DOG POPULATION DEMOGRAPHICS AND ECOLOGY IN ASEMBO, SIAYA COUNTY: IMPLICATIONS FOR RABIES CONTROL

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DEDICATION

This work is dedicated to all young people who desire to get to the world of science and research.

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LISTOFABBREVIATIONS

CDC- Centre for Disease Control and Prevention

CFSPH- Centre for Food Security and Public Health

CGHR- Center for Global Health Research

CI – Community Interviewers

CNS- Central Nervous System

DALYs- Disability Adjusted Life Years

dRIT- Direct Rapid Immunohistochemical Test

FAD- Flea Allergy Dermatitis

GARC- Global Alliance for Rabies Control

HDSS- Health and Demographic Surveillance System

KEMRI- Kenya Medical Institute of Research

PCR- Polymerase Chain Reaction

PDA- Personal Digital Assistant

PEP- Post exposure prophylaxis

TVT- Transmissible Venerial Tumor

USD- US Dollars

WHO- World Health Organization

ZDU- Zoonotic Disease Unit

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ABSTRACT

Every year an estimated 59,000 people die from rabies globally. Domestic dogs transmit over 99% of human rabies cases, and mass dog vaccination is a key strategy for achieving elimination of dog-mediated human rabies global target by 2030. Achieving and maintaining herd immunity against rabies within domestic dog populations can be influenced by dog demographic and ecological factors. To estimate parameters for these factors, a six-month dog health and demographic surveillance study was conducted within an ongoing linked Human-Animal Syndromic Surveillance System covering 1500 households in rural Western Kenya. Structured questionnaires were administered to study households to collect information related to dog demographics, ecology and health relevant to rabies transmission. These data collected included dog ownership patterns, age and sex structure, dog management practices, rabies vaccination status, birth rates, death rates, survival rates, dog morbidity and mortality rates and their associated risk factors, human-dog mediated movements and dog bite information. Data were analysed using R statistical software (version 3.4.1) and QGIS (version 2.18.14). In total, 1213 households in 10 study villages consented to participate in the study.A total of 460 (38%) of the households owned dogs, with an average of 1.7 dogs per dog-owning households and 802 dogs were recruited at the beginning of the study. The estimated dog to human ratio was 1:6.9 and the dog density ranged between 50-57 dogs/km^2. Half of the dog population was $\leq$ 1 year pointing to high dog population turnover rate. The birth rate was 1.8 puppies/female dog/year, mean litter size 3.9 was reported. The litter size increased to a maximum of 4.9 for bitches in age category 3-4 years, similarly the fecundity rates peaked (3.3) in age category of 2-3 years.

Mortality rate was higher (43%) in dogs less than one year. Females had a lower life expectancy (2.8 years) compared to males (4.1 years).

New additions to the initial recruited population of dogs were mostly own litters (55.7%) and gifts from neighbors(37.1%) while losses were mainly attributed to dogs that disappeared(63.9%) from households and never returned or 32.6% given away as gifts.

Dog population management was low with only 5.1% of the males and 0.3% of the females castrated and spayed, respectively. In the absence of mass dog vaccination campaigns, rabies vaccination coverage was 5.1%. A larger proportion of the dogs either roamed freely (61.2%) or were partially (38.4%) restricted with only 0.4% of the dogs completely restricted within households. Most (97.4%)dogs were not fed at home but left to scavenge for leftovers from household garbage dumping sites and elsewhere. The dogs were predominantly the local mongrel breed (98%), and mainly kept for security purposes (97%). Twenty-seven (27) human dog bites cases translating to a bite incidence of 820bites /100,000 peopleand 6 dog rabies confirmed cases translating a rabies incidence rate of 125 in 100,000 dog population were reported.

In the absence of active rabies elimination program, the low vaccination coverage, unrestricted dog movement, and the high dog turnover rates support rabies endemicity among domestic dogs. High turn-over rates may make it necessary to conduct vaccination campaigns for dogs several times a year to maintain the herd immunity. Canine rabies control programs should encourage good dog management and promote responsible ownership to minimize spread of the rabies virus among dog populations. Effective dog rabies control plans should improve rabies vaccination coverages and reduce dog turnover rates to maintain herd immunity for longer. More active surveillance of rabies in both human and animal populations is required

CHAPTERONE

1.0 Introduction

Rabies is a neglected zoonotic disease that has been reported in all continents exceptAntarctica and is endemic in Africa, Asia and South America (Hampson *et al*., 2009)**.** Rabies kills an estimated 59,000 people annually with 59.6 % and 36.4% of the burden in Asia and Africa, respectively(Hampson *et al*., 2015). Globally, the economic cost due to rabies is estimated at 8.6 million USD annually and about 3.7 million Disability Adjusted Life Years estimated globally by the year 2015(Hampson *et al*., 2015).Rabies is endemic in Kenya with varying incidence levels. Kitala *et al.* (2000) estimated a rabies incidence of 2.5 rabies deaths per 100,000 people and 234 bites per 100,000 people annually during an active surveillance for the disease in Machakos and Makueni districts. Approximately 860 rabid dogs per 100 000 dogs per year were confirmed yet only 12 per 100 000 confirmed rabid dogs had been reported by the existing passive surveillance system.

In Africa, the domestic dog is the principal reservoir and the maintenance host for the rabies virus and is responsible for the transmission of 95% of the human rabies cases. Therefore, elimination of rabies from domestic dogs is likely to reduce rabies cases in humans and other species (Lembo *et al*., 2010; Morters *et al*., 2013). Mass dog vaccination reaching 70% of the dog population is required to break dog-dog transmission and has been identified as the most cost effective strategy for elimination of human-dog mediated rabies (WHO, 1987; Coleman, 1996).

Achieving 70% vaccination coverage allows for “population immunity” breaking rabies transmission chains. Population immunity is, however, influenced by dog population demographics and dynamics. High dog population turnover rate leads to rapid decline in herd immunity between vaccination intervals as new naïve dogs are introduced into the

population mostly through births (Hampson *et al.,* 2009; Gsell *et al*., 2012). Information on dog population demographics and dynamics is critical in the design and implementation of rabies control and prevention programs.

In prioritization of zoonotic diseases in Kenya based on the severity of illness in humans, epidemic potential, socioeconomic impact, prevalence/incidence and potential for effective intervention, neglected zoonotic diseases in Kenya were ranked highly with rabies the third in priority (Munyua *et al*., 2016).

In 2014, the Kenyan government through the Zoonotic Disease Unit launched a National Rabies Elimination Strategic Plan which focuses on elimination of dog-mediated human rabies by the year 2030.The pillars for this strategy are mass dog vaccinations, timely provision of post exposure prophylaxis to dog bite cases, strengthen both animal and human surveillance, advocacy, communication and resource mobilization(ZDU, 2014).Effective planning of vaccination campaigns requires a good understanding of dog population sizes, ecology and dynamics. Studies on dog health and demographics can be informative in providing data towards sound planning of dog vaccination campaigns and sustaining herd immunity towards rabies elimination.

This study identifies and estimates the key dog demographics and ecological parameters underlying rabies transmission, and rabies infections in Asembo, Siaya County.

1.1 Objectives

1.1.1 Overall objective

To determine dog population demographics and ecology and its implications for rabies control in Asembo, Siaya County.

1.1.2 Specific objectives

1. To identify factors of dog population demographics and ecology relevant to spread of rabies in Asembo, Siaya County.
2. Using information obtained in objective 1, develop a rabies control strategy for Siaya County.

CHAPTER TWO

2.0 Literature review

2.1 Background

Rabies is an important zoonotic disease affecting mostly low and middle-income countries and has huge burden on both animal and human health, economy and wildlife conservation (Lembo *et al.*, 2010). Globally rabies kills about 59,000 people annually mostly in Asia (59.6%) and Africa (36.4%)(Hampson *et al.*, 2015). The general reservoirs to the rabies virus are the dog, cat, fox, skunk, racoon, bobcat, coyote, mongoose and other small carnivorous animals (Swango, 1995). In most parts of Africa, the domestic dog (*Canis familiaris*) is the main reservoir host of the rabies virus but in southern Africa the jackal (*Canisadustus* and *Canismesomelas*) and the yellow mongoose are reservoir hosts too (Bingham, 2005).

In Kenya, animal rabies is a notifiable disease stated under the Disease Control Act and Rabies Act Cap 365. Any suspected outbreaks should be reported to the Director of Veterinary Services. Confirmatory diagnosis of rabies suspect samples from animals is done at The Central Veterinary Laboratories in Kabete.

2.2 Epidemiology of rabies

2.2.1 Aetiology

Rabies virus is a Lyssavirus belonging to the Rhabdoviridae family (WHO, 2014).

Thereare five main genotypes of the rabies virus and Genotype 1 (Rabies virus, RABV) is the most common in Kenya(WHO, 2014). The others are Genotype 2 (Lagos bat virus, LBV), Genotype 3 (Mokola virus, MOKV), Genotype 4 (Duvenhage virus, DUVV), and the newly isolated Shimoni bat lyssavirus isolated in bats in Shimoni caves in Kwale County(Kuzmin *et al.*, 2010). The Lagos bat virus has also been isolated in bats in Mount

Elgon caves (Kuzmin *et al*., 2010). Human rabies is mostly due to canine biotype of RABV (WHO, 2014). The rabies virus is heat labile and susceptible to destruction by common disinfectants (Swango, 1995).

2.2.2. Geographical distribution

Rabies has been reported in all continents except Antarctica and is endemic in Africa, Asia and South America(Hampson *et al*., 2009). Some countries like the United Kingdom, Japan, New Zealand, Ireland, Sweden, Norway, Australia, Singapore, Papua New Guinea, Pacific Islands and Indonesia have been free of classical rabies for many years(CFSPH, 2009). Western Europe and North America have eliminated rabies in dog populations (Hampson *et al.*, 2009). In Ireland and other rabies free countries, introduction of rabies was prevented through restriction of entry of dogs from outside the country (Radostits*et al.*, 1994). However, in the industrialized world, after controlling rabies in domestic dogs, the virus has established itself in wildlife species especially the fox, skunks, racoon dogs and coyotes (Swango, 1995).

2.2.3Reservoirs and maintenance hosts

All warm-blooded mammals are susceptible and can harbor the rabies virus but birds are resistant to the virus. The most susceptible animals are the skunks, wild canids/foxes, racoons, bats and cattle. Horses, dogs, sheep, cats, goats, nonhuman primates and humans are also susceptible (Swango, 1995). In Africa, the domestic dog is the primary maintenance host for the rabies virus although bats and other wildlife carnivores play a role in sustaining the infection hence a barrier to rabies elimination in the continent(Alexander, 1994;Lembo *et al*., 2008). Most human rabies deaths in American countries have been caused by bats although other deaths from raccoons, foxes, mongoose, jackals and skunks have been rare(Bingham, 2005).A studyin Tanzania concluded that domestic dogs are the

only population essential for persistence of the virus although other carnivores are non-maintenance hosts of the rabies virus (Lembo *et al*., 2008).

2.2.4 Transmission and pathogenesis of rabies

The rabies virus has a broad mammalian host range and is transmissible among mammals of same or different species(WHO, 2004;Bingham, 2005; CFSPH, 2009).The virus is mostly transmitted in saliva through bite of an infected animal (Bingham, 2005). Transmission cannot occur through intact skin species (WHO, 2004; CFSPH, 2009).The virus then replicates at the site of inoculation and travels through the peripheral nerves by retrograde axoplasmic flow to the central nervous system (CNS). The incubation period ranges between 2 weeks and 6 years with an average of 2-3 months and is dependent on the site of bite and amount of inoculum of the rabies virus, strain of the virus and innervation of the bite site(WHO, 2004). The more proximal the site of virus entry is to the CNS, the shorter the incubation period. During the incubation, virus shedding and clinical disease cannot be seen(Bingham, 2005).From the CNS, the virus then moves outwards via anterograde axoplasmic flow within peripheral nerves infecting non-nervous tissues adjacent especially salivary glands(WHO, 2004). It is the infection of the salivary glands that leads to the shedding of virus in saliva (Bingham, 2005). The blood does not contain any virus, but it is present in many tissues and organs such as the kidneys, CNS, salivary glands and muscle(WHO, 2004). Rabies has also been transmitted during organ transplant from infected donors(Guarner *et a*l., 2005: Bronnert *et al*., 2007). In China, rabies was transmitted during kidney transplant from an infected donor(Zhou *et al.*, 2016).

2.3 Control and prevention

The most epidemiologically feasible and cost-effective approach to elimination of human-dog mediated rabies and rabies in all species is through vaccinations(Lembo *et al*., 2010; Morters *et al*., 2013; Cleaveland *et al.,* 2014). To break rabies transmission cycles, 70% dog vaccination coverage is recommended (WHO 1987; Coleman, 1996).The government of Kenya through the Zoonotic Disease Unit developed a rabies elimination strategic plan that seeks to eliminatedog mediated human rabies by the year 2030. The main pillars for this strategy include; eliminating rabies from dogs through mass dog vaccinations targeting 70% of the dog populations for three consecutive years; prevention of rabies in humans through timely provision of post-exposure prophylaxis to the bite cases, strengthening human and animal rabies surveillance and prompt response to rabies outbreaks; conducting operational research to support implementation, and advocacy and communication through increased community awareness on rabies prevention and control(ZDU, 2014). Mexico, Indonesia and Philippineseliminated rabies through dog population control and massive vaccinations, management of dog bites, public awareness and rabies surveillance. Western Europe and North America have eliminated rabies in dog populations (Hampson et al., 2009).

One of the major setbacks in rabies control in Africa is unavailability of accurate data on the real public health impact of the disease due to underreporting and neglect(Cleaveland *et al*., 2001). (Lembo *et al*.(2010)noted that there is scarce knowledge about sizes of dog populations for effective planning of mass vaccination campaigns. Most of the domestic dogs in Africa are accessible for vaccination, therefore factors like low vaccination coverage can be improved through community engagement and education awareness programs(Lembo *et al*., 2010).High dog population turnover rates have been a major obstacle to controlof rabies in developing countries(Hampson *et al*., 2009). The high birthrates and death rates lead to rapid replacement of anti-rabies immunized ones with

new susceptible ones. The decrease in herd immunity should be accounted for in designing and implementing rabies control strategies (Gsell *et al.*, 2012).

In addition to improved surveillance, a One Health approach involving the veterinary, public health, wildlife conservation and animal welfare sectors is required for rabies control Cleaveland *et al*., 2006;Hampson *et al*., 2015). Effort should be directed towards public education on the need to confine free-roaming dogs and vaccination of all dogs regardless of age (Davlin*et al.*, 2013).

2.4 Public health and economic burden of rabies

Rabies is one of the neglected diseases yet it poses a huge burden on human and animal health, the economy locally and nationally as well as wildlife conservation(Knobel *et al*., 2005).The burden of rabies is estimated in form of mortality, morbidity, Disability Adjusted Life Years (DALYs) and the economic impact it causes. Globally, human deaths due to rabies are estimated at 59,000 annually with majority occurring in Asia (56.6%) and Africa (36.4%) with the highest per person death rate in poorest sub-Saharan countries (Hampson *et al.*, 2015).

About 3.7 million DALYs are lost globally mostly in Asia and Africa due to rabies. The greater portion of DALYs was due to premature deaths occurring following rabies exposure. Anxiety and psychological trauma of human dog-bite cases and their families from suspected rabid dogs accounts for substantial burden that cannot be quantified in monetary terms (Hampson *et al*., 2015). The horrifying symptoms of human rabies and the possible fatal outcomes not only traumatizes the families but also to the communities and health care workers (Lembo *et al*., 2010).

The economic burden of rabies is reflected both directly and indirectly in the government and household budgets. The direct costs arise from post-exposure prophylaxis and vaccination and surveillance costs in control of rabies among dogs(Knobel *et al.*, 2005).

Theglobal economic cost of canine rabies was estimated at 8.6 billion USD. This comprises mainly costs due to productivity losses following premature deaths from rabies (2.27 billion USD), direct costs of post exposure prophylaxis (PEP) (1.70 billion USD) and thelost income while seeking PEP (1.31 billion USD) (Hampson *et al*., 2015). Deaths in livestock due to rabies amounts to 512 million USD annually with great losses in livestock-dependent African countries and Asia. Vaccination of dogs amounted to < 1.5% ($130 million) of the total economic burden but this varied between countries (Hampson *et al*., 2015).

In Kenya, the exact economic and social burden of rabies has not been clearly quantified and there is need for such studies.From unpublished sources, the cost of anti-rabies vaccine following a dog bite varies greatly between counties in Kenya. For instance, the vaccine is free in Makueni County, the cost is subsidized atKshs 500 (5 USD) per dose in Siaya County while it remains at Kshs 1500 (15 USD) per dose in the rest of the counties.The major challenges to PEP seeking are unavailability of the anti-rabies vaccine in most of health facilities except the subcounty and referral health facilities, the high cost of the doses, extra cost of movements in search of the vaccine and lack of knowledge on the need for PEP following exposure.

2.5 Dog population demographics and ecology

The key dog demographics and ecology parameters relevant to transmission and elimination of rabies include; birthrates, death rates, age and sex ratios, litter size, litter frequency, puppy survival, population growth and density, dog management and handling practices*(*Kitala *et al.,* 2001;Hampson *et al*., 2009). Dogs depend almost entirely on humans for shelter and food in Africa hence correlating dog populations to human population both by size and distribution (Hambolu *et al*., 2014). High human:dog ratios, high dog densities and a high percentage of dogs that have not been vaccinated have play a role in rabies transmission and maintenance (Hambolu *et al*., 2014). Most studies have

reported a male predominance, and a considerable proportion of young dogs (30%) of the dog population is composed of puppies below 3 months (Jibat *et al*., 2015). High dog population turnover rates due to high birth rates and high death rates lead to rapid replacement of the anti-rabies immunized dogs with new susceptible ones hence a decline in populationimmunity. This has been a major obstacle to controlling rabies in Africa(Hampson *et al*., 2009;Gsell *et al*., 2012).

In Africa, most dogs are owned and therefore accessible for vaccination against rabies if it is performed without a fee (Jibat *et al*., 2015). Most owned dogs are free-roaming and unrestricted especially in areas with higher dog population density and the vaccination coverage remains very low(Ortega-pacheco *et al*., 2007). Dogs that roam freely may be arisk to health of humans through bites, possibility of accidents on the roads and the potential spread of other diseases that are zoonotic(Schildecker *et al*., 2016).

Beside previous longitudinal studies in *et al.* Kenya (Kitala *et al.*, 2001), South Africa (Conan *et al.*, 2015*)*, Tanzania (Hampson *et al.*, 2009; Czupryna *et al.*, 2016) and Uganda (Hyeroba *et al*, 2017) in Africa, most other studies on demographics and ecology have been cross-sectional. The main weakness of cross-sectional studies is that it is difficult to estimate demographic parameters such as birth rates, death rates and causes of morbidity and mortality which inform on the dog population turn over. The longitudinal study platform provides an invaluable opportunity to demographic and health dynamics of dog population in a rural setting overtime. Establishing dogs' morbidity, survival and mortality rates and the associated risk factors related to rabies allows to estimate their impact on various rabies control and elimination strategies. Health and Demographic Surveillance System (HDSS) sites provide platforms for various research activities and intervention studies (Sankoh and Byass, 2012). The INDEPTH Network lists 36 HDSSs in Africa which can be utilized for conducting dog surveillance alongside human and animal studies.

CHAPTER THREE

3.0 Materials and methods

3.1 Study area

This study was conducted in Asemboin Rarieda Sub County, Siaya County, Western Kenya withinan existing Health Demographics and Surveillance System (HDSS) platform run by Kenya Medical Research Institute (KEMRI) in collaboration with Centers for Disease Control, Kenya (CDC)(Odhiambo *et al*., 2012).The HDSS area covers 385 villages that lie to the North-East of Lake Victoria including Siaya, Rarieda and Gem Sub-counties in Siaya County. The HDSS has demarcated villages and households using Geo-coordinates. Within the HDSS is an ongoing Linked Human-Animal Syndromic Surveillance study working in 1500 households in 10 villages randomly selected from the 33 villages of Asembo(Thumbi *et al*., 2015). All households participating in the Linked Human-Animal Syndromic surveillance study were legible forrecruitment into the study.

The County is one of the five pilot counties for the rabies elimination strategy in Kenya launched in 2014 by the government of Kenya to eliminate human-dog mediated rabies by the year 2030 (ZDU, 2014).Asembo was selected for this study because of the linked human-animal surveillance study on the Health and Demographic Surveillance System (HDSS). Figure 3.1 is a map showing the study villages and distribution of households.

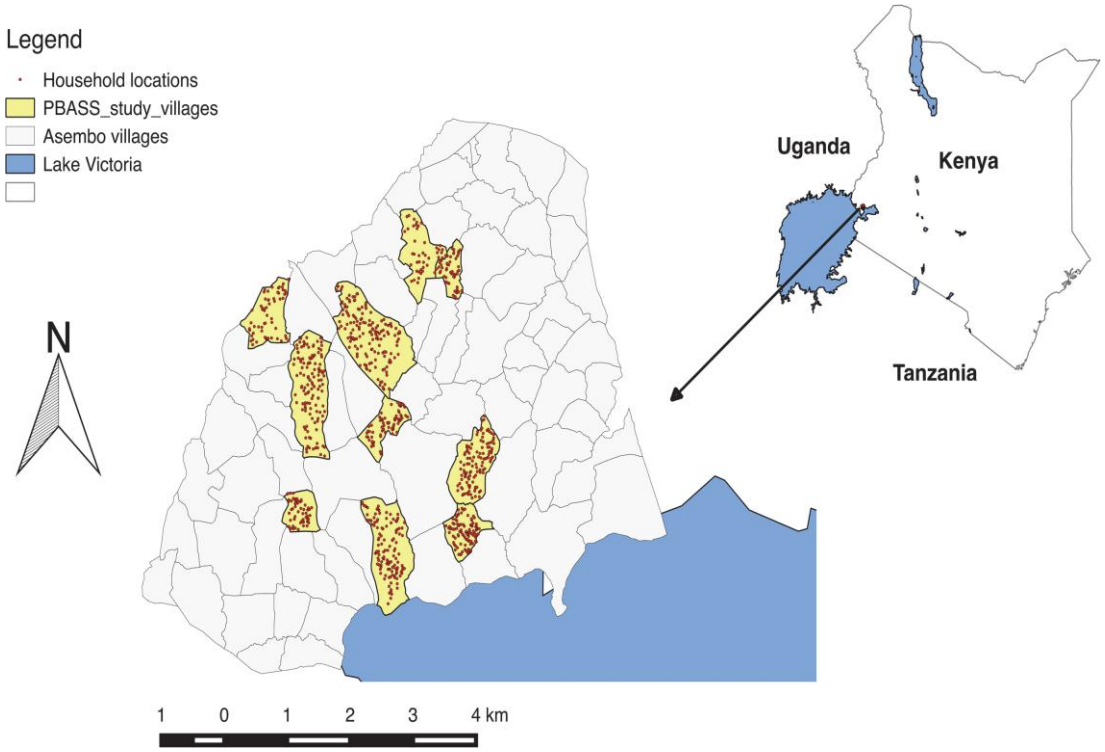


Figure 3.1: A map of Kenya showing the location of Asembo in Siaya County.

3.2 Sampling and study design

One stage cluster sampling was used to identify the study villages. Ten villages were randomly selected from the 33 villages of Asembo. All the households within the 10 villages (1500 households) were legible for enrolment into the study.

This was a longitudinal study whereby dogs, both dog owning and non-dog owning households were followed-up monthly for 6 months. Eachdog and the household were given a unique identification number which they retained till the end of the study.Figure 3.2 shows the study design and the types of data collected.

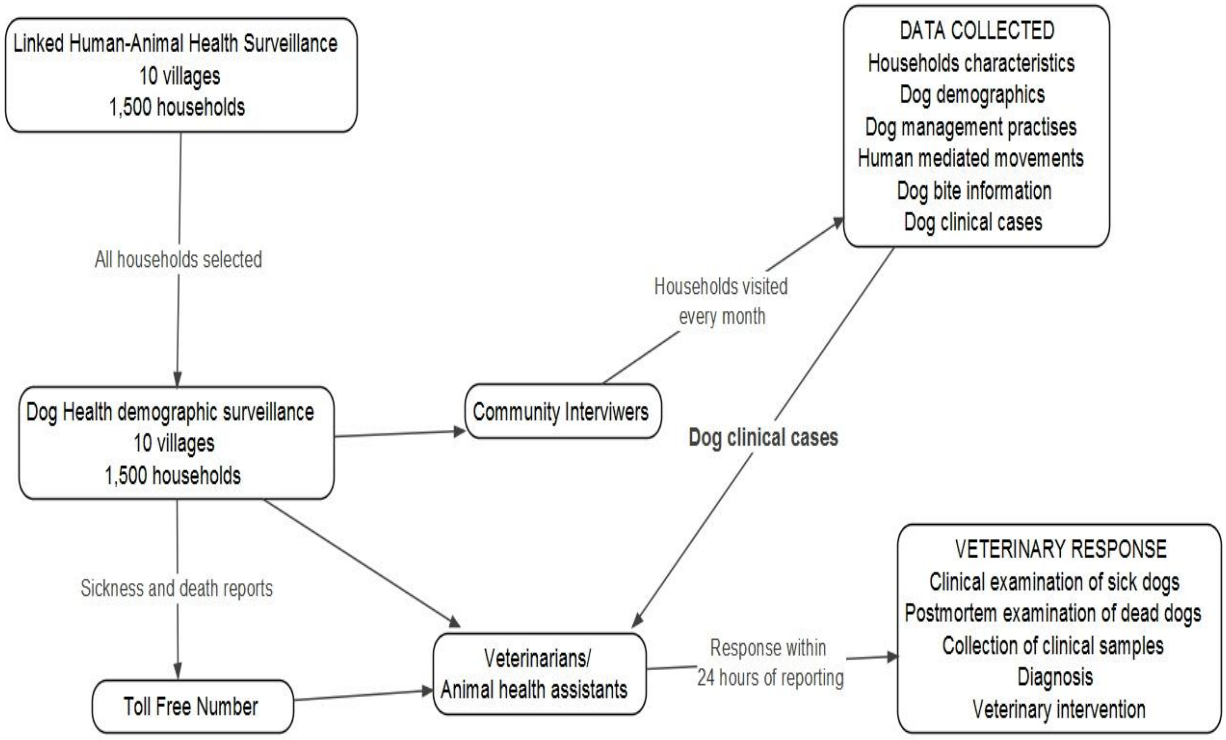


Figure 3.2:Schematic diagram of the design and implementation of the dog cohort study in Siaya County, 2017.

3.3To identify factors of dog population demographics and ecology relevant to spread of rabies in Asembo, Siaya County.

Three sets of questionnaires including dog ecology and demography questionnaire (Appendix 1), follow-up questionnaire (Appendix 2) and a clinical response questionnaire (Appendix 3) were designed and programmed on a personal digital assistant (PDA) for electronic data capture. The questionnaires were administered via personal interviews to either the head of the household, spouse or any adult member of the household. A questionnaire was administered during the recruitment visit, while additional questionnaire administered once a month during the follow up visits. The clinical response questionnaire was administered by the veterinarian/animal health assistants during veterinary response following dog sickness and death reports. Information on dog demography and ecology was collected including dog numbers per household, sex, age, reproductive indices, dog

management practices and dog handling were collected (Appendix I). Appendix II contains data collected during monthly follow up visits including mortality, births, dog movements since last visit and additions. Data on dog health collected deaths, sickness and disease diagnoses (Appendix III).

3.3.1DRIT (Direct Rapid Immunohistochemical Test)

Polyclonal antibody labelled with a biotin-moiety was used. An impression of the brain tissue was done allowing an anatomic-pathologic appreciation of viral inclusions in neurons. The linker antibody was negated by the subsequent addition of streptavidin that has a high affinity for the biotin moiety. The streptavidin was tagged to a reporter enzyme that was used to catalyze the formation of a colored precipitate once the antibodies are bound to the rabies virus (RABV) antigens in the presence of an appropriate substrate,hydrogenproxide(H_2O_2) and chromogen (AEC). The stained tissue was then observed under alight microscope (x40) for Negri inclusion bodies.

3.3.2Conventional PCR

The brain tissue was extracted using QIAGEN kit and a master mix was prepared using rabies virus specific primers. The extracted brain tissue was mixed with mastermix and subjected to PCR (via thermocycler) and finally to gel electrophoresis. The amplified viral DNA were then observed under gel illumination instrument for their presence or absence. This was compared against a positive control.

3.4 Using information obtained in objective 1, develop a rabies control strategy for Siaya County

The following demographic and ecological parameters will be used to develop a rabies control strategy for Siaya County; dog population turnover-birthrates and death rates, dog

management practices- feeding, movement restriction and breeding control, rabies incidence, human- dog bites and vaccination coverage.

3.5 Data handling and analysis

Data were downloaded from PDAs in an access format at the end of each working day and backed-up. Data were then imported to R statistical software (Version 3.4.1) for cleaning and analysis. Qgis software (version 2.18.14) was used for mapping of dog owning, non-dog owning households and rabies positive cases. Life expectancies were computed using Microsoft Excel.

Number of households, dogs and ages were summarized as means (95%CI) and percentages (%) while dog sex, dog management practices, dog movement, causes of morbidity and mortality as proportions. The data were also summarized as graphswhere applicable.

The total number of dogs in Asembo was calculated by multiplying the average number of dogs per household by the total number of households or multiplying the total number of people by the dog: human ratio. The number of dogs obtained was then divided by the size of Siaya Countyin square kilometresto estimate dog density.

Dog population mortality ratesfor different age classes were computed using the approximate denominator method as (number of dogs dying in a specific age group)/ Initial plus final number of dogs divided by 2. This was then extrapolated to one year(Martin *et al*, 1987).

Fecundity rateswere calculated as the number of female puppies per female dog per year Caughley (1977). Life expectancies were computed in Excel using the method of Chiang (1984)

Dog bite incidence was calculated as number of people bitten by dogs divided by total number of people in the 10 households multiplied by 100,000. Incidence of rabies was calculated as number of rabies positive cases in dogs divided by total number of dogs in the 10 households multiplied by 100,000.

3.6 Ethical clearance

The study received ethical approval from KEMRI/Scientific and Ethics Review Unit (SERU) (Ref No. KEMRI/SERU/CGHR/046/3268). A written consent was also obtained from the household head to participate in the study.

CHAPTER FOUR

4.0 RESULTS

4.1 Response rate

A total of 1213 (80.7%)of 1500 households agreed to participate in the study, 12.1%(182) were consistently not at home while 7% (105) refused to participate in the study.However, during the follow up visits, there was a variation in the number of households visited because some had no one at home for 3 consecutive visits per follow up.

4.2 Household characteristics and dog ownership

The mean number of people per household was 4.7. Children under 15 years of age accounted for 37.5% of the total human population in the study households.Dog ownership was not common with only 38.7% of the surveyed households owing dogs (Table 4.1). The mean number of dogs per household was 0.7 and 1.8 dogs per dog-owning households. Dog ownership was steady in the 6-month follow-up period (7 visits) and ranged from 37.9% to 39.8%. The dog:human ratio was 1:6.9 (Table 4.1). Figure 4.1 shows the distributionof dog owning and non-dog owning households, the distribution was uniform. Out of the 714 non-dog owning households, 69.9% had owned dogs previously but did have them at the time ofvisit because the dogs had either died from disease (62.5%), killed through trauma (18.8%), given away(11.2%) while 7.5% did not know what happened to their dogs. Of those who did not own dogs, 43.6% said they did not like dogs, 22.5% said dogs were expensive to maintain while 33.9% did not give a reason on why they did not keep dogs. About 11.8% households that did not own dogs at recruitment acquired dogs during the observation period. Only 12(2.7%) of the surveyed households had secure fences around their homesteads that completely restrained the dogs' movement whereas 55.4% and 41.9% had no fence at all and partial fence, respectively. This allowed dogs to move in and out of the homesteads. Most households (42.5%) disposed their garbage at a

corner within the homestead and 18.6 % outside the homestead and 38.9% had special pits for garbage disposal.

Table 4.1: Longitudinal household characteristics and dog ownership patterns in Asembo, Siaya County, February- August 2017

Visit No.	No. of HH*	No.of Dog owning HH*	Dog ownership (%)	No. of dogs	No. of HH* members	Dog: human ratio
1	1213	460	37.9	802	5679	1:7.1
2	1074	414	38.5	769	5010	1:6.5
3	1134	438	38.6	760	5424	1:7.1
4	1214	483	39.8	866	5630	1:6.5
5	1177	447	38.0	753	5436	1:7.2
6	1190	462	38.8	801	5548	1:6.9
7	1150	455	39.6	780	5511	1:7.1
Mean	**1165**	**451**	**38.7**	**790**	**5463**	**1:6.9**

HH* Household

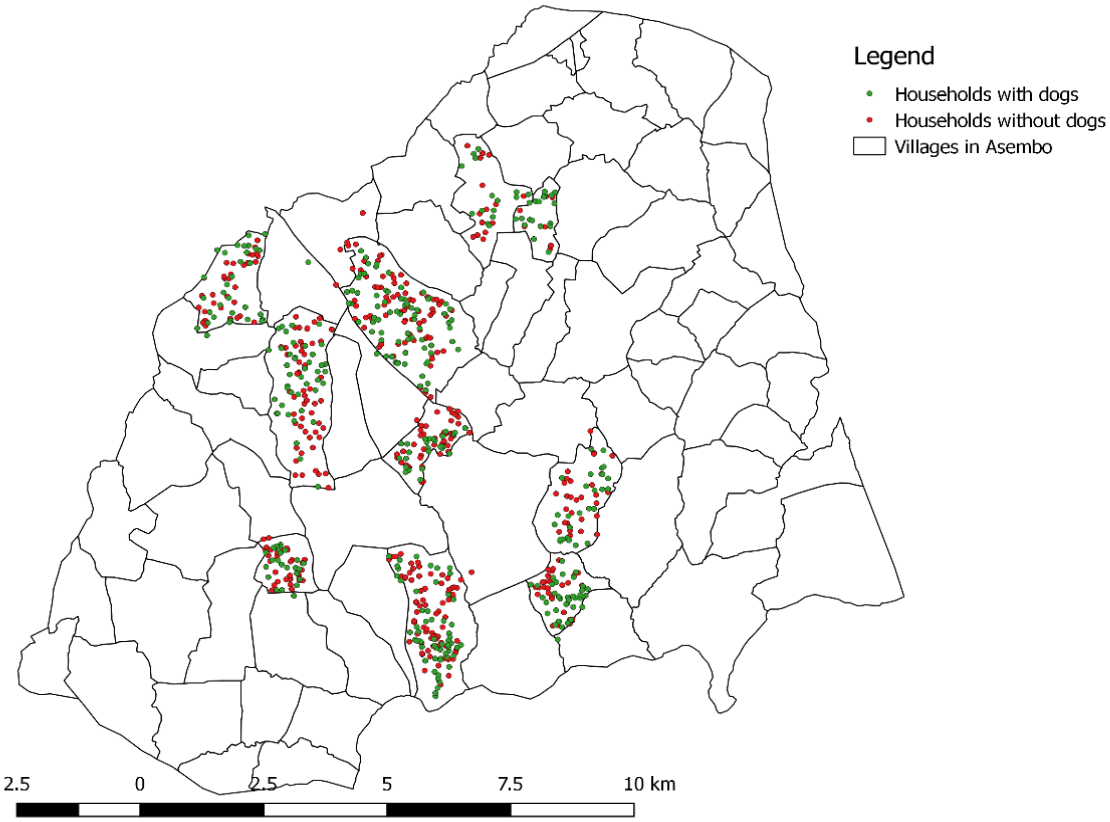


Figure4.1: The distribution of households with dogs and without in the 10 villages of Asembo, Siaya County, 2017

4.3 Dog population

A total of 802 dogs were found in the 1213 surveyed households converting to 0.7 dogs/ household (Table 4.2). Dog numbers remained unchanged during the 6-month follow-up period. Using the average number of dogs per household, the total number of dogs was calculated at 139,324 dogs and 122,073 using the dog:human ratio of 1:6.9. The dog density was estimated at 50dog/km^{-2} and 57 dog/km^{-2} using the dog: human ratio and average number of dogs per household, respectively.

Table 4.2:Dog population dynamics in a longitudinal study of dog owning households in Asembo, Siaya County, 2017.

Visit No	No. of HH	Number of dogs	No of dogs/dog-owning HH	No. of dogs/HH
1	1213	802	1.7	0.7
2	1074	769	1.9	0.7
3	1134	760	1.7	0.7
4	1214	866	1.8	0.7
5	1177	753	1.7	0.6
6	1190	801	1.7	0.7
7	1150	780	1.7	0.7
Average	1165	790	1.8	**0.7**

HH*Household

4.4 Age structure, sex and breed distribution

Of the 802 dogs at the beginning of the study, 110 were of unknown ages. Of the remaining 692 with known ages, 152 (22%) were puppies 3 months of age and less, 175 (25.3%) were more than 3 months of age and equal to or less than a year old, and 365 (52.7%) a year and above. This was a young dog population with about a half (47.3%) less than a year old. Figure 4.2shows the age-sex structure of the surveyed dogs. There were more male dogs than females over the 6 monthly visits. Overall, the male:female ratio was 1.4:1. Almost (98%) all the surveyed dogs were of the local mongrel breed and a few crossbreeds (1.1%) and purebreds (0.9%).

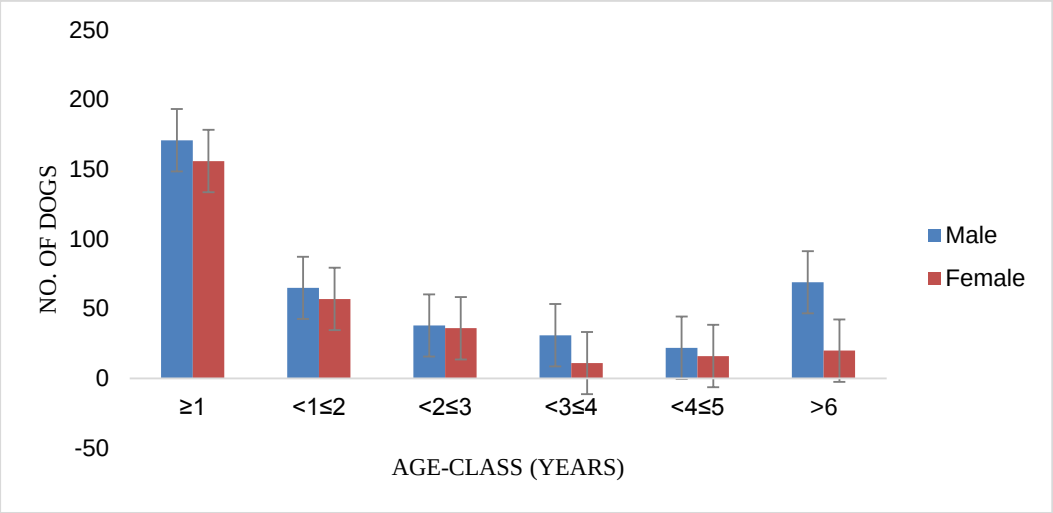


Figure 4.2:Age-sex distributionof 692 dogs in 1213 households in Asembo, Siaya County, 2017.

4.5 Reproductive Indices

During the six-month follow up of 324 bitches, 94 whelped for a litter rate of 1.8. The litter size increased by age to a maximum of 4.9 for bitches in the age category 3 to 4 years (Table 4.3). Similarly, the fecundity rates increased with age reaching a peak of 3.32 in age category of 2 to 3 years.

Table 4.3; Reproductive indices of 324 female dogs followed up for six months in Asembo, Siaya County, 2017.

Age class (Months)	No. of females	No. whelped	No. of puppies born	Litter size	No. of female puppies	Fecundity rate/6 months	Fecundity rate/year
<12	160	1	3	3.0	2	0.01	0.02
>12≤24	64	35	130	3.7	62	0.97	1.94
>24≤36	35	26	112	4.3	58	1.66	3.32
>36≤48	20	9	44	4.9	19	0.95	1.9
>48	45	23	72	3.4	36	0.80	1.6
Total		94	363				
Mean				**3.9**		0.88	1.76

4.6Mortality and survivorship

Dog mortality rates for different age classes were calculated using the approximate denominator method (Table 4.4). The rate of mortality was higher in dogs less than 12 months compared to other ages.

Table 4.4; Mortality rates of 692 dogs followed-up for six months in Asembo, Siaya County, 2017.

Age-class (months)	Initial No.	Final No.	No. dying	Mortality rate/6 months	Mortality rate/year
<12	327	355	148	**0.43**	0.86
>12≤24	122	69	28	**0.29**	0.58
>24≤36	74	87	14	**0.17**	0.34
>36≤48	42	73	18	**0.31**	0.61
>48≤60	38	36	9	**0.24**	0.48
<60	89	101	0	0.00	0.00

Using the life expectancy at birthestimated using the method of Chiang (1984), females had a lower life expectancy (2.8years) compared to males which had a life expectancy of 4.1 years.

4.7 Dog handling and management practices

Household dogs were handled almost equally by household heads (30.6%) and wives (34.9%). Children, surprisingly reportedly were able to handle only 10.9% of the surveyed dogs. Some dogs (23.6%) could be handled by any other member of the households. Feeding of owned dogs was uncommon with a huge majority (97.4%) of the dogs reportedly feeding on garbage and household wastes. Household garbage was fed by a

variety of dogs including household dogs (27.2%), neighbors' dogs (43.8%) and unknown dogs (29%). Dog population control through castration and spaying were rare with only 48 of the 395 surveyed male dogs (12.2%) having been castrated and 4.4% (13/291) of the female dogs having been spayed.

Dogs' movement restriction within owner's homestead was minimal. A high proportion (61.2%) were never restricted at any time of the day or night and were free to roam freely. A further 38.4% of the dogs were partially restricted in their movement through fencing, chained or being kept in a kennel. These dogs were free to roam either at night or during the day. Only 12 of the 1213 (1%) surveyed households had secure fences to keep their dogs within their compounds. Almost all (97.4%) of the surveyed dogs were reportedly kept for security purposes with only a small proportion (2%) being kept as pets and 0.6% as hunting dogs. Only 38 of the 745 surveyed dogs (5.1%) had reportedly been vaccinated against rabies and none against any other disease.

Dogs acquisition was fairly easy with 55.7% of the dogs being offsprings of own bitch, and 37.1% being gifts from within the neighborhood. Thus, the Asembo dog population was a closed one with minimalimmigration and emigration out of Asembo.

4.8 Humandog-bite cases

Between February and August 2017, 27 humandog-bites were reported. This translates to a bite incident rate of 1640per 100,000 persons per year. Eighteen of these bite cases were unprovoked. The most common bites were inflicted on the legs/feet (64.7%)as well as body trunk (23.5%) and arms/hands (11.8%).Of the total dog bite cases, 17/27 (63%) werechildren less than 15 years old. Only 5/27 (18.5%) bite casesreportedly had access to rabies post exposure prophylaxis.

4.9 Rabies confirmed cases

For the six-month follow up period ,10 brain specimens from rabies suspect animals were submitted for rabies diagnosis- 8 dogs (80%) and 2 cows. Of the dogs' specimens, 6(75%) were positive for rabies and 1 cow in dRIT and PCR. This translates to an incidence rate of 250 rabies cases in 100,000 dogs per year clustered in two villages of Asembo. Figure 4.3 shows the distribution of the positive samples.

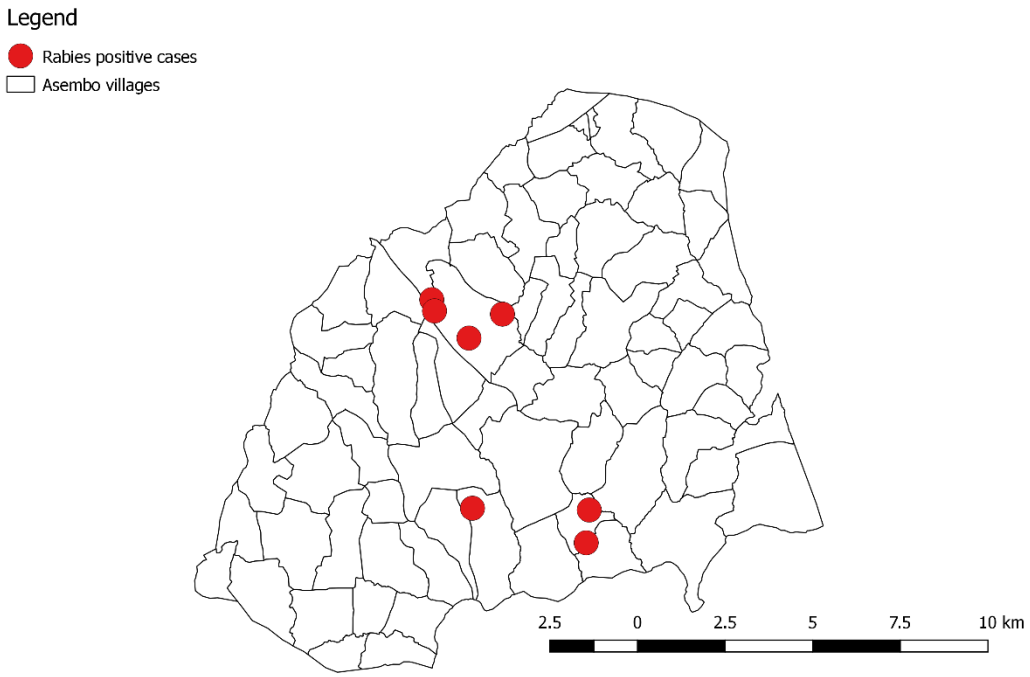
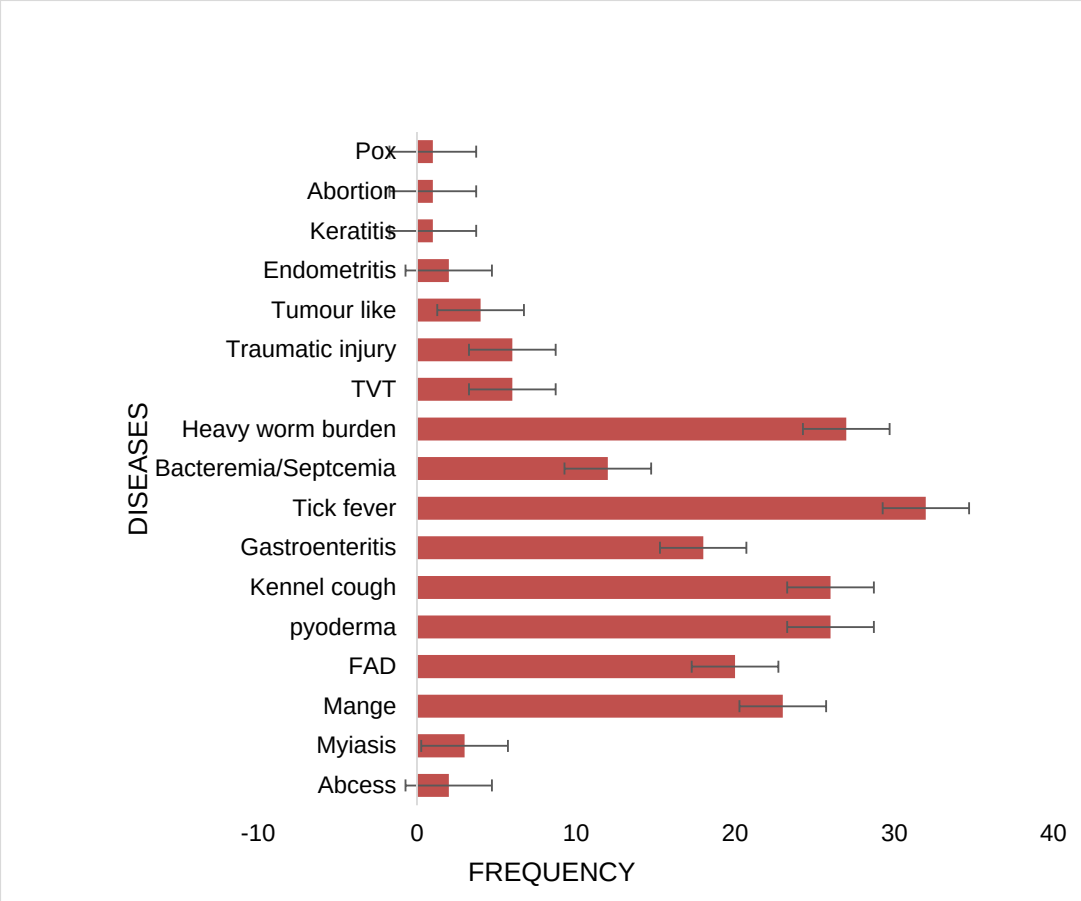


Figure 4. 3; Distribution of laboratory confirmed rabies cases (6 dogs, 1 cow) in Asembo between February-August, 2017.

4.10Morbidity and mortality in dogs

There were 500 reports of morbidity and death (298 sick dogs and 202 dead dogs) from community interviewers and the toll-free number but only 421 reports were responded to

by a team of veterinarians and animal health technicians. Following assessment by the veterinary team, 334/421 (79.3 %) reports were confirmed actual cases. Out of the 334, it was possible to provide a tentative clinical diagnosis for only 300 cases (215 sick dogs and 85 dead dogs). The common causes of sickness in dogs were tick fever, heavy worm infestation, kennel cough, pyoderma, mange, flea allergy dermatitis, gastroenteritis and bacteremia/septicemia in order of importance (Figure4.4). On the other hand, the common causes of mortality were bacteremia/septicemia, gastroenteritis, tick fever, poisoning, heavy worm infestation and rabies in order of importance (Figure 4.5).



FAD* Flea allergy dermatitis, TVT* Transmissible Venerial Tumor

Figure 4.4: Diseases of 294 surveyed dogs in Asembo, Siaya County, 2017.

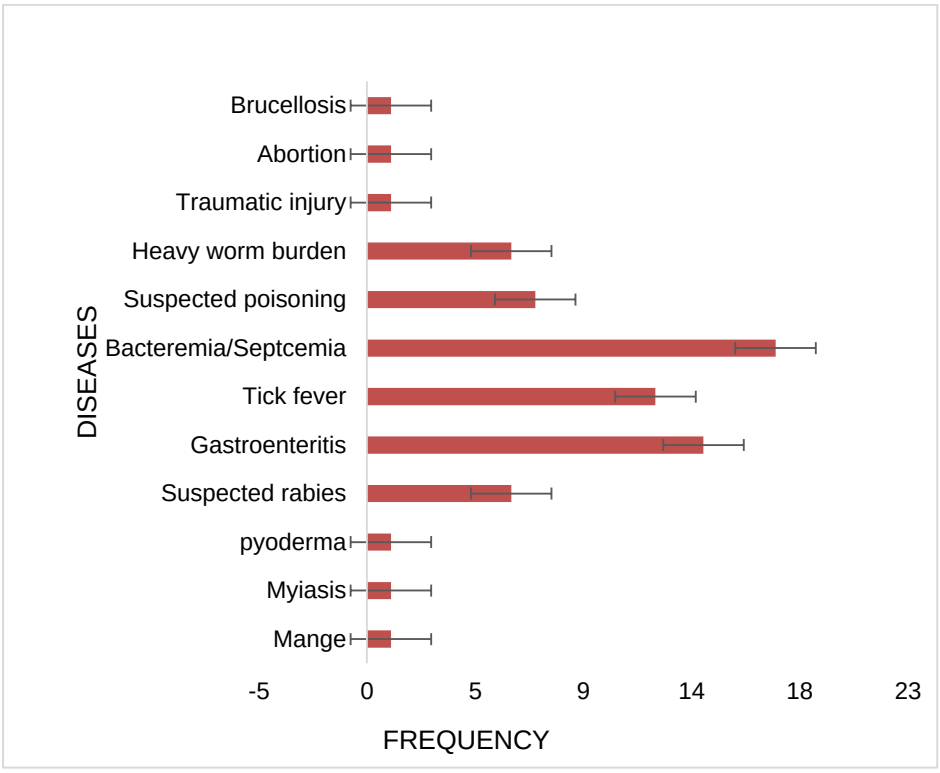


Figure 4.5: Causes of mortality in survey dogs in Asembo, Siaya County, 2017.

CHAPTER 5

5.0 DISCUSSION

This study describes key demographic, ecological and health factors that underlie rabies transmission and rabies infection in Asembo, Siaya County. Using findings from this study, a rabies control strategy has been designed which can be adopted by the county government of Siaya.

The high proportion of dogs under 1year of age points to a high dog population turnover rate. This means that these dogs were not there in the previous year of intervention. The high turnover rate is likely to be due to high birth rate and death rate reported in the study area. High population turnover rates lead to a rapid replacement of anti-rabies immunized dogs with new susceptible ones hence a rapid decline in herd immunity between vaccination campaigns(Hampson *et al*., 2009;Gsell *et al*., 2012).High turn-over rates may make it necessary to vaccinate dogs twice annually or continuously instead of the traditional once yearly vaccination campaigns by many African countries. Indeed, theoretical studies appears to support twice-a-year vaccination versus once-a-year vaccination (Kitala *et al*., 2002). However, theoretical and empirical studies show that if 70% of the population is protected against rabies through vaccination at any time, this would be adequate to protect the spread of the disease (Kitala *et al*., 2002). Unfortunately, in Kenya, and most of Africa, very low vaccination coverages are achieved during government initiated rural vaccination campaigns. This was observed in the current study where only 5.1 % of the surveyed dogs were reportedly vaccinated. Thus, dynamics of dog populations have a greater effect on the effectiveness of any rabies control program and should be factored in during planning (Hambolu *et al*., 2014).

The dog: human ratio of 1:7 is close to 1: 8 in Machakos District(Kitala *et al.*, 2001)and 1: 6 in Makueni County (ZDU, 2014) but differs with 1:4 in Bohol (Davlin*et al*., 2013)1:3.6

and 1: 4.1 in Siaya and Kisumu counties, respectively (Muriuki *et al*., 2016). Although the ratio obtained from the study is within the recommended range of dog-human interaction, a larger proportion of the dogs not vaccinated against rabies still poses a threat to the public health. Other areas have reported lower ratios like 1:18.1 in Malawi(Gibson *et al.*, 2016) and 1:13.5-19.5 in Bhutan(Tenzin and Wangchuk, 2013). This knowledge of human to dog ratio combined with vaccination the current vaccination coverage is very useful in planning of vaccination campaigns. The ratio can be used to estimate dog population sizes in the County while the vaccination coverage will inform on the amount of vaccines needed during a vaccination campaign.

As the case of most African countries, most dogs in the current study area are owned and therefore accessible for vaccination if it is performed without a fee (Jibat*et al*., 2015)

The low vaccination coverage of dogs against rabies of 5.1% in absence of vaccination campaigns reported in the study points to a large proportion of unvaccinated dogs hence low immunity which poses a threat as far as rabies transmission is concerned. This differs from the findings in Bohol Philistine which registered a high vaccination coverage of 67% in absence of vaccination campaigns (Davlin*et al*., 2013). With the high population turnover reported in Asembo, the herd immunity is likely to go lower if there will be no intervention (Hampson *et al*., 2009; Gsell*et al*., 2012). A review by Jibat*et al* (2015) reported that most dogs in Africa are owned and accessible for vaccination. The vaccination coverage was closer to the WHO recommended 70% when performed without a fee (Jibat *et al.*, 2015). Rabies elimination programs should therefore consider vaccination campaigns that are free of charge to raise the herd immunity and achieve the recommended 70% coverage. However, in the long term, and for sustenance purposes, studies on willingness to pay for vaccination by dog owners would be essential. Combining vaccination strategies in a vaccination campaign was reported to yield a high coverage. In

Malawi, static point vaccination and door-to-door vaccination strategies were combined which resulted to a coverage of above 70% (Gibson *et al*., 2016). In Bohol, the odds of vaccination increased with increase in age implying that people were more likely to vaccinate adult dogs compared to puppies (Davlin*et al*., 2013). Good seroconversion of rabies vaccine has been reported in puppies less than three months old and therefore all dogs (inclusive of puppies <3 months) especially in endemic areas should be vaccinated (Morters*et al*., 2015). More public health education should be conducted to counter the believe that puppies cannot be vaccinated against rabies. In developing continents like Africa and Asia, dogs live shorter lives hence the need for more frequent vaccination campaigns (Davlin*et al.,* 2012).

Majority of the surveyed dogs were either partially or freely allowed to roam freely with only 0.4% completely restricted (both day and night). This agrees with other studies in Machakos District, Haiti and Siaya County (Kitala*et al.*, 2001; Muriuki*et al.*, 2016; Schildecker *et al*., 2016). However, this differs with a finding in Bohol where 67% of the dogs were confined both day and night (Davlin*et al*., 2013). As aforementioned, free roaming of most dogs play a big role in disease spread and may pose a big challenge as far as rabies elimination is concerned since dogs that roam may impact negatively on the health of humans through increased events like bites, possibility of accidents on the roads and the potential spread of diseases that are zoonotic (Schildecker *et al*., 2016). Security as the main reason for dog keeping agreed with findings from other studies (Kitala*et al.,* 2001; Davlin*et al.,* 2013:Muriuki*et al.*,2016).

The male predominance has been reported by other studies in Machakos District (Kitala*et al.,* 2001), Bohol (Davlin*et al.,* 2013), Siaya County (Muriuki*et al.*, 2016), Antananarivo (Ratsitorahina *et al*., 2009) and Chile (Acosta-jamett *et al.*, 2010). This may be attributed to a belief that male dogs make good hunters and guard dogs compared to female dogs.

Females on estrus attract a lot of free roaming intact male dogs in search for mates. These males end up fighting and biting each other over the mates hence a potential risk to spread of rabies. The fighting and roaming play a key role in rabies spread. Indeed, Kitala *et al.* (2000)have shown that peak rabies incidence occurs immediately following the breeding season of dogs in the months of May, June and July. This has implications for rabies control. Planning vaccinations to coincide with this period may increase public compliance. Castration and spaying of dogs not only allows stabilization of dog population but also minimizes roaming and fights during the mating spree which can reduce disease spread. The predominant breed of dogs kept was the local breed. This may explain the poor management of dogs reported in this study since most people tend to be keen with exotic breeds of dogs because their value is higher. Poverty is also a factor. Poor management of dogs by not feeding dogs well and failure to restrict their movement renders them scavengers.

The presence of human-dog bites and confirmed rabies cases from suspected rabid dogs and cow points to endemicity of the disease and a serious threat to the public.In the current study, only 5 of the 27 bite human cases of animal dog bites received post exposure treatment.

The high turnover rate is due to high fecundity rates and death rates. The most common syndromes causing morbidities and mortalities in the study were gastrointestinal disorders, respiratory disorders and skin disorders. Timely veterinary care (curative and preventive) of affected dogs is likely tothe prolong the lifespan of dogs hence herd immunity. Population control techniques such as castration of males and spaying of females will reduce breeding and lowered birth rates which in turn would reduce the number of new susceptible dogs introduced into the population through births.

5.1 Rabies control strategy for Siaya County

The findings of this study identify the domestic dog as the most important reservoir and transmitter of the rabies virus to humans and animals. Of the 7 confirmed animal rabies cases, the domestic dog accounted for 85.7% unprovoked human-dog bites. A study in Machakos District reported that 97% of the human animal-bites reported were due to dogs (Kitala*et al*., 2000). Considering the role played by dogs in the epidemiology of rabies, it is logical that efforts in controlling rabies should target the domestic dog population. In this setup, the wildlife plays no significant role in the overall epidemiology hence effort should concentrate on the domestic dog population. The study reports 66.7% unprovoked human-dog bites. Children under 15 years of age were more vulnerable to the bites accounting for 63% of the bite victims. This translates to 198,994 children bitten in Siaya County and therefore 994,972 doses of human antirabies vaccines required for children in 6 months. Considering the rabies confirmed cases from the same area, there is a serious public health problem which is likely to cause anxiety to the bite victims and their associations. Only 18.5% of the bite victims had access to post-exposure-prophylaxis. The national government and county governments should ensure sufficient, affordable and accessible anti-rabies vaccine following a dog-bite. The supply of human rabies should be maintained and expanded to include peripheral health facilities. This will be a good incentive for the public to participate in rabies control activities.

Dog owners in the study area use dogs for security purposes. The number of dogs per household and per dog owning households were 0.7 and 1.8, respectively. The overall dog density was estimated between 50-57 dogs/km2. Majority of the dogs were left to scavenge for left overs in garbage sites and either roamed freely or were confined partially. It was noticed that in this rural setup, most dog owners had economical constrains to properly feed and restrict their dogs' movement. Given this economical constrain, dog confinement

may not be socially practical, as a method of rabies control. However, this strategy may be used temporarily during vaccination campaigns or rabies outbreaks.

The reproductive potential was high with a fecundity rate of 1.88 per year. The overall dog population was young (47.3% of the dogs ≤1 year). The population was replaced through births, deaths, disappearances or being given away. This indicates a highly dynamic population with a high dog population turnover rate. Thus, registration of dogs as practiced by the developing counties is impractical in Siaya County. Factoring in the high dog turn over, annual vaccinations against rabies may not be adequate to achieve and maintain at least 70% coverage at any point in time. This is because a year later when the next campaign is due, half of the dog population would have entered the population and will be naïve. There is loss of herd immunity given new births and deaths hence difficult to maintain 70% of the population immunized. Therefore, vaccination strategy needs to be increased from once a year to at least twice a year to cover the new naïve population. There is a need for field trials to test these hypotheses.

The large uncontrolled population due to unrestricted dogs point to a very high social contact between dogs and humans leading to uncontrolled reproduction and disease transmission. Public education could play a big role in promoting more responsible dog ownership. A small proportion of the dog owners were practicing reproduction control as shown by castrated males and spayed females. This was done mainly to prevent them from roaming around in search of mates but instead concentrate on their guarding role. This should be encouraged, because it not only controls breeding but also reduces dog-to-dog contact rates witnessed mostly during the mating period. In addition, proper waste disposal should be emphasized so that dogs do not get access to garbage dumping sites. Public education should encourage fenced off dumping sites or covered pits.

Active surveillance as opposed to passive surveillance of both animal and human rabies is important in unveiling the actual burden of rabies and the efforts required towards its elimination. There is a high likelihood of underreporting of rabies cases in a passive surveillance system. A one-year active surveillance in Machakos District confirmed 860 rabid dogs/100,000dogs yet only 12 rabid dogs/100,000 dogs had been reported with the existing passive surveillance system (Kitala*et al.,* 2000). The surveillance should actively involve both the human and animal health practitioners and the community. Prompt and timely diagnosis of rabies cases in both humans and animals should be adopted.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- The dog population was young with almost half of the dogs being less than 1 year old.
- The low rabies vaccination coverage is not sufficient to break dog-to-dog rabies transmission in dog populations.
- The presence of human dog bites and confirmed rabies cases confirms rabies endemicity in Asembo, Siaya County.
- The free roaming and scavenging dogs increase the risk of spread of rabies.
- Breeding control through castration and spay was rare.
- The dog population turnover is due to high birthrates and death rates

6.2 Recommendations

- Vaccination campaigns to be done at least twice a year as opposed to the traditional once a year.
- Public awareness on responsible dog ownership through proper feeding and movement restriction should be encouraged.
- Breeding control through castration and spaying of dogs should be encouraged to stabilize the dog population and also minimize roaming and fighting during the mating season.
- Causes of high dog population turnover should be investigated and manipulated to increase longevity of dogs' lives. This will prolong herd immunity in the dog population.

- More active human and animal rabies surveillance as opposed to passive surveillance is important in unveiling the actual burden of rabies and the efforts required towards its elimination.

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APPENDICES

7.0 APPENDIX 1: Dog ecology and demography questionnaire

Dog ecology and demographic questionnaire

SECTION 1: HOUSEHOLD IDENTIFICATION

Visit Number		LOCATION ID	
Interviewer ID		SSID	
Interview Date		HHID	

SECTION 2: BACKGROUND CHARACTERISTICS

N	Questions	Coding Categories	Skip to
201	Respondents date of birth		
202	Respondents gender	**a) Male** **b) Female**	
203	Highest education level of the respondent?		
204	Years spent in highest level of education		
205	How many people live in this household?		
206	How many people in this household are under 15?		

SECTION 3: DOG OWNERSHIP

N	Questions	Coding Categories	Skip to
301	Do you own dogs?	a) YES b) NO c) D/K	➔ **Q303** ➔ **302** ➔ **Q302**
302	Have you ever owned dogs in your household?	a) YES b) NO c) D/K	➔ **Q304** ➔ **Q305**
303	What is the Purpose/function and duties of your dog?	Security/watchdog Guard/Herd livestock Hunting Breeding for sale Pet dog Other (Specify)	➔
304	What happened to the dogs?	a) Stolen/Lost b) Expensive to maintain c) Died from disease d) Killed e) Lost f) Other (specify)….	➔ **End of Questionnaire**

305	Why haven't you ever owned dogs?	a) I don't like dogs b) They are dangerous c) Expensive to maintain d) My religious beliefs are against it. e) I don't have a reason f) Any other (specify)….	➔ **End of Questionnaire**

SECTION 4: DOG DEMOGRAPHICS

N	Questions	Coding Categories	Skip To
401	How many dogs do you have?		
402	How many of your dog(s) are adults? (above 3 months)		
403	How many are puppies? (below 3 months)		
405	Individual dog identity(dog1, dog2, dog 3(max=5 dogs)	Name Sex -(male or female) Coat colour- (brown, black,white,brownblack,mixed(specify), other(Specify) Breed- (Local ,Pure,crossbreed) Age(open)	
406	Has your dog been vaccinated in the last12 months? (dog 1, dog2, max 5)	YES NO	
407	If yes, what disease have your dog(s) been vaccinated against	a) Rabies b) Parvo c) Leptospirosis d) Hepatitis e) Canine distemper f) Parainfluenza Other (specify)	
408	How much was spent on vaccinations (Kshs.) (dog1, dog2. Dog3 , max5)		
411	Does the female dog (s) have puppies?	a) YES b) NO	

	(Female Dog 2, Female dog 3 etc…)		
412	When was the last time the female dog whelped?		
413	How many puppies were born?		
414	How many survived to weaning?		
415	Where did you get the dogs from?	☐ Gift ☐ Bought ☐ Found ☐ Brought itself ☐ Own Litter ☐ Came with family member who moved here ☐ Other (specify)	
416	Where did the dog(s) originate from?	☐ In the village ☐ In the same sub-county ☐ In another county ☐ Other (specify)…….	

SECTION 5: REPRODUCTIVE STATUS OF DOGS

N	Questions	Coding Categories	Skip To
501	Has any dog whelped in the last 12 months?	➔ **YES** ➔ **NO**	➔ **502** ➔ **503**
502	How many dogs have whelped in the last 12 months?		
503	When was the last time the female whelped? (Individual dog)		
504	Has this female whelped before the last 12 months?	**YES** **NO**	➔ **505**
505	How many times has the female whelped?		
506	Are the puppies still nursing?	**YES** **NO** **DON'T KNOW**	➔ **507**
507	When did they stop nursing?		
508	What was the litter size in the last whelping?	**How many males and females ?**	
506	Have you lost any puppies?	a) YES b) NO	
507	How many puppies survived to weaning?		

508	Where are the rest of the puppies?			
		Gave away		
		Killed		
		Died		
		Sold		
		Abandoned		
		Lost		
		Present		
		Other (specify)		
509	If female, Has your dog been neutered?	a.) YES b.) NO		
510	If male, has your dog been castrated?	a) YES b) NO		
511	In the last one month have any of your dog(s) died? If yes, put in a table for puppies and adults	a) YES b) NO		
512	How many dog (s) died?			
513	What was the age of the dog that died? (Dog 1, dog 2…)			
514	What was the sex of the dog that died? (Dog 1, dog 2…)			
515	What was the cause of death? (Dog 1, dog 2…)	a) Sick b) Killed c) I don't know		

SECTION 6; DOG MANAGEMENT

N	Questions	Coding Categories	Skip To
601	Do you restrict your dog's movement?	YES NO	➔ **602** ➔ **604**
602	How do you restrict your dogs movement?	□ In kennels □ Chained within homesteads □ Other	
603	When do you restrict your dog's movement?	Sometimes Day only Night only Both day and night.	
604	Where does your dog go to if not restricted?	Roam within the homestead Roam In the neighbourhood Other(Specify)	

605	What is the source of food for the dog(s)? ?	☐ we do not feed the dog/Left overs ☐ Commercial preparations ☐ Other	
606	How much do you spend feeding your dog (dogs) in a month?		
607	Who handles/cares the dogs?	☐ Men ☐ Women ☐ Children ☐ Any household member	
608	Does your home stead have a secure fence to restrict dogs movement?	☐ No fence ☐ Partial fence ☐ Complete fence	
609	How do you dispose the garbage/leftovers?	Pits Throwing outside the homestead Within homestead	
610	Have you observed dogs feeding on the family garbage/leftovers?	☐ Yes ☐ No	
611	Which dogs feed on family garbage/leftovers?	☐ Own dogs ☐ Neighbours dogs ☐ Unknown dogs	

7.1 APPENDIX 2: Monthly follow-up questionnaire

MONTHLY FOLLOW UP QUESTIONNAIRE

SECTION 1: HOUSEHOLD IDENTIFICATION

Visit Number		Location ID	
Interviewer ID		SSID	
Interview Date		HHID	

SECTION 2: BACKGROUND CHARACTERISTICS

N	Questions	Coding Categories	Skip to
201	How many people live in this household?		
202	How many people in this household are under 15?		

SECTION 4: DOG DEMOGRAPHICS

N	Questions	Coding Categories	Skip To
401	How many dogs do you have?		
402	How many of your dog(s) are adults? (above 3 months)		
403	How many are puppies? (below 3 months)		
404	Have you acquired a new dog(s) in the last 1 month?	YES NO	➔ **405** ➔ **409**
405	How many new dogs have you acquired?	No of puppies No of adults	
406	What is the names of the dog(s) acquired?	1. 2. 3. 4 5	
407	Where did you get the new dog(s) from?	□ Gift □ Bought □ Found	

		□ Brought itself □ Own litter □ Came with family member who moved here □ Other (specify)	
408	Where did the new dog(s) originate from?	□ In the village □ In the same sub-county □ In another county □ Other (specify)…….	
409	Has any dog that was a puppy become an adult in the last one month?	YES NO	➔ **410** ➔ **412**
410	How many dogs?		
411	What are the names of these dog(s)	1 2 3 4 5	
412	Have you lost any adult dog(s) in the last one month?	YES NO	➔ **413** ➔ **418**
413	How many adult dogs?		
415	What are the names of the dogs you've lost?	1 2 3 4 5	
416	What happened to the dogs?	□ Gave away □ killed □ Died □ Sold □ Abandoned □ Lost □ Other(specify	
417	What is the date when the dog(s) died/lost?	1 2 3 4	

		5	
418	Have you lost any puppies in the last 1 month?	YES NO	➔ **419** ➔ **422**
419	How many puppies?	No of males No of females	
420	What happened to the puppies?	□ Gave away □ killed □ Died □ Sold □ Abandoned □ Lost □ Other (specify	
421	What is the date when the puppies died/lost?	1 2 3 4 5	
422	Individual dog identity(all adult dogs both old and new. There PDA should not restrict the number)	Name **Sex** -(male or female) **Coat colour**- (brown, black,white,brownblack,mixed(specify), other(Specify) **Breed**- (Local ,Pure,crossbreed) **Age**(open)	
423	Has your dog been vaccinated in the last 1months?	a) YES b) NO	
424	If yes, what disease have your dog(s) been vaccinated against	□ Rabies □ Parvo □ Leptospirosis □ Hepatitis □ Canine distemper □ Parainfluenza □ Other (specify)	
425	How much was spent on vaccinations ?		
426	What is the total cost of cost of vaccination for the dogs?		

SECTION 5: REPRODUCTIVE STATUS OF DOGS

N	Questions	Coding Categories		Skip To
501	Has your female dog whelped in the last 1 month?			**YES** **NO**
502	What was the litter size in the last month whelping?	**Give an option for specifying the number of male and female puppies**		
503	Have you lost any puppies from the last whelping?	c) YES d) NO		➔ **If no skip to 507**
504	Where are the rest of the puppies?	All are present		
		Gave away	➔ **506**	
		Killed		
		Died	➔ **505**	
		Sold		
		Abandoned		
		Lost	➔ **505**	
		Other (specify)		
505	What is the date when the puppies died/lost?	1 2 3 4 5		
506	At what age were the puppies given away? (in weeks)			
507	If female, Has your dog been neutered?	c.) YES d.) NO		
508	If male, has your dog been castrated?	c) YES d) NO		

SECTION 6: HEALTH STATUS OF DOGS

701	Has your dog been unwell in the last one month?	a) YES b) NO	➔ **Q702**
702	In the last one month, what symptoms apply to your dog?	1) Gastro-intestinal disorders- 2) Respiratory distress- 3) Neurologic signs/disorder 4) Skin disorders 5) Musculoskeletal disorders	

		6) Urogenital disorders	
703	For how long has your dog been exhibiting this behavior?		
704	What is the date of the onset of signs?		
705	Are the signs still there?	a) YES b) NO	→**Q706**
706	If No, When did the signs end?		
707	Is your dog on any medications, supplements?	a) YES b) NO N/A	
708	Has your dog been vaccinated against any disease in the last 1 month?	a) YES b) NO c) N/A	➔ **Q709** ➔ **711**
709	What disease has your dog been vaccinated against?	a) Canine parvovirus. b) Canine distemper virus c) Leptospirosis. d) Rabies N/A	
711	In the last one month have any of your dog(s) died?	c) YES d) NO	
712	How many dog died?	No of puppies No of adults	
713	On which date did the dog(s) die?	1 2 3 4 5	
714	What was the age of the dog that died?		
715	What was the sex of the dog that died?		
716	What was the cause of death?	d) Sick e) Killed I don't know	

SECTION 8: DOG BITE INFORMATION -

801	Has any of your family member been bitten by a dog in the last one month?	YES NO	

802	Do you know anyone who has been bitten by a dog in the neighbourhood in the last one month?.	YES NO	
803	Which dog bit your family member?	Family dog Neighbours dog Strange dog Other (specify)	
804	What is the identity of the dog that bit the household member	Name Sex- male/ female CoatColour – Light brown, dark brown, white, black, grey) Age	
805	What is the age of the bitten individual?		
806	What were the circumstances of the dog bite?	Day/date/location	
806	Which part of the body was bitten?	□ Head/neck □ Arms/hands □ Trunk □ Legs □ Feet □ Other (specify)	
807	Was there any first aid done at home?	a) YES b) NO	
808	What was the First Aid done at home?	□ Wound washing with soap and water □ Wound washing with water □ Kerosene □ Salt □ Local herbs □ Others: specify	
809	Did the victim visit a health facility?	YES NO D/K	➔ **810**
810	What type of health facility did the victim visit?	a) Dispensary /health center b) Sub-county hospital c) County referral hospital d) Private hospital/clinic e) Other (specify)	
811	What was the treatment given at the health facility?	□ Wound washing □ Painkillers □ Antibiotics □ Tetanus □ PEP injection □ RIG injection □ Unknown □ Other (specify)	

812	What was the total cost of treatment?		
813	Was the dog provoked?	YES NO Don't know	
814	Is the owner of the biting dog known?	a) Known b) Unknown c) NA	
815	What is the relationship to the dog's owner?	a) Self b) Neighbor c) Relative d) Other (Specify)	
816	Do you know of anyone else who was bitten by the same dog in the last one month?	YES NO	
817	Do you know of any animals that has been bitten by a dog in the last one month?	YES NO	
818	Do you know of any dog that has died of rabies in the last one month?	YES NO	

7.2 APPENDIX3: Clinical response questionnaire

CLINICAL RESPONSE QUESTIONNAIRE

Interviewer ID	
Interview Date	
HHID	
DogID	

1. When did you notice the first signs of illness in the dog?

- ☐ Less than a week ago
- ☐ 2-4weeks ago
- ☐ 1-2 weeks ago
- ☐ More than a month ago

2. What signs/symptoms has the dog shown since the onset of the illness? tick the appropriate signs below

Digestive upsets (gastro intestinal disorders)

□ blood in stool	□ tarry (blackish) stool	□ constipation
□ diarrhea	□ worms in stool	□ abdominal distension
□ vomiting	□ anal itching	□ weight gain
□ flatulence	□ weight loss	□ poor appetite
□ straining to defecate	□ bad mouth smell (halitosis)	□ difficulty in chewing

Respiratory distress

□ coughing	□ loud breathing	□ sneezing
□ difficulty in breathing	□ nasal discharge	□ snoring

Neurological disorders

□ disorientation	□ head shaking	□ loss of balance
□ head pressing	□ head tilt	□ seizures
□ Noise sensitivity	□ Light sensitivity	

Skin disorders

□ rough hair coat	□ ectoparsites
□ Hair loss	□ skin lump
□ wounds?	
□ excessive scratching of the skin	□ Ringworms

Vision problems

☐ Blindness

☐ Cloudy cornea

☐ Conjunctivitis

☐ Other_____

Hearing problems-

☐ ear discharge

☐ Loss of balance

Urinary and reproductive system disorder

- blood in urine
- dark urine
- Unusual vaginal discharges
- Preputial discharges
- Scrotal swelling
- frequent urination
- low urine production
- straining during urination

Musculoskeletal system disorders

- vocalization (dog barking,howling, whining)
- limping
- paralysis, stiffness
- muscle tremors
- muscle pain

Behavioral changes Can be combined with nervous disorders

- Aggressiveness
- appearing unusually tame around strangers
- attacking or biting anything that comes near
- Tail chasing
- Restless
- Hiding in dark places
- eating unusual things (pica)
- excessive grooming/licking
- Star gazing
- Light chasing
- Staring
- Fly chasing
- Over active
- Lazy/in active

TREATMENT

3. Was the dog treated before for the same condition?

Yes/No

4. Who treated the dog?

- Animal health care provider / Technician
- Veterinarian
- Family member
- Other

5. What medication (s) was given to treat the condition?

- Antibiotics/anti protozoans
- Supplements
- Spraying
- dewormers
- herbs
- Antivirals
- Vaccine??

6. What does the dog feed on?

- Same food as family food
- Commercial preparations
- We do not feed the dog

7. How often do you feed the dog?

- Once a day
- twice a day
- thrice a day
- whenever food is available

8. What time of the day does the dog feed?

- morning
- afternoon
- evening

9. Have you changed the dog's diet? Yes No

10. How would you describe the dog's appetite?

- Normal
- Decreased
- Voracious
- Picky
- Don't Know

11. Have you changed the dog's housing? Yes No

12. Where does the dog sleep at night?

- Kennel
- Human house
- Shaded areas near human dwelling
- no shelter

13. Is your dog on any parasite control program? Yes No

14. How often do you deworm your dog?

- Every month
- Every three months
- Never

15. How often do you control for fleas and other external parasites?

- Weekly
- Bi weekly
- Monthly
- I don't

16. Have you vaccinated your dogs in the past 12 months? Yes No

17. What diseases have your dog vaccinated against?

- rabies
- leptospirosis
- hepatitis
- parvovirus
- canine distemper
- Parainfluenza