DOG ECOLOGY AND POTENTIAL ROLES OF DOGS AND SOME WILDLIFE IN THE EPIDEMIOLOGY OF RABIES IN BAUCHI STATE, NIGERIA

BY

ATUMAN, YAKUBU JOEL

DVM (ABU, Zaria)

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DECLARATION

I declare that the work in the thesis entitled "Dog Ecology and Potential Role of Dogs and some Wildlife in the Epidemiology of Rabies in Bauchi State, Nigeria" has been performed by me in the Department of Veterinary Medicine, under the supervision of Prof. A.B.Ogunkoya, Prof. D.A.Y. Adawa, and Prof. A.J. Nok.

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

Atuman, Yakubu Joel _____ _____

Name of student **Signature** **Date**

CERTIFICATION

This thesis entitled "Dog Ecology and Potential Role of Dogs and Some Wildlife in the Epidemiology of Rabies in Bauchi State, Nigeria" by Atuman, Yakubu Joel meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

_____ _____

Professor A.B. Ogunkoya — Date
Chairman, Supervisory Committee
Department of Veterinary Surgery and Medicine
Ahmadu Bello University, Zaria.

_____ _____

Professor D.A.Y. Adawa — Date
Member, Supervisory Committee
Veterinary Teaching Hospital
Ahmadu Bello University, Zaria

_____ _____

Professor A.J. Nok — Date
Member, Supervisory Committee
Department of Biochemistry
Ahmadu Bello University, Zaria

_____ _____

Professor A.K.B. Sackey — Date
The Head
Department of Veterinary Surgery and Medicine
Ahmadu Bello University, Zaria

_____ _____

Professor A.A. Joshua — Date
Dean, Postgraduate School
Ahmadu Bello University, Zaria

DEDICATION

I dedicate this work to my dear mother Mrs. Liatu Joel Atuman of blessed memory, for her selfless service to humanity during her life time on earth.

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ABSTRACT

A study of dog ecology and the potential roles of dogs and wildlife species in the epidemiology of rabies were carried out in Bauchi State Nigeria using direct street counts and questionnaire survey administered on 10% of the city streets selected by stratified random sampling. The questionnaire was designed to obtain data in order to determine the dog to man population ratio, dog management and care, cases of dog bites, consequences of the bites and frequencies of rabies outbreak. In addition, identification and assessment of level of conflicts from wildlife/human/domestic animal interfaces was carried out in the three game reserves located in Bauchi State for rabies. Brain samples from dogs and wildlife species were purchased from dog and wildlife meat markets within the study area and examined using the direct fluorescent antibody test. Data generated were analysed using SPSS, chi-square tests for association and odds ratio. Values of $P<0.05$ were considered significant. The estimated dog population of street count and compound counts were 5,310 and 7,670, respectively. The overall human to dog ratio of 4.1:1 and 7.9:1 were established in urban and rural settlements, respectively. The mean number of individuals per dog owning compound was 9.6±0.498 (SEM) and the mean number of dogs owned per compound was 2.3±0.108 (SEM). Majority of the dogs owned were local breeds (62.8% - 86.9%) aged between 1-5 years old and managed under partial or no confinement. The dogs were mostly used for security (69.5%) and hunting purposes (40.9%). Dog owners reported low vaccination coverage in both urban (43.5%) and rural (9.5%) settlements, levels considered not sufficient to prevent rabies transmission. Of the 34.4% cases of dog bites reported by respondents, about 12.4% of the victims died after manifesting nervous signs. On conflicts as a result of wildlife/ human/domestic animal interface, it was observed that 29.7% of human victims of wildlife bites or attacks died. Domestic animals were killed by wild animals and farm

crops were destroyed by wildlife species. Hyenas, jackals, mongooses, wild cats, squirrels, monkeys, and baboons were identified as the offending wildlife species. Rabies virus was detected in the brain tissues of dogs and wildlife species. Dogs had the highest prevalence of rabies, 22.8% followed by wild cats with 21.4%, hyrax16.7%, mongooses 11.1%, jackals 9.2%, and squirrels 8.3%. The chi square test results showed statistically significant relationship ($P<0.05$) in dogs and jackals in the occurrence of rabies. Domestic dog has been shown from this study to be the major reservoir host of rabies and of increasing risk to human rabies. The detection of rabies virus in the brain tissues of wild animals has obvious wider implications because of the presence of large number of wildlife populations located in the three major game reserves in the State.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The earliest historical records of human suffering due to infectious diseases include two ancient Egyptian hieroglyphs; one depicting a man with a withered leg probably suffering from polio and another frieze depicting a man bitten by a dog and displaying symptoms of rabies (Bacon, 1985). Rabies and rabies-related viruses are members of the *Lyssavirus* genus (Family: Rhabdoviridae) of neurotropic, single-stranded, negative-sense RNA viruses capable of producing fatal encephalitis in a wide variety of mammalian species (Nadin-Davis, 2000; WHO, 2002). Rabies is found throughout the world, but a few countries claim to be free of the disease due either to implementation of successful elimination programs and /or to being islands that instituted the enforcement of rigorous quarantine measures (Okoh, 2008). Pasteur's development of a successful vaccine treatment for patients exposed to rabies was among the first grand successes of the Germ Theory of Disease and this success has been celebrated widely in literature and film (Real and Childs, 2005). Despite the development of even safer and more successful treatments, the availability of better and more effective vaccines, rabies still remains the most important and devastating viral zoonotic disease worldwide. Human mortality due to rabies is estimated to be 60,000 deaths per year worldwide and millions of persons, primarily in the developing countries of the tropical and sub-tropical regions undergo costly post exposure treatment (PET) (Rupprecht *et al*., 1995; WHO, 2005).

In Nigeria, available records showed that the first report of human rabies was in 1912 and the first canine rabies was diagnosed in 1925 at Yaba Rabies Laboratory (Oboegbulem, 1994).

About 10,000 people are exposed to rabies each year in Nigeria (Okoh, 2007). A concomitant rise in rabies in both dog and human populations in Nigeria portends danger (Osinubi *et al.,* 2003). The most widely used test for rabies diagnosis is the direct immunofluorescence test (FAT) on acetone-fixed smears of hippocampus, cerebellum or medulla oblongata (OIE, 2000). RT-PCR is rapid and sensitive for the detection of RV and RRV (Heaton *et al*., 1997).

In North America and Europe, wildlife species have replaced dogs as the most important reservoirs of rabies (Cliquet and Picard-Meyer, 2004). In South Africa, Angola, Botswana, Namibia, Zambia and Zimbabwe, canine rabies represents an important risk for humans (Nel *et al*., 1993). The situation is complicated by independent rabies cycles in wild mammals (Cliquet *et al*., 2004). Rabies has been reported in wildlife species (lynx, civet cat, chimpanzee, lion, insectivorous bats, monkey and hyrax in Nigeria (Anon, 1969 and 1972; Isoun 1973; Kasali 1977; Okoh, 1976; 1986a; Enurah *et al*., 1988; Ogunkoya *et al* .2008; Dzikwi *et al.*, 2010a). Historical data on wildlife rabies in Nigeria has been mainly from laboratory based activities with few epidemiological studies. Thousands of dogs are vaccinated annually with Flury low egg passage vaccine strain, but the prevalence of the disease in domestic animals has not declined (Nottidge, 1994; Ogunkoya *et al*., 2003).

1.2 STATEMENT OF THE RESEARCH PROBLEM

Rabies remains a global zoonosis of major public health, agricultural and economic significance. Dogs are the major animal reservoirs in developing regions while wildlife maintain the cycle of infection even in developed countries and new viral etiologic agent continue to emerge (Repprecht *et al*., 2006). Although sporadic rabies cases in wild mammals (wildcats, wild-dogs, monkeys, bats, rodents, jackals, and hyenas) have been documented throughout the African

continent, the disease has not been extensively studied in these countries (Cliquet and Picard-Meyer, 2004). In developing countries the major constraints to effective rabies control are economical and logistical rather than technical, with poor infrastructure, lack of political will and inadequate resources hampering control programs (Perry, 1993; Kitala *et al.*, 2001). In Nigeria, the epizootiology of rabies has been described by several authors (Adeyanju and Addo, 1973; Umoh and Belino, 1979; Ogunkoya *et al*., 1984; Aghomo, 1987; Okoh, 1989; Bello *et al*., 2007; Dzikwi *et al.*, 2010a, 2010b; Garba *et al*., 2010). There is however scanty information on the prevalence of rabies in wild animals. Records from the National Veterinary Research Institute (NVRI) Vom, indicated that cases of rabies have been diagnosed in wild animals (rat, lion, monkey and chimpanzees) between January 1986 to January 2005. There are frequent interactions between humans, domestic animals and wildlife in certain parts of Nigeria, especially in Bauchi State which has the Yankari Game Reserve, Lame-Bura Game Reserve and Sumu Wildlife Park and many other forest reserves which harbor many wildlife species. These wildlife species are used for tourist purposes and in many cases hunted either for food or economic reasons. One problem in Nigeria is the lack of field data on the conflicts, risk and impacts of diseases from interactions among wildlife, humans and domestic animals. To appreciate the public health significance that lyssaviruses continue to play as persistent and emerging infectious agents (Rupprecht *et al*., 1995), one must understand certain human activities, such as the recent animal translocations, i.e., the natural or purposeful changes by man of the normal habitats or geographic distribution of an animal and on animal ecology. Reports on studies relating to dog ecology is limited and currently information is only available for Kaduna, Jos, Lagos, Maiduguri and Makurdi (Ezeokoli and Umoh, 1986; Okoh, 1986a; Oboegbulem and Nwankonobi, 1989; El-Yuguda *et al*., 2007; Akombo, 2009).

1.3 JUSTIFICATION OF THE STUDY

Surveillance is the basis on which any rabies control program is set (WHO, 1984; OIE, 2010). Well designed dog ecology and demographic studies are necessary (Perry, 1993). Such studies have proved useful in planning rabies control in Asia, Latin America, and in the North, East, and Southern Africa (WHO, 1984; WHO/WSPA, 1990; WHO, 1992). Collection, correlation, evaluation and rapid dissemination of diagnostic data are needed for planning, organization, and implementation of rabies control programs (Cliquet and Picard-Meyer, 2004). The surveillance of rabies has, at present, reached a satisfactory standard in only a few countries and this has a direct bearing on the treatment of exposed persons and on rabies control activities in animals (Cliquet and Picard-Meyer, 2004).

Nigeria is particularly important for lyssavirus surveillance because the initial isolation of Lagos bat virus and Mokola virus occurred in the country (Dzikwi *et al.,* 2010a). Yet, effective surveillance carried out in the country is poor. Bello *et al*., (2007) reported high cases of rabies in some parts of Bauchi State and attributed it to religious and cultural practices of the people which encouraged dog ownership. The presence of Yankari and Lame Bura game reserves which harbor many wildlife may also be an important factor in the epidemiology of the disease. The pace of urbanization has increased substantially in Bauchi State, with concomitant encroachment by humans and domestic animals into wildlife communities resulting into disturbance of the normal wild life habitats and conflicts at the level of the interface. The epidemiology of this disease is directly associated with the ecology of the reservoirs. There is need for better understanding of these factors in order to design appropriate control measures (Kitala *et al*., 2001). It is therefore imperative to enforce surveillance of rabies virus in dogs and wild animals

for a better understanding of the epidemiologic situation, including circulation patterns and public health significance of the disease in order to establish effective control strategies in Bauchi State, Nigeria.

1.4 GENERAL AIM OF THE STUDY

The aim of the study was to determine dog ecology and potential role of dogs and some wild life species in the epidemiology of Rabies in Bauchi state.

1.5 SPECIFIC OBJECTIVES OF THE STUDY

The specific objectives of the study were as follows:

1. To estimate the size and distribution of the dog population (dog ecology) in the study area.

2. To determine the presence (abundance) of wildlife and assess the occurrence of conflicts between wildlife, humans, and domestic animals through the use of a structured questionnaire.

3. To determine the prevalence of rabies virus antigen among slaughtered dogs and some wildlife species hunted for food or killed.

CHAPTER 2

LITERATURE REVIEW

2.1 EPIDEMIOLOGY OF RABIES

Rabies is a fatal zoonosis characterized by encephalomyelitis. It is a disease of public health concern because the human fatality rate is almost 100% (Rupprecht *et al.*, 2006). The epidemiology of the disease is influenced by events at cellular and molecular levels, as well as the overt dynamics of different lyssavirus infections with local animal host species in terms of distribution, abundance, demographic, behavioral ecology, dispersal, and interactions with other species (Cliquet and Picard-Meyer, 2004; Rupprecht *et al*., 2006).The disease exists in two epidemiological patterns; urban rabies involving dogs and cats and sylvatic rabies involving wild carnivores and bats (Paez *et al*., 2003). Sylvatic rabies occurs mostly in developed countries like in North America where canine rabies have been eradicated (WHO, 2005). Urban rabies occurs mostly in less developed countries where the dog is the principal host and vector giving rise to a greater opportunity for spillover infections into human populations. This pattern of rabies is by far more dangerous to humans accounting for an estimated 99% of all recorded human cases and 92% of all human post exposure related treatments (Pastoret *et al.*, 1995).

2.2 STRUCTURE AND MOLECULAR MECHANISMS OF THE RABIES VIRUS

The rabies virus has been classified as a member of the Genus Lyssavirus (from Greek lyssa meaning "frenzy") within the Rhabdoviridae Family (from Greek rhabdo meaning "rod-shaped") and Order Mononegavirales. Each virus is bullet-shaped and approximately 180 nm long and 75 nm wide. The lipid bilayer membrane is coated with numerous 10 nm spikes composed of

glycoprotein. Inside the membrane is a lining of matrix protein, and a core containing the ribonucleoprotein complexes (Fig.1.1). The genome of the rabies virus is made up of approximately 12,000 nucleotides of single-stranded RNA (Smith *et al*., 1999). This contains five genes which code for each of the five viral proteins. The largest of these proteins is the L protein, or large (244 kDa) polymerase. It is a multifunctional protein, but its main activity is as a polymerase which allows the genomic RNA to be copied during virus multiplication within the cell. Between 30 and 60 copies of the L protein form the ribonucleoprotein core with the RNA genome and two other proteins N (approximately 1,800 copies) and NS (approximately 900 copies) (Cliquet and Picard-Meyer, 2004). The N protein is a 55 kDa protein which is the main structural component of the ribonucleoprotein core and binds tightly to the RNA allowing it to be packed in an orderly helical structure. The NS protein is a highly phosphorylated protein whose role has not yet been fully determined but is suspected to be involved in viral RNA transcription and/or replication (Bourhy *et al*., 1993; Baer, 1994). The other two proteins encoded for by the rabies genome are the M (or matrix) protein, which has been shown to be crucial in the ability of a newly formed virus to bud from the host cell membrane, and the transmembrane G protein, which is involved in host cell attachment and invasion (Baer and Tordo, 1994). The G protein is also the main target for antibody therapy against rabies, as it is the only exposed protein on the virus and binding of antibody to it can block its function during host cell infection (Smith *et al*., 1999)

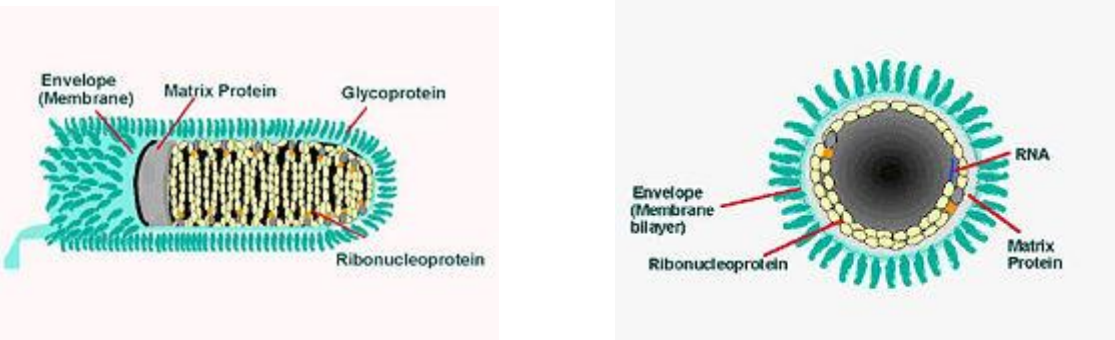


Figure 2.1: Longitudinal and cross-sectional schematic view of rabies virus (Albertini *et al.*, 2006)

2.3 TECHNIQUES FOR DIAGNOSIS OF RABIES IN ANIMALS AND HUMANS

2.3.1 Techniques for Diagnosis of Rabies in Animals

2.3.1.1 Antigen detection

The fluorescent antibody (FA) technique is a rapid and sensitive method for diagnosing rabies infection in animals and humans (Bourhy, 1989). It is the gold standard for rabies diagnosis; however, the accuracy of this test depends upon the expertise of the examiner, and the quality of anti-rabies conjugate and the fluorescence microscope. The test is based upon microscopic examination under ultraviolet light of impressions, smears or frozen sections of tissue after they have been treated with anti-rabies serum or globulin conjugated with fluorescein isothiocyanate. The diagnostic conjugate should be of high quality and the appropriate working dilution must be determined in order to detect the different genotypes of lyssavirus. Impressions (or smears) of tissue samples from brainstem, thalamus, cerebellum, and the hippocampus (Ammon's horns) are recommended for increased sensitivity of the test.

Also rabies antigen can be detected by the method of Direct Rapid Immmnohistochemistry Test (DRIT), an unlicensed procedure designed for consideration as a potential confirmatory measure of the DFA test according to the national standard operating procedure for the diagnosis of rabies in animals in America (CDC, 2008). In addition DRIT may be used to enhance field surveillance among suspect wildlife. It is rapid and sensitive.

2.3.1.2 enzyme-linked immunosorbent assay (ELISA)

Detection of lyssavirus nucleocapsid antigen by enzyme-linked immunosorbent assay (ELISA) has been described and used for many years in some laboratories (Bourhy, 1989). It is rapid and

can be useful for epidemiological surveys. Many KITs are now commercially available for this type of diagnostic technique.

2.3.1.3 Virus isolation

Virus isolation may be necessary to confirm the results of antigen detection tests and for further characterization of the isolate (Bourhy, 1989). Virus isolation can be performed on neuroblastoma cells or upon intracranial inoculation of mice. Murine neuroblastoma (NA C1300) cells are more susceptible to field isolates of rabies virus than are other cell lines tested. Virus isolation in cell culture (with neuroblastoma cells) is at least as efficient as mouse inoculation for demonstrating small amounts of rabies virus (WHO,2005). It also reduces the time required for diagnosis from 10–15 days for the mouse inoculation test to 1–2 days using neuroblastoma cells. When compared with the FA technique, the gold standard, the sensitivity of virus isolation in neuroblastoma cells is higher than 98% (Bourhy, 1989). However, false negative results may be obtained with decomposed brains. Where cell culture facilities are not available, mouse inoculation should be used. The technique is sensitive and robust (Bourhy, 1989). If a more rapid answer is necessary, suckling mice (less than 3 days old) are preferred to weanling or adult mice since they are more susceptible to rabies virus. The observation period may be shortened by FA examination of brains of inoculated mice killed 3–4 days (or more) after inoculation (WHO, 2005).

2.3.1.4 Antibody titration

Virus neutralization tests, rapid fluorescent focus inhibition tests (RFFIT) and fluorescent antibody virus neutralization tests (FAVN), are used primarily to evaluate vaccinal antibody responses against rabies virus (OIE, 2000).

2.3.1.5 Detection of rabies by molecular techniques

RT-PCR is rapid and sensitive for the detection of RV and RRV (Heaton *et al*., 1997). The use of the polymerase chain reaction (PCR) and other amplification techniques is not currently recommended for routine postmortem diagnosis of rabies. However, these molecular techniques can be applied for epidemiological surveys in laboratories with strict quality control procedures in place and that have experience and expertise with these techniques (WHO, 2005).

2.3.2 Techniques for the Diagnosis of Rabies in Humans

The sensitivity of techniques for rabies diagnosis varies greatly according to the stage of the disease, antibody status, intermittent nature of viral shedding and the training of the technical staff. While a positive result is indicative of rabies, a negative result does not necessarily rule out the infection. Brain biopsy taken solely for the diagnosis of rabies is not recommended (Hemachudha and Wacharapluesadee, 2004).

2.3.2.1 Rabies antigen detection in humans

Viral antigen may be detected by using the FA test on skin biopsies from patients with clinical rabies. Test results are independent of the antibody status of the patient. Substantial numbers of rabies patients have FA-positive skin specimens during the early phase of the disease (Hemachudha and Wacharapluesadee, 2004). Skin biopsies are usually taken from the nuchal area of the neck, with hair follicles containing peripheral nerves (WHO, 2005). Examination of at least 20 sections is required to detect rabies nucleocapsid inclusions around the base of hair follicles (WHO, 1987). The quality of skin biopsy samples is of paramount importance. Though

sensitive, this technique may not be practical in all settings, because of the need for a cryostat to prepare frozen tissue sections. FA testing on corneal impressions is rarely reliable in most clinical settings and is therefore not recommended (WHO, 2005).

2.3.2.2 Rabies Virus isolation

Rabies virus isolation can be performed using neuroblastoma cells or the intracranial inoculation of mice. Virus isolation is preferably performed on saliva samples or other biological fluids such as tears and cerebrospinal fluid (Jackson, 2004). The success rate depends upon the antibody status (more positive results are obtained in antibody-negative patients) and on the intermittence of viral shedding. Liquid specimens conserved as such or in swabs should be maintained frozen after collection. The contents of the swab should be expelled into the collection medium. Under no circumstances should preservatives be added to the collection medium (WHO, 2004). It should be noted that infectious virus may be absent from these specimens even during the late stage of the disease.

2.3.2.3 Antibody titration

Neutralizing antibodies in the serum or cerebrospinal fluid of non-vaccinated patients can be measured using a virus neutralization test such as the rapid fluorescent focus inhibition test (RFFIT) or the fluorescent antibody virus neutralization (FAVN) test (Bourhy, 1989). Virus-neutralizing antibodies in serum tend to appear on average 8 days after clinical symptoms appear. Rabies antibodies are infrequently found in cerebrospinal fluid (WHO, 2005). An ELISA using purified rabies glycoprotein has been used to determine antiglycoprotein antibody levels in

the serum of humans and of some animal species. This assay can be useful when the RFFIT is not available (Bourhy, 1989).

2.3.2.4 Molecular techniques

Molecular detection by polymerase chain reaction and nucleic acid sequence based amplification techniques has the highest level of sensitivity but requires standardization and very stringent quality control (Crepin, 1998). Rabies virus RNA can be detected in several biological fluids and samples (e.g. saliva, cerebrospinal fluid, tears, skin biopsy sample and urine). Serial samples of fluids (e.g. saliva and urine) should be tested, owing to intermittent shedding of virus. Such techniques can produce false positive or false negative results, and should only be used in combination with other conventional techniques (Heaton, 1997).

2.4 DEMARCATION CRITERIA IN THE GENUS LYSSAVIRUS

Prior to 1956, the rabies virus was believed to be unique and antigenically distinct from other members of the family *Rhabdoviridae* (Tordo, 2004) until when the first isolations of rabies related viruses were made in Africa. This warranted the creation of the genus *Lyssavirus* (Greek *lyssa*: rabies) for viruses responsible for rabies-like encephalitis. The genus was at first divided into four serotypes by antigenic cross-reactivity with sera and monoclonal antibodies. The classical rabies virus (RABV) as serotype 1, the Lagos bat virus (LBV) as serotype 2, the Mokola virus (MOKV) as serotype 3, and the Duvanhage virus (DUVV) as serotype 4. Further isolations of new bat lyssavirus in Europe and Australia, and progress made in genetic characterization of several genes (N, P, and G) of the virus supported the delineation into seven distinct genotypes. This led to the confirmation and expansion of the antigenic data from four to

seven; namely the RABV as genotype 1, the LBV as genotype 2, the MOKV as genotype 3, the DUVV as genotype 4, the European bat lyssavirus 1(EBLV1) as genotype 5, the European bat lyssavirus 2 (EBLV2) as genotype 6, and the Australian bat lyssavirus as genotype 7.Within each genotype, sublineages corresponding to variants circulating in specific geographical regions and animal hosts (WHO, 2004) were identified. The genotypes were further segregated in two phylogroups with genotypes 1, 4, 5, 6 and 7 as phylogroup I and genotypes 2 and 3 as phylogroup II. Viruses of each phylogroup differ in their biological properties including pathogenicity, induction of apoptosis and cell receptor recognition (Badrane, 2001; Nadin-Davis, 2002). Genotypes in phylogroup I show cross protection with the rabies vaccine while those in phylogroup II do not (Nel *et al*., 2005).

It is important to note that bats are reservoirs and vectors for six out of the seven genotypes characterized so far while the precise reservoir and vector for genotype 3 (MOKV) remains to be determined (WHO, 2004). Five of the seven genotypes have bats as the exclusive vectors, while only genotype 1(RABV), has terrestrial vectors (mainly carnivores). Genotype 1 corresponds to the classical rabies virus and is spread in domestic or wild animals worldwide. Genotypes 2 to 7 have a narrower geographical and host-range distribution with most of them were being confined to the Old World and Australia. A review of this classification will evolve, particularly as surveillance for bat lyssaviruses is reinforced (Botvinkin, 2003).

Four recent isolates of bat lyssavirus in Central Asia, East Siberia and the Caucasian region were characterized as new genotypes (Botvinkin, 2003). These viruses are Aravan virus (ARAV), Khujand virus (KHUV), Irkut virus (IRKV) and West Caucasian bat virus (WCBV).

Lyssaviruses show a broad antigenic cross-reactivity at the nucleocapsid level, mainly because of sequence conservation of the N protein: amino acid identities with a range from 78% in the MOKV and EBLV-1 to 93% in the DUVV and EBLV- 1 (WHO, 2004). This allows the use of similar reagents for diagnosis by immunofluorescence. The ectodomain of the G protein which carry the main antigenic sites is more variable and cross-neutralization exists among lyssaviruses of the same phylogroups in which amino acid identities in the ectodomain are greater than 74%, but not between phylogroups in which the amino acid identities in the ectodomain are less than 62%). Experimental evidence obtained so far indicates that vaccine strains (all belonging to genotype 1 within phylogroup I) are ineffective for protection against infection by lyssaviruses from phylogroup II (Botvinkin, 2003). Rabies vaccines that are currently used do not have cross –neutralizing activity against members of phylogroup 2 (Nel *et al*., 2005)

2.5 HOST RANGE

The increasing incidence of dog and wildlife rabies in Africa (King, 1993) is causing concern, not only for public health but also for the conservation of some endangered canids (Macdonald, 1993). In order to control rabies effectively we need to identify which animals are reservoirs and by what mechanisms the disease is maintained in reservoir populations. The rabies virus infects a wide range of mammalian hosts, including raccoons, skunks, foxes, coyotes, bats, domesticated dogs and cats, and human beings. While infection can occur in any warm-blooded animal, some (such as foxes, coyotes and wolves) are highly susceptible, while others (such as opossums and birds) are much less susceptible. Laboratory reared rodents are rarely, if ever infected, hence bites by laboratory mice or rats are usually not considered as sources of exposure, except rodents used in rabies diagnosis or research (Okoh, 1986b). Rodents represented <1% of all species tested for rabies in the United States (Childs *et al*. 1997), and virtually all of those tested and

found rabid were large species such as woodchucks (*Marmota monax*) and beavers (*Castor canadensis*). An extreme under-representation of small terrestrial mammals was obvious in this dataset. However, the factors contributing to this size-bias are confounded by (a) the reliance on human observations of suspicious animal behavior,(b) the problems inherent to mixing small body-size with RABV transmission by bite, (c) the financial constraints that limit diagnostic laboratories to testing only specimens from animals directly involved in a human or domestic animal exposure to RABV (Wilson *et al.* 1997), and (d) the public health community's general assumption that rodents, with the exception of large-bodied species, carry little risk of transmitting RABV (Real and Childs, 2005). However, rodent species examined are fully susceptible to rabies infection, can transmit RABV by bite, and have been implicated in human rabies infection (Winkler, 1991). In some countries rodents have been implicated in the maintenance of RABV, but critical data to support these contentions are elusive (Okoh, 1986; Summa *et al*. 1987). Small terrestrial mammals usually account for the greatest number of individuals and biomass in any mammalian community, and potentially these populations could benefit from rabies epizootics reducing predation pressure. However, virtually nothing is known of the direct effect of rabies on small mammal populations within a community. Therefore, any discussion of the community ecology of rabies is severely limited by the profound, possibly insurmountable, deficit of any representative information on wildlife rabies; most notably rabies among smaller mammals (Real and Childs 2005).

The susceptibility of bats appears to vary from place to place. Apart from the vampire bats of Central and Southern America, rabies has been reported in 26 out of 40 species of insectivorous and fungivorous bats in North America. (Smith and Baer, 1988). Bats rabies is most commonly

reported among domesticated dogs in underdeveloped nations, especially in parts of Africa and Asia. However, in nations where canine rabies has been controlled through mass vaccination protocols, wildlife rabies accounts for the vast majority of reported cases (WHO, 1999). In 1995, only 8% of sighted cases in the United States were in domesticated animals, while more than 50% were in raccoons, 22% in skunks, 10% in bats, and 6% in foxes (Cleaveland and Dye, 1995; WHO, 1999).

2.6 TRANSMISSION

Exposure to rabies virus occurs when an animal or person comes into physical contact with saliva from a rabid animal or with an environment containing live rabies virus (WHO, 2005). However, exposure does not always lead to contraction of the disease (Baer and Tordo, 1994). The type of infected animal, as well as the location and severity of the bite, all appear to influence the chance of infection. For example, if left untreated, severe bites by infected wolf on the face result in 80% to 100% mortality, while a more superficial bite by an infected dog on the leg only results in a 3% mortality rate (Baer and Tordo, 1994). In general, the proximity of the bite to the head determines the severity of the risk, presumably because the virus faces a more direct route to the central nervous system. The risk of exposure to the victim is most likely dependent on the differences in the amount of virus present in the saliva at the time of bite (NIAID, 1998). Despite the fact that rabid dogs only present a modest risk when compared to wolves or even cats, the vast majority of human rabies deaths worldwide (99%) result from dog bites (WHO, 1999). This is due to the imbalance of cases which occur in countries where canine rabies has not been controlled and humans and dogs live in very close contact (CDC, 1998). On the other hand, in developed nations where canine vaccinations are well established, rabies cases

are dramatically reduced in number, and reported bites are almost always from wild animals such as raccoons and skunks (Hanlon *et al*., 1998; WHO, 2005). While bites account for the vast majority (about 99.8%) of rabies cases, other forms of transmission have been reported, including contamination of mucous membranes, faulty vaccines, corneal transplants, and aerosol transmission (CDC, 1998). Movement of animals provides a route for the transfer of pathogens between animals and the spread of diseases to new areas. Movement of animals occurs in relationship to trades involving pet, laboratory, food, farming and hunting animals as well as for the purpose of conservation, reintroductions and rehabilitation of animals. These trades are large, increasingly globalised and without adequate disease surveillance (Daszak and Cunningham 2003). Globally, outbreaks resulting from wildlife trade have resulted in severe economic losses involving hundreds of billions of dollars (Karesh, 2005).

2.7 GENERALIZED PATHOGENESIS OF RABIES

Rabies is almost always caused by the bite of a rabid animal (Rupprecht *et al*., 2006). Lyssa viruses are transmitted from the periphery to the central nervous yystem (CNS) by progressive centripetal retrograde trans-synaptic spread from infected sensory and motor neurons to the spinal cord ganglia and brain (Dietzschold *et al*., 2005). The mechanism by which the rabies virus infects a cell is similar to that of many other viruses. The infection is started when G protein projections on the virus interact with the cell membrane of the host. After host cell attachment via the viral G protein, the virus is adsorbed into the cell via engulfment with the plasma membrane. Once inside the cell, the viruses congregate inside endosomes which quickly drop in pH. As the pH changes the conformation of the G protein changes such that it causes the viral membrane to fuse with the endosomal membrane. This leads to the expulsion of viral proteins and RNA into the cytoplasm. Once in the cytoplasm, the viral L protein transcribes five

mRNAs from the RNA genome using free nucleotides from the host cell cytoplasm. These mRNAs are 5'-capped and poly-adenylated, allowing them to be translated into their corresponding five viral proteins using the cell's translation machinery. These proteins also undergo post-translational modification within the host cell, including the glycosylation of the G protein and phosphorylation of the NS protein (Baer and Tordo 1994). The viral RNA genome is replicated using a complex made up of the L and NS proteins (Finke and Conzelmann, 2005). All the viral components congregate in one location of the cytoplasm, which leads to the characteristic staining seen in the diagnostic test (Dietzschold *et al.*, 2005). At this site the ribonucleoprotein complex is formed and it, along with the M and G proteins, are recruited to the host cell membrane.

At the membrane, M protein is implicated in the bundling of the virus into a particle and initiating the budding off process which releases new virion, ready to infect a nearby cell. Inside the neuron virus spread can occur very fast, as viral particles within the cell can simply travel the length of the axon before budding off, therefore being able to cover a large distance in less time and with fewer replication cycles. This may be one reason why the disease can spread so quickly from the peripheral to central nervous system (Baer and Tordo 1994). One thing that is extraordinary about the rabies virus is its high affinity for nervous tissue, the precise mechanism for passage of virus from nervous system to glandular sites such as the salivary gland during the infection process has not been determined (Rupprecht *et al*., 2006). After multiple rounds of CNS replication, the virus spreads centrifugally to the salivary glands and other innervated sites (Finke and Conzelmann, 2005; Rupprecht *et al.,* 2006). Pathology associated with infection is subtle and typical of non suppurative viral encephalomyeilitis. Histologic changes include

perivascular cuffing, gliosis, and neuronophagia (Dolman and Charlton, 1987; Dunlop *et al*., 1996). The prodromal period typically lasts between two and ten days, and is characterized by nonspecific symptoms which can be mistaken for a common cold or flu. These include headache, fever, fatigue, sore throat, cough, and gastrointestinal discomfort. Occasionally, the individual experiences pain or numbness at the site of the bite (Dietzschold *et al*., 2005).

2.8 GLOBAL DISTRIBUTION OF RABIES

Rabies is worldwide in distribution except for few island nations like Australia, New Zealand and Antarctica (Rupprecht *et al*., 2006). No account of global rabies distribution can proceed without an introductory discussion of humans and the domestic dog. Domestic dogs serve as the major reservoir and principal source of RABV transmission to human and other animals in many countries of Asia, Africa, and South America (WHO, 1999). Other domestic and wild animals are typically infected through secondary transmission of RABV variants maintained by dogs, or in many locations, variants of RABV maintained by wild carnivore hosts traceable to a domestic dog origin (WHO, 1999).

In Asia, the main transmission route for human rabies is through a rabid dog bite, between 94% and 98% of rabies deaths are due to canine bites (Dodet and Meslim, 2001). Over the last few years, there has been a decrease in mortality rates in countries where efficient disease control measures have been implemented, e.g. Thailand and Vietnam (Kamoltham *et al*., 2003). In other countries, such as the People's Republic of China and the Philippines, the number of cases has increased over the years. There are several possible reasons for this increase which include an increase in rabies surveillance, an increase in dog population, inadequate post-exposure

treatment, and the lack of availability of effective rabies vaccines (Yongxin and Qing, 2001; Xianchun *et al.*, 2005). Most people (usually children) who died of rabies had not been treated or have not received adequate treatment because of the high cost of vaccines and rabies immunoglobulins. Furthermore, both rabies immunoglobulins and vaccines are not always available. In Asia, dog populations can be divided into three groups; owned dogs, community dogs and stray dogs (Yongxin and Qing, 2001).

Data from Thailand for the year 2000 showed that 53% of human cases of rabies were caused by dogs with owners while 47% were caused by stray dogs (Puanghat, 2001). It is much more difficult to implement control measures (particularly the parenteral antirabies vaccination) for strays. Until recently, very few studies of rabies isolates had been conducted in Asia, but over the last few years four new isolates have been described in insectivorous bats. The Aravan virus was isolated in *Myotis blythii* in Kyrgyzstan (Arai *et al.*, 2003) in 1991 and the Khujand virus in *M. mystacinus* in Tajikistan in June 2001 (Kuzmin, 2002). The Irkut virus, which is phylogenetically similar to genotype 4 and genotype 5, was detected in a *Murina leucogaster* in 2002 in eastern Siberia and the West Caucasian bat virus was isolated in a *Miniopterus schreibersii* in the Caucasus. West Caucasian bat virus is phylogenetically similar to the cluster of genotype 2 and genotype 3 and is the most distinct lyssavirus detected so far (Botvinkin *et al*., 2003).

In the 1950s, canine rabies was endemic in the United States of America (USA), but carefully planned control measures and parenteral vaccination have brought it under control (Ciquet and Picard-Meyer, 2004). In the USA and Canada today, rabies reservoirs are to be found among wildlife. Different epidemiological cycles exist in which the percent number of cases in raccoons

(*Procyon lotor*), skunks (*Mephitis mephitis*), bats and red and grey foxes (*Vulpes vulpes* and *Alopex lagopus*) were 40%, 30%, 17%, and 6% respectively. These species are infected with several variants of the genotype 1 rabies virus (RV).

Usually, the geographical distribution of the virus strains which belong to a particular species is delimited. The virus variants circulating in the raccoons are located along the Atlantic coast as far as the Appalachians, those variants circulating in the skunk are found in California and in the North Central and South Central states of the U.S.A, while those circulating in the grey fox (*Urocyon cinereoargenteus*) are found in Alaska, Arizona and Texas (Cliquet and Picard-Meyer, 2004).On the border between Texas and Mexico, coyotes (*Canis latrans*) and unvaccinated dogs maintain rabies cycle with canines, on the other hand, the cycle maintained by insectivores bats is distributed throughout the USA (Rupprecht *et al*., 2006). One study has shown that cats and dogs are usually infected by the most common wild reservoir species (McQuiston *et al.*, 2001). Since the 1950s, at least 39 human cases of rabies linked to infection by a rabid bat have been recorded in the USA. In most of these cases it was unclear how the victims were infected because most had no memory of being scratched or bitten. The species most often involved are the eastern pipistrelle bat (*Pipistrellus subflavus*) and the silver-haired bat (*Lasionycteris noctivagans*) (Krebs *et al.*, 2002). Spillover infection has been observed from other wild animals into domestic carnivores. In the same way, the viruses present in bats are sporadically found in cats and dogs (McQuiston, 2001). Since 1990, these viruses have been implicated in 92% of indigenous human cases of rabies (Krebs *et al*., 2002).

In Latin America there are two epidemiological cycles, both involving genotype 1 (Cliquet and Picard-Meyer, 2004). The first cycle is terrestrial and is maintained by dogs; canine rabies being

enzootic in most Latin American countries, including the Caribbean islands. The second is aerial and is carried by bats. Several species of haematophagous bats, the main one being vampire bat (*Desmodus rotundus*) (Warner *et al.,* 1999), represent the principal transmission vectors of RV to domestic carnivores and livestock, causing considerable economic losses (Martinez-Burnes *et al.,* 1997). In historical terms, the presence of RV in Latin America was suggested for the first time in insectivorous bats in Brazil in approximately 1910, and confirmed in the insectivorous and frugivorous bat in Trinidad in 1931. In Latin America, as in the USA, several variants of RV exist (Smith and Baer, 1988). Sporadic cases are recorded in humans and the risk of transmission from vampire bats to people was estimated at 0.96 cases for every 100 inhabitants in Arizona region in Brazil (Cliquet and Picard-Meyer, 2004).Insectivorous bats can also infect humans as they represent an important reservoir for rabies particularly in urban environments whereas haematophagous bats on the other hand are found in rural environments, close to livestock breeding areas (Favi *et al*., 2002).

In Europe, the main reservoir and vector of rabies, since the late 1930s, has been the red fox (*Vulpes vulpes*), followed by the raccoon dog (*Nyctereutes procyonoides*) in Central and Baltic Europe. In Estonia, the raccoon dog is the primary infected species, accounting for more than 44% of the rabies cases in 2003 (Anon, 2003). With the exception of islands (i.e. Britain, Ireland) and large peninsulas (Norway, Sweden), rabies infection occurs in most European countries (Steck and Wandeler, 1980). At the end of the 1970s, the farthest limits of the rabies wave to the north, south and west were the Netherlands, Italy and France, respectively. Turkey is the only European country where the domestic dog is the principal vector of rabies. However, a molecular analysis of different isolates (Johnson *et al*., 2003) suggests that there has been recent

spillover from the domestic dog to the fox, which could imply the development of an endemic cycle in wildlife. Cliquet and Picard-Meyer (2004) reported that seven European countries are free of rabies as a result of oral vaccination programmes. These countries include Finland and the Netherlands since 1991; Italy since 1997; Switzerland since 1998; France since 2000; and Belgium and Luxembourg since 2001. Since the first case of rabies in bats was recorded in Europe in 1954, genotype 5 (EBLV-1) and genotype 6 (EBLV-2) have been detected throughout the continent. The EBLV-1 strain seems to be more prevalent, infecting approximately 95% of all bats testing positive for the presence of the virus between 1977 and 2000 (Fooks *et al*., 2003). Bats infected with EBLV-1 and EBLV-2 have been reported throughout Europe, ranging from Russia to Spain, particularly in coastal regions (Cliquet and Picard-Meyer, 2004). Isolates of EBLV-2 have been recorded in central Europe, Switzerland, eastern Europe and the Ukraine (Johnson *et al.*, 2003), whereas EBLV-1 strains are distributed principally throughout western European countries. The EBLV-1a strain has been found in Germany, the Ukraine, Russia, Poland, the Netherlands, and Denmark, while EBLV-1 has been reported from France, Spain and the Netherlands (Allworth *et al*., 1996; Serra-Cobo, 2002).

2.8.1 Distribution of Rabies in Africa

In Africa, the dog is the principal vector and reservoir of rabies (Blancou, 1988; Rupprecht *et al.*, 2006). Dogs represent more than 75% of rabid animals in most African countries and most of the reported human infections occur in children under ten years of age (Cliquet and Picard-Meyer, 2004). Although sporadic rabies cases in wild mammals have been documented throughout the African continent, the disease has not been extensively studied in these countries. This is understandable, because applying control measures and educating the general public is difficult

when there are so many other public health priorities, e.g. acquired immune deficiency syndrome (AIDS), malaria, and tuberculosis. Canine rabies has existed in Algeria, Morocco, Tunisia and Egypt for centuries and in each of these countries, more than 100 cases a year are reported in dogs (Cleaveland *et al*., 2003).

In Tunisia, a national rabies control programme was implemented in 1982. Mass campaigns of parenteral dog vaccination were conducted every two years at first, then, with the rapid dog population turnover, annually, using quality vaccines produced locally. The number of rabies cases decreased significantly (Black *et al.,* 2000). In 1999, 178 cases of rabies were recorded in animals and there was one case in humans.

In Morocco, in 2002, there were 446 cases of rabies in animals and 23 cases of human mortality due to the disease. These human cases were transmitted through dog bites and occurred mainly in rural and suburban areas. It is important to note that 86% of the people who died of rabies between 1995 and 2001 in Morocco had not received any anti-rabies vaccine treatment (Cliquet and Picard-Meyer, 2004).

Canine rabies is present in all of the countries situated between the Sahara desert and the Equator. The role of jackals and hyenas (*Crocuta crocuta*) is occasionally important in some areas, but as spillover from dogs (i.e. additional to canine rabies) rather than as an independent disease cycle (Cliquet and Picard-Meyer, 2004). The area between Sudan and Guinea presents the same epizootic characteristics in the south as those that exist in the sub-Saharan zone to the north, but with the addition of accidental infection of wildlife species including monkeys, bats,

rodents, etc. Nigeria occupies a special place having been the source of numerous rabies related viruses (RRV) isolates from shrews (*Sorex* spp.) and bats infected by the LBV and the MOKV.

In Tanzania, it has been demonstrated that the number of cases of human rabies is clearly underestimated, with a recent study by Cleaveland *et al*. (2003) suggesting that there are actually 4.9 human deaths per 100,000 inhabitants, 100 times more than the number officially recorded.

Rabies in Ethiopia is primarily a disease of dogs. However, many people receive post exposure anti-rabies treatment annually all over the country. Most people are at increased risk of being exposed to rabies, as man-dog contact is very common in the country (Eshetu *et al*., 1999).

Studies by Kitala et al., (2001) in Kenya showed that the dog population is growing with poorly supervised and inadequate vaccination against rabies.

In South Africa, Angola, Botswana, Namibia, Zambia and Zimbabwe, canine rabies represents an important risk for humans (Cliquet and Picard- Meyer, 2004). The situation is complicated by independent rabies cycles in wild mammals and by the presence of RRV genotypes 2, 3 and 4 in wild cats (Nel *et al*., 1993; Hofmeyr *et al.*, 2004). Two distinct RABV variants have been identified from specimens of over 30 different carnivore species belonging to four families of Carnivora namely, Viverridae, Canidea, Mustelidae, and Felidae (Bingham *et al*. 1999a,b; Johnson *et al*. 2004; Cliquet and Picard-meyer, 2004). The two virus variants are maintained by independent cycles; one primarily associated with canids, originating with, and primarily involving domestic dogs, but also affecting several species of jackal (genus *Canis*), and bat-eared foxes (*Otocyon megalotis*); and the second cycle associated with viverrids and genets belonging to the genera *Cynictis*, *Herpestes*, *Suricata*, *Genetta,*and *Civettictus*) (Nel *et al*., 1997; von Teichman *et al*., 1995). The viverrid subtype of RABV probably arose recently from spillover of

the canid subtype and each of these RABV "biotypes" have crossed species barriers to infect other mammals, with no evidence of genetic modification in the virus recovered from non-reservoir host species (Nel *et al.* 1997). Jackal populations support the epidemic of canine RV generally associated with the domestic dog. The same RV found in canines has also been discovered in the bat-eared fox (*Otocyon megalotis*). Several variants of this strain also exist. One is the canine biotype closely related to the European strains of RV, which is maintained by members of the Canidae family, the bat-eared fox, jackal species, and the domestic dog (Cliquet and Picard- Meyer, 2004). The incidence of canine rabies is increasing in sub-Saharan Africa, and few successful dog vaccination programmes have been implemented in the last twenty years (Cleaveland *et al.,* 2003). Some attempts at oral vaccination have been conducted in jackals (Bingham *et al*., 1999c), in *Lycaon pictus* i.e. the free-ranging African wild dogs (Knobel *et al*., 2002; Hofmeyr *et al*., 2004) and domestic dogs (Aubert, 1992). Lagos bat virus (Genotype 2), Mokola virus (Genotype 3) and Duvenhage virus (Genotype 4) have been isolated in Africa. The isolation of Mokola virus has been reported sporadically and rather infrequently from only a small number of African countries. This is the only lyssavirus that has never been isolated in a bat. However, surprisingly, it has been isolated in a number of other different hosts, such as shrews, cats, dogs and rodents (Cliquet and Picard-meyer, 2004). To date, RRV of genotypes 2, 3 and 4 have never been isolated outside of Africa, with the exception of one case of rabies in the frugivorous bat (*Rousettus aegyptiacus*), reported in France in May 1999. This bat had been imported from Africa to France through Belgium, and molecular data demonstrated that the virus was an LBV (Cliquet *et al*., 1999).

2.8.2 Distribution of Rabies in Nigeria.

Evidence of the long history of rabies is contained in the fact that every Nigerian Language has a name for rabies in dogs (Nuru, 1973; Oboegbulem, 1994). The first diagnosis of canine rabies in Nigeria was done in 1925 by the Rabies Laboratory Unit at Yaba, by the demonstration of negri bodies (Oboegbulem, 1994). There have been reported cases and outbreaks of rabies in Nigeria since then (Anon, 1927, 1932; Okoh, 1983; Onunkwo *et al.*, 1980; Ezebuiro,1980; Fagbemi *et al*.,1981; Ogunkoya, 1986; Ezeokoli and Umoh, 1987; Ogunkoya *et al*., 1990; Kwasari and Baba, 2002; Bello *et al*., 2007; Dzikwi *et al*., 2010 b). Information on rabies death is however scarce due to misdiagnoses and under reporting (Ehizibolo *et al*., 2008). In recent decades, the frequency of rabies reporting had increased in Nigeria (Kwasari and Baba, 2002). Controlling this disease will require a deeper understanding of its biology (Okonko *et al*., 2010). When interpreting rabies case data for epidemiologic analysis, we must distinguish between the concept of maintenance (the ability of local populations to support a disease cycle) and persistence (the presence of one or more infected local population) in a host metapopulation (Okonko *et al*., 2010). Many animal and human cases are probably unreported especially in rural areas where veterinary and hospital facilities are inadequate. Data from diagnostic laboratories and field surveys show that over 94% of rabies outbreaks in Nigeria involve domestic dogs (Ezeokoli and Umoh, 1987; Ogunkoya, 2008). Available records (Oboegbulem, 1994) have indicated that from 1928 to 1990 the rabies diagnosis unit of NVRI Vom had diagnosed a total of 3770 rabies positive cases from dogs, cats, domestic and wild animals. Of this number 3555 (94.3%) were in dogs, 114 (3.0%) were in cats and 101 (2.7%) were in other domestic and wild animals. Data collected from the records of the Rabies Diagnostic Unit of NVRI Vom between January1991 and December 2005 showed that out of the 2141 brain samples submitted for rabies diagnosis,

1039 (48.5%) were positive for rabies. Of the 1039 samples tested that were positive for rabies, (1030) (99.1%) were from dogs, 5(0.5%) in cats, while 3(0.29%) and 1(0.10%) were in other domestic and wild animals, respectively (Garba *et al*., 2008). Strains of rabies virus were isolated from a monkey and two hyraxes at the University of Ibadan Virus Research Laboratory(Anon, 1969; 1972; Kasali, 1977) and one each from a Caracal lynx (Okoh, 1986a) and a Civet cat (Enurah *et al*., 1988) at the Ibadan and Jos Zoological Gardens respectively. In addition, two rabies related viruses, Mokola virus isolated from wild shrews caught in Ibadan (Shope *et al*., 1970) and Lagos bat virus isolated from fruits bats in Yaba, Lagos (Boulger and Porterfield, 1958) which have been known to exist in Nigeria are still in circulation among apparently healthy dogs (Dzikwi *et al*., 2010b). Bats are recognized as important reservoir of many emerging infectious agents, including lyssavirus in Nigeria. The results of sero- surveillance study using bat sera in northern Nigeria using lyssavirus-neutralizing antibodies have shown that 19% of the 140 sera samples tested neutralized Lagos bat virus (Dzikwi *et al.,* 2010a). Chalmers and Scott (1969) have proposed a model in which rabies virus survives by adaptation to the preferred host (dog) such that a mutually non-detrimental ecological balance or "climax" is established. In the "canid climax" in Africa, they suggest that the dog suffers in-apparent infection or transient illness, and recovered animals become "healthy carriers" capable of transmitting the disease to other animals. Occasionally infection of the climax hosts may result in overt disease and death and spill over into the less adapted wildlife or human hosts which result in epidemics. There is some evidence to support this model which includes:

(a) The well adapted existence in West Africa of 'Oloufato' a non-fatal disease of dogs which has been identified as rabies (Chalmers and Scott, 1969).

(b) Occasional reports of the disease being transmitted from apparently healthy carriers in Nigeria and other parts of Africa (Fekadu, 1972; Ogunkoya *et al.,* 1990; Baba, 1999; Ajayi *et al*., 2006; Garba *et al*., 2010; Dzikwi *et al*., 2010b). More work is needed to confirm this hypothesis.

Alternative to the "climax" hypothesis is that rabies can be continually transmitted from infected to susceptible dog before the sick dog dies. The long and variable incubation period ensures that the virus can exist in a host for up to one year before clinical disease and death occur. This allows time for new susceptible hosts to accumulate. Transmission is further facilitated by the peculiar property of the virus that forces the diseased animals to actively seek and bite other animals (Ezeokoli and Umoh, 1986). The habit of dogs to congregate and fight during the mating season also enhances transmission (Nawarthe, 1980). Regardless of the exact method of maintenance, the domestic dog is the primary source of human infection in Nigeria (Nawarthe, 1980; Ogunkoya *et al*., 2003; Okoh, 2007). Human exposure is more likely to occur through bites from owned unvaccinated dogs than stray dogs, although because of their tendency to roam far and wide, stray dogs appear to serve as primary source of spread from one community to the other (Ezebuiro *et al*., 1980; Ezeokoli and Umoh, 1986). Human exposure is more common in cities and large cosmopolitan areas than villages in Nigeria, perhaps because of cultural practices in most village communities which limit existence of stray dogs, and ensure rapid destruction of dogs showing aberrant behavior (Nawarthe, 1980; Ezeokoli and Umoh, 1987).

2.8.3 Rabies in Bauchi State

The history of rabies in Bauchi State appears to be very long as evidenced by the fact that every tribe of the State has a name for rabies in dogs. For example the Dugurawa call it Grinyal, the Gerawa call it Yaddabori, the Sayawa call Kaditawaye, the Fulanis call it Ginnaji, the Warjawa call it Iyambahachakai, and the Hausawa call it "Ciwon Haukan Kare". Canine rabies is wide spread in Bauchi state. A fifteen year retrospective study of the prevalence of rabies in Bauchi State by Bello *et al*, (2007) showed that forty-four (44) reported cases of rabies were spread across 13 of the 20 Local Government Areas (LGAs) that constitute the three Senatorial Districts of the state, out of which southern zone had 6 (47.2%), the central zone 5 (38.5%) and the northern zone only 2 (15.3%) indicating that cases of rabies are distributed in the State among all the three Senatorial zones. Cases of dog bites inflicted on people appear frequently in Bauchi hospitals and health clinics. Recent studies by Bello *et al*. (2007) showed that 92 persons were exposed with five (5) deaths. Out of the 92 persons exposed 80 (13.0%) were bitten by owned dogs. The study gave an average of human exposure of seven persons annually. A total of 62 animals of different species came down with clinical rabies of which 58 were dogs (93.6%), 1 cow (0.6%), and 3 sheep (4.8%). Out of the 58 dogs that came down with clinical rabies 57 (98.3%) were adults while 1(1.8%) was a 3- months old puppy (Bello *et al.,* 2007). Clinical rabies has been documented involving species of animals like dogs, cats, sheep, goat, cattle and monkeys based on records from the State Veterinary Clinic and NVRI Diagnostic laboratory based in Bauchi. Under-reporting and ignorance on the dangers of rabies among some health-care workers and the general public are contributing factors to problems of rabies control in Bauchi State. There are only few reported attempts made towards epidemiological study of dog bites locally and nationwide (Fagbami *et al.,* 1981; Osinubi *et al.,* .2003; El-Yuguda *et al.,*

2007). The frequency of the administration of post exposure prophylaxis (PEP) and the epidemiology of rabies in Bauchi State remain to be studied (Bello *et al*., 2007).

2.9 CONTROL OF RABIES

The ultimate solution to the rabies problem lies in the control and eventual elimination of the disease from animal population, prevention in human beings, livestock and in the reservoir hosts. The control is based primarily on breaking the cycles of transmission in the reservoir hosts and secondarily on protection of these alternate hosts from exposure or infection (Beran, 1982; Okonko *et al.*, 2010).

2.9.1 Control of Rabies in Dogs

Canine rabies can be eliminated, as has been demonstrated in North America, Western Europe, Japan and many areas in South America (WHO, 2004). However, canine rabies is still widespread, occurring in over 80 countries and territories, which are predominantly in the developing world (Cliquet and Picard-Meyer, 2004). In more than 99% of all human rabies cases, the virus is transmitted to the victims from dogs; half of the global human population lives in canine rabies-endemic areas and is considered at risk of contracting rabies (WHO, 2004). Effective animal vaccines that provide a considerable duration of immunity have been developed and mass parenteral vaccination programmes remain the mainstay of canine rabies control (Green and Gipson, 1994; WHO, 2002). Dog destruction alone is not effective in rabies control. The principal challenge is effective delivery of vaccines to ensure adequate vaccination coverage in the reservoir dog population. Studies coordinated by the World Health Organization on dog populations have shown that, in many communities in Africa, Latin America, and Asia, a

substantial proportion (at least 60–75%) of the total dog population is accessible for parenteral immunization (WHO, 2002). During the last two decades, a significant reduction in human rabies has been achieved in Mexico, United States of America and the Caribbean by the programme for the elimination of canine rabies initiated and coordinated by the Pan American Health Organization/WHO Regional Office for the Americas (Green and Gipson, 1994). In contrast, over the past two decades cases of rabies have been increasing in parts of sub-Saharan Africa and Asia. This increase has been attributed to the rapidly growing dog populations and increasing urbanization, and increase in density and mobility of human populations (Gipson and Green, 1994; WHO, 1984). To ensure effective coverage, vaccination programmes should consider the local ecology of the dog population, involve coordination of related sectors and incorporate culturally appropriate education efforts (WHO, 2004; OIE, 2010). Canine rabies control programmes should incorporate three basic elements, with priorities of which should vary according to the prevailing social, cultural and economic factors. The basic elements are: (a) epidemiological surveillance; (b) mass vaccination; and (c) dog ecology and population control. Such control efforts require community participation, managerial skills and legislation (OIE, 2010).

Epidemiological surveillance of rabies is the basis for any programme of rabies control (WHO, 1984). Rabies should be a notifiable disease within the national health and veterinary systems (WHO, 2004). Epidemiological data should be collected, processed, analyzed and disseminated rapidly between sectors and different administrative levels. Surveillance of areas in which laboratory-confirmed cases in animals are reported should be encouraged. Attempts should be made to isolate the virus for characterization of prevalent strains (CDC, 1998). Reporting of

laboratory-confirmed human rabies cases alone may lead to a severe underestimation of the true number of human cases, resulting in a low priority being given to rabies control. Therefore, data on the number of humans suspected as being rabid based on clinical evaluation should also be reported (WHO, 2004). The number of people seeking and receiving post-exposure prophylaxis should be reported in order to provide additional epidemiological information on disease burden and to evaluate the effectiveness and cost–benefit of rabies control programmes (CDC, 1998). There is need to adopt or establish systems of rabies reporting, especially for the investigation of rabies outbreaks and identification of the rabies virus strains involved, in view of increased international travel and transfer of animals (WHO, 2004).

Mass canine vaccination campaigns have been the most effective measures for controlling canine rabies (Matter, 2000). The organization of the campaigns is based on intersectoral collaboration, community participation, and strong media support. The success and sustainability of these campaigns depends on political commitment, acquisition and supply of canine anti rabies vaccines by the ministries of health, free delivery of these vaccines, and local-level commitment in the planning and execution of the campaigns and effective coordination and supervision of the campaigns by the health services. At least 70% of the dog population in each community should be vaccinated in areas where canine rabies is endemic (WHO, 2004). Rabies vaccination campaigns are generally conducted annually but more frequent campaigns may be required in areas where population birth and death rates are high (Cleaveland *et al*., 2006). All dogs and cats, when presented, should be immunized, regardless of their age, weight or state of health. Given the high birth rates of many populations, particular attention should be paid to ensuring adequate vaccination coverage of puppies (Dodet and Meslim, 2001). In order to apply strategic planning

and management, an estimate of the dog population and evaluation of a mass vaccination campaign is required. WHO has produced guidance for estimating dog population size (Matter, 2000). All personnel handling dogs during vaccination campaigns should receive pre-exposure prophylaxis. Registration and permanent identification of vaccinated dogs is recommended (WHO, 2002). Three basic approaches to mass vaccination campaigns have been adopted especially in canine rabies endemic areas involving house-to- house visits, the use of fixed vaccination posts in well-recognized sites within the community, and mobile teams which set up temporary vaccination posts (Dodet and Meslim 1997; Cleaveland *et al*., 2006).

Oral vaccination of dogs offers a new approach that may significantly improve dog vaccination coverage (especially of free-roaming and poorly supervised dogs) when applied either exclusively or in combination with parenteral vaccination. As dog accessibility to vaccination by the parenteral route is one of the major obstacles for canine rabies control in many different parts of the world (Dodet and Meslim, 2001; WHO, 2002). Acknowledging the limitations of the parenteral route for canine rabies elimination, WHO stimulated studies on oral vaccination of dogs and the development of safer and effective vaccines and baits for such vaccination (WHO, 1993; WHO, 2004). Although the preferential vaccine for dog immunization should be parenteral, oral vaccination should be used whenever there is high population of inaccessible dogs (Dodet and Meslim, 2001). Further field studies to evaluate economy, efficiency and effectiveness, and demonstrate safety are encouraged and strategies for vaccine bait distribution must be studied further as new innovations are required for economical distribution (WHO, 2004).

2.9.2 Control of Rabies in Terrestrial Wildlife Species

Until the 1970s, wildlife rabies control centered largely on efforts to decrease population levels of rabies vector species (Rupprecht *et al.*, 2006). The objective of wildlife culling is to lower population densities below the threshold necessary to maintain the disease. Culling techniques include hunting, trapping, poisoning, and den gassing (OIE, 2004). Studies on the effect of culling reservoir species on the control of rabies show that there are only very few examples where such methods alone have either eliminated the disease or have prevented its spread to previously uninfected areas (Rupprecht *et al.*, 2006). Any predator control technique should be directed not toward extinction of a reservoir species but toward reduction of a species population to a level too low to support an epizootic of rabies (Uhaa *et al*., 1992; OIE, 2010). Many limitations of cost and danger restrict the effective wide scale use of trapping, poisoning, gassing and hunting. The resilience of these Carnivora to persecution, their high reproductive potential, together with the capacity of the environment to provide food, water and shelter, most often render population control efforts futile (WHO, 2005). A more promising approach would be to combine population reduction with immunization, as has been successfully applied in Canada in 1999 to stop the advancing raccoon rabies epizootic (OIE, 2004). Promising results have been obtained in experiments on immunization of foxes with vaccine (European Commission, 2002) and the procedure has also been applied in field conditions namely in Europe and Canada (Steck and Wandeler, 1980). Vaccination has received increasing attention as a potential means of wildlife rabies control (European Commission, 2002). Attempts in Europe to trap wild carnivores and to release them after parenteral vaccination were rapidly abandoned, though such trap–vaccinate–release procedures are still used with apparent success in some areas of Canada. It appears more promising to lure the wild mammal into vaccinating itself. This is possible when

oral vaccines are included in baits targeted at the principal host species (Uhaa *et al*., 1992; European Commission, 2002). As in Europe, the first rabies control measures applied in the USA consisted of attempts to reduce the reservoir populations, but these were unsuccessful (Smith, 1996). Oral vaccination has proved to be effective in significantly reducing the number of rabies cases in red and grey foxes, as well as in raccoons and coyotes. However, oral vaccination is much more difficult in the USA than in Europe where the number of reservoir animals is limited and the surface areas to be covered by vaccination are much smaller (WHO, 2002; Randal *et al*., 2004). As far as rabies control in wild terrestrial animals is concerned, the only efficient and cost-effective technique thus far has been oral vaccination (Aubert, 1992; Randal *et al.,* 2004).

2.9.3 Bat Rabies Control

Vampire bat-transmitted paralytic rabies of cattle can be controlled by vaccination of cattle. The only presently available approach to control in the vector species is culling (Cliquet and Picard-Meyer, 2004). This can be achieved by administration of anticoagulant to vampire bats, either by direct application of the substance on the backs of captured bats or by the intramuscular injection of warfarin to cattle. Non-specific methods that indiscriminately destroy haematophagous, frugivorous, nectarivorous, and insectivorous bat species must be avoided. Approaches to control the transmission of insectivorous bat rabies to people should include education of the public to avoid potentially infectious contact with bats, to seek proper treatment after exposure and to prevent bats from establishing colonies in certain sensitive buildings (e.g. hospitals and schools) (Rupprecht *et al.,* 1995; Rupprecht, 2003). Preventive immunization of populations living in highly endemic areas should be considered (WHO, 2004).

It is recommended to provide education to avoid direct contact with wildlife in general, and with abnormally behaving and sick animals in particular. Any person bitten by a wild animal, including bats, must seek medical attention. Translocation of wildlife for any purpose, except conservation, should be banned or strongly discouraged (WHO, 2004; OIE, 2010). Another possibility is the principle of population control by interrupting the reproduction cycle through the use of hormones (WHO, 2004; OIE, 2004).

2.10 RABIES POST EXPOSURE PROPHYLAXIS

2.10.1 General Considerations

All people exposed to rabies should promptly and thoroughly cleanse their wound(s) and apply appropriate antiseptics. Professional assistance is advised. This should be followed, if careful medical assessment requires it, by a complete vaccine series using a potent and effective vaccine that meets WHO criteria and passive immunization in category III exposure (WHO, 2005). Rabies vaccines for human use that meet WHO requirements for production and control are safe and effective and are free from the neuroparalytic adverse reactions associated with nerve tissue-derived products. Pregnancy, infancy, old age and concurrent illness are not contraindications for rabies post-exposure prophylaxis in the event of an exposure (WHO, 2005; Khawplod *et al*., 2006). Prolonged incubation periods have been associated with human rabies; therefore people who present for treatment even months after a possible rabies exposure should be evaluated and treated as if the event had occurred recently. Factors that should be considered in deciding whether or not to initiate post-exposure prophylaxis include: The nature of the contact or injury, the presence of rabies in the area where the contact occurred or where the animal responsible originated, the availability of the animal for laboratory examination or observation, the species of

the animal, clinical status of the animal responsible, the vaccination history of the animal, and type and timing of vaccine used (Cleaveland *et al*., 2002; WHO, 2005). The decision to administer post-exposure prophylaxis after an exposure to an apparently healthy animal should be based on a careful risk assessment by a qualified medical professional. The risk assessment should consider the criteria outlined above. A history of rabies vaccination in an animal is not always a guarantee that the biting animal is not rabid. Animal vaccine failures may occur because of improper administration or poor quality of the vaccine, poor health status of the animal, and the fact that one vaccine dose does not always provide long-lasting protection against infection in dogs (Cleaveland *et al*., 2002). Whether a dog bite was provoked rather than unprovoked should not be considered a guarantee that the animal is not rabid as it can be difficult to understand what an attacking dog considers provocation for an attack (Cleaveland *et al*., 2002). If the animal involved in the exposure is a potential rabies vector in a rabies-endemic region, initiation of post-exposure treatment is indicated (WHO, 2005). Prophylaxis should never await the results of laboratory examination, nor should the responsible animal be observed for signs of rabies prior to starting post-exposure prophylaxis (Willoughby *et al*., 2004). Wound treatment and administration of rabies biologicals, including a passive immunization product, when required, and vaccine, should be started as soon as possible after exposure (WHO, 1987). Immediate humane killing of the animal and examination of the brain at a reliable laboratory should be performed whenever possible. If the species involved is unlikely to be infected with rabies, treatment may be deferred pending the outcome of laboratory testing, providing that results can be obtained within 48 hours (WHO, 1993; WHO, 2003). If the attacking animal is a pet dog or cat that is available, it should be kept under observation for 10 days, preferably under the supervision of a veterinarian. Prophylaxis can be discontinued if the dog or cat remains

healthy for at least 10 days after the exposure occurred (WHO, 2005). The natural history of rabies in mammals other than dogs or cats is not fully understood and therefore the 10-day observation period may not be applicable. Humans exposed to other species of mammals suspected to be rabid, including bats and other wild animals involved in the transmission of rabies should therefore receive post-exposure prophylaxis unless the animal can be captured, humanely killed and immediately examined at a reliable laboratory (Willoughby *et al*., 2004; WHO, 2005).

2.11 DOG POPULATION STUDIES

Domestic dogs are the main reservoir of rabies throughout the developing world. As such, understanding domestic dog ecology has been recognised as central to the design of effective rabies control programmes (Beran, 1985; Beran and Frith 1988; WHO 1987; WHO/WSPA, 1990; Wandeler *et al.,* 1993; Kitala *et al*., 1993). Standard procedures for collecting and applying such ecological information were developed by the WHO in the 1980s (WHO, 1987; WHO, 1992; WHO/WSPA, 1990; Sutherland, 2006). The methods of data collection, based on questionnaire surveys and mark recapture techniques (Beck, 1973; Facka *et al*., 2008), were designed to estimate population size, density, and demographic parameters. The guidelines also stressed the importance of understanding the relationship of dogs to the human society (Beran 1985; Beran and Firth, 1988; Wandeler *et al*., 1988), and a system of classifying dog populations based on the level of dependence on owners was also introduced (WHO 1987). The guidelines recommended that the planning of rabies control should include an assessment of the different sections of the dog population in terms of accessibility to vaccination and the appropriateness of applying culling measures (WHO, 1987, 1992). The dog population data also provides the

baseline information needed to evaluate the success of a given intervention (Bogel and Joshi, 1990; Butler and Bingham, 2002).

Before any rabies control programme is initiated, data should be obtained on patterns of dog ownership, the relationship of animals to the human society, population, density, age, structure and turnover, habitat, relationship of dogs to other reservoir species, etc. (WHO, 1992). Population estimates are necessary for making realistic plans for dog population management and zoonosis control, and for monitoring the success of such interventions. However, for designing effective management plans, data on population sizes alone are insufficient. Additional information is required, such as degrees of supervision of owned dogs, the origin of ownerless dogs and accessibility (OIE, 2010). Considerable experience has been gained in projects coordinated by WHO in the development of methodologies related to dog ecology and dog population management in Ecuador, Nepal, Sri Lanka, Tunisia, and other ecological studies conducted in South America and Asia. However, data collection needs to be continued in other areas and in countries with different social and ecological conditions (WHO, 2004). Priority should be given to obtaining such ecological data from areas where the risk of exposure and the likelihood of spread of infection are greatest. Wide variations exist in the relationship of dogs to human society throughout the world and the success of a canine rabies control programme in a specific country will depend largely on its adaptation to local ecological and social patterns (WHO, 1984; OIE, 2010). In broad terms, dogs can be divided into two distinct groups, on the basis of their relationship to human society.

The first category is identified as owned dogs which are considered as the property, or part of, a specific household to which it provides economic or social value. An owned dog may be

restricted or unrestricted in movement. In rabies control programmes, these dogs may be vaccinated and/or harborage, at least during part of the year, from more than one household. Depending on the society, such dogs may be vaccinated or removed at the initiative of the community, but not of the individual. In many developing countries, these dogs hold the key to the success or failure of programmes (WHO, 1984; OIE, 2010). The second category is identified as stray (un-owned) dogs. Owned dogs not wanted by residents of the community. Stray dogs may be found individually or in packs. In rabies control programmes, they can usually be removed without producing objections from the public (WHO, 1984; OIE, 2010). In most of the world and especially in tropical countries, the animal reservoir of rabies is the dog, and the magnitude of the problem of human rabies depends basically on the relationship of dogs and people. The maintenance of the disease essentially reflects transmission of the virus from dogs to other domestic animals, and to man, with human beings as dead-end hosts. The most cost-effective and logical approach to the control of the disease is via the animal reservoir host (WHO, 1984). In ecological studies, it is often necessary to estimate the number or abundance of animals. There are various techniques for doing this (Bookhout, 1994; Sutherland, 2006) but only some have practical application for use in rabies control and when assessing the effectiveness of a dog control programmes (OIE, 2010). These methods are modifications of ecological techniques developed for wild species and precise validity must be stressed. No practical method can determine the exact number of dogs in a population size (Sutherland, 2006). At this time, the best validation will be to use several methods within the same population (OIE, 2010). The choice of methods for assessing the size of dog population depends on the ratio of the owned versus ownerless dogs, which may not always be easy to judge (OIE, 2010). For populations with a large proportion of owned dogs it may be sufficient to consult dog registration

records or to conduct house hold surveys. These surveys should establish the number of owned dogs and the dog to human ratio in the area. In addition, questions on dog reproduction and demographics, care provided, zoonosis prevention, dog bite incidences may be asked and standard polling principles should be applied (OIE, 2010). Estimate of abundance tend to be validated when several methods, differing conceptually give comparable results (WHO/WSPA, 1990).

Dog abundance is related to different epidemiological situations, to different culture areas, to different rural and urban habitats, to areas of different human settlement patterns and also to different social strata of human rural and urban populations (Pain, 1997). Dog population density is commonly indicated as a dog to human ratio, occasionally also as dogs per household. In many situations it would be more meaningful to express it as numbers of dogs per unit areas, or to have it related to both surface area and human population (WHO, 1984).

Various methods are available for estimating the number of free-roaming carnivores, all of which are based on two assumptions (OIE, 2010). The first states that mortality, emigration and recruitment into the population are minimal during the period of census, or that corrective factors can be incorporated into resultant estimates while the second assumption states that all individuals within the population to be estimated have an equal chance of being counted (Okoh, 1986a; Kitala *et al.,* 2001).

2.11.1 Total or Direct Counts Estimation Techniques

Counting of dogs visible in a defined area is the simplest approach to getting information on population size (OIE, 2010). This method simply consists of making direct visual counts of

individual dogs in a defined geographical area and within a limited period of time in order to meet the assumptions mentioned above. One has to take into account that the visibility of dogs depends on the physical environment, but also on dog and human activity patterns (Bogel and Joshi, 1990; Pain, 1997). The visibility of animals changes with the time of the day and with seasons as a function of food availability, shelter (shade), disturbance, etc. Repeated standardized counting of dogs visible within defined geographical localities (e.g. wards) and specific times will provide indications of population trends (OIE, 2010). Direct counting is most reliable if it is applied to small and relatively confined dog populations, e.g. in villages, where it might be possible to recognize individual dogs based on their physical appearance. Under certain conditions, estimates of density may also be obtained by counting dogs along stratified samples of randomly selected streets or in quadrants. These data can then be extrapolated to the entire study area. In some circumstances, data derived from this technique may also be used to compare dog densities between areas when expressed, for example, as the mean number of dogs observed per unit of land area (i.e. number of dogs per hectare (Brooks, 1990; Sutherland, 2006).

2.11.2 Mark-recapture Estimation Technique

Methods using mark-recapture procedures are often considered more reliable (OIE, 2010), however, they also produce trustworthy results only when a number of preconditions are met. Mortality, emigration, and recruitment into the population should be minimal during the census period (Wandeler, 1985; Rautenbach *et al*., 1991). One may be able to incorporate corrective factors into the calculations. It is therefore important that the recommended census procedures are applied at times of low dispersal and that one selects study plots of shape and size that minimize the effect of dog movements in and out of the observation area (Sutherland, 2006).

Census surveys should be completed within a few days to a maximum of two weeks in order to reduce demographic changes. In addition, all individuals in the population should have an equal chance of being counted (OIE, 2010). This is a highly improbable condition for dogs whose visibility depends on ownership status and degrees of supervision. It is therefore recommended that the investigator determines what fraction of the total population he/she might cover with an observational method and how much this part overlaps with the owned dog segment that he/she assesses with household surveys. There are essentially two ways to obtain a population estimate if it is possible, in a defined area and within a few days, to tag a large number of dogs with a visible mark, e.g. a distinctive collar or a paint smudge. The first method requires that the capture (marking) effort remains reasonably constant for the whole length of the study. By plotting the daily number of dogs marked against the accumulated total of marked dogs for each day one can extrapolate the value representing the total number of dogs in the area. More commonly used in wildlife studies are mark-recapture methods (Peterson-Jackson, Lincoln indices) (White, 1996; Serverson and Plumb, 1998). Dogs are marked (tagged) and released back into the population. The population is subsequently sampled by direct observation. The numbers of marked and unmarked dogs are recorded. One multiplies the number of dogs that were initially marked and released by the number of subsequently observed dogs divided by the number of dogs seen as marked during the re-observation to obtain a total population estimate (Schemnitz, 1980; Brooks, 1990; WHO/WSPA, 1990; Sutherland, 2006; Facka *et al.*, 2008). The population estimate is then obtained as follows:

$$\text{Estimated dog population} = \frac{\text{No. dogs subsequently caught}}{\text{No. marked dogs recaptured}}$$

$$\text{No. dogs caught, marked and released}$$

2.11.3 Photographic "Recapture" Estimation Method

Dogs in urban areas do not have to be physically captured in order to mark them. Studies by Daniels (1983) used a method whereby dogs were "marked" by photographing them. Subsequent sampling then determined the number of "recaptures" on any given day based on the number of dogs that had been photographed previously. In other studies a modification of Schnabel's statistical analysis for multiple recaptures (Severson and Plumb, 1998) was adopted. This technique has the advantage of reducing sampling error since capture ratios are averaged. Photographic recapture has several advantages over actual capture as there is no possibility of developing trap shyness or proneness as the animal does not know it has been trapped. Photographing the dogs is faster and easier than trapping and is acceptable to the general public (White, 1996; Kitala *et al*., 2001). While the photographic multiple recapture method may be suitable for smaller areas where the dog population consists of mixed breeds and individuals can be distinguished on the basis of colour, identifying markings and size. Native dogs in some geographical areas are more physically uniform in appearance and distinguishing individuals would be difficult or impossible. In such area physically marking individuals may be necessary (Severson and Plumb, 1998; Brooks, 1990).

2.11.4 Indices Estimation Technique

The techniques involve establishing a relationship between the numbers of animals present in an area and some measurable environmental factor. So far the only published attempt to establish relative figures of dog abundance and distribution in a city used the number of sightings of dogs at large by school children in Bristol, United Kingdom (Harris, 1981).

Another index which could possibly be used is the widely recorded frequency of reported dog bites in relation to the dogs present in an area. But this figure depends on a great variety of factors. Indices of relative abundance generally require less effort to obtain than actual densities and are particularly valuable for determining changes in population size over time or for comparisons between environmentally similar areas. As with all other techniques previously discussed, certain assumptions must be made in order to obtain valid indices (White, 1996; Severson and Plumb, 1998). The density and distribution of dogs, whether in urban or rural areas vary depending upon environmental factors, availability of food, water and shelter, and human cultural practices and customs. Because of these variations, the selection of sampling units or methods of stratification of study areas, the results of which are later extrapolated to estimate total densities, have to be carefully considered (Brooks, 1990). For example, the commonly used procedure of sampling to obtain a dog to human ratio and applying it to the total human population in a city to estimate total dog numbers, does not take into account variations in the frequency of dog ownership as a result of such factors as economic status. Sampling procedures are therefore an extremely important component of population estimation techniques (Severson and Plumb, 1998; Facka *et al*., 2008).

2.11.5 Questionnaire and Household Survey Estimation Technique

The number of owned dogs may be established by questionnaire surveys, or from the records of licensing of dogs (Okoh, 1986a; OIE, 2010) or during vaccination campaigns (Brooks, 1990; Kitala *et al*., 2001). If there is any indication that a sizeable proportion of a dog population escapes these censuring procedures, the techniques used for estimating wildlife abundance have to be applied (White, 1996). Also, canine and feline population estimates of different households

in urban, sub-urban, and rural localities have been made from stratified random sampling or completely random sampling of either the rural or urban communities (Franti *et al*., 1980). Several methods for estimating dog population densities based on questionnaire surveys and capture/mark/re-observe studies are available (Matter, 2000). The combination of these two methods allows collection of accurate information on the whole dog population and subpopulations, defined in terms of confinement levels or other parameters. Questionnaire surveys conducted in the community can be useful where residents recognize the dogs present in their communities (WHO, 1992).

CHAPTER 3

MATERIALS AND METHODS

3.1 STUDY AREA

3.1.1 Bauchi State

Bauchi State is located between longitude 9˚ 15'E to 10˚ to 43'E and latitude 9˚ 55'N to 12˚ 45'N in the Northern Guinea/Sudan savannah zone of Nigeria (Figure 3.1). It covers a total land area of 66,514 square kilometers and has 20 LGAs. The State has an estimated population of about 5 million people based on 2006 census. It has an annual rainfall of between 875 to 1075mm. It shares borders with Plateau and Kaduna States to the west, Kano and Jigawa States to the north, and Yobe, Gombe, and Taraba States to the north-east (Odunlami, 2003; Bello *et al.,* 2007). Bauchi town, located at latitude 10°17 ' north and longitude 9°49 ' north, is the dominant urban centre in the State. It covers an area of over 35,400 square kilometers and most of the 398,190 inhabitants of Bauchi LGA live within the city and its environs. Bauchi town enjoys an annual rainfall total of up to 1091.4 mm. Its hottest month is usually April (with 40.56 ℃), while the coldest months are December and January with average temperatures of 6.1˚C and 7.2˚C respectively. The minimum and maximum annual temperatures in the city are, respectively, 18.3˚C and 32.4˚C. Bauchi State is considered home of tourism because of the presence of the Yankari, Lame-Bura Game reserves and the Sumu wildlife park with many other forest reserves which harbor many wildlife species. These game reserves are located in Central and Southern Senatorial Zones of the State. Reports on cases of rabies from the LGAs within these Senatorial Zones were significantly high.

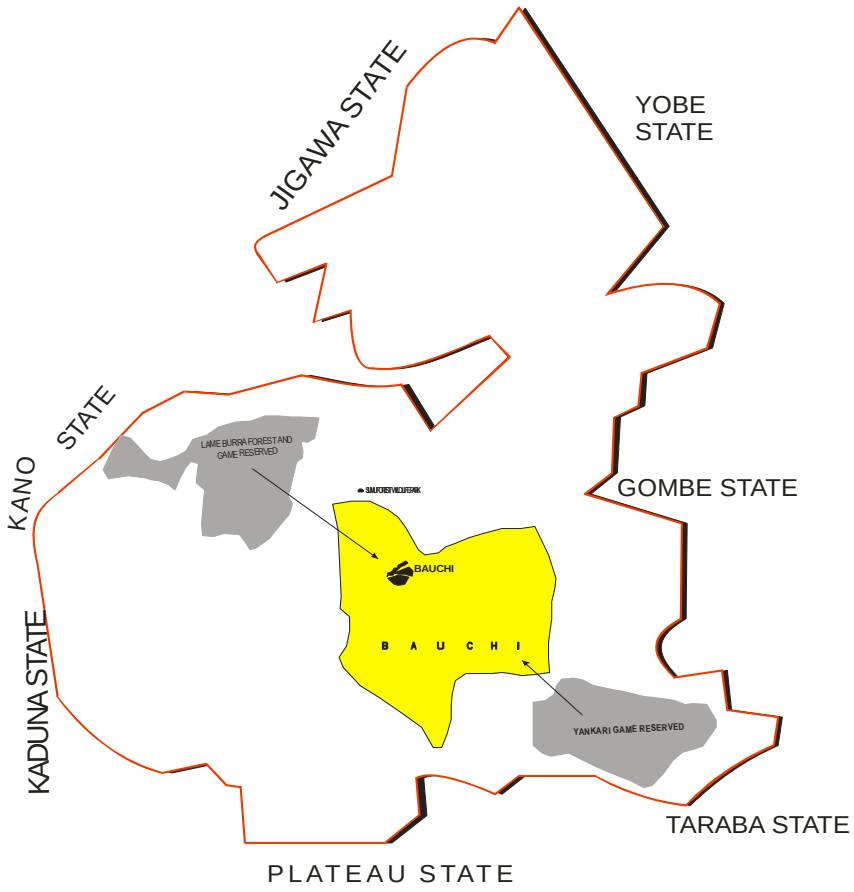


Figure 3.1: Map of Bauchi State, showing Area of studies.

3.1.2 Yankari Game Reserve (YGR)

The YGR is located in the south-central part of Bauchi State; it covers an area of about 2,244 square kilometers. It is located in the heartland of the West African savannah which makes it a unique place for tourists and holiday makers to watch wildlife species in their natural habitat. It is also one of the most popular eco-destination in West Africa (Olokesusi, 1990). YGR has rich wildlife resources. The game reserve is an important refuge for over 50 species of mammals and over 350 species of birds. It is one of a few remaining areas left in West Africa where wild animals are protected in their natural habitat (Odunlami, 2003). In 2000, YGR hosted over 20,000 tourists from over 100 countries, which makes it the most popular tourist destination in Nigeria. If properly managed, it could become a significant part in the development and promotion of tourism throughout Nigeria.

3.1.3 Lame-Burra Game Reserve (LBGR)

Most often, the prime attention of visitors is focused on YGR at the expense of other game reserves in the State. One of such game reserve that is attracting attention is the LBGR which is the second largest in the State. The special significance of the reserve is its beautiful scenery and unique varieties of fauna and flora species which are of particular interest to botanists and zoologists. The LBGR is also noted for its attractive historical sites such as the Barma Danwara Ghittu fishing pond and historical caves. Animals and birds including giraffes, ostriches etc, which are rarely sighted at the YGR, were known to exist in the LBGR. Presently, most of these wildlife species are no longer seen in the game reserve because of activities of poachers who hunt the animals. Other human activities like, farming, cutting of trees for fire wood, and grazing of livestock also contributed in the reduction in number of these wildlife species.

3.1.4 Sumu WildLife Park (SWP)

In the year 2006, about 250 animals - including, impala, springbok, oryx, kudu, blue wildebeest, eland, zebra and giraffe were imported from Namibia to the SWP to boost the tourist potentials of Bauchi State. The Government of Bauchi State decided to develop the Sumu forest reserve and fenced about 40 square kilometer of it to develop the park which is located about 14 kilometres from Kafin-Madaki, the Local Government Headquarters of Ganjuwa Local Government. Most of the animals were young when they were brought into the park and were allowed to properly adapt to the Nigerian climate and vegetation. Presently, the animals have fully adapted and have reproduced in large numbers. The tourism potential of the SWP is great because of the variety of animal species that are unique and hardly found in the other parks and game reserves in Nigeria. This made it to be of particular interest to zoologists and has started to attract tourists. The game rangers and guards and some local farmers living at the fringes of the SWP and the forest reserves were used for the wildlife ecology and abundance studies.

3.2 STUDY DESIGN

3.2.1 Dog Population Study

The dog population study was carried out in Bauchi Township and some selected villages in Alkaleri and Ganjuwa LGAs, in which a structured questionnaire (Appendix 3.1) was developed and used for compound dog counts and a profoma form (Appendix 3.2) designed and used for street dog counts. Students from the School of Agriculture, Bauchi, the Federal Polytechnic Bauchi, and some staff of NVRI Diagnostic Laboratory Bauchi were trained on how to administer the structured questionnaire for the compound dog survey and on the street dog

counts using the profoma form. A pilot study was carried out for two days in order to train the participating assistants which allowed for assessment of the quality of the structured questionnaire before the commencement of the actual dog population survey.

3.2.2 Wildlife Abundance and Assessment of Wildlife/Human/Domestic Animal Conflicts

The study on wildlife abundance and the assessment of wildlife/human/domestic animal conflicts were carried out in the three game reserves located in the State and included some villages located at the fringes of these game reserves. A separate structured questionnaire (Appendix 3.3) was designed for this aspect of the study. Assistants were identified and included some staff members of the game reserves, farmers, hunters, and community leaders. These were used extensively during the study. Similarly, a pilot study was carried out for three days prior to the commencement of the actual survey.

3.3 PROCEDURE

3.3.1 Dog Population Estimation in Bauchi

As indicated in section 3.2.1, the dog population estimation was carried out using the street dog count and the compound questionnaire survey. Using a detailed map of the Bauchi Township obtained from Bauchi State Urban Development Board. The various socioeconomic and land use districts were plotted and the Bauchi township was stratified into five areas for the purpose of the study. These areas are (a) the Government Reservation Area (GRA); (b) Bauchi township consisting of Wunti,Fadaman Mada, Igbo quarters, and Mudalawal; (c) Bauchi native town consisting of Fada, Nasarawa, Jahun, and Bakaro; (d) the Railway,Zango, and gudum area;

(e)Yelwa consisting of Yelwan makaranta, Yelwan lebra, Gwallameji, Unguwan Angas, and Kagadama areas.

3.3.1.1 Street dog count

The streets in each of the identified areas were listed and numbered serially. Ten percent of the streets were randomly selected for the street dog study counting using random sampling without replacement. Students from the School of Agriculture Bauchi, and Federal Polytechnic Bauchi volunteered and were used as volunteers and trained to assist in the study. A team of the students surveyed the areas one at a time, walking up and down each of the selected streets and counted in a stratum and recorded the dogs seen in each of the street, taking advantage of local areas that were best for observation such as specific market streets, rubbish dump sites, and known pathways. On each day, the study areas were surveyed and every dog within a given distance was recorded on the proforma. The counting of dogs was carried out early in the morning between 6 a.m and 7.30 a.m. This time was selected because it corresponded with the period of maximum dog activity, less human activity and good visibility. A multiple observation/re-observation technique was employed and average counts were determined in order to reduce sampling errors. The number of counted dogs in the selected streets in each of the identified areas was used to estimate the population of dogs in each area. An estimate of the entire dog population in the entire Bauchi city was determined based on all the counts from the five areas. With this approach, the underlining assumption was that dogs were uniformly distributed in the various zones.

3.3.1.2 Compound questionnaire survey of dogs.

The compound survey was carried out using the same streets used in the street count. In addition to dog population studies, the compound survey was used to obtain information on zoographic and demographic aspects of dog ownership and attitudes of dog ownership. An adult member of every tenth compound on each side of the selected street was interviewed for about 10-20 minutes using the questionnaire designed for compound survey which consisted of three parts. Part one covered information about household and dog population structure, part two dealt with the management of dogs and vaccination program while part three covered cases of dog bites, post exposure management, consequences, and possible frequency of rabies outbreaks.

3.3.2 Survey of Wildlife Abundance and Assessment of Wildlife/Human/Domestic Animal Conflicts

The wild life survey was to determine the presence or absence of some wildlife species including lions, hyenas, monkeys, jackals, mongooses, hyraxes, baboons, foxes, wild cats, wild dogs, and squirrels) in the three game reserves located in Bauchi State. The two survey methods used included (a) direct observation of wild mammals, and (b) the interview and Questionnaire administration for the survey of wild mammals

3.3.2.1 The direct observation survey method

Game warders were used to identify those areas to concentrate field visits to sites where wild canids and felids were located within the game reserves. Direct observation and documentation of the species of animals available were then made.

3.3.2.2 Questionnaire survey of wild mammals

Selected people including staff of the protected reserves (i.e game warders and conservation officers), hunters, farmers, and others (possible data holders) in the game reserves and communities living at the fringes of the game reserves were interviewed using the structured questionnaire. The questionnaire also consisted of three parts. Part one was concerned with biodata of the respondent. Part two covered information on wild mammals' ecology and abundance while part three covered information on wild predator conflicts with human and domestic animal communities.

3.4 SAMPLE COLLECTION

Two hundred and two heads of slaughtered dogs were obtained from dog meat markets locally referred to as 'mammy markets' located at the Army barracks, and Anguwan Ngas in Yelwa, Bauchi State. Bars and restaurants existed in these places where dogs were slaughtered as delicacy for human consumption. Also, seventy six heads of jackals, 18 heads of mongoose, 24 heads of squirrel, 28 heads of wild cats and 30 heads of hyraxes were obtained from the available wildlife meat markets located in Alkaleri, Bauchi, Toro, Ningi and Ganjuwa LGAs. Staff of these game reserves (game warders), farmers, and community leaders from the villages at the fringes of the game reserves assisted in obtaining the samples. Samples of the hippocampus, brain stem, cerebellum, and cerebrum were removed according to the method described by CDC (2008). A ventral midline incision from the symphysis of the mandible to several centimeters caudally beyond the larynx was made. The musculature attachment of the tongue was rostrally severed on both sides to free the larynx, trachea and oesophagus and the musculature was then retracted to expose the ventral surface of the spinal column. The area was then palpated to

identify the atlanto-occipital joint and dissected to expose the tough connective tissue located on the ventral surface of the joint. A tip of scalpel blade was carefully used to cut through the connective tissue to expose the brainstem/spinal cord. The exposed brainstem and spinal cord tissue were then severed again as far caudally and rostrally as possible to yield central nervous system tissue suitable for rabies testing. The brain samples collected from both dogs and wild mammals were stored at -20˚C until analyzed.



Plate I Photograph of dog heads (*Canis familiaris*)



Plate II Photograph of head of jackal (*Canis aureus*)



Plate III Photograph of heads of hyraxes (*Procavia capensis*)



Plate IV Photograph of head of a mongoose (*Mungos mungo*)

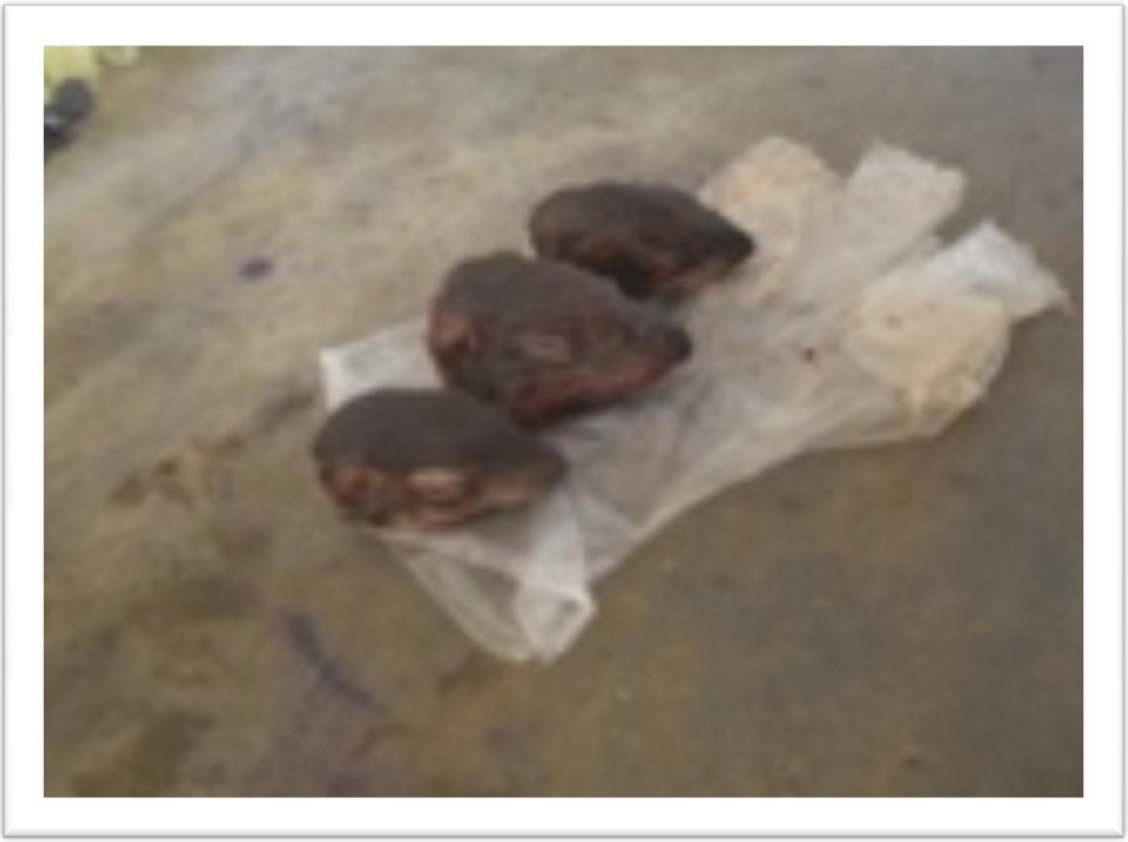


Plate V Photograph of heads of squirrels (*Spermophilus elegans*)

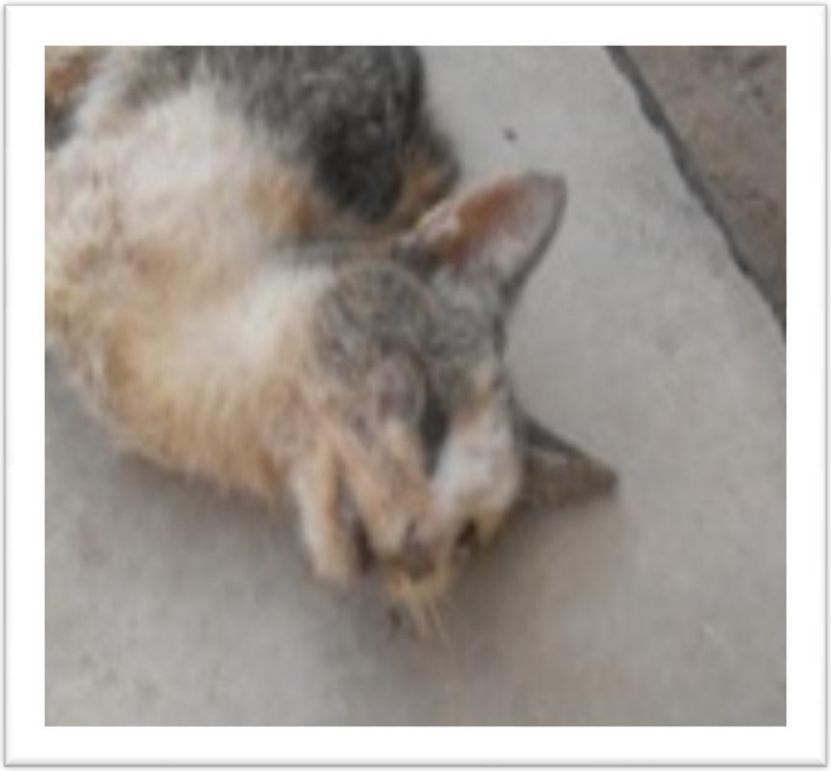


Plate VI Photograph of a wild cat (*Felis silvestris*)

3.5 SAMPLE PROCESSING

The brain samples collected were transported to NVRI Vom in plastic ice packed coolers. The samples were processed at the Rabies Laboratory of the Central Diagnostic Division of NVRI Vom, for the determination of rabies antigen using the direct fluorescent antibody test (DFA) according to the method described by Dean *et al*. (1996) and CDC (2008).

3.5.1 The Fluorescent Antibody Test (FAT) procedure.

A monoclonal antibody labeled with fluorescein-isocyothionate rabies fluorescent antibody assay DFA (monoclonal antibody FITC-conjugate) Catalog Number 5100 reagent (Chemicon International Inc. 1-800-437-7500) was used. Aliquots of the DFA reagent diluted 1:40 in working phosphate buffered saline (PBS) pH 8.0 for testing were stored in a freezer. A known positive dog brain sample (positive control) and a three-week old normal non- rabies infected mouse brain sample (negative control) were used as controls. Thin impression smears of each of the test brain specimens were made at the centre of clean glass slide and properly labeled. Similarly, smears of the positive and negative controls were made on different slides, which were also properly labeled. The smears were air-dried, fixed in cold acetone contained in coplin jars for 30 minutes in a freezer. The slides were then brought out and air-dried for about three minutes and the smears were encircled with wax pencil for easy identification. The slides were then placed onto a moist chamber to prevent drying as improvised using petri dishes with adsorbent cotton wool wetted in the dishes and placing two fragments of sterile strips of wood material on the cotton to which the smear slides were place on. Two drops each of the diluted aliquot DFA reagent were added to cover the smears within the encircled areas of the slides in the moist chamber and were incubated for 30 minutes at 37˚C. The slides were then rinsed four

times in distilled water for about 5 minutes to remove the unbound DFA reagent from the smears. The stained smears were then observed for apple green fluorescence under leitz Ortholux fluorescent microscope.

The smears were examined at x20 magnification for the presence of clusters of apple green fluorescence indicating the presence of rabies antigen. Contrary results indicated absence of rabies antigen. The findings in the test sample smears were compared with the findings in the positive and negative control smears. Samples were considered positive when brilliant apple green shining inclusions/particles of varying shapes and sizes were found under the microscopic field and were negative when such inclusions/particles were absent.

3.6 DATA ANALYSIS

All the data generated in this study were analyzed using the Statistical Packages for Social Sciences (SPSS) for Windows, Version 15.0. (Standard Version SPSS Inc., Chicago, IL, USA) to carry out descriptive analysis of data obtained from the study. Chi-square test for association and odds ratio analysis were used to test for association between categorical variables. Values of $P < 0.05$ were considered significant.

CHAPTER 4

RESULTS

4.1 STREET AND COMPOUND DOG COUNTS IN BAUCHI METROPOLIS

The results obtained from the estimate of dog population in Bauchi metropolis based on compound and street counts are presented in Table 4.1. The overall population of dogs based on streets counts was 5310 while the dog population based on compound counts was 7670. Figure 4.1 showed summary of details of streets and compound counts in relation to the five strata of the city. The Nassarawa-Jahun area showed fewer dogs by street and compound dog counts than Gudum area, GRA and Bauchi city. However, Yelwa (stratum 1) a community predominantly inhabited by students and staff from (Abubakar Tafawa Balewa University, Federal Polytechnic and School of Agriculture Bauchi) with many people from different tribes whose cultures allow dog ownership has high population of dogs in both street and compound counts.

Table 4.1: Street and compound dog counts in Bauchi metropolis

Area(Stratum)	Street Count		Compound Count	
	Actual[+]	Estimate[++]	Actual*	Estimate**
Yelwa	160	1600	176	1760
GRA	105	1050	184	1840
Gudum	101	1010	137	1370
Bauchi city	109	1090	213	2130
Nassarawa-Jahun	56	560	57	570
Total	531	5310	767	7670

Key

+ Number of dogs in 10% street in the area (randomly sampled)

++ 100% estimate of street count.

* Number of dog in 10% compounds in the area (randomly sampled)

** 100% estimate compound count.

4.1.1 Demographic Factors

A total of 422 households were visited but only 329 compounds involving over 3,105 people were properly interviewed within the Bauchi metropolis. No response could be obtained from the remaining 93 houses because the people were not interested and did not cooperate with the interviewers. The pattern of dog ownership in the sampled households according to the identified areas in Bauchi is presented in Tables 4.2 and 4.3. The total number of dogs counted in all the areas was 767. The average number of owned dogs per compound was 2.3 while the mean number of individuals per dog owning compound was 9.6±0.498 (SEM). The human to dog ratio of 4.1:1 per dog owning household was recorded. The population size per compound ranged from 1 – 70 individuals (Figure 4.1).

The results also showed that 105 compounds involving 1381 people were appropriately interviewed in the rural (peri- urban) settlements of Bauchi State. All the households cooperated with the interviewers. The number of dogs counted in all the four areas was 176. The mean number of individuals per dog owning compound was 16.3±3.365 (SEM) while the dog density i.e number of dogs per dog owning household was 1.7. A human to dog ratio of 7.9:1 per dog owning house- hold was obtained (Table 4.2). Table 4.4 shows compound dog counts in relation to the four wards in rural settlements of Bauchi State. The overall population of dogs in the four rural settlements was estimated to be 1760.

From the results of the surveyed dogs in the urban settlements 33.44 % were owned by household heads with 29.48 % owned by children mostly young boys while girls owned 8.21 %, mothers owned 17.93 %, and others like aunties and uncles owned 10.94 % (Figure 4.2). The results also showed that 39.82 % of dogs were sourced as gift from neighbors while 35.26% were obtained from dog breeders. Household bitches also contributed 14.82 % of the dog sources while the sources of 10.03 % of the dogs surveyed could not be specified by the respondent owners (Figure 4.3). On the main purpose for keeping dogs, 69.47 % of the owners indicated security (guard) reasons. A total of 14.42 % of the respondents were keeping the dogs as pets while 8.41 %, 7.21 %, and 0.48 % indicated keeping dogs for hunting, breeding, and herding purposes respectively (Figure. 4.3).

Table 4.2: Selected demographic variables of compounds based on dog ownership in urban and rural settlements of Bauchi State, Nigeria

Variable	Urban	Rural
Number of compounds interviewed	329	105
Total persons in all compounds	3105	1381
Total number of dogs in all compounds	767	176
Mean number of individuals per dog owning compound	9.6	16.3
Mean number of dogs/dog owning household (dog density)	2.3	1.7
Human:dog ratio	4.1:1	7.9:1

Table 4.3: Patterns of dog ownership in sampled households by sub-locations in Bauchi metropolis

Area	Parameter		
	No.households interviewed	No. of dogs	dog per household
Yelwa	76	176	2.32
GRA	86	184	2.14
Gudum	66	137	2.08
Bauchi-city	80	213	2.66
Nassarawa-jahun	21	57	2.71
Total	329	767	2.32

Table 4.4: Household visit counts of dogs in rural (peri-urban) settlements of Bauchi State

Area Name	Compound count	Estimated number of dogs
Duguri	30	300
Pali	33	330
Gwana (Futuk)	55	550
Soro	58	580
Total	176	1760

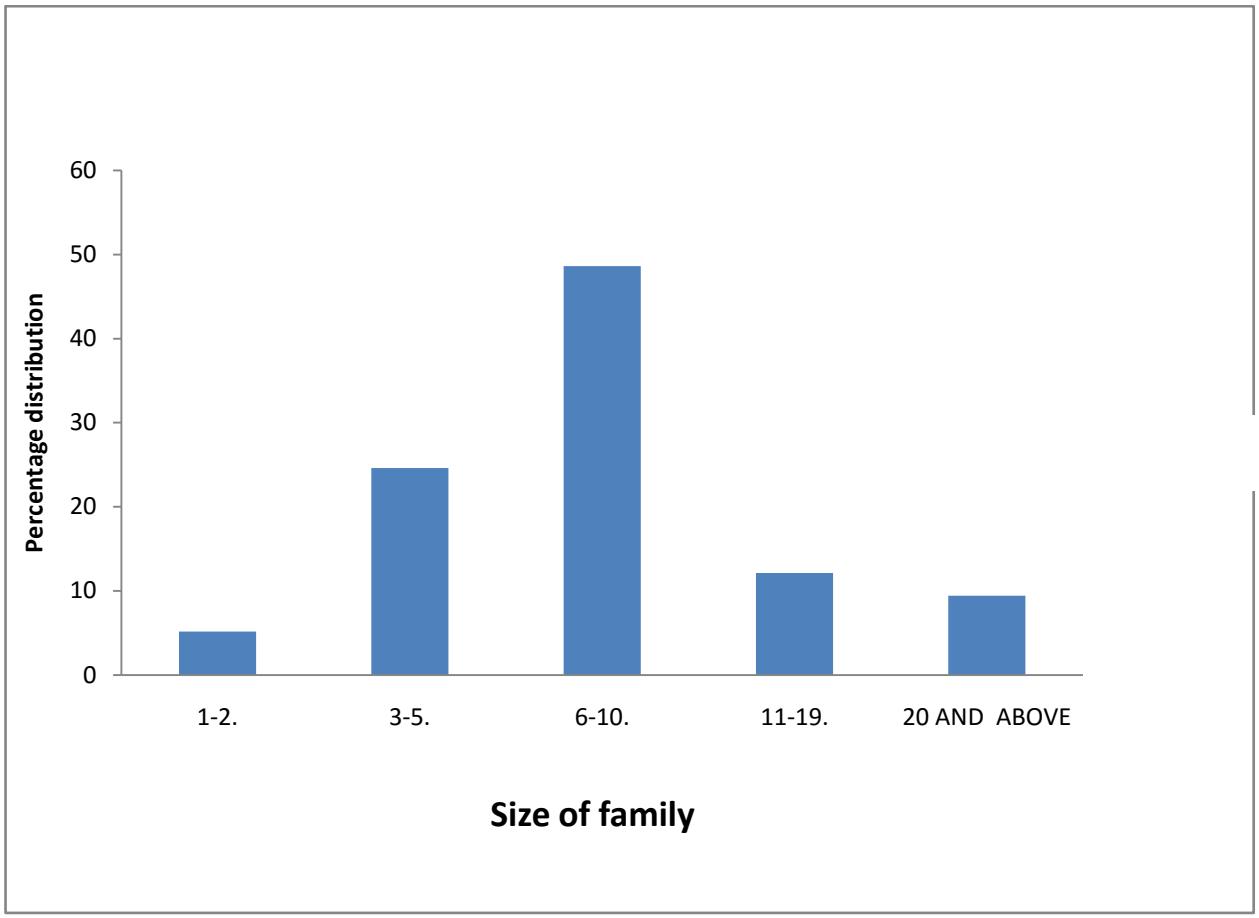


Figure 4.1: Distribution of family size of dog owners in Bauchi metropolis.

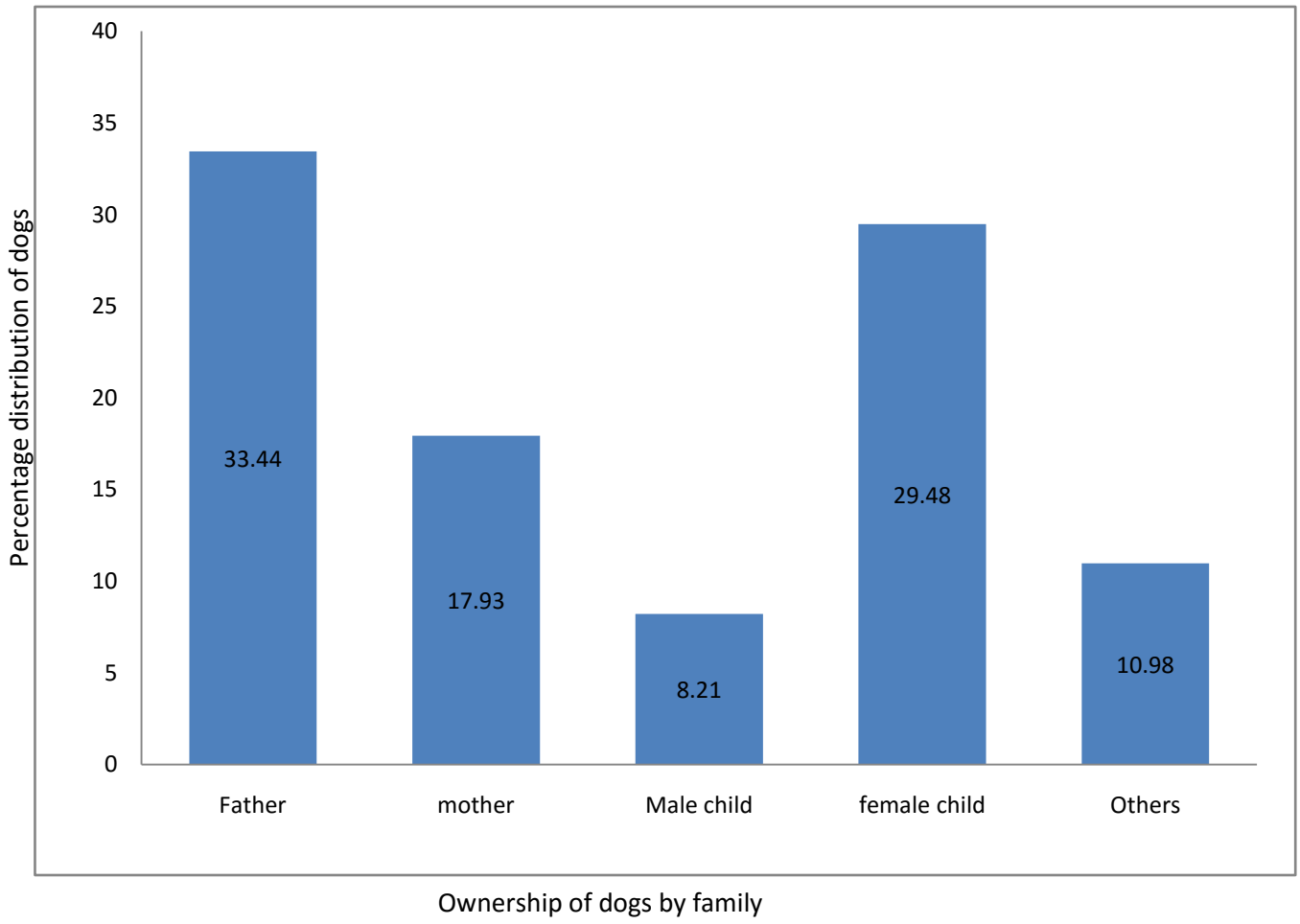


Figure 4.2: Distribution of dogs based on ownership by different members of the family in Bauchi metropolis.

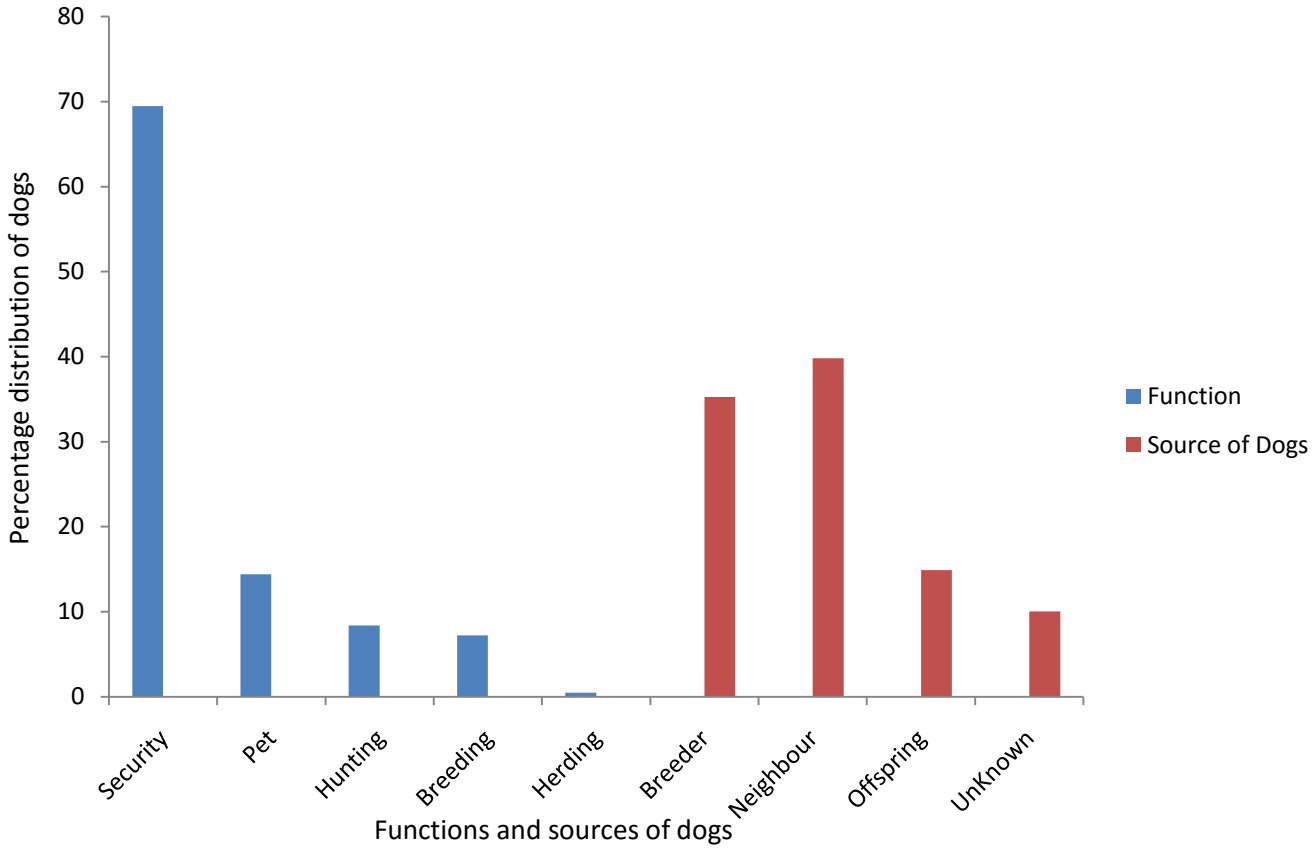


Figure 4.3: Distribution of dogs based on functions and sources of obtaining the dogs by owners in Bauchi Metropolis.

4.1.2 Age, Sex and Breed Distribution of Dogs

The results obtained from the survey has indicated the age distribution of the dogs for less than 1 year old, 1-5years old, and over 5 years old to be (33.68 %), (56.58 %) and (9.64 %), respectively. The result also showed that 53.46 % of the dogs counted were males while the remaining 46.54 % were females (Fig. 4.5). This gave a male to female sex ratio of 1.2:1 based on the compound dog counts (Table 4.3). However the result of the street dog counts showed that 58.19 % wee males and 41.81 % were females with a male to female sex ratio of 1.4:1 (Fig. 4.6). Majority of the surveyed dogs during the compound dog counts were mongrels (62.84 %), 19.95 % were exotic breeds, and 17.21 % were crossed breeds (Fig. 4.5).

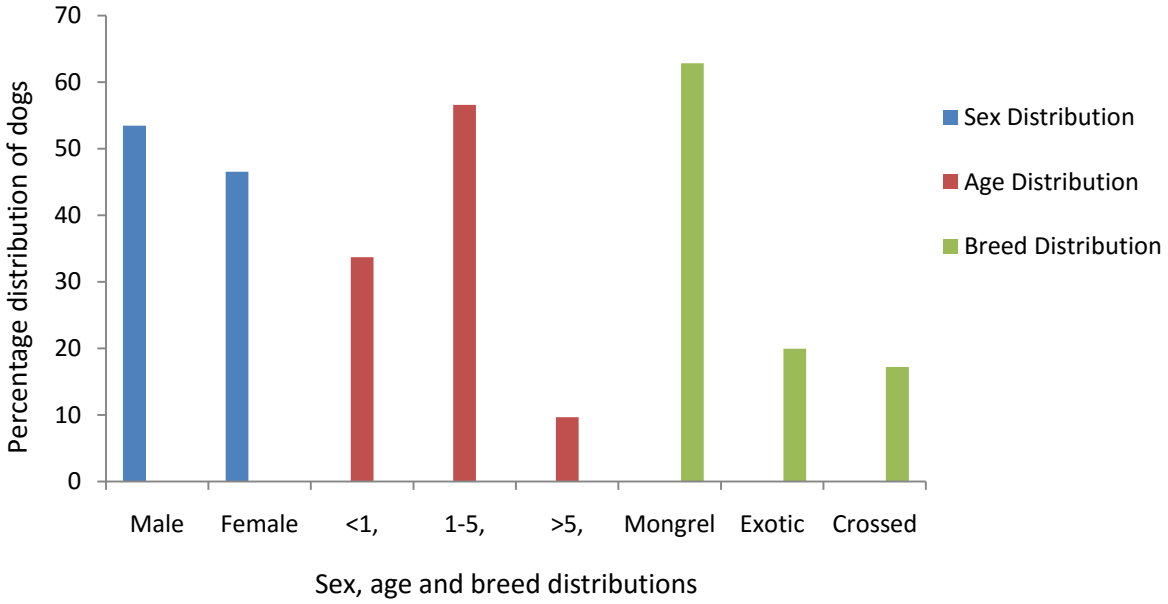


Figure 4.4: Distribution of owned dogs based on sex age and breed in Bauchi Metropolis.

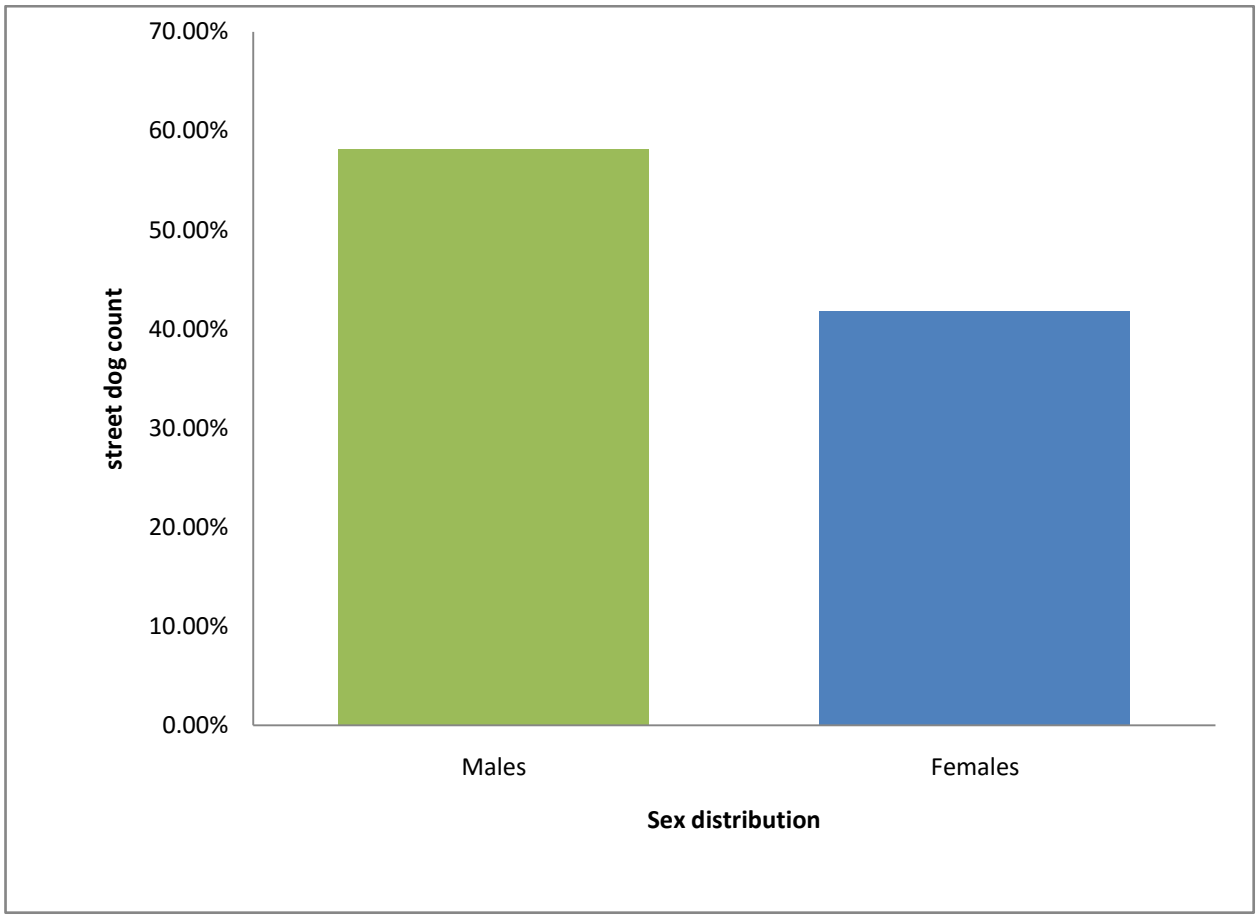


Figure 4.5: Sex distribution of street dogs in Bauchi metropolis.

4.1.3 Management and Care of Dogs

The results obtained based on those who responded showed that 35.87 % were not confining their dogs while 26.74 % of them were confining them. The results also indicated that 22.80 % of the respondents were partially confining their dogs while 14.59 % of the respondents did not know the confinement status of their dogs (Fig.4.6).

On general care and feeding of the dogs, 62.0 % of the respondents indicated that every member of the family was responsible. However, 15.20 %, 13.07 %, and 9.73 % of the respondents believed the responsibility was based on children, the mother, and father, respectively (Fig.4.6). Most of the respondents (62.9 %) indicated that they fed their dogs with the family left over food. However, 25.84 % of the respondents cook special food for their dogs while 11.24 % used commercially prepared food to feed their dogs (Fig.4.7). The results also showed that 49.24 % of the respondents had their dogs depopulated by giving them away, while 18.24 % attributed it to death of the dogs. 13.98 % of the respondents had their dogs just disappearing, 9.42 % believed they were intentionally killed, while 4.12 % attributed it to automobile accidents (Fig.4.7).

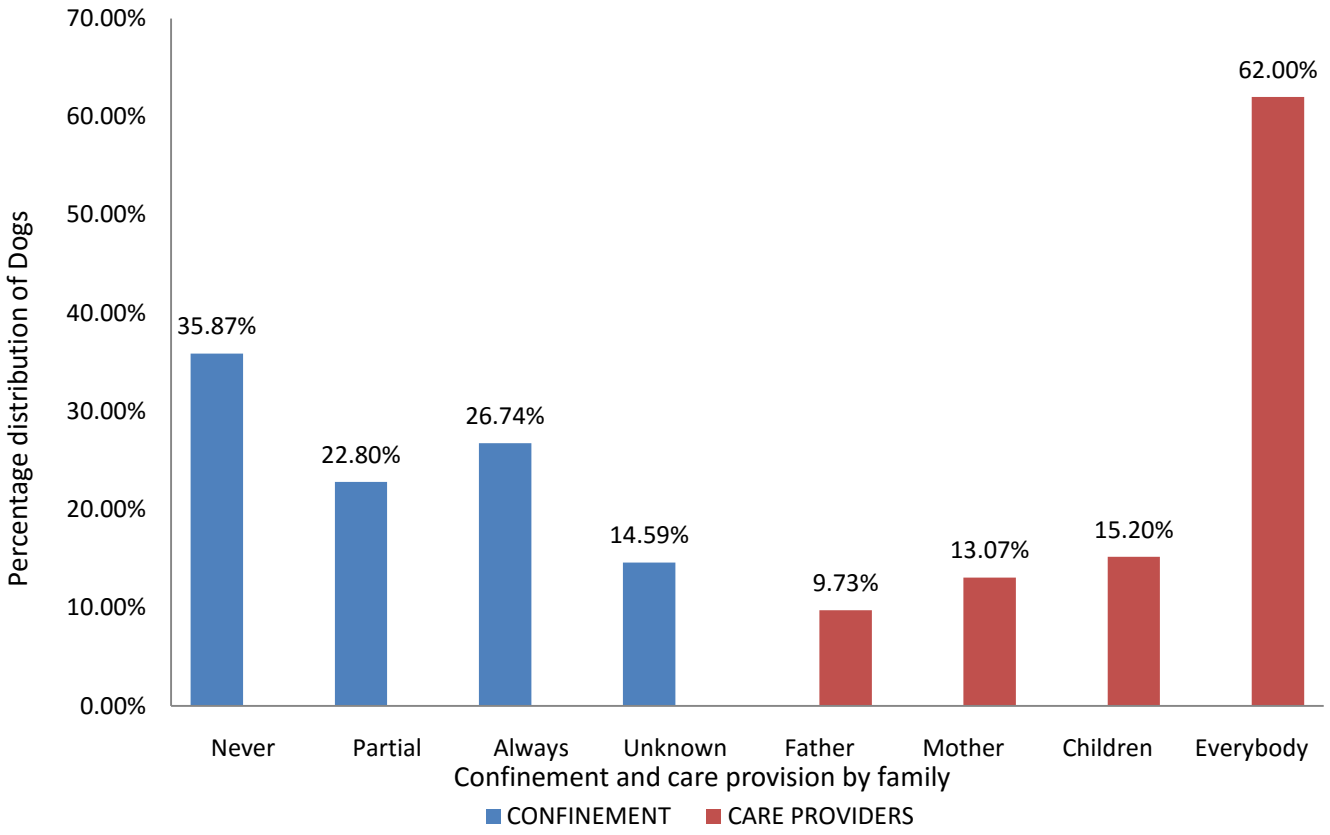


Figure 4.6: Distribution of dog in relationship to confinement and care provision by the family

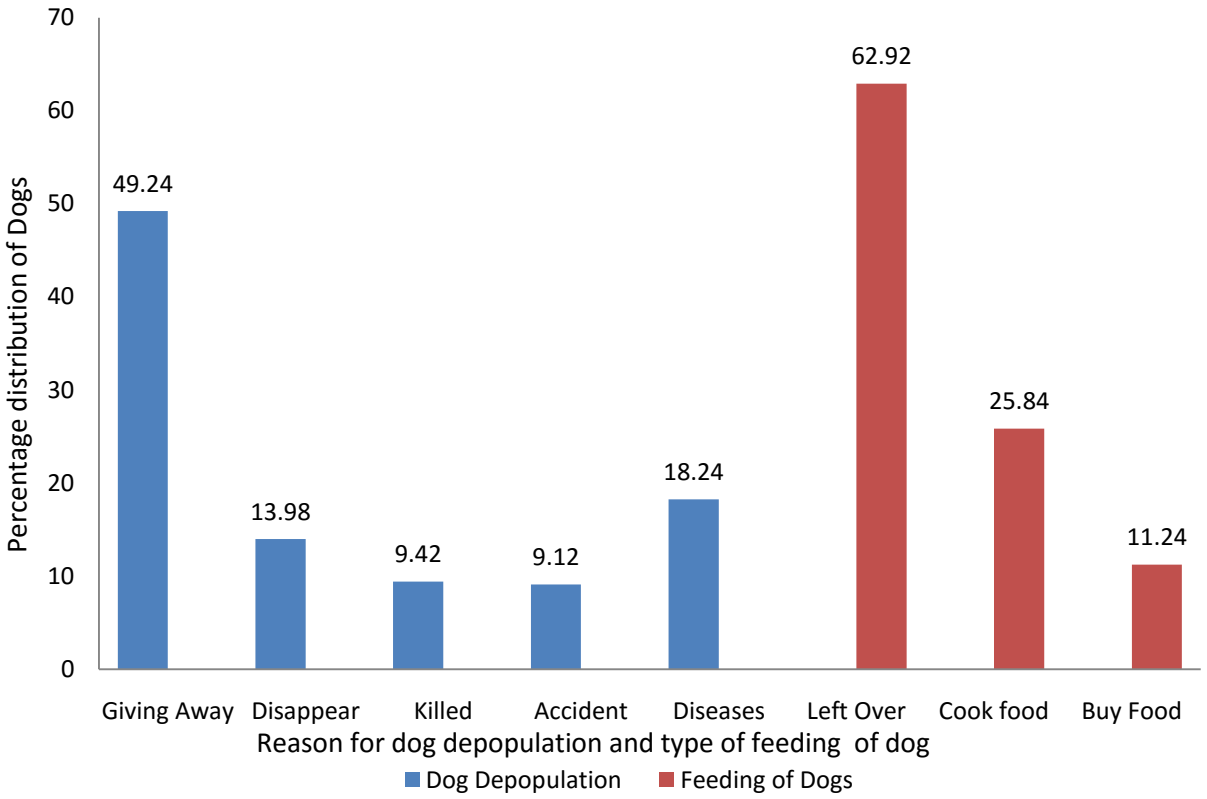


Figure 4.7: Distribution of the dogs based on type of feeding and reasons for depopulation of dogs by the family in Bauchi metropolis.

4.1.4 Vaccination of Dogs.

The results obtained from the respondents indicated that 63.83 % of them did not vaccinate against rabies 26.45 % of the respondents reported to have vaccinated their dogs against rabies. Only 9.72 % of the respondents did not know the vaccination status of their dogs against rabies (Figure 4.8). On the personnel who performed the vaccination, 6.29 % of the respondents indicated that they vaccinated their dogs by themselves while 53.85 % were vaccinated by veterinarians. However, 18.18 % of the respondents indicated that veterinary superintendents vaccinated their dogs while 21.68 % stated that personnel with unknown qualification status vaccinated their dogs (fig.4.9).

On the type of set up where the vaccination was carried out, 49.65 % of the respondents reported that their dogs were vaccinated at home, 25.87 % State Veterinary Clinic, 20.28 % at the NVRI laboratory at Bauchi, and 4.20 % at the School of Agriculture Veterinary Clinic (Fig.4.8). With respect to the age at which dogs were first vaccinated against rabies, 10.49 % of the dog owners indicated 2 month of age, 17.48 % at 3 months, 28.67% at six months, 13.99 % at one year, above one year, and 16.08 % stated above one year. Of the respondents, 13.29 % did not know the age at which their dogs were vaccinated (Fig. 4.9).

On the source of the antirabies vaccines used, 44.06 % of the respondents indicated NVRI-Vom, 16.08 % were foreign vaccine, while 39.86 % of the respondents did not know the source (Fig. 4.9). The results also revealed that 39.86 % of the respondents could not show any evidence of

vaccination given to their dogs while 34.97 % had presented pet green book as evidence. Also, as evidence of vaccination, 25.8 % of the respondents presented certificates of vaccination (Fig.4.9). The results obtained from the study have shown that 91.49 % of the respondents did not vaccinate their dogs against other preventable diseases like canine distemper, canine hepatitis, leptospirosis, canine parvovirus enteritis and parainfluenza, whereas 8.51 % indicated giving such vaccines (Fig 4.10). The results have also indicated that 19.15 % of the respondents reported that their dogs were either castrated or spayed (Fig.4.10). On willingness to have their dogs vaccinated, 85.41 % of the respondents indicated that they were willing provided the programme could be organized. Majority of the respondents, 67.48 % were of the opinion that veterinary services within their community were inadequate while 32.52 % were satisfied with the adequacy of the services (Fig.4.10).

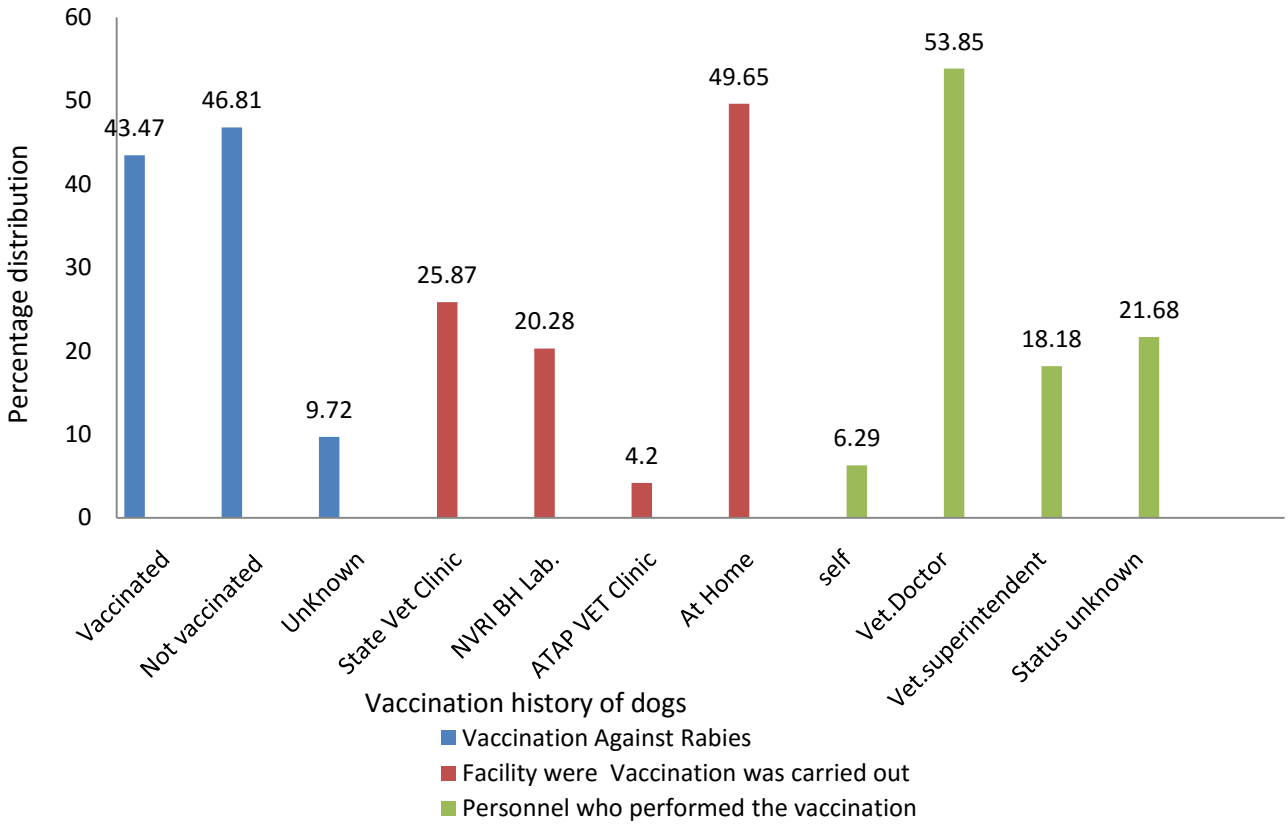


Figure 4.8: Anti rabies vaccination history of dogs associated with dogs as expressed by respondents within Bauchi Metropolis.

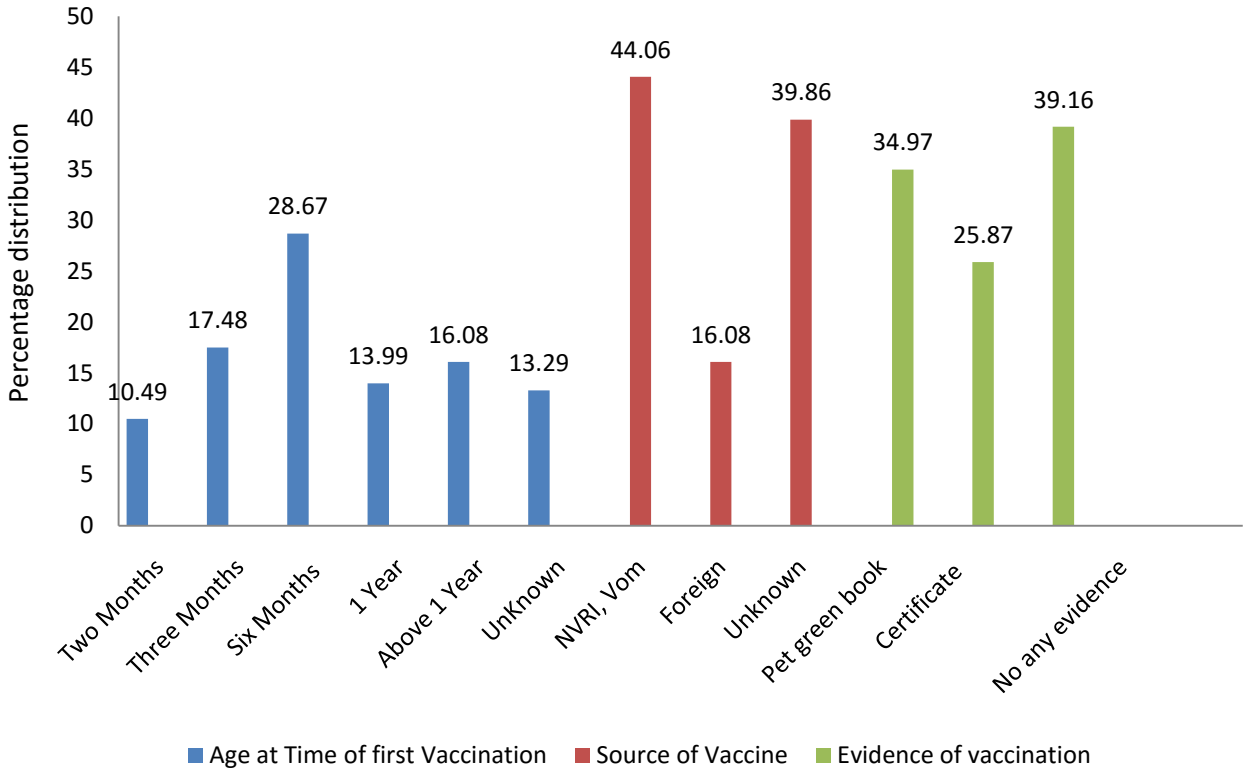


Figure 4.9: Distribution of the age of dogs at first vaccination, source of vaccine and evidence of vaccination as expressed by respondents in Bauchi metropolis.

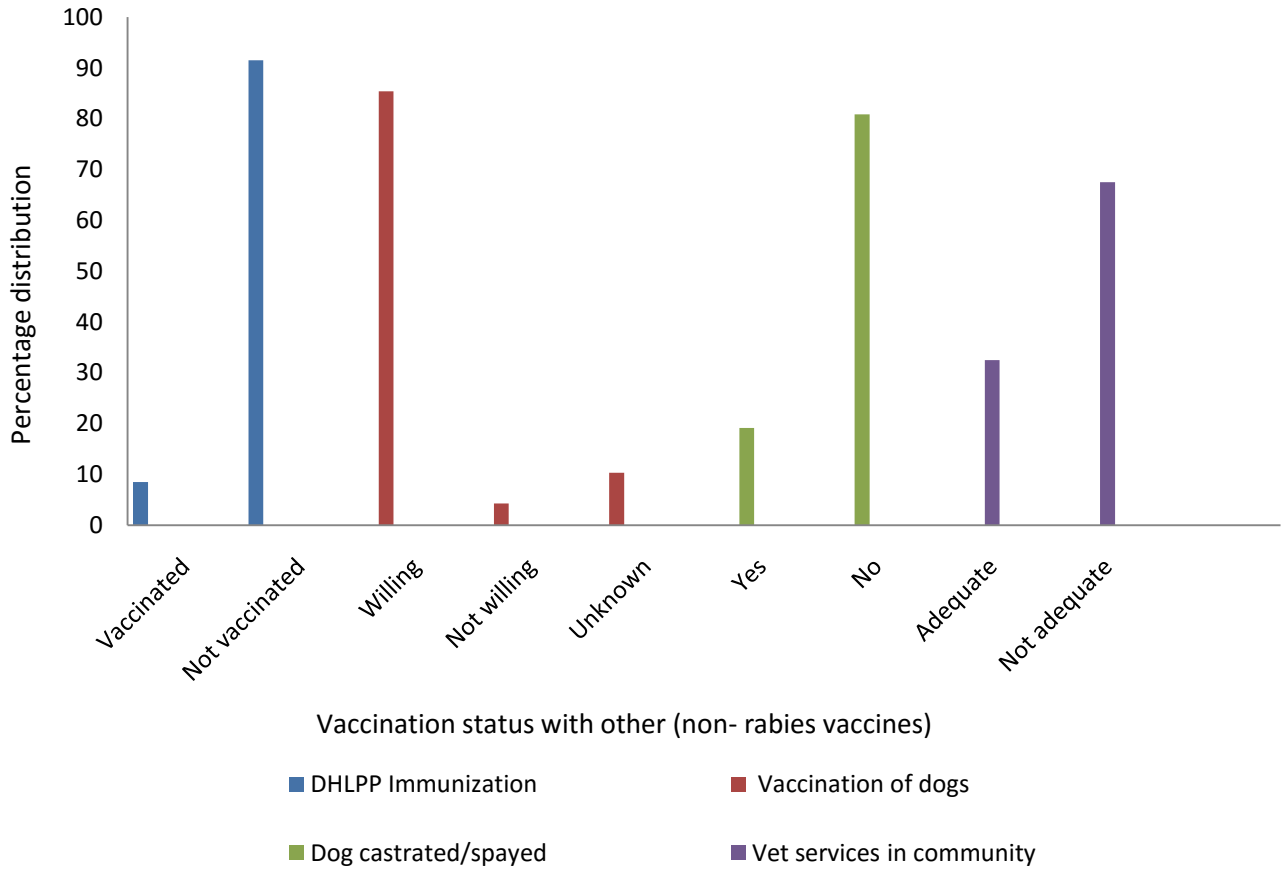


Figure 4.10: Respondents' opinions on vaccination status with other (non-rabies) vaccines, willingness to have their dogs vaccinated against rabies, information on neutering, and adequacy of veterinary services in the community.

4.1.5 Occurrence of Dog Bites and their Management.

The results of the study have also shown that 34.35 % of the respondents had cases of dog bites in the family. The remaining respondents (65.65 %) did not have such incidences involving any member of their family (fig.4.11). Of the respondents who reported cases of dog bite, 46.02 % stated that neighbor's dogs were responsible for the bites while 30.09 % indicated their own household dogs being involved. Out of these cases of bites, 3.54 % of the respondents indicated that the biting dog died a few days after the bite while 22.12 % stated that the biting dog was immediately killed by the owners. However, 44.25 % of the respondents did not know what happened to the biting dog afterwards (fig. 4.11). On the issue of management of dog bites in affected victims, 35.40 % of the respondents stated that the victims received post-exposure anti-rabies vaccination treatment while 22.12 % of the respondents indicated that the victims received traditional dog bite treatment. On this too, 15.93 % of the respondents indicated that the victims received local wound treatment while 26.55 % of the respondents said that the victims did not receive any treatment (fig, 4.12).

The results also have shown that 12.39 % of the respondents indicated that the bite victims died of rabies and 90 % of them exhibited abnormal nervous behavior including hallucination, convulsive seizures, nightmares, staggering gait and difficulty in swallowing prior to death (Fig. 4.12). Of the dog bite cases resulting in death of the victims, some of the respondents declined to cooperate to provide further details to the interviewers believing the incident to be an act of God.

The results of the study of dog bite cases involving household dogs showed that 32.56 % of the respondents indicated that their dogs were given anti-rabies vaccination while 34.88% of the respondents stated that their dogs were not vaccinated. Another 32.56 % of the respondents did not know the vaccination status of their dogs (Fig. 4.13).With respect to the health status of the biting dogs at the time of bite, 8.14 % of the respondents indicated that their dogs were sick while 48.54 % of the respondents said that the dogs were healthy. However, 43.02 % of the respondents did not know the health status of their dogs at the time of bite (Fig. 4.14). When asked about the management of dog bites victims 4.46 % of the respondents indicated that the dogs died naturally, while 33.72 % of the respondents indicated that the dogs were killed. On this same matter, 38.37 % of the respondents stated that the dogs were healthy while 23.26 % of the respondents said that they did not know what happened to the biting dog after the incident (Fig.4.14). It was observed that 38.37 % of the respondents did not give anti-rabies post exposure treatment to the victims while 27.91 % of the respondents claimed to have been given such treatment. Apart from this, 19.77 % of the respondents said that the victims received antibiotic treatment in addition to the local wound management. However, 13.95 % of the respondents claimed that the victims received traditional dog bite treatment (Fig. 4.14). On the outcome of the bite on victims, 23.26 % of the respondents indicated that such victims died, with 46.51 % of the respondents stating that they survived and remained healthy, while 30.23 % of the respondents could not provide any details on the outcome (Fig. 4.15). The results have also shown that 70.0 % of the cases where the victims died reported observing some abnormal nervous behavior prior to death while 30.0 % of the respondents indicated observing no abnormal behavior prior to death of the victim (Fig. 4.15).

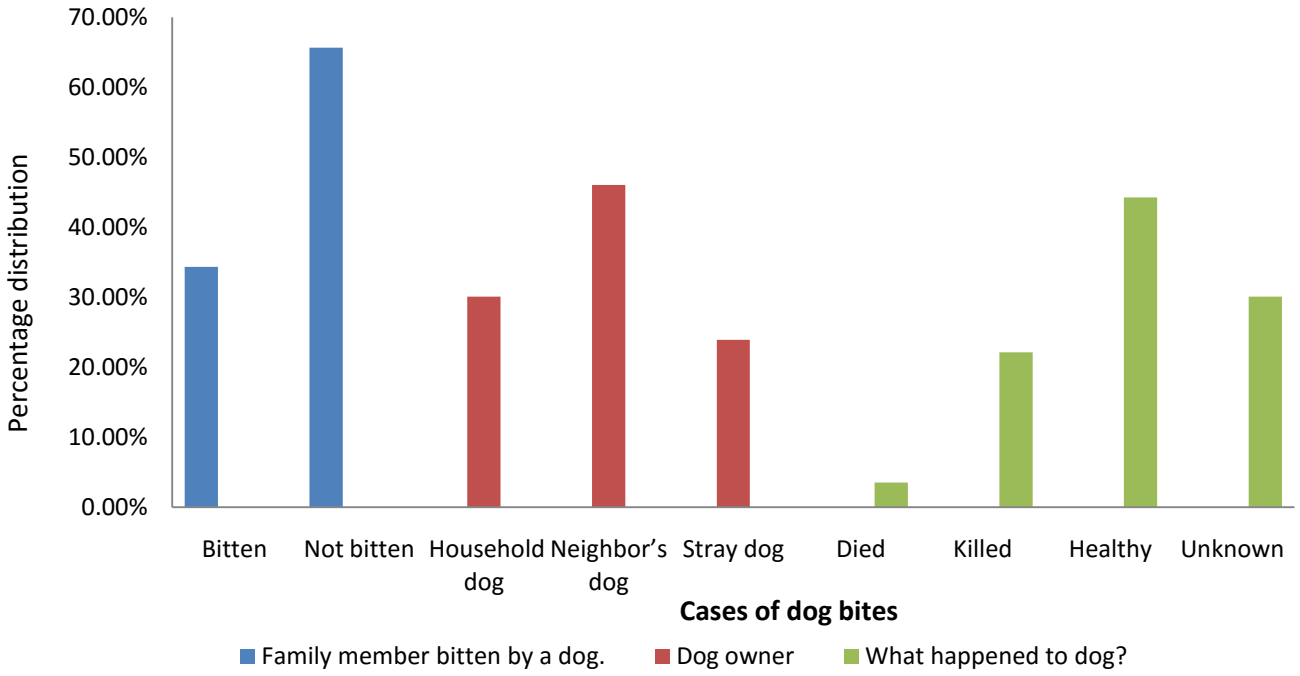


Figure 4.11: Cases of dog bite according to respondents in Bauchi metropolis.

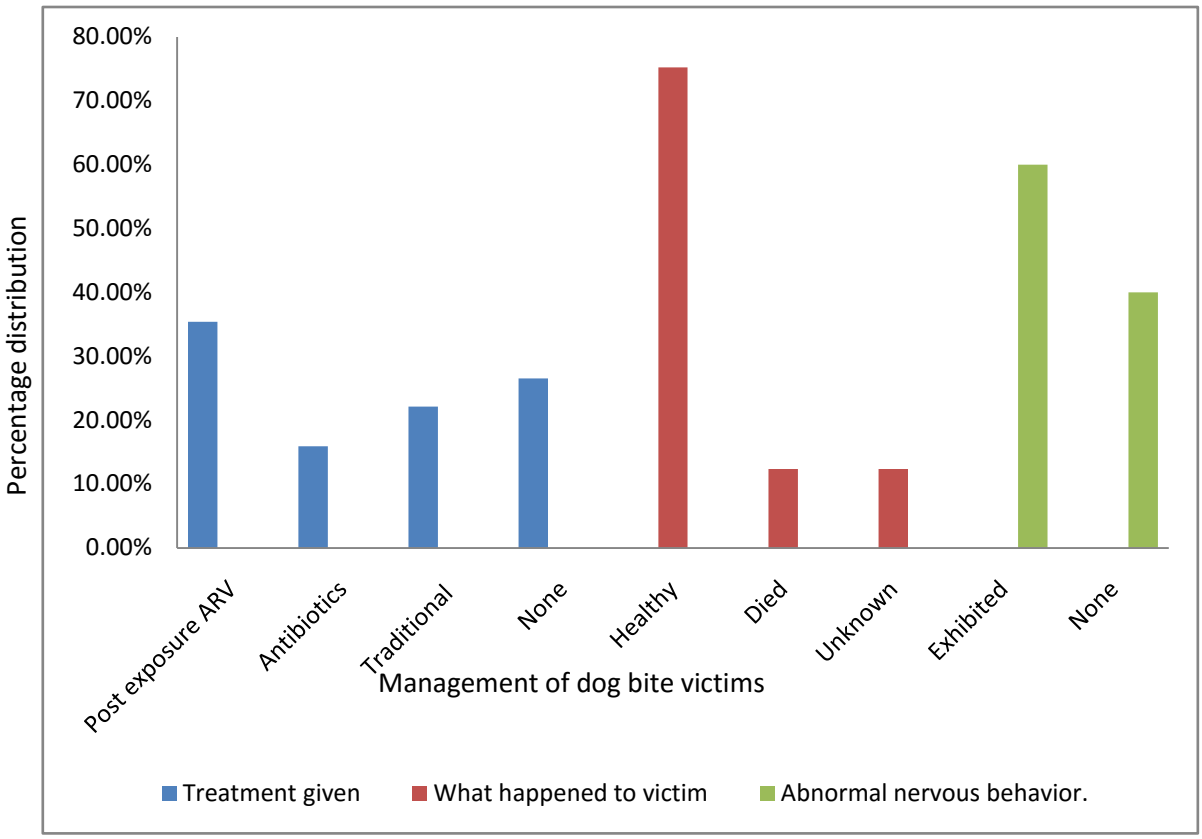


Figure 4.12: Types of dog bite management given to victims and outcomes of the cases according to respondents in Bauchi metropolis.

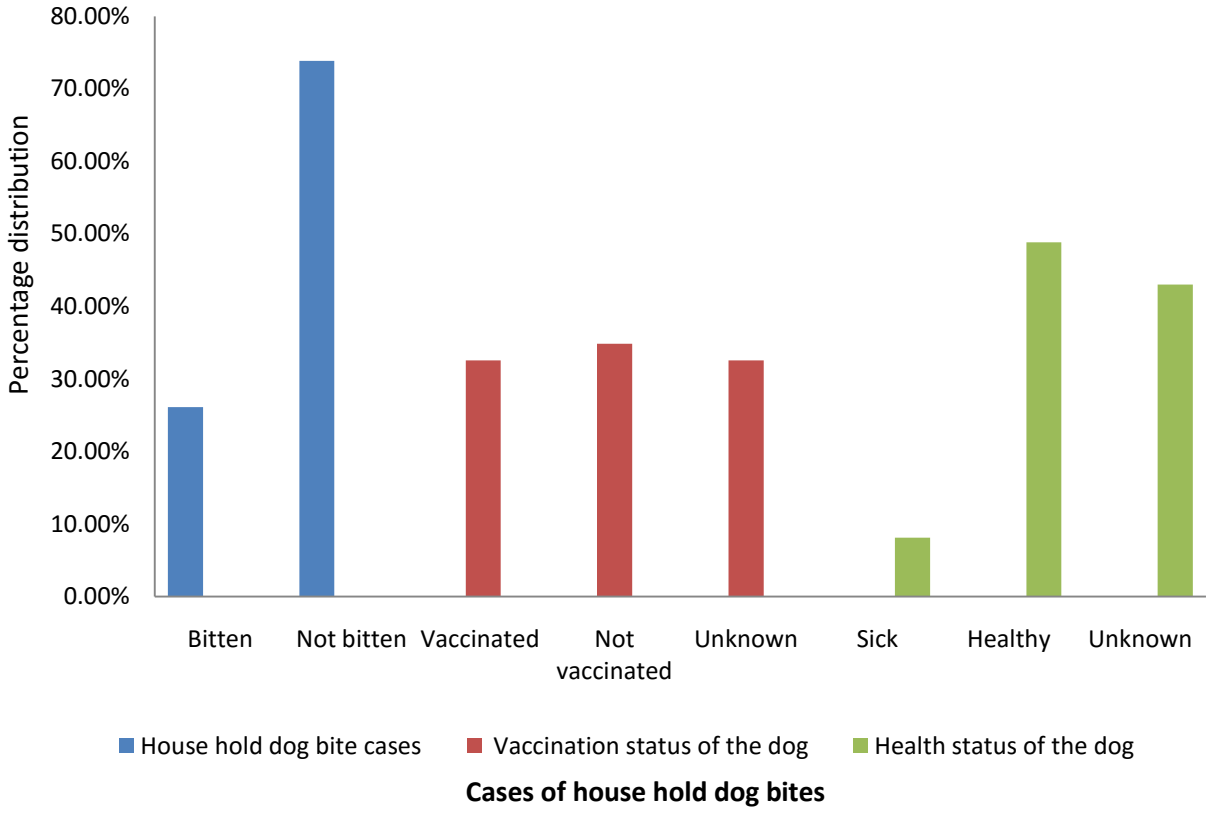


Figure 4.13: Cases of household dog bite, vaccination status, and health outcomes of biting dogs in Bauchi metropolis.

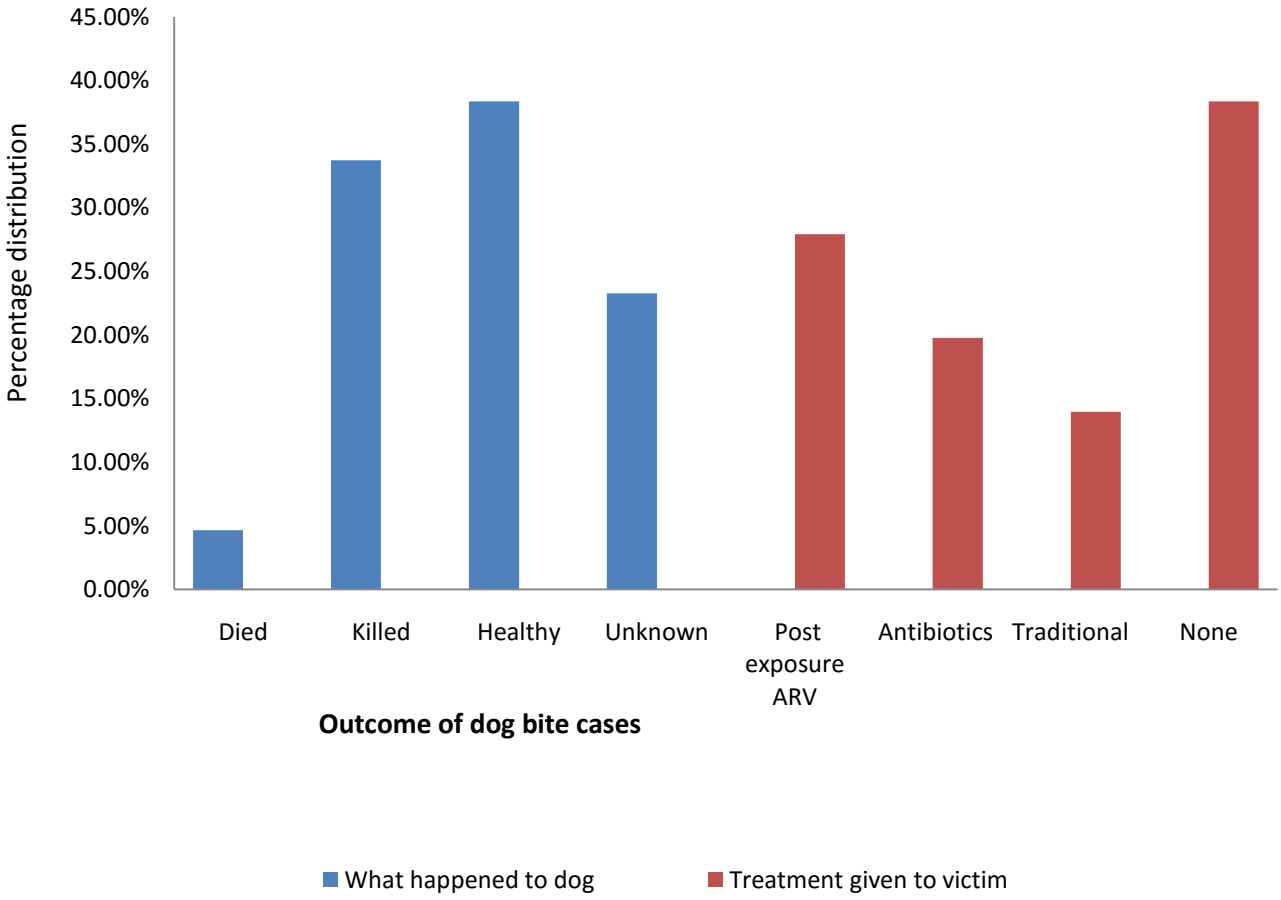


Figure 4.14: Outcomes of bitting dogs and management actions taken on victims following dog bites in Bauchi metropolis.

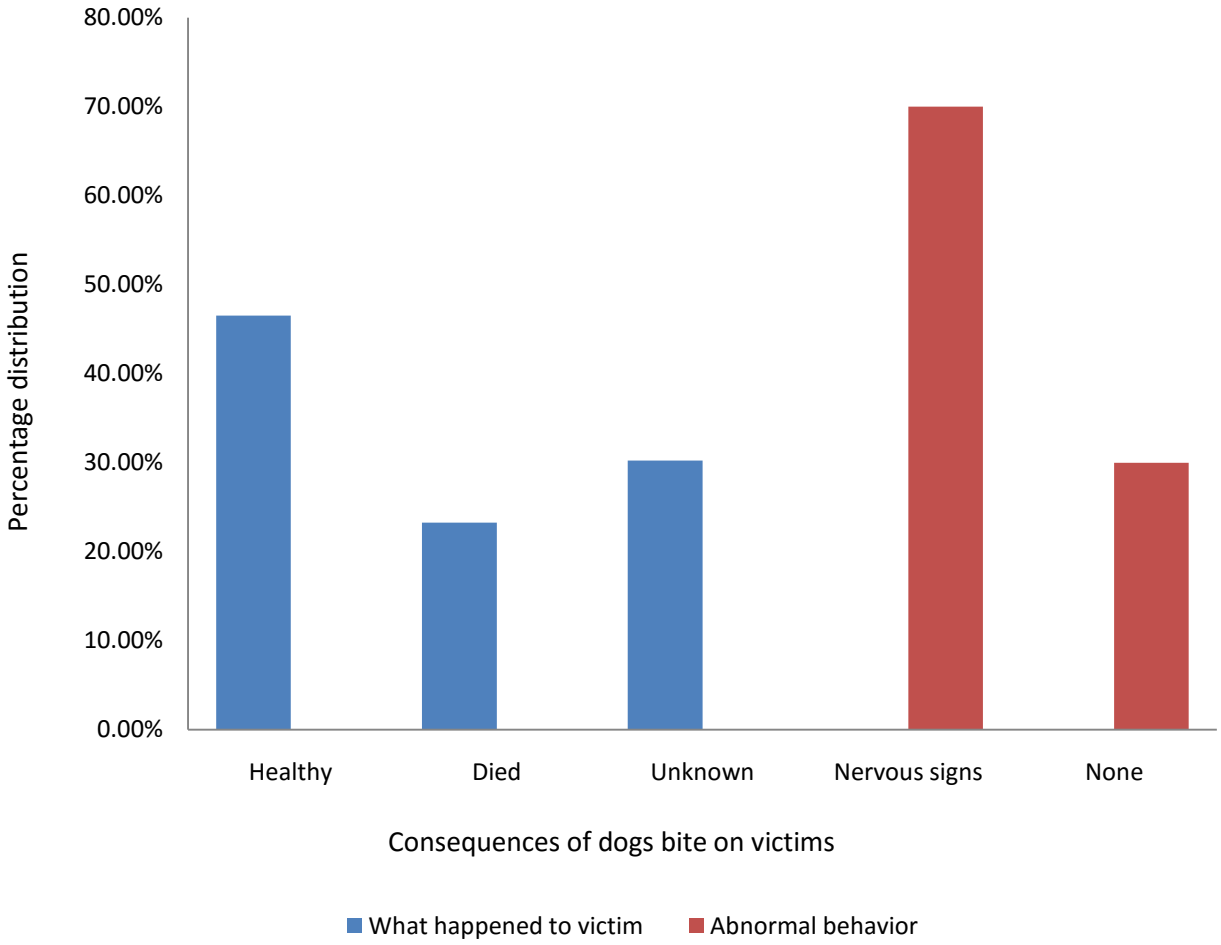


Figure 4.15: Consequences of dog bites on victims in Bauchi metropolis.

4.2 DOG POPULATION STRUCTURE IN PERI-URBAN SETTLEMENTS IN BAUCHI STATE

4.2.1 Age, Sex, and Breed Distribution

The distributions on sex, age, breed and purpose of keeping dogs according to the respondents is presented in Fig.4.16. With respect of this, 53.41 % of the dogs were aged 1-5 years old with 23.86 % aged more than 5 years old while 22.73 % were aged less than one year old. Of the total dogs evaluated, 62.5 % were males while 37.5 % were females giving a male to female ratio of 1.7:1. The results have also shown that 86.95 % were mongrels, 10.23 % were crossed breeds, while 2.84 % exotic breeds. On the purpose for keeping dogs, 42.62 % were guard dogs, 40.78 % were hunting dogs, while 10.38 % were used in herding. However, 3.83 % were dogs kept by breeders, and 2.19 % were solely kept as pets (Fig.4.16).

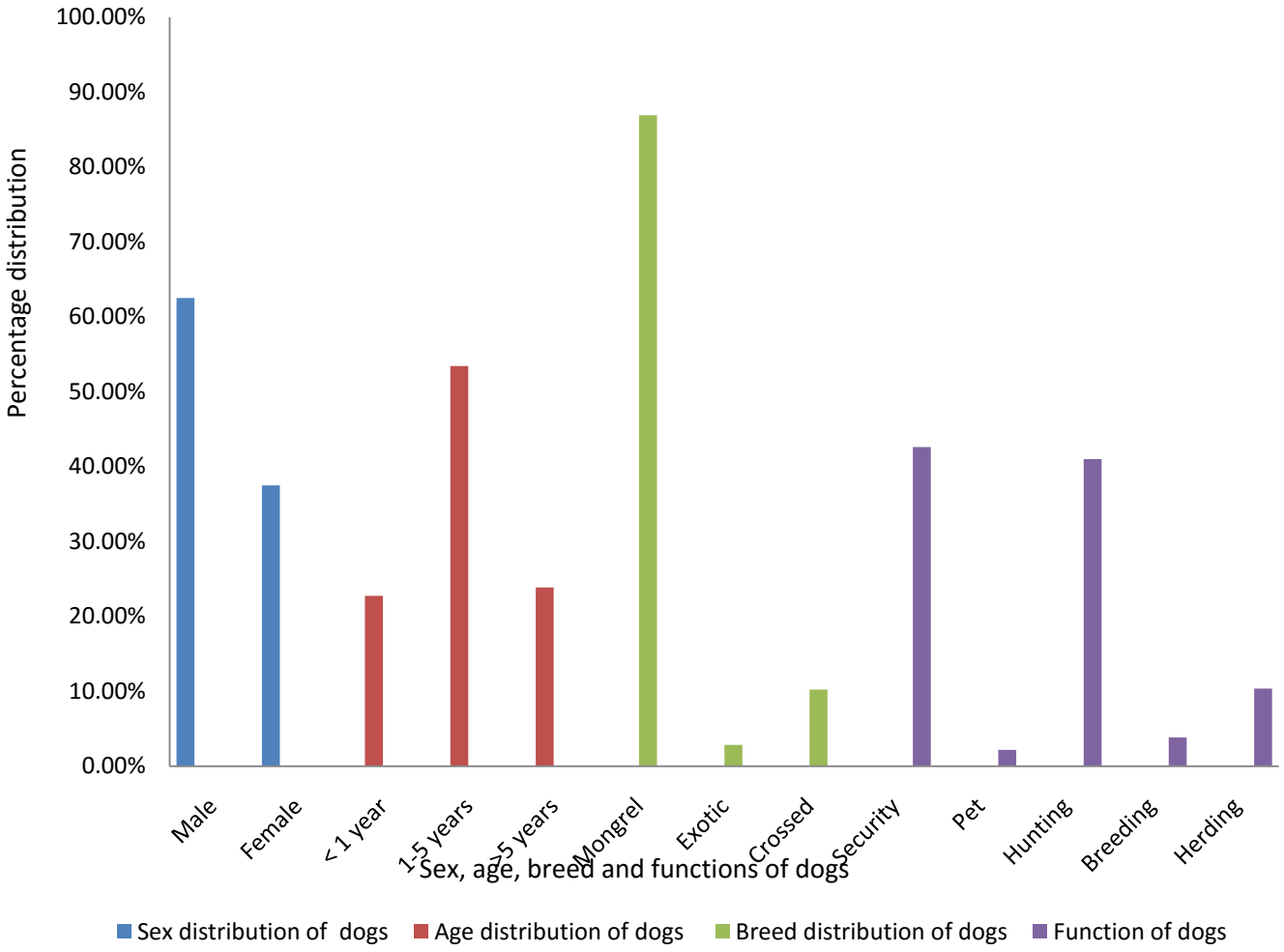


Figure 4.16: Distribution of dogs according to sex, age, breed and purpose of keeping dogs in some rural settlements in Bauchi State.

4.2.2 Vaccination Status and Health Management of Dogs

The result of the study showed that 85.72 % of the respondents did not vaccinate their dogs against rabies and only 9.53 % of the respondents said they have vaccinated their dogs while 4.76 % of the respondent did not know the vaccination status of their dogs (Fig. 4.17). On the personnel that were involved in the vaccination of their dogs, 53.33 % of the respondents reported that veterinary superintendents were mostly involved, while 16.67 % of the respondents stated that they vaccinated the dogs themselves. However, 6.67 % of the respondents indicated that veterinarians were involved while 23.33 % of the respondents did not know the professional qualification of those who vaccinated their dogs (Fig. 4.17). Up to 40 % of the respondents indicated that the vaccinations were carried out when the dogs were aged above 1 year, with 6.67 % of the respondents indicating that their dogs were vaccinated at three months of age. Of the respondents, 10.00 % of them indicated that vaccination was carried out at 6 months while 20.0 % of the respondents stated vaccinating at 1 year of age. Only 3.33 % of the respondents stated vaccinating at 2 months of age (Fig.4.18).

The results of this study showed that 90.0 % of the respondents stated that the source of the anti-rabies vaccine used in vaccinating their dogs was from NVRI-Vom while 3.33 % of the respondents indicated a foreign imported anti rabies vaccine. However, 6.67 % of the respondents could not remember the source of the vaccine (Fig.4.18). On the evidence of vaccination, 10 % of the respondents showed vaccination certificates in respect of the vaccination of their dogs. However, 13.33 % of the respondents showed the pet green book as

evidence while 76.67 % of the respondents did not show any evidence of vaccination of their dogs even though they claimed the dogs were vaccinated (Fig.4.19).

On whether the dogs were vaccinated against other infectious diseases (specifically canine distemper, hepatitis, leptospirosis, parvovirus enteritis and parainfluenza), 97.14 % of the respondents indicated that they did not while 2.86 % of the respondents stated that they did (Fig. 4.19). On vaccination of dogs, 51.43 % of the respondents indicated their willingness to take their dogs for vaccination provided a workable programme could be arranged. On this matter, 28.57 % of the respondents indicated their unwillingness toward the vaccination of their dogs while 20.0 % of the respondents could not decide (Fig. 4.19).

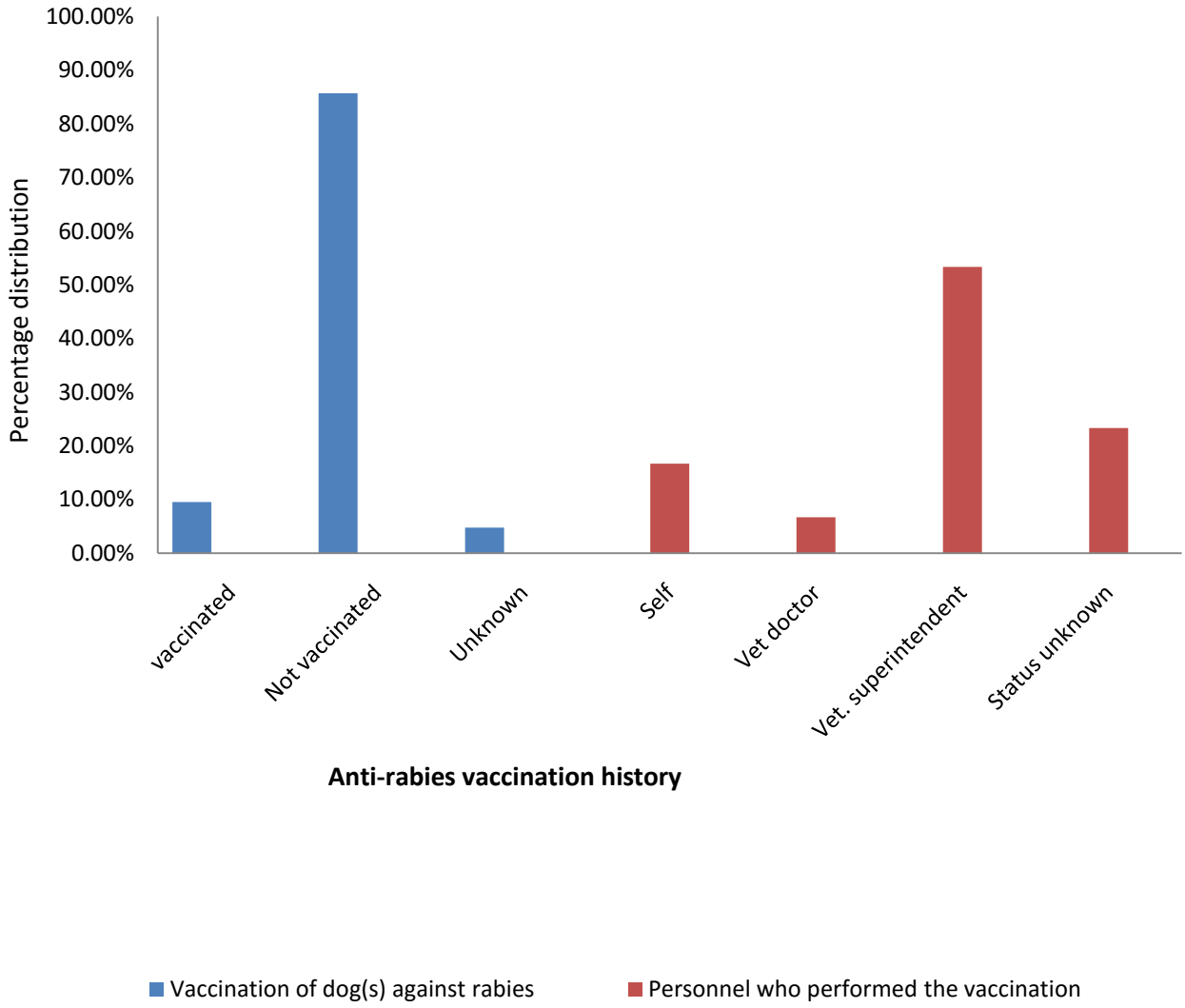


Figure 4.17: Anti rabies vaccination status of the dogs in rural settlements of Bauchi State according to the respondent dog owners.

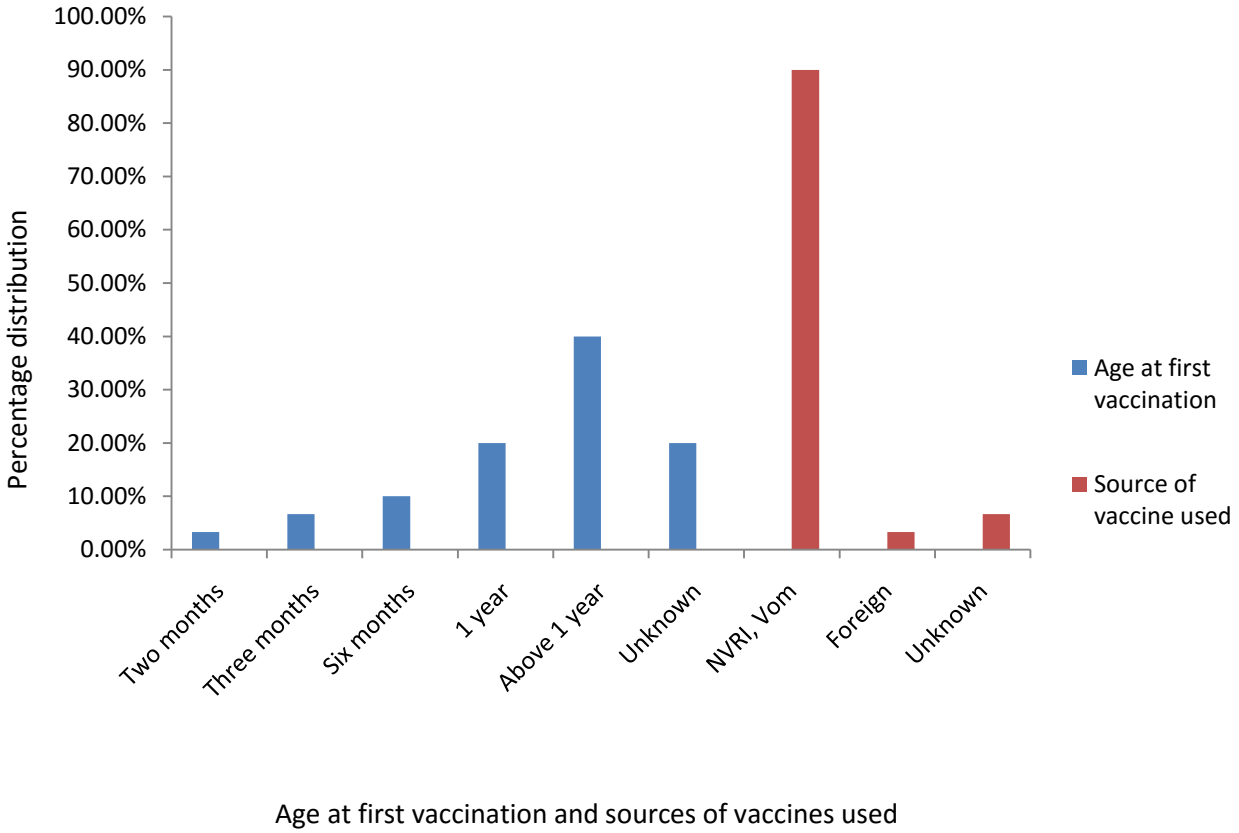


Figure 4.18. Age at first vaccination and source of vaccines used in dogs from rural settlements of Bauchi State.

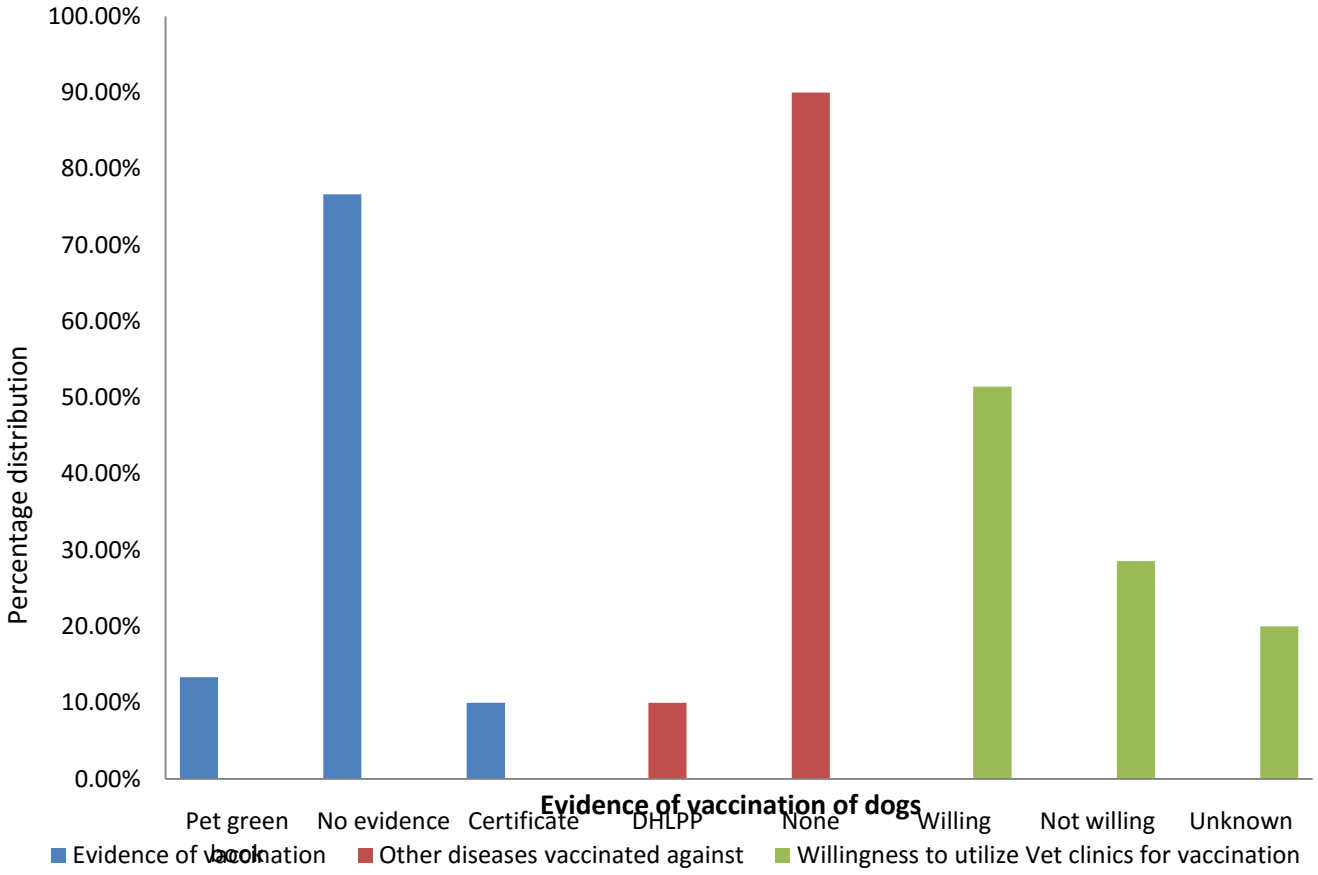


Figure 4.19: Response of dog owners on evidence of anti-rabies vaccination and willingness of owner to vaccinate their dogs in rural settlements of Bauchi State.

4.2.3 Conflicts Between Wild Mammals and Human/Domestic Animals Communities.

On conflicts between wildlife and humans, 17.31 % of the respondents indicated that they were keeping wild mammals as pets or for economic reasons. The results showed that 29.70 % of the respondents had knowledge of victims of wildlife bite or attack and 23.33 % of the respondents stated that such victims actually died after exhibiting some nervous manifestations (Fig. 4.20). The results of the study, based on the opinion of the respondents, have shown that the wild animals involved in human bites included hyenas, lions, wildcats, monkeys, jackals and squirrels. However, local hunters indicated that the most feared among these wild animals was the squirrel. Wild animal attacks or bites occurred mainly through hunting activities. On conflicts between wildlife and domestic animal communities, 40.0 % of the respondents indicated that such conflicts were encountered involving their domestic animals. The results of this study revealed that dogs, sheep, goats, cattle and chickens were involved in such conflicts. The major domestic animal involved in the wildlife conflicts was the domestic dogs used in hunting. However, wild animals were reported by the respondents to be attacking domestic animals in villages located at the fringes of the game reserves. Hyenas, lions, jackals, wildcats, mongoose, monkeys, baboons and squirrels were identified as the wild animals involved in these conflicts (Fig. 4.21).

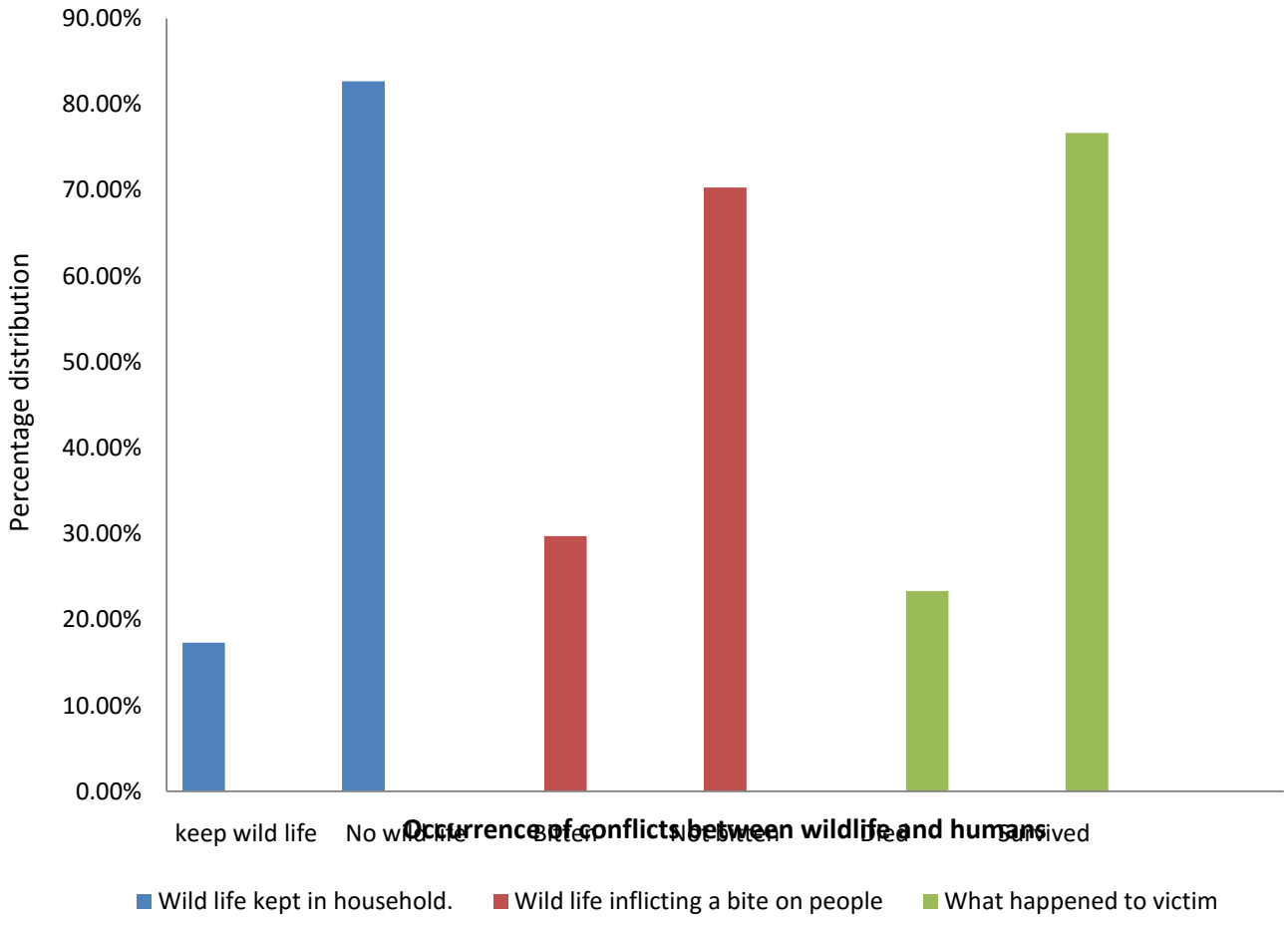


Figure 4.20: Occurrence of conflicts between wildlife and humans in rural settlements in Bauchi State.

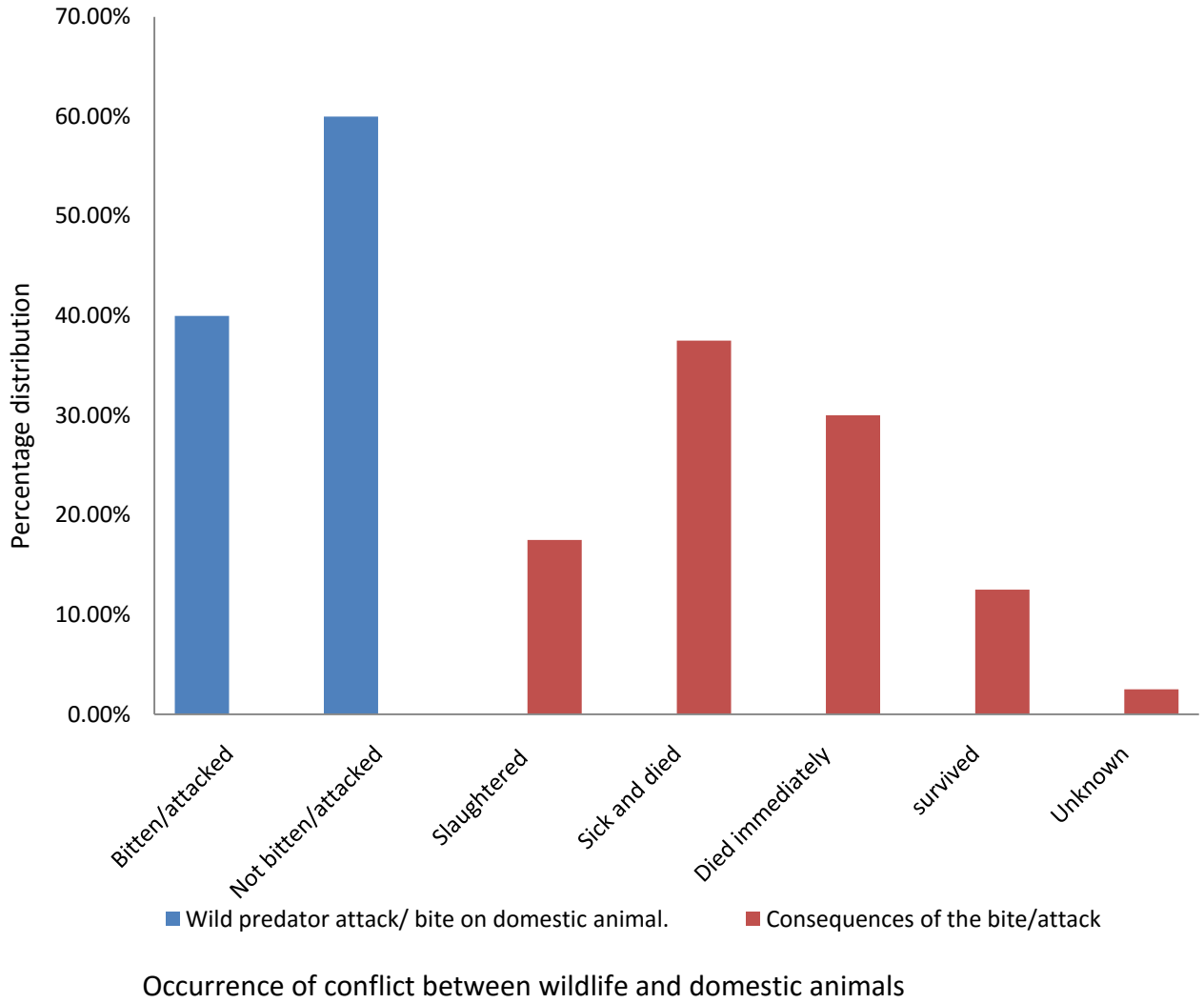


Figure 4.21: Occurrence of conflicts between wildlife and domestic animals in rural settlements in Bauchi State.

4.3 COMPARATIVE OBSERVATION ON DOG POPULATION IN URBAN AND RURAL SETTLEMENTS

The results of this study have shown that the ratio of human to dog owning compounds was 4.1: 1 in the urban areas and a ratio of 7.9:1 in the rural settlements (Table 4.4). Also, a male to female sex ratio of 1.2:1 was observed in the urban while the ratio was 1.7:1 in the peri -urban settlements of Bauchi State. On age distribution of dogs the results showed that 56.58 % of respondents indicated keeping dogs within the age range of 1 to 5 years in the urban areas compared to 53.41 % of respondents who indicated the same age range in the rural settlements of the state. On the breeds of dogs kept by respondents in the two settlement types, 62.84 % of the urban respondents kept mongrel dogs compared to 86.93% in rural settlements. With respect to use of dogs, the results showed that in the urban areas, the respondents kept dogs mainly for security purposes other purposes included pets, hunting, breeding and herding. In the rural settlements, dogs were mainly used for security and hunting purposes (Fig. 4.22).

With respect to anti-rabies vaccination history, 43.47 % of urban respondents stated vaccinating their dogs compared to 9.52 % of rural respondents who vaccinated their dogs. Also 53.33 % of the dogs of rural respondents were vaccinated by veterinary superintendents. On the evidences of vaccination, 25.80 % of urban dog owning respondents presented certificates of vaccination while 34.97 % of such respondents had the pet green book as evidence. However, when this was compared with the rural settlement respondents, only 10.00 % of the respondents showed certificates and 13.33 % presented the pet green book as evidence. Also, 39.00 % of urban respondents could not show any evidence and 76.67 % of the rural settlement respondents could

not show evidence of vaccination (fig. 4.23). The results also indicated that the age at first vaccination in 28.67 % of the urban respondents was 6 months whereas 40.00 % of the rural settlement respondents indicated that the age at first vaccination was more than a year. As to the source of vaccine, 44.06 % urban respondents used vaccines produced by NVRI, Vom as compared to 90.00 % of rural settlement respondents who used the same vaccine (Fig. 4.24).

On vaccination against other diseases, 91.49 % of the urban respondents and 90.00 % of the rural respondents did not vaccinate against such diseases like canine distemper, hepatitis, leptospirosis, parvovirus enteritis and parainfluenza (DHLPP). Also, 85.41 % of urban dog owners indicated their willingness to have their dogs vaccinated against rabies provided such opportunities were provided compared to 51.43 % of rural respondent dog owners who equally indicated willingness to do so (Fig. 4.25).

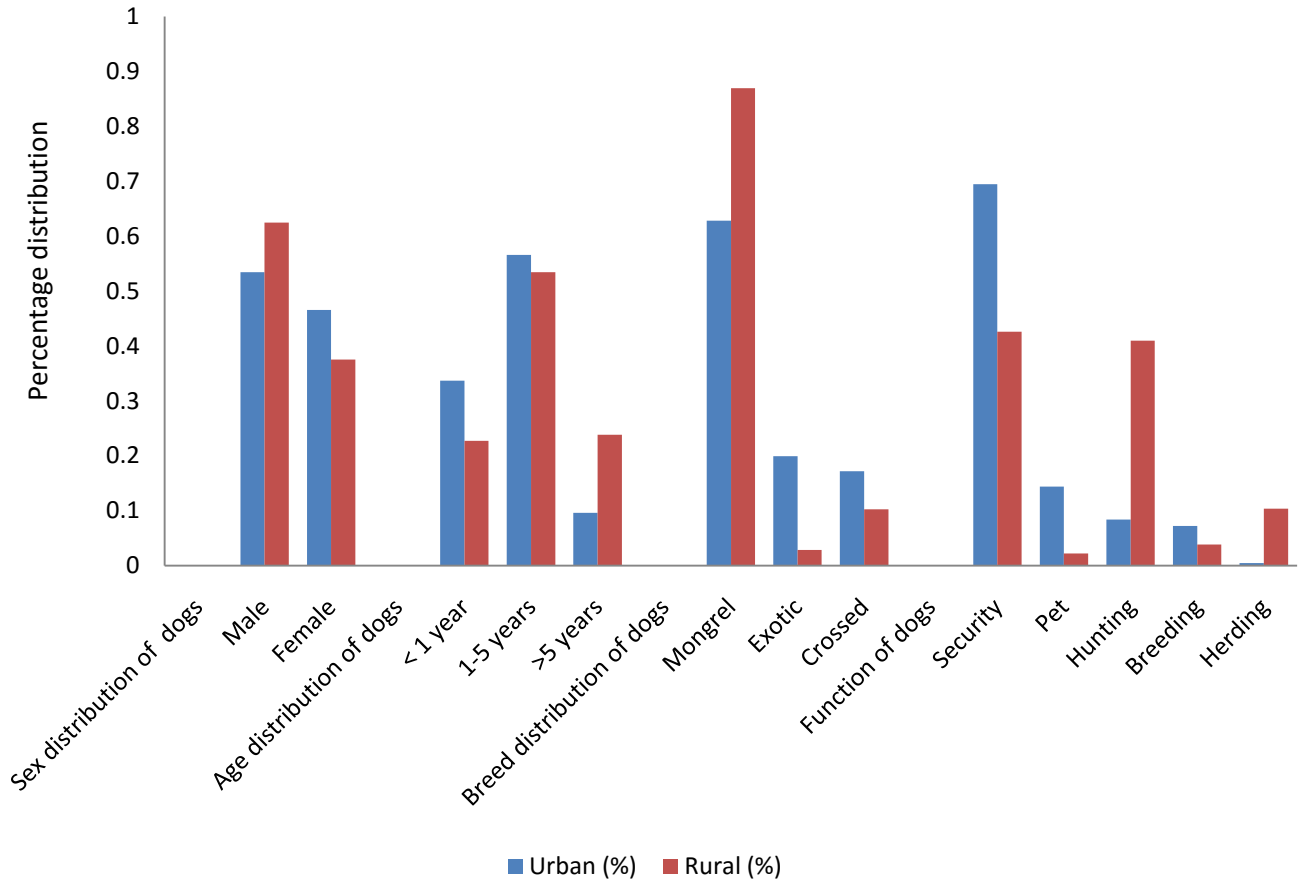


Figure 4.22: Comparison of the distribution of dogs by sex, age, breed and functional use according to urban and rural respondents in Bauchi State.

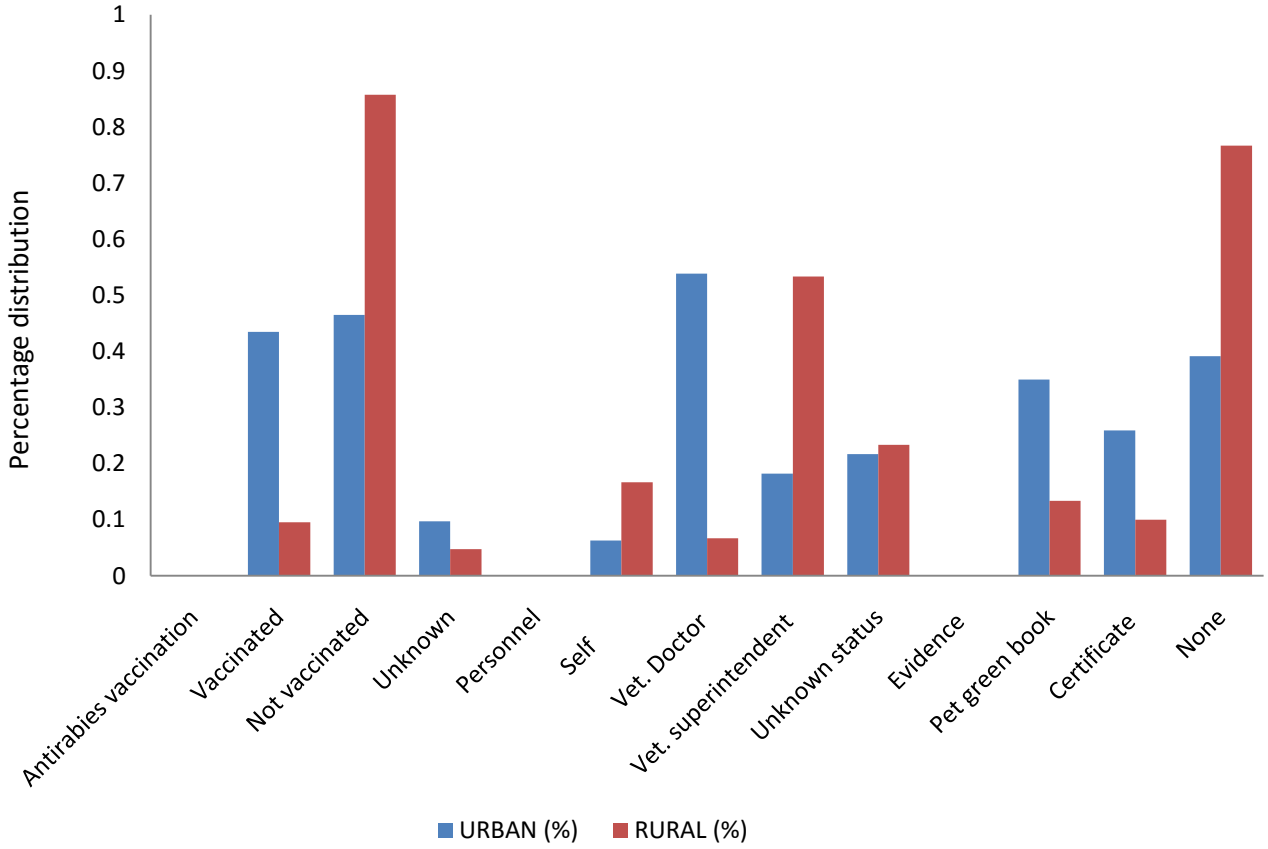


Figure 4.23: Comparison of responses of urban and rural dog owners on anti-rabies vaccination history, vaccine administration and evidence of vaccination in Bauchi State.

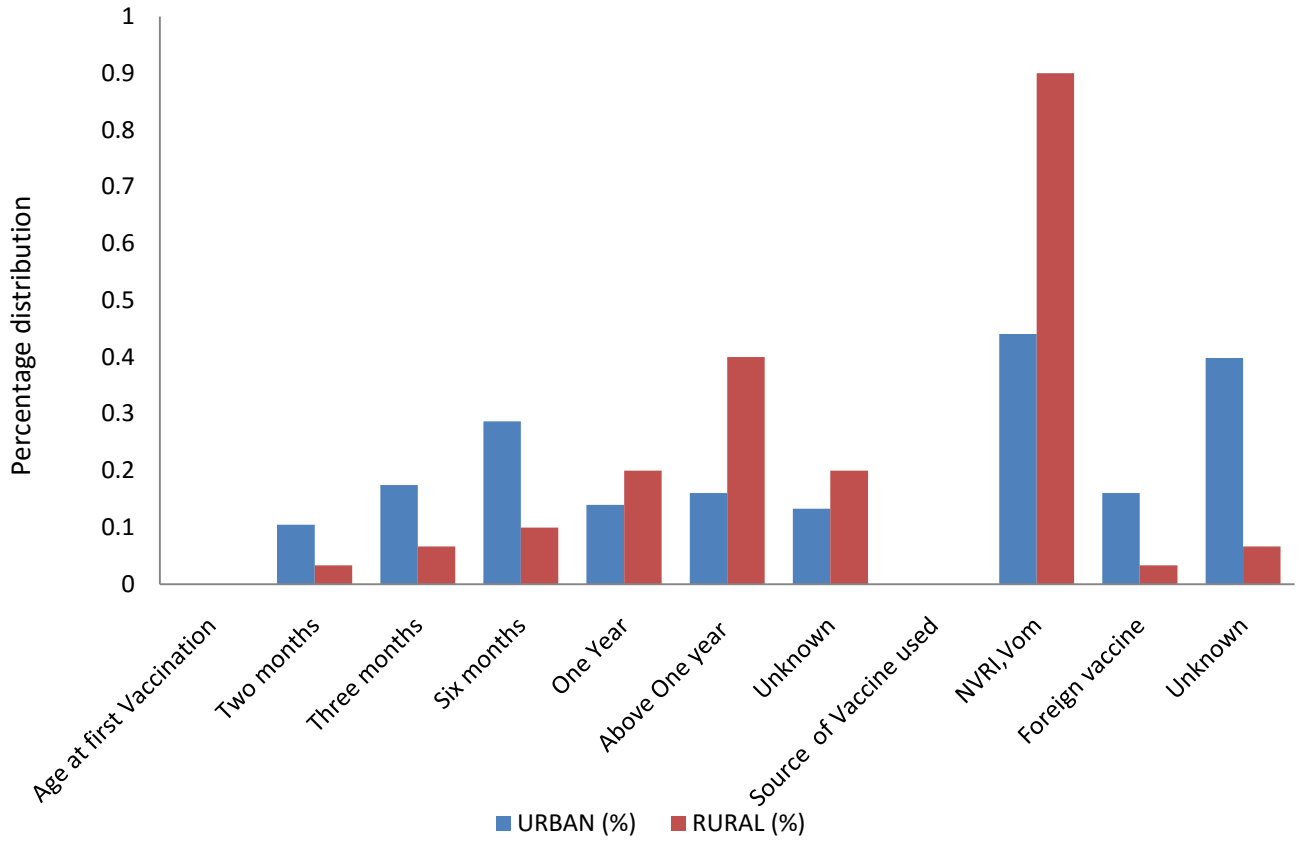


Figure 4.24: Comparison on age at first vaccination according to urban and rural dog owning respondents in Bauchi State.

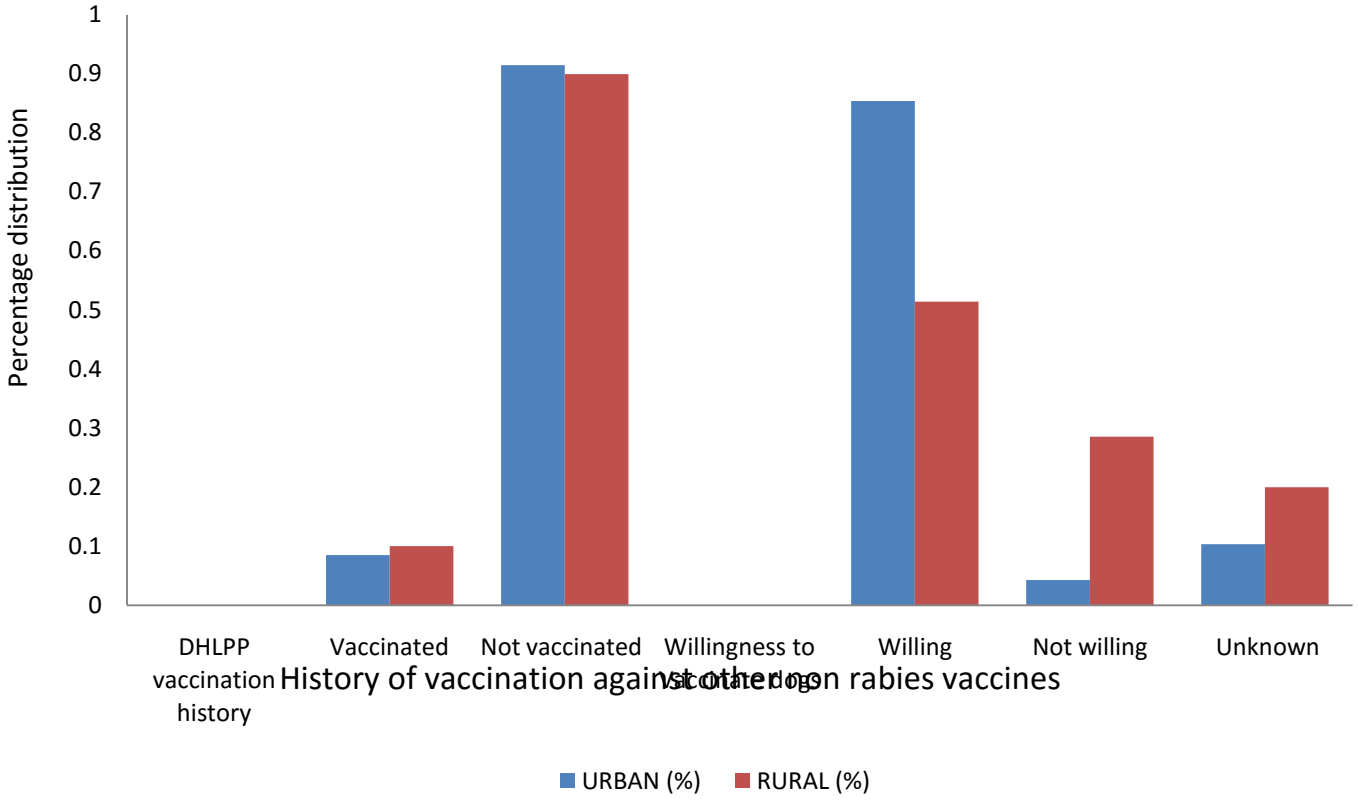


Figure 4.25: Comparison of vaccination against DHLPP diseases and willingness of urban and rural dog owning respondents to vaccinate their dogs provided the suitable conditions are organized.

4.4 RABIES VIRUS SURVEILLANCE IN DOGS AND WILDLIFE SPECIES IN BAUCHI STATE

Out of a total of 202 dog brain samples obtained from dog markets, 49 were positive for rabies antigen (Table 4.5) indicating a prevalence rate of 24.3 %. Of the 28 wild cat brain samples tested, 6 were positive for rabies antigen giving a prevalence rate of 21.4 %. Likewise, 5 out of the 30 hyrax brain samples tested were positive for rabies antigen giving a prevalence rate of 16.7 % while from the 18 mongoose brain samples examined, 2 were positive for rabies antigen representing prevalence of 11.1 % . Of the 76 jackal brain samples evaluated, 7 were positive for rabies antigen giving a prevalence rate of 9.2 %, likewise 2 brain samples out of 24 squirrel brains examined were positive for rabies antigen giving a prevalence rate of 8.3 % (Table 4.5).

The chi square analysis results showed statistically significant relationship with respect to dogs and jackals tested and the occurrence of rabies antigen.

Table 4.5: Occurrence of Rabies Antigen using DFA Test carried out on the Brain Tissues of Dogs and Wild Animals in Bauchi State.

Animal Specie	No. Tested	No. Positive	Odd Ratio	Prevalence	X^2	P- Value
Dog (*Canis familiaris*)	202	49	0.484	24.3	6.727	0.009
Mongoose (*Mungos mungo*)	18	2	1.796	11.1	0.606	0.436
Squirrel(*Spermophilus elegans*)	24	2	1.796	8.3	0.606	0.436
Jackal (*Canis aureus*)	76	7	2.495	9.2	4.969	0.026
Wild cat (*Felis silvestris*)	28	6	0.789	21.4	0.242	0.622
Hyrax (*Procavia capensis)*	30	5	1.105	16.7	0.036	0.844

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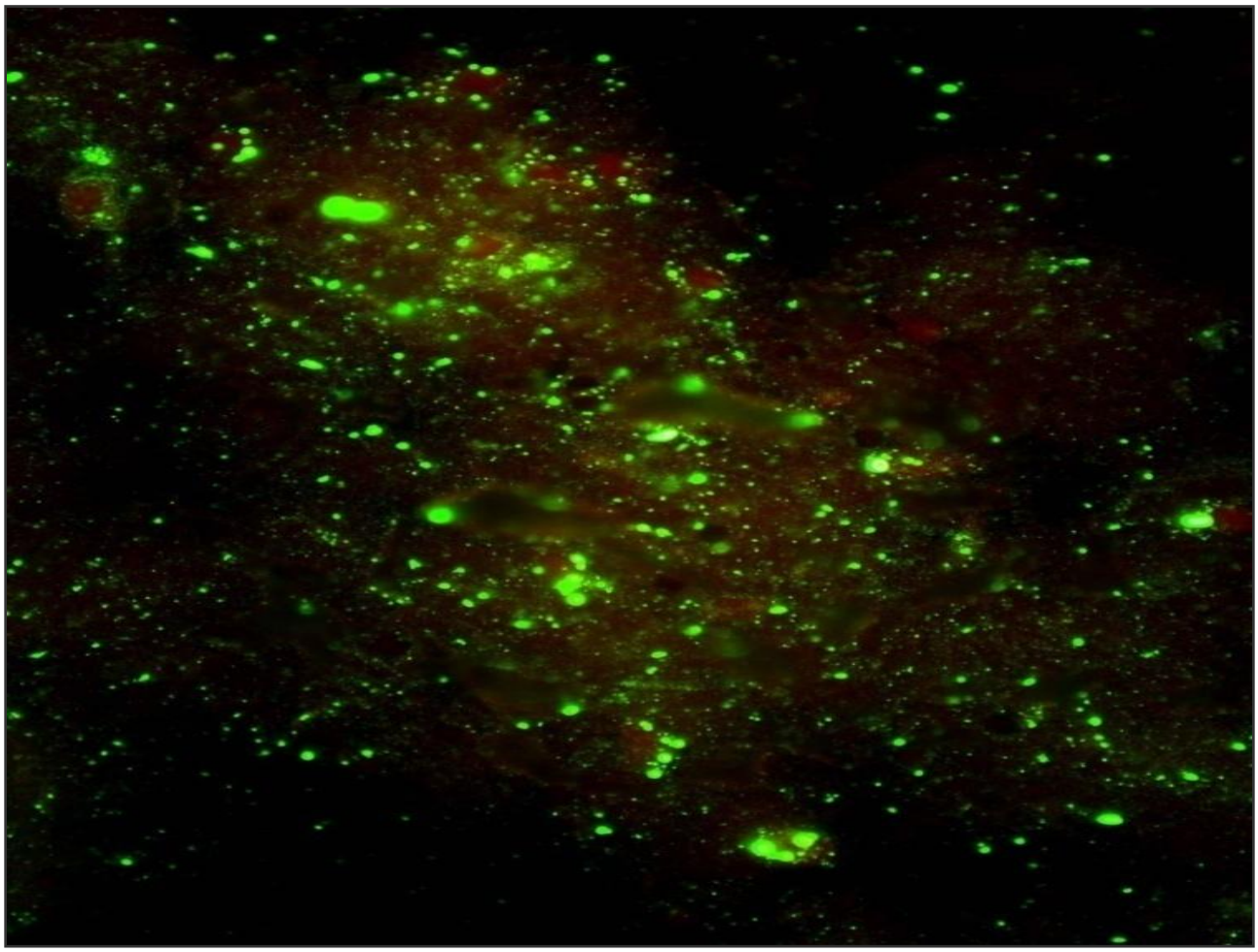


Plate VI A photomicrograph (x20) following DFA test indicating a clear positive reaction on brain tissue sample from a dog. (Aliquots of the DFA reagent diluted in ratio of 1:40 in PBS)

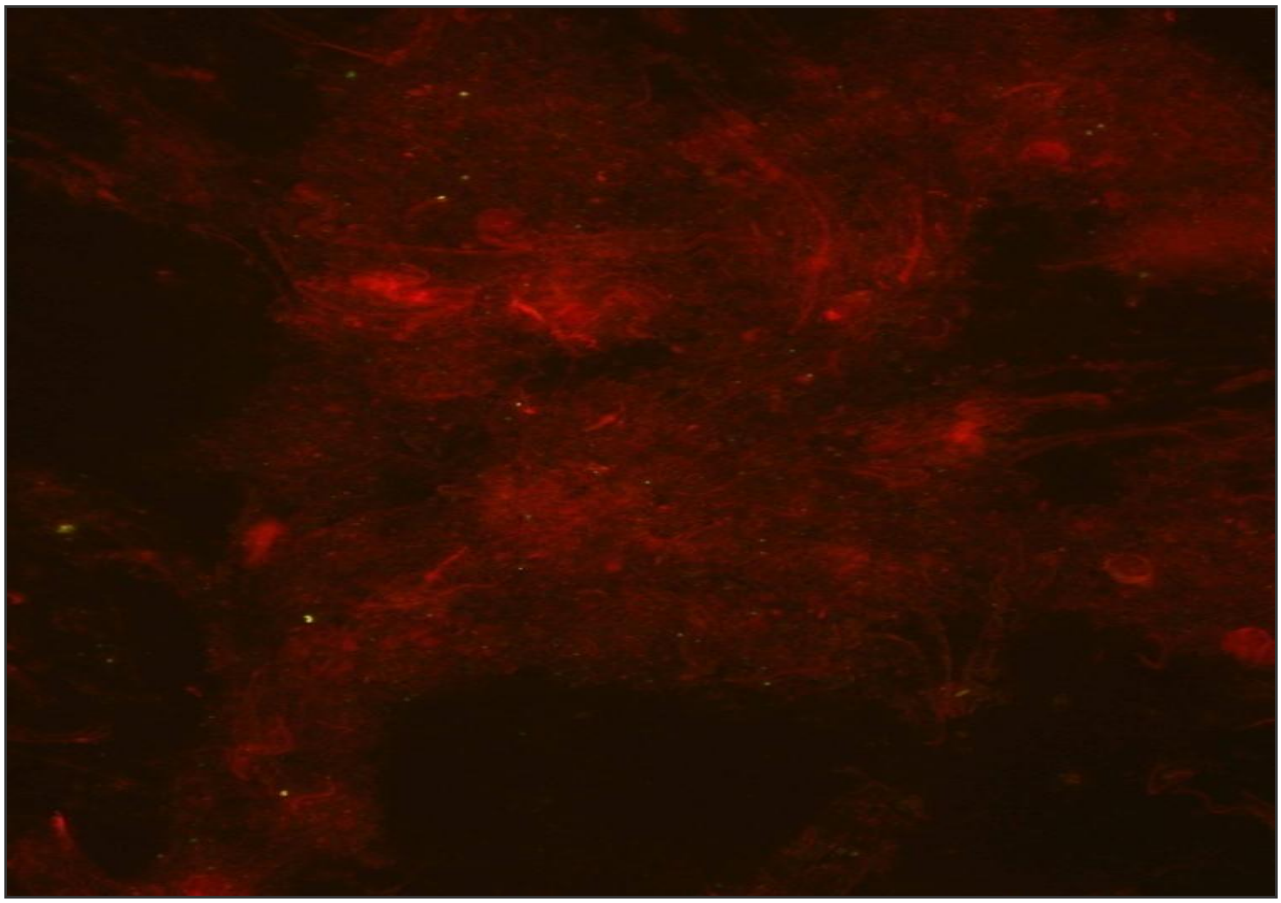


Plate VII A photomicrograph indicating a negative reaction due to absence of fluorescence from brain tissue sample from a dog. (Aliquots of the DFA reagent diluted in 1:40 in PBS)

CHAPTER 5

DISCUSSION

The domestic dog has been shown to be the most important reservoir host of rabies in Nigeria and is responsible for the transmission of the disease to humans and other animals (Umoh and Belino, 1979; Aghomo *et al*., 1987; Ogunkoya *et al*., 2003). Dogs have been incriminated in 98-99% of all deaths due to rabies in humans and other animals (WHO, 1999; Ogunkoya, 2008).

A lot of concern has been expressed by researchers on why rabies has continued to be a scourge to both humans and animal populations. Investigators are increasingly becoming interested in understanding the dynamics by which the domestic dog has effectively served in maintenance and transmission of rabies in the country (Umoh and Belino, 1979; Ogunkoya, 2008). The results obtained from this study in Bauchi State have also shown the role played by the domestic dog as the most important source of human rabies to the human populations in the State. As observed from this study in Bauchi State, the nature of interactions between the dog and human population, and the lack of an effective control on the part of owners and the authorities in ensuring restricting the free movements of both owned and stray dogs have become the major contributing factors that promote the transmission of rabies from dog to dog and from dog to humans. The likely periods in which transmission can be promoted could be related with the breeding season of the dogs when packs of males are seen trooping in pursuit of bitches that are on heat. The aggressive nature of the competition by the male dogs results into serious fight for dominance.

Another observation in this study was that the cost of puppies was very cheap and many could be acquired freely as gift as opposed to exotic breeds that are more expensive. In Bauchi State, about 55%-60% of newly acquired puppies were obtained as gifts.

The lack of effective implementation of the leash law and regular vaccination of dogs against rabies by State Veterinary authorities also facilitated the possibility of the spread of rabies within both the dog and human population in the State. In addition to this, there was also lack of proper care in the management of dogs by owners in Bauchi State. Many dog owners were not feeding their dogs properly resulting in many of these dogs scavenging in refuse dumps and around slaughter slabs and abattoirs serving as an increased source of dog to dog and dog to human conflicts and therefore as an increased risk to rabies transmission. The results of this study have also revealed the potential risk of rabies infection to both human and domestic animal populations from conflicts involving rabies infected wild animals particularly in those communities living at the fringes of the game reserves in Bauchi State. In north America and Europe, wildlife assume greater importance in the epidemiology of rabies compared to domestic dog (Cliquet and Picard-Meyer, 2004), however, the results of this study have indicated the important role the domestic dog plays as a reservoir for human infection and at the same time exposing the potential role wild animals could play in the epidemiology of rabies in the State.

Ecological studies on dog populations have been shown to assist in the design of measures in the control and eradication of rabies in some countries (Ratsitorahina, *et al*., 2009). The results of

dog population in Bauchi State showed that the average dog owning household had an average of 2.33 dogs, a finding which is in conformity with that of Kitala *et al*. (2001) in Kenya who reported an average estimate of 2.1 dogs per dog owning household. The mean dog to human ratio obtained in this study in both the urban and rural settlements of Bauchi State was 1:4.1 and 1:7.9 respectively. This is nearly consistent with the findings of Kitala *et al*. (2001) with a ratio of 1:8 in Kenya, Brooks (1990) with a ratio of 1:4.5 in Zimbabwe, Flore-Ibarra *et al*. (2004) with a ratio of 1:4.3 in Mexico, and the report of Kongkaew *et al*. (2004) with a ratio of 1:4.6 in Thailand. Similarly, in both urban and rural areas of Borno State in Nigeria, El-Yuguda *et al*. (2007) reported a ratio of 1:4.1 and 1:3.2 respectively. In Plateau State, Okoh (1986) reported a ratio of 1:4.0 in Jos. Oboegbulem and Nwankonobi (1989) reported urban and rural ratios of 1:2.1 and 1:4.5 in Lagos State. There is no doubt that the abundance of dogs varies considerably from country to country and even within different geographical regions of many countries (Matter and Daniel, 2000; Kitala *et al*., 2001).

Dog owners in Bauchi State kept dogs primarily for security purposes including safeguarding livestock from attacks by predators. Despite this important service provided by the dogs, their care and management were mostly poor. Many were poorly fed and not confined and so forced to move around the neighborhood in search of what to eat from rubbish dumps. According to the WHO (1992), such dogs are referred to as “neighborhood” or “community” dogs. This type of management of the domestic dog has also been reported in Ecuador (Beran and Frith, 1988), Zambia (De Balogh *et al*., 1993), Zimbabwe (Butler and Bingham, 2002), and Kenya (Kitala *et al*., 2001).

The relatively higher dog to human ratio obtained in Bauchi State in this study could be attributed to the major reason why dogs were kept by the owners mainly for providing security for household and livestock, reasons that are similar to reports from other countries, Zimbabwe (Brooks, 1990), Zambia (De Balogh *et al.*, 1993), Mexico (Rangel *et al.,* 1981), Philippines (Beran,1982), Ecuador (Beran and Frith, 1988), Chad (Mindeken *et al*., 2005), and in Madagascar (Ratsitorahina *et al*., 2009).

The breed, age, and sex structures of the dog population obtained in Bauchi State are suggestive of a very high reproductive turnover. However, majority of the dogs were aged between 1-5 years in both urban and rural settlements. This age range has been identified to be the most active in the lives of dogs by Oboegbulem and Nwakonobi (1989), Adeyemi *et al*. (2000), and El-Yuguda *et al*. (2007). The results of the study in both urban and rural settlements of Bauchi State indicated that people keep more male dogs as compared to female dogs. This is consistent with reports by other investigators (Beran and Frith, 1988; Brooks, 1990; Kitala, 1993 and Ratsitorahina *et al*., 2009). This preference appears to be due to the belief that male dogs make better guards and hunters and also female dogs attract a lot of male dogs to the house during their mating periods. The results of this study have also shown that majority of the dogs kept by owners in both settlement types in the State were mongrel dogs which were used mainly for security and hunting purposes.

An explanation for the relatively high population of domestic dogs in Bauchi State could be because natural breeding occurs without any restriction and the fact that only a few of the dogs were castrated. The views of owners towards castration were to limit their roaming about during

the breeding season and thereby be effective as guard dogs. Limited numbers of bitches were spayed only in the urban areas of Bauchi metropolis since professional Veterinary services by qualified veterinary surgeons were deficient in the rural settlements.

The study has shown that to carry out an effective rabies control in Bauchi state, a well coordinated rabies vaccination campaign in dogs should be mounted regularly to be supported by effective rabies legislation and impounding of stray dogs. This is because the study showed low vaccination coverage in both urban and rural communities which could be considered to be insufficient to have effective control of the disease. To have an effective control of rabies vaccination coverage of 70-75% is considered to be necessary to prevent outbreak of dog rabies (WHO, 1992; 2004). Thus, the need to institute vaccination campaigns of this magnitude is essential for effective control of rabies in Bauchi State.

The need to consider certain demographic factors in instituting an effective rabies control in Bauchi state has arisen from the study. The type of rabies vaccination programme to be adopted should depend on the dog population density and on the socio-economic orientation of the owners as has been reported by Kitala *et al.* (2001) in Kenya. It would be more appropriate to use the method of Perry *et al.* (1997) to target achieving 70% vaccination coverage in Bauchi metropolis but in the rural areas of the state, further investigations on the role of other factors involved in achieving a successful control including issues relating to access to the dogs, the cost of administering the vaccine, and educating the rural populace on the dangers of allowing dogs accessing garbage dumps due to inadequate care or the need to be able to limit the dog population through encouraging owners to castrate their dogs. The study in Bauchi state showed

that just above 50% of victims of dog bites involving household members died with typical manifestation of clinical signs of rabies. This is very alarming and is a possible reflection of lack of concern about the disease as nearly 40% of dog owners involved with this study have indicated that dog bite victims were not normally given post-exposure prophylactic treatment. Post exposure management of such cases may have been grossly inadequate. Some of the other management approaches could be said to be non-specific or even lack scientific justification, i.e. the use of antibiotics only, or traditional roasting the liver of the biting dog to be eaten by the victim, or the application of the offending dog's hair on the wounds, or the use of traditional herbs. There is therefore the need for public education in Bauchi State in order to raise the level of awareness of the communities on the proper actions needed to be taken on dog bites. The need to come up with a very effective means of subsidizing the cost of the post exposure vaccine treatment and the availability of the vaccine should be given top priority by the health authorities. The study shows that wildlife rabies occurs in Bauchi State and measures should be put in place in order to reduce the rate of wildlife transmission to dogs, domestic animals and humans. If the disease can be controlled in dogs and cats successfully, the next focus should be shifted to control of rabies in wildlife in the State.

With respect to conflicts between wildlife and humans and between wildlife and domestic animals, this study has shown that human settlement pressures were increasingly occurring involving the movement of humans with their domestic animals. Some of the activities like hunting are threatening the survival of some of the wildlife species in Yankari, Lame-Burra, and Sumu game reserves. Such interactions predispose the different communities to increasing risk of rabies among other diseases (Boyd *et al.,* 1999; Bengis, 2002; Daszak and Cunningham, 2003). This study showed that wildlife animal bites cases resulting in the manifestation of

abnormal nervous signs and eventual death of human victims in the communities living at the fringes of the three game reserves in the State. Also, a significant number of dog owners (about 40%) reported losing their domestic animals including dogs, goats, sheep, chickens and cattle as a result of attacks by wild animals. Apart from killing domestic animals, hyenas, lions, wild cats, mongooses, monkeys, and squirrels were involved in also destroying crops. Squirrels were most feared by hunters in Bauchi State. The hunters reported that most victims of squirrel bite hardly survived any treatment regiment and they considered such bites to be highly fatal. During this study a farmer killed four jackals and claimed that they were destroying his crops. Most farmers at the fringes of these game reserves in Bauchi State used dogs specifically to guard their farm crops from wildlife.

Rabies virus antigen was detected in brain samples of different animals including dogs, jackals, mongooses, wildcats, hyraxes and squirrels using DFA which is the gold standard diagnostic test for rabies. A prevalence rate of 24.3% was recorded in the domestic dogs obtained mostly from special dog meat markets in the state. Among wild animals examined, the highest prevalence rate of 21.4% was obtained in wild cats and 8.3% in squirrels. Thus, despite the fact that dogs had the highest prevalence for rabies and are also reservoirs of rabies, wildlife species may equally be assuming significant importance in the epidemiology of rabies in Bauchi State. The poor state of antirabies vaccination coverage in dogs in both the urban and rural areas of the State may explain the high prevalence rate of rabies in dogs. The detection of rabies virus antigen in apparently healthy dogs from dog meat markets is in agreement with previous studies by Aghomo *et al*., (1987); Ogukoya *et al.*, (1990); Baba, (1999); Ajayi *et al*., (2006) and Garba *et al*., (2010).

The detection of rabies virus antigen in the brain specimens of the wildlife species purchased from wildlife meat markets in the state poses serious questions as to how these wildlife species contacted rabies. It may be postulated that certain human activities at the fringes of the game reserves may actually promote the transmission of the virus from dogs the wildlife species. First of all, Fulani herdsmen were found with their cattle at the fringes of these game reserves and they normally keep dogs for security and herding purposes. These dogs were not routinely vaccinated against rabies and could be a source of rabies for the wildlife. Secondly, rural hunters in the settlements located at the fringes of the game reserves in the State use dogs for hunting and similarly such dogs were not routinely vaccinated against rabies and are likely to serve in transmitting the virus to the wild animals. Thirdly, farmers from villages living at the fringes of the game reserves do keep dogs to guard their crops from destruction by wildlife species. Evidence gathered on these dogs showed that they live on the farmland and were hardly vaccinated against rabies. Since these dogs were free to roam about they constantly come in contact with the wildlife species and if infected with the rabies virus the dogs could easily transmit rabies virus to susceptible wild animals.

This is the first time that rabies antigen has been demonstrated in a large number of brains of wild animals in Bauchi State and Nigeria at large. Such infections with the virus have been reported in wild cats in South Africa (Nel *et al*., 1993); in the mongoose (Nel *et al.*, 2005; Markotter *et al.*, 2006) and jackals (Bingham *et al.*, 1999). Rabies is a widespread disease in African domestic dogs and certain wildlife populations in South Africa (Bingham, 2005). The current study in Bauchi State in which the virus has been demonstrated in domestic dogs and some wildlife species indicated that there is need to determine the dynamics of rabies in the

wildlife populations to determine whether such wild animals would serve as reservoirs to the infection. Elsewhere in Africa, wildlife has been shown to serve as reservoirs (Smith *et al*., 1993; Swanepoel *et al*., 1993; Bingham, 2005). It should be noted however that this is not the first time the virus was isolated in Nigeria. Reports from the University of Ibadan Virus Research Laboratory (Anon, 1969, 1972) and by Kasali (1977) reported rabies virus from two hyraxes and a Civet cat respectively. Similarly Okoh (1976) and Enurah *et al*. (1988) reported rabies in a Caracal lynx and a Civet cat respectively at the Jos Zoological Garden.

The detection of rabies virus antigen in wildlife species samples obtained from wildlife markets in different locations in Bauchi State is strongly suggestive that the virus could be actively circulating within the wildlife populations found within the three game reserves. Detection of rabies virus antigen in the squirrel has not been reported before in Nigeria. The existence of rabies in wildlife in Bauchi study calls for much more studies of sylvatic rabies in the State and the rest of Nigeria.

The detection of rabies virus antigens from domestic and wild canids in Bauchi State should be of great concern about the public health significance of the disease. This concern has been expressed on the increasing incidence of rabies in both domestic and wild animals in Africa (King, 1993; Macdonald, 1993). The result of the finding in Bauchi State has exposed the potential dangers and risks of rabies to humans, domestic animals and wildlife from dog rabies. Likewise, wildlife species harboring the virus may be a threat to humans and other domestic species.

It is also important to note that the DFA test used in detecting the virus antigen could only indicate the presence of lyssavirus but could not differentiate between the different lyssavirus genotypes. Further studies are indicated to isolate and characterize the virus in dogs and the wildlife species in which lyssavirus was detected. One may speculate, from the results of this study in which wildlife rabies virus antigen were detected that it is possible for wildlife species to feature significantly in the epidemiology of rabies in Bauchi State of Nigeria. While the reservoir host of Lagos Bat Virus was established to be frugivorous bats, those of Mokola virus were suspected to be rodents and bats (Nadin-Davis, 2007) considering the fact that the virus was first isolated in rodents in Nigeria (Shope *et al*,1970). It is also possible that wildlife species in Bauchi State could be serving as reservoirs of the rabies and rabies related viruses.

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY

1. In summary, the domestic dog has been shown, from the study, to be the major reservoir host of rabies and of increasing risk to human rabies in Bauchi State.

2. The results have also indicated the existence of lyssavirus antigen in the brain tissues of wild animals. This finding has obvious wider implications because of the presence of large number of wildlife populations located in the three major game reserves in the state.

3. The estimated dog population of street count and compound counts were 5,310 and 7,670, respectively and human to dog ratio of 4.1:1 and 7.9:1 were established in urban and rural settlements, respectively.

4. Dog owners reported low vaccination coverage in both urban (43.5%) and rural (9.5%) settlements and therefore considered not sufficient to prevent rabies transmission.

5. Poorly coordinated sanitary measures allowed collection of garbage which serves as sources of feeding of the dogs and thereby allow free contact of dogs in the neighborhood facilitating transmission of rabies.

6. Cases of dog bites were alarmingly high in Bauchi State from the results obtained and this was the case in both the urban and rural areas of the state.

7. Lack of effective surveillance of rabies and other rabies related viruses in Bauchi state, coupled with inadequate diagnostic facilities and public awareness on the significance of the disease contributed immensely to the current position of lack of information on the epidemiology of rabies and rabies related viruses in the area.

6.2 CONCLUSIONS

The results of this study have revealed that:

1. Rabies in the domestic dog in Bauchi State was a very serious problem that is threatening the lives of the human population in both the urban and rural settlements.

2**.** The population of dogs in the state is growing and highly dynamic in a situation whereby the dogs were poorly cared for in terms of their feeding and health requirements, in addition to the fact that vaccination against rabies was highly inadequate making the risk of occurrence of rabies in humans very high. Therefore, human rabies through dog bites was encountered in the state.

3**.** The results of the study have also shown that inadequate measures existed in both the urban and rural areas of the state in assisting victims of bites by rabies infected dogs under a situation whereby post-exposure prophylactic treatment was hardly available particularly to victims in the rural areas of the state.

4. The detection of rabies virus antigen in the brain tissues of some wildlife species in the state is a pointer to the possible role of wild animals in the epidemiology of rabies considering the existence of the three game reserves located in Bauchi State.

6.3 RECOMMENDATIONS

Based on the results obtained from this study in Bauchi State, the following recommendations are hereby presented.

1. The Bauchi State Government should give adequate attention to the surveillance and control of rabies in the State through special anti-rabies campaign programmes, improved awareness to medical personnel and the general public on rabies, and the implementation of the leash law in order to control the population of stray dogs.
2. There is need to carry out a study for the isolation and characterization of the lyssaviruses in domestic dogs and wildlife species in order to adequately understand the epidemiology of rabies in Bauchi state.
3. There is need to carry out a detailed ecological study in relationship to lyssaviruses in the wildlife species located in the game reserves in the State and relate it to the conflict situations that are encountered between the domestic dog, wildlife, and human populations.
4. Similar studies should be carried out in other States of Nigeria bordering Bauchi State, particularly taking into consideration difference in geographical and climatic setups which may favour different wildlife species.
5. It is also recommended that in order to safeguard the lives of the people of Bauchi State against rabies, vaccines for post-exposure prophylactic treatment should be made readily available at the major health centers of the State and be subsidized so that people from all parts of the State can afford them. There should also be routine vaccination of people at risk working in different sectors of the State.

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APPENDICES

APPENDIX 3.1 COMPOUND QUESTIONNAIRE SURVEY OF DOGS

Respondents biodata

1. Age: Below 25 years [ ] 25-34 years [ ] 35-50 years [ ] above 50 years [ ]

2. Sex: Male [ ] Female [ ]

3. Level of education: None [ ], Primary [ ] Secondary [ ] Tertiary [ ] others [ ]

4. How many people are resident in your compound? ……....

Dog population structure.

1. Do you have dog(s) in your compound? Yes [ ] No [ ]

2. If yes, how many do you have? ……

3. Source of dog(s) Gift from neighborhood [ ], Bought from breeders [ ], Offspring of a bitch from house hold [ ] I don't know [ ]

4. Who owns the dog? Father [ ] Mother [ ] Daughter [ ] Son [ ] Others……

5. Sex distribution of dog (s) in the compound. Male……. Female……

6. Age of the dog (s). < 1year [ ], 1-2 years [ ], 2-3years [ ], 3-5 years [ ], >5years [ ]

7. Breed of dog in the compound. Native [ ] Exotic [ ] Cross breed [ ]

8. Function of the dog. Security [ ] Pet [ ] Hunting [ ] Breeding [ ] Herding [ ]

Dog management and Vaccination program.

1. Is your dog under confinement? Never [ ] Partial [ ] Always [ ] I don't know [ ]

2. Who takes care of the dog? Father [ ] Mother [ ] Children [ ] Everybody [ ]

3. How do you feed the dog? Family left over [ ] Cook special pot [ ] Buy commercial dog feeds [ ].

4. How many times do you feed the dog in a day? Once [ ] Twice [ ] Thrice [ ] I don't know [ ]

5. Has your dog ever received any immunization against rabies? Yes [ ] No [ ] I don't know [ ]

6. If the dog has been immunized against rabies:-

a. Who vaccinated the dog for you: Myself [ ], Veterinary Doctor [ ], Livestock superintendent [ ], I don't know his/her professional qualification [ ].

b. Where did you do the vaccination? State Vet clinic Ran road [ ], NVRI Bauchi Lab. [ ] School of Agric clinic Yelwa [ ], in my house [ ].

c. Age of the dog at the time of vaccination. Two months [ ] three months [ ], Six months [ ], One year [ ] above one year [ ] I don't know [ ]

d. Source of the vaccine used? NVRI-Vom [ ] Foreign vaccine [ ] I don't know [ ]

e. What do you have to show as evidence that you vaccinated your dog? Pet green book [ ] Certificate issued by the person who vaccinated the dog [ ] I don't have anything as evidence [ ].

f. What other disease(s) has the dog been immunized for? .....

g. If an animal vaccination clinic is being organized in your community/village to vaccinate dogs for rabies, would you take your pet to be vaccinated? Yes, [ ] No [ ] I don't know [ ]

6. Has your dog been castrated or spayed? Yes [ ] No [ ]

7. Do you think Veterinary Services are adequate in your community? Yes [ ] No [ ]

8. How are your dogs depopulated? Giving away to people [ ] Disappear [ ] intentionally killed [ ] Automobile accident [ ] Died due to disease [ ]

Cases of dog bites, management and sequela.

1. Have you or any member of your house been bitten by a dog? Yes [ ] No [ ].

a. If yes, who owns the dog? Household dog [ ], Neighbors' dog [ ], Stray dog [ ]

b. What happened to the dog? Died [ ] killed [ ] Healthy [ ] I don't know [ ]

c. What treatment was the victim given? Post exposure anti rabies vaccination [ ], Local wound treatment with antibiotics [ ], Traditional dog bite treatment [ ], No any specific treatment [ ]

e. What happened to the victim? Healthy [ ] Died [ ] I don't know [ ]

f. If the victim had died, did he/she exhibit any abnormal nervous behavior or sickness before dying? Yes [ ] No [ ].

2. Has your dog ever bit somebody? Yes [ ] No [ ].

a. If yes, what was the vaccination status of the dog at the time of bite? Vaccinated with anti rabies vaccine for dog (ARV-D) [ ], Not vaccinated with ARV-D [ ], I don't know [ ]

b. Health status of the dog at the time of bite. Sick [ ] Healthy [ ] I don't know [ ]

c. What happened to the dog? Died [ ] killed [ ] Healthy [ ] I don't know [ ]

d. What treatment was the victim given? Post exposure anti rabies vaccination [ ], Local wound treatment with antibiotics [ ], Traditional dog bite treatment [ ], No any specific treatment [ ]

e. What happened to the victim? Healthy [ ] Died [ ] I don't know [ ]

f. If the victim had died, did he/she exhibit any abnormal nervous behavior or sickness before dying? Yes [ ] No [ ].

APPENDIX 3.2:PROFORMA FORM ON STREET DOG CENSUS DATA, BAUCHI STATE, NIGERIA

Area……Socio economic level ……..Date……..Reported by……

BREED			SEX		AGE		LACTATING FEMALE		
Street Name	Dog Number	Exotic breed	Cross breed	Local breed	Male	Female	Puppy	Adult	Litter size

APPENDIX 3.3: QUESTIONNAIRE ON WILD LIFE ABUNDANCE/CONFLICTS FROM WILD LIFE/HUMAN/DOMESTIC ANIMAL INTERFACE

Bio data of the respondent/information about the community.

1. Age: Below 25years [ ] 25-34 years [ ] 35-50 years [ ] above 50 years [ ]

2. Sex: Male [ ] Female [ ]

3. Level of education: None [ ] Primary [ ] Secondary [ ] Tertiary [ ] others [ ]

4. Name of community / town/ village……

5. For how long have you been in this place/ community? < 5 years [ ] 5-10 years [ ] 11-15 years [ ] 16-20 years [ ] >20years [ ]

6. How many people are resident in your compound?.....

7. Nationality……..

8. Occupation: Hunting [ ] Farming [ ] Civil Servant [ ] Others……..

9. Availability of schools in the town/village: None [ ] Primary [ ] Secondary [ ] Tertiary [ ] others [ ]

10. Availability of health care services delivery in the town/village: None [ ] Dispensary [ ] Hospital [ ] Vet. Clinic [ ] Others [ ]

11. Access road for motorist to the village. None [ ] 'Coal' tarred road [ ] un-tarred road [ ]

12. Tribe……..

Wild life abundance

1. Have you ever seen any of the under listed wild mammals in your locality (Area)? Yes [ ] No [ ]

Lion, Hyena, Jackal, Wild cat, Shrew, Cheetah, Leopard, Wild Dog, Mongoose, Fox, Monkey, Chimpanzee, Squirrel, Deer, Hyrax.

a. If Yes, Indicate by **ticking** the appropriate animal above.

b. When last did you see it/them? < 2 years ago [ ] 3-5 years ago [ ] 6-10 years ago [ ] > 10 years ago[ ]

c. How many did you see? < 5 [ ] 5-10 [ ] 11-15 [ ] 16-20 [ ] > 20 [ ]

d. Do you have any **specimen/evidence** to show that the wild Animal exist in this place Example; Skulls and Bones collected in recent times, Skin, Scats, Live or Dead wild animal (carcass) etc Yes [ ] No [ ]

e. If Yes, Can you show me……..

Wild life conflicts with human and domestic animal communities.

1.Do you keep wild mammal(s) in your place (House)? Yes [ ] No [ ].

2.If Yes, Why do you keep them?.....

3. Have you or any member of your family been attacked or bitten by a wild mammal? Yes [ ] No [ ]

a. If yes, which wild animal(s)?.....

b. What was the circumstance of the bite? ……

c. What treatment was the victim given? Post exposure anti rabies vaccination [ ], Local wound treatment with antibiotics [ ], Traditional Animal bite treatment [ ], No any specific treatment [ ]

d. What happened to the victim? Died [ ] Survived [ ] I don't know [ ]

e. If the victim had died, has he/she exhibited any abnormal behavior? Yes [ ] No [ ]

f. What happened to the wild animal? Killed [ ] Escaped [ ] I don't know [ ]

4. Has any of your domestic animal(s) been attacked or bitten by a wild animal? Yes [ ] No[ ]

a. If yes, which of your domestic animal species? …….

b. What was the circumstance of the bite/ attack? …….

c. What happened to the domestic animal? Slaughtered immediately [ ] developed illness and died later [ ] Died immediately [ ] Survived [ ] I don't know [ ]

Dog ownership and vaccination program

1. Do you have dog(s) in your house/compound? Yes [ ] No [ ]

2. If yes, how many do you have? ……

3. Sex distribution of dog (s) in the compound. Male……. Female……

4. Age(s) of the dog (s). < 1year [ ], 1-2 years [ ], 2-3years [ ], 3-5 years [ ], >5years [ ]

5. Breed of dog in the compound. Native [ ] Exotic [ ] Cross breed [ ]

6. Function of the dog. Security [ ] Pet [ ] Hunting [ ] Breeding [ ] Herding [ ]

7. Has your dog ever received any immunization against rabies? Yes [ ] No [ ] I don't know [ ]

8. If the dog has been immunized against rabies:-

a. Who vaccinated the dog for you: Myself [ ], Veterinary Doctor [ ], Livestock superintendent [ ], I don't know his/her professional qualification [ ]

b. Age at which vaccine was administered: Two months [ ] three months [ ], Six months [ ], One year [ ] above one year [ ] I don't know [ ]

c. Source of the vaccine used? NVRI-Vom [ ] Foreign vaccine [ ] I don't know [ ]

d. What do you have to show as evidence that you vaccinated your dog? Pet green book [ ] Certificate issued by the person who vaccinated the dog [ ] I don't have anything as evidence [ ].

e. What other disease(s) has the dog been immunized for? .....

f. If an animal vaccination clinic is being organized in your community/village to vaccinate dogs for rabies, would you take your pet to be vaccinated? Yes, [ ] No [ ] I don't know [ ]