14-16,61] What accounts for this is not well understood and this is one of the aspects that this study seeks to unravel.

Last but not the least, anecdotal evidence as well as experiences from Chad in West Africa and Bhutan in Southeast Asia suggest that when resources from animal and human health sectors are pooled together, programme outcomes can improve remarkably. In Chad for example, a joint programme between human and animal health sectors that sought to deliver immunization services to children and women in a nomadic population and their cattle yielded very encouraging results.[62] According to the authors, the good health of the animals of the nomadic pastoralists is pivotal and therefore animal health may provide a key entry point for the provision of both human and animal health interventions and services. Conversely, in a community where human health is pivotal, the key entry point for the provision of both services might be human health. This observation underscores the need for the two

sectors to come together to share ideas and resources in order to maximise programme outcomes. However, this is only feasible if the two groups perceive the added value that they can derive from their collaboration, and is one important aspect this study seeks to explore through interviewing personnel from each of the two groups.

3.1.4 BARRIERS AND ENABLERS OF ONE HEALTH COLLABORATION FOR RABIES ELIMINATION

One Health recognizes the interconnectedness of people, animals, and the environment and seeks to promote collaboration across sectors to optimize health outcomes. [18] Its main objective is to improve the health of humans, animals, and the environment.[63] Although One Health interventions can significantly promote health, their implementation is often hindered by barriers. [64]. Key among the barriers are lack of political will, weak governance, and lack of human, financial and material resources. [64] Johnson and Hansen in Australia conducted a qualitative study among academic experts in order to explore how professionals in these fields perceive a One Health approach to zoonotic disease surveillance, aiming to identify the challenges to the implementation of an integrated system in Australia. They found that the absence of a clear definition and subsequent vision for the future of One Health was a barrier to interdisciplinary collaboration, and that siloed approaches by different sectors restricted the ability for professionals to work collaboratively across disciplines.[53] The authors suggested the establishment of a formal governance body with representatives from each sector as a means of overcoming long-standing barriers of privacy and distrust. They also recommended training in One Health concepts for medical, environmental and veterinary students to foster cross-disciplinary collaboration.[53]

One key enabler of One Health implementation is the formulation of policies that focus on improving human, animal, and environmental health while fostering cooperation and collaboration among different sectors. Formulating strategic documents and operationalizing One Health collaboration is relevant to strengthening coordination.[65] Identification and engaging One Health technical working groups on a national platform can boost One Health implementation facilitates the process. [65,57]Other enablers include political commitment, sustainable financing, program development, knowledge sharing, institutional collaboration, capacity enhancement, engagement of civil society, and active participation of the communities.[53,65-66]

One Health collaboration is critical for rabies elimination in Ghana. Ghana has developed the National Rabies Control Strategy (NRCS) in collaboration with stakeholders, such as the Ministry of Health, MOFA, and WHO. The NRCS outlines goals, objectives, and action plans to eliminate dog mediated human rabies deaths in Ghana, with emphasis on surveillance, vaccination, community engagement, and capacity-building.[108][9]. Successful implementation of this strategy and achievement of the set

goals will be a direct reflection of how well Ghana is able to implement One Health as a country, using rabies control and elimination as a test case for One Health.[51] [10].

4.0 MATERIALS AND METHODs

4.1 STUDY DESIGN

The study design was a cross sectional study involving mixed qualitative and quantitative methods of data collection as well as a retrospective spatiotemporal mapping and analysis of routinely reported rabies-related data in Ghana from routine management information systems. The data collection methods, data sources, sampling and analytical approaches are summarized by study objectives in the table below and elaborated in the sections that follow:

Table 1: Summary of research methodology

Research Question	**Study Objective**	**Data, sampling and analysis**
RQ1: Are dog bites and incidence of dog and human rabies clustered in space or space and time?	1. To describe the temporal, spatial and spatiotemporal distribution of the incidence of dog bites, and incidence of dog and human rabies in Ghana in the period 2015-2021.	-Retrospective analysis and mapping of routine management information system data on dog bites, dog and human rabies from veterinary and human health sectors -All relevant and available national data for the period 2015 – 2021 were utilised
RQ2: What is the spatiotemporal relationship between dog bites, dog vaccination coverages, and incidence of dog and human rabies in Ghana?	2. To analyse the spatiotemporal relationships between dog bites, dog vaccination coverages and dog and human rabies in Ghana for the period 2015-2021.	-Fitting of spatiotemporal models to routinely reported data on dog bites, dog vaccination coverages, dog and human rabies at the district level over the period 2015-2021.
RQ3: What is the extent of collaboration, data sharing and harmonization across medical and veterinary fields of practice in relation to human and dog rabies prevention and control; and what can be done to improve the situation?	3. To assess existing mechanism for collaboration across medical and veterinary fields of practice in relation to human and dog rabies control.	--Document review -Key informant interviews. Qualitative data analysed for theme commonalities and contrasts using NVivo [67]
RQ4: What is the knowledge, perception and practices of frontline health workers in the Human Health and	4. To assess knowledge, perception and practices of key personnel in the medical and	- Key informant interviews. Qualitative data were analysed using NVivo [67]

Research Question	Study Objective	Data, sampling and analysis
the Animal Health sectors on One Health collaboration	veterinary sectors on collaboration	-Cross sectional survey of key personnel. Quantitative data were analysed using Stata version 13.SE
RQ5: What are the barriers to and enablers of One Health collaboration for policy decisions and implementation for the successful elimination of dog-mediated human rabies deaths as a public health problem in Ghana?	5. To identify the barriers and enablers of One Health collaboration for policy decisions and implementation for elimination of dog-mediated rabies in Ghana.	-Key informant interviews. Qualitative data analysed using NVivo software [67] -Desk review of national policy documents on dog rabies control and elimination of dog-mediated human rabies control under One Health collaboration

QUANTITATIVE DESIGN

Retrospective spatiotemporal mapping and analysis of rabies related data

One aspect was a retrospective spatiotemporal mapping and analysis of rabies-related data from the Animal and Human Health sectors. This included data from the District Health Information Management System 2 (DHIMS2), surveillance data from the Disease Surveillance Department of Ghana Health Service, and animal health data from the Veterinary Services Directorate of the Ministry of Food and Agriculture (MoFA).

Cross sectional survey among personnel of animal and human health sectors

The other quantitative component of the study was a cross-sectional survey conducted among personnel of the animal health and human health sectors in twelve districts chosen purposively from 6 regions in the three ecological zones of Ghana. This survey assessed the knowledge, perception and practices of the personnel with respect to collaboration for control and elimination of rabies in Ghana as required by the One Health initiative.

QUALITATIVE DESIGN

Key Informant Interviews

Key informant interviews were conducted with 35 selected key personnel working at the national, regional and district levels in the Ghana Health Service and the Veterinary Services Department of the Ministry of Health and MoFA respectively.

Desk review of grey and published literature on national policies and programmes

There was a document review of existing national policies on dog and human rabies control and elimination in Ghana at the national, regional and district levels to understand the policy environment under which the observations in the study were made.

4.2 STUDY SETTING

Ghana has a population of 30,832,019 as reported by the Ghana Statistical Service in the 2021 Population Census report.[68] It has a total land area of 238,533 square kilometers and a population density of 129.3 persons per square kilometers. Ghana lies between latitudes 4^0 N and 12^0 N and longitude 1^0 12′ E and 3^0 15′ W. Politically, Ghana is divided into 16 administrative regions which are subdivided into 260 metropolitan/municipal/district assemblies (MMDAs) around which the Human Health and Animal Health Administrations are organized (Figure 2).

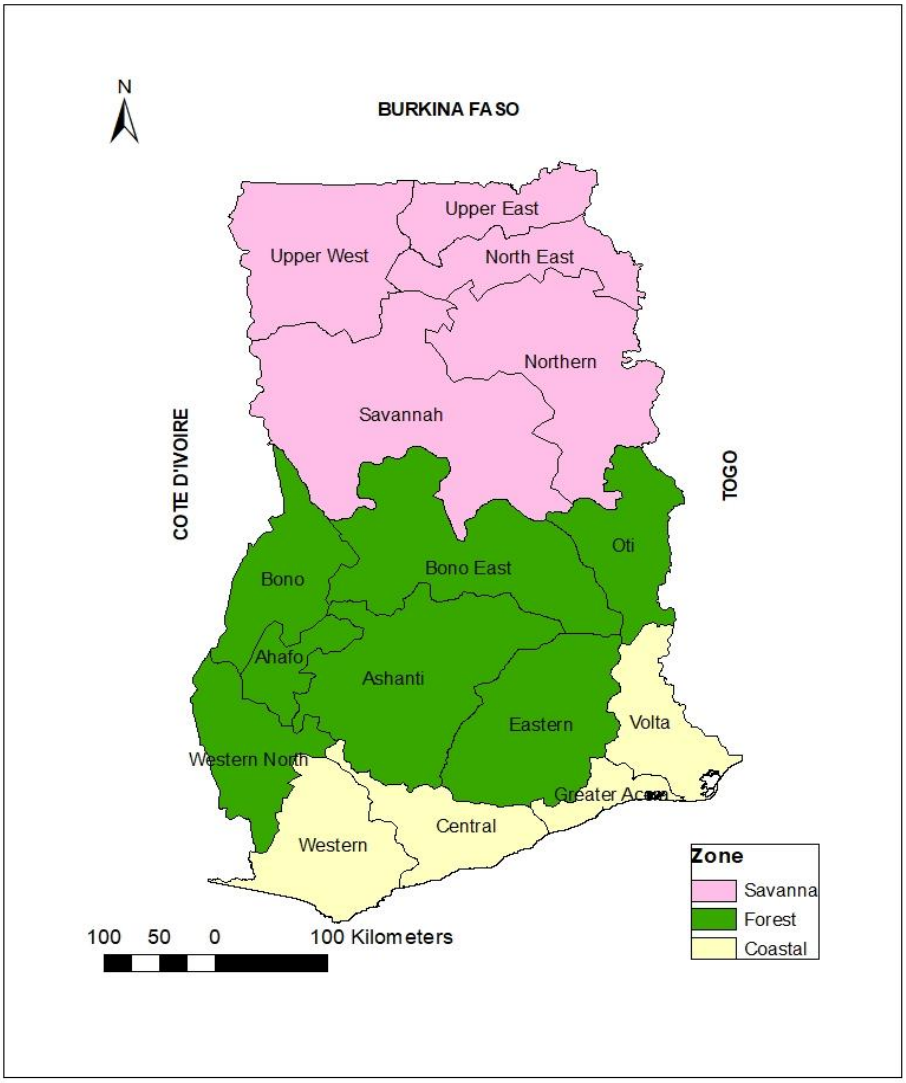

Figure 2: Administrative Regions of Ghana and their ecological designations (Adapted from Nuñez et al.(2023)[69] & Bukari et al (2014) [71]

Health service delivery in Ghana is organized on a three-tier system of care namely: primary, secondary and tertiary levels. At the primary and secondary levels, the Ghana Health Service is the main agency responsible for delivery of public health service nationwide which is geographically organized as community, sub-district, district and regional. Community and sub-district levels provide primary care, with district and regional hospitals providing secondary health care. At the national level are the teaching hospitals which are autonomous and provide tertiary/specialized care. Complementing these at various levels are quasi-government institutions (37 Military Hospital, Police Hospital, Trust Hospital), the not-for-profit health institutions (CHAG and other faith-based health institutions) and the purely private healthcare facilities. In addition, traditional and alternative medicine practised at traditional healing centres, herbal and homeopathic clinics by traditional healers including herbalists,

spiritualists, homeopaths and other non-conventional health service providers form part of the primary health care services available and are duly recognized by the Ministry of Health.

The District Health Information Management System 2 (DHIS or DHIMS2) is the current data collection, compilation and storage tool for health information from the primary care level to the tertiary level. This is a web-based application introduced in April 2012 and managed by the Centre for Health Information Management (CHIM) of the Ghana Health Service. By policy, all healthcare facilities including private and public ones are to report clinical and public health data using agreed format in the DHIMS2 on regular basis, mostly monthly. Health Information Officers working in the various health facilities and administrative levels are directly responsible for the management of DHIMS2 data under supervision of the institutional heads.

Veterinary service delivery in Ghana is offered through both public and private outlets under the auspices of the Directorate of Veterinary Services of the Ministry of Food and Agriculture. Clinical services are offered at the community, district and regional levels whilst laboratory services are mainly at the regional and national levels. All the regional laboratories are equipped enough to test for rabies, anthrax and brucellosis (rapid test).

Routine monthly reporting is done by the veterinary clinics at the community level through the district offices to the regional, and thence to the national level. Reports produced at the district level are forwarded to the regional level where they are consolidated with data from other districts. The reports are then transmitted electronically to the national level using Microsoft office application (mainly Excel spreadsheet and Word). A consolidated national report is prepared at the national level and shared with MoFA, OIE and AU-IBAR. According to reports from the Veterinary Services Directorate, an average of twenty-two (22) human deaths was reported annually during the period 2006-2012. In the period (2008-2012), a total of seventy thousand, nine hundred and fifty-three (70,953) dog bite cases were reported.[8] Dog vaccination coverages however remained low at 5%-30% nationwide in the period.

4.3 STUDY POPULATION

All available data from all the 260 districts in Ghana were included in the study for the retrospective analysis of routine HMIS data from the human health and veterinary services on dog bites and rabies over the period 2015-2021. For the surveys and key informant interviews, samples of personnel of the human health and veterinary services from the national level, 6 selected regions and 12 selected districts in Ghana were used.

4.4 SAMPLE SIZE CALCULATION FOR HUMAN AND ANIMAL HEALTH STAFF SURVEY

Using Cochran formula with an assumption that 50% of the staff would report maximum collaboration for rabies control between both sectors, (this is the most conservative estimate often used in the absence of prior estimates from literature, since it gives the largest possible sample size), holding the precision and other variables constant, a precision of 5%, an alpha of 5% we obtain [70]

Sample size, $n=\frac{z^2\,pq}{d^2}$

z =1.96 (for α=0.05)

p =proportion reporting being satisfied=50% (0.5)

q =1-p=0.5

d=precision=0.05

Sample size, $n=\frac{1.96^2\,(0.5*0.5)}{0.05^2}$ =384

Adjusting for an estimated non-response rate, r = 10%,

$n_{adjusted}$ = n/(1-r)=384=384/(1-0.1)=384/0.9=426

Thus, from each of the 12 districts selected from the three ecological zones, at least 36 frontline staff from the animal and human health sectors were expected to be enrolled into the study. In all 468 frontline staff were enrolled in the study.

4.5 SAMPLING FOR KEY INFORMANT INDEPTH INTERVIEWS

At the national level, the head of the Disease Surveillance Department of Ghana Health Service, and the head of the Epidemiology Unit of the Veterinary Services Directorate were purposively selected to be interviewed as key national level decision-makers for human health and for animal health. To get regional implementer and decision-maker perspectives, the country was divided into 3 ecological zones representing coastal savanna, middle forest belt and northern savanna ecological zones. This classification has been used in previous spatial studies such as those by Nuñez et al.[69] and Bukari et al. [71](See figure 2):

- Zone 1: Savanna (Northern, Savannah, North East, Upper East and Upper West Regions)
- Zone 2: Forest (Western North, Bono, Bono East, Ahafo, Ashanti, Eastern and Oti Regions) and
- Zone 3: Coastal (Western, Central, Greater Accra and Volta Regions)

From each zone, 2 regions were randomly selected. In each region 1 Regional Disease Surveillance Officers or where available the Deputy Director (Public Health)) and the Regional Veterinary Officer were purposively selected and interviewed. In each of the regions 2 districts were purposively selected to include one urban and one peri-urban or rural district where veterinarians could be found. Within each district, 1 District/Municipal/Metropolitan Veterinary Officer and 1 District /Municipal/ Metropolitan Directors of Health Services were purposively interviewed to get the perspectives of the veterinary and human health services leadership at the district level. Other officers also interviewed in lieu of or in addition to the above mentioned to get the perspectives of frontline implementers were the Medical Director of the referral hospital in the district, District Disease Control Officer and the District Health Information Officer**.** This brought the least number of those expected to be interviewed to 39. However, after the 30th interview, saturation appeared to have been reached and no new information was emerging from the interviews. To be certain, five more interviews were conducted and when the findings remained the same it was concluded that saturation had been reached and so interviewing ended with a total number of 35 KI interviews.

4.6.2 Sampling for Cross-sectional Surveys

For the cross-sectional staff survey to assess knowledge, perception and practices of key personnel in the human health and veterinary services on collaboration, frontline health workers and veterinary officers from the same 12 districts in which the district level qualitative interviews were conducted were interviewed. In a chosen district, a list of all frontline heath workers including doctors, nurses, pharmacists/pharmacy technicians, disease control officers/technical officers, laboratory technicians at post as frontline health workers in the healthcare facilities was obtained from the District Health Directorate and the healthcare facility. A similar list of veterinary professionals was obtained from the Veterinary Services Department of MOFA in the district. This list included all veterinary doctors, veterinary technical officers, veterinary nurses, and animal health officers at post in the veterinary clinic as frontline workers. Using these lists as sampling frame and with the use of a table of random numbers, a random sample of 36 potential respondents was selected per district for the survey. These were contacted individually through phone calls for their consent to be enrolled into the study. Those who declined were replaced by randomly sampled staff from the list. In the absence of such a list often arising from reluctance of the administrators of the facility to share staff information with the research assistants, all frontline staff at post in health facilities and veterinary clinics in the district of interest were enrolled in the study after obtaining their consent. Interviews were conducted in English using a self-administered questionnaire after obtaining their consent (See appendix O).

Inclusion criteria for respondents:

1. Respondent should be permanently employed in the human or animal health sector (public or private) for at least 1 year

2. Respondent should have been at post for at least one year in the district.

Exclusion criteria:

1. Students on rotation or attachment

2. Refusal to consent to the study

4.7 DATA COLLECTION TECHNIQUES AND TOOLS

Data collection took place between October 2021 and August 2022. Rabies-related data pertaining to each district and covering the period 2015-2021 were abstracted electronically from DHIMS2. This included number of recorded cases of dog bites by age and sex of victims for each month within the period 2015-2021 and the monthly recorded cases of human deaths due to rabies within the period. The data was abstracted on excel spreadsheet. A case of dog bite was defined as any person with the diagnosis of dog bite in a health facility or veterinary clinic and having same recorded as such in the DHIMS2, or the available hospital records or in a veterinary facility record. A case of human rabies was defined as death from clinical rabies that occurred in the period 2015-2021 in Ghana and same recorded in the DHIMS2 or the IDSR weekly reporting form or case investigation form. Estimated human population data for each district over the period was based on projections from the 2010 Population and Housing Census data for Ghana using the formula, $P = Po\ (1 + r)^t$ where P is the projected total, Po the reference population, r the annual population growth rate for the region and t the time difference measured in years between the year for which the projection is being made and the year 2010.

In addition, rabies-related surveillance data from the Surveillance Department of the Ghana Health Service was abstracted from the IDSR dataset at the national level for comparison. At the national level, rabies-related data for each district over the period was obtained from the Animal Health database at the Veterinary Services Directorate. This included monthly reported cases of dog bites, dog rabies, dog vaccination coverages, and estimated dog population over the period. A case of dog rabies was defined as a diagnosis of dog rabies made by a veterinary officer either clinically or laboratory-confirmed and having same reported in the veterinary monthly records or other official reports. Map data including shapefiles for Ghana, the districts and regions were obtained from Ghana Statistical Service.

Using interview guides, in-depth interviews of key informants were conducted at the national, regional and district levels in both sectors. This included the aforementioned officers in both sectors. The Principal Investigator conducted all the interviews at the national, regional and district levels.

The interview guides used were as shown in appendices I, J, K, L, M & N. These guides were different for officers in the Human Health and the Animal Health sectors, and even for officers at the national, regional and district levels within the same sector. However, they had similar themes. These were:

- Background, work history and current role of key informant
- Extent of involvement in the prevention and control of rabies at their level
- Policies and programmes for prevention and control of rabies at their level
- Extent of collaboration with the other sector in respect of case detection, reporting and response to rabies /dog bites
- Extent of collaboration with the other sector in terms of data sharing and harmonisation
- Understanding of One health approach, extent of implementation of One Health, barriers and enablers at their level
- Recommendations

Interviews were audio-recorded with the permission of the interviewee. Copies of relevant reports such as rabies outbreak investigation reports, annual reports, and reports on collaborative meetings and joint operations between the two sectors, if available, were also obtained with their express permission.

For the survey in the 12 selected districts, a structured self-administered questionnaire was used to interview both animal health and human healthcare providers to assess their knowledge, perception and practices regarding collaboration for rabies control and elimination in Ghana. Same questionnaire was used for both groups. Variables included staff category of respondent, workplace of respondent, sector to which respondent belongs, respondent's working experience etc. See appendix P for the key variables, their definitions and measurement.

Desk Review

The desk review focused mainly on available national policy documents including legislations, guidelines, action and strategic plans that could influence dog rabies control and the elimination of dog-mediated human rabies under One Health collaboration since the One Health policy document was still in draft form and had not been sanctioned at the time of the study.

The documents reviewed included:

- Public Health Act, 2012, (Act 851) [72]

- Infectious diseases Act, 1908 (L I 1968) [73]
- Animal Ordinance (cap.247) of 1935 [74]
- Diseases of Animals, Act 1961, (Act 83)[75]
- Criminal Code 1960 (Act 29) Section 302 [76]
- Veterinary Surgeons Act, 1992 (P.N.D.C.L. 305C) [77]
- Local Governance Act, 2016 (Act 936)[78]
- District Assemblies Common Fund Act, 1993 (Act 455)[79]
- Ghana Health Service and Teaching Hospitals Act 1996, (Act 525)[80]
- National Action Plan for Health Security (NAPHS)[81]
- Technical Guidelines for Integrated Surveillance and Response in Ghana, 3rd Edition 2020[82]
- Ghana Standard Treatment Guidelines, MOH 2017[83]
- Ghana Rabies Control and Prevention Action Plan, 2018-2030 (unpublished document from VSD) [84]
- Ghana Rabies Strategic Programme for Elimination, 2015-2030 (unpublished document from VSD) [8]
- Ghana roadmap for attaining universal health coverage 2020-2030[85]
- National Health Policy: Ensuring Healthy Lives for All. Revised Edition Jan 2020[86]

Relevant information as they relate to rabies elimination and the One Health approach were abstracted and analyzed for barriers and facilitators in respect of One Health collaboration and elimination of dog-mediated human rabies.

4.8 DATA MANAGEMENT, PROCESSING, ANALYSIS AND PRESENTATION OF RESULTS

Data Processing and Management

From the attribute table of the district shapefile a standard unique identification code was obtained to identify each district. Using the same codes, a large dataset was created on excel spreadsheet. The columns in the dataset included the annual incidence computed for dog bites, human rabies and dog rabies, district dog vaccination coverages, age groups, sex, year and the district unique identification code. Data for each of the 260 districts corresponding to these variables were entered as rows on the spreadsheet. The dataset was read into SaTScan, and R version 4.2.0 with installed INLA.[87-89]

For the survey among staff, responses were entered on a form (data entry screen) created in Epi Info version 7.2.2.2.[90] Data was checked for accuracy and consistency, and cleaned before being exported to Stata version 13 for final analysis.[91]

Qualitative data in the form of audio-recorded in-depth interviews were transcribed verbatim in English and coded according to themes. The data was checked for consistencies and any inconsistencies resolved by method triangulation**.**

Data Analysis

Objective 1: To describe the temporal, spatial and spatiotemporal distribution of the incidence of dog bites, and incidence of dog and human rabies in Ghana in the period 2015-2021.

For the identification of clusters, SaTScan was used as it is thought to perform better in identifying clusters compared to the other spatial techniques available.[92-95] This is because, it can identify a cluster at any location up to a set maximum size thereby obviating the need for multiple testing. It is also known to have a higher statistical power for detecting clusters compared to the other methods used.[92-95]

The technique is based on the null hypotheses that each of the events (dog bites, human and dog rabies) is randomly distributed throughout the districts and that the expected event count is proportional to the population at risk. Rejection of the null hypothesis for each scanning window is based on a likelihood ratio statistic whose p-value is calculated from a Monte Carlo hypothesis testing, by comparing the rank of the maximum likelihood from the real data set with the maximum likelihoods from random datasets.

For each location and size of the scanning window, SaTScan uses a Monte Carlo simulation to test the null hypothesis that there is no elevated risk within the window as compared to the outside.

Under the Poisson assumption, the likelihood function for a specific window is proportional to:

$$\left(\left(\frac{n}{\mu}\right)^{n}\right)\left(\left(\frac{N-n}{N-\mu}\right)^{N-n}\right)I \quad (n > \mu)$$

where n is the observed number of cases within the window (district)

μ is the indirectly age-adjusted expected number of cases within the window (in that district) under the null hypothesis

N is the total number of cases in the study area, and

I is an indicator function that is equal to 1 when the window has more new cases than expected under the null hypothesis and 0 if otherwise. Both n/μ and (N-n)/(N-μ) are

proportional to the age-standardized incidence ratios within and outside the window, respectively.

Based on this assumption, purely spatial, purely temporal and spatiotemporal analysis were performed using the scan statistic technique to detect and evaluate the statistical significance of spatial or space-time clusters that could not be explained by the assumption of spatial or space-time randomness,

focusing on the number of observed and expected observations inside the window at each location. The scanning window is an interval (in time), a circle or an ellipse (in space), or a cylinder with a circular or elliptic base (in space-time). The distribution of the reported monthly dog bite, dog rabies and human rabies cases were explored and different discrete regression models (including discrete Poisson-based models) fitted to the data as described by Martin Kulldorff.[95]

Objective 2: To analyze the spatiotemporal relationships between dog bites, dog vaccination coverages and dog and human rabies in Ghana for the period 2015-2021.

For each of the observed count variable a corresponding expected count variable was created and the values estimated by multiplying the cumulative incidence (C/P) by the population in the location of interest p, as in the equation:

E_c= p*C/P, where E_c is the expected number of cases and p the population in the location of interest with c cases observed, while C and P are the total number of cases and population respectively

Monthly and annual data for each of the 260 districts corresponding to the variables were entered as rows on the spreadsheets to produce monthly and annual datasets for analysis.

The datasets were cleaned and together with the shapefiles, read into R version 4.2.0 (coupled with INLA (Integrated Nested Laplace Approximation).[88-89]

Several spatiotemporal models were fitted to the datasets with dog bites as the outcome variable and dog vaccination coverage, dog rabies and human rabies cases as covariates.

For each area we assume:

$y_i \sim \text{Poisson}(\lambda_i)$ $\lambda_i = E_i\rho_i$ $\log(\rho_i) = \eta_i$,

so that the mean λ_i is defined in terms of a rate ρ_i and of the expected number of cases E_i

A log linear model could then be specified on the linear predictor η_i as:

$\eta_i = b_0 + u_i + v_i$, ...model 1

where b_0 is the intercept of the regression model, u_i is the structured (autocorrelation) area specific effect, v_i is the unstructured area specific effect (unobserved/latent risk at specific area).

Similarly, a parametric space-time disease mapping model:

$\eta_{it} = b_0 + u_i + v_i + (\beta + \delta_i) *t$ .....model 2

which includes the main spatial effect $(u_i + v_i)$, the main linear trend β, which represents the global time effect, and a differential trend δ_i, which identifies the interaction between time and space was fitted together with a non-parametric dynamic trend model with a temporally structured dynamic effect with a random walk of order 1 or 2 (model 3):

$\eta_{it} = b_0 + u_i + v_i + \gamma_t + \phi_t$ ..... model 3

where γ_t is the temporally structured effect, and ϕ_t is the Gaussian prior.

In addition, attempt was made to explore space-time interaction models (model 4):

$\eta_{it} = b_0 + u_i + v_i + \gamma_t + \phi_t + \delta_{it}$ ..... model 4

in order to assess the interaction between neighbourhood and time given by the differential trend δ_{it}, but these were computationally overwhelming given the large dataset and the limited computer resources available.

Objectives 3, 4, 5:

Continuous data from the survey were summarized with summary statistics such as the mean, median, standard deviation or interquartile range whilst categorical data were summarized using proportions and percentages. Inferences on population parameters were made at an alpha of 0.05.

Qualitative data in the form of audio-recorded in-depth interviews were transcribed verbatim in English, coded and analysed by themes using NVivo software.[67]

5.0 ETHICAL AND LEGAL CONSIDERATION

Before contact with potential respondents, approval was sought from the Ghana College of Physicians and Surgeons, the Veterinary Services Directorate of MoFA, and the Ethics Review Committee of the Ghana Health Service. The study was carried out in compliance with the ethical requirements of the bodies concerned.

Informed Consent

The study protocol took into consideration ethical requirement for informed consent. Participants were admitted into the study only after informed consent had been obtained from them. Oral and written information were provided to the individual participant on the rationale and method for the study. Opportunity was given to the individual to ask questions that bothered him/her about the study and effort was made to clarify as much as possible any such issues raised. Consenting individuals were given two copies of informed consent forms to endorse. One copy was kept by the participant and the other filed by the Principal Investigator.

In situations where the interview was conducted over the phone, after oral consent had been given over the phone, the investigator filled out the consent form on behalf of the participant (with his/her permission) and wrote the participant's name in place of a signature. A check box was ticked on the consent form to indicate that consent was obtained over the phone.

In each case, consent was obtained without coercion, undue influence or misrepresentation of the potential benefits or harm**.** Refusal to take part in the study was not to bring upon the respondent any adverse consequences.

Potential Harm

It was envisaged that this study might potentially pose some risk of exposure to COVID-19 as a result of physical interaction between participants and the research team. However, this risk was reduced to the barest minimum by strict adherence to COVID-19 prevention protocols and guidelines (See section on COVID-19 Guidelines below). These were explained to the participant as part of the informed consent process.

Benefits

Participants were told to not expect any direct benefits in kind or in cash from the study. The long-term benefit of having no one die from dog-mediated rabies in Ghana was explained to them.

Confidentiality

All abstracted data pertaining to individuals were anonymised. Steps were taken to ensure that confidentiality of all participants was protected to the fullest extent possible. Codes were used to label audio recorded interviews. These codes together with the names of participants were recorded on a separate sheet. However, no participant was identified by name in the interview or in reporting. Likewise, any information from participants was used solely for the intended purpose of the study as had been explained to participants in the informed consent process. Audio-recorded materials along with questionnaires and all other study materials bearing personal information are being kept under lock and key by the Principal Investigator and would be destroyed 5 years after the end of the study.

Stopping or Discontinuation of the Study

Participants were free to opt out at any time before the end of the study. The study could also be discontinued when asked to do so by the Ethics Review Committee of Ghana Health Service, the Veterinary Council or the Ghana College of Physicians and Surgeons.

Guidelines for COVID-19

In view of the COVID-19 Pandemic, strict adherence to COVID-19 protocols was ensured so as to avoid undue exposure of both the research team and participants to the virus when conducting the study. As much as feasible, virtual or phone interviews were used in place of face-to-face interviews where the engagement was deemed to go beyond 15 minutes. However, if physical meeting was unavoidable, then the following were put in place for researchers and participants:

1. All recruited research assistants were taught handwashing, and how to wear, remove and care for reusable facemasks. All members of the study team had to practice personal hygiene including regular hand hygiene and wearing of facemasks for adequate protection.

2. Any participant arriving at a scheduled meeting place without a facemask was given one for free and encouraged to put it on throughout the engagement.

3. Hand hygiene facilities including hand sanitisers were provided on site for use by the research team and participants as they engaged each other and handled research materials including stationery.

4. As much as possible physical distancing of at least 1 metre was observed among research assistants and participants.

5. Research team and participants were equally to comply with any restrictions to movements imposed by national or local response teams (e.g., Lockdown, quarantine etc).

Compliance with the above guidelines was stressed during training of recruited research assistants

Quality Assurance and Control

In order to ensure data quality, abstracted rabies-related data from the DHIMS2 were cross-checked with those from other sources such as the Surveillance Department of Ghana Health Service, and the Veterinary Services Directorate when available.

Key Informant Interviews were all conducted by the Principal Investigator in order to ensure consistency and also not miss out on the non-verbal aspects of the responses. As already mentioned, method triangulation was used to validate the responses and claims. Annual reports, outbreak reports, and other relevant documents were consulted when deemed necessary for validation of facts.

6.0 RESULTS

The results are presented by the 5 specific objectives of the study:

1. To describe temporal, spatial and spatiotemporal distribution of incidence of dog bites, dog vaccination coverages and incidence of dog and human rabies in Ghana in the period 2015-2021.
2. To analyze the spatiotemporal relationships between dog bites, dog vaccination coverages and dog and human rabies.
3. To assess existing mechanism for collaboration, data sharing and harmonisation across medical and veterinary fields of practice in relation to human and dog rabies control.
4. To assess knowledge, perception and practices of key personnel in both medical and veterinary sectors on collaboration.
5. To identify the barriers and enablers of One Health collaboration for policy decisions and implementation for elimination of dog-mediated human rabies in Ghana.

6.1 Objective 1: Description of frequency, temporal, spatial and spatiotemporal distributions of dog bites, dog vaccinations and dog and human cases in Ghana

Monthly dog bite cases, human rabies cases, dog rabies cases and dog vaccination data for all the 260 districts in Ghana for the 7-year period were available and aggregated into regional, zonal and national aggregates. A total of 116,728 dog bites, 137 human rabies cases, 602 dog rabies cases and 426,664 dog vaccinations against rabies were reported within the period 2015-2021. Average annual dog bites, human rabies cases, dog rabies cases, and dogs vaccinated were 16,675, 19, 86, and 60,952 respectively translating into annual dog bite incidence of 58.9 bites per 100,000 population, human rabies incidence of 0.07 per 100,000 population, dog rabies incidence of 8 rabies cases per 100,000 dogs and average annual dog vaccination coverage of 5.7%. Table 2 summarizes the estimated annual morbidity rates and dog vaccination coverage over the period.

Table 2: Annual estimates of morbidity rates and vaccination coverage from routinely reported data, 2015-2021

National estimates	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Estimated human population	26,511,793	27,049,388	27,650,601	28,329,499	29,080,494	29,901,114	30,832,019
Estimated dog population	993,546	1,013,604	1,035,386	1,058,524	1,083,231	1,109,635	1,137,838
Human: dog ratio	26.7/1	26.7/1	26.7/1	26.8/1	26.8/1	26.9/1	27.2/1
Number of dogs vaccinated	38,234	46,758	59,026	58,647	90,713	70,142	63,144
Dog Vaccination coverage (%)	3.85	4.61	5.70	5.54	8.37	6.32	5.54
Number of dog bites	17,652	17,878	18,043	16,205	15,368	15,296	16,286
Dog bite incidence/100,000 population	66.6	66.1	65.3	57.2	52.8	51.2	52.8
Number of dog rabies cases	62	58	70	64	59	158	131
Dog rabies incidence/100,000 dogs	6.24	5.72	6.76	6.05	5.45	14.24	11.51
Number of human rabies cases	22	16	24	16	22	24	13
Human rabies incidence /100,000 population	0.08	0.06	0.07	0.06	0.08	0.08	0.04

SOURCE: Estimated from routinely reported monthly data from VSD and GHS together with projections from Ghana Population and Housing Census, GSS 2010, 2021

Figure 3 shows the trend in annual vaccination coverage, morbidity rates of dog bites, dog rabies and human rabies during the period.

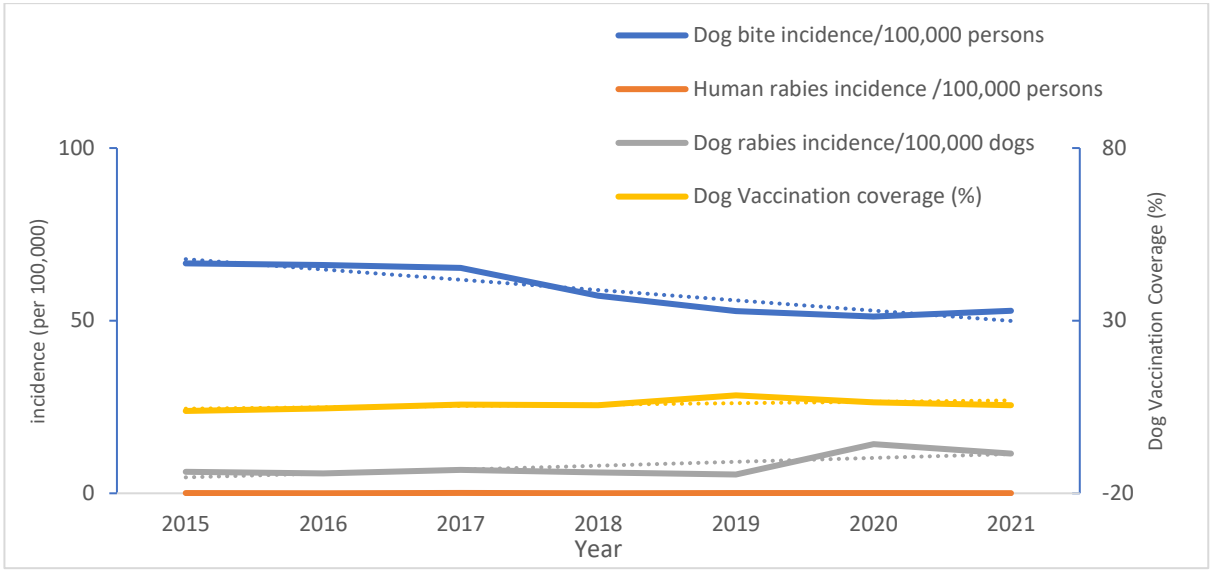

Figure 3. Trend of annual dog bite, dog and human rabies incidence, and dog vaccination coverage, Ghana, 2015-2021

SOURCE: Estimated from routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Age and Sex Distribution of Dog Bite Cases in Ghana, 2015-2021

Of the total of 116,728 dog bites recorded in the period, 62,779 (53.8 %) were males. The median age for the recorded dog bite cases was 18.1(IQR=28.0) years. Among males, the median age was 15.5 (IQR =26.0) years whilst among females the median age was 21.6 (IQR=31.0) years. The predominant age group was 5–14-years (see figure 4).

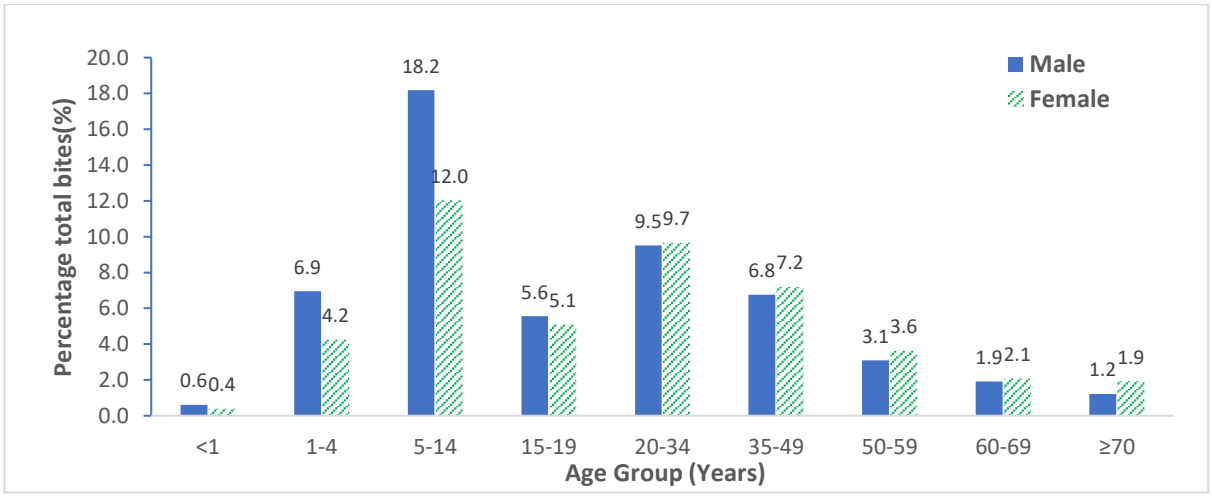

Figure 4. Age and sex distribution of dog bite cases in Ghana, 2015-2021

SOURCE: Estimated from routinely reported monthly data from GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Again, the most affected age group in terms of bite incidence was the 5–14year age group recording as high as 75.1 dog bites per 100,000 population (See figure 5).

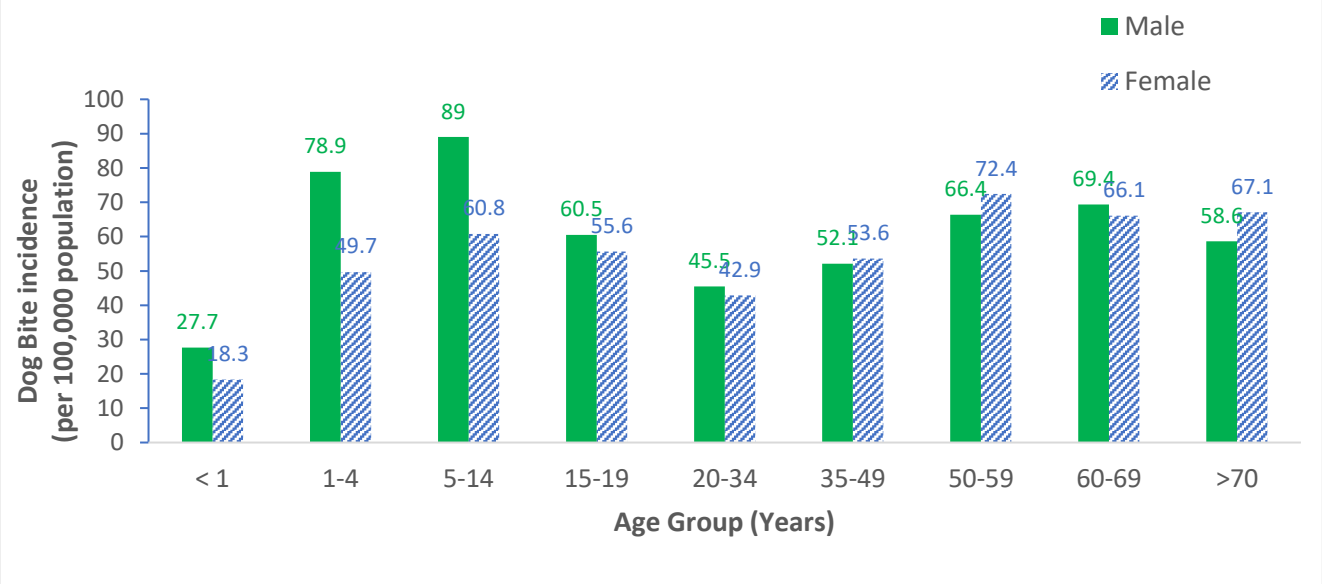

Figure 5. Dog bite rate by Age and Sex, Ghana, 2015-2021

SOURCE: Estimated from routinely reported monthly data from GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

District and Regional Distribution of Dog Bite Incidence in Ghana, 2015-2021

The highest average annual dog bite incidence (78.4 per 100,000 population) was observed in the Eastern Region and the lowest average annual dog bite incidence (7.04 per 100,000 population) was observed in the Northern Region. Ashanti Region recorded both the highest average annual dog rabies rate (19.9 per 100,000 dogs) and the highest average annual dog vaccination coverage (10.3%). No dog or human rabies cases were recorded in the North East and Ahafo regions during the period although average annual vaccination coverage remained low at 1.3% (lowest among the regions) and 5.3% respectively. Likewise, no human rabies case was recorded in the Northern Region during the period. The highest average annual human rabies incidence (0.31 per 100,000 population) was recorded in the Upper West Region. (Table 3).

The highest average annual dog bite incidence (260.3 per 100,000 population) was observed in New Juaben South district in the Eastern Region and the lowest average annual dog bite incidence (0.36 per 100,000 population) was observed in North East Gonja district in the Savannah Region. Highest average annual human rabies incidence, dog rabies incidence and dog vaccination rates were 3.38 per 100,000 population, 252.8 per 100,000 dogs and 36.1% respectively reported by Daffiama-Busie-Issa, Adansi Akrofuom and Ahafo Ano North.

Table 3: Average annual rates of dog bites, dog rabies, human rabies and dog vaccinations by region, Ghana, 2015-2021

Region	Dog bite rate (per 100,000 population)	Dog Rabies rate (per 100,000 dogs)	Human Rabies rate (per 100,000 population)	Dog Vaccination rate (percent)
Ahafo Region	67.7	0.0	0.00	5.3
Ashanti Region	58.6	19.9	0.04	10.3
Bono East Region	61.8	11.7	0.03	6.8
Bono Region	69.3	1.3	0.12	8.6
Central Region	66.8	12.0	0.03	6.3
Eastern Region	78.4	3.4	0.08	6.4
Greater Accra Region	66.2	14.6	0.06	5.6
North East Region	16.5	0.0	0.00	1.3
Northern Region	7.0	5.9	0.00	1.6
Oti Region	23.2	1.8	0.04	2.9
Savannah Region	15.2	0.6	0.02	1.6
Upper East Region	58.1	13.6	0.19	4.3
Upper West Region	69.1	1.6	0.31	4.2
Volta Region	55.4	1.7	0.04	3.8
Western North Region	72.9	1.9	0.07	10.2
Western Region	78.1	1.9	0.16	4.5

SOURCE: Estimated from routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Spatial Cluster Analysis of dog bite cases using SaTScan

Spatial cluster analysis of dog bite cases recorded in the period 2015-2021 in Ghana showed that cases were not randomly distributed but were clustered in space at the regional and district levels (See figures 6 &7). Clustering of cases was seen mainly in the south western, north western and north eastern parts of the country.

Using a maximum spatial cluster size of 50% of the total population, one most likely cluster (the primary cluster) and 44 secondary clusters were identified (See figures 8&9). The overall relative risk for the most likely cluster was 1.53 with an observed 70,193 cases compared with a calculated 58,019 expected cases. The relative risk is the ratio of the risk of dog bite within a cluster to the risk of dog bite outside the cluster. The log likelihood ratio was 2555.6. It is highest for the most likely cluster (the primary cluster) and is an indication of the extent to which occurrence of the cluster is least likely due to chance. Its corresponding p -value was less than 0.05 meaning there was sufficient evidence against the null hypothesis that it was due to chance. All except 2 of the 44 secondary clusters had p-values less than 0.05 for their corresponding log likelihood ratios (See table 4 for the scan statistics of the first 10 most likely clusters and Appendix Q for all the clusters).

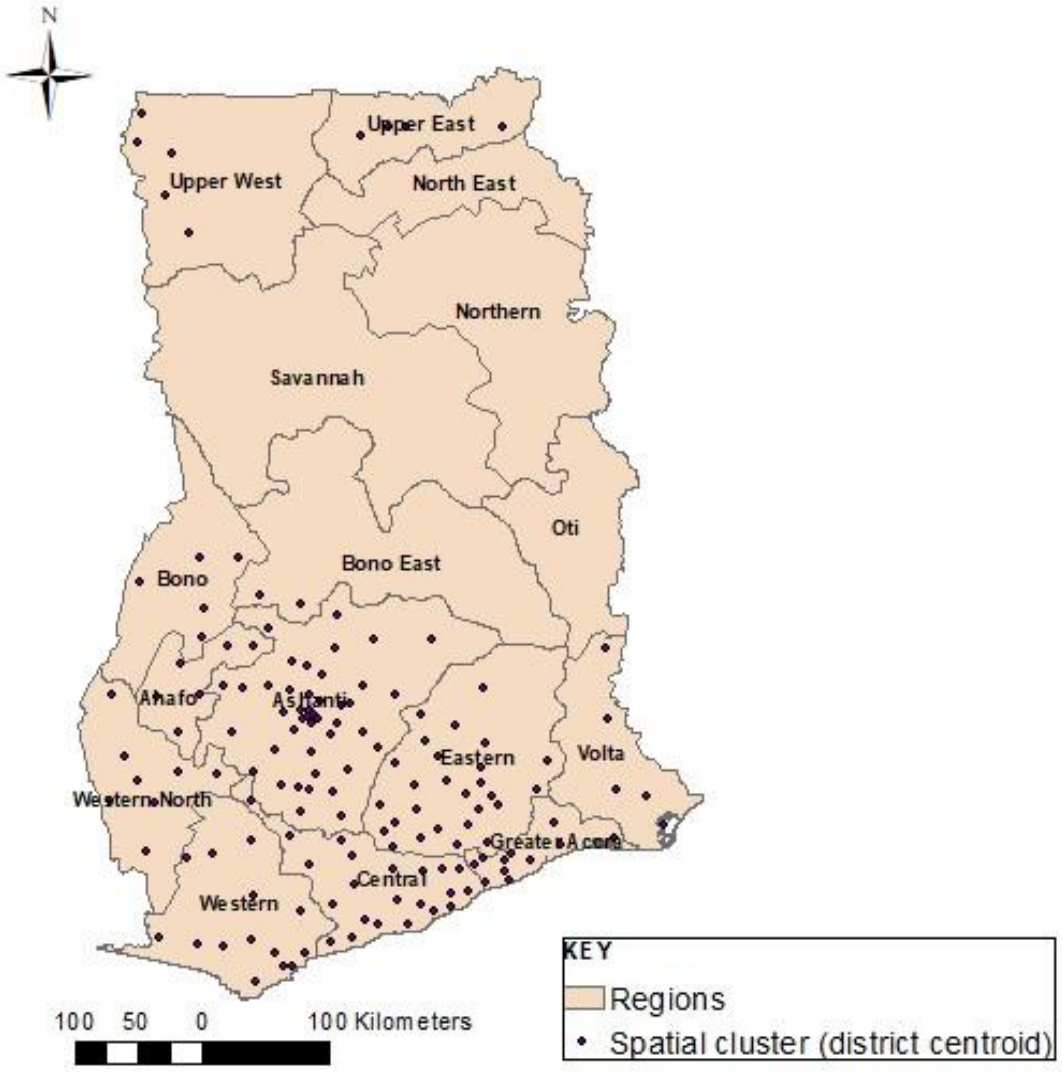

Figure 6.Spatial clustering of dog bites in the Regions of Ghana, 2015-2021

SOURCE: Estimated from routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

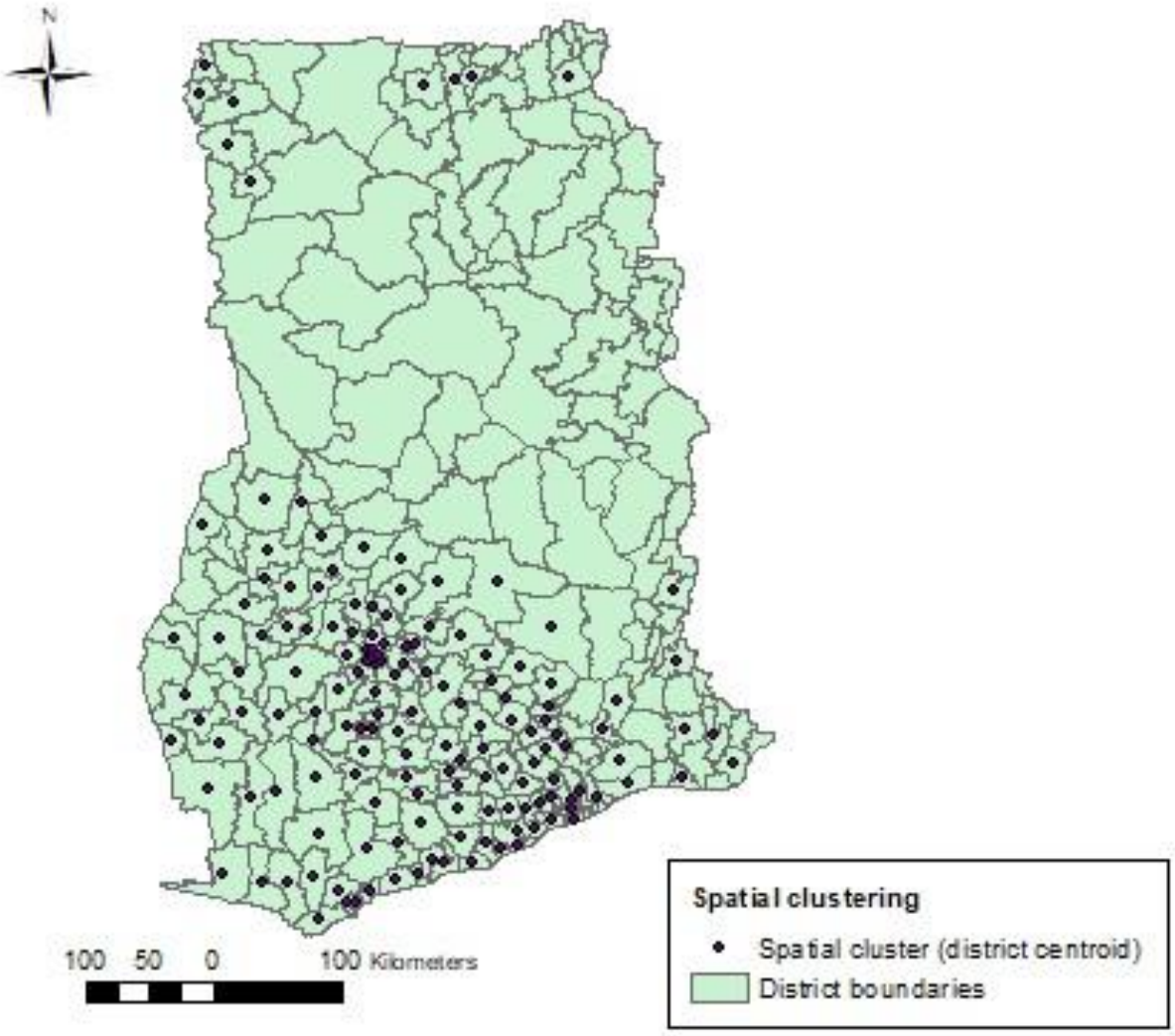

Figure 7. Spatial clustering of dog bites in the Districts in Ghana, 2015-2021

SOURCE: Estimated from routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

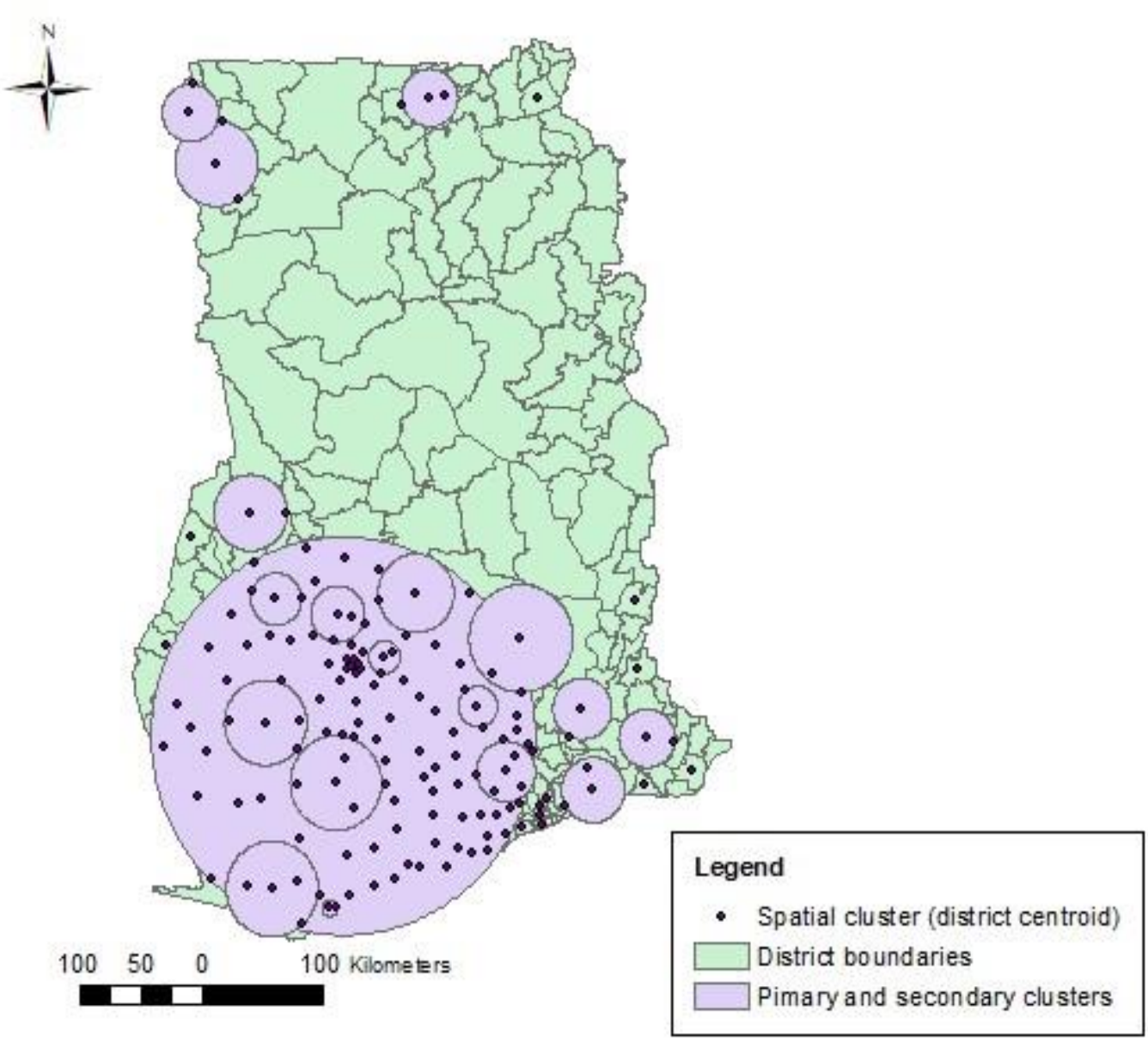

Figure 8. Spatial clustering of dog bites showing primary and secondary clusters, 2015-2021

SOURCE: Estimated from routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

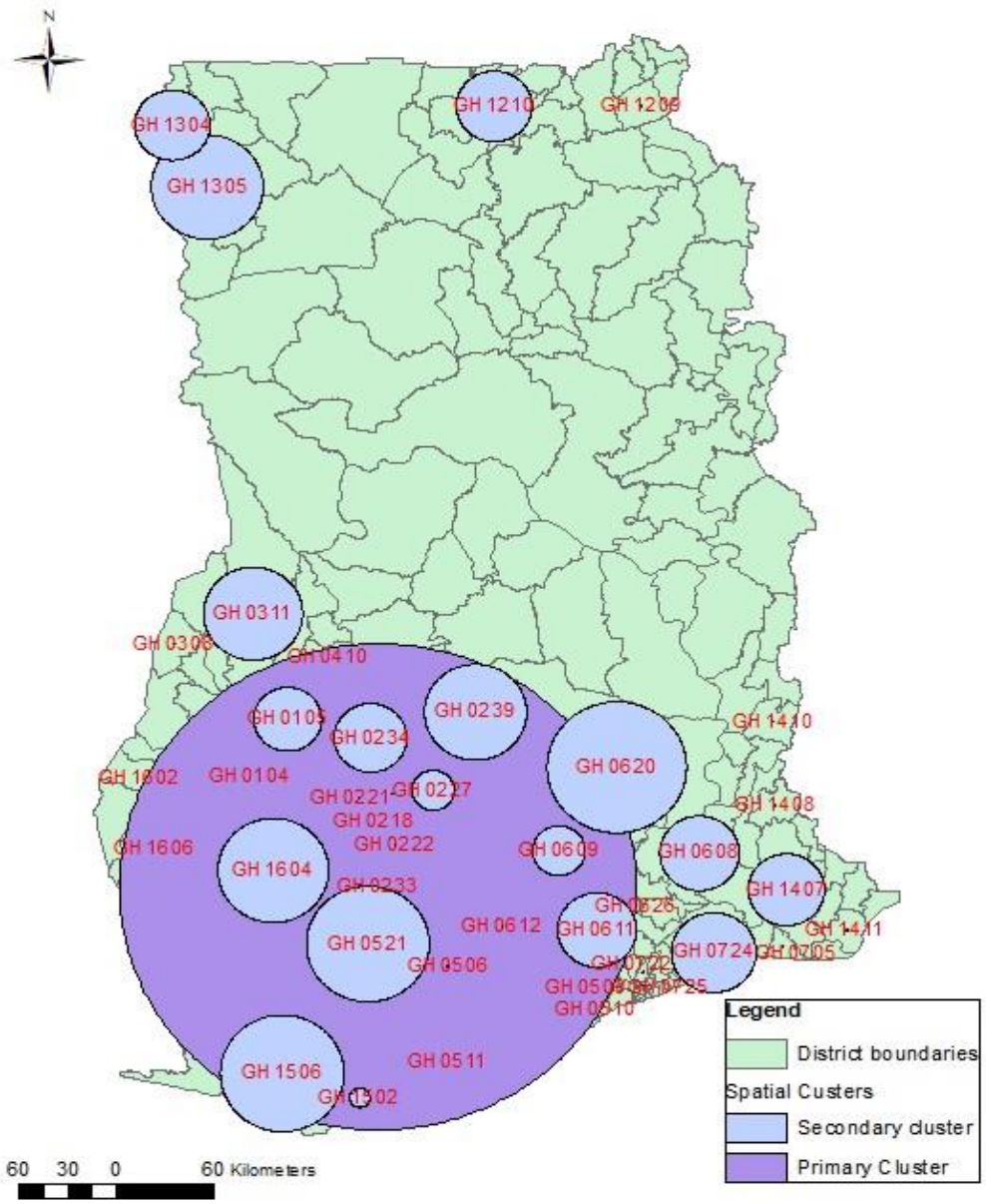

Figure 9. Spatial clustering of dog bites showing primary and secondary clusters among districts in Ghana, 2015-2021

SOURCE: Estimated from routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Table 4: Spatial scan statistics for the first 10 most likely clusters of dog bites, Ghana, 2015-2021

CLS	LOC_ID	DIST	POP	RAD_KM	NO. LOC	OBS	EXP.	OBS/ EXP	RR	LLR	P_VAL
1	GH0233	Obuasi Mun.	14152432	158.0	122	70193	58019.9	1.21	1.53	2555.6	p<.00001
2	GH0626	New Juaben South Mun.	124818	0.0	1	2274	510.9	4.45	4.52	1645.8	p<.00001
3	GH0410	Techiman Mun	300340	0.0	1	3037	1230.3	2.47	2.51	951.8	p<.00001
4	GH0724	Ningo/Prampram	444969	25.9	3	3725	1824.9	2.04	2.08	773.7	p<.00001
5	GH0722	La-Nkwantanang-Madina	199208	0.0	1	2115	816.5	2.59	2.62	721.8	p<.00001
6	GH0105	Tano North Mun.	259963	20.7	2	2434	1066.7	2.28	2.31	648.8	p<.00001
7	GH0609	Atiwa East	188744	16.1	2	1956	773.3	2.53	2.56	638.4	p<.00001
8	GH1604	Bibiani-Anhwiaso-Bekwai Mun.	478218	33.8	4	3553	1965.3	1.81	1.83	527.2	p<.00001
9	GH1506	Nzema East	505368	37.9	4	3663	2075.8	1.76	1.79	504.2	p<.00001
10	GH0521	Techiman Mun.	487158	37.6	5	3507	2002.3	1.75	1.77	470.8	p<.00001

CLS=Cluster;LOC_ID=Location ID;DIST=DISTRICT;RAD=Radius;No.LOC=No. of Locations LLR=Log likelihood ratio; P VAL=P-value; OBS=Observed cases; EXP=Expected cases;RR=Relative Risk; POP=Population

SOURCE: Estimated using routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Spatial Cluster Analysis of human rabies cases using SaTScan

Spatial cluster analysis of human rabies cases recorded in the period 2015-2021 in Ghana showed that cases were not randomly distributed but were clustered in space at the regional and district levels (See figures 10 &11). Clustering of cases was seen mainly in the upper regions and a few southern and coastal regions. The districts mostly affected were Sissala East district, Jirapa district, Bolgatanga municipality Asante -Akim Central municipality, Ahanta West municipality and Ashaiman municipality.

Using a maximum spatial cluster size of 50% of the total population, one most likely cluster (the primary cluster) and 5 statistically significant secondary clusters were identified (See figure 10&11). The overall relative risk within the most likely cluster was 7.60 with an observed 28 cases compared with a calculated 4.48 expected cases. The log likelihood ratio was 30.0 with a corresponding p-value less than 0.05 meaning the cluster was least likely due to chance. The five (5) significant secondary clusters identified had p-values less than 0.05 meaning they were unlikely to have occurred due to chance. The remaining clusters had p-values greater than 0.05 meaning they were likely to have occurred due to chance. (See table 5).

Figure 10. Spatial Clustering of human rabies cases in Ghana, 2015-2021

SOURCE: Estimated using routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

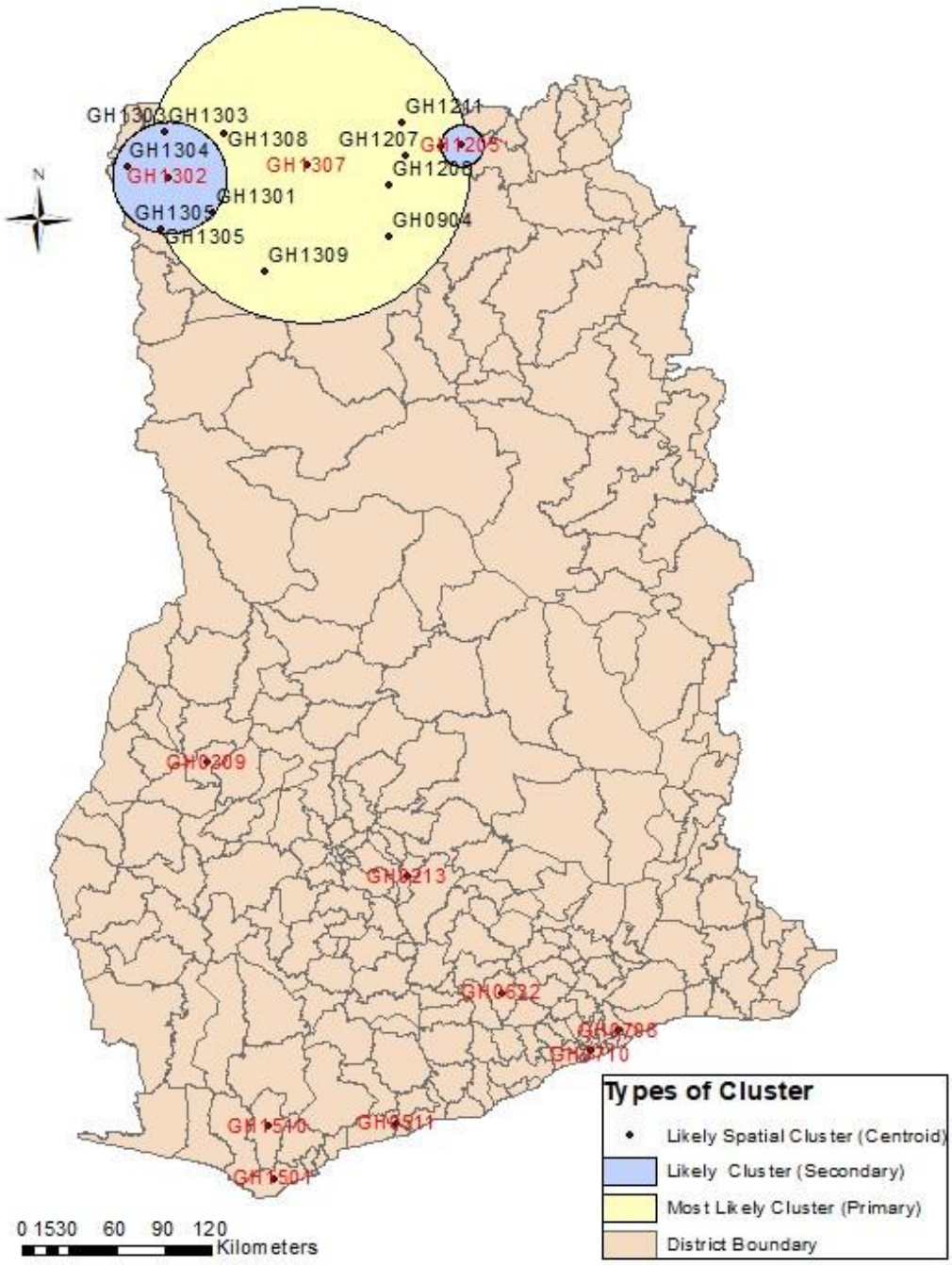

Figure 11. Spatial clustering of human rabies cases showing primary and secondary clusters in the districts, Ghana, 2015-2021

SOURCE: Estimated from routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Table 5: Spatial Scan statistics for cluster analysis of human rabies cases in Ghana, 2015-2021

CLS	LOC_ID	DIST	POP	RAD_KM	NO_LOC	OBS	EXP	OBS/EXP	RR	LLR	P_VAL
1	GH1307	Sissala East	931590	100.2	13	28	4.48	6.25	7.60	30.0	p<0.0001
2	GH1302	Jirapa	305275	35.4	5	18	1.47	12.26	13.96	29.6	p<0.0001
3	GH0213	Asante Akim Central Mun.	85417	0.0	1	9	0.41	21.90	23.37	19.5	p<0.0001
4	GH1205	Bolgatanga Mun.	229805	13.2	2	12	1.11	10.85	11.80	18.2	p<0.0001
5	GH1501	Ahanta West Mun.	138402	0.0	1	9	0.67	13.52	14.40	15.4	p<0.0001
6	GH0708	Ashaiman Mun.	202611	0.0	1	8	0.97	8.21	8.65	10.0	0.007
7	GH0309	Sunyani Mun.	170803	0.0	1	5	0.82	6.09	6.28	4.9	0.503
8	GH0511	Cape Coast Metro	184268	0.0	1	5	0.89	5.64	5.82	4.6	0.608
9	GH0632	West Akim	115727	0.0	1	4	0.56	7.19	7.37	4.5	0.646
10	GH0710	Ayawaso East Mun.	59913	0.0	1	3	0.29	10.41	10.62	4.3	0.692
11	GH1510	Tarkwa Nsuaem	173218	0.0	1	4	0.83	4.80	4.91	3.1	0.974

CLS=Cluster;LOC_ID=Location ID;DIST=DISTRICT;RAD=Radius;No.LOC=No. of Locations LLR=Log likelihood ratio; P VAL=P-value; OBS=Observed cases; EXP=Expected cases;RR=Relative Risk; POP=Population

SOURCE: Estimated using routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Spatial Cluster Analysis of dog rabies cases using SaTScan

Spatial cluster analysis of dog rabies cases recorded in the period 2015-2021 in Ghana showed that cases were not randomly distributed but were clustered in space at the regional and district levels (See figures 12 &13). Clustering of cases was seen mainly in the Upper East, Ashanti, Bono East and Savannah regions. The districts mostly affected were Asokwa municipality, Cape Coast metropolis, Accra metropolis, and Atwima-Mponua district.

Using a maximum spatial cluster size of 50% of the total population, one most likely cluster (the primary cluster) and 14 significant secondary clusters were identified (See figure 12&13). The overall relative risk for the most likely cluster was 3.3 and a log likelihood ratio of 76.7. ($p < 0.0001$) with an observed 194 cases compared with a calculated 76.8 expected cases. The 14 significant secondary clusters had p-values less than 0.05. The role of chance could however, not be excluded as a possible explanation for 4 other clusters as their p-values were more than 0.05. They were thus not considered as significant secondary clusters. (see table 6).

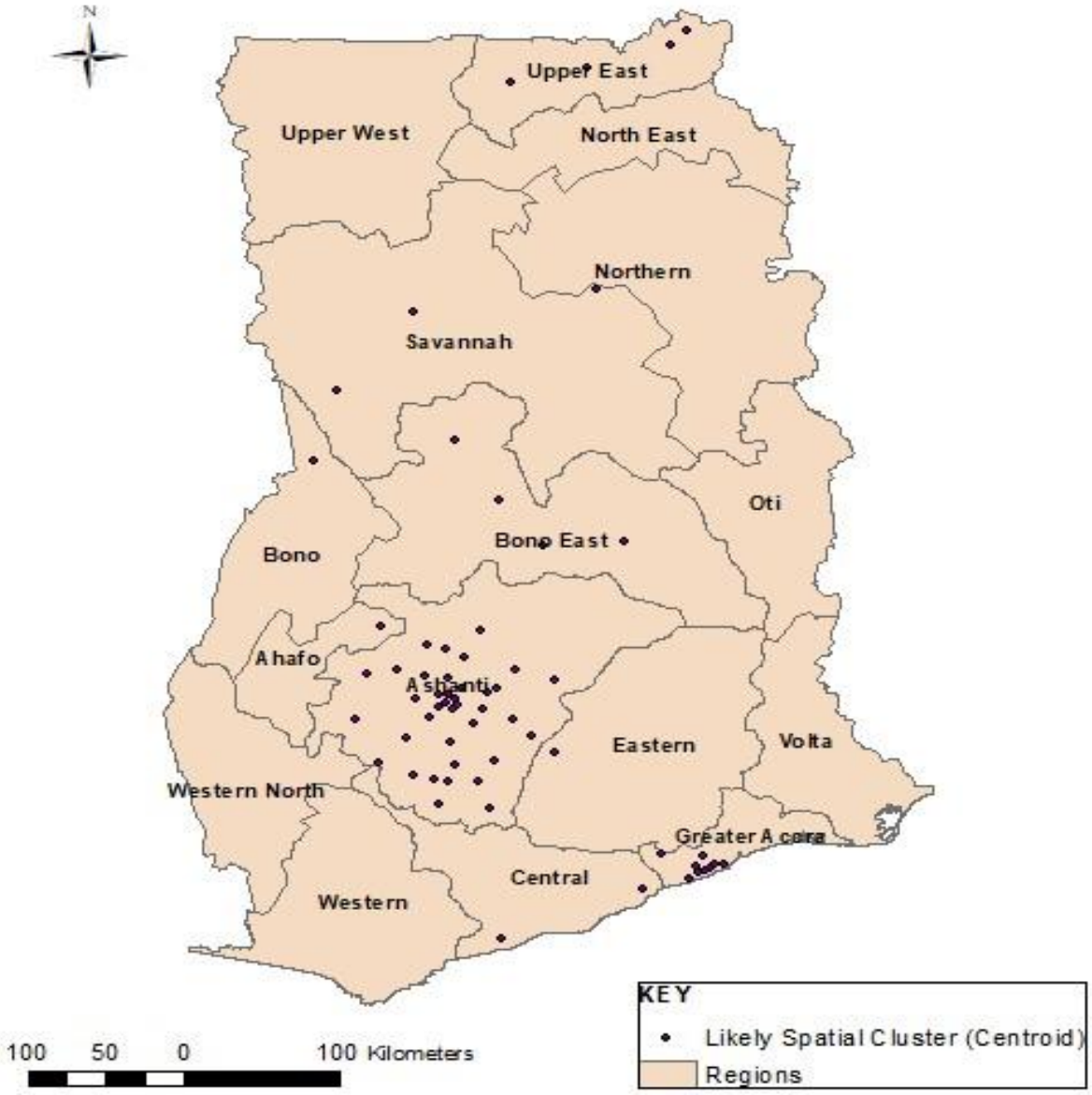

Figure 12. Spatial clustering of dog rabies cases in the regions of Ghana, 2015-2021.

SOURCE: Routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

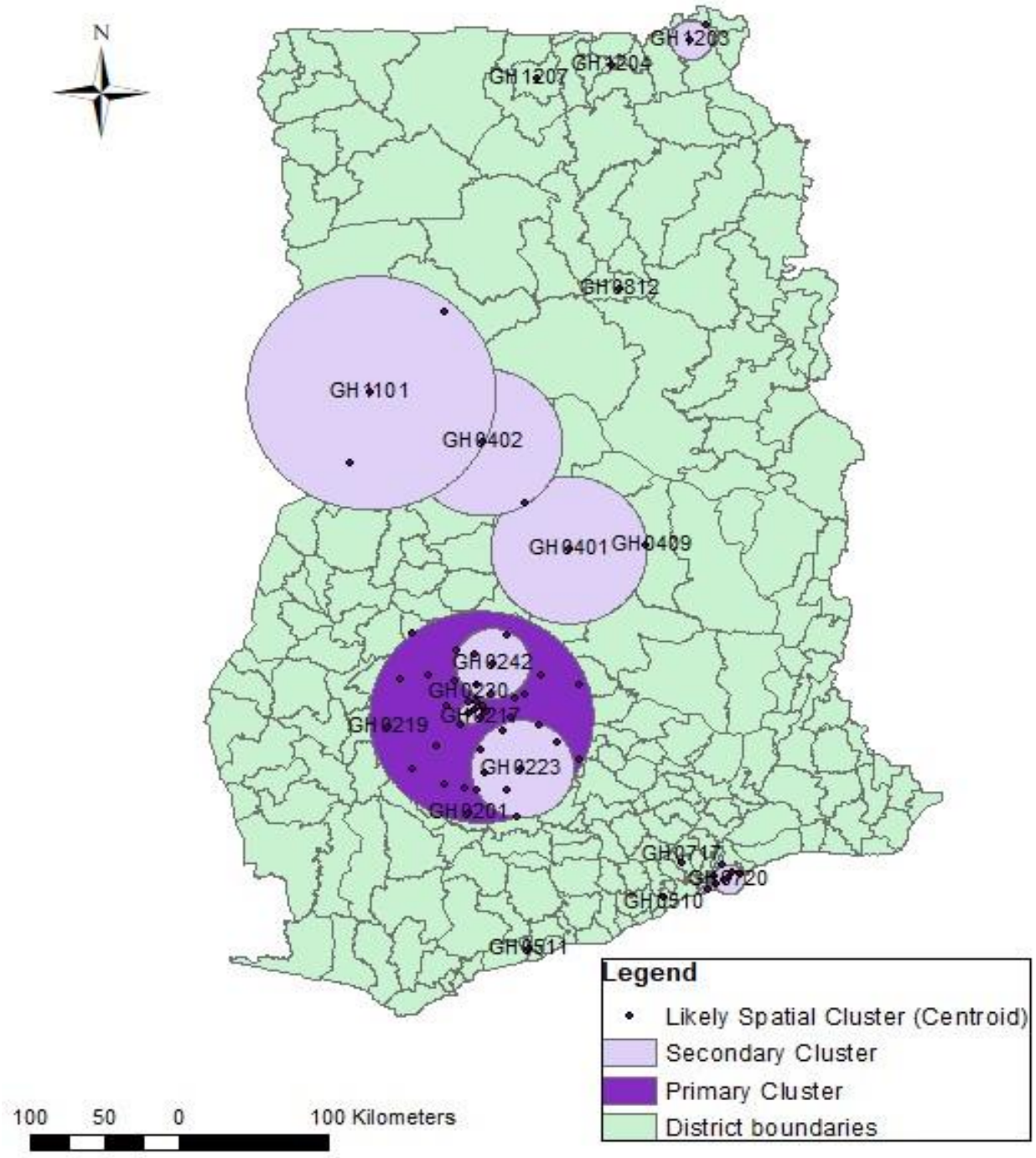

Figure 13. Spatial clustering of dog rabies cases showing primary and secondary clusters in the districts, Ghana, 2015-2021

SOURCE: Routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Table 6: Spatial Scan statistics for cluster analysis of dog rabies cases in Ghana, 2015-2021

CLS	LOC_ID	DIST	POP	RAD_KM	NO _LOC	OBS	EXP	OBS/EXP	RR	LLR	P_VAL
1	GH0217	Asokwa Mun.	135490	74.8	40	194	76.8	2.5	3.3	76.7	p<0.0001
2	GH0511	Cape Coast Metro.	5191	0.0	1	36	2.9	12.2	12.9	58.0	p<0.0001
3	GH0201	Adansi Akrofuom	1487	0.0	1	24	0.8	28.5	29.6	57.7	p<0.0001
4	GH0704	Accra Metro.	6625	0.0	1	33	3.8	8.8	9.2	43.2	p<0.0001
5	GH0219	Atwima Mponua	3882	0.0	1	24	2.2	10.9	11.3	35.9	p<0.0001
6	GH0812	Tamale Metro	6163	0.0	1	26	3.5	7.4	7.7	30.1	p<0.0001
7	GH0242	Sekyere South	22018	24.9	6	47	12.5	3.8	4.0	28.8	p<0.0001
8	GH0230	Kwadaso Mun.	22076	7.8	3	43	12.5	3.4	3.6	23.4	p<0.0001
9	GH0401	Atebubu Amantin	14443	52.1	3	33	8.2	4.0	4.2	21.7	p<0.0001
10	GH1203	Binduri	14418	13.9	2	32	8.2	3.9	4.1	20.3	p<0.0001
11	GH0402	Kintampo North Mun.	10440	51.9	2	26	5.9	4.4	4.5	18.7	p<0.0001
12	GH1204	Bolga East	2769	0.0	1	12	1.6	7.6	7.8	14.1	0.0003
13	GH0720	Krowor Mun.	22109	10.7	7	34	12.5	2.7	2.8	12.9	0.0008
14	GH0409	Sene West	3612	0.0	1	11	2.0	5.4	5.5	9.6	0.0120
15	GH0510	Awutu Senya East	5442	0.0	1	13	3.1	4.2	4.3	8.9	0.0250
16	GH1101	Bole	15507	82.9	4	20	8.8	2.3	2.3	5.3	0.4240
17	GH0717	Ga West	4863	0.0	1	9	2.8	3.3	3.3	4.4	0.7220
18	GH0223	Bosome Freho	22073	34.5	9	24	12.5	1.9	2.0	4.3	0.7800
19	GH1207	Builsa North	4390	0.0	1	8	2.5	3.2	3.2	3.9	0.8870

CLS=Cluster;LOC_ID=Location ID;DIST=DISTRICT;RAD=Radius;No.LOC=No. of Locations LLR=Log likelihood ratio; P VAL=P-value; OBS=Observed cases; EXP=Expected cases;RR=Relative Risk; POP=Population

SOURCE: Estimated using routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021.

Spatial Cluster Analysis of dog vaccinations using SaTScan

Spatial cluster analysis of dog rabies vaccinations recorded in the period 2015-2021 in Ghana showed that vaccinations were not randomly distributed but were clustered in space at the regional and district levels. Clustering of vaccinations was seen mainly in the central and southwestern part of the country.(See figures 14 & 15).

Using a maximum spatial cluster size of 50% of the total population, one most likely cluster (the primary cluster) and 43 significant secondary clusters were identified some of which overlapped with the primary cluster. (See figure 15 and table 7). The overall relative risk within the most likely cluster was 2.3 with a log likelihood ratio of 32886.4 ($p < 0.0001$). The observed cases within the cluster were 293,609 compared with a calculated 210,818 expected cases. One of the clusters had a p-value more than 0.05 and was thus not considered to be a significant secondary cluster. (See table 8 for the spatial scan statistics of the first 10 most likely clusters and Appendix R for all the clusters).

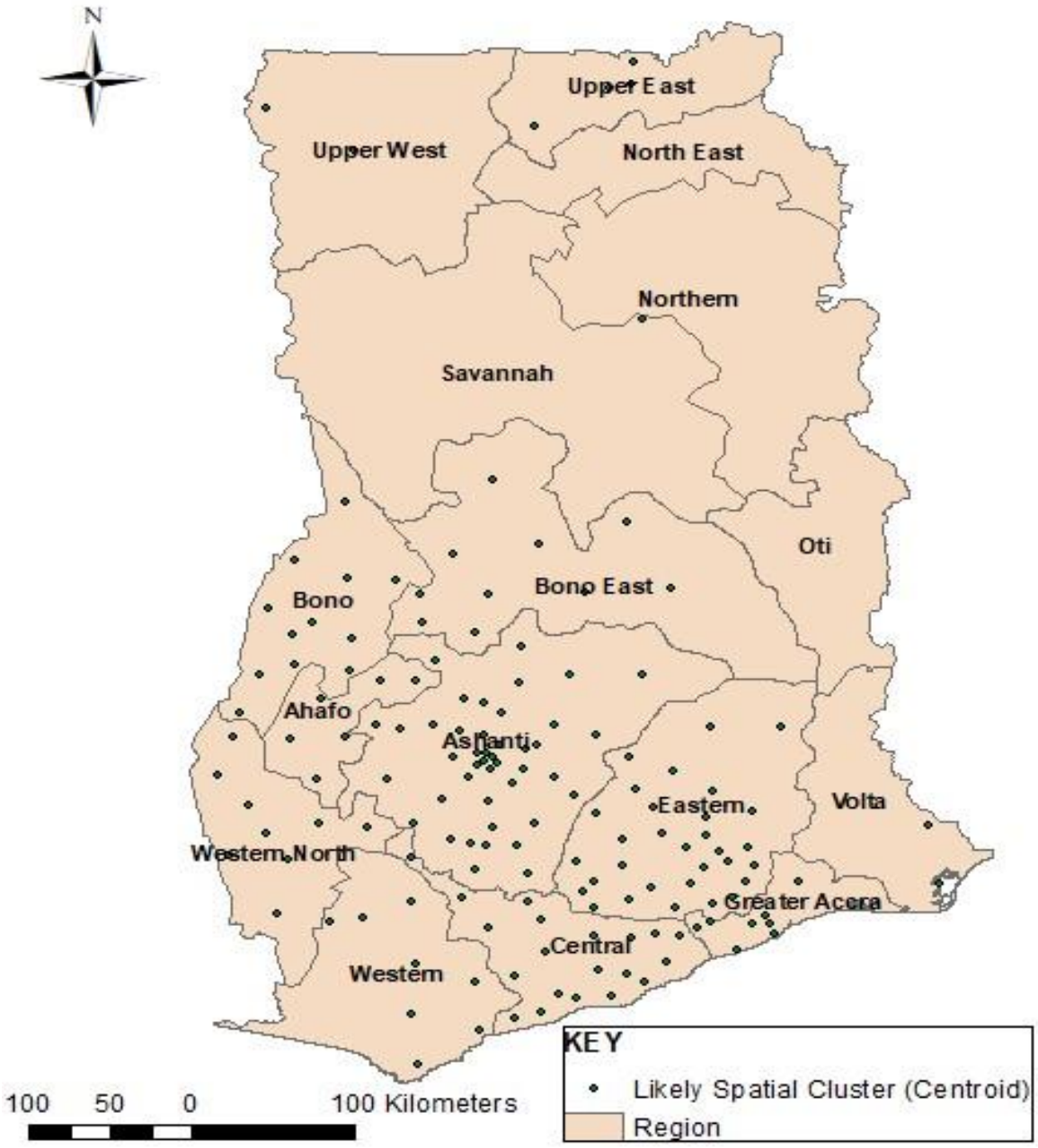

Figure 14. Spatial clustering of dog vaccinations in the regions of Ghana, 2015-2021

SOURCE: Estimated using routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

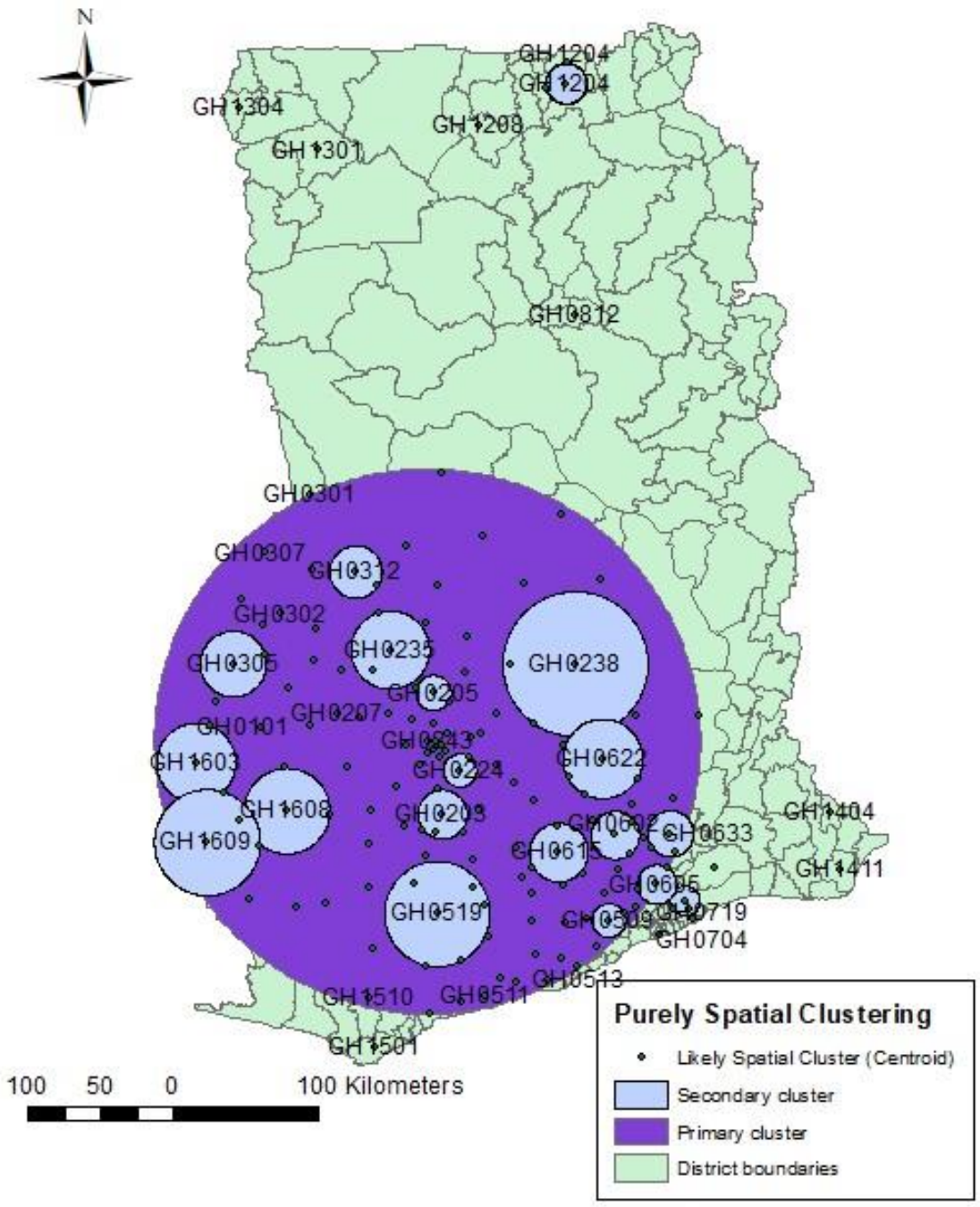

Figure 15. Spatial clustering of dog vaccinations showing primary and secondary clusters in the districts, Ghana, 2015-2021

SOURCE: Estimated using routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Table 7: Spatial scan statistics for cluster analysis of dog vaccinations in Ghana, 2015-2021

CLS	LOC_ID	DIST	POP	RAD_KM	NO. LOC	OBS	EXP.	OBS/ EXP	RR	LLR	P_VAL
1	GH0243	Suame Municipal	524623	187.0	140	293609	210818.4	1.39	2.3	32886.4	p<.0001
2	GH0235	Offinso North	18245	26.9	3	23287	7331.5	3.18	3.3	11265.0	p<.0001
3	GH0224	Bosomtwe	7925	11.3	2	13895	3184.8	4.36	4.5	9895.7	p<.0001
4	GH0727	Tema Metropolitan	3617	0.0	1	7542	1453.6	5.19	5.3	6373.0	p<.0001
5	GH0207	Ahafo Ano North	2501	0.0	1	6319	1004.8	6.29	6.4	6338.1	p<.0001
6	GH0228	Kumasi Metropolitan	14013	0.0	1	15370	5631.2	2.73	2.8	5807.6	p<.0001
7	GH1608	Sefwi-Wiawso	10785	29.4	2	12457	4333.9	2.87	2.9	5107.7	p<.0001
8	GH0602	Abuakwa South	10548	16.5	3	11680	4238.6	2.76	2.8	4463.9	p<.0001
9	GH0221	Atwima Nwabiagya South	3682	0.0	1	6062	1479.4	4.10	4.1	3992.0	p<.0001
10	GH0238	Sekyere Afram Plains North	4969	49.7	3	6971	1997.0	3.49	3.5	3769.9	p<.0001

CLS=Cluster;LOC_ID=Location ID;DIST=DISTRICT;RAD=Radius;No.LOC=No. of Locations LLR=Log likelihood ratio; P VAL=P-value; OBS=Observed cases; EXP=Expected cases;RR=Relative Risk; POP=Population

SOURCE: Estimated using routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Temporal Cluster Analysis of Dog bite Cases in Ghana using SaTScan

Purely temporal cluster analysis of dog bite cases recorded in the period 2015-2021 in Ghana showed that dog bites were not randomly distributed but were clustered in time (See figure 16). A cluster is statistically significant when its log likelihood ratio is greater than the standard Monte Carlo critical value of 5.17 for 0.05 significance level. Applying this to the data with a time aggregation unit of 3 months, only one statistically significant (p-value<0.05) purely temporal cluster was detected and this spanned the period from October 2015 to June 2017 with a log likelihood ratio of 309.8 and relative risk of 1.2. Annual dog bite rate for this cluster was 66.6 per 100,000 compared to the average annual rate of 58.9 per 100,000 population for the entire period under study.

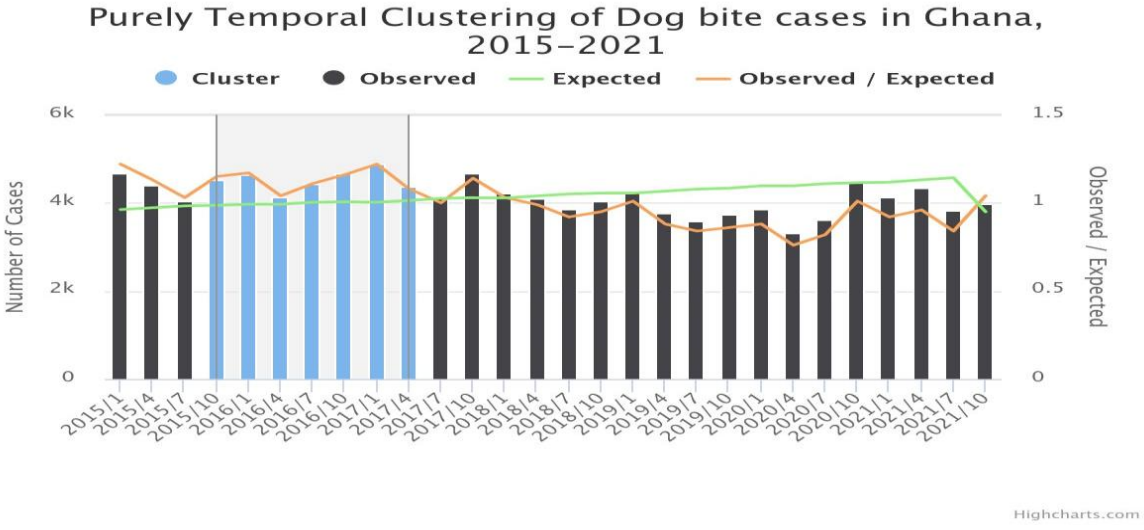

Figure 16. Purely temporal clustering of dog bite cases in Ghana, 2015-2021

SOURCE: Routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Temporal Cluster Analysis of Human rabies Cases in Ghana using SaTScan

Purely temporal cluster analysis of human rabies cases recorded in the period 2015-2021 showed that human rabies cases were also not randomly distributed but were clustered in time (See figure 17). Using a Monte Carlo critical value of 5.14 for 0.05 significance level, and a time aggregation length of 3 months, one statistically significant purely temporal cluster was detected and this spanned the period October 2015 to March 2016 with a log likelihood ratio of 10.2, p-value of 0.002 and a relative risk of 3.1. Annual human rabies incidence for this cluster was 0.2 per 100,000 population compared to the average annual rate of 0.07 per 100,000 for the entire study period.

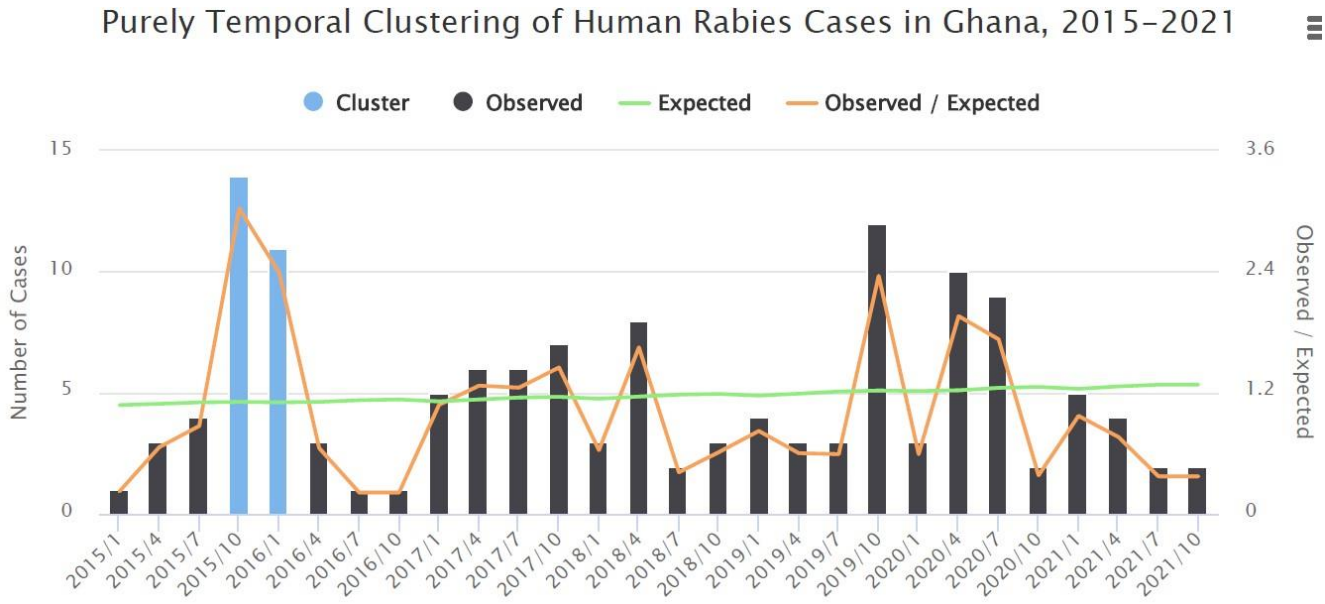

Figure 17. Purely temporal clustering of human rabies cases in Ghana, 2015-2021

SOURCE: Routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Temporal Cluster Analysis of Dog Rabies Cases in Ghana using SaTScan

Purely temporal cluster analysis of dog rabies cases recorded in the period 2015-2021 showed that the cases were not randomly distributed but were clustered in time (See figure 18). Using a Monte Carlo critical value of 6.378 for 0.05 significance level and a time aggregation length of 3 months, one statistically significant purely temporal cluster was detected and this spanned the period from January 2020 to September 2021. Annual dog rabies incidence for this cluster was 13.8 per 100,000 dog population compared to the average annual rate of 8.1 per 100,000 population for the entire study period. The relative risk was 2.3 with log likelihood ratio of 48.3 and a p-value of 0.001.

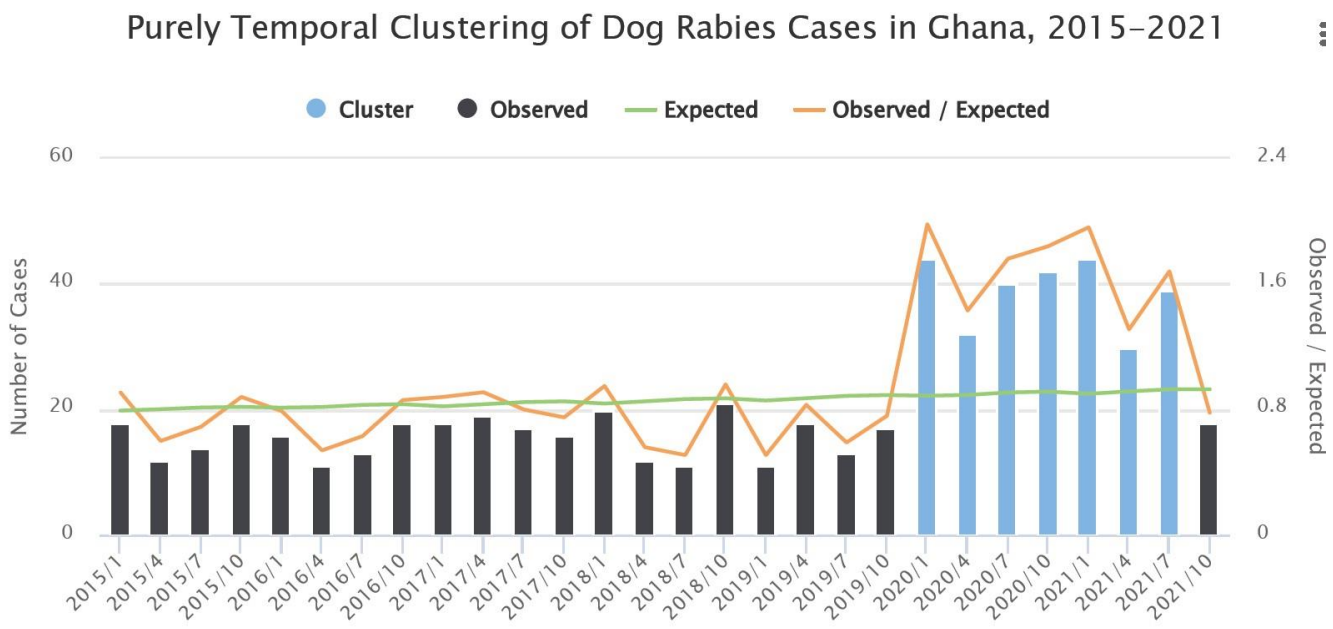

Figure 18. Purely temporal clustering of dog rabies cases in Ghana, 2015-2021

SOURCE: Routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Temporal Cluster Analysis of Dog vaccinations in Ghana using SaTScan

Purely temporal cluster analysis of dog rabies vaccinations recorded in the period 2015-2021 showed that the vaccinations were not randomly distributed but were clustered in time (See figure 19). Using a standard Monte Carlo critical value of 6.792 for 0.05 significance level and time aggregation length of 3 months, one statistically significant purely temporal cluster was detected spanning the period April 2019 to June 2019. Annual dog vaccination rate for this cluster was 157.3 per 1000 dogs compared to the average annual rate of 57.7 per 1000 dogs for the entire study period. The relative risk was 2.9 with log likelihood ratio of 16565.7 and a p-value of 0.001.

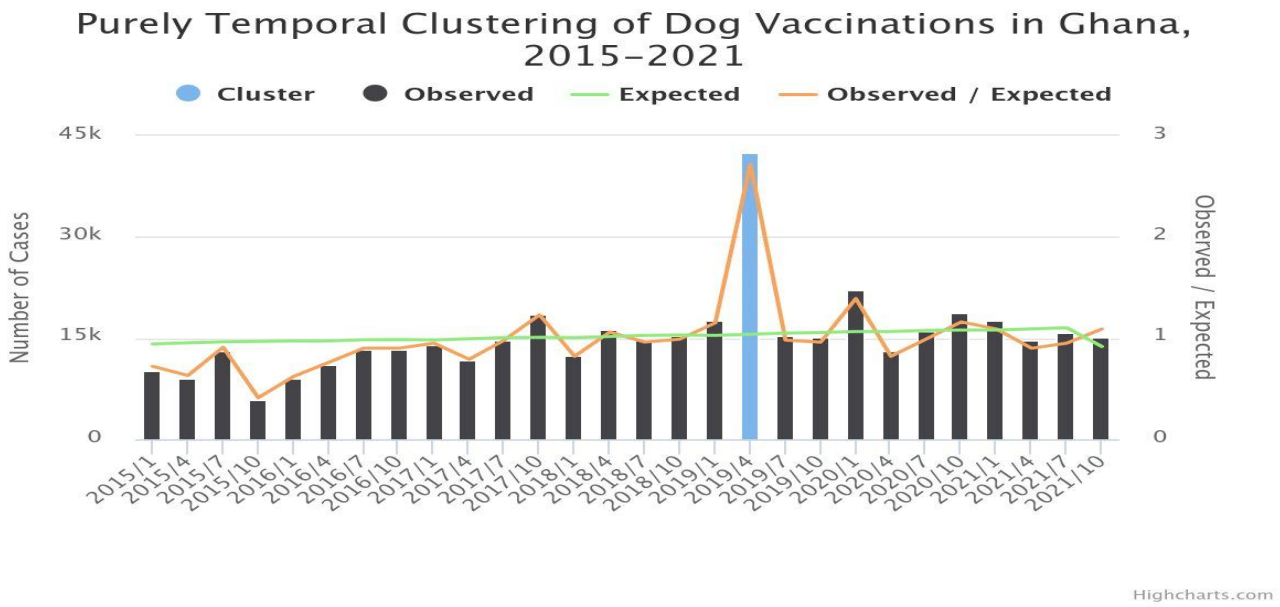

Figure 19: Purely Temporal clustering of dog vaccinations in Ghana, 2015-2021

SOURCE: Routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Spatial effects and temporal trends in dog bites in Ghana using Besag-Yorke-Mollie Model in R-INLA

The posterior mean of the main spatial effect and the posterior mean of the differential time effect as in model 2 are shown in figures 20 and 21 respectively.

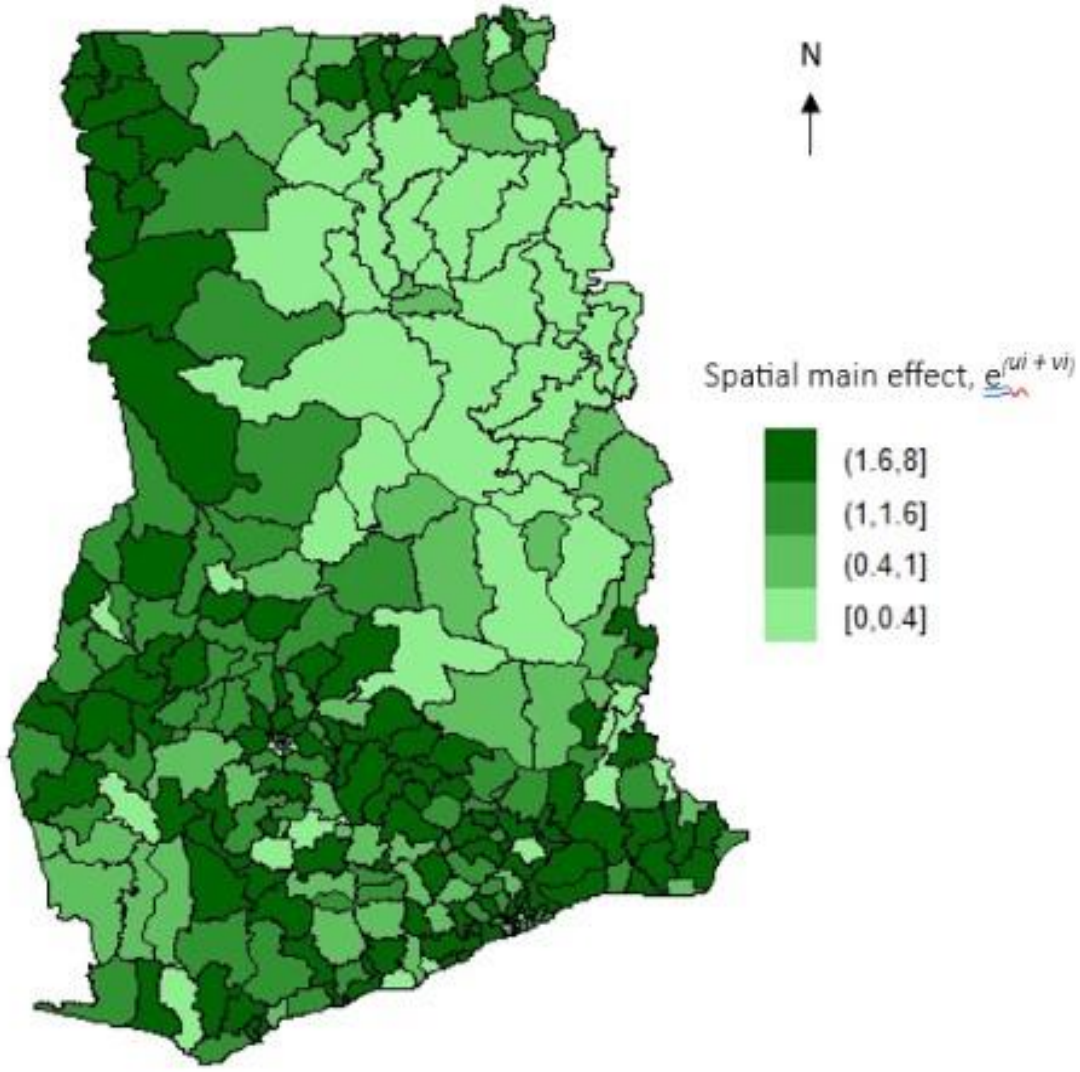

Figure 20: Posterior mean of the spatial main effect, exp ($u_i + v_i$), of dog bites in Ghana, 2015-2021

SOURCE: Routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

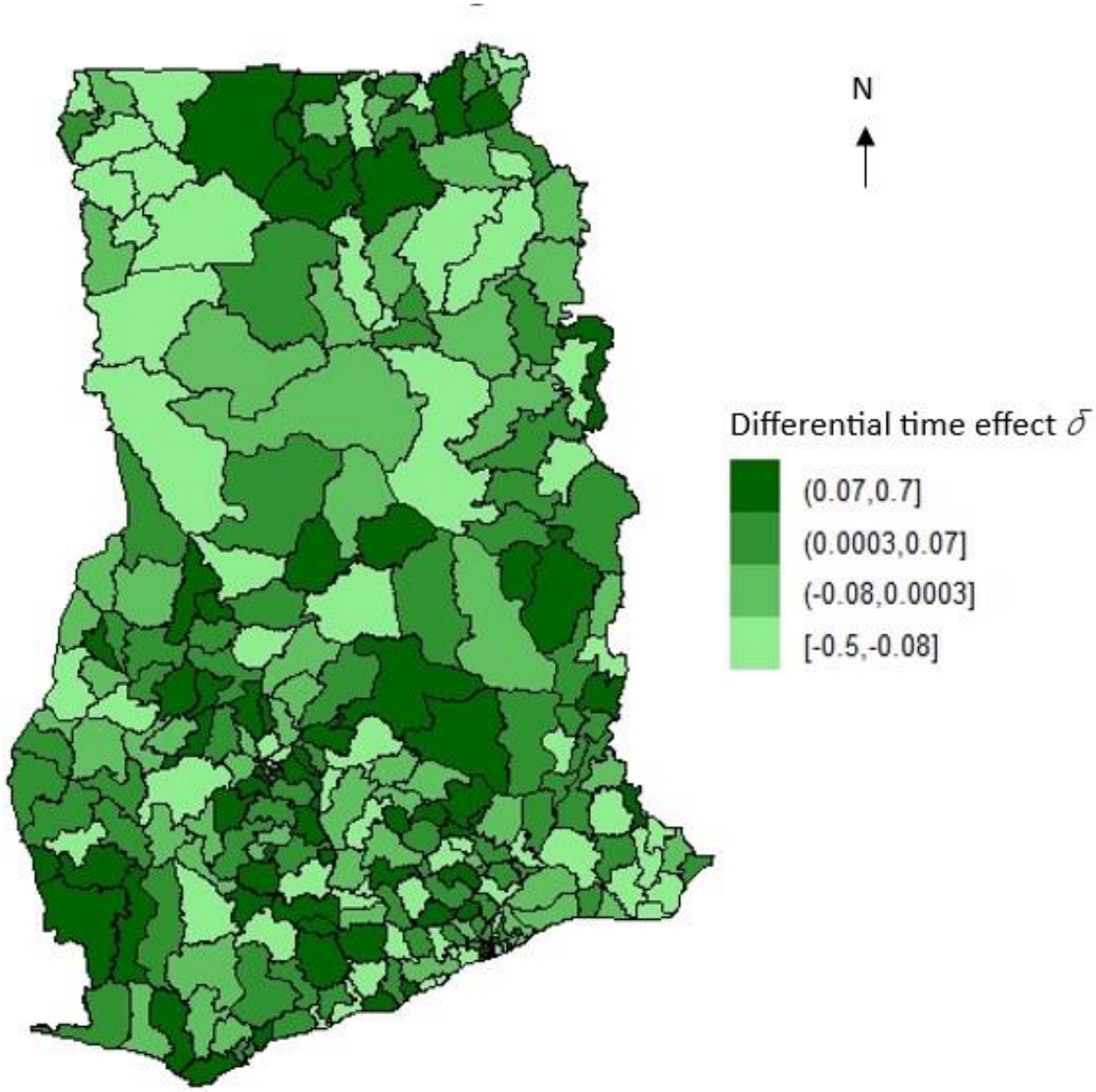

Figure 21: Posterior mean of the differential time effect δ_i of dog bites in Ghana, 2015-2021

SOURCE: Routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

The spatial effect is seen to be much higher in the southern and north-western parts of the country (figure 20). The differential temporal trend is below the average mostly in the northern part of the country while the southern and middle zones generally show a differential trend higher than the average (figure 21). Darker areas, with positive differential time effect, δ_i depict areas where the area-specific trend is steeper than the mean (global) time trend whilst the lighter areas with negative differential time effect depict areas where the global trend is steeper than the area-specific trend.

Modelled dynamically with random walk of order 2 using the nonparametric dynamic trend model (model 3), the temporally structured effect γ_t , together with the unstructured effect ϕ_t specified by means of a Gaussian exchangeable prior is as shown in figure 22.

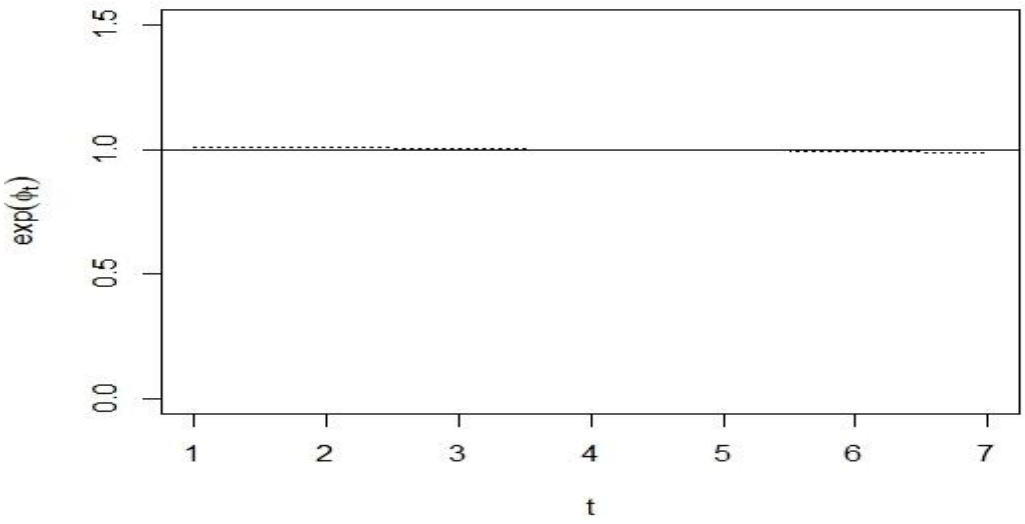

Figure 22: Posterior temporal trend for dog bites in Ghana, 2015-2021: unstructured effect (solid line) and temporally structured effect (dashed line).

SOURCE: Routinely reported monthly data from VSD and GHS together with population projections from Ghana Population and Housing Census, GSS 2010, 2021

Both the temporally structured effect (dashed line) and the unstructured effects (solid line) do not show any visible increasing or decreasing trend as they both lie horizontally on the reference line exp (ϕ_t) = 1.0. The dynamic component of the temporal effect for dog bites is thus negligible in this model. This means the primary variations in the dog bite data are more spatially driven than temporally driven.

6.2 Objective 2: Analysis of the spatiotemporal relationships

In order to investigate the relationship between dog bites, dog rabies cases, human rabies cases and dog vaccination coverages, a parametric space-time disease mapping model (model 2 described above) was fitted to the data using R-INLA with Besag-York-Mollie (BYM) specification as described by Besag et al.[96] With dog bite as the outcome variable and dog rabies cases, human rabies, month of the year and vaccination coverages as covariates the output shown in table 8 was obtained:

Table 8: Posterior estimates (mean, standard deviation (SD), and quantiles) for the Parametric space- time regression model for dog bites, 2015-2021.

	mean	Sd	0.025quantile	0.5quantile	0.975quantile
(Intercept)	-0.225	0.038	-0.299	-0.224	-0.150
Human rabies	0.027	0.014	-0.002	0.027	0.054
Vacc. cov.	0.572	0.172	0.228	0.574	0.902
Dog rabies	0.032	0.011	0.009	0.032	0.054
Feb	0.006	0.014	-0.022	0.006	0.035
Mar	0.012	0.014	-0.016	0.012	0.039
Apr	0.004	0.014	-0.023	0.004	0.032
May	0.003	0.014	-0.025	0.003	0.032
Jun	0.011	0.015	-0.018	0.011	0.040
Jul	0.016	0.015	-0.014	0.016	0.045
Aug	0.008	0.015	-0.021	0.008	0.036
Sept	0.010	0.014	-0.018	0.010	0.038
Oct	0.007	0.014	-0.021	0.007	0.035
Nov	0.001	0.014	-0.027	0.001	0.029
Dec	0.016	0.014	-0.012	0.016	0.044

SOURCE: Estimated from routinely reported monthly data from VSD and GHS together with projections from Ghana Population and Housing Census, GSS 2010, 2021

Excluding months from the model on the basis of their not contributing significantly to the outcome variable, showed very little effect on the posterior estimates of the mean coefficients of the remaining covariates (Table 9).

Table 9 : Posterior estimates (mean, standard deviation (SD), and quantiles) for the Parametric space- time regression model for dog bites (with months excluded from covariates)

	mean	Sd	0.025quantile	0.5quantile	0.975quantile
(Intercept)	-0.219	0.034	-0.286	-0.219	-0.152
Human rabies	0.026	0.014	-0.002	0.027	0.054
Vacc. cov.	0.570	0.171	0.227	0.572	0.900
Dog rabies	0.032	0.011	0.009	0.032	0.054

SOURCE: Estimated from routinely reported monthly data from VSD and GHS together with projections from Ghana Population and Housing Census, GSS 2010, 2021

Exponentiating the estimated mean coefficients in table 9 produced posterior estimates of the relative risk with the corresponding credibility intervals shown in table 10.

Table 10: Posterior estimates (mean RR, standard deviation (SD), and quantiles) for the parametric space-time regression model for dog bites (with months excluded from covariates), 2015-2021

	Mean RR	Sd	0.025quantile	0.5quantile	0.975quantile
(Intercept)	0.803	1.035	0.751	0.803	0.859
Human rabies	1.026	1.014	0.998	1.027	1.055
Vacc. cov.	1.768	1.186	1.255	1.772	2.460
Dog rabies	1.033	1.011	1.009	1.033	1.055

SOURCE: Estimated from routinely reported monthly data from VSD and GHS together with projections from Ghana Population and Housing Census, GSS 2010, 2021

Dog bites were spatiotemporally associated with dog vaccination coverage (RR: 1.77; 95% Credible Interval:1.26-2.46) but much less significantly so with dog rabies (RR:1.03; 95% Credible Interval :1.01-1.06) and human rabies cases (RR: 1.03; 95% Credible Interval: 1.00-1.06).

Responses from Veterinary Officers who were interviewed as key informants in the KIIs suggested that dog vaccinations were mostly reactionary responses to reported cases of dog bites or dog rabies . The following direct quotes from veterinary officers who were describing their experiences with dog vaccinations were typically suggestive:

"……..About a month ago there was a positive rabies case in a human being and the case was coming from Community X, so afterwards the Assemblyman decided that okay, we should try and do mass vaccination for the animals there" (Interview with MVO0 1)

"…… when people go there (the Hospital) with dog bite by all means they will refer them to us. Yes, they refer to us so that we go back to check. There are stubborn ones they (who) won't vaccinate their dogs. Such stubborn ones when we realize that they have not vaccinated, we will force them to buy the vaccine to vaccinate the dog". (Interview with MVO040)

Veterinary Officers cited unwillingness or genuine inability of pet owners to bear the cost of dog vaccinations (which at the time of the study cost between GHC 15.00- GHC30.00) as a contributory factor to the low patronage of dog vaccination services and hence the reactionary approach. The following direct quote from a Veterinary Officer who lamented on the situation is illustrative:

"when you take your personnel there (to the community), they (dog owners) expect that you are coming to do it for free. Yes, affordability was virtually the main problem. They expect that you are

actually coming to do it for free. Unfortunately, I buy everything. The vaccine I buy" (Interview with MVO0 1).

6.3 Objective 3: Collaboration across medical and veterinary fields of practice

Table 11 and 12 summarize the background characteristics of the 35 key informants who were interviewed at the national, regional and district levels.

Table 11: Distribution of Key Informant Interview (KII) Respondents

Position/Job Title	**National**	**Zone 1**	**Zone 2**	**Zone 3**	**Total**
Head DSD, GHS	1	-	-	-	1
Head of Epidemiology Unit, VSD	1	-	-	-	1
Regional Surveillance/Disease Control Officers, GHS	-	1	1	-	2
Medical Director (Reg/District Hospital)	-	-	-	2	2
Deputy Director (Public Health)	-	1	1	2	4
Regional Veterinary Officers, VSD	-	1	2	2	5
District/Municipal/Metro Health Directors, GHS	-	-	2	4	6
District/Municipal/Metro Veterinary Directors, VSD	-	2	2	3	7
District Disease Control Officer	-	2	-	1	3
District Health Information Officer	-	-	1	3	4
Total	2	7	9	17	35

SOURCE: FIELD WORK, 2021-2022

Table 12 shows the sociodemographic characteristics, relevant professional details and distribution of the 35 respondents who were selected for the key informant interviews.

Table 12: Sociodemographic characteristics of personnel selected for in-depth interviews

Characteristic	Human Health (Medical)	Animal Health (Veterinary)
Number of years in service:		
<2 year	0	1
2-5 years	0	2
>5 years	22	10
TOTAL	**22**	**13**
Sex:		
Male	19	12
Female	3	1
TOTAL	**22**	**13**
Highest Educational Level Attained:		
Certificate/Diploma	2	1
Bachelor's degree	9	7
Master's/Mphil degree	11	5
TOTAL	**22**	**13**
Staff category		
Doctors (Medical/Veterinary)	9	9
Public Health Nurses	2	-
Disease Surveillance/Control Officers	7	-
Health Information Officers	4	-
Animal Health Officers	-	4
TOTAL	**22**	**13**
Position		
National Head (DSD/Epid. Unit)	1	1
DDPH/RVO	4	5
RSO	2	-
DDHS/DVO	6	7
DDCO/DHIO	7	-
Medical Director	2	-

Characteristic	Human Health (Medical)	Animal Health (Veterinary)
TOTAL	**22**	**13**
Level		
National	1	1
Regional	7	4
District	12	8
Facility	2	-
TOTAL	**22**	**13**
Zone		
Zone 1 (Northern Savanna)	4	3
Zone 2 (Forest Belt)	5	4
Zone 3 (Coastal Belt)	13	6
TOTAL	**22**	**13**

SOURCE: FIELD WORK, 2021-2022

Existing Mechanism for collaboration

Generally, dog bite victims report to either a veterinary clinic or a healthcare facility for management. In the case of a victim reporting to a veterinary clinic, veterinary personnel often take a history and other relevant information on the dog (e.g., age and sex of the dog, vaccination status of the dog, ownership of the dog, owner of the dog, behaviour of the dog, whereabouts of the dog etc) as well as circumstances of the bite including when the bite occurred, location of the incident, whether or not the bite was provoked, other victims including animals bitten by the offending dog. The human victim is often referred to a healthcare facility for the appropriate medical care. Where the dog is still alive and appears healthy, the owner is asked to produce the offending dog and all other animals he owns which are suspected to have been exposed. The suspect dog or animal is quarantined for a period of 10-14 days. If the dog or suspect animal is found to exhibit abnormal behaviour or signs suggestive of rabies, the dog or animal is euthanised and the brain removed, kept on ice and transported to the veterinary laboratory for testing using Polymerase Chain Reaction (PCR), direct Fluorescent Antibody Test

(dFAT) or Seller's Staining Test (SST). The result is often shared with the clinician at the healthcare, if requested, to guide management of the victim or exposed contacts. In instances where the offending dog has been killed and buried by household or community members, but a strong suspicion of rabies is held, the carcass may be exhumed and tested for rabies. Exposure risk assessment of those who handled the carcass prior to burial is done in collaboration with healthcare professionals to guide management of contacts which may include administration of rabies vaccine with or without anti-rabies immunoglobulins as Post-Exposure Prophylaxis (PEP).

In the case of a dog bite victim who reports to a healthcare facility for medical treatment, history is taken by the clinician. This often includes date and time of bite, the anatomical site of the bite, the circumstances of the bite (provoked or unprovoked), ownership status of the dog (stray or owned), the location of the event, the vaccination status of the dog (with documented evidence), and the state of the dog (i.e., alive or dead, any strange behaviour noticed). The patient is examined clinically and the site of bite assessed but most often the injury is not categorised using the WHO guidelines for dog bite management. [1,97]

Post-exposure treatment commences with washing the site with soap and copious amount of water for about 15 minutes. An antiseptic such as iodine solution is applied. Antibiotics are often prescribed together with tetanus toxin (TT). Most clinicians will usually commence administration of rabies vaccine with or without anti-rabies immunoglobulin ahead of notifying veterinarians of the bite if they perceive the need to do so. No available national treatment guideline or policy explicitly mandates them to notify the veterinarians of dog bite cases even though that is recommended by WHO for One Health collaboration. [98]

Generally, informants from the Animal Health and Human Health sectors alluded to some form of collaboration between the two sides in respect of case detection, reporting and response to human cases of rabies. Suspected cases of human rabies in health facilities often get reported along the routine reporting lines for reporting immediately-reportable conditions or events within Ghana Health Service. This starts from the facility through the district/municipal/metropolitan level to the regional and then to the national level as stated in the IDSR technical guidelines.

In addition, the veterinary professionals at the Veterinary Services Department or Office are notified by the clinical team or the public health team at any of these levels for the necessary response to the suspected case of human rabies.

In the words of a Veterinary Officer at the regional level:

" Last year the DDHS from District A called me to report a case. He even sent me pictures of the case……. and I think one also happened at the Teaching Hospital before the COVID (COVID-

19 Pandemic). That one too we were notified. We went to (visit) the family. So, in most cases we are notified, but I can't say all." (Interview with RVO04)

In the words of a Veterinary Officer at the district level:

"So, whenever there is a rabies case, that means the case has been confirmed either through clinical signs which presented to the clinicians, I'm fortunate that I'm always being informed, when it comes to rabies cases through phone calls but they are not through written documents. Through phone calls I'm informed that this is the case at hand, that there is a suspected rabies case and then with that, my involvement is to help locate the carrier or the dog that is in question which is able to bite or transmit the disease to the human. And so, we do that by, contact tracing or doing, asking the people involved or the people around to be able to identify the, the said dog. So that is what we do in terms of the collaboration. Whenever there is a case they always, they always contact me through phone calls" (Interview with DVO0102)

Another area where collaboration is common is the laboratory confirmation of human rabies either antemortem or post-mortem. The veterinarians are often involved in sample-taking, transport and confirmation of the samples. The major veterinary laboratories used for PCR tests are the NMIMR in Accra and Kumasi Centre for Collaborative Research in Tropical Medicine (KCCR) in Kumasi. In addition, the Pong- Tamale Veterinary College also helps with laboratory confirmation of cases seen in the northern belt.

In the words of a senior veterinary officer at the regional level:

"Mostly the doctors will certainly call me, I know all the cases the doctors call me. I think there is even one of my own staff that the doctor suspected to be a rabies case so I had to go there and we took all the samples including all the fluids, the spinal cord, and so on and we sent it into the laboratory as well as the veterinary laboratory." (Interview with RVO06)

In the words of a senior officer at a regional level:

"When we suspect a case (Human rabies) we alert the Veterinary Service within the various districts. When they are alerted, we come together and the samples are confirmed by the Veterinary Service close to where the district is. If the region is not able to confirm then they bring the sample to Accra to have the case confirmed. So, it is the district where it is confirmed, they notify them of the case and I think it is their regional office that tells them where the sample should go for confirmation. So, this is what essentially, we do and then when it is confirmed, the follow-up steps of tracing of dogs takes place and they work together to make sure this is done." (Interview with RHO03)

In the words of a senior veterinary officer interviewed:

"We in the Veterinary Service have a world class facility for detecting rabies through PCR. At times the human specimens are brought to our place for rabies confirmation." (Interview with RVO07)

However, the general picture appears a bit different for a case of dog bite victim reporting to a health facility. Collaboration with the veterinary professionals is often not seen as much. Whilst the veterinarians often refer their human victims to the health facilities for treatment, little is seen vice versa regarding notification of the vets when a case of dog bite reports to a health facility.
There seem to be conflicts in the approach to the management of dog bites between the two professionals as seen in the words of some of the veterinary officers.
In the words of a regional veterinary officer:

"Yes, you see if there are bites that are clearly from a rabid dog, we try our best to get the dog killed and then the head is sent to our main lab in Accra……. But that, as I said, sometimes, there have been conflicts between vets and the medical professionals because, immediately a dog bite was (is) reported, the medical professional was (is seen) recommending the post-exposure (prophylaxis) to be given immediately. Meanwhile, such cases, they (the pet owners) might be the people who religiously vaccinate their pets. So, they will come complaining. Because of that, then there is no reason for vaccinating their dogs...." (Interview with RVO03)

In the words of a senior officer at the district level who was expressing his view on working together with the vets in the management of dog bite:

"You see I don't know, this thing you are talking about veterinarians; Where are the veterinarians at all? Where are they? Is it that I should be going to the community and be looking for where the veterinarians are? where are they? I told you there is no channel for communication. I don't know what you really want to hear?"(Interview with MHD0301)

Corroborating this point at the regional level, a senior officer said:

"The area where it has been a challenge is the collaboration between the two organisations as far as the management of the condition (dog bite) when it occurs. i.e. our reporting to them that a case has occurred and they taking the necessary steps to investigate. Even this investigation we should have done it together but it is usually not done. So either they do it alone or sometimes it is not done at all and if the client does not report early to start the inoculations and unfortunately develops rabies that'll be a sad situation. The responsibility more lies with the vets to ensure that we have least animals in the community who are not dangerous to the population. I think, for that most of the responsibility lies with the vets and the collaboration is not quite optimal. There have also been instances where the vets are seen in action but encountered resistance from the community.

The aspect of community engagement and other things have to be looked at. So it is a whole barrage of things but as I said the communication and the responses should have been coordinated and be done together. More often than not this does not happen. So you hear nothing again about the rabid dog or if investigation is done, we do not get feedback on the results and other things. Unless you have a close personal relationship with the vet officer or that thing of a sort otherwise you don't get feedback. This is quite a challenge". (Interview with RHO05)

In the words of a senior officer at the district level from the same region:

"Okay so with collaboration with the veterinary service, we don't have an effective collaboration when it comes to rabies. What I can say is that they are just doing their activities and we are also doing our activities and we don't have any collaboration. I think the only time we worked together is about four years back when the District Health Director received information that there are a lot of rabies cases from the veterinarians so the Director asked us to do investigations by collaborating with the Veterinary Service and then also for them to give us data on the cases for us to also learn from the investigations to the communities to follow up on this cases and in fact the guy who reported couldn't give us the data, he couldn't produce any data. Is like when they report the general dog bite data to them, they just deal with it but not keeping it, I don't know how they treat that data. Since they couldn't produce any data, that investigation couldn't come on. Apart from that there is nothing we do with veterinary." *(Interview with DHO0501)*

A senior officer at the district level from another region had this to say:

"……..and the veterinary services too there is no collaboration it is almost not in existence because they virtually don't ask us and tell us about their rabies status or what's happening, if somebody has come with, dog bite or anything. It's not there." (Interview with MHO10201)

In the words of a senior officer from the VSD:

"Of course (the collaboration is) not very big because some of the doctors do not know this. So when people report with dog bite cases sometimes, they don't refer to us. When they go to the hospital, they try to manage it on their own and sometimes it ends fatal because they ignore the offending dog. Maybe that dog didn't bite only the person that came but because they take it to treat that person, the others you will not even hear of it because there haven't been any investigations. So you will see that people will die afterwards. Sometimes, even the victim who went there they don't handle it well because of concept. Some doctors think that if the person says I was scratched it means it's not dangerous. Sometimes it's not a scratch, it's even a bite just that the dog didn't get a full grip so you will see that it will just scratch the place, and they will say no it's just a scratch. …….. I

have personally seen cases where doctors or medical staffs have taken it lightly and people have died. I've investigated all those things, but when you go, they will say when the person came, he said it was not a bite it was scratch and, so that is the misunderstanding and I have had the opportunity to talk to medical staffs to educate them on rabies severally." (Interview with RVO02)

The collaboration is even worse when the bite is from a stray dog. Medical professionals just go ahead with administration of the PEP without notifying the veterinarians.

In the words of a medical superintendent at a district hospital

"Once somebody reports of a dog bite, we will want to be sure if really there was a dog bite, a scratch or something like that then we take up the protocol to start. The protocol is such that we will wash the site, we will dry the site. If we are thinking of some infections maybe because of the situation you can start with your antibiotics to take care of other bacterial infections then you start with your anti-rabies. In fact, previously we used to examine the vaccination cards of the dogs from the owners but I understand in Komfo Anokye (Teaching Hospital) they did a research there to realize that most of the dog owners were getting the vaccination cards even if the dogs were not vaccinated. Maybe for the fear of the fact that they are going to be prosecuted because their dog bit somebody or something like that, so most of them were getting the vaccination cards. Funny enough somebody told me that in Ghana even if you request for somebody's death certificate that person can show you his death certificate so it's easy coming out with documents and cards and all those things. So in Komfo Anokye (Teaching Hospital) they realized that even though some of the dogs were vaccinated the victims were dying so I think the conclusion was that when there is a real dog bite that you can ascertain that there is a dog bite, it is better to start with the anti-rabies by testing the person whether they can take it then you start with it." (Interview with MD10201)

Existing Mechanism for data-sharing and harmonization

Analyses of the responses to questions focusing on mechanism of sharing of routine data on dog bites, dog vaccination, dog and human rabies suggest that little or no formal arrangement or mechanism exists for sharing routine dog bite and dog vaccination data across both sectors. Some formal arrangement however, exists particularly for reporting suspected or confirmed cases of human rabies across the two sectors. However, this mostly exists at the regional and district levels and rarely at the facility level. Data sharing occurs on ad hoc basis mostly in response to a reported case of rabies in an area and less so in the case of dog bites.

Thus, for example, on routine data sharing of dog bite and rabies data at regional level with Veterinary Services Department (VSD) the response below from an officer in the health service is typical:

"*……...For the data that we collect for our general surveillance data, we do not particularly share it with them (VSD). There is no means that I know of, but when we report some zoonotic diseases, or, in particular rabies we do inform the district and we do inform the veterinary officers in that district about that case. In that aspect we share but for general cases, we do not share. Those that we feel it concerns them like zoonotic diseases, we do share the data with them" (Interview with RHO03)*

In the words of a senior veterinary officer at the regional level:

"Sometimes they request (our data). i.e. the Metro Health Director, she sometimes requests for these things, that the Vet should come and present their activities. They invite them. Sometimes they bring the letter to me before I send it to the vet officer, you see. So we are not being compelled to do anything, it is based on request." (Interview with RVO04)

Another way data sharing occurs in some districts and regions is through presentations at annual performance review meetings where one sector, often the health sector, invites the vets to participate.

"……..at the just ended annual review of the Ghana Health Service… I was there... It was during one of their presentations that I got to know that two people died of rabies last year. In fact, the Deputy Director-General of Ghana Health Service was there. Yes, two of them from the top were there. So I raised my hand and then, I told them that mine wasn't a question…. because I don't see why in this present time people should die of rabies." (Interview with RVO03)

At the national level however, some level of data-sharing seems to take place through an informal arrangement in which the head of the epidemiology unit of VSD has been given some access to disease surveillance data platforms of Ghana Health Service e.g., SORMAS and DHIMS whilst the Director of Public Health has also been given some access to disease surveillance data platform of the VSD. According to one of the officers at the national level, this arrangement was purely informal and there is no policy to that effect.

In the words of a senior veterinary officer at VSD:

"We are supposed to share all the data between Ghana Health Service and VSD especially the 6 priority diseases we have agreed to share i.e. rabies, anthrax, avian influenza, bovine TB, trypanosomiasis, and AVHF. We are supposed to share this data weekly, although GHS in terms of weekly reporting they are doing far better than VSD. ……I have access to the weekly reporting of GHS through SORMAS. All these things I am talking about are at the National level." (Interview with RVO07)

The officer however admitted that this informal arrangement was very recent and not backed by any policy. In his own words, he had this to say in response to a question enquiring when and how this arrangement started:

"That was during COVID-19 era. At least, between GHS and VSD, occasionally we share data but it is not constant. There is no formal/written agreement to that effect. There must be a policy to that effect. Yes, (for) example when there is Avian Influenza, I share that data with the Director Public Health of GHS but I can't say that I share all the data with him. We share some of those data."

(Interview with RVO07)

6.4 Objective 4: Knowledge, perception and practices of frontline health workers in the Human Health and the Animal Health sectors on One Health collaboration

Sociodemographic characteristics of respondents whose knowledge, perceptions and practices were assessed

A total of 468 respondents were interviewed and this sample was made up 421 medical professionals constituting the Human Health (HH) group and 47 veterinary professionals constituting the Animal Health(AH) group. The sociodemographic characteristics of the respondents are as shown in table 13:

Table 13: Sociodemographic Characteristics of respondents in the survey

	Human Health (Medical) Professionals (n_1= 421)		**Animal Health (Veterinary) Professionals (n_2= 47)**	
Characteristics of respondents	Number /Value	(%)	Number /Value	(%)
Gender				
Male	191	45.4	24	51.1
Female	230	54.6	23	48.9
Total	**421**	**100.0**	**47**	**100.0**
Age in completed years				
20-29	136	32.3	10	21.3
30-39	184	43.7	24	51.0
40-49	43	10.2	6	12.8
50-59	10	2.4	3	6.4
60-69	1	0.2	0	0.0
Not stated	47	11.2	4	8.5
Total	**421**	**100.0**	**47**	**100.0**
Minimum Age	20	-	24	-
Median Age	31	-	32	-
Interquartile Range (IQR)	8	-	8	-
Maximum Age	63	-	58	-
Highest Educational Level attained				

Characteristics of respondents	Human Health (Medical) Professionals (n_1= 421)		Animal Health (Veterinary) Professionals (n_2= 47)	
	Number /Value	(%)	Number /Value	(%)
Postgraduate	25	5.9	1	2.1
Bachelor's degree	132	31.3	7	14.9
Higher National Diploma (HND)	2	0.5	0	0.0
Diploma	168	39.9	14	29.8
Certificate	90	21.4	24	51.1
Not stated	4	1.0	1	2.1
Total	**421**	**100.0**	**47**	**100.0**
Staff Cadre				
(Human Health)				
Medical Doctor	20	4.7		
Physician Assistant	49	11.6		
Nurse	302	71.7		
Pharmacist	15	3.6		
Pharmacy Technician	2	0.5		
Dispensary Assistant	2	0.5		
Disease Control Officer	12	2.9		
Other Allied Health Professional	19	4.5		
Total	**421**	**100.0**		
(Animal Health)				
Veterinary Doctor			4	8.5
Veterinary Nurse			1	2.1
Veterinary Technical Officer			27	57.5
Animal Health Officer			15	31.9
Total			**47**	**100.0**
Number of years of practice				
1-2	127	30.2	4	8.5
3-4	64	15.2	15	31.9
5 and above	197	46.8	22	46.8
Not stated	33	7.8	6	12.8
Total	**421**	**100.0**	**47**	**100.0**
Minimum years of practice	1.0	-	1.0	-
Median years of practice	5.0	-	5.0	-
Interquartile Range (IQR)	8.0	-	7.0	-
Maximum years of practice	37.0	-	34.0	-
Minimum years of practice	1.0	-	1.0	-
Place of Work (Region)				
Ashanti	77	18.3	6	12.8
Bono	56	13.3	11	23.4
Central	62	14.7	7	14.9
Northern	85	20.2	12	25.5
Savannah	78	18.5	7	14.9
Western	63	15.0	4	8.5
Total	**421**	**100.0**	**47**	**100.0**
Facility Type				

Characteristics of respondents	Human Health (Medical) Professionals (n_1= 421)		Animal Health (Veterinary) Professionals (n_2= 47)	
	Number /Value	(%)	Number /Value	(%)
Hospital	225	53.4	N/A	N/A
Polyclinic	43	10.2	N/A	N/A
Clinic	15	3.6	N/A	N/A
Health Centre	138	32.8	N/A	N/A
Veterinary Clinic/VSD	N/A	N/A	47	100.0
Total	**421**	**100.0**	**47**	**100.0**
Facility Ownership				
Public (Government-owned)	316	75.0	47	100.0
Faith-Based (CHAG)	97	23.0	0	0.0
Quasi-Government	8	2.0	0	0.0
Total	**421**	**100.0**	**47**	**100.0**

N/A=Not Applicable VSD=Veterinary Services Directorate CHAG=Christian Health Association of Ghana

SOURCE: FIELD WORK,2021-2022

In the HH group, respondents were predominantly female (54.6%), and their median age was 31 years (IQR=8 years) whilst in the AH group, respondents were predominantly males (51.1%) with a median age of 32 years (IQR=8 years). In terms of highest educational qualification attained, the predominant qualification among the HH group was diploma (39.9%) whilst in the AH group the predominant qualification was certificate (51.1%). Respondents in the HH group were predominantly nurses (71.7%) whilst in the AH group, respondents were predominantly Veterinary Technical Officers (57.5%). Respondents in both groups had practised their profession between 1 to 37 years with a median professional experience of 5 years (IQR=8 years for HH and 7 years for AH). Most (75% for HH and 100% for AH) respondents were from government-owned facilities. The distribution of respondents in terms of location, facility type and ownership is as shown in table 13**.**

Respondents' most recent experience with management of dog bite and rabies cases in their facilities

Respondents were asked to indicate when they last saw a case of i) dog bite and ii) rabies in their facilities and whether or not they were involved in the management. Their responses were as shown in table 14.

Table 14: Respondents' most recent experience with management of dog bite and rabies cases in their facilities

Item	Human Health (Medical) Professionals (n_1= 421)		Animal Health (Veterinary) Professionals (n_2= 47)	
	Number	**%**	**Number**	**%**
Last time respondent saw a case of dog bite in their facility				
Less than 1 week ago	27	6.4	12	25.5
1-3 weeks ago	52	12.4	5	10.6
1-3 months ago	73	17.3	11	23.4
4-6 months ago	42	10.0	5	10.6
About 1 year ago	37	8.8	1	2.1
More than 1 year ago	73	17.3	5	10.6
Never	113	26.8	8	17.2
Not stated	4	1.0	0	0.0
Total	**421**	**100.0**	**47**	**100.0**
Respondent's involvement in management of the case of dog bite				
Yes	206	48.9	29	61.7
No	92	21.9	11	23.4
Not Applicable	112	26.6	6	12.8
Not stated	11	2.6	1	2.1
Total	**421**	**100.0**	**47**	**100.0**
Last time respondent saw a case of rabies in their facility				
Less than 1 week ago	8	1.9	5	10.7
1-3 weeks ago	9	2.1	1	2.1
1-3 months ago	14	3.3	7	14.9
4-6 months ago	18	4.3	4	8.5
About 1 year ago	29	7.0	7	14.9
More than 1 year ago	73	17.3	11	23.4
Never	267	63.4	12	25.5
Not stated	3	0.7	0.0	0.0
Total	**421**	**100.0**	**47**	**100.0**
Respondent's involvement in management of the case of rabies seen				
Yes	93	22.1	26	55.3
No	57	13.5	9	19.2
Not Applicable	267	63.4	12	25.5
Not stated	4	1.0	0.0	0.0
Total	**421**	**100.0**	**47**	**100.0**

SOURCE: FIELD WORK, 2021-2022

More than half of the respondents in both the HH group (54.9%) and the AH group (76.6%) had seen a case of dog bite in their facility in the one-year period preceding the survey. However, about 27% and 17% of respondents in the HH and AH groups respectively reported they had never seen a case of dog bite in their facilities.

With regard to rabies, whereas 51.1% of the respondents from the AH group had seen a case of rabies (dog rabies) in their facilities within 1-year period preceding the survey, 18.6% from the HH group had seen a case of human rabies in the 1-year period preceding the survey.

In terms of management of cases, more than half of respondents who had seen dog bite cases were involved in their management. (i.e. 70.0% of those from HH and 72.5% of those from AH). Similarly, more than half of the respondents who had seen rabies cases were also involved in their management (i.e. 62.0% of those from HH and 74.3% of those from AH).

Respondents' knowledge and perception of the role of veterinarians in dog bite management and rabies prevention.

To determine respondents' knowledge and perception about rabies prevention and the need for collaboration across both sectors for effective implementation of One Health, respondents were asked basic questions about rabies and the role of veterinarians/veterinary professionals in the management of dog bite and rabies prevention. Table 15 summarizes the responses from the participants.

Table 15:Respondents' knowledge about rabies and the role of veterinarians in the management of dog bite cases

Item	**Human Health (Medical) Professionals (n_1= 421)**		**Animal Health (Veterinary) Professionals (n_2= 47)**	
	Number	**%**	**Number**	**%**
Is rabies curable?				
Yes	163	38.7	3	6.4
No	186	44.2	42	89.4
Don't Know	46	10.9	1	2.1
Not answered	26	6.2	1	2.1
Total	**421**	**100.0**	**47**	**100.1**
Is rabies preventable?				
Yes	396	94.1	46	97.9
No	3	0.7	0	0.0
Don't Know	10	2.4	0	0.0
No response	12	2.8	1	2.1
Total	**421**	**100.0**	**47**	**100.0**
Do veterinarians /veterinary professionals have a role to play in the management of dog bites?				

Item	Human Health (Medical) Professionals (n_1= 421)		Animal Health (Veterinary) Professionals (n_2= 47)	
	Number	**%**	**Number**	**%**
Yes	380	90.3	46	97.9
No	21	5.0	1	2.1
Don't Know	19	4.5	0	0
No response	1	0.2	0	0
Total	**421**	**100.0**	**47**	**100.0**

SOURCE: FIELD WORK, 2021-2022

Of the 421 respondents from HH, 186 (44%) knew that rabies was not curable whilst 209 (49.6%) did not know this basic fact. Twenty-six (6.2%) of the respondents from HH gave no response. On the other hand, among the 47 respondents from the AH group, 42(89.4%) knew rabies was not curable whilst 4(8.5%) did not. One person gave no response.

With respect to veterinarians' role in the management of dog bites, over 90 % of respondents from both groups knew that they (veterinarians/veterinary professionals) had a role to play in this. However, 40 (9.5%) respondents from the HH group did not know this whilst 1 (2.1%) person from the AH group thought they had no role to play.

When respondents were asked to select which roles veterinarians had to play from a list of 9 roles, the responses obtained were as shown in table 15: 'Quarantining suspicious dogs and conducting investigations to rule out rabies', 'Vaccinations of dogs, cats and other reservoirs against rabies', and 'public education on responsible pet ownership' were the veterinarian roles mostly identified by respondents from both groups.

Table 16: Respondents' knowledge about role of veterinarians in the management of dog bite cases and rabies prevention

Item	Role	Human Health (Medical) Professionals (n_1= 421)		Animal Health (Veterinary) Professionals (n_2= 47)	
		Number selecting role	**%***	**Number selecting role**	**%***
1	Quarantining suspicious dogs and conducting lab investigations to determine rabies status	343	81.5	45	95.7
2	Administration of rabies PEP to human victims	164	39.0	13	27.7
3	Vaccinations of dogs, cats and other reservoirs against rabies	345	82.0	43	91.5
4	Rabies outbreak investigations and response	292	69.4	33	70.2
5	Referral of dog bite cases to healthcare facilities for medical attention	298	70.8	41	87.2
6	Assisting clinicians to do risk assessment of dog bites for choice of appropriate	256	60.8	32	68.1

Item	Role	Human Health (Medical) Professionals (n_1= 421)		Animal Health (Veterinary) Professionals (n_2= 47)	
		Number selecting role	%*	Number selecting role	%*
	interventions to implement				
7	Public education on responsible pet ownership	329	78.2	40	85.1
8	Vaccination of high-risk humans against rabies	164	39.0	14	29.8
9	Sharing rabies related data with medical professionals and vice versa	286	67.9	34	72.3

**Multiple responses allowed*

SOURCE: FIELD WORK, 2021-2022

Respondents' perception of each other's role and their assessment of the level of collaboration with each other in the performance of these roles

Respondents were asked to rate on a scale of 1 to 10 (where 1 means 'no collaboration' and 10 means 'maximum collaboration') the level of collaboration that exists between them and their counterparts in carrying out a list of activities for prevention and control of rabies. Median scores obtained together with their corresponding interquartile ranges were as shown on table 17.

Table 17: Respondents' ratings of the level of collaboration between the two sectors in the performance of rabies related activities

No.	Activity	HH Professionals			AH Professionals			*Kruskal-Wallis H, (df=1)	p-value
		n_1	median	IQR	n_2	median	IQR		
1	Quarantining suspicious dogs and conducting lab investigations to determine their rabies status	409	2.0	5.0	45	7.0	4.0	39.688	p<0.0001
2	Administration of PEP to human victims	403	5.0	8.0	38	6.5	8.0	0.475	P=0.4907
3	Vaccinations of dogs, cats and other reservoirs against rabies	406	4.0	7.0	45	9.0	3.0	28.934	p<0.0001
4	Rabies outbreak investigations and response	402	3.0	6.0	44	7.0	4.5	27.882	p<0.0001
5	Referral of dog bite cases to healthcare facilities for medical attention	404	7.0	8.0	45	9.0	2.0	15.568	P<0.0001
6	Assisting clinicians to do risk assessment of dog bites for choice of appropriate interventions to implement	398	3.0	6.0	43	6.0	5.0	17.285	P<0.0001
7	Public education on responsible	407	4.0	6.0	45	8.0	4.0	37.483	P<0.0001

No.	Activity	HH Professionals			AH Professionals				
		n_1	median	IQR	n_2	median	IQR	*Kruskal-Wallis H, (df=1)	p-value
	pet ownership								
8	Vaccination of high-risk humans against rabies	406	2.0	4.0	41	3.0	9.0	3.849	P<0.05
9	Sharing rabies related data with medical professionals and vice versa	376	2.0	4.0	44	5.5	5.0	26.04	P<0.0001
10	Timely notification of veterinarians by health professionals whenever a case of dog bite is first seen at a health facility	394	2.0	6.0	44	7.0	5.5	18.803	P<0.0001

*Krukal-Wallis test for 2 groups=Mann Whitney/Wilconsin two sample test; df=degrees of freedom

SOURCE: FIELD WORK, 2021-2022

The median ratings were generally higher among the AH group compared to the HH group. When Kruskal-Wallis test was conducted to assess the differences in ratings between the two groups using a significance level, $\alpha=0.05$, and the analysis revealed significant differences (p-value<0.05) in all except one pair of ratings between the two groups. This shows there was little or no collaboration between the two groups in the performance of 9 out of 10 listed activities. In the performance of activity no. 2 where there was no significant difference between the two ratings, the level of collaboration as suggested by the magnitude of the median ratings was 5.0-6.5 (on a scale of 1-10). The combined median rating for this activity was 5.0 (IQR=8) implying some collaboration but still suboptimal.

These findings which suggest little or no collaboration on most of the activities tie in well with the responses from the key informant interviews under section 6.2 (Objective 3).

Respondents' Knowledge and Perception of One Health collaboration

In order to assess respondents' knowledge and perception about collaboration under One Health, specific questions were posed regarding their awareness of the initiative, how often they held joint activities such as meetings, and how they perceived cross-data sharing with each other and the importance of having a joint surveillance system for dog bite. Their responses were as shown in table 18.

Table 18: Respondents' knowledge and perception of One Health collaboration

Item	Role	Human Health (Medical) Professionals (n_1= 421)		Animal Health (Veterinary) Professionals (n_2= 47)	
		Number	**%**	**Number**	**%**
1	**Have you heard of One Health?**				
	Yes	43	10.2	25	53.2
	No	372	88.4	22	46.8
	No response	6	1.4	0	0.0
	Total	**421**	**100.0**	**47**	**100.0**
2	**How often do you hold joint meetings with your colleagues from the other sector (Human Health/Animal Health)?**				
	Always	2	0.5	2	4.3
	Sometimes	105	24.9	23	48.9
	Never	306	72.7	22	46.8
	No response	8	1.9	0	0.0
	Total	**421**	**100.0**	**47**	**100.0**
3	**How important is data-sharing between the human health sector and the animal health sector**?				
	Extremely important	175	41.6	29	61.7
	Very important	222	52.7	17	36.2
	Somewhat important	11	2.6	0	0.0
	A little important	1	0.2	0	0.0
	Not important	2	0.5	0	0.0
	No response	10	2.4	1	2.1
	Total	**421**	**100.0**	**47**	**100.0**
4	**Would you recommend a joint system of reporting dog bite and rabies cases between Human Health and Animal Health?**				
	Yes	394	93.6	44	93.6
	No	17	4.0	2	4.3
	No response	10	2.4	1	2.1
	Total	**421**	**100.0**	**47**	**100.0**
5	**How satisfied are you with the level of collaboration that exists between vets and medical professionals in rabies control and prevention?**				
	Extremely satisfied	7	1.7	5	10.6
	Very satisfied	49	11.6	6	12.8
	Somewhat satisfied	84	19.9	13	27.7
	A little satisfied	82	19.5	13	27.7
	Not satisfied	184	43.7	9	19.1
	No response	15	3.6	1	2.1
	Total	**421**	**100.0**	**47**	**100.0**

SOURCE: FIELD WORK, 2021-2022

Almost 90 % of respondents from the Human Health group and close to 50% from the Animal Health group had not heard about One Health. Over 90% of respondents from both groups thought cross-data

sharing between Animal Health and Human Health sectors was very, if not extremely, important. About 60% of respondents from the HH group expressed little or no satisfaction with the level of collaboration existing between the two sectors with respect to rabies prevention and control. Among the Animal Health group 46.8 % expressed little or no satisfaction with the level of existing collaboration between the two sectors. Same proportion (93.6%) of respondents from each group would recommend a joint reporting system for dog bites and rabies cases at both the facility and district levels.

The recognition of data-sharing as important across both sectors and the recommendation of a joint reporting system for rabies and dog bites were corroborated by officers from both sectors who were interviewed as key informants.

The following response from a Senior officer from GHS at the regional level when asked about his opinion on a joint system (common reporting form) for reporting dog bites and rabies cases is typical:

If you ask me my opinion on it, I think both institutions can use the same form and each institution can also focus on their data, I don't think it will bring any problem. Because if we have one standardized form it will strengthen the collaboration and we know we are collecting the same type of information. Of course, there are areas where we will need information from them and areas where they will need information from us. So, if we are using one common form it will compel each of these institutions to work together. I will recommend there is that common form. (Interview with RHO05)

The direct quote below from a Municipal Veterinary Officer on the subject of data-sharing further buttresses the point:

" ……the collaboration we were talking about is that there should be a means by which the data which is being produced from Veterinary Services, that from the Environmental Health, and that from the Ministry of Health should be linked so that if I want information on dog bite cases, it should be easier for me to receive and that same information should be available. We shouldn't be having disconnected information, like different data on the same subject, that is dog bite or rabies cases. So it should be shared or linked. That means that all health facilities reporting rabies cases should be able to see all those cases that we can all work hand in hand to control if there is any outbreak of rabies". (Interview with DVO0102)

6.5 Objective 5: Barriers to and enablers of collaboration for implementation of a One Health approach

The diagram below summarizes the barriers and the enablers of data sharing and collaboration for implementation of a One Health approach for rabies elimination (See figure 23).

Barriers to collaboration under One Health

Officers from both sectors acknowledged the need for collaboration and the significant benefits to be derived therefrom some of which include a strong surveillance system, cross-sharing of resources between the VSD and Ghana Health Service for improved service outcomes, improved preparedness, detection and response to outbreaks among others. However, some real barriers as well as those perceived were identified. These include lack of clear policy on One Health which is vital to fostering collaboration, lack of awareness of the One Health approach especially among health workers, inadequate veterinary workforce and infrastructure, inadequate funding and resources to push forward the One Health agenda, and lack of motivation among staff of the two sectors to work together towards a common goal.

Figure 23: Enablers and Barriers to data-sharing and One Health collaboration

SOURCE: FIELD WORK, 2021-2022

Responding to a question on challenges in implementation of One Health in Ghana, a senior officer from GHS said:

The lack of a policy is the main challenge although, like most public health activities, funding may likely become a challenge should the policy implementation not be supported with adequate funding. (Interview with RHO07)

A senior officer from the VSD identified lack of awareness even among the policy elites as the main challenge needed to be addressed. In the words of the senior officer:

…….I will say it is the lack of awareness of it (One Health) by the policy elites. I am talking about the presidency, cabinet and at the ministerial level. Basically, if they know about these things and can see the benefits, they will provide the resources to make it happen. (Interview with RVO07)

In the words of a senior officer at the regional level on the question of potential implementation barriers:

……like I told you how many districts will have veterinary officers and even if they exist how many are they? Can they be joining these committees and teams and still be working? So it's human resource. Do they have what it takes to respond to some of these outbreaks and some of these threats from animals etc. So those are the issues but I think it all boils down to resources, personnel and materials (Interview with RHO01)

Barriers to Data sharing and harmonization

Although officers from both sectors acknowledged significant benefits to be derived from cross-data sharing, the lack of policy on data-sharing was the main barrier identified at all levels. Other barriers identified, real or perceived, included lack of a common data-platform, different data-formats being used by each sector, different levels of sophistication in terms of data infrastructure, and potential misinterpretation of each other's data.

In the words of a senior officer from Ghana Health Service:

These have not been established and this is the main challenge. Once there is clarity on the modality for data sharing, I am certain this will work effectively. One good thing is that both agencies acknowledge the need for data sharing. (Interview with RHO07)

In the words of a senior officer from Ghana Health Service at the regional level:

The perceived challenges could be on the policy level as we have not decided on the policy level to include them in our information sharing. Because now that most of the times information are shared electronically, it shouldn't be any difficulty. It's just a matter of including them, and at which level should we include them when it comes to information sharing? Should it be limited to the regional level? Or we go down to the district level, or even down to the facility level, or just Central level. So, that decision to me I think we have not really thought of it as to what extent we should share information, that's what I think could be the main challenge (Interview with RHO03)

On the barriers for data sharing a senior officer from the VSD had this to say:

I think I have already said logistics not just sharing of data but at least and I think it could have also been easier if the Veterinary Services were having their zoonotic data in the cloud. They could have equally shared that with the Ghana Health Service so that they can pull data from here to here and also from there to there. I think as at now some of the veterinary services labs are doing COVID test and that data they are sharing with Ghana Health Service. We could have done that with the main zoonotic diseases that we are battling with such as preventable anthrax etc. so that we could share all those data. ((Interview with RVO06)

A senior officer from GHS at the regional level had this to say on the barriers to data-sharing:

Maybe the other thing that will be a problem is (that) the system that has to be put in place to ensure the transmission of data will add additional responsibilities to whoever will be in charge. We have a system that is the format for our data reporting and so if that system is to be developed, then there should be a discussion at the higher level where the veterinary services can be given access to some of our data repository (like the format) and we monitoring them. (Interview with RHO06)

Enablers of collaboration, data-sharing and harmonization

The existence of a multisectoral Public Health Emergency Management Committee (PHEMC) at the national, regional and district levels, the successful operationalization of the 3rd edition of the Integrated Disease Surveillance and Response (IDSR) technical guidelines built on the One Health approach in the Ghana Health Service and a general agreement among key officials of both agencies on the need to work together, and some form of collaboration already going on between the two agencies are positive pointers to a successful implementation of a One Health policy should it come into force in the near future. In addition, the existence of electronic data platforms such as DHIMS and SORMAS already in use in Ghana Health Service and the EMI software used by VSD for real time

data entry and transmission provide resources that can be leveraged and harmonized to facilitate cross-sectoral data sharing under One Health Approach.

A senior officer from GHS working at the regional level had this to say on the level of collaboration between medical professionals and veterinary professionals in her region.

Okay, alright, here in X region, we work very closely with the veterinary section, because it is One Health. We are all part of the emergency operations set-up in the Region. We are part of the rapid response team depending on the kind of disease outbreak that we get. So, for instance in rabies like this, we are in close collaboration with them. And one of the things that we do often is collaborating with them; that is our health promotion division collaborating with the vet lab so that we get officers; so that when we have slots on the airtime, we are able to go to the radio stations and then educate people on it. Indeed, I would admit that we need to be able to expand our education and also the frequency as well. Because as you will agree with me, when we use mediums like the radio and others yes it gets far, but still some of our rural folks are still left out, and so we will need to employ other ways of education together with the vet lab to be able to tackle them. One thing that stands in our way often, is resources to do this. Resources to able to sustain this kind of (engagement). Even the radio stations even the funding. So sometimes resources come in our way, and of course there are also other competing programmes so you will not be able to get the opportunity to do the sensitization on it as it should. (Interview with RHO02)

On what could facilitate cross data-sharing the officer had this to say:

You know when you (are) looking at a platform to enter data on a particular disease, it doesn't have to be (one) duplicatory and it has to be simple for health workers and Vet officers to be able to do it. I will recommend that we should use what is existing already like the DHIMS, or for instance the SORMAS that we are migrating on to gradually. For now the SORMAS takes care of epidemic prone diseases mainly, and rabies can be there. But on the SORMAS just as laboratory, Public Health laboratory department, are now even given access to enter the data in there or to access data there, they could also give some kind of access to the vet lab to also share and also for them to view what is of interest to them and really that particular one. For that, it is already existing. Health workers know about it; they are already using it, so it becomes largely, affordable and efficient to use, and it will serve the purpose that we are all looking at. (Interview with RHO02)

Grey literature and published national policies and programmes on Rabies Control and One Health Collaboration in Ghana.

Ghana recognizes rabies as a significant public health concern and has been working towards eliminating dog-mediated human rabies within the framework of the One Health approach through various policies (including legislations), programmes, strategies, action plans and guidelines ahead of the finalization, approval and implementation of a more comprehensive One Health policy (in draft at the time of the study). Key among the policies, programs and action plans are the Ghana Rabies Strategic Programme for Elimination (GRSPE) 2015-2030, and the Ghana Rabies Control and Prevention Action Plan (GRCPAP), 2018-2030.[8,84] Both documents provide direction and some details on what ought to be done by Ghana as a country to achieve the 'Zero by 30' goal. Being a requirement in the GRSPE, the GRCPAP was a product of a baseline assessment of Ghana's strengths and weaknesses by multi-disciplinary team of experts. The team used the Stepwise Approach towards Rabies Elimination (SARE) tool to assess the country's strengths and weaknesses in terms of data collection and analysis, rabies prevention and control, laboratory diagnosis, dog population management, information, education and communication, legislation and other cross-cutting issues. The GRCPAP focuses on addressing the weaknesses in these domains whilst leveraging the existing strengths and opportunities. Clear timelines with monitoring indicators have been set for the country over the entire 13-year period. Both the GRSPE and the GRCPAP recognise the importance of One Health collaboration with the various stakeholders. The GRCPAP encourages, to a large extent, joint planning, joint implementation, joint assessments and more importantly data-sharing for meaningful progress towards the set goal.

In terms of providing the legal framework for effective collaboration particularly between the medical professionals and veterinary officers, even in the absence of a One Health policy, the Public Health Act, 2012 (Act 851) makes substantial provision for this collaboration to take place for the control of both communicable and non-communicable diseases.[72] The Act provides for a range of collaborations between medical officers and veterinary officers including educating the public about communicable diseases (especially zoonoses), case detection, case investigations, outbreak investigations, isolation and management of cases including provision of veterinary facilities for treatment of a person or an animal suffering from a disease or detection of the disease, post-mortem examination, vector control, disinfection etc. With the appropriate legislative or executive instruments these provisions in the Act can be leveraged to provide a stronger legal framework for effective collaboration between the two professionals for rabies elimination under One Health.

With respect to providing the enabling governance structures for One Health collaboration to thrive, the Ghana Health Service and Teaching Hospitals Act, 1996 (Act 525) and the Local Governance Act,

2016 (Act 936) recognize, to a large extent, the multidisciplinary, multidimensional and cross-sectoral nature of health issues and make provision for inclusion of members of local government, representatives of relevant departmental agencies, religious and traditional leaders on their Boards, Health Committees and Councils.[80] Also, the Technical Guidelines for Integrated Disease Surveillance and Response in Ghana, 3rd Edition, June 2020 which seeks to improve the early detection and prompt effective response to outbreaks and other diseases, conditions and events of public health importance in Ghana makes intersectoral collaboration central to the composition and operations of the Public Health Emergency Management Committee, National Technical Coordination Committees and the Public Health Emergency Rapid Response Teams at the various levels.[82] Committee and team composition clearly demonstrate the One Health approach. This augurs well for One Health implementation.

Likewise, the National Action Plan for Health Security (NAPHS) and the National Health Policy (Ensuring Healthy Lives for All) Revised Edition of Jan 2020 both adopt the One Health approach in order to achieve better public health outcomes.[81,86] In seeking to address the gaps identified in the 2017 WHO Joint Evaluation Exercise (JEE) of IHR capacities in Ghana, the NAPHS has One Health approach as one of its guiding principles and encourages interdisciplinary, holistic and integrated approach for coordination within and across health sectors for disease surveillance, outbreak investigation and response activities over the 5-year period it covers. In the same vein, the National Health Policy (Revised Edition, Jan 2020 dubbed "Ensuring Healthy Lives for All") seeks to ensure that Ministries, Department and Agencies (MDAs) and other identifiable organizations work within the principles of the Health-in-All Policy and the One-Health Policy frameworks (WHO) to achieve the desired healthy life status of people living in Ghana. Like the NAPHS, the policy seeks to strengthen surveillance and response systems to prevent, detect, investigate, protect against, control and provide a public health response to the spread of diseases resulting from epidemics and disasters. It expects the system to operate across all levels (community, district, metropolitan, regional and national) and to recognize the animal-human interface as well (One-Health approach).

An interesting finding was that the "Ghana roadmap for attaining universal health coverage, 2020-2030" does not specifically mention One Health nor rabies elimination in any of its sections. However, it recognises the fact that the National Action Plan for Health Security is in place and aims to prevent avoidable epidemics; detect disease outbreaks; establish a system for multisectoral responses; establish and sustain capacity for effective public health response at the points of entry; and develop and maintain core capacities for chemical and radio-nuclear emergencies and events. The roadmap further recognizes the need to strengthen animal and public health disease surveillance, control, elimination and eradication at the primary health care level. However, elimination of dog-mediated human rabies

deaths is conspicuously missing from the list of diseases earmarked for elimination provided on page 10 of the document. The listed diseases are onchocerciasis, yaws, yellow fever, schistosomiasis and other soil transmitted helminth. This omission, if deliberate, may not augur well for One Health collaboration for rabies elimination.

Moreover, in respect of management of dog bite, the Standard Treatment Guidelines (STGs) which are systematically developed statements that assist healthcare providers in deciding on appropriate treatments for specific clinical problems were available to provide guidance.[83] Although the current edition (7th edition, 2017) prescribes observation of the offending animal for 10 days in the case of dog bite, it does not specifically mention who does this observation, and involvement of veterinarians in this is not clearly stated. This does not augur well for the One Health collaboration.

In terms of legislation on dog vaccinations, aside a few bye-laws that are enforced by local authorities in isolated cases, none of the existing national laws in Ghana prescribe sanctions for refusal of dog owners to vaccinate their dogs who have not bitten anyone and have not been found to have symptoms suggestive of rabies. In other words, the existing laws can be invoked only when there is a dog bite or a veterinary officer or medical officer has cause to suspect that the dog has rabies. For instance, Section 302 of the Criminal Code 1960 (Act 29) captioned "Destruction of dog or other Animal suspected to be rabid and penalty on owner" provides for the release to health authorities or destruction by a Police Officer of any dog or animal suspected or confirmed to be rabid. [76] It states:

"(1) A Police Officer may destroy any dog, or any other animal at large, which he has reasonable cause to suspect to be in a rabid state, or which has been bitten by any dog or other animal which he has reasonable cause to suspect to be in a rabid state, or may seize and detain the animal and hand it over to a health officer.

(2) If the owner or person in charge of any dog or other animal knowingly suffers it to be at large in a rabid state; or if any dog or animal is confined, and the owner or person in charge of it does not destroy it, or cause it to be destroyed, after it has shown evident and distinct symptoms of being in a rabid state, or of having been bitten by any dog or other animal in a rabid state; the owner or person shall be liable to a fine not exceeding ¢500,000.00. [76]

Similarly, section 9 of the Public Health Act, 2012 (Act 851) titled "Destruction of Animals" empowers a veterinary officer, or an authorised health officer to destroy an animal that is suspected to be an agent in the transmission of a communicable disease and to dispose of the carcass in the manner specified by the officer." Clearly, none of the two Acts can be invoked unless there is enough ground to suspect that the animal in question is rabid or there is an instance of a bite. They are hardly applicable to a healthy-looking dog or animal that has not bitten anyone or has not been bitten by

another animal that has rabies. The Animal ordinance Act (Cap 247) of 1935 which is largely seen being enforced at the various ports of entry empowers the Minister of Food and Agriculture (MOFA) to ban the importation of animals into the country in order to prevent the introduction of diseases into Ghana.[74] This obviously will ensure that rabid animals are not brought into the country and every imported animal is vaccinated. Supporting this are the Infectious Diseases Act, 1908 (LI 1968) and the Diseases of Animals Act, 1961 (Act 83) which set out guidelines for the prevention of the spread of infectious and contagious diseases.[74,75] In the case of an outbreak, the Diseases of Animals Act, 1961 (Act 83) and the Public Health Act, 2012 (Act 851) can empower the Minister for Health or the Minister for Food and Agriculture to declare a place to be an infected area where a disease outbreak has occurred in order to prevent spread.

Last but not the least, the District Assemblies Common Fund (DACF) Act, 1993 (Act 455) presents an opportunity for rabies prevention and One Health implementation to be locally funded from the (DAFC).[79] Parliament is mandated by article 252(2) of the constitution of Ghana and section 126(1), 2016 (Act 936) to make provision for the allocation of not less than 5% of the total revenue of the Country to the District Assembly Common Fund (DACF) for the implementation of developmental programmes in the Metropolitan, Municipal and District Assemblies (MMDAs). By provision of section 129(a) of the Local Government Act, 2016 (Act 936), the Administrator of the fund is to propose annually for consideration and approval by Parliament a formula for the distribution of the DACF. The formula often takes into consideration 'Basic Needs' which includes Health Service, Education Service, Water Coverage and Tarred Roads Coverage. This presents an opportunity to advocate for rabies prevention and One Health activities to be funded from this source.[79] [66]

7.0 DISCUSSION

This study has shown the spatial, temporal and spatiotemporal relationships between dog bites, dog vaccinations, dog and human rabies cases in Ghana using cross-sectoral data from the Animal Health(AH) and Human Health (HH) sectors. The results are being reported for the first time making these findings unique even though a few localized studies have been conducted to show time trends and spatial patterns of rabies and dog bite morbidity in the past.[9,14,24, 99-100] The study also attempted to assess the level of collaboration between key personnels in both sectors, the barriers and enablers of this expected collaboration and how to improve this in the spirit of One Health for rabies elimination in Ghana.

This section discusses the findings under the following broad headings pertaining to the specific objectives:

1. Disease frequency, temporal, spatial and spatiotemporal distributions of dog bites, dog and human rabies, and dog vaccinations in Ghana

2. Spatiotemporal relationships between dog bites, dog and human rabies cases and dog vaccinations in Ghana

3. Collaboration across Veterinary and Medical fields of practice for rabies elimination

4. Knowledge, perceptions and practices of key personnel on One Health Collaboration for Rabies Elimination

5. Barriers to and enablers of collaboration for implementation of One Health

1. Disease Frequency, Temporal, Spatial and Spatiotemporal Distributions of Dog Bites, Dog and Human Rabies Cases, and Dog Vaccinations.

Age and Sex Distribution of Dog Bite Cases

The observation that more males than females were affected and the most affected age group was 5-14 years is consistent with the epidemiology of dog bites studied in Ghana and elsewhere.[14,16,31 99-103]

A study in Ethiopia by Yibrah et al. in 2015 had reported that 38.5% of human rabies exposures were among children less than 15 years.[101] Our study found 30.2% of the total bites occurring in children 5-14 years with majority being males. This finding agrees more with a study in Kenya by Ngugi et al. in which 30% of all dog bite cases were among children aged 5-14 years and were mostly males. [102]

Children below the age of 15 years are more prone to dog bites for several reasons including curiosity, lack of awareness, tendency to misinterpret dog behaviour, engaging in playful and rough behaviour with dogs and spending more time with them as pets.[103-104] These make them highly vulnerable to attacks by stray dogs.[105] Educating children about dog safety, teaching them how to interact safely

with their pets, supervising their interactions with owned dogs and avoiding stray dogs can significantly reduce their risk of exposure.[103-106] A study in Philippines found that most children with animal bites do not seek treatment so might benefit from pre-exposure prophylaxis in selected population groups especially school-aged children in rabies endemic areas with limited access to animal and human rabies prevention and control services. [106]

The higher incidence of dog bites in males compared to females can be attributed to behavioral, occupational, cultural and social factors.[31,101-104] Addressing these factors requires comprehensive strategies that promote responsible dog ownership, public education about behaviour and safety around animals particularly, dogs and cats, and equitable access to health care services for prompt post-exposure prophylaxis in case of a bite or scratch.[25,107]

District and Regional Distribution of Dog Bite Cases, Dog and Human Rabies and Dog Vaccinations in Ghana

Eastern Region that emerged as the region with the highest annual incidence of dog bites (78.4 per 100,000 population) within the period under study had earlier come under similar study by Adomako et. al. in 2018 who set out to characterise the reported cases of dog bites and rabies within the period 2013-2015 and to explore the state of rabies surveillance in the Region.[14] They reported a dog bite incidence of 172 cases per 100,000 population over a 3-year period. This translates into an annual incidence of 57.3 cases per 100 000 population which is remarkably lower than the average annual dog bite incidence of 78.4 per 100,000 population found in our current study. New Juabeng municipality which was the district with the highest annual dog bite incidence (260.3 per 100,000 population) in our current study ranked second in the earlier study by Adomako et. al with a cumulative incidence of 380 per 100,000 population for the 3-year period which translates into an annual incidence of 127 cases per 100,000 population. Although a real increase in risk of dog bites over the period cannot be completely ruled out, changes in data collection method just before the period 2013 - 2015 might account for the difference. This drawback was duly acknowledged by the authors in their report. The authors had observed a wide disparity between the cases reported in 2013 (which were markedly lower) compared to those reported in 2014 and 2015 (which were much higher). They attributed the disparity to the DHIMS that had just been introduced by Ghana Health Service in 2012 as a new electronic data capturing system.

Our findings pertaining to dog bite incidence in the Volta Region was comparatively more similar to those of Gborie et al. who conducted a descriptive analysis of DHIMS data on dog bites from 2015 to 2019 in the Volta Region.[100] They reported a dog bite incidence of 248 per 100,000 population for the 5-year period which translates into an annual incidence of 49.6 per 100,000 population whilst we

found an average annual dog bite incidence of 55.4 per 100,000 population. The discrepancy is likely to have come from the extension of our study beyond 2019 to cover 2020 and 2021.

Ironically, it was observed that Ashanti Region with the highest dog rabies incidence also recorded the highest annual vaccination coverage. This is explained by the reactionary approach to dog vaccinations in the country with free mass campaigns often following reported cases of rabies in the community. Such cases often provide the impetus for local health authorities to link up with veterinarians and local government (including opinion leaders in the community) to mobilise the required resources for free mass dog vaccinations in the affected communities. Although this is often done to interrupt transmission, it also presents to them an opportunity to demonstrate their responsiveness to public health threats. While these knee-jerk responses play a critical role in controlling rabies outbreaks, promoting proactive vaccination strategies is a more sustainable way to achieve rabies elimination in Ghana by 2030.[108]

Interestingly, Northern Region, which recorded the lowest dog bite incidence of 7.0 cases per 100,000 population, also recorded no human rabies cases during the period. Likewise, North East and Ahafo regions recorded neither human nor dog rabies cases over the 7-year period. Whilst underreporting of cases may account for this, the underlying factor is possibly inadequate capacity to detect and confirm rabies in dogs and humans through standard laboratory tests. There is therefore the need to critically assess the surveillance system including laboratory infrastructure in these regions for possible capacity strengthening. Fortunately, strengthening laboratory diagnostic capacity has been prioritized in the Ghana Rabies Strategic Programme for Elimination 2015-2030 and the Ghana Rabies Control and Prevention Action Plan, 2018-2030.[8,84]

The high human and dog rabies incidence recorded in some districts in Ghana such as Daffiama-Busie-Issa and Adansi Akrofuom together with the persistently low vaccination rate is a cause for worry since those lives could have been saved if the needed interventions were put in place. Concerted effort is required to investigate the contributing factors so as to institute the needed intervention to reverse the trend. Meanwhile, broad interventions such as mass dog vaccination campaigns, public awareness creation and prompt administration of post-exposure prophylaxis could be pursued in the interim.[108]

Vaccination coverage in Ghana has been persistently low over many years with no significant change with time. The reported overall coverage of 5.7 % with regional coverages ranging from 1.3 to 10.3% is in keeping with estimates reported by Guri et al in 2019: national (5.5 %), Regional (Bono) (8.5 %) and 7.1% for Sunyani West municipality.[99] These are far below the 70% required to achieve 'herd immunity', for effective control of the disease.[46] Compared to vaccination coverages reported from

studies in other countries in the sub-region and elsewhere, ours is much lower and should be a cause for concern. Examples include Sierra Leone (14%), Mali (17.6%), Chad (19%), Nigeria (26%), Zambia (8.7%), Namibia (50%).[109-114] It must, however, be noted that these reported coverages were from household surveys rather than routinely reported monthly data in those countries. Household surveys often give higher and better estimates compared to routine surveillance data.[110,115]

From the Key Informant Interviews (KIIs), one important factor that could be driving the persistently low vaccination coverage is the reluctance of dog owners to voluntarily vaccinate their dogs and bear the cost of vaccination as lamented on by some of the veterinary officers interviewed. (See section 6.2). This observation is in keeping with findings from Chad where it was reported that owner-charged vaccination campaigns result in low vaccination coverages compared with free campaigns. [116] Together with weak legislation and poor law enforcement, sociocultural factors are potential contributing factors.[117] Cultural beliefs about dogs, dog owners' knowledge and understanding of the benefits of vaccinations, geographical and financial accessibility of veterinary services, urban-rural classification of place of residence as well as socio-economic status are all factors that can determine dog vaccinations. [109,117-119] If dogs are not valued as pets, dog owners may not vaccinate them. [117] Higher awareness of the benefits of vaccination among dog owners often leads to higher vaccination rates. [118] Also, dog owners from rural areas and those living far from veterinary service delivery points a less likely to vaccinate their dogs. [109,119] Generally, dog owners of low socioeconomic status are less likely to vaccinate their dogs. [119]

Spatial Clustering of Dog Bites, Dog and Human Rabies Cases and Dog Vaccinations in Ghana

Spatial cluster analysis helps to identify the geographic areas with higher-than-expected concentration of cases for targeted interventions and control measures. Spatial clustering of dog bite cases mainly in the southern, central and western parts of the country which are relatively more urbanized than the other parts of the country, could be explained partly by increased opportunities for human-animal interactions with increasing urbanization.[68,120] Indiscriminate waste disposal in densely populated urban areas often attract free roaming dogs to human dwellings thus increasing the risk of dog bites.[120] Other factors that could account for the spatial clustering include spatial distribution of healthcare facilities and veterinary clinics, population density, socioeconomic and sociocultural factors.[23,31,120] A spatial exploratory study of the incidence of reported cases of dog bite in Pakistan (2016–2019) found that risk of dog bite attacks was relatively higher in districts with low human population density (per sq. km), poor literacy rate, more rural population (% of total population), and lower median nighttime lights.[121] Further studies are required to investigate how some of these population or community level factors influence spatial clustering of dog bites in Ghana.

The observed clustering of dog bite cases mainly in the Greater Accra, Eastern, Central, Ashanti, Western, Western North, Ahafo and Bono regions suggests that targeting interventions in these regions will be most impactful. Secondary clusters not overlapping with the primary cluster could be targeted as well.[9,23]

The apparent similarity and overlap between dog bite clusters and those of dog vaccinations only goes to further buttress the point that dog vaccinations in Ghana are mostly reactionary responses to dog bites or rabies cases as already mentioned.[30]

Moreover, the apparent disconnect between primary clusters of dog and human rabies is partly a result of underreporting of cases due to inadequate human and laboratory capacity to suspect and confirm cases. The Seller's Staining Test (STT) for rapid confirmation of rabies in dogs which is still being used by some veterinarians in Ghana is less sensitive and should be replaced by direct fluorescent antibody test antibody (dFAT).[100,122] Likewise modern methods for ante mortem diagnosis of human rabies such as the use of PCR on multiple samples should be encouraged among human health professionals and supported with adequate training.[1,123] Another reason is the poor collaboration in terms of routine data sharing between the Animal Health and Human Health professionals as evidenced from the key informant interviews and also reported elsewhere.[9,123] There is the need to optimize collaboration through dialogue, advocacy and formulation of the needed policies and guidelines to formalize the collaboration under One Health.[53]

Temporal Clustering of Dog Bites, Dog and Human Rabies Cases and Dog Vaccinations in Ghana

The one significant temporal cluster of dog bites in the period October 2015 to June 2017 overlaps remarkably with the significant temporal cluster of human rabies cases in the period October 2015 to March 2016. This is a significant observation given that not all dog bites are from rabid dogs and the incubation period of rabies may vary from just a few days to several years following exposure.[1] This means that some of the rabies cases in the cluster might have come from recent exposures within the temporal dog bite cluster or none might have come from this observed cluster but rather from exposures that preceded the study period.

Also it is worthy of note that dog rabies clustered in the period January 2020 - September 2021 when the COVID-19 pandemic was possibly raging and the already scarce resources had been redirected into fighting the pandemic as was observed in many countries including Ghana.[124] As a result, most public health programmes were affected including dog vaccinations and rabies surveillance and this might have led to the observed temporal clustering of dog and human rabies cases during the period.

Dog vaccinations were seen to have clustered narrowly from April-June 2019 several months before the pandemic. This was a result of a nationwide dog vaccination campaign embarked upon by the VSD with support from FAO to vaccinate 1,000,000 dogs during the period as part of efforts to improve vaccination coverage Ghana. These efforts focused on regions with high dog populations and rabies incidence. Trained veterinary personnel administered inactivated rabies vaccines to dogs free of charge in both urban and rural areas. However, after the campaign efforts could not be sustained due to the COVID-19 pandemic as earlier mentioned and lack of funds.[108, 124]

Last but not the least, the relatively more remarkable spatial effect compared to temporal effect of recorded cases of dog bite in the period has been reported in a similar study in Tunisia by Kalthoum et. al.[125] who found no significant time effect in the spatiotemporal distribution of dog rabies in Tunisia and the associated factors from 2019 to 2021.They reported that variations in the risk of dog rabies observed were primarily associated with spatial effects. Spatial variation of the risk factors can be potential reasons for the different risk among the different geographical units. [125]

In our study, whilst acknowledging the potential effect of data quality and methodological issues, this could mean little or no impactful change in the national approach to rabies control over the period. New changes, if any were ever introduced, were likely to have been isolated interventions at the subnational level (regional or district) with negligible effect on the national temporal trend of cases. This observation is a bit worrying considering the fact that since 2015 when the global strategic framework to eliminate rabies was introduced, 7 years down the line and still counting, no major interventions have been implemented to reduce the temporal trend of cases on a national scale. The need for more concerted efforts by both sectors to reverse this unfortunate trend cannot be overemphasized. The challenges of policy formulation and implementation, funding, public awareness creation on responsible pet ownership, weak legislation on dog vaccination and operating an integrated rabies surveillance system must be urgently addressed. [65,108]

2. Spatiotemporal relationships between Dog bites, Dog and Human Rabies Cases and Dog Vaccinations in Ghana

The relationship between dog bites and dog vaccinations has been shown in few studies.[47-49][33-35] In a study conducted in Tanzania by Cleaveland et al.[47][33] to show how a vaccination strategy could result in successful control of rabies in a rural African dog population, after four central point successful campaigns in 72 villages with a mean interval of about a year, both dog rabies incidence and human bite injuries from suspected rabid animals declined significantly. The positive association found in our present study, in contrast to the aforementioned study can be explained by the reactionary nature of dog vaccinations in most districts in Ghana as pointed out by some of the veterinary officers interviewed (See section 6.2) and also reported by Dsane et al.[30] as part of an outbreak response. As a result of poor funding of mass vaccinations by government, the high cost of dog vaccinations and the unwillingness of pet owners to pay for vaccinations of their pets, dogs get vaccinated mostly when they bite a victim and the case is reported to the Veterinary Services Department for assessment. Once this happens, the dog owner is compelled by law and other existing bye-laws to release the animal to the veterinarians for observation and possible vaccination at the end of the observation period. The dog owner often bears the cost of vaccination of his dog and the medical bills of the bite victim.[75-76]

As earlier discussed, the reactionary approach to dog vaccinations partly explains why Ashanti Region which recorded the highest vaccination rate also recorded the highest human rabies rate in this study. A similar observation had been made by Lopes et al. in the Greater Accra Region in Ghana. They compared vaccination coverages to the number of rabies outbreaks in the Greater Accra Region within the period 2007-2011. They reported that in 2011 when the highest vaccination coverage (17.6 %) was recorded, that same year the highest number of outbreaks was also observed (55 outbreaks). They argued that vaccination coverage of 17.6% was too low to break transmission cycle as it was clearly below the minimum recommended level of 37.5%. Thus, no significant reduction in dog rabies incidence could be expected. [24]

On the other hand, Kalthoum et al.[125] in Tunisia found no association between dog vaccination coverage and dog rabies incidence. Whilst acknowledging the effect of underreporting and data quality issues, they also thought that this could be due to the rather high vaccination coverage recorded within the population resulting in limited variability in vaccination status and consequently insufficient power to detect significant association.[125] Other factors such as vaccine effectiveness, non-availability of accurate dog population figures, variation in exposure to rabies virus across the geographical regions could play a role.[125]

The remarkably low dog vaccination coverages across the regions (1.3-10.3%) is very worrying when viewed against the backdrop of the widely established scientific benchmark of 70 % dog vaccination coverage required for rabies herd immunity in an area.[5] According to reports from VSD, before 1994, rabies vaccination was free.[8] During that period, nationwide mass dog vaccination campaigns were organised regularly and dog rabies vaccination was compulsory. Owners of unvaccinated dogs were prosecuted and stray dogs destroyed. All these were legally backed by bye-laws from the local authority and enforced by the traditional councils and MMDAs. With the abolition of the free vaccination, the bye-laws became passive. [8] Currently, unlike countries like the United States of America and Brazil with legislation that requires registration and vaccination of dogs, the legislation in Ghana on dog vaccination is weak, existing as bye-laws that are rarely enforced. [8,123] The existing laws are applicable mostly when there is evidence of dog bite or rabies to compel the owner to release the offending animal for observation, testing and/or destruction. [72,74-75] Obviously, there is the need to re-introduce free mass dog vaccinations and stricter legislation that requires registration and compulsory vaccination of dogs in order to achieve high vaccination coverages for rabies elimination by 2030 as planned. [24,108, 123]

The very weak association between dog bites and dog rabies as well as human rabies could be the result of data errors and underreporting as already alluded to. Inadequate infrastructure, human resource and diagnostic capacity to suspect and confirm cases are possible factors. [100,108,123] The poor collaboration in terms of routine data sharing between veterinary professionals and medical staff often result in cases being missed by one sector. Also, most human rabies cases in the DHIMS database were not laboratory-confirmed cases. There is thus the need to have all human rabies cases confirmed either ante-mortem or post mortem for more reliable surveillance data for decision-making. [1,24].

The finding that there was no significant seasonality exhibited by the trend in dog bites and dog rabies over the period is consistent with Turkson et al. who found no seasonal variation in dog rabies cases in Ghana.[9] Whilst some studies done elsewhere have demonstrated significant seasonal variation in dog rabies incidence others have not. Khalthoum et al. in Tunisia found a negative association between mean monthly temperatures and dog rabies incidence which could be related to the influence of temperature on the survival of the virus given the setting of the study. This could also be due to reduction in activity level in dogs in warmer climates with decrease likelihood of encounters between rabid dogs and susceptible animals. [126] Some studies had rather found the contrary where warmer temperatures were associated with increased rabies incidence as had been reported by Putra et al in Indonesia. [127] Regional variations, and local conditions among other factors might explain the different observations.[127]

3. Collaboration across Veterinary and Medical fields of practice for rabies elimination

The observation that routine sharing of rabies-related across both sectors and the attendant mechanisms to do so are non-existent is consistent with the findings by Adomako et al.[14], who analyzed routinely reported rabies data in the Eastern Region of Ghana by the Ghana Health Service (GHS) and the Eastern Regional Veterinary Unit (RVU) over the period 2013-2015. They observed that 'the GHS and RVU operated independent systems of zoonotic disease reporting, collected markedly different sets of information and had no platform for reconciliation'. Afakye et al.[15] as well as Obonyo et al.[128] made similar observations when conducting rabies outbreak investigations in Ghana and Kenya respectively. Besides posing data challenges in outbreak investigations as was observed by both authors, this lack of data sharing and reconciliation often delays case detection and prompt management of those exposed to rabies virus. Also, the resulting wide disparities between dog bite data reported by both sectors as observed by Adomako et al. [14] in their study does not augur well for monitoring progress towards elimination goals in both sectors. Both sectors should pursue integrated case bite management that encourages routine data sharing, harmonization and pooling of resources in order to achieve a shared goal of eliminating rabies by 2030.[25]

It is refreshing to note that some collaboration already exists between the two sectors but to varied extent at the various levels of the surveillance system. Whilst some of these collaborations are formal, others are only informal arrangements among the officers from both sectors to work together on selected issues. Such informal arrangements are not sustainable because they are built around specific individuals who can be in and out of the service at any given point. Gleaning from the responses from the key informant interviews, one would notice that lack of a clear policy largely accounts for these ad hoc collaborations we are seeing. The One Health policy currently being drafted will hopefully address this gap.[53,129] Guidelines are needed to address critical issues relating to data sharing and harmonization particularly what is to be shared, by what means and in what format, frequency and at what level it should be shared. Sanctions for non-compliance must also be clearly spelt out. Another grey area needing guidance is the harmonization of protocols for management of dog bites between the two sectors. Roles must clearly be spelt out alongside what needs to be done at each stage of the management. Protocol development must be a collective responsibility with inputs from both sides. This is to avoid duplication and to ensure smooth implementation. Staff training and awareness creation on One Health must be a priority.[129]

With regard to leadership in One Health implementation, the Ministry of Health appears to be the unanimous choice for both groups in contrast to what pertains in other countries where One Health implementation has often been led by the veterinary professionals.[18] In any case, which ever organization takes up the leadership role must ensure that there is equity, fairness and transparency in

the allocation of resources, and assignment of roles and functions should be guided by these key principles for smooth implementation. [53,129]

4. **Knowledge, perceptions and practices of key personnel on One Health Collaboration for Rabies Elimination**

Although most respondents from the Animal (AH) and the Human Health (HH) sectors had some knowledge about rabies, significantly large proportions (90% from HH and 50% from the AH) had not heard about One Health. This is very worrying considering the fact that rabies elimination in Ghana by 2030 is to be based on One Health approach and rabies elimination in itself is being considered as a test case for One Health implementation.[51] The finding that more AH than HH staff had heard about One Health is consistent with findings from other studies.[130] This is mainly because the advocacy drive for One Health implementation has often emanated more strongly from veterinary field of practice compared to the medical field.[18] This observation calls for intensive awareness creation among professionals from both sectors particularly the HH sector.

In terms of collaboration with each other in rabies prevention and control activities, the wide discrepancy between the ratings by the two groups clearly shows little or no collaboration. Only 1 out of the 10 listed activities requiring collaboration had ratings that were not significantly different between the two groups. Even in this particular case, the ratings by the two groups in terms of level of collaboration was just about average. This observation from the survey is well supported by responses from the key informant interviews where it was evident that the two groups were not collaborating effectively. This observation is also consistent with other studies previously conducted in Ghana and elsewhere.[14,128]

The good news is that more than 90% of the survey respondents from each group perceive the need for joint reporting of dog bite and rabies cases and a significant proportion are not satisfied with the existing level of collaboration between the two groups. Clearly, the willingness to work closely with each other exists but what is missing is the impetus in terms of policy drive from the top and the needed resources.[53] It is expected that the One Health policy being drafted and its smooth implementation will help address this gap. So long as the two groups have a shared vision and a common goal for collaboration, the implementation is likely to be smooth if well managed.[58]

5. **Barriers to and enablers of collaboration and implementation of One Health collaboration**

The identified barriers to One Health collaboration were mainly lack of policy to guide implementation, limited funding, infrastructure and human resource capacity especially, in respect of animal health professionals. This finding is in keeping with findings in Australia by Johnson and

Hansen [53] where lack of a clear definition of One Health by way of policy was reported as a potential barrier to One Health implementation. Inadequate coordination and communication between stakeholders especially at the district, facility and community levels was also identified as a barrier in our current study as had been found by Obonyo et al.[128] in Kenya.

Addressing these challenges will require accelerating the processes for finalizing the One Health policy (in draft at the time of the study), getting it approved by the relevant ministries, creating awareness of One Health and committing adequate resources to its successful implementation. Training of the relevant professional bodies on the policy and equipping them with the required skills for its implementation should be prioritized.[129,131]. Provision of the necessary infrastructure to enhance seamless cross-sectoral data-sharing should be another priority.[53,129].

With respect to facilitators (enablers), the existing structures that support One Health implementation e.g. the existing local government structures like the Public Health Emergency Management Committee, District Health Committees, District Health Management Teams, District composite planning and budgeting, that support multidisciplinary and intersectoral collaboration should be strengthened and leveraged at the lower levels to support One Health implementation. Existing policies, guidelines, frameworks and legislations such as the IDSR, Public Health Act, 2012 (Act 851), and the National Action Plan for Health Security can be leveraged and harmonized to provide the necessary legal and policy framework for One Health implementation before the finalisation and approval of the One Health policy itself.[67,82,129]

The willingness of some identified stakeholders namely AH and HH to work together as found in this study should provide the needed impetus to begin or strengthen stakeholder engagements, joint meetings and joint surveillance on pilot basis to generate more evidence for informed decisions on One Health implementation. Existing collaborations should be further strengthened and leveraged across all levels.[129]

Joint planning meetings at the district level should provide an entry point for harmonizing individual stakeholder plans that can be integrated into a composite One Health plan and budget for joint implementation at the district level. [67,129,131].

Conclusion

The spatial and temporal relationships between dog bites and vaccination coverages have revealed operational gaps in Ghana's approach to achieving the set goal of eliminating dog-mediated human rabies deaths by 2030 and frantic effort should be made to address these gaps at all levels lest the achievement of the goal by Ghana will remain a mirage.

Recommendations

On the basis of our findings, we make the following recommendations to key stakeholders:

To the Government of Ghana:

At the policy level,

1. Government should revisit the initial policy drive to fund free mass dog vaccination across the country in order to attain universal dog vaccination coverage
2. Government should consider introducing stronger legislation or stricter law enforcement that will compel all dog owners to vaccinate their dogs.
3. Dedicated funds should be allocated to the relevant ministries for implementation of One Health policy
4. A percentage of the District Assembly Common Fund should be dedicated to One Health implementation at the district level and for management of outbreaks

To MOFA and MOH:

At the policy level,

1. The processes leading to finalization of the One Health policy should be completed without delay since this is crucial for successful implementation of One Health in Ghana.
2. Efforts should be driven at institutionalizing and integrating dog bite surveillance in the two sectors with cross-data sharing being a major component of the surveillance system.
3. The National Health Insurance Scheme should be made to cover rabies post-exposure prophylaxis if not available for free at public health outlets.

To the service providers (GHS, VSD):

At the national, regional and district level,

1. Clear guidelines should be developed to address key areas such as routine data-sharing on zoonotic diseases in the relevant ministries, agencies and departments.
2. Clear guidelines should be developed spelling out roles and responsibilities among veterinary professionals and human health professionals in the management of dog bites at the community, facility and district levels with the aim of strengthening surveillance and improving care outcomes for dog bite victims
3. Institutionalization of integrated bite case management and dog bite surveillance should be pursued

4. There must be extensive awareness creation about One Health at the regional, district and community levels bringing on board all stakeholders for its smooth implementation

To the community and local government:

1. Bye-laws on responsible pet ownership should be enacted and enforced by the Local Assemblies in collaboration with the security agencies, Environmental Health Unit and Veterinary Services Directorate at the district level
2. Local Government should coordinate and ensure joint composite planning and budgeting for One Health activities at the district level
3. Local Government should commit a percentage of internally-generated funds towards supporting rabies elimination and One Health activities

Limitations of the study

The study is largely limited by non-availability of yearly dog population figures at the district level. District dog population figures were thus estimated from projections from available dog population figures at the national level. Another limitation was the large proportion of suspected human rabies cases that were not laboratory confirmed and some of whom 'survived'. Thus, to increase the specificity of the case definition, death as a reported outcome of human rabies was included as criterion, since case fatality is almost 100%. This was required to exclude suspected rabies cases that appeared to have 'survived' per the data available and could bias our findings.

Last but not the least, the study is potentially limited by underreporting of cases. This is typical of most surveillance data that are passive and facility-based. Nonetheless, findings from the study are still novel for Ghana and can serve as baseline indicators for monitoring progress towards dog-mediated rabies elimination and One Health implementation.

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9.0 APPENDICES

APPENDIX A: PARTICIPANT'S INFORMATION SHEET FOR IN-DEPTH INTERVIEWS

STUDY TITLE**: Spatiotemporal Relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021.**

PRINCIPAL INVESTIGATOR**: ERIC ODEI**

CONTACT NUMBER: **0543519231**

INTRODUCTION:

My name is Dr. Eric Odei. I am doing a fellowship residency programme at the Ghana College of Physicians and Surgeons in Accra, Ghana. As part of the requirement of the programme I am conducting a study entitled: **"Spatiotemporal relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021".**

I would very much appreciate your participation in this study. Taking part in the study is completely voluntary.

WHAT THE STUDY IS ABOUT:

The study seeks to:

1. analyse rabies-related data in the human and animal health sectors

2. determine the extent of collaboration, data harmonization and sharing across both sectors for informed policy and programme decision-making and implementation in the context of One Health.

WHAT I WANT YOU TO DO:

I would be very grateful if you could respond to a few questions and share your experience and thoughts about collaboration, data sharing and harmonization of rabies-related data across both sectors. With your permission the interview may be audio-recorded **and will take 30-45 minutes of your time.**

RISK AND BENEFITS

Apart from the potential risk of exposure to COVID-19 due to our physical interaction which we are keeping to the barest minimum by strictly adhering to the COVID-19 protocols I do not anticipate any other risk the study may pose to you. There are no direct benefits. However, I hope you will participate since your contribution to the study will help to improve the system as we all strive to eliminate dog-mediated rabies by 2030.

COMPENSATION

There is no direct compensation for participating in this study. However, where interviews have to be conducted remotely due to prevailing circumstances, the researcher will bear the cost of data bundle or airtime used.

CONFIDENTIALITY

Any information you provide will be used only for the purpose of this study. Your information will be **protected** and will be destroyed at least 5 years after the study. No names are required. You are assured of anonymity in my report and any subsequent publication of the findings of this study.

TAKING PART IS VOLUNTARY

Taking part in this study is completely voluntary. You may skip any questions that you do not want to answer. You may also decide to withdraw from the study at any time. Refusal to take part in the study should not bring upon you any adverse consequences. If you have further concerns you may contact

Dr. Eric Odei on 0543519231/0270713679 OR The ERC Administrator, Ghana Health Service Ethics Review Committee, Accra (Contact No: 0503539896). Note that the ERC Administrator must be contacted for ethical issues only.

APPENDIX B: SURVEY PARTICIPANT'S INFORMATION SHEET

STUDY TITLE: **: Spatiotemporal Relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021.**

PRINCIPAL INVESTIGATOR**: ERIC ODEI**

CONTACT NUMBER: **0543519231**

INTRODUCTION:

My name is Dr. Eric Odei. I am conducting a study entitled: Spatiotemporal relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health,2021.

I would very much appreciate your participation in this study. Taking part in the study is completely voluntary.

WHAT THE STUDY IS ABOUT:

The study seeks to:

1. analyse rabies-related data in the human and animal health sectors

2. determine the extent of collaboration and sharing of information across both sectors for informed policy and programme decision-making and implementation in the context of One Health.

WHAT I WANT YOU TO DO:

I would be very grateful if you could respond to a few questions and share your experience and thoughts about collaboration for rabies elimination in Ghana. **This will take about 10-15 minutes of your time**.

RISK AND BENEFITS

Apart from the potential risk of exposure to COVID-19 due to our physical interaction which we are keeping to the barest minimum by strictly adhering to the COVID-19 protocols I do not anticipate any other risk the study may pose to you. There are no direct benefits. However, I hope you will participate since your contribution to the study will help to improve the system as we all strive to eliminate dog-mediated rabies by 2030.

COMPENSATION

There is no direct compensation for participating in this study. However, where interviews have to be conducted remotely due to prevailing circumstances, the researcher will bear the cost of data bundle or airtime used.

CONFIDENTIALITY

Any information you provide will be used only for the purpose of this study. Your information will be will be **protected** and will be destroyed at least 5 years after the study. No names are required. You are assured of anonymity in my report and any subsequent publication of the findings of this study.

TAKING PART IS VOLUNTARY

Taking part in this study is completely voluntary. You may skip any questions that you do not want to answer. You may also decide to withdraw from the study at any time. Refusal to take part in the study should not bring upon you any adverse consequences. If you have further concerns you may contact

Dr. Eric Odei on 0543519231/0270713679 OR The ERC Administrator, Ghana Health Service Ethics Review Committee, Accra (Contact No: 0503539896) . Note that the ERC Administrator must be contacted for ethical issues only

APPENDIX C: CONSENT FORM FOR IN-DEPTH INTERVIEWS

STUDY TITLE: **Spatiotemporal Relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021.**

PRINCIPAL INVESTIGATOR**: ERIC ODEI**

CONTACT NUMBER: **0543519231**

PARTICIPANT'S STATEMENT

I acknowledge that I have read or have had the purpose and contents of the Participants' Information Sheet read and all questions satisfactorily explained to me in English which I understand. I fully understand the contents and any potential implications as well as my right to change my mind (i.e. withdraw from the research) even after I have signed this form.

I voluntarily agree to be part of this research.

Name of Participant……..

Participant's Signature ……...OR Thumb Print……

Date:…….

☐ **Consent was obtained over the phone**

CONSENT TO BE AUDIO-RECORDED: I have granted the interviewer permission to audio-record my responses and any information I will voluntarily share with him during the interview as he so wishes.

Signature of participant……OR Thumbprint……

Date……..

☐ **Consent was obtained over the phone**

INTERPRETER'S STATEMENT

I interpreted the purpose and contents of the Participants' Information Sheet to the afore named participant to the best of my ability in the English language to his proper understanding.

All questions, appropriate clarifications sort by the participant and answers were also duly interpreted to his/her satisfaction.

Name of Interpreter……

Signature of Interpreter…….. OR Thumb Print …….....

Date:…… Contact Details……

☐ **Consent was obtained over the phone**

STATEMENT OF WITNESS

I was present when the purpose and contents of the Participant Information Sheet was read and explained satisfactorily to the participant in English which he/she understood.

I confirm that he/she was given the opportunity to ask questions/seek clarifications and same were duly answered to his/her satisfaction before voluntarily agreeing to be part of the research.

Name:……

Signature…….. OR Thumb Print …….....

Date:……

INVESTIGATOR'S STATEMENT AND SIGNATURE

I certify that the participant has been given ample time to read and learn about the study. All questions and clarifications raised by the participant have been addressed.

Researcher's name…….

Signature …….

Date…….

☐ **Consent was obtained over the phone**

APPENDIX D: CONSENT FORM FOR SURVEY PARTICIPANTS

STUDY TITLE **: Spatiotemporal Relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021**

PRINCIPAL INVESTIGATOR**: ERIC ODEI**

CONTACT NUMBER: **0543519231**

PARTICIPANT'S STATEMENT

I acknowledge that I have read or have had the purpose and contents of the Participants' Information Sheet read and all questions satisfactorily explained to me in English which I understand. I fully understand the contents and any potential implications as well as my right to change my mind (i.e. withdraw from the research) even after I have signed this form.

I voluntarily agree to be part of this research.

Name of Participant……..

Participant's Signature ……...OR Thumb Print……

Date:…….

☐ **Consent was obtained over the phone**

INTERPRETER'S STATEMENT

I interpreted the purpose and contents of the Participants' Information Sheet to the afore named participant to the best of my ability in English to his proper understanding.

All questions, appropriate clarifications sort by the participant and answers were also duly interpreted to his/her satisfaction.

Name of Interpreter……

Signature of Interpreter…….. OR Thumb Print …….....

Date:……

Contact Details:……

☐ **Consent was obtained over the phone**

STATEMENT OF WITNESS

I was present when the purpose and contents of the Participant Information Sheet was read and explained satisfactorily to the participant in English which he/she understood.

I confirm that he/she was given the opportunity to ask questions/seek clarifications and same were duly answered to his/her satisfaction before voluntarily agreeing to be part of the research.

Name:……

Signature…….. OR Thumb Print …….....

Date:……

☐ **Consent was obtained over the phone**

INVESTIGATOR STATEMENT AND SIGNATURE

I certify that the participant has been given ample time to read and learn about the study. All questions and clarifications raised by the participant have been addressed.

Researcher's name…….

Signature …….

Date…….

☐ **Consent was obtained over the phone**

APPENDIX E -DATA ABSTRACTION SHEET FOR DOG BITES

Zone	region	district	District_id	District code	Period name	Month_Year	Male_ agegroup	Female_ agegroup	Male _total	Female_ total

APPENDIX F -DATA ABSTRACTION SHEET FOR HUMAN RABIES CASES

Zone	region	district	District_id	District code	Period name	Month_ year	Male_ agegroup	Female_ agegroup	Male _ total	Female_ total

APPENDIX G-DATA ABSTRACTION SHEET FOR DOG RABIES CASES

Zone	region	district	District_id	District code	Period name	Month_year	Male	Female	Male _total	Female_ total

APPENDIX H -DATA ABSTRACTION SHEET FOR DOG VACCINATION COVERAGES

Zone	Region	District	District_id	District code	Period name	Mth_year	No. of dogs vaccinated	Estimated dog population	Estimated coverage

APPENDIX I -INTERVIEW GUIDE FOR INTERVIEWING OFFICERS AT THE NATIONAL LEVEL: (VETERINARY SERVICES DIRECTORATE, MOFA)

STUDY TITLE **: Spatiotemporal Relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021**

PRINCIPAL INVESTIGATOR**: ERIC ODEI**

CONTACT NUMBER: **0543519231**

1. Self-introduction
2. Brief work history
3. Current position and job description
4. Extent of involvement in rabies prevention and control activities in the country
5. Major programmes and policies for rabies prevention and control in the last 5 years
6. Extent of collaboration with the Ghana Health Service with respect to:
    a Case detection (Any reasons?)
    b. Reporting (Any reasons?)
    c. Response (Any reasons?)
7. Extent of collaboration with Ghana Health Service (GHS) in terms of:
    a. Data-sharing
        i. Description of existing mechanisms for data-sharing with GHS; what information is being shared; adequacy of the data being shared in terms of quantity and quality (completeness, accuracy, timeliness, frequency, relevance)
        ii. Perceived benefits of data-sharing between the GHS and VSD
        iii. Perceived disadvantages; and why?
        iv. Real/perceived challenges/barriers to data-sharing with GHS. Reasons for the challenges. How the challenges could be addressed
        v. How much of rabies-related data should be shared between the two sectors; Any limits and why?
        vi. Whether or not data-sharing with GHS is considered a priority in the organization (VSD). Any practical examples or evidence to support the response (eg. existing policies or guidelines; joint meetings and reviews held).
        vii. What should be done to facilitate/enhance data-sharing; any other recommendations

    b. Data harmonization

        i. Description of existing reporting mechanism (including formats) for rabies-related data in the VSD
        ii. Perceived benefits of harmonizing rabies-related data between the two sectors (eg. using an integrated rabies /dogbite surveillance reporting format)
        iii. Perceived disadvantages; and why?
        iv. Real/perceived challenges or barriers to data harmonization; and why? How they can be addressed.
        v. Whether or not data harmonization is considered a priority in the organization (VSD). Any practical examples or evidence to support the response (eg Any existing policies or guidelines; joint meetings held in that regard)
        vi. What should be done to facilitate data harmonization? Any recommendations?
8. What is your understanding of One Health?
    a. How far have we gone as a country in its implementation ? Any policies or guidelines?
    b. What are the challenges? And why?
    c. What will facilitate its implementation?

d. Which Ministry do you think should lead in its implementation? and why?
e. Any recommendations

APPENDIX J -INTERVIEW GUIDE FOR INTERVIEWING OFFICERS AT THE NATIONAL LEVEL: (DISEASE SURVEILLANCE DEPARTMENT, GHS)

STUDY TITLE **: Spatiotemporal Relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021**

PRINCIPAL INVESTIGATOR**: ERIC ODEI**

CONTACT NUMBER: **0543519231**

1. Self-introduction
2. Brief work history
3. Current position and job description
4. Extent of involvement in rabies prevention and control activities in the country
5. Major programmes and policies for prevention and control of rabies in the country
6. Extent of collaboration with the VSD with respect to:
    a Case detection (Any reasons?)
    b. Reporting (Any reasons?)
    c. Response (Any reasons?)
7. Extent of collaboration with VSD in terms of:

a. Data sharing

i. Description of existing mechanisms for data sharing with VSD; what information is being shared; adequacy of the data being shared in terms of quantity and quality-completeness, accuracy, timeliness, frequency, relevance)
ii. Perceived benefits of data-sharing between the GHS and VSD
iii. Perceived disadvantages; and why?
iv. Real/perceived challenges/barriers to data-sharing with GHS. Reasons for the challenges. How the challenges could be addressed
v. How much of rabies-related data should be shared between the two sectors; Any limits and why?
vi. Whether or not data -sharing with VSD is considered a priority in the organization (GHS). Any practical examples or evidence to support the response (eg. existing policies or guidelines; joint meetings and reviews held).
vii. What should be done to facilitate data-sharing; any other recommendations

b. Data harmonization

i. Description of existing reporting mechanism (including formats) for rabies-related data in the GHS
ii. Perceived benefits of harmonizing rabies-related data between the two sectors (eg. using an integrated rabies /dog bite surveillance reporting format)
iii. Perceived disadvantages; and why?
iv. Real/perceived challenges or barriers to data harmonization; and why? How they can be addressed.
v. Whether or not data harmonization is considered a priority in the organization (VSD). Any practical examples or evidence to support the response (eg Any existing policies or guidelines; joint meetings held in that regard)
vi. What should be done to facilitate data harmonization? Any recommendations?

8. What is your understanding of One Health?
    a. How far have we gone as a country in its implementation?
    b. What are the challenges? And Why?
    c. What will facilitate its implementation
    d. Which Ministry do you think should lead in its implementation? and why?
    e. Any recommendations?

APPENDIX K -INTERVIEW GUIDE FOR INTERVIEWING OFFICERS AT THE REGIONAL LEVEL: (VETERINARY SERVICE, MOFA)

STUDY TITLE: **Spatiotemporal Relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021**

PRINCIPAL INVESTIGATOR**: ERIC ODEI**

CONTACT NUMBER: **0543519231**

1. Self-introduction
2. Brief work history
3. Current position and job description
4. Extent of involvement in rabies prevention and control activities in the Region
5. Programmes and policies for prevention and control of rabies in the Region
6. Extent of collaboration with the GHS with respect to:
    a Case detection (Any reasons?)
    b. Reporting (Any reasons?)
    c. Response (Any reasons?)
7. Extent of collaboration with Ghana Health Service (GHS) in terms of:

    a. Data-sharing

    i. Description of existing mechanisms for data-sharing with GHS; what information is being shared; adequacy of the data being shared in terms of quantity and quality (completeness, accuracy, timeliness, frequency, relevance)
    ii. Perceived benefits of data-sharing between the GHS and VSD
    iii. Perceived disadvantages; and why?
    iv. Real/perceived challenges/barriers to data-sharing with GHS. Reasons for the challenges. How the challenges could be addressed.
    v. How much of rabies-related data should be shared between the two sectors; Any limits and why?
    vi. Whether or not data-sharing with GHS is considered a priority in the organization (VSD). Any practical examples or evidence to support the response in the Region (eg. existing policies or guidelines; joint meetings and reviews held).
    vii. What should be done to facilitate/enhance data-sharing; any other recommendations

    b. Data harmonization

    i. Description of existing reporting mechanism (including formats) for rabies-related data in the VSD
    ii. Perceived benefits of harmonizing rabies-related data between the two sectors (eg. using an integrated rabies /dogbite surveillance reporting format)
    iii. Perceived disadvantages; and why?
    iv. Real/perceived challenges or barriers to data harmonization; and why? How they can be addressed.
    v. Whether or not data harmonization is considered a priority in the organization (VSD). Any practical examples or evidence to support the response (eg Any existing policies or guidelines; joint meetings held in that regard)
    vi. What should be done to facilitate data harmonization? Any recommendations?

8. What is your understanding of One Health?

   a. How far have you gone as a Region in its implementation ? Any policies or guidelines?
   b. What are the challenges? And why?
   c. What will facilitate its implementation?
   d. Which Ministry do you think should lead in its implementation? And why?
   e. Any recommendations?

APPENDIX L -INTERVIEW GUIDE FOR INTERVIEWING OFFICERS AT THE REGIONAL LEVEL: (GHANA HEALTH SERVICE)

STUDY TITLE: **Spatiotemporal Relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021**

PRINCIPAL INVESTIGATOR**: ERIC ODEI**

CONTACT NUMBER: **0543519231**

1. Self-introduction
2. Brief work history
3. Current position and job description
4. Extent of involvement in rabies prevention and control activities in the Region
5. Programmes and policies for prevention and control of rabies in the Region
6. Extent of collaboration with the Veterinary Service with respect to:
    a. Case detection (Any reasons?)
    b. Reporting (Any reasons?)
    c. Response (Any reasons?)
7. Extent of collaboration with Veterinary Service in terms of:

    a. Data sharing

        i. Description of existing mechanisms for data sharing with Veterinary Service; what information is being shared; adequacy of the data being shared in terms of quantity and quality- completeness, accuracy, timeliness, frequency, relevance)
        ii. Perceived benefits of data-sharing between the GHS and Veterinary Service
        iii. Perceived disadvantages; and why?
        iv. Real/perceived challenges/barriers to data-sharing with GHS. Reasons for the challenges. How the challenges could be addressed
        v. How much of rabies-related data should be shared between the two sectors; Any limits and why?
        vi. Whether or not data-sharing with Veterinary Service is considered a priority in the organization (GHS). Any practical examples or evidence to support the response (eg. existing policies or guidelines; joint meetings and reviews held).
        vii. What should be done to facilitate data-sharing; any other recommendations

    b. Data harmonization

        i. Description of existing reporting mechanism (including formats) for rabies-related data in the GHS
        ii. Perceived benefits of harmonizing rabies-related data between the two sectors (eg. using an integrated rabies /dog bite surveillance reporting format)
        iii. Perceived disadvantages; and why?
        iv. Real/perceived challenges or barriers to data harmonization; and why? How they can be addressed.
        v. Whether or not data harmonization is considered a priority in the organization (GHS). Any practical examples or evidence to support the response (eg Any existing policies or guidelines; joint meetings held in that regard)
        vi. What should be done to facilitate data harmonization? Any recommendations?

8. What is your understanding of One Health?

a. How far have we gone as a Region in its implementation?
b. What are the challenges? And Why?
c. What will facilitate its implementation?
d. Which Ministry do you think should lead in its implementation? And why?
e. Any other recommendations?

APPENDIX M -INTERVIEW GUIDE FOR INTERVIEWING OFFICERS AT THE DISTRICT LEVEL :(VETERINARY SERVICE, MOFA)

STUDY TITLE: **Spatiotemporal Relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021**

PRINCIPAL INVESTIGATOR**: ERIC ODEI**

CONTACT NUMBER: **0543519231**

1. Self-introduction
2. Brief work history
3. Current position and job description
4. Extent of involvement in rabies prevention and control activities in the district
5. Programmes and policies for prevention and control of rabies in the district
6. Extent of collaboration with the Veterinary Service with respect to:
    a. Case detection (Any reasons?)
    b. Reporting (Any reasons?)
    c. Response (Any reasons?)
7. Extent of collaboration with Ghana Health Service (GHS) in terms of:

    a. Data-sharing

    i. Description of existing mechanisms for data-sharing with GHS; what information is being shared; adequacy of the data being shared in terms of quantity and quality (completeness, accuracy, timeliness, frequency, relevance)
    ii. Perceived benefits of data-sharing between the GHS and VSD
    iii. Perceived disadvantages; and why?
    iv. Real/perceived challenges/barriers to data-sharing with GHS. Reasons for the challenges. How the challenges could be addressed.
    v. How much of rabies-related data should be shared between the two sectors; Any limits and why?
    vi. Whether or not data-sharing with GHS is considered a priority in the organization (VSD). Any practical examples or evidence to support the response in the District (eg. existing policies or guidelines; joint meetings and reviews held).
    vii. What should be done to facilitate/enhance data-sharing; any other recommendations

    b. Data harmonization

    i. Description of existing reporting mechanism (including formats) for rabies-related data in the Veterinary Service
    ii. Perceived benefits of harmonizing rabies-related data between the two sectors (eg. using an integrated rabies /dog bite surveillance reporting format)
    iii. Perceived disadvantages; and why?
    iv. Real/perceived challenges or barriers to data harmonization; and why? How they can be addressed.

v. Whether or not data harmonization is considered a priority in the organization (VSD). Any practical examples or evidence to support the response (eg Any existing policies or guidelines; joint meetings held in that regard)
vi. What should be done to facilitate data harmonization? Any recommendations?

8. What is your understanding of One Health?

a. How far have you gone as a District in its implementation? Any policies or guidelines?
b. What are the challenges? And Why?
c. What will facilitate its implementation?
d. Which Ministry do you think should lead in its implementation? And why?
e. Any other recommendations?

APPENDIX N -INTERVIEW GUIDE FOR INTERVIEWING OFFICERS AT THE DISTRICT LEVEL (GHANA HEALTH SERVICE)

STUDY TITLE: **Spatiotemporal Relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021**

PRINCIPAL INVESTIGATOR**: ERIC ODEI**

CONTACT NUMBER: **0543519231**

1. Self-introduction
2. Brief work history
3. Current position and job description
4. Extent of involvement in rabies prevention and control activities in the district
5. Programmes and policies for prevention and control of rabies in the district
6. Extent of collaboration with the Veterinary Service with respect to:
    a. Case detection (Any reasons?)
    b. Reporting (Any reasons?)
    c. Response (Any reasons?)
7. Extent of collaboration with Veterinary Service in terms of:

a. Data sharing

i. Description of existing mechanisms for data sharing with Veterinary Service; what information is being shared; adequacy of the data being shared in terms of quantity and quality- completeness, accuracy, timeliness, frequency, relevance)
ii. Perceived benefits of data-sharing between the GHS and Veterinary Service
iii. Perceived disadvantages; and why?
iv. Real/perceived challenges/barriers to data-sharing with GHS. Reasons for the challenges. How the challenges could be addressed
v. How much of rabies-related data should be shared between the two sectors; Any limits and why?
vi. Whether or not data-sharing with Veterinary Service is considered a priority in the organization (GHS). Any practical examples or evidence to support the response (eg. existing policies or guidelines; joint meetings and reviews held).
vii. What should be done to facilitate data-sharing; any other recommendations

b. Data harmonization

i. Description of existing reporting mechanism (including formats) for rabies-related data in the GHS
ii. Perceived benefits of harmonizing rabies-related data between the two sectors (eg. using an integrated rabies /dog bite surveillance reporting format)
iii. Perceived disadvantages; and why?
iv. Real/perceived challenges or barriers to data harmonization; and why? How they can be addressed.

v. Whether or not data harmonization is considered a priority in the organization (GHS). Any practical examples or evidence to support the response (eg Any existing policies or guidelines; joint meetings held in that regard)
vi. What should be done to facilitate data harmonization? Any recommendations?

8. What is your understanding of One Health?

    a. How far have we gone as a District in its implementation?
    b. What are the challenges? And why?
    c. What will facilitate its implementation?
    d. Which Ministry do you think should lead in its implementation? And why?
    e. Any other recommendations?

APPENDIX O- QUESTIONNAIRE

STUDY TITLE **: Spatiotemporal Relationships between Dog Bites, Dog and Human Rabies Cases and Dog Vaccination Coverage in Ghana: Implications for One Health, 2021**

PRINCIPAL INVESTIGATOR**: ERIC ODEI**

CONTACT NUMBER: **0543519231**

1. Date of interview……..

2. Serial no……..

3. Tel no……

4. Age: …….

5. Sex: Male ☐ Female ☐ (*Tick as appropriate*)

6. Sector: MOH ☐

MOFA ☐

Other ☐ (Specify)……..

7. Name of Facility where you work: ……

8. Location: Town/City……District…… Region……

9. Facility Ownership: Public (Government-owned) ☐ (*Tick the appropriate option*)

CHAG(Mission) ☐

Quasi-Government ☐

Private ☐

Other ☐ (Specify)……

10. Staff category: Which of the following categories of staff do you belong to?

Medical Doctor	☐	Veterinary Doctor/Surgeon	☐
Physician Assistant	☐	Veterinary Nurse	☐
Nurse (Med/Surg/PH/CHN/NAC/NAP/Midwife)	☐	Veterinary Technical Officer	☐
Pharmacist	☐	Animal Health Officer	☐
Disease Control Officer/Disease Surv. Officer	☐	Other Anim. Health worker	☐ (specify)…
Allied Health Professional (Lab/Xray/Physio etc)	☐	……	
Other Medical Professional	☐ (Specify)……		

11. Rank……

12. Years of experience in your professional practice in Ghana……..

13. How long have you been working at your current post?.....(State in years)

14. When was the last time you saw a case of dog bite in your facility?

Less than a week ago ☐

1-3 weeks ago ☐

1-3 months ago ☐

4-6 months ago ☐

7- 12 months ago ☐

More than 1 year ago ☐

I have never seen a case of dog bite in this facility ☐

15. Were you involved in the management of the case? Yes ☐ No ☐ Not applicable ☐

16. When was the last time you saw a case of rabies in your facility?

Less than a week ago ☐

1-3 weeks ago ☐

1-3 months ago ☐

4-6 months ago ☐

About 1 year ago ☐

More than 1 year ago ☐

I have never seen a case of rabies in this facility ☐

17. Were you involved in the management of the case? Yes ☐ No ☐ Not applicable ☐

18. Is rabies curable? Yes ☐ No ☐ Don't know ☐

19. Is rabies preventable? Yes ☐ No ☐ Don't know ☐

20. Does your facility have a protocol for managing dog bites? Yes ☐ No ☐ Don't know ☐

21. Do veterinarians (Animal health workers) have a role to play in the management of dog bites?

Yes ☐ No ☐ Don't know ☐

22. If yes, indicate which role(s) they have to play: (*Tick all that apply*)

A. Quarantine of suspicious dogs +/- lab investigation to determine rabies status ☐

B. Administration of post-exposure prophylaxis to human victims ☐

C. Vaccination of dogs, cats and other animal reservoirs for rabies ☐

D. Rabies outbreak investigation and response ☐

E. Referral of dog bite victims (Humans) to health facilities for medical attention ☐

F. Assisting clinicians (medical professionals) to do risk assessment of dog bites and the choice of appropriate interventions to implement ☐

G. Public education on responsible pet ownership and rabies ☐

H. Vaccination of high-risk humans against rabies (Pre-exposure prophylaxis) ☐

I. Sharing of rabies-related data with medical professionals and vice-versa ☐

23. On a scale of 0-10 where 1 means **no collaboration** and **10** means **excellent collaboration** indicate for each of the above activities the level of collaboration that exists with the other sector in carrying out the above functions in your district/facility. (*Indicate score 0-10)*

A. Quarantine of suspicious dogs +/- lab investigation to determine rabies status ……

B. Administration of post-exposure prophylaxis to human victims ……..

C. Vaccination of dogs, cats and other animal reservoirs for rabies ……..

D. Rabies outbreak investigation and response ……..

E. Referral of dog bite victims (Humans) to health facilities for medical attention ……..

F. Assisting clinicians (medical professionals) to do risk assessment of dog bites and the choice of appropriate interventions to implement ……..

G. Public education on responsible pet ownership and rabies prevention ……..

H. Vaccination of high-risk humans against rabies (Pre-exposure prophylaxis) ……

I. Sharing of rabies-related data with medical professionals and vice-versa ……..

24. How often do you hold joint meetings with your colleagues from the other sector (Human Health/Animal Health)

Always ☐ Sometimes ☐ Never ☐

25. Have you heard of the One Health Initiative? Yes ☐ No ☐

26. If yes, what is it about?……

……

27. How important is data-sharing between the Human Health and Animal Health sectors?

Extremely important	Very important	Somewhat Important	A little important	Not important
☐	☐	☐	☐	☐

28. Would you recommend a joint system of reporting dog bite and rabies cases (Joint/Integrated Surveillance system) between Human Health and Animal Health sectors at the district level?

Yes ☐ No ☐

Give reasons for your response:

……

……

29. How satisfied are you with the level of collaboration that exists between Vets and Medical professionals in rabies control and prevention.

Extremely satisfied	Very satisfied	Somewhat satisfied	A little satisfied	Not satisfied
☐	☐	☐	☐	☐

30. What do you think accounts for the current state?

……
……
……

……..

31. What are your recommendations for improved collaboration?

……

……
……
…….

Thank you for your time.

APPENDIX P- VARIABLES

Variable	Definition	Measurement	Data collection technique/instrument
Age of respondent	Age in years of respondent at last birthday	Eg. 35, 36, 37…. years	Interview guide Questionnaire
Sex of respondent	State of being male or female	male, female	Questionnaire
Staff category of respondent	Profession which respondent belongs to	medical doctor, veterinary doctor, nurse, veterinary nurse, etc	Interview guide Questionnaire
Rank of respondent	Highest position attained by respondent in their professional hierarchy	Physician Specialist, Principal Nursing Officer, Senior Technical Officer etc	Interview guide, Questionnaire
Workplace of respondent	Place or facility where respondent works	Hospital, Health Centre, Veterinary clinic	Interview guide, Questionnaire
Facility type (by ownership)	Type of facility defined by which entity owns it	Public, Private, Quasi-Government etc	Questionnaire
Location of facility	Town, district and region where facility is located	Name of town, District, Region	Questionnaire
Sector	Ministry that oversees the activities of the organization to which respondent belongs	Ministry of Health, MoFA	Questionnaire
Years of experience	Number of years for which the respondent has been working in a given sector	2,3,4……. years	Questionnaire
Knowledge about rabies prevention and control	Respondent's knowledge or appreciation of rabies as a disease that can be prevented and controlled	Percentage of Yes / No responses to 18,19 and 21	Questionnaire
Perception about collaboration in rabies control	What respondent thinks /views about collaboration for rabies control and prevention	-Responses to 23,25, 26, 30, 31 on questionnaire -Responses to question 7 on interview guide	-Questionnaire -Interview guide
Practices in rabies management, prevention and control	What respondent does or sees being done in their facilities in respect of rabies and dog bite management, control and prevention	-Responses to 20,21 and 23 on questionnaire -Responses to question 6 on interview guide	-Questionnaire -Interview guide -Desk review
Extent of collaboration in rabies management & prevention	The degree to which collaboration is being practiced between animal and human health professionals in respect of rabies management and prevention	-Responses to questions 23 and 29 on questionnaire -Responses to 6&7 on interview guide	-Questionnaire -Interview guide -Desk review
Extent of data sharing	The degree to which data is being shared between the human health and animal health sectors	-Response to question 23i on questionnaire -Response to question 7a on interview guide	-Questionnaire -Interview guide -Desk review
Extent of data harmonization	The degree to which reporting formats and data from both sides agree with each other and can be	-Response to question 7b on the interview guide	-Interview guide -Desk review

Variable	Definition	Measurement	Data collection technique/instrument
	integrated		
Barriers of collaboration	Factors militating against collaboration between the two sectors	-Responses to questions 30 and 31 on questionnaire -Responses to question 6 on interview guide	-Questionnaire -Interview guide
Enablers of collaboration	Factors promoting collaboration	-Responses to questions 30 and 31 on questionnaire -Responses to question 6 on interview guide	-Questionnaire -Interview guide
Influence of barriers to collaboration on policies and programme decision- making	The extent to which barriers to collaboration have affected implementation of policies and programmes	-Responses to question 5 and 8 on the interview guide	-Interview guide -Desk review
Influence of enablers of collaboration on policies and programme decision- making	The extent to which enablers of collaboration have contributed to implementation of policies and programmes for rabies elimination	-Responses to questions 5 & 8 on the interview guide	-Interview guide -Desk review

APPENDIX Q- SPATIAL SCAN STATISTICS FOR CLUSTER ANALYSIS OF DOG BITES IN GHANA, 2015-2021

CLS	LOC_ID	DIST	POP	RAD_KM	NO. LOC	OBS	EXP.	OBS/ EXP	RR	LLR	P_VAL
1	GH0233	Obuasi Mun.	14152432	158.0	122	70193	58019.9	1.21	1.53	2555.6	p<.00001
2	GH0626	New Juaben South Mun.	124818	0.0	1	2274	510.9	4.45	4.52	1645.8	p<.00001
3	GH0410	Techiman Mun	300340	0.0	1	3037	1230.3	2.47	2.51	951.8	p<.00001
4	GH0724	Ningo/Prampram	444969	25.9	3	3725	1824.9	2.04	2.08	773.7	p<.00001
5	GH0722	La-Nkwantanang-Madina	199208	0.0	1	2115	816.5	2.59	2.62	721.8	p<.00001
6	GH0105	Tano North Mun.	259963	20.7	2	2434	1066.7	2.28	2.31	648.8	p<.00001
7	GH0609	Atiwa East	188744	16.1	2	1956	773.3	2.53	2.56	638.4	p<.00001
8	GH1604	Bibiani-Anhwiaso-Bekwai Mun.	478218	33.8	4	3553	1965.3	1.81	1.83	527.2	p<.00001
9	GH1506	Nzema East	505368	37.9	4	3663	2075.8	1.76	1.79	504.2	p<.00001
10	GH0521	Techiman Mun.	487158	37.6	5	3507	2002.3	1.75	1.77	470.8	p<.00001
11	GH0718	Korle Klottey Mun.	80458	0.0	1	933	329.2	2.83	2.85	369.8	p<.00001
12	GH1502	Effia Kwesimintsim	453686	6.3	2	3120	1858.6	1.68	1.70	361.7	p<.00001
13	GH0612	Birim Central Mun.	73708	0.0	1	825	301.3	2.74	2.75	308.4	p<.00001
14	GH0510	Awutu Senya East	192504	0.0	1	1523	788.3	1.93	1.94	270.6	p<.00001
15	GH0511	Cape Coast Metro	184268	0.0	1	1475	754.8	1.95	1.97	270.3	p<.00001
16	GH1305	Nadowli-Kaleo	330228	33.8	3	2199	1351.3	1.63	1.64	226.2	p<.00001
17	GH0611	Ayensuano	505616	24.1	5	3059	2072.1	1.48	1.49	208.9	p<.00001
18	GH0227	Juaben Mun.	282156	12.9	3	1909	1154.5	1.65	1.66	208.0	p<.00001
19	GH1606	Juaboso	78915	0.0	1	749	324.8	2.31	2.31	202.4	p<.00001
20	GH0221	Atwima Nwabiagya South	136718	0.0	1	1088	559.5	1.94	1.95	196.2	p<.00001
21	GH1210	Kasena Nankana East	285690	22.9	3	1893	1169.5	1.62	1.63	190.4	p<.00001
22	GH0237	Old Tafo Mun.	123597	0.0	1	976	505.4	1.93	1.94	172.6	p<.00001
23	GH0717	Ga West Mun.	234988	0.0	1	1582	963.4	1.64	1.65	167.7	p<.00001
24	GH1411	Keta Mun.	71711	0.0	1	626	293.0	2.14	2.14	142.8	p<.00001
25	GH0714	Ga East	238339	0.0	1	1480	977.3	1.51	1.52	112.6	p<.00001
26	GH1304	Lawra	106268	22.8	2	720	435.3	1.65	1.66	77.9	p<.00001
27	GH0222	Bekwai Mun.	131154	0.0	1	825	536.6	1.54	1.54	66.8	p<.00001
28	GH0234	Offinso Municipal	300242	22.2	3	1643	1231.4	1.33	1.34	62.9	p<.00001
29	GH0729	Weija Gbawe Mun.	206840	0.0	1	1177	847.5	1.39	1.39	57.5	p<.00001
30	GH1407	Central Tongu	174633	23.3	2	974	712.4	1.37	1.37	43.3	p<.00001
31	GH0218	Atwima Kwanwoma	183092	0.0	1	1006	749.6	1.34	1.35	39.9	p<.00001
32	GH0506	Assin Fosu	87045	0.0	1	537	356.9	1.50	1.51	39.4	p<.00001
33	GH0311	Tain	219970	30.2	2	1175	902.3	1.30	1.31	37.9	p<.00001
34	GH0608	Asuogyaman	211180	24.3	2	1122	862.6	1.30	1.30	35.9	p<.00001
35	GH0509	Awutu Senya	136446	0.0	1	768	558.2	1.38	1.38	35.4	p<.00001
36	GH0239	Sekyere Central	179694	31.2	2	938	736.5	1.27	1.28	25.5	p<.00001
37	GH1209	Garu	66778	0.0	1	383	273.1	1.40	1.40	19.7	p<.00001
38	GH0705	Ada East	74705	0.0	1	409	305.6	1.34	1.34	15.8	0.00007
39	GH1602	Bia East	44322	0.0	1	263	182.9	1.44	1.44	15.4	0.00009
40	GH0308	Jaman South Mun.	103325	0.0	1	541	422.7	1.28	1.28	15.3	0.00011
41	GH0725	Okaikwei North Mun.	176420	0.0	1	872	722.6	1.21	1.21	14.6	0.00020
42	GH0620	Kwahu Afram Plains South	217612	42.6	3	1057	894.4	1.18	1.18	14.1	0.00032
43	GH0104	Asutifi South	63662	0.0	1	338	262.1	1.29	1.29	10.1	0.01300
44	GH1408	Ho Mun.	206544	0.0	1	931	842.6	1.10	1.11	4.5	0.76700
45	GH1410	Hohoe Mun.	119597	0.0	1	553	489.1	1.13	1.13	4.0	0.88800

CLS=Cluster;LOC_ID=Location ID;DIST=DISTRICT;RAD=Radius;No.LOC=No. of Locations LLR=Log likelihood ratio; P VAL=P-value; OBS=Observed cases; EXP=Expected cases;RR=Relative Risk; POP=Population

SOURCE: Estimated using routinely reported monthly data from VSD and GHS together with projections from Ghana Population and Housing Census, GSS 2010, 2021

APPENDIX R- SPATIAL SCAN STATISTICS FOR CLUSTER ANALYSIS OF DOG VACCINATIONS IN GHANA, 2015-2021.

CLS	LOC_ID	DIST	POP	RAD_KM	NO. LOC	OBS	EXP.	OBS/ EXP	RR	LLR	P_VAL
1	GH0243	Suame Municipal	524623	187.0	140	293609	210818.4	1.39	2.3	32886.4	p<.0001
2	GH0235	Offinso North	18245	26.9	3	23287	7331.5	3.18	3.3	11265.0	p<.0001
3	GH0224	Bosomtwe	7925	11.3	2	13895	3184.8	4.36	4.5	9895.7	p<.0001
4	GH0727	Tema Metropolitan	3617	0.0	1	7542	1453.6	5.19	5.3	6373.0	p<.0001
5	GH0207	Ahafo Ano North	2501	0.0	1	6319	1004.8	6.29	6.4	6338.1	p<.0001
6	GH0228	Kumasi Metropolitan	14013	0.0	1	15370	5631.2	2.73	2.8	5807.6	p<.0001
7	GH1608	Sefwi-Wiawso	10785	29.4	2	12457	4333.9	2.87	2.9	5107.7	p<.0001
8	GH0602	Abuakwa South	10548	16.5	3	11680	4238.6	2.76	2.8	4463.9	p<.0001
9	GH0221	Atwima Nwabiagya South	3682	0.0	1	6062	1479.4	4.10	4.1	3992.0	p<.0001
10	GH0238	Sekyere Afram Plains North	4969	49.7	3	6971	1997.0	3.49	3.5	3769.9	p<.0001
11	GH0719	Kpone Katamanso	14044	10.2	3	12288	5643.6	2.18	2.2	2969.6	p<.0001
12	GH0205	Afigya Kwabre North	4859	12.1	2	5958	1952.7	3.05	3.1	2660.0	p<.0001
13	GH0605	Akwapim South	11009	13.6	3	9888	4423.8	2.24	2.3	2524.5	p<.0001
14	GH0309	Sunyani Mun.	9351	0.0	1	8584	3757.7	2.28	2.3	2292.5	p<.0001
15	GH0302	Berekum East Mun.	5578	0.0	1	5873	2241.5	2.62	2.6	2041.1	p<.0001
16	GH0203	Adansi North	6404	16.9	3	6116	2573.3	2.38	2.4	1766.8	p<.0001
17	GH0301	Banda	1405	0.0	1	2305	564.6	4.08	4.1	1505.5	p<.0001
18	GH1510	Tarkwa Nsuaem	6209	0.0	1	5649	2495.2	2.26	2.3	1473.8	p<.0001
19	GH0511	Cape Coast Metro.	5191	0.0	1	4837	2086.1	2.32	2.3	1325.9	p<.0001
20	GH0229	Kwabre East	6252	0.0	1	5252	2512.5	2.09	2.1	1141.9	p<.0001
21	GH1204	Bolga East	21281	14.1	3	12828	8551.6	1.50	1.5	947.4	p<.0001
22	GH0519	Twifo Atti-Mokwa	11755	36.1	5	7825	4723.8	1.66	1.7	859.6	p<.0001
23	GH1603	Bia West	5440	27.1	2	4048	2186.2	1.85	1.9	636.1	p<.0001
24	GH1205	Bolgatanga Mun.	10013	0.0	1	6226	4023.7	1.55	1.6	521.3	p<.0001
25	GH1501	Ahanta West Mun.	4953	0.0	1	3492	1990.3	1.75	1.8	464.1	p<.0001
26	GH0717	Ga West Municipal	4863	0.0	1	3442	1954.2	1.76	1.8	463.2	p<.0001
27	GH1208	Builsa South	2838	0.0	1	2296	1140.6	2.01	2.0	452.5	p<.0001
28	GH1204	Bolga East	11268	13.7	2	6602	4527.9	1.46	1.5	420.7	p<.0001
29	GH1301	Daffiama Bussie Issa	3209	0.0	1	2460	1289.7	1.91	1.9	419.9	p<.0001
30	GH0622	Kwahu South	9919	27.3	3	5933	3985.9	1.49	1.5	417.3	p<.0001
31	GH0726	Shai Osudoku	1811	0.0	1	1601	727.7	2.20	2.2	390.0	p<.0001
32	GH0615	Denkyembour	10166	20.1	3	5596	4085.2	1.37	1.4	252.9	p<.0001
33	GH1304	Lawra	4976	0.0	1	3065	1999.4	1.53	1.5	245.1	p<.0001
34	GH0312	Wenchi Mun.	11048	18.0	2	5633	4439.7	1.27	1.3	149.3	p<.0001
35	GH0307	Jaman North	5847	0.0	1	3227	2349.6	1.37	1.4	147.5	p<.0001
36	GH0305	Dormaa Mun.	9549	22.6	2	4757	3837.2	1.24	1.2	103.3	p<.0001
37	GH0101	Asunafo North	5049	0.0	1	2702	2029.0	1.33	1.3	101.5	p<.0001
38	GH0704	Accra Metropolis	6625	0.0	1	3422	2662.1	1.29	1.3	100.1	p<.0001
39	GH0812	Tamale Metropolis	6163	0.0	1	3173	2476.4	1.28	1.3	90.5	p<.0001
40	GH0513	Ekumfi	1563	0.0	1	984	628.0	1.57	1.6	86.0	p<.0001
41	GH0509	Awutu Senya	10354	11.6	2	5027	4160.6	1.21	1.2	85.4	p<.0001
42	GH0633	Yilo Krobo	10935	15.8	3	5018	4394.0	1.14	1.1	42.8	p<.0001
43	GH1609	Suaman	8824	36.4	4	4006	3546.1	1.13	1.1	28.9	p<.0001
44	GH1411	Keta Mun.	2678	0.0	1	1273	1076.1	1.18	1.2	17.1	p<.0001
45	GH1404	Akatsi North	1136	0.0	1	524	456.7	1.15	1.1	4.7	0.6740

CLS=Cluster;LOC_ID=Location ID;DIST=DISTRICT;RAD=Radius;No.LOC=No. of Locations LLR=Log likelihood ratio; P VAL=P-value; OBS=Observed cases; EXP=Expected cases;RR=Relative Risk; POP=Population

SOURCE: Estimated using routinely reported monthly data from VSD and GHS together with projections from Ghana Population and Housing Census, GSS 2010, 2021

APPENDIX S- APPROVAL LETTERS

GHANA COLLEGE OF PHYSICIANS AND SURGEONS

OUR REF: BA.100.001.008
Tel: +233-(0)302-238650/238703
Cell: 0243-690073
Fax: +233-(0)302-256727
Email: exams@gcps.edu.gh

P. O. Box MB 429
Ministries-Accra
Ghana

16th July 2021

The Chairman
Faculty of Public Health
GCPS

Dear Sir,

REQUEST FOR ETHICAL APPROVAL

Dr. Eric Odei, a Senior Resident in the Faculty of Public Health, at the Ghana College of Physicians and Surgeons, has submitted the revised Proposal of his Dissertation. Comments by the College Dissertation Review Committee have been duly addressed.

Kindly arrange for this Research Proposal to be submitted to the Research and Ethics Committee of the Ghana Health Serrvice for ethical approval to enable him start his research work. This is a requirement for the award of the Fellowship of the College.

Attached is a copy of the Research Proposal.

Counting on your usual cooperation.

Yours Sincerely

Prof. Richard Adanu
RECTOR

cc: Dr. Eric Odei

GHANA HEALTH SERVICE ETHICS REVIEW COMMITTEE

In case of reply the number and date of this Letter should be quoted.

My Ref. GHS/RDD/ERC/Admin/App 121432
Your Ref. No.

Research & Development Division
Ghana Health Service
P. O. Box MB 190
Accra
Digital Address: GA-050-3303
Mob: +233-50-3539896
Tel: +233-302-681109
Fax + 233-302-685424
Email: ethics.research@ghsmail.org
8th October, 2021

Dr. Eric Odei
Public Health Unit
Korle-Bu Teaching Hospital
Accra

The Ghana Health Service Ethics Review Committee has reviewed and given approval for the implementation of your Study Protocol.

GHS-ERC Number	**GHS-ERC: 020/08/21**
Study Title	Spatiotemporal Relationships between Dog Bites, Dog Vaccination Coverages, Dog and Human Rabies, Ghana: Implications for One Health, 2021
Approval Date	8th October, 2021
Expiry Date	7th October, 2022
GHS-ERC Decision	**Approved**

This approval requires the following from the Principal Investigator

- Submission of a yearly progress report of the study to the Ethics Review Committee (ERC)
- Renewal of ethical approval if the study lasts for more than 12 months,
- Reporting of all serious adverse events related to this study to the ERC within three days verbally and seven days in writing.
- Submission of a final report after completion of the study
- Informing ERC if study cannot be implemented or is discontinued and reasons why
- Informing the ERC and your sponsor (where applicable) before any publication of the research findings.

You are kindly advised to adhere to the national guidelines or protocols on the prevention of COVID -19

Please note that any modification of the study without ERC approval of the amendment is invalid.

The ERC may observe or cause to be observed procedures and records of the study during and after implementation.

Kindly quote the protocol identification number in all future correspondence in relation to this approved protocol

SIGNED.....Bannerman.....
Dr. Cynthia Bannerman
(GHS-ERC Chairperson)

Cc: The Director, Research & Development Division, Ghana Health Service, Accra

GHANA COLLEGE OF PHYSICIANS AND SURGEONS
FACULTY OF PUBLIC HEALTH

OUR REF:
Tel: +233-(0)302-238650
+233-(0)302-238703
Email: fph@gcps.edu.gh

P. O. Box MB 429
Ministries
Accra

1st November, 2021

REGIONAL DIRECTORS OF HEALTH SERVICES,

REGIONAL HEALTH DIRECTORATES,

GHANA HEALTH SERVICE.

Sir/Madam,

LETTER OF INTRODUCTION-DR. ERIC ODEI

I wish to introduce to you Dr. Eric Odei, a Senior Resident in the Faculty of Public Health who is conducting a study titled "**Spatiotemporal relationships between dog bites, dog vaccination coverages, dog and human rabies, Ghana: Implications for One Health, 2021**" as part of the requirement for the award of Fellowship in Public Health which he is pursuing at the College.

The study aims to investigate spatiotemporal relationships between dog bites, dog vaccination coverages, dog and human rabies and their implications for One Health collaboration for elimination of rabies in Ghana. It involves mapping and analysis of national rabies-related data in Ghana from routine management information systems' data from both the animal and human health sectors as well as a desk review of policies and programs related to dog and human rabies control and elimination. Key informant interviews will be conducted among personnel of both sectors at the national, regional and district levels. Lastly, a survey to assess the knowledge, perception and practices of personnel from both sectors with respect to One Health collaboration in 12 selected districts in Ghana will be conducted. At all stages and levels of implementation, he has committed to complying with the relevant ethical requirements. Please find attached a copy of the ethical approval he has obtained from the Ghana Health Service Ethics Review Committee.

It is anticipated that findings of the study will be of applied policy and practice relevance to help identify gaps in the formulation and implementation of One Health policy in Ghana. In addition, it is expected that findings of the study will help foster closer collaboration between staff from both sectors as Ghana sets out to eliminate human deaths from dog-mediated rabies by 2030 using the One Health approach.

In addition, it is expected that findings of the study will help foster closer collaboration between staff from both sectors as Ghana sets out to eliminate rabies by 2030 using the One Health approach.

Grateful if he could be given the necessary assistance, support and cooperation from you as he begins, with your permission, data collection from selected facilities in your Region.

Thank you in advance.

Yours faithfully,

Dr. Delanyo Dovlo
Chair, Faculty of Public Health, GCPS.

REPUBLIC OF GHANA

MINISTRY
OF
FOOD AND AGRICULTURE

(VETERINARY SERVICES
DIRECTORATE)

P.O. BOX M 161, ACCRA
Digital Address: GL-005-6899
Kindly quote this number and date on all correspondence.
My Ref. No VSD/TRG/11/21/03
Your Ref. No. _____
Date. 09/11/2021

LETTER OF INTRODUCTION- DR. ERIC ODEI

I have the pleasure to introduce to you **Dr. Eric Odei**, a Senior Resident in the Faculty of Public Health who is conducting a study titled "**Spatiotemporal relationships between dog bites, dog vaccination coverages, dog and human rabies, Ghana: Implications for One Health, 2021**" as part of the requirement for the award of Fellowship in Public Health which he is pursuing at the College.

The main aim of the study is to investigate spatiotemporal relationships between dog bites, dog vaccination coverages, dog and human rabies and their implications for One Health collaboration for elimination of rabies in Ghana. He has been granted permission by the Veterinary Services Directorate to start data collection at the national, regional and district levels as per the approved protocol.

Kindly give him the needed assistance and cooperation for the successful implementation of the study at the aforementioned levels. It is envisaged that his findings could potentially be of policy and practice relevance to rabies elimination in Ghana through the One Health initiative.

Thank you in advance.

DR. PATRICK ABAKEH
(AG. DIRECTOR OF VSD)

CC: ALL REGIONAL VETERINARY OFFICERS