ASSESSMENT OF MAJOR LIVESTOCK DISEASES AND ASSOCIATED PRODUCTION CONSTRAINTS IN A SMALLHOLDER PRODUCTION SYSTEM IN MACHAKOS COUNTY, KENYA.

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

This thesis is dedicated to the memory of my late son Allan Bwire Wesonga who had keen interest in what ever I did and his chronic illness gave me inspiration to work hard in life.

And

My wife Esther and Children, Sheila, Stella, Sandra and Seith

(*Their love, prayers and endurance to my absence while undertaking field work was the driving engine for my perseverance*).

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF THE FIGURES

LIST OF APPENDICES

ABSTRACT

This thesis describes livestock production constraints in a smallholder production system in Machakos District with special reference to tick-borne diseases. The objectives of the study were:

(i) To identify the constraints that limit smallholder livestock production as perceived by various stakeholders in Machakos District;
(ii) To establish the socio-economic and demographic characteristics of livestock farmers in the district;
(iii) To estimate the seroprevalences of tick-borne diseases in the district;
(iv) To estimate the morbidity, mortality and productivity parameters of livestock in the district;
(v) To evaluate the efficacy of East Coast fever immunization of cattle by the infection and treatment method in the district.

A three-stage cluster sampling method involving (in descending order of size) divisions, sub-locations, and households was used to select farms for the cross-sectional survey. A total of 200 farms were selected in four divisions. Farm level and individual animal data were collected using a standard questionnaire. Blood samples were collected from cattle in the farms and their sera screened for antibodies to *Theileria parva, Babesia bigemina* and *Anaplasma marginale* using ELISA tests.

Fourteen farms were randomly selected for a one-year follow-up study. Data collected during follow-up included birth weights, disease occurrence, herd dynamics, weaning weights and ages, fertility and breeding female management, milk production, tick challenge, and tick control.

Twenty-eight farms were randomly selected for conducting the controlled trial of the infection and treatment method of immunization of cattle against East Coast fever. Only calves and yearlings were recruited into the study. Study animals were randomly allocated to either the treatment or control group in each of the 28 farms. Animals in the

treatment group were injected with a long acting tetracycline (30%) followed by injection of the Marikebuni strain of *Theileria parva* vaccine stabilate. All the study animals on the 28 farms were followed-up equally via monthly visits for a period of 12 months. Data were collected on pre and post-immunization serological status of the animals including morbidity and mortality during the follow-up period.

The main constraints to livestock production identified in order of importance included livestock diseases (mostly tick-borne diseases), poor access to livestock and livestock product markets, poor veterinary infrastructure and inadequate feed. The mean antibody sero-prevalence rates in the study sub-locations for *Theileria parva, Anaplasma marginale* and *Babesia bigemina* were 58.9%, 35% and 41.1%, respectively. East Coast fever was found to exit in a state of endemic stability characterized by high antibody prevalence and a constant tick challenge while anaplasmosis and babesiosis appeared to exist in a state of endemic instability, characterized by low antibody prevalence in all the four study divisions. In univariate analyses five factors (age, breed, division, grazing system, and tick infestation) were significantly ($p<0.05$) associated with testing positive to *Theileria parva* infection while age, division, grazing system and tick infestation were significantly ($p<0.05$) associated with testing positive to *Anaplasma marginale* infection; age, grazing system and division were associated ($p<0.05$) with testing positive to risk of exposure to *Babesia bigemina* infection.

In multivariate analysis the only factors that were associated with testing positive to *T. parva* were age, division, grazing system and tick infestation while for anaplasmosis only age and division were significant. The same factors that were significantly associated with babesiosis in univariate analysis did not change in the mutltivariate analysis suggesting that the association was not confounded by any of the considered factors.

Twenty-six (26) cases of ECF were confirmed on the 14 farms during the longitudinal study converting to an annual incidence rate of 30.7% per cow-year. Factors that were significantly ($p< 0.05$) associated with the risk of infection with by *T. parva* were age, tick control, frequency of acaricide application, season, and division. Four cases of anaplasmosis were confirmed converting into an annual incidence rate of 4.26%. Other conditions/infections observed in cattle during follow-up included malnutrition, mange, mycosis and diarrhoea. Eleven cattle died during the follow-up period converting to an overall crude mortality rate of 11.6% per cow-year. The cause-specific annual mortality rates of ECF, non-specific disease condition, and diarrhoea were 6.56%, 8.74% and 2.19% per cow-year, respectively.

The commonest causes of morbidity in sheep and goats were helminthosis and pneumonia. Diarrhoea due to bacterial infections, severe flea infestations and mange were the other diseases detected in small ruminants.

Livestock productivity was found to be sub-optimal. Cattle were reared primarily as long-term investments while goats, sheep and poultry were often sold to meet immediate family financial needs. The daily mean milk production for cattle was 1.98 litres. Breeding intervals for goats and sheep were once every 12 month and the mean off- take rates for cattle and small ruminants were 9% and 4%, respectively.

A high proportion (93.7%) of the cattle sero-converted following immunization against East Coast fever using the infection and treatment method. The annual incidence rate of ECF in the control group was 42.2% per cow-year and 7.8% per cow-year in the vaccinated group. The efficacy of the vaccine was 82%, indicating a significant protective effect in the study area. Use of the vaccine was found to be financially profitable and realized a net return of Ksh.2, 838 per animal.

In conclusion, farmers need to be encouraged to keep improved livestock breed, particularly the exotic dairy (breeds) to address the problem of low milk production in the district. There is also a need to create awareness on the use of East Coast fever vaccine to reduce mortality from East Coast fever among calves and also enable more widespread introduction of exotic breeds of cattle. Co-operatives dealing in livestock and livestock products should also be formed or existing ones strengthened to assist in the marketing of livestock and livestock products. There is need to improve on the delivery of animal health services particularly the revival of tick control programmes in the district so as to optimize livestock productivity.

CHAPTER 1

GENERAL INTRODUCTION

1.1 Constraints to livestock production

Livestock is an integral part of the livelihood of smallholder farmers in Kenya ranging from the high potential areas where mixed crop and rearing of various types of livestock is the main agricultural activity to the arid and semi-arid rangelands where pastoralism and extensive livestock rearing are the main methods of keeping cattle and small ruminants.

Inability to feed animals adequately throughout the year is the most widespread technical constraint to livestock production particularly in the developing world (Winrock International, 1992). Poor management and diseases have been cited as the most important constraints to livestock production in sub-Saharan Africa (Brumby and Scholtens, 1986; De Leew *et al*., 1995). Inadequate support services in livestock disease control in Africa are also a significant constraint to livestock production in the region. This is as a result of the deterioration in the quality of animal health delivery systems, a consequence of attempts by governments to meet an increasing demand from farmers and pastoralists for veterinary services with a dwindling set of resources (Curry, 1991). In Kenya, the smallholder dairy cattle production in particular is beset by many constraints which are manifested by relatively low milk production per cow, long calving intervals and high mortality rates (Gitau, 1992; Omore, 1997; Karanja, 2002).

There is insufficient data on livestock production constraints and disease incidence in Kenya especially because the majority of reports have been based on passively derived data from County, provincial and aggregated annual national reports. These mainly focused on vector-borne diseases with limited focus on productivity constraints on Kenyan smallholder livestock farming systems (Gitau, 1992 and 1998; Maloo, 1993; Odima *et al.*, 1994; Omore, 1997; O'Callaghan, 1998). Studies targeted on identification of production constraints in various livestock production systems in the country are largely lacking. Data generated from such studies would be invaluable in the formulation of appropriate evidence based mitigation measures.

1.2 Livestock Industry in Kenya

Agriculture directly influences rural livelihoods by providing incomes, employment and products for home consumption. It also directly influences prices of commodities and labour markets, amongst other farm-non-farm linkages. In Kenya, this sector accounts for over 27% of Kenya's gross domestic product (GDP) and 70% of foreign exchange earnings (Ochieng-Odhiambo, 1998).

Livestock contributes about 43% of the gross domestic product (GDP) and over 30 % of the farm gate value of agricultural commodities (ILRI, 2011).This sub-sector employs over 50% of the agricultural labour force (KARI, 1994, ILRI, 2011), and it is dominated by small producers (FAO, 2005). Only twenty percent of the country's land mass is suitable for both rainfed arable and livestock farming. The rain-fed arable land consists of medium and high potential lands mainly in the Central Rift Valley, Nyanza, and Western, Central and Central parts of Eastern provinces. The remaining territory is arid and semi-arid lands (ASALs) and are mainly located in the Rift Valley, Eastern and North Eastern Provinces of Kenya. They are the key production areas of animal meat (beef, mutton, goat and camel meat).

In mixed crop-livestock systems in the high and medium potential lands of Kenya, livestock provide manure used to improve soil fertility resulting in better crop yield (GoK, 1997). Traction power from cattle is also useful in land preparation, weeding and transportation.

In Machakos County livestock are kept for milk, meat, manure and draught power (Mukhebi and Gituna, 1985). Use of oxen for tilling land is especially important in the County. Livestock are also kept for investment purposes (Mukhebi and Gituna, 1985) and are, especially the small ruminants sold in bad times such as drought to raise school fees and meet other family needs. Sheep and goats also play an important role in the nutrition and income of smallholders (Mtenga *et al*., 1986; Connor *et al.*, 1990). They provide meat, milk, skins and manure and also serve as an investment that can easily be converted into cash when the need arises (Njombe, 1993). This feature of keeping small ruminants as a source of emergency family income is a characteristic of smallholder livestock production systems in the country (Stotz, 1979; Maichomo, 2008). On the other hand, cattle are sold for cash to pay school fees, pay medical bills and other emergencies that require relatively considerable amount of money. In 2000, the estimated total farm incomes in the County from livestock sales and livestock products were 72 million and 73 million shillings, respectively (Kinuthia, 2001).

1.3 Constraints to livestock production in Kenya

In Kenya, reports on livestock production constraints are based on passively derived data from monthly and annual reports from the Ministry of Livestock, Farmer's Training Centres (FTCs) and research institutes, mainly the Kenya Agricultural Research Institute (KARI). Past epidemiological studies on livestock in Kenya narrowed their scope only to cattle. These include studies by Gitau (1992 and 1998), Maloo (1993), Onchoke (1993), Maloo et *al.* (1994), Omore (1997), O'Callaghan (1998), Okuthe and Buyu (2006) and Gachohi *et al.* (2010). Little has been done to study all livestock species together to identify the social and economic importance of each species to the farmers and constraints to their production. All the studies mentioned above were done in the Coastal lowlands, Central and Western highlands. Moreover, the studies mainly targeted smallholder dairy farming systems with exotic or improved breeds of cattle with little or no attention paid to small ruminants which play a significant role in the livelihood of many smallholder farming systems (Winrock International, 1992).

In Machakos County, a significant number of smallholder farms keep both cattle and small ruminants (GoK, 1997; KNBS, 2009). An earlier survey conducted in the County showed that 90% of the households kept livestock, of which 88% kept both cattle and small ruminants (Small ruminants-CRSP, 1995). In such a production system, it is important to assess the constraints that limit production and their effect on the different species. The estimated cattle and small ruminants population in the County is 1,089,376 cattle and small ruminants mainly kept under traditional mixed farming system: 319,911 cattle, 105,731 sheep and 663,734 goats (KNBS, 2009).

Despite having a large livestock population, no detailed studies focusing on animal health and production have been conducted in Machakos County. The only documented studies on constraints to livestock productivity in the County were cross-sectional surveys undertaken by Mukhebi and Gituna (1985) and Emongor *et al.* (2000). These studies were very limited in scope and the data collected were largely qualitative. It is essential to integrate various methodologies in the identification of livestock production constraints as no methodology offers a universal panacea (Kirsopp-Reed, 1994, Okuthe e*t al*., 2003). The aim of adopting a holistic approach is to assess and offer solutions which should show tangible impact to farmers' problems. Such an approach entails the use of informal techniques followed by traditional and more formal methods to produce quantifiable results. The present study used both qualitative and quantitative methods to identify constraints to livestock production in the County.

1.4 Objectives

1.4.1 Broad objective

To determine constraints to livestock production in a smallholder livestock production system, in Machakos County, Kenya.

1.4.2 Specific objectives

(i) To determine the constraints that limit smallholder livestock production as perceived by various stakeholders in Machakos County.

(ii) To determine the socio-economic and demographic characteristics of livestock farmers in the County.

(iii) To estimate the seroprevalence of tick-borne diseases in the County.

(iii) To estimate morbidity, mortality and productivity parameters in livestock (ruminants) in the County.

(iv) To evaluate the efficacy of East Coast fever immunization of cattle by the infection and treatment method in the County.

1.5 Structure of the thesis

The thesis has eight Chapters. The first Chapter lays the background of the study followed by literature review of the main topics addressed in the whole thesis. Perceptions of the various stakeholders on constraints to livestock production are described in Chapter 3. Description of the socio-economic and demographic characteristics of the study farmers are presented in Chapter 4. Chapter 5 covers the specific objective of quantifying the risk of tick-borne diseases in the study area as assessed from cross-sectional data. Chapter 6 addresses morbidity and livestock productivity estimates in the smallholder farms. Chapter 7 presents the findings of a controlled trial, conducted to assess the efficacy of the East Coast fever vaccine in a smallholder cattle production system. The general conclusions and recommendations derived from the overall study are outlined in Chapter 8.

CHAPTER 2

LITERATURE REVIEW

2.1 Livestock productivity constraints

In the sub-humid zones of sub-Saharan Africa, vector-borne diseases limit the expansion of cattle production systems (Desai, 1989; Mburu, 1989; Maloo *et al*., 1994). Disease sharply reduces the productivity of livestock in all agro-ecological zones (AEZs) and production systems with trypanosomosis as the most important one in sub-Saharan Africa. Tick transmitted and tick associated diseases together with those caused by internal parasites are the next most important group of diseases limiting cattle productivity (Winrock International, 1992). Past studies in Kenya have enumerated various cattle productivity constraints. Studies in Kiambu County indicated that the two main constraints lowering milk production in smallholder dairy farms were limited availability of feed (Omore, 1994) and high calf mortality (Gitau, 1994b). The high mortality is worsened by slow growth rate due to underfeeding of calves that result in delayed puberty and age at first calving (Omore, 1997).

Studies carried out at the Coast Province of Kenya showed that the major vector-borne disease in smallholder dairy farms that caused substantial losses was East Coast fever (Maloo *et al*., 1994). Surveys in Kisii and Homa Bay Countys documented calf mortality, diseases, poor artificial insemination (AI) services and feed shortages during the dry season as major constraints to dairy cattle development (Mbugua *et al*., 1994). Other factors that limit cattle productivity in smallholder livestock production systems include poor veterinary services, insufficient marketing channels and lack of farm inputs (ILRAD, 1984; Winrock International, 1992).

Small ruminant production is constrained by biological, technical and social factors. High mortality (40% pre-weaning) leading to low off-take is considered to be an important constraint to this class of ruminants with disease as the most important constraint in Kenya (Devendra, 1982; Shavulimo, 1987). Apart from diseases, poor management and lack of efficient veterinary clinical and extension services limit productivity of small ruminants (Devendra, 1982). Cross-sectional studies carried out in Machakos (Mukhebi and Gituna, 1985; Emongor *et al*. (2000) identified diseases, lack of adequate veterinary services, unavailability of water, high costs of animal concentrate feeds and labour shortages as key constraints to livestock production. However, the studies did not quantify these constraints in terms of economic losses or their impact on the different livestock species kept by the farmers. In the survey by Mukhebi and Gituna (1985), Foot and Mouth Disease (FMD), trypanosomosis, Contagious Bovine Pleuropneumonia CBPP) and East Coast fever (ECF) were ranked as the main constraints to livestock production based solely on farmers' perception. The cross-sectional survey undertaken by Emongor *et al*., (2000), lists feed and tick-borne diseases as the main constraints to cattle production in the County. However, these studies were not designed to determine the prevalence and incidence of these diseases and the associated mortalities. These are key parameters with regard to determining disease risk and in the design of appropriate intervention measures. Measurements of these parameters were the basis of quantification of the risk and economic importance of the tick-borne diseases (TBDs) and other diseases in the County in the current study.

2.2 Tick-borne diseases

2.2.1 Cattle

In the livestock industry, ticks are the most important vectors leading to global losses of approximately US $ 7 billion (Griffiths and McCosker, 1990). Ticks are most prevalent and numerous and exert their greatest impact in disease transmission in the tropical and subtropical regions (Bram, 1983).The major tick-borne diseases (TBDs) of cattle as evaluated by the economic impact they exert on the farming communities where they occur, include ECF caused by the protozoa, *Theileria parva*, anaplasmosis caused by ricketssia *Anaplasma marginale*, babesiosis caused by the protozoan *Babesia bigemina* and heartwater caused by the rickettsia *Ehrlichia ruminantium.* Transmission of these TBDs is largely influenced by the distribution of the tick vectors (Norval *et al*., 1992; Swai *et al.*, 2006; Bazarusanga *et al.,* 2007). Dermatophilosis, which is associated with *Amblyomma variegatum* ticks, is also of economic importance in vast areas of sub-Sahara Africa and the Caribbean region (Brown, 1997). In addition to disease transmission, tick infestations reduce productivity of cattle, damaging hides and predisposing them to bacterial and fungal infections and screw worm attack.

2.2.2 Small ruminants

Although theileriosis, anaplasmosis and babesiosis have previously been described in sheep and goats (Wenyon, 1926; Markov and Abromov, 1957; Kreier and Ristic, 1963; Ngeranwa *et al.*, 1998), heartwater is the only tick-borne disease of economic importance in small ruminants in Eastern Africa (Uilenberg, 1983).

2.2.3 Theileriosis/ East Coast fever (ECF)

2.2.3.1 *Aetiology*

Theileriosis refers to a complex of infections caused by several species of protozoan parasites of the genus Theileria. In Kenya, *Theileria parva* which causes the classical syndrome referred to as East Coast fever (ECF), is the most economically important tick-borne disease. It is widely believed that theileriosis in cattle originated from buffalo populations in Eastern and Central Africa (Young, 1981; Grootenhuis e*t al.*, 1987). The main species of Theileria which infect cattle include: *Theileria annulata, Theileria mutans, Theileria buffeli, Theileria parva, Theileria taurotragi* and *Theileria velifera* (Norval *et al*., 1992).

East Coast fever was first reported in Kenya in 1904 and spread fast from the two main foci; the Lake Victoria basin and the Coastal strip, as ox transport increased (Norval *et al*., 1992). The economic impact of the disease escalated as the more susceptible *Bos Taurus* cattle continued to be kept in endemic areas by the European settlers (Norval *et al*., 1992). *Theileria parva* until recently was thought to exist in three sub-species, namely, *T. parva parva, T. parva lawrencei* and *T. parva bovis* causing ECF, Corridor disease and January disease, respectively (Lawrence *et al*., 1994). However, new methods of studying the parasites using monoclonal antibodies (Minami *et al.*, 1983; Conrad *et al*., 1987) and deoxyribonucleic acid (DNA) characterization (Allsopp and Allsopp, 1988; Conrad *et al*., 1987; Allsop *et al.*, 1993) have shown that the three subspecies are not genetically different. Therefore, the parasite is characterised as either cattle or buffalo derived *T. parva*.

2.2.3.2 *Transmission and life cycle*

The main vector of ECF is *Rhipicephalus appendiculatus*, a three-host tick, commonly known as the brown ear tick. Although the vector for *T. parva* was identified as early as 1904 (Norval *et al.*,1992) details of the life cycle of the parasite in both the tick and in the host animals, has been elucidated only recently (Bronwen, 2007)**.** Transmission of *T. parva* in the tick vector is transstadial whereby it is passaged through the larval or nymphal stages to the adult stage as the tick molts. After ingestion of infected blood by the vector tick, the infected erythrocytes are lysed leading to the release of piroplasms. In the mid gut of the tick, the piroplasms undergo sexual stages of development leading to formation of macro-gametes, which then undergo syngamy to form kinetes (Mehlhorn *et al*., 1978). The kinetes develop further into motile forms which then infect salivary glands epithelium (Young *et al.*, 1983). Tick feeding triggers the process of sporogony where kinetes develop into the infective sporozoites within 3-4 days of feeding (Fawcett *et al.*, 1985).

Following a bite by an infected tick, *T. parva* sporozoites are injected with the tick's saliva, enter the host's lymphoid cells and initiate a reversible transformation of infected cells (Ole-Moi Yoi, 1989). This leads to a rapid and exponential increase of infected cells which infiltrate all lymphoid and other tissues (Irvin *et al.*, 1983). The *T. parva* sporozoites develop into spherical schizonts then into merozoites leading to the destruction of lymphoid cells 12-14 days after infection. The merozoites are then released and may infect the erythrocytes. In the erythrocytes, merozoites develop into comma or bar-shaped piroplasms (Young *et al*., 1978). The life cycle is displayed in Figure 2.1.

2.2.3.3 *The clinical syndrome*

The predominant clinical signs of ECF include pyrexia, lymphadenopathy, pulmonary and subcutaneous oedema, petechiation and corneal opacity. Acute cases are characterized by sudden weight loss while complete blindness is common in chronic cases (Ndungu *et al.*, 2005). In terminal cases, recumbency, cachexia, hypothermia and nervous signs are common.

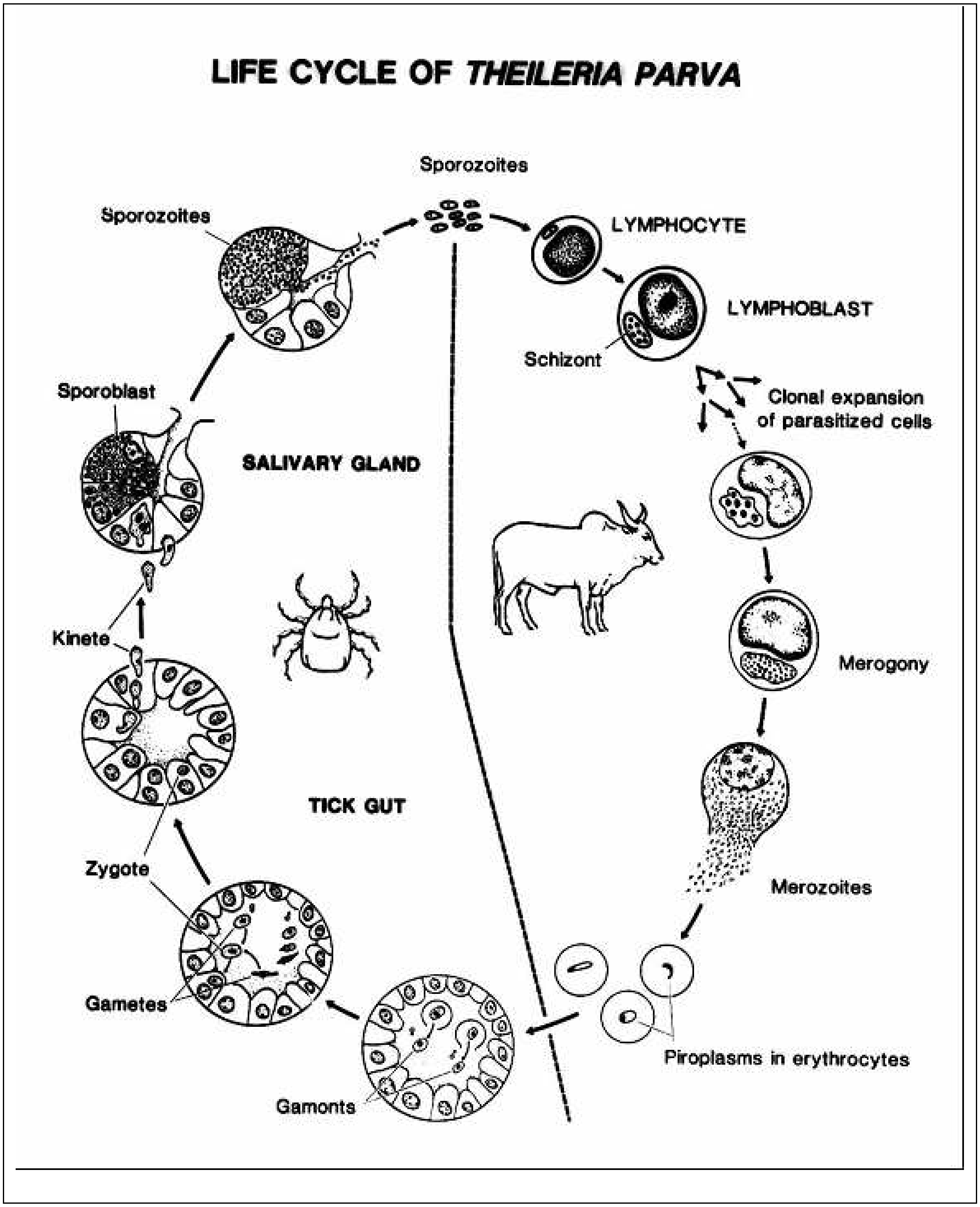

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Figure 2.1: Life cycle of *Theileria parva* in cattle and in the vector tick (*R. appendiculatus*).

Source: Norval *et al.,* (1992).

2.2.3.4 *Diagnosis*

Diagnosis of ECF in the field continues to be predominantly based on clinical signs as a result of inadequate laboratory facilities. The presence of vector ticks feeding on cattle and knowledge of the distribution and occurrence of the disease contributes towards the diagnosis. In some rare instances, confirmation of diagnosis is achieved through examination of stained blood for piroplasms and lymph node biopsy smears for macroschizonts (Kochs blue bodies). Confirmation of Theileria species on microscopic morphology is highly dependent on quality of the smears and skill of the operator (FAO, 1984).

Development of serological tests started after it became possible to grow *T. parva* schizonts *in vitro* (Malmquist *et al*., 1970; Cunningham, 1977) and its immunology was further elucidated (Morrison *et al*., 1989 and 1995). The most widely used serum antibody assay for *T. parva* is the indirect fluorescent antibody (IFA) test using crude schizont antigen (Burridge and Kimber, 1972; Gooderis *et al*., 1982).
Unfortunately, the assay is relatively slow, labour intensive, requires a subjective assessment of the degree of fluorescence and exhibits cross-reactivity with other).

Confirmation of *T. parva* infections can be done using laboratory diagnostic tests. An enzyme- linked immunosorbent assay (ELISA) test was developed using a recombinant polymorphic immunodominant molecule (PIM) specific to *T. parva* and has demonstrated sensitivity in excess of 99% and a specificity of between 94% and 98% in experimental and field sera (Katende *et al*., 1998).

2.2.3.5 *Treatment*

Although treatment of ECF was for long attempted using various antibiotic formulations (Neitz, 1953; Brockleysby and Bailey, 1962; Brown *et al.* 1977) with variable success, it was not until naphaquinones menoctone was shown to have antitheilerial activity (McHardy *et al.*, 1976) that a definitive treatment for ECF was developed. Further development of this compound and evaluation through laboratory and field studies (McHardy *et al.*, 1976; Dolan *et al*., 1984; McHardy and Morgan, 1985; Chema *et al.*, 1986) culminated in the launching of the first and widely used definitive drug for ECF, parvaquone (Clexon,® Wellcome Pharmaceutical Ltd, UK) and buparvaquone (Butalex®, Scheling-Plough Animal Health, UK). The efficacy and reliability of these compounds is dependent upon early diagnosis and administration of full therapeutic doses (Muraguri *et al*., 2006). Unfortunately, the prohibitively high cost of these drugs has resulted in their limited use by smallholder farmers.

2.2.4 Anaplasmosis

2.2.4.1 *Aetiology, biology and clinical syndrome*

Anaplasma marginale and *A. centrale* are the most important anaplasma parasites of cattle in Africa and are rickettsial organisms which infect erythrocytes of cattle (Ristic, 1968). *Anaplasma marginale* are found near the margins of the erythrocytes while

Anaplasma centrale parasites occupy a more central position. Susceptibility of cattle to anaplasmosis increases with age and adult cattle of any breed are susceptible. Young animals often do not exhibit clinical signs of the disease (Magona *et al.*, 2008).

Anaplasmosis presents as an acute, sub-acute or chronic clinical syndrome characterized by high fever and progressive anaemia manifested as pale mucuos membrane and jaundice. In chronic cases, debility and emaciation are common. In addition to direct effects, pathogenicity due to anaplasma infections is mainly related to destruction of erythrocytes that predisposes the animals to other conditions (Magona *et al*., 2008).

Although *Boophilus decoloratus* ticks are incriminated as the main vectors for anaplasmosis, mechanical transmission and biting flies are also important modes of transmission. Mechanical transmission through repeated use of hypodermic needles as in vaccination campaigns is common (Maloo, 1993; Scole *et al*., 2008).

2.2.4.2 *Diagnosis*

Diagnosis of anaplasmosis is dependent on clinical signs, case history and microscopic detection of initial bodies in stained thin blood films. Knowledge of the micro-distribution of the disease is important in the diagnosis as the clinical signs are not pathognomonic (Rubaire-Akiiki *et al*., 2004).

Antibody-detection serological tests have been developed and validated in laboratory and field studies. The main serological tests include card agglutination test, indirect haemaglutination assay (FAO, 1975) and ELISA (Katende, 1994; Nielsen *et al*., 1996).

2.2.4.3 *Treatment*

Anaplasmosis is routinely treated with oxytetracylines based formulations and Imidocarb . The success of the treatment is, however, variable depending on the stage and severity of the disease.

2.2.5 Babesiosis

2.2.5.1 *Aetiology, biology and clinical syndrome*

Babesiosis is caused by babesia parasites that are intra-erythrocyte protozoa with worldwide distribution. The main species of babesia that infect cattle in Africa are *Babesia bovis* and *Babesia bigemina*. The main tick vector for *B. bigemina* is *Boophilus decoloratus. Boophilus microplus* transmits both *B. bovis* and *B. bigemina*. The mode of transmission between the ticks and hosts is transovarial where either the nymphs or adult ticks can transmit the disease (Soulsby, 1982).

Clinical manifestations of bovine babesiosis varies from a very mild and often symptom less infection to acute and often fatal episodes depending on the species of babesia and the susceptibility of the host animal (Bock *et al.,* 2005). The clinical signs of the acute form are pyrexia, anorexia, depression, weakness and a fall in milk yield. Pale mucuos membrane is the main clinical manifestation. As a result of the destruction of erythrocytes (which is mediated by the release of pharmacologically active sustances), haemoglobinuria and jaundice are the common signs especially in the terminal stages. In the chronic cases, colic, tenesmus and diarrhea are other common signs. Nervous signs may be observed in chronic cases of *B. bovis* infections (Soulsby, 1982).

2.2.5.2 *Diagnosis*

Babesiosis is diagnosed by clinical signs especially haemoglobinuria, pale mucuos and jaundice. Examination of Giemsa-stained blood smears from affected animals is essential for confirmation (Soulsby, 1982).

The complement fixation test (CFT) was the most commonly applied serological test in the assessment of exposure of animals to the disease before development of ELISA tests. Card and capillary agglutination tests have also been developed but their specificities are low.

The ELISA techniques have been improved and validated and standardized methods are available for detection of antibodies to *B. bigemina* (Katende, 1994; Nielsen *et al*., 1996). There is also increasing use of DNA probes in the diagnosis of babesia infections (Bose *et al*., 1995).

2.2.5.3 *Treatment*

Various drugs are available for the management of babesia infections but the response depends on the parasite species and clinical stage of the disease. Some of the most commonly used chemotherapeutic compounds include trypan blue, quinoronium sulphate, phenamidine isothionate, diminazene aceturate and amicarbalide isethionate (British Veterinary Association, 1976; Dolan, 1991).

2.2.6 Heartwater

2.2.6.1 *Aetiology, biology and clinical signs*

Heartwater is the second most important tick-borne disease of ruminants in Eastern Africa, causing substantial economic losses due to mortality and indirectly, through losses associated with its control (Pegram *et al*., 1993). It is the most important tick-borne disease of small ruminants (Uilenberg, 1983). Heartwater affects cattle, sheep, goats and Asian buffaloes (Camus *et al*., 1996). Ticks of the genus *Amblyomma* are the only known vectors of *Ehrlichia ruminantium*. Of these *A. variegatum* is the main vector species throughout most of sub-Sahara Africa.

The distribution of heartwater in Kenya is not well mapped out as is the case with East Coast fever. Though the vector is widely distributed in Western, Eastern and parts of the Rift Valley, the disease is more prevalent in more arid areas of the country such Machakos, Narok, Baringo and Galana (Ngumi *et al*., 1997).

Clinical signs of which fever and nervous signs are the main ones, range from peracute to innaparent. Invasion of brain tissues leads to the characteristic nervous symptoms including a high-stepping unsteady gait, walking in circles, exaggerated blinking of eyes and chewing movements. Diarrhea and gastro-enteritis may also be observed. Prostration and death are often preceded by convulsions (Souslby, 1984; Njenga and Mugera, 1989).

2.2.6.2 *Diagnosis*

Since the disease is characterized by sudden death, provisional diagnosis is based on case history, clinical signs and postmortem lesions. Confirmation of diagnosis is by examination of Giemsa-stained brain crush smears where colonies of the organism are detectable in the cytoplasm of vascular endothelial cells (Purchase, 1945).

Van Vliet *et al.* (1995) developed the indirect MAP1-B ELISA which detects antibodies to *E. ruminantium*. The test has proved to be highly specific and sensitive for use with experimental and field ovine and caprine sera (de Waal *et al*., 2000; Peter *et al*., 2002).

2.2.6.3 *Treatment*

The sudden death syndrome makes it impossible to treat the majority of cases of heartwater (Uilenberg, 1983). If diagnosed early, tetracylines formulations are effective (Purnell and Schroder 1984; Purnell, 1984).

2.3 Economic impact of ticks and tick-borne diseases

There are few reports on the direct effects of ticks and tick-borne diseases on productivity. There is evidence that tick infestations lead to reduction in body weight and milk production. In Zimbabwe, Norval *et al*. (1989) showed that *Amblyomma hebreum* caused a reduction in weight of 9-19 gm for each engorging tick while *R. appendiculatus* caused a reduction of 3-8 gm. In Zambia, Pegram *et al*.(1991) estimated the damage coefficient caused by every engorging female of *A. variegatum* to be 45 to 60 gm. Data on the direct effects of tick infestation on milk yields are unavailable.

Transmission of diseases by ticks is considered the most important direct economic effect. Tick-bone diseases lead either to death of affected cattle, drastic reduction in milk production, while recovered animals may suffer weight loss (Norval *et al*., 1992). The mortality rate due to ECF varies from zero to 50 % in endemically stable conditions (Staak, 1981; Moll *et al*., 1986). In endemically unstable conditions, ECF mortality may be as high as 80-100% (Julla, 1985). Although not fully quantified, milk production decreases significantly during the clinical and recovery phases of any TBD infection. Infected animals also provide less draught power and their fertility may be reduced. Perhaps the main economic losses of TBDs in Kenya have been incurred from control costs. Importation of chemical acaricides remains a big drain on foreign exchange. The tick control policy in Kenya was designed based on the need to reduce the risk of ECF (Cunningham, 1977). Annual expenditure on ticks and TBD control services by the Kenya government was in excess of Ksh.855 million (GoK, 2009) although this figure may have decreased following the more recent policy of tick control as a private good.

In Kenya, TBDs, especially ECF, are considered a major constraint to the development of the dairy industry. The diseases not only impede productivity but also limit the area where high producing cattle can be reared (Kariuki, 1990). The economic impact of ticks and TBDs is highest in the smallholder dairy farms and hence increase in milk production from this sector may not reach projected targets (Mbogoh, 1984). Studies to quantify the risk of TBDs in various production systems have mainly been carried out in Kiambu (Gitau *et al*., 1994a, 1994b and 1994c; Gitau *et al*., 2000) and Muranga Countys (Gitau *et al*., 1997; Gitau, 1998) in central Kenya and the Coastal low lands (Deem *et al*., 1993; Maloo, 1993).

Information on the prevalence of TBDs in the high potential area of Eastern Kenya is scanty. Most of the information available on the prevalence of TBDs in Machakos County in particular is based on annual reports from the Department of Veterinary Services of the Ministry of Livestock Development (MLD). The figures from these reports are not reliable as many cases of TBDs may not be reported especially in instances where farmers seek veterinary services of unqualified personnel. Besides, the reported cases are largely based on clinical signs alone (Machakos DVO, personal communication).

The only recently verifiable report on tick-borne diseases in the County was the survey on the prevalence of ECF in 6 divisions of Machakos County carried out by Ngumi *et al*. (2005) (unpublished). In the study the prevalence of *Theleria parva* was 40.4%.

Morbidity and mortality data as well as productivity losses and financial costs associated with the control of TBDs are lacking. This study aims to generate information that will address these knowledge gaps.

2.4 Control strategies for ticks and tick-borne diseases

de Castro (1997) has reviewed the methods applied in the control of ticks and TBDs. Whereas many technically tested packages for ticks and TBDs control are available in Africa, the main thrust should be to convince policy makers, veterinarians and farmers on their implementation and impact. In addition, any intervention for ticks and TBD control needs to match the problem as well as being economically justified, socially acceptable in the production system, and environmentally friendly (de Castro, 1997).

2.4.1 Acaricide tick control

The main method used to control TBDs in Kenya is application of acaricides to reduce vector challenge. The methods used for application of the acaricides include plunge dipping, spray races, hand spraying or hand dressing. Several easier methods of acaricide application including the use of impregnated ear-tags, neck-bands, tail bands and pour-ons have been developed (Young *et al*., 1988). The principle objective is to kill the infesting ticks in order to break the life cycle and therefore total coverage of all predilection sites of the various tick species is essential. However, intensive tick control using acaricides has many inherent problems including high costs (Kariuki, 1990; Ocaido *et al.*, 2008), increased environmental pollution (de Castro, 1997), development of residues in meat, milk and other products, and eventual development of acaricide resistance (Wharton, 1976).

Tick control costs are a burden especially to the resource poor farmers. A recent study undertaken on tick control costs using either cattle dips or hand sprays in an agro-pastoral farming system in Uganda indicated that the average annual cost of controlling ticks on an adult cow or bull was USD 4.154. This constitutes 73.8% and 85.6 % of the total disease control costs on ranches and agro pastoral farming systems, respectively (Ocaido *et al.*, 2008).

Keating (1983) has reviewed the history of tick control in Kenya using acaricides. Despite the enactment of the Cattle Cleansing Act (GoK, 1976) which led to the initiation of a national tick control program, adequate control of ticks and tick-borne diseases is far from being achieved. Thus, ticks and TBDs continue to be major constraints to the development of the livestock industry. The escalating costs of acaricides, relevant infrastructure and monitoring services for intensive tick control strategies advocated by the Cattle Cleansing Act led the government to suspend the programme. Poor management of dips by local communities in many ticks and TBD risk zones virtually led to the collapse of the tick control facilities as a result of inadequate funds, inadequate technical information and low managerial skills.

In Machakos County, most of the communal cattle dips are not functional and most farmers rely on hand sprays to control ticks. The problem of tick control in the County is compounded by the fact that there are hardly any veterinary extension services to guide the farmers on acaricide application (County Veterinary Officer, personal communication).

2.4.2 Novel methods of tick control

Other novel methods of tick control have been developed but they have not found a wide application. The most common methods include pasture spelling, rotational burning of pastures, use of tick-repelling grasses (Mwase *et al*., 1990), use of tick vaccines (Willadsen *et al*., 1995), and restriction of livestock movement. Confinement of animals as in zero-grazing management systems also reduces the level of tick challenge (Gitau, 1998; Gitau *et al*., 1999; Gitau *et.al*., 2000). However, total confinement is seldom achieved even in smallholder management systems as forage from outside the farms which may be infested with ticks, is normally fed to the cattle. Confinement of animals may also lead to the maintenance of highly susceptible populations and hence a shift of primary infection to older animal groups (O'Callaghan *et al*., 1998; Gachohi *et al*., 2012).

2.4.3 Utilization of genetic resistant cattle

Breed variations in genetic resistance to ticks in cattle are well known (Utech *et al*., 1978). In general, *Bos indicus* breeds have higher resistance to ticks than *Bos Taurus* breeds (de Castro and Newson, 1993). In Africa, the majority of the indigenous cattle breeds are resistant to ticks to a large degree and probably also to some TBDs (de Castro, 1997). The N'Dama breed of cattle of West Africa is shown to have a high degree of genetic resistance to ticks and trypanosomosis (Mattioli and Cassama, 1995). The productivity of these cattle breeds however is low and hence this virtue is normally disregarded. In Australia, Zebu cattle have been introduced recently in order to utilize this characteristic (de Castro, 1997). In order to utilize fully the characteristics of resistance to ticks and high productivity, appropriate crossbreeding programmes need to be revitalized.

2.4.4 Immunization against tick-borne diseases

The level of immunization of cattle against ECF in Kenya is generally low while immunization against other TBDs is virtually absent. Development of an effective attenuated v accine against hearwater has been hampered by limited cross-protection by different stocks of *Ehrlichia ruminantium* (Totte *et al.*, 1993; Sumption *et al*., 2003; Bell-Sakyi, 2004).

Currently, immunization against ECF using “infection and treatment” is the only method that has been widely evaluated for application at field level. This method was developed following observations that animals that recovered from natural infection acquired solid immunity (Tumusiime, 2007).

The method involves infecting cattle with a predetermined dose of *T. parva* sporozoites and simultaneously treating them with tetracylines. The tetracylines reduce the rate of multiplication of *T. parva* parasites (Neitz, 1953; Brockley and Bailey, 1962; Di Guillo *et al*., 2009; McKeever, 2009).

In Kenya field immunization trials against ECF using the infection and treatment method have been carried out for the last twenty years. This followed the isolation and subsequent characterization of a broad protecting *T. parva* stock referred to as *T. parva* (Marikebuni) (Irvin *et al.*, 1983). Several immunization trials carried out on calves at least once month old, have been conducted in the Coastal region (Morzaria *et al*., 1988), Central highlands region (Mbogo *et al*., 1994) and the Rift Valley region (Wesonga *et al*., 2000; Wanjohi *et al*., 2001; Di Giulio *et al.,* 2009). The *T. parva* (Marikebuni) stock has been found to be efficacious with protection levels of 80-92%. The level of protection offered by the stock under field conditions was very similar to that observed under laboratory conditions (Irvin *et al*., 1983).

A mild strain of theileria known as *T. parva* (Lanet) (Mbogo *et al*., 1996) has been found to offer protection against a wide spectrum of theileria stocks. It has the advantage over the other immunizing stocks in that tetracylines are not needed to block the multiplication of the parasite following immunization. Thus, it is safer as there are usually no reactors, and also cheaper because tetracylines are not needed. The only drawback that limits wide future application is that the parasites do not easily multiply both in *vivo* and *vitro* thus limiting bulk preparation of the vaccine (Mbogo and Kariuki, 1995). The economic viability of the process of immunization has been verified through many analyses (Nyangito *et al*., 1994; Mukhebi *et al*., 1995; Muraguri *et al*., 1998; Babo Martins *et al.,* 2010).

Machakos County was among the first Countys outside Coast Province to get approval for national delivery immunization at commercial level (Mbogo *et al*., 1999). However, no study or trial has ever been undertaken in the County to determine either the efficacy of the vaccine or financial impact of immunizing against ECF in a Dual Purpose Cattle Small Scale farming system (Peeler and Omore, 1997). This was the first time that this kind of intervention was undertaken in this kind of farming system in the country. All previous studies mentioned above on immunisation against ECF targeted dairy cattle in high potential areas.

CHAPTER 3

CONSTRAINTS TO LIVESTOCK PRODUCTION IN MACHAKOS COUNTY: A RAPID APPRAISAL

3.1 INTRODUCTION

Previous studies carried out in Machakos County (Mukhebi and Gituna 1985; Emongor *et al*., 2000) identified diseases, lack of adequate veterinary services, unavailability of water, high costs of animal concentrate feeds and labour shortages as key constraints to livestock production. Among the tick-borne diseases, ECF and heartwater were identified as the major constraint to the development of the livestock sector in the County (Emongor *et al*., 2000). However, none of the studies quantified these constraints in terms of economic losses or their impact on the different livestock species kept by the farmers.

The main objective of the rapid appraisal was to assess the constraints limiting the development of the livestock sector in Machakos County, as perceived by the farmers and local veterinary personnel. The farmers' responses to these constraints especially with respect to the control of the main tick–borne diseases were also evaluated.

3.2 MATERIALS AND METHODS

3.2.1 Study area

The study was conducted in the larger Machakos County, one of the Countys in Eastern Province. The County has since been subdivided into seven Countys, namely Athi River, Kangundo, Machakos, Matungulu, Mwala and Yatta. The County lies between latitudes 0.45'S and1.31'S and longitudes 36.45'E and 37.45'E and covers an area of 6,850 km^2. It borders Mwingi and Kitui Countys to the East, Embu to the North, Nairobi and Thika to the West and Makueni to the South. The County is divided into ten administrative divisions namely, Athi River, Kathiani, Central, Matungulu, Kangundo, Mwala, Yathui, Yatta, Ndithini and Masinga. The location of the County in Kenya shown in Fig. 3.1. The average annual rainfall in the County ranges from 500-1,300 mm. The rains are normally concentrated in two short seasons: end of March to May, and end of October to December. The highest rainfall is received in April. The mean temperature range is 18-25^0C. The County consists of small hills and plateaus varying in altitude from 1,800 to 2,100 metres above sea level.

The farming system in the area is described as Dual Purpose Cattle Small Scale (DPCSS)/ Sheep and Goats Small Scale (SGSS) (Peeler and Omore, 1997). Other livestock kept include donkeys, pigs, poultry, and rabbits. The grazing system is predominantly traditional free ranging system (Kinuthia, 2001) but a few farmers practice zero grazing. The majority of cattle reared are the indigenous zebu cattle but some farmers also keep improved breeds of dairy cattle, especially in Matungulu and Kangundo Divisions.

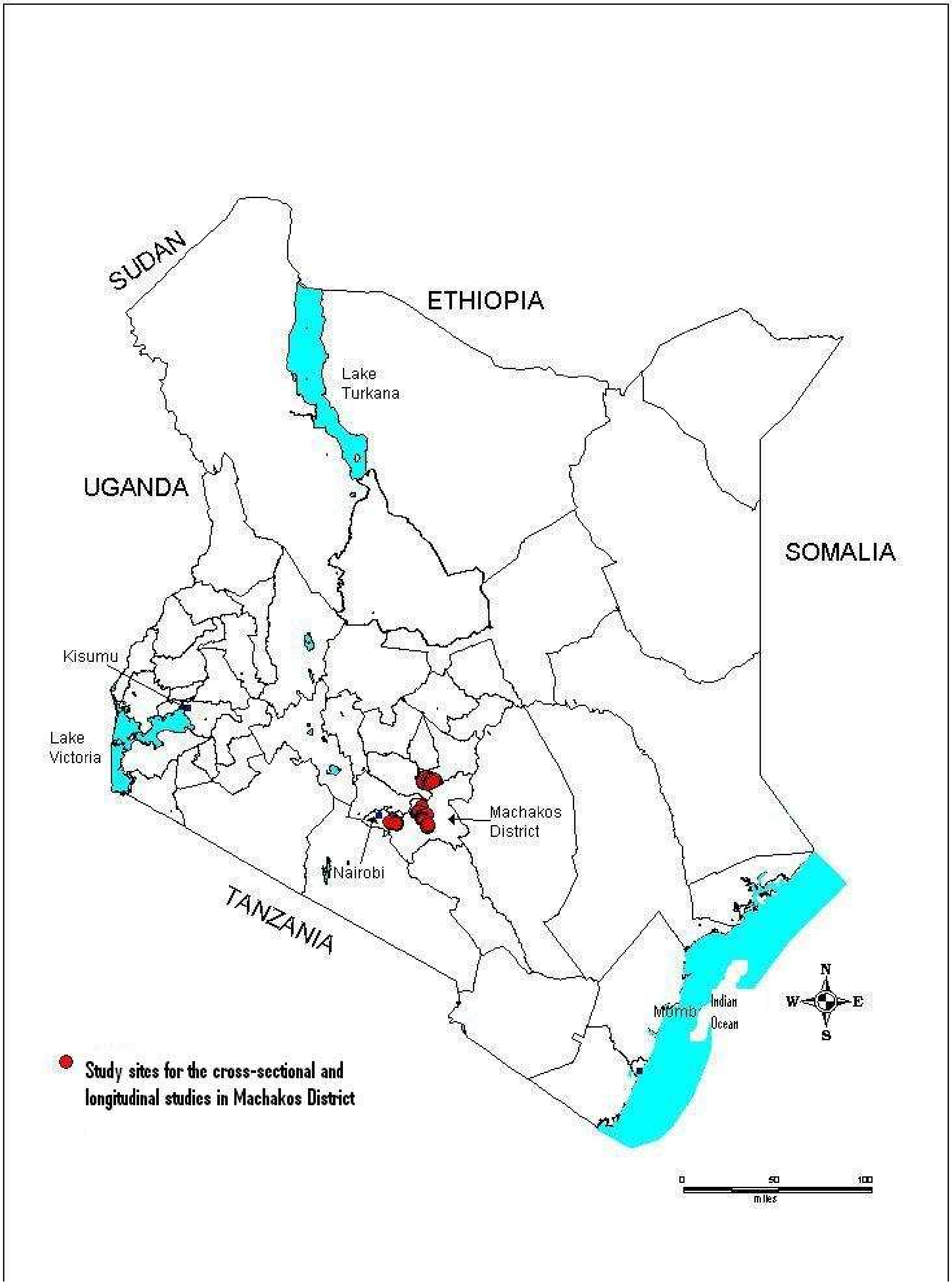

Figure 3.1: Map of Kenya showing the location of Machakos County, 2007.

3.2.2 Rapid Rural Appraisal

The study was conducted between May and October 2007. The tools that were applied included ranking and key informant interviews, collation of secondary data, formal group interviews and farm observations. The interviews were conducted in either English (for DVOs, LPO) or Kiswahili (for the farmers).

Before the start of the informal surveys, the objectives were discussed with the Chief Field Investigation Officer (CVFIO), the regional Provincial Director of Veterinary Services (PDVS) and the local County Veterinary Officers. They gave approval of the work plans. The programme was discussed and circulated to the local administrative officers (County Officers and chiefs) and the veterinary personnel. The concepts and objectives of the meetings were communicated in writing to prospective farmers and the local administrative chiefs two weeks prior to the dates they were to be implemented.

3.2.2.1 *Key Informant interviews*

Two categories of key informants were interviewed.

Two local veterinarians (the DVO of Machakos County and his deputy based in Kangundo), one livestock production officer and one animal health assistant (AHA) operating in the study area were interviewed on the cost of production, livestock and product prices.

Sixteen local farmers were selected with the assistance of the local chiefs, animal health assistant and livestock officer. They were selected on the basis of their keen interest and dedication to livestock rearing. Two farmers were selected from each of the eight study sub-locations where the study took place. A semi-structured interview was conducted to assess their perceptions on livestock production constraints.

3.2.2.2. *Farmer focus group meetings*

Gender balanced groups of twenty farmers were selected from each study sub-location with the assistance of the local AHAs, V.Os and assistant chiefs. Four farmer focus group meetings were held. The meetings were organized in such a way that separate meetings were held for each division. The objectives of the focus group interviews were to assess farmers' perception on constraints to livestock production, current methods of disease control and assess farmers' attitude towards veterinary services.

The first farmer focus group meeting was held at the Kangundo co-operative hall on 28th June 2007. Ten farmers attended from each of the two sub-locations (Ndunduni and Kathome). Five of the participants were women. Other participants included the assistant chiefs from the two sub-locations, the local veterinary officer and the meat inspector. The two assistant chiefs were women who greatly encouraged other women participants to contribute to the discussions.

The farmer focus group meeting for Ndithini Division, which comprises of Kiatineni and Milani sub-locations, was held on 5th July 2007. A total of 12 participants attended the meeting. Ten of the participants (one of whom was a woman) were from Kiatineni while only two farmers were able to attend from Milani sub-location. This was due to severe communication and transport problems prevailing in the area at the time of the study.

The farmer focus group meeting in Tala market was held on 19th July 2007. The meeting brought farmers from Kalandini and Katine sub-locations. A total of 16 participants (10 from Katine and 6 from Kalandini) attended the group meeting. Five of the participants were women (all from Katine sub-location).

The farmer focus group meeting for Athi River Division was held on the 16th October 2007 at the Agricultural Extension Office in Athi River town. The meeting brought farmers from Katani and Ngelani sub-locations. A total of 11 participants (7 from Katani and 4 from Ngelani) attended the group meeting. One of the participants (from Ngelani sub-location) was a woman.

A standard checklist was prepared for all the farmer focus group meetings. The major issues that were addressed included:

- Mapping of the sub-locations. The farmers were asked to draw maps of their respective sub-locations indicating key animal health infrastructures like water dams, agro vet shops, cattle dips and cattle crushes.
- Source of livelihood of the residents of the sub-location. The participants were asked to list the main crops grown either for food or sale and reasons for keeping livestock.
- The farmers were also asked to list the main species of livestock kept. Proportional piling was used to determine the most important species from the economic point of view.

- Constraints to livestock production. The farmers were asked to list and rank constraints to livestock production other than diseases. The ranking of the constraints was done by "pair wise ranking".
- Disease constraints to livestock production. Farmers were asked to list and rank disease constraints to livestock production according to perceived economic importance.
- Institutional linkages (Venn diagram). A Venn diagram was drawn and farmers asked to draw circles within the Venn diagram representing key veterinary infrastructure whose size is proportional to the importance that the farmers attaches to the facility.
- Seasonal calendars to indicate when diseases were most prevalent.

The groups' general perception of TBDs and other livestock diseases that are common in the study sites were assessed by semi-structured interviews, guided by a checklist. The farmers were asked to list all the constraints they faced in keeping livestock. After the constraints were exhaustively discussed, they were then asked to rank them in order of their importance. Following the same procedure, disease constraints were listed and ranked according to their perceived economic losses resulting from mortality, quarantine measures or cost of treatment. The farmers working as a group then constructed seasonal calendars for prevalence of TBDs and other diseases that were identified as the main disease constraints. They were also asked to rank the relative importance of the different livestock species reared in the study area.

3.2.3 Rapid Rural Appraisal data collection methods

3.2.3.1 *Ranking procedure*

Disease as well as general constraints to livestock production were ranked using the pair wise ranking technique as described by Catley and Mohamed (1996). The technique involved farmers listing the key diseases that limit livestock production in their respective sub-locations. The list of the diseases was then entered into the first row of a Table. Using the same sequence in which the diseases were listed in the first row, the list of the diseases was entered into the first column of the Table. Diseases were then compared in pairs across the table from the left to the right side of the Table. For every comparison between two diseases, the disease that was perceived to be of more importance in terms of economic losses resulting from mortality, quarantine measures or cost of treatment was entered into the Table. The diseases were then ranked based on the frequency with which they appeared in the Table.

Participants from neighbouring sub-locations undertook the ranking jointly. Using the results from the farmers' ranking of diseases, each disease ranking was given scores as follows:

1st Disease = 6 points

2nd Disease = 5 points

3rd Disease = 4 points

4th Disease = 3 points

5th Disease = 2 points

6th Disease = 1 point.

The same technique was used to rank the general constraints to livestock production.

3.2.3.2 *Construction of seasonal calendars*

Proportionate lengths of sticks were used to represent relative prevalence of the main diseases against the month of the year. The farmers were allowed to use as many categories (lengths) as they required. However, all the four groups used a maximum of three rank categories. The shortest stick used was 3 inches in length. This was used to denote “low” prevalence. “Medium” prevalence was denoted by a 6 inch long stick and “high” prevalence by a 9 inch stick.

Data on rainfall and mean temperatures for the year 2007 in each of the four divisions was obtained from the Meteorological Department station in the County at the Kenya Agricultural Research Institute (KARI) in Katumani.

3.2.3.3 *Proportional piling*

The livestock species were ranked in importance using the proportional piling technique (Catley and Mohamed, 1996) where by a hundred (100) beans were distributed by a group of farmers over diagrams representing the different livestock species. The livestock were ranked in terms of economic importance.

3.2.3.4 *Transect walks*

Transect walks were conducted on two to three randomly selected farms close to each of the four venues where the focus group meetings were held. The purpose of the walks was to make independent observations on farming enterprises, estimate the size of the farms, type of livestock kept and animal husbandry practices.

3.2.4 Secondary data

Retrospective data on reported cases of tick-borne diseases in the County were collated from County Veterinary reports. Although a ten-year time span (1997-2007) was proposed, only a six year period was analyzed, as records for the period 1997 to 1999 were found to be unreliable as they had many gaps for all the three TBDs (ECF, anaplasmosis and babesiosis).

3.3 RESULTS

3.3.1 Previous cases of tick-borne diseases in cattle

The number of cases of the main tick-borne diseases reported (based on clinical diagnosis) in cattle in the County in the previous seven years is shown in Table 3.2.There were no data on the number of cases of East Coast fever recorded for the period 1997 to 2003. The County Veterinary Officer (DVO) of Machakos County estimated that only about 30% of the total cases were reported annually due to the few veterinary personnel and poor veterinary infrastructure in most sub-locations in the County. Thus, the data were most likely a gross underestimation of the occurence of the diseases. Anaplasmosis and babesiosis were the most consistently reported tick-borne diseases (Table 3.2).

Table 3.1: Number of cases of tick-borne diseases reported in cattle in Machakos County between 2000 and 2006.

Year	Number of tick-borne diseases reported			
	ECF	Anaplasmosis	Babesiosis	Heartwater
2000	-	827	49	-
2001	-	823	76	-
2002	-	807	58	-
2003	-	635	43	-
2004	624	864	77	80
2005	486	543	128	129
2006	824	840	130	114

3.3.2 Previous disease cases in sheep and goats

Tables 3.3 and 3.4 show the number of cases of diseases reported in sheep and goats respectively, in the period under review. There were no records on diseases from the year 2000 to 2003 as the record forms could not be retrieved. According to the DVO, farmers and the field veterinary staff often tended to focus more on cattle when it came to disease reporting. Thus, the majority of small ruminant diseases were either not reported or recorded. Helminthosis, pneumonia and diarrhea were the main diseases reported with helminth infestations and pneumonia occurring more in sheep and goats, respectively. No tick-borne disease was reported in these two species.

Table 3.2: Diseases reported in sheep in Machakos County between 2000 and 2006.

Year	Number of disease cases			
	Helminthosis	Pneumonia	Diarrhoea	Foot root
2000	-	-	-	-
2001	-	-	-	-
2002	-	-	-	-
2003	-	-	-	-
2004	956	221	210	1
2005	506	232	142	3
2006	503	227	133	6

Table 3.3: Diseases reported in goats in Machakos County between 2000 and 2006.

Year	Number of disease cases				
	Helminths	Pneumonia	Diarrhoea	Eye infection	Dermatitis
2000	-	-	-	-	-
2001	-	-	-	-	-
2002	-	-	-	-	-
2003	-	-	-	-	-
2004	4410	808	419	131	140
2005	2019	598	189	104	30
2006	1975	578	179	93	25

3.3.3 State of veterinary infrastructure, market access and water availability

During the study, there was only one functional communal cattle dip in all the four study divisions (Table 3.5). There were only two veterinarians (one employed by the government and the other private), one Animal Health Assistant (AHA) and one Livestock Production Officer (LPO) in all the four divisions. Agrovet outlets were available in the study sub-locations of Kangundo and Kalandini Divisions. No Agrovet shops were present in the study sub-locations of Athi River and Ndithini Divisions (Table 3.5). The two divisions of Kangundo and Matungulu also had active livestock markets. Apart, from Ndithini Division, which borders the river Tana, all other divisions had very few permanent natural water sources.

Table 3.4: Distribution of livestock infrastructure, water sources and livestock markets by division in Machakos County, 2007.

Division	Sub-location	Veterinary infrastructure			Water sources	Availability of livestock market (s)
		No of functional dips	Animal health personnel	Agrovet shops		
Kangundo	Ndunduni	1	1 vet (government vet)	1	1 dam, several seasonal rivers	A market within walking distance.
	Kathome	0	1 vet (private)	2	1 bore hole and a seasonal river	None
Ndithini	Kiatineni	0	1 AHA	0	2 permanent rivers and a dam (Masinga)	None
	Milani	0	0	0	2 permanent rivers and a dam (Masinga)	None
Matungulu	Katine	0	0	3	1 seasonal river/ three seasonal dams	One active market ,Tala town
	Kalandini	0	1 livestock production officer	3	4 seasonal dams	One active market, Tala town
Athi River	Katani	0	0	0	2 communal dams and 3 bore holes	None
	Ngelani	0	0	0	1 dam	None

3.3.4 Disease constraints to livestock production

From the list of diseases provided by the farmers, only the first six diseases were ranked (Table 3.6). Pneumonia, East Coast fever, trypanosomiasis, blackquarter and anthrax were ranked by the farmers as the most important disease constraints to the rearing of cattle in the County with respective scores of 22, 20, 7, 7, 5 and 5 (Table 3.6). East Coast fever and to a less extent anaplasmosis were perceived by the farmers to be the most mportant tick-borne diseases of cattle in the County. There were also differences in the disease rankings by divisions for example pneumonia was ranked as the most important disease in three of the divisions and was ranked third most important in Matungulu Division (Table 3.6). On the other hand, East Coast fever was ranked first in Matungulu Division but was ranked second in both Ndithini and Athi River Divisions and third in Kangundo Division.

Table 3.5: Disease constraint identification and ranking by farmers in Machakos County, 2007.

Disease	Ranking per division					
	Ndithini	Matungulu	Kangundo	Athi River	Overall Score	Position
Pneumonia	1	3	1	1	22	1
Anaplasmosis	6	6	5	3	7	
ECF	2	1	3	2	20	2
Mastitis	8		4	9	3	
Heartwater	7	7		8	0	
Helminthosis	5		6		3	
Rabies	4			5	3	
Trypanosomosis	3	4			7	3
Lumpy Skin Disease		5		6	3	
Mange				4	3	
Eye worm				11	0	
Black Quarter		2			5	4
FMD		9		7	0	
Brucellosis				10	0	
Anthrax			2		5	5

Key: FMD= Foot and Mouth Disease
The smaller the numerical value the higher the ranking

3.3.5 General constraints to livestock production

The most important general constraints to livestock production as perceived by the farmers in order of importance were problems with accessing markets for livestock products, lack of cattle dips, lack of artificial insemination (AI) services, lack of adequate feed and shortage of agrovet shops (Table 3.7). The importance of the constraints differed according to the division. For example absence of AI services was considered important only in Kalandani/ Katine sub-locations of Matungulu Division and

Kathome/ Ndunduni sub-locations of Kangundo Division; it was not even ranked in Kiatineni/ Milani and Katani/ Ngelani sub-locations of Ndithini and Athi River Divisions, respectively (Table 3.7). Lack of livestock markets was considered important in all study divisions, while lack of functional dips and poor veterinary services were considered important in all divisions except Kangundo. Predation was only ranked as important in Ndithini Division.

Table 3.6: Non-disease constraints to livestock production as perceived by farmers in Machakos County, 2007.

Constraint	Ranking by sub-location				
	Ndithini	Matungulu	Kangundo	Athi River	Overall Score
Feed		1	4	7	9
Water		7	5	8	2
A.I		3	1		10
Drugs			2		5
Marketing	3	5	3	3	14
Infertility			6		1
Predation	1				6
Agrovet	2			4	8
Dip	4	2		1	14
Vet services	5	6		6	4
Finances		4			3
Livestock thefts				2	5
Poor breeds				5	2

3.3.6 Perceived seasonal occurrence of diseases

Since all groups used a three point ranking system (3 lengths of sticks), it was possible to represent the seasonal prevalence of two of the main diseases (ECF and pneumonia) in relative terms as ‘low’, ‘medium’ or ‘high’ and made comparisons between the four divisions (Figures 3.3 and 3.4). The mean monthly rainfall and temperatures for 2007 are also included.

With the exception of Kangundo Division, the highest perceived prevalence of ECF was observed between March and July, shortly after the peak rainfall season. In Kangundo Division, “medium” perceived prevalence was observed between March and July while the highest prevalence was observed between July and October. The highest perceived prevalence of pneumonia was observed during the cooler months of the year (May to September) in all the study divisions.

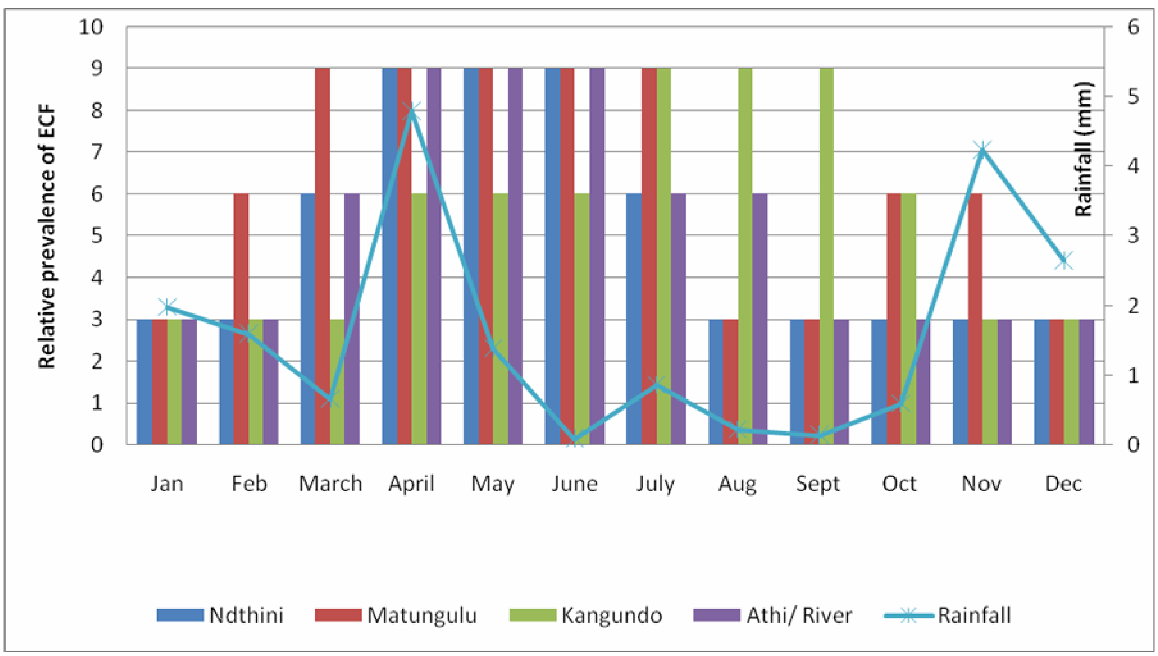

Figure 3.2: Relative perceived prevalence for East Coast fever in four divisions of Machakos County, 2007.

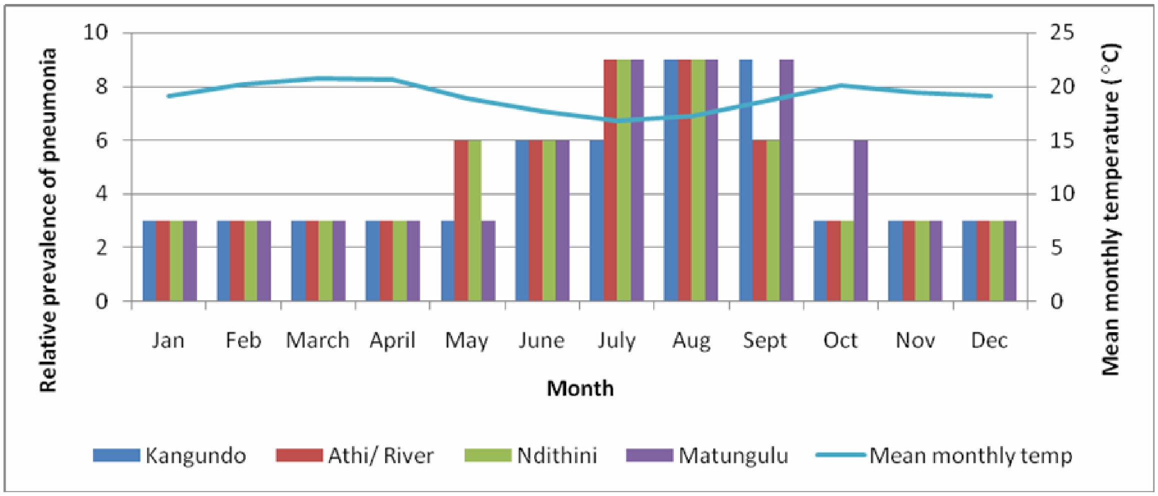

Figure 3.4: Relative perceived prevalence for pneumonia in four divisions of Machakos County, 2007.

3.3.7 Relative importance of the different livestock species

The indigenous zebu cattle were ranked first in the two study sub-locations (Kiatineni and Milani) of Ndithini Division, first in one sub-location (Katine) of Matungulu Division and first in Katani sub-location of Athi River Division (Table 3.8). On the other hand, improved breeds (crosses) of cattle were ranked first in Kalandini (Matungulu Division), Ndunduni and Kathome (Kangundo Division) and Ngelani (Athi River Division) sub-locations. Overall cattle were ranked as the most important livestock species in all the study sub-locations and goats second.

Chicken were ranked third in four of the sub-locations while sheep were ranked third in two of the sub-locations. Pigs and rabbits were only listed in Ndunduni and Kathome sub-locations (Kangundo division). However they were ranked seventh and eighth, respectively.

Table 3.7: Relative importance of the different livestock species reared in eight sub-locations in Machakos County in 2007.

	Ranking by farmer groups in the eight sub-locations							
Species	Kiatineni	Milani	Kalandini	Katine	Ndunduni	Kathome	Katani	Ngelani
Cattle (Crosses)	4		1	5	1	1		1
Zebu cattle	1	1	5	1	5	2	1	
Borancattle		3						
Dairy goats					2	4		
Galla goats		2						
Local goats	2	5	2	2	3	5	2	2
Sheep	3	4	3	4	4	6	4	4
Pigs					7	7		
Rabbits					8	8		
Chicken	5		4	3	6	3	3	3

3.4 DISCUSSION

Secondary data on disease occurrence obtained from veterinary departments is often incomplete based on tentative diagnosis and unreliable as was the case in this study. A similar observation was made by Muraguri (2000) in a study carried out in the Coast Province of Kenya. The data were often characterised by under reporting presumably due to a shortage of field staff and limited access to laboratory facilities. In the current study the secondary data ranked ECF, anaplasmosis, babesiosis and heartwater as the main TBDs of cattle in Machakos County. The data needs to be treated with caution as diagnosis by field staff is often based on clinical signs provided by the farmers. Diagnosis of diseases such as heartwater and ECF can only be confirmed through laboratory examination of appropriate biological samples. Furthermore, there were gaps in the disease data collected prior to 2004. It was not possible to establish the reason for the missing data for the period.

Nonetheless, the secondary data were most likely a gross underestimate of the true disease incidence. However, the data can still be useful as indicators of presence of disease trends over time.

The secondary data on diseases of small ruminant were less comprehensive than for cattle. This observation was similar to results of earlier studies carried out in the County (Mukhebi and Gituna, 1985; Emongor *et al*., 2000). This gross under reporting of small stock diseases may be a reflection of the little economic importance that farmers attach to them compared to cattle. The other possibility is that sheep and goats are naturally resistant to diseases. Indeed sheep and goats were ranked second and third in terms of economic importance relative to cattle. It is also conceivable that farmers may have resorted to purchasing drugs from approved agrovet outlets to treat the animals themselves without consulting government veterinarians. This is a dangerous practice considering the possibility of drug resistance development in a situation where animals are given sublethal doses. Farmers need to be sensitized on the importance of a holistic disease control approach since it has been demonstrated that small stock could be important sources of diseases such as foot and mouth disease, heartwater and helminths if ignored in disease control strategies on farms where they are kept alongside cattle (Lughano and Kambarage, 1996; Barnet and Cox, 1999; Kitching and Hughes, 2002).

The fewer number of qualified veterinarians meant less professional contact while the presence of only one functional cattle dip meant less tick control. The few available agrovet shops were located in the main towns as is normally the case and in fact there were no agrovet shops in four of the study sub-locations. The only active livestock market in the study area was in Tala town, far away from most of the farmers. The poor state of the veterinary infrastructure and limited access to livestock markets is a major hindrance to the development of livestock production in the County.

The use of qualitative methods to identify disease constraints to livestock production was useful in providing an insight into the most important diseases in the County from the farmers' perceptive. The farmers identified the main diseases prevalent in the County. Similar results were obtained in other studies in different livestock production systems in Kenya where farmers were shown to possess high levels of knowledge on livestock diseases (Catley and Mohamed, 1996; Muraguri, 2000; Okuthe *et al.*, 2003). The diseases identified by farmers to be prevalent in Machakos County included ECF, anaplasmosis and trypanosomiasis. Indeed, the presence of these diseases was confirmed by laboratory tests in the cross-sectional phase of the study (Chapter 4).

In this study, the farmers were able to indicate the period(s) of the year when the most important diseases are most prevalent. Seasonal calendars are often used in Rapid Rural Appraisal studies to highlight temporal patterns of occurrence and changes in human activities, production and biological events, including diseases (Ghirotti, 1993). The data on perceived seasonal occurrence of disease were similar in all the four divisions. East Coast fever reportedly occurred throughout the year but the highest prevalence was reported between April to September. This peak in ECF corresponded to the period during and immediately following the long rains season in the County. However, farmers in Matungulu identified a second peak in the prevalence of ECF in October and

November corresponding to the short rains season. The observed prevalence pattern may have been explained by the fact that temperature and rainfall have a significant influence on the abundance and longevity of *Rhipicephalus appendiculatus*, the tick vector of the disease (Newson and Punyua, 1978; Cumming, 2002; Ocaido *et al*., 2006).

Pneumonia in livestock was perceived to be more prevalent during the coldest months of the year (May to September). It was observed that adult animals were kept in open enclosures at night while calves and small ruminants were kept in sheds that hardly protected the animals from severe conditions (rain, strong winds and low temperatures) (Chapter 6). Diseases such as pneumonia as noted by the farmers are likely to occur under such conditions.

The ability of farmers to identify peaks in the prevalence of disease similar to peaks observed in formal surveys indicated that farmers have the capacity to conduct their own research and analyses (Farrington and Martin, 1988; Anon, 1991). Thus, farmers' indigenous knowledge on animal diseases prevalent in their regions should not be ignored and can greatly complement conventional surveys especially in the event of outbreaks of notifiable diseases. It was also interesting to note that some farmers ranked predation as a major constraint to livestock production. The observation was made on the ranking prepared by farmers from Ndithini Division, where hyenas and baboons preyed on calves, kids and lambs. This information is never found in the County or Department of Veterinary Services annual reports. The ranking of a constraint that was missing from the conventional annual reports was consistent with the observations by Kumar (1993) that rapid appraisal methods are more flexible than formal surveys and are capable of exploring new ideas and issues that may not be anticipated. A similar observation was made during a RRA carried out by Okuthe *et al*. (2003) in the western highlands of Kenya. The findings of all these studies further demonstrate that communities within close proximity to each other may not share the same problems.

Despite its informality, RRA is useful at obtaining a quick, systematic and cost-effective status of livestock conditions and veterinary problems, particularly in agropastoral communities (Ghirotti, 1993). In the survey by Okuthe *et al*. (2003), it was estimated that a structured survey costs up to twice as much as a RRA. The survey also established that structured surveys are much more time consuming. Similar results were also reported by studies undertaken by McCauley *et al.* (1983) and Perry *et al.* (1984).

Using the process of triangulation as described in Catley (1999), it was possible to verify most of the data collected during the RRA studies. For example, the main constraints to livestock production were identified and confirmed by secondary data, key informants and farm observations. The farm observations were also useful in understanding the importance of mixed farming enterprises to the livelihoods of the farmers (Chapte 4). However, the mostly descriptive data gathered needs to be validated by conducting exploratory studies that allow comparisons to be made between different study groups. Only a holistic approach can generate information that can be used to design appropriate strategies required to improve livestock production in the farming system.

CHAPTER 4

SOCIO-ECONOMIC AND DEMOGRAPHIC CHARACTERISTICS OF SMALLHOLDER LIVESTOCK FARMERS IN MACHAKOS COUNTY

4.1 Introduction

In any livestock or agricultural production system, the interaction between factors of production, land, human resources and labour significantly influence the levels of production. In the livestock industry, various socio-economic factors influence the production systems at various levels. Socio-economic factors such as size of households, gender, farm level profiles and farm demographic variables do influence the level and speed of adoption of new production technologies and cattle management practices (Cicek *et al.*, 2008; Twomlow and Kizito, 2009; Nwakor *et al.*,2011 *).* Farmers also apportion land to various farm enterprises according to anticipated production. Farming systems are not static and factors such as climate, agricultural technology, population pressures and resource availability exert their influence continually (Rushton, 1996). It was therefore important in this study to identify and quantify farm and human factors likely to influence livestock production in the study region.

Information on livestock farming systems in Machakos County is scanty. The farming system in the area has previously been described as Dual Purpose Cattle Small Scale (DPCSS)/ Sheep and Goats Small Scale (SGSS) (Peeler and Omore, 1997). In the higher potential areas of the County such as Kangundo, the system has been described as Small Scale Dairy Meat Production (SSDMP) (Peeler and Omore, 1997).

The purpose of this chapter is to describe the characteristics of smallholder livestock farming systems in Machakos. The farm demographic variables, including the main methods applied in the control of vector-borne diseases, as well as the socio-economic characteristics of the households are examined.

4.2 MATERIALS AND METHODS

4.2.1 Study sites

The study area and selection of the study 200 farms are described in

Chapter 5. The farms were visited during the months of September and November 2007.

4.2.2 Data collection

The data on household variables, labour profiles, veterinary practices and farm inputs were collected using a questionnaire (Appendix 4.1) administered to household heads via personal interviews. The questionnaire was administered in Kiswahili or translated into the local Kikamba language in case the respondents had limited knowledge of Kiswahili.

A second questionnaire to gather farm level data (Appendix 5.1) was administered to the heads of the household or the persons normally in charge of livestock**.** The questions were designed to identify and rank various livestock production constraints and the disease control strategies. Additional data were sought on household information and demographics, grazing management, delivery of animal health services, occurrence of diseases and mortality in cattle, sheep and goats.

The questionnaires were pretested on ten farms. This was also part of the refresher training of the technicians who assisted in the administration of the questionnaire. The field veterinarians were also present to give their opinion and suggestions after which a consensus on questionnaire administration style was agreed upon. All necessary corrections to the questionnaire were made at this stage.

Although some of the farmers were literate and could provide English names of the main livestock diseases on their farms, the majority of the farmers were semi-literate.

One hundred and seventy three of the selected farmers had 6 to 10 years experience of keeping livestock while the rest (27) had 1 to 5 years experience. Thus, the majority of the farmers were familiar with the common livestock diseases on their farms. The farmers listed diseases in the local Kikamba names. The names were then translated into English with the help of either the local animal health assistant (AHA) or veterinarian who were fluent in the local Kikamba language. A comprehensive probing of the farmers on the symptoms, time of the year when disease is common and animal species or breeds affected by the diseases listed in Kikamba was undertaken before the final translation into the English names. Details of the Kikamba names and their translation into English are indicated in Appendix 5.3.

Farm observations were also made to verify some of the information given by the respondents or to estimate some farm variables. In some instances, transect walks were made across the farms to estimate some unavailable estimates of parameters or verify information, for example proportion of land under pastures, main crops grown, cattle breeds and their numbers.

4.2.3 Data handling and analysis

Responses to the questionnaires and animal records were coded and entered into a data set in Microsoft Access program. After screening, the files were combined and exported to Statistix® Analytical (Statistix for Windows Version 4.0, 1998, St Paul, MN) program for generation of descriptive statistic including frequency distribution and means. Statistical analysis to compare the average household, farm and livestock sizes was undertaken using the *Chisquare* Test.

4.3 RESULTS

4.3.1 Farm characteristics

The distribution of various farm characteristics is shown in Table 4.1. The majority (74%) of the farmers had more than 10 years experience in rearing livestock.

Other than cattle which were the most common species in 70% (147/200) of the surveyed farms, sheep and goats were found in 30% of the farms. Indigenous chicken, commercial chicken (improved chicken breeds) and pigs were reared together with cattle or small ruminants on 32.5% of the farms.

Cattle were managed in zero-grazing units in only 12.5% (25/200) of the study farms. The majority of cattle (87.5%) were managed under the free grazing system. Of the free-grazing farms, cattle were occasionally or routinely grazed on pastures outside the designed farms (roadside, communal or neighbouring farms) in 76.6% (134/175) of the farms. The vast majority (72.5%) of the farmers kept indigenous cattle.

Table 4.1: Characteristics of 200 smallholder farms surveyed in Machakos County September-November 2007.

Variable	Number of farms (n=200)	Proportion (%)
Land utilization and apportionment		
Wholly livestock keeping	13	6.5
Mixed livestock and crops	187	93.5
Experience in keeping livestock		
Up to 5 years	18	9.0
6-10 years	35	17.5
Over 10 years	147	73.5
Composition of all livestock species		
[a]Cattle (predominantly)	140	70.0
[b]Sheep and goats	60	30
[c]Commercial chicken	1	0.5
[c]Free range chicken	60	30.0
[c]Pigs	4	2.0
Grazing Management		
Zero grazing	25	12.5
Free grazing	175	87.5
Cattle breeds		
Indigenous	145	72.5
Crosses	25	12.5
Both Indigenous and crosses	30	15

[a]No of farms mainly keeping cattle
[b]No of farms mainly keeping sheep and goats
[c]No of farms keeping either chicken or pigs together with cattle or small ruminants

4.3.2 Land resource

4.3.2.1 *Size of the farms*

The average farm and livestock herd sizes in the four study divisions are shown in Table 4.2. The average farm sizes varied greatly from a low of 4.14 acres in Kangundo Division to a high of 36.55 acres in Ndithini Division. Two of the selected farms in Ndithini

Division were ranches with an average size of 325 acres and an average herd size of 35 cattle.

The overall average number of cattle per farm was 11.9 and was higher than that for goats (9.4) and sheep (5.2) (Table 4.2). Athi River Division had a significantly ($p < 0.05$) higher average number of all the three livestock species compared to the rest of the divisions.

Table 4.2: Average farm and livestock herd size in the four divisions of Machakos County, 2007.

Division	Average farm size (acres)*	Average livestock herd size		
		Cattle	Goat	Sheep
Athi River	22.0 (2.25- 93.0)	23.10 (1-112)	17.8 (0-60)	11.0 (0-70)
Kangundo	4.14 (1-25)	4.10 (1-20)	2.68 (0-26)	1.42 (0-8)
Matungulu	15.83 (0.25-20)	6.70 (1-30)	4.2 (0-20)	2.56 (0-10)
Ndithini	36.55 (1-350)	12.25 (0-50)	13.5 (0-60)	6.8 (0-70)
Overall	21.13 (1-350)	11.9 (1-112)	9.4 (0-60)	5.2 (0-70)

* Figures in brackets indicate range

4.3.2.2 *Allocation of land to enterprises*

Mixed farming (livestock and crops) was widely practiced in the study area. On average, it was estimated that approximately 40% of the land was allocated to livestock production activities and 60% to growing crops.

Coffee was the main cash crop grown in Kangundo and Matungulu Divisions (Table 4.3). In Ndithini Division, fruits such as mangoes and paw paws were grown as cash crops as well as for home consumption. A variety of food crops including maize, beans, cowpeas bananas, arrow roots and cassava were also common in the study area. Vegetables were grown mainly for home consumption.

4.3.2.3 *Rented land*

In general, renting land was not common in the whole region. During the time of the survey, only 10.5% (21/200) farmers rented land either for grazing or for cultivation. The number of farmers with rented land in Athi River, Kangundo, Matungulu and Ndithini Divisions was 1% (2/200), 2.5% (5/200), 4% (8/200) and 3% (6/200) respectively. Eighteen (9%) of the farmers rented land for cultivation while 3 rented land for grazing. Thirteen (6.5%) farmers rented land throughout the year, 1.5% (3/200) during the rainy season and 2.5% (5/200) during the dry season. The mean rent was Ksh.1, 000 per acre per year.

Table 4.3: The main food and cash crops grown in the four divisions of Machakos County, 2007.

Division	Sub-location	Crops grown	
Kangundo	Ndunduni	Cash Crops	Coffee is the main cash crop.
		Food crops	Maize is the main food crop. The other food crops grown include beans, sugar cane, arrow roots, bananas, cassava, guavas, paw paw, sweet potatoes, kale, tomatoes, beet root, sunflower, water melons and onions
	Kathome	Cash crops	Coffee is the main cash crop. Water melons, mangoes, sugar cane
		Food crops	Maize, beans, bananas, peas, paw paw, cassava, pumpkins, tomatoes, onions, kale, oranges, cabbages, mangoes, avocadoes, arrow roots, sugar cane, French beans, carrots, beans and water melons.
Ndithini	Kiatineni	Cash Crops	Fruits such as mangoes, water melons and oranges
		Food crops	Maize, beans, cowpeas, oranges, mangoes, pigeon peas, watermelons, tomatoes and kales.
	Milani	Cash Crops	Water melons, mangoes, paw paw and oranges
		Food crops	Beans, pigeon peas, cassava, bananas.
Matungulu	Katine	Cash crop	Coffee is main cash crop, water melons, mangoes
		Food crops	Maize, beans, cassava, sweet potatoes, avocado, peas, bananas, onions, watermelons, oranges, mangoes, pumpkins, paw paws, guava, pepper and Napier grass.
	Kalandini	Cash crop	Coffee, water melons, paw paw, avocado, mangoes
		Food crops	Maize, beans, cowpeas, millet, watermelons, paws paw, avocado, mangoes, sweet potatoes, Irish potatoes, cassava and sweet pepper.
Athi River	Katani	Cash Crop	Fruits such as mangoes, oranges, bananas, tomatoes, sugar cane
		Food Crops	Maize, beans, cassava, sweet potatoes, Irish potatoes, cow peas, oranges, mangoes, bananas, tomatoes, pumpkins, cassava and sorghum
	Ngelani	Cash crops	Maize and tomatoes
		Food crops	Maize, beans, tomatoes, vegetables, cowpeas, pumpkins and sweet potatoes.

4.3.2.4 *Household characteristics*

The distribution of family sizes is shown in Figure 4.1. The households had family sizes ranging from 1 to 20 (mean of 7.1 members). Some of the households had extended family members staying in the same homestead. Athi River Division had a significantly ($p < 0.05$) smaller mean number per household (6.5) compared to the other divisions. Overall 80% of the farms had family sizes in the range 4 to 9 family members (Figure 4.1). Approximately 71% (993/1406) of the household members lived on the farms indicating low levels of off- farm employment. The mean number of family members (3.7) living on the farms was significantly ($p<0.05$) smaller in Katani sub-location compared to the other sub-locatio of Athi River Division. Katani and Ngelani are newly settled sub-locations and the majority of homesteads had other homes. The *de jure* heads of the households were almost invariably men although 45 % of them either did not live on the farms or were involved in alternative income activities (employment or as business) with little or no input into farming activities. In this case, their wives were *de-facto* household heads.

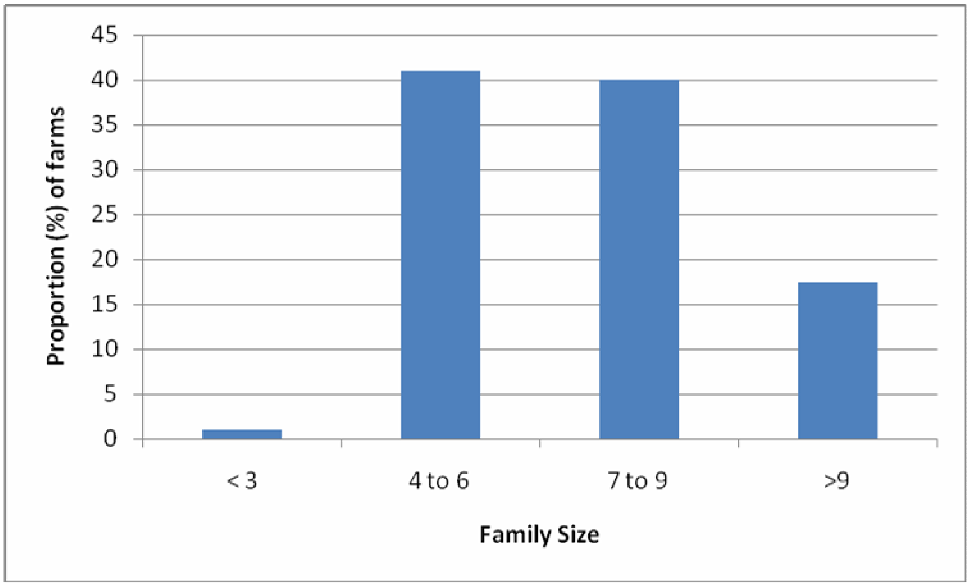

Figure 4.1: Frequency distribution of family sizes in 200 farms surveyed in Machakos County, 2007.

4.3.3 Farm labour profiles

4.3.3.1 *Farm labour*

The bulk (97.5%) of the farm labour was provided by members of the family under the direction of the head of the household. The head of the household discharged all duties pertaining to farm management including sale and disposal of animals, apportionment of the farm to various enterprises and utilization of family income. In 46% (91/ 200) of the farms, the head of the household had employment outside the farm and the daily management of the farm reverted to another member of the family who in most instances (75.3%) was the wife (Table 4.4). Specified employees only managed the farms in cases of the owners staying away in towns. The average number of hours spent working on the farm per day was 5.3 hours. Most of the off–farm employment was on a part time basis either in nearby towns or neighbouring farms.

Table 4.4: Frequency distribution of 200 study farms in Machakos County by the management personnel other than the head of the household, 2007.

Alternative head of farm management	Number of farms	Proportion (%)
Wife	150	75.3
Son	16	8.0
Daughter	3	1.5
Employee designated as farm manager	25	12.7
Others[1]	6	2.5

[1] Brothers, sisters, father, mother or parents in law

4.3.3.2 *Non-family labour*

Utilization of hired labour was a common observation among the study farms. Labour was hired on 64% (128/200) of farms surveyed. Farm workers were hired on either a permanent or daily casual basis. The farms that hired external labour at any one time of the year employed 1.9 persons on average throughout the year.

About 34.5% (69/200) of the farms where free-grazing system of cattle was practiced hired an average of 1.7 people throughout the year. Only 54 (7/13) of the farms that kept cattle as the main enterprise hired labour throughout the year while 41.1% (77/187) mixed farms hired labour throughout the year. However, 59% (111/187) of the mixed farms hired labour at some point of time during the course of the year suggesting hiring of labour was to some extent influenced by the farming of crops. The distribution pattern of hiring labour is shown in Figure 4.2 .

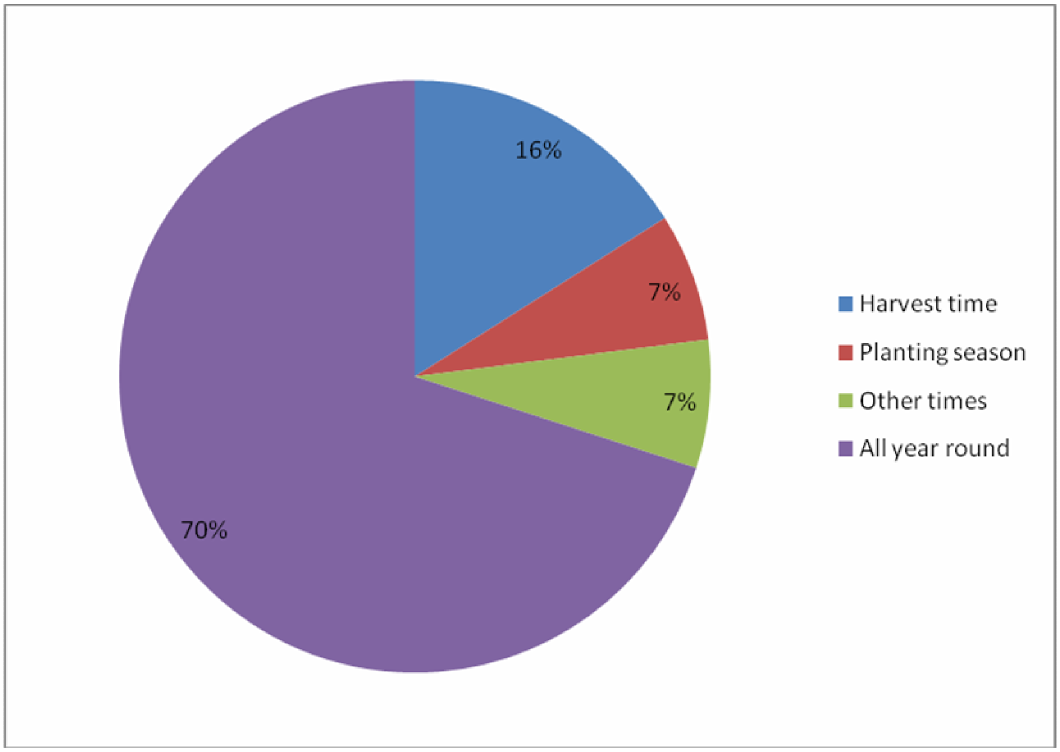

Figure 4.2: Patterns of hiring external labour in 128 farms that engaged non-family labour in Machakos, County.

4.3.3.3 *Cost of hired labour*

The cost of labour ranged from Ksh.3,000.00 to Ksh 4,500 .00 per month per employee. Labour costs were highest in areas close to major urban centres such Athi River (Athi River Division), Tala (Matungulu Division) and Kangundo (Kangundo Division). Therefore, on an eight hour working day (five days a week) the cost of farm labour ranged from Ksh. 18.75 to Ksh.28.13 per man per day equivalent to Ksh. 2.34 to 3.52 per man–hour. The average number of workers hired during the various farming activities and the average number of months when such labour was normally engaged is shown in Table 4.5.

Table 4.5: Estimated amount of hired farm labour in 128 farms which engaged out-of-farm labour, in Machakos County, 2007.

Season of hiring external labour	Mean No. of months hired	Mean No. of workers hired
All year round	12	1.8
Harvesting season only	2	2.4
Planting season only	2	2.1
Planting and harvesting seasons	4	2.6
Other activities	4	1.8

4.3.4 Variable farm inputs

Purchase of farm inputs was done throughout the year but in varying intensity depending on farming activities. The common inputs purchased at farm level included fertilizer, manure, forage, feed, mineral supplement and various veterinary drugs and acaricides.

4.3.4.1 *Application of commercial fertilizers and manure*

Commercial fertilizers were used in 55.5% (111/200) of the farms (Table 4.6). The highest proportion (94%) of commercial fertilizer usage was in Kangundo Division and the lowest proportion (8%) in Athi River Division. Commercial fertilizers were applied to both cash crops and food crops. Where routine and consistent application of fertilizer was practiced, the annual mean cost was Ksh.7,000 per farm with a range of Ksh 5,400 to Ksh 11,000.

A total of 83.5% (167/ 200) farmers used manure on their farms with the majority 93.5% (157/167 applying it to both subsistence and cash crops (Table 4.6). In 4.1% (7/167) of the farms, manure was exclusively used on cash crops while on 2.4% (4/167) of the farms fertilizers were exclusively used on food crops. Thirty-two of the farms that used manure purchased it from other farms within or from outside the County. The annual mean cost was Ksh. 4,943.50 per farm with a range of Ksh.750.00 to Ksh.32,400.00.

Table 4.6: Fertilizer and manure usage on 200 farms in four divisions of Machakos County, in 2007.

Division	Proportion (%) using fertilizers	Proportion (%) using manure
Athi River	4 (8%)	37 (74%)
Matungulu	43 (86%)	48 (96%)
Kangundo	47 (94%)	49 (98%)
Ndithini	17 (34%)	33 (66%)
Overall	111 (55.5)	167 (83.5%)

4.3.5 Membership to co-operatives

Membership to co-operative societies dealing with livestock products was low. Only 14% (28 /200) of the farmers interviewed were co-operative members. There were only two active co-operatives, all in Kangundo Division, while a third one was in the formative stages. One of the co-operatives (Ndunduni dairy co-operative) promoted marketing of dairy products while the Kathome Utuini co-operative promotes the marketing of coffee.

4.3.6 Other Livestock species reared

About 30.5% (61/200) of the surveyed farms reared chicken of which 93.4% were the free-range indigenous type. The mean number of chicken was 22.1 (range 5-120). Farms with more than 30 chicken were considered to be commercial enterprises. Only one farm in Kathome sub-location reared exclusively exotic chicken (120 layers). Three farms reared both exotic (layers) and free-range indigenous chicken. The main markets for the sale of live chicken and their products (eggs and meat) were the local market or neighbours.

Two farms in Athi River kept ducks, geese and turkeys. Only four farms, three of which were in Athi River Division and the other in Matungulu Division kept pigs.

4.3.7 Sale and prices of milk

The number of farms with milking cows at the time of the survey was 135 of which 68.9% (93/135) sold milk at a mean cost of Ksh. 27.30 per litre (Table 4.7). The main outlets for milk were neighbours (54 %), co-operatives (16%) and home consumption (30%). There was no significant ($p>0.05$) difference in the volume of milk sold in the four divisions (Table 4.7).

Table 4.7: Milk sales in four divisions of Machakos County, 2007.

Division	Number of farms selling milk	Mean Milk Sales (litres) per day	95% CI of Mean Milk Sales
Athi River	23	5.02	[3.18, 6.87]
Kangundo	31	6.94	[5.08, 8.80]
Matungulu	17	4.26	[2.74, 5.78]
Ndithini	22	4.83	[2.48, 7.18]
Overall	93	5.45	[4.45, 6.45]

4.3.8 Provision of veterinary services

Delivery of government veterinary services in the study region was reportedly low. In the four the study divisions, only 22% (44/200) of the farmers had access to veterinarians and relied on family members to treat sick animals (Table 4.8). Kangundo Division had the highest 58% (29/50) reported access to trained veterinarians and animal health assistants. In Ndithini and Matungulu Divisions, 74% and 56% of the farmers respectively had access either to animal health assistants or veterinarians. Athi River Division had the lowest (2%; 2/50) access to veterinary personnel where 78% of the farmers reportedly treated their sick animals. A farmer from the division indicated that he relied on services of a herbalist to treat his animals. Private veterinarians were reported to be more available in Kangundo Division. In Matungulu Division, a retired livestock officer was reported to be providing animal health care services to 36% (18/50) of the recruited farmers.

Table 4.8: Animall health providers of veterinary services at farm level by division in Machakos County, 2007.

Division	Type of personnel that undertakes treatments when animals are sick (No.of house holds per division =50)					
	Family member	Animal Health Assistant	Private Vet	Government Vet	Livestock officer	Traditional herbalist
Ndithini	26% (13)	64% (32)	8% (4)	2% (1)	0 (0%)	0% (0)
Matungulu	8% (4)	40% (20)	2% (1)	14% (7)	36% (18)	0% (0)
Kangundo	0% (0)	42% (21)	30% 15)	28% (14)	0% (0)	0% (0)
Athi River	78% (39)	14% (7)	0% (0)	4% (2)	2% (1)	2% (1)

4.3.9 *Tick control*

Acaricides were applied on animals to control ticks on 198 farms 99% (198/200) by use of hand sprays. Tick control generally commenced at the age of 1 month. More than 40% of the farmers applied acaricides on all the three livestock species by the age of 1 month. Other farms (1%) applied acaricides only when ticks were observed on the animals.

Acaricides based on amidines were the most (92%) commonly used and the three main brands were Triatix® (Cooper Kenya Ltd), Alimatix® (Unga Feeds Kenya Ltd) and Tix Fix® (Twiga). Acaricides based on organo–phosphorus compounds were used in 4% (8/200) of the farms and included Stelladone® (Norvatis East Africa Ltd) and Supadip® (Cooper Kenya Ltd). One brand of synthetic pyrethroid, Dominex (FMC chemicals), was used on 7 3.5% (7/200) of the farms. One farmer was not certain of the brand of acaricides used on his farm.

4.4 DISCUSSION

The study showed that 93.5% (187/200) of the study farms practiced mixed farming. This proportion was similar to what was observed by Maichomo (2008) in a pastoral livestock production system in Kajiado County where 95% of pastoralists were found to have other sources of income besides livestock. Engaging in mixed farming indicated the degree of diversification of sources of income in order to better manage risks as observed by Little *et al*. (2001). The farmers indicated that they sold up to 50% of the food crops such as maize and beans during bumper harvest. Apart from improved incomes, mixed farming is of value to the farmers as the crop and livestock enterprises are interdependent. About 83.5% (187/200) of the study farms use livestock manure for growing of cash and food crops. Some of the large livestock farmers sold surplus manure thus providing an extra source of income. However, on some of the farms, purchase of manure was part of the farming expenses, with farms spending on average Ksh.4, 943.00 annually. The growing of crops and keeping of livestock complemented each other, as livestock were a source of manure while maize/ sorghum stovers were used as animal fodder.

The proportion of farms in all divisions that used manure was higher than those that used fertilizers probably because of the higher cost of commercial fertilizers. Moreover, most farmers who used manure did not have to spend money buying the manure as the livestock produced sufficient quantities. Kangundo Division, which was the most arable of the four divisions, had the highest proportion of farmers that used both manure and commercial fertilizers. The relatively low usage of manure in Athi River and Ndithini Divisions, which had higher mean livestock populations compared to Kangundo and

Matungulu Divisions was rather surprising. A possible explanation could be that the farmers considered livestock production more reliable in the prevailing environment due to frequent crop failures. In addition, they sold the manure to farmers outside the divisions. Athi River and Ndithini were the major sources of manure to farmers outside the divisions.

The mean size of the farms was 21.83 acres, with a range of 0.25 to 350 acres. This was considerably larger than the average land size in high potential Countys such as Kiambu (3.0 acres) (Gitau *et al*., 1994a), Kisii (1.8 acres) (Waithaka *et al*., 2000), Bungoma (10.0 acres) (Waithaka *et al*., 2000), Vihiga (1.24 acres) (Nyangweso *et al.*, 2007) and Uasin Gishu (8.64 acres) (UG, 2012). Thus, shortage of land was not considered a constraint to livestock production. This may also explain why only 16.5 % (13/200) of the farmers rented land for either cultivation or grazing throughout the year. Communal grazing was practiced in Ndithini. Although the average size of the farms was considered higher than in many other smallholder farming areas of the country, large tracts of land were undeveloped in the division with only 10% to 40% of the land being available for pastures as was onbserved by the author

The mean household size of 7.10 resident members probably explained the low levels of formal employment outside the region. Thus, labour was easily available at the farm level. In some of the farms, the head of the household had employment elsewhere. Given that the households had other off farm employment, there was a likelihood of conflict in farm level decision making process especially on matters related to animal health. It was noted that some vital decisions on management, including detection and diagnosis of sick animals as well as tick control were delayed. However, some farmers had employed at least one worker either on a full time or part time basis all year round. These findings were consistent with those of Muraguri (2000) in the Coastal lowlands of Kenya.

While cattle were kept as an integral main source of family income, sheep, goats and chicken were frequently sold to cater for short falls in the family incomes. For example sheep and goats were commonly sold for school fees, family functions like weddings, purchase of cloths, repair of houses, payment of medical bills and payment of labour. Indigenous chicken were mainly kept for home and local consumption. The feature of keeping various other livestock as a source of emergency family income is characteristic of smallholder livestock production systems in similar regions of the country (Stotz, 1979; Little *et al*., 2001; Maichomo, 2008). The findings of the study do further emphasize the importance of designing studies that encampas all livestock species as each (species) plays significant social and economic roles in the lives of the smallholder farmer. Nearly all previous studies in the country have focused on cattle largely ignoring the small ruminants (Winrock International, 1992).

The amount of labour hired in the study area may have been influenced by herd sizes, size of farmland and farming of crops. Athi River and Ndithini Divisions had both the largest average herd and farm sizes while Kangundo was the most arable division in the study. These characteristics may explain why the three divisions hired the highest average number of workers per farm and also had the highest proportion of farms that hired labour. Although the average land and herd size of livestock was smaller in Kangundo Division than in Athi River and Ndithini Divisions, crop farming was much more intensive in the division. This made it necessary for a large proportion of farmers in Kangundo Division to hire external labour all year round. The relatively high cost of hiring labour particularly in Athi River and Kangundo Divisions appears not to have been a hindrance, underlying the importance the farmers attached to either farming or rearing livestock.

Milk sales in the four divisions of the County were very low at the time of the survey. In a national survey on milk production undertaken by Karanja (2002), the County was ranked very low both in terms of milk production and sales in the country. The main reason for the low milk production in the County was attributed to the small numbers of farmers who keep improved dairy cattle breeds and inadequate veterinary extension services. This was observed during the current study. The other constraint to the poor marketing of milk in the County was the underdeveloped dairy co-operatives. Inspite of Kangundo Division having the highest milk sales in the study area, the daily milk production per farm of 5.45 litres were considerably less than those recorded in the central highlands regions of the country where the mean daily milk sales can be as high as 16.6 litres (Staal *et al.*, 1997; Karanja, 2002).. The current poor animal genetic resources could not sustain an effective dairy cattle production system (Thorpe *et al.*, 1995). Exploitation of a crossbreeding system between a suitable *Bos taurus* breed and local breeds has been identified as one way of improving the genetic potential of local breeds (Syrstad, 1988; Kang'ethe and Thorpe, 1992). It was however encouraging that some farmers, particularly in Kangundo and Matungulu Divisions had adopted rearing of crossbred cattle under an intensive production system.

With the exception of Kangundo Division, animal health delivery was generally poor, with most of the treatments of sick animals being undertaken by farmers themselves for example in Athi River. The above indiscriminate use of drugs such as antibiotic could result in drug resistance by microbes or high drug residues in milk and meat. Although most of the farmers indicated that they undertook tick control on a regular basis it was likely that few of the farmers applied the acaricides as recommended as ticks could still be found attached on animals that had been sprayed a day or two prior to the visit.

Of concern was the finding that some of the farmers (3.5%) were already using synthetic pythrethroids to control ticks on their farms. This was contrary to the current policy of the Department of Veterinary Services whereby synthetic pyrethyroids are only recommended to be used in tsetse-infested areas such as parts of the Coast Province, Narok and Teso Countys. Synthetic pyrethroids are reserved for use as the last line of "defence" for the control of ticks if widespread resistance against the current recommended acaricides (Amitraz group of compounds) is confirmed.

CHAPTER 5

SERO PREVALENCE OF VECTOR- BORNE DISEASES AND ASSOCIATED RISK FACTORS IN SMALLHOLDER FARMS IN MACHAKOS COUNTY

5.1 INTRODUCTION

Relatively few studies on animal health have been carried out in Machakos County (Mukhebi and Gituna, 1985; Emongor, 2000; Kinuthia, 2001; Ngumi, 2004, unpublished). These studies were very limited in scope and the data collected were largely qualitative. The studies identified theileriosis, anaplasmosis, babesiosis and heartwater as the major tick-borne diseases (TBDs) of livestock as evaluated by the economic impact they exerted on the farming communities in the County. No published study has been carried out to assess factors associated with the risk of tick-borne diseases (TBDs) in the County.

Farmers in the County traditionally practice mixed livestock/crop farming, rearing predominantly local breeds of cattle and small ruminants (GoK, 2006). However, there is potential for replacing the indigenous breeds with improved ones as a means of improving livestock production in the County. There are efforts by some farmers particularly in Kangundo Division of the County to replace indigenous breeds with improved breeds such as Friesian crosses. This transition is expected to result into an upsurge of tick-borne diseases since the latter are more susceptible to ticks and tick-borne diseases. The current survey was intended to provide information on the risk of tick-borne diseases in the County. Once the risk factors are identified and quantified, they form the basis upon which appropriate control strategies for TBDs will be formulated.

The present study is the first to be undertaken in the County to determine seroprevalence of the main tick-borne diseases. In addition the study was designed to assess factors associated with the risk of the tick-borne diseases. Both farm and animal level factors associated with prevalence of antibodies to TBDs (*T. parva*, *A. marginale* and *B. bigemina*) are investigated.

5.2 MATERIALS AND METHODS

5.2.1 Study population

5.2.1.1 *Selection of farms for the cross-sectional study*

The study population consisted of farms keeping both cattle and small ruminants.
A three-stage cluster sampling method was used to select the study farms. First, four administrative divisions out of ten were randomly selected using a random -number table**.** All the sub-locations in each of the four selected divisions were listed and then two sub-locations per division randomly selected for eight sub-locations. A list of all livestock farmers in each selected sub-location was compiled with the assistance of the local administration chiefs and their assistants. Then twenty-five farmers were randomly selected from each sub-location for a total of 200 farms. The sampling frame used to select sub-locations and farms is shown in Table 5.1 and the location of the selected study farms is shown in Figure 5.1.

Table 5.1: The sampling frame used to select study sub-location and farms in Machakos County, 2007.

Administrative Division	Total number of Sub-locations in the division	Name of Selected Sub-location	Total number of farms in sub-location
Ndithini	8	Kiatineni	107
		Milani	101
Matungulu	29	Kalandini	148
		Katine	200
Kangundo	21	Ndunduni	211
		Kathome	65
Athi River	6	Katani	34
		Ngelani	39

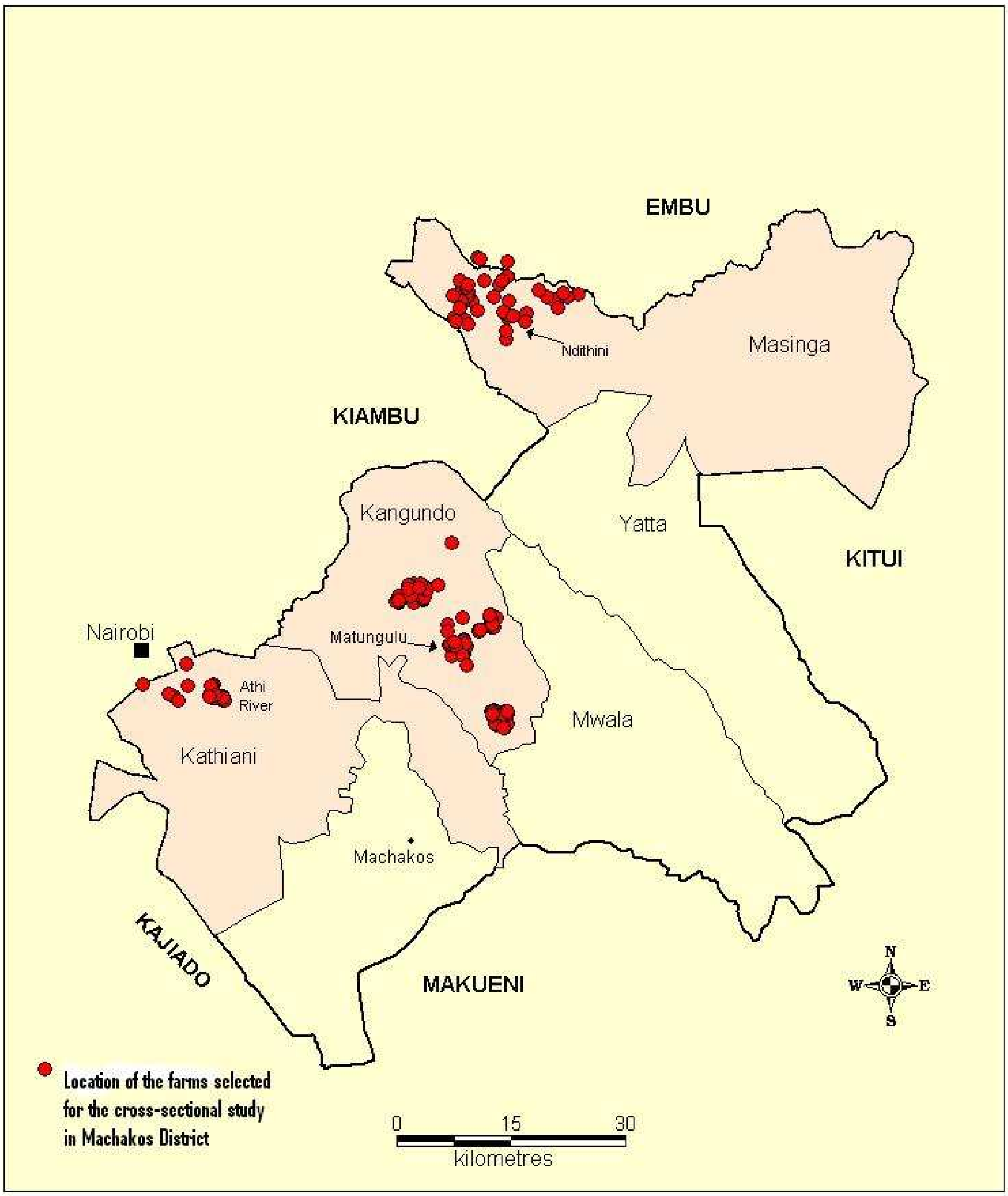

Figure 5.1: Map of Machakos County showing administrative divisions and the location of the study farms, 2007.

5.2.2 Data collection

Farm level and individual animal data were collected using a standard questionnaire as described in Chapter 4 (Appendices 5.1 and 5.2).

5.2.3. Sample size determination

The sample size of animals required to estimate the antibody prevalence of TBDs infections in the County was determined according to the method described in Martin *et al*. (1987):

$$n = \frac{Z_{\alpha}^{2} p\,(1-p)}{L^{2}}$$

Where n = The required sample size, Z_{α} is the normal deviate that provides 95% confidence interval (the value of Z_{α} is 1.96), p is *a priori* estimate of the prevalence of disease (TBD), and L was the level of precision. The antibody prevalence of the TBDs infections was not known *a priori* and so, 50% prevalence (p) was assumed. Setting L at 5%, a sample size of 384 animals was obtained.

5.2.4 Collection of biological samples

5.2.4.1 *Sampling*

A proportional allocation approach was used to sample individual animals in each farm. Since the farm herd sizes were not known ahead of time, a constant 50% of animals in each farm were selected using systematic random sampling to ensure that each animal had the same probability of selection. In herds that had 6 or less animals all animals in the herd were sampled. Calves less than four months of age were not sampled to minimize the possibility of detecting passively derived colostral antibodies (Burridge and Kimber, 1973; Gitau *et al.*, 1999; Swai *et al.*, 2005).

Cattle were categorised into calves (from birth to 12 months of age), yearlings (13-24 months) and adults (over 2 years of age). In cases where farmers could not recall the animal's age, the ages were technically determined by the presence or absence of permanent incisors (Sisson and Grossman, 1975).

Each animal was ear-tagged and given an individual animal code. The following parameters were recorded for each animal: age category (calf, yearling or adult), sex, breed, live weight (estimated by heart girth measurements using weigh bands), level of tick infestation and any disease manifestation at the time of sampling.

Lymph node and blood smears were made from any animal with a body temperature of more than 39.4^0C. The smears were fixed in methanol and stained with Giemsa on site but were examined for tick-borne diseases parasites (*Theileria parva* schizonts/ piroplasms, anaplasma and babesia) at VRC-Muguga. Infected animals were treated free of charge as an incentive to the farmers.

Animals were bled between 0700 and 1100 hours by venopuncture of the jugular vein and the blood collected in vacutainer tubes (10 ml without anticoagulant; Becton Dickinson). Each sample was labeled with the individual animal code and kept at room temperature overnight for serum separation. The serum samples were then placed on ice in a cool box and transported within 48 hours to VRC-Muguga where they were stored in serum vials at -20 ^{0}C in a freezer until laboratory analysis.

5.2.5. Serological testing

5.2.5.1 *The ELISA procedure for TBDs*

Evaluation of the levels of antibodies to *T. parva, gemina* and *A. marginale* were carried out using ELISA tests as described in Nielsen *et al*. (1996) and Katende *et al*. (1998). Briefly, the specific antigens (the polymorphic immunodominant antigen for *T. parva*, p32 kilodalton, antigen for *A. marginale* and p 200 kilo-dalton antigen for *B. bigemina*) were coated in Starwell polysorp micro-ELISA plates (Polysorp, Nunc, Denmark). The coated plates were incubated for 2 hours at 37^o C in an Insel incubator/ shaker. At the end of the incubation, excess antigen was discarded by flicking out the contents into a sink. The remaining antigen was discarded by flicking out the contents into a sink. Any remaining antigen was drained by slapping the inverted plate onto hand paper towels, then leaving the inverted plate on the towels for 15 minutes.

Casein 0.25% was used as the blocking agent. The test sera was diluted 1:200 for *T. parva* and 1:100 for *B. bigemina* and 1:40 for *A. marginale* in Dulbeco's phosphate buffered saline (DPBS) (pH7.4), containing 0.1% Tween 20 and 5% skimmed milk. Positive and negative sera were used for each parasite. The control sera were reconstituted using sterile distilled water. The presence of antibodies to specific parasite antigens was tested by addition of the test sera into wells of the antigen-coated plates in duplicates. The plates were then incubated for 25 min at 25^{0}C to allow antibodies if present to bind to specific antigens. The plates were then washed 5 times with washing buffer. To detect the antigen–antibody reaction anti-bovine IgG monoclonal antibodies conjugated to Horse-Radish Peroxidase (HRP) were added. The plates were then incubated at 37^0 C for 30 minutes and washed 5 times with washing buffer. The reaction was then revealed by addition of 1% hydrogen peroxide as substrate and 40nM 2, 2'-amino-bis (3-ethylbenz-thiazoleline-6-sulphuric acid), diammonium salt (ABTS) as chromogen in sodium citrate buffer pH 4.0. The plates were incubated at room temperature in the dark for one hour for colour development.

The intensity of the colour developed (optical density; OD) was determined using an ELISA reader. Optical density (OD) readings from the reference strongly positive control sera were used to compute the percent positivity (pp) for the test sera (Wright *et al*., 1993), expressed as: pp= (OD of the test serum/ OD of strong positive) X 100). For ease of interpretation and comparison, animals were classified as seropostive if the pp was 20% for *T. parva* and 15 % for *A. marginale* and *B. bigemina* (Katende *et al*., 1998; Morzaria *et al*. 1999).

5.2.6 Tick infestation

Using the technique of Muraguri (2000), tick challenge was assessed by observing tick infestation on at least five randomly selected cattle, sheep or goats on each farm. The species of the infesting ticks were recorded. Ticks collected were stored in methanol and transported to VRC laboratories at Muguga for identification up to species level according to Kaiser *et al*. (1988) whenever identification *in-situ* was doubtful. Tick challenge was recorded on a four point scale:

None=0
Low = < 10
Moderate = >10-20
High= > 20 ticks

5.2.7 Data management and analysis

5.2.7.1 *Data entry and handling*

All the data were entered and managed in the Microsoft Access data base (Microsoft Corporation, USA).

5.2.7.2 *Data analysis*

Unless otherwise stated in the relevant sections, data were analysed using the STATA, statistical package (StataCorp, 2007, version 10). The chi-square (χ^2) statistic was used to assess simple associations of both animal level factors (age, disease history, sex, and breed) and farm level factors (grazing system, tick control and tick infestation) with seropositivity to the TBDs in univariate analysis. A logistic regression model was later fitted (controlling for confounding} to assess associations between the potential risk factors for seropositivity to the TBDs.

The logistic regression model was fitted using the stepwise backward elimination approach (Hosmer and Lemeshow, 1989). Potential risk factors were screened for association with seropositivity. In this analysis, an independent variable was retained in the model when it satisfied a $p \leq 0.1$ significance level. After analysis of the main effects, interactions between the significant variables were only tested in the models if they were deemed biologically plausible.

The logistic models for the probability of *pi* of the *i*th animal being positive for any TBD infection with only one variable was computed as:

Logit (p_i) = ßo+ ßX_i + e_i., where ßo denotes the logit of the probability of disease if all variables were “absent” (that is equal to zero) whereas ß represented the amount the log odds of exposure increased (or decreased) when the factor was present. For a categorical variable with multiple categories, ß represented the effect of that level compared to the reference category. $X_{i,}$ represented the variable under analysis and e the random error with mean 0 and variance σ^2. Subsequent to univariate analyses, the significant variables were tested for multi-collinearity with the phi-coefficient (*Φ*), if the variables were highly correlated, demonstrated by a phi-coefficient greater than 0.70 (Fleiss, 1981), the more biologically plausible variable was left in the model. The multivariable logistic regressions models were built by extending the univariate models to include other variables as follows:

Logit (p_i) = ßo+ $ß_iX_i$ + …. + $ß_kX_{ki}$ + e_i.

The relationship between each TBD infection serostatus and the significant risk factors was finally examined by fitting mixed effect models with farm as a random effect and the latter step was done to provide, as much as possible, statistically unbiased estimates of sero-prevalence with associated uncertainty adjusted for clustering responses within the farms.

5.3 RESULTS

5.3.1 Characteristics of the study farms

The characteristics of the selected farms are displayed in Table 4.1 (Chapter 4). One-hundred and eighty seven (93.5%) of the farms practiced mixed farming while 6.5% (13/200) of the farms exclusively kept livestock. Of the 200 farms, 140 had at least two heads of cattle while the other 60 farms predominantly kept goats, sheep, or both with only one head of cattle or no cattle. On 15 of the farms that predominantly had small ruminants at the time of the survey, cattle had been transferred to other farms outside the study area to ease pressure on the pastures, while five farms did not keep cattle at all.

5.3.2 Livestock species kept and herd sizes

The types of livestock kept in the surveyed farms, their composition and tick control practices are shown in Tables 5.1 and Table 5.2 for cattle and sheep/goats, respectively. In all study sub-locations, the red head sheep and the small East African goat were the predominant species reared. Goat herd sizes were generally larger than sheep ranging from an average of 1.3 goats per farm in Ndunduni sub-location to 20 in Milani sub-location (Table 5.2). Sheep herd sizes ranged from a low of 0.8 sheep per farm in both Ndunduni and Kathome sub-locations to a high of 13.5 sheep per farm in Katani sub-location.

All the study farms in Ndithini Division kept indigenous zebu cattle while in Kathome and Ndunduni sub-locations of Kangundo Division, 60% (18/30) kept exotic crosses of cattle in addition to Zebu breeds.

In Kalandini sub-location of Matungulu Division, all the surveyed farms kept zebu cattle while only 27% (3/11) of the selected farmers in Katine kept exotic crosses.
Zebu cattle were the only breed of cattle kept in Ngelani sub-location of Athi River Division. Although zebus were the main breed of cattle kept in Katani, 13% (3/23) of the selected farmers kept Friesian crosses.

5.3.3 Age and sex distribution of livestock

The age and sex distribution of cattle recruited into the study is shown in Table 5.1 as well as the proportion of calves, yearlings and adults. Overall 50% (200/399) of the sampled cattle were adults while calves and yearlings accounted for 17.3% (69/399) and 32.6% (130/399), respectively (Table 5.1). Ndunduni, Katani and Kiatineni had the highest proportion of calves with 26.1% (18/69), 20.2% (14/69) and 14.5% (10/69) of the calves sampled respectively, from the three sub-locations (Table 5.1). There were no legible calves (calves more than four months) in the selected farms in Milani while only 2 calves 2.8% were sampled from Kathome.

Kalandini, Kiatineni and Ndunduni had the highest proportions of yearlings sampled with 28.5% (37/130), 15.3% (20/130) and 13.8% (18/130) of the yearlings sampled from the sub-locations, respectively. Katine and Kathome had the smallest number of yearlings with 6.9% (9/130) and 5.3% (7/130) of the animals respectively, sampled from the sub-locations.

Kiatineni, Ndunduni and Katani sub-locations had the largest numbers of adult cattle sampled accounting for 21% (42/200), 19.5% (39/200) and 14.5% (29/200) of the cattle. Twenty-six (13%) adult cattle each were sampled from Katine and Ngelani sub-locations. Kalandini and Kathome had the least number of adult cattle sampled with only 9 cattle each (4.5%) sampled from each of the two sub-locations.

More female 67% (267/399) than male cattle were available on the farms at the time of the survey (Table 5.1). The same sex pattern was observed in all sub-locations except in Milani where almost equal numbers of male and female cattle were sampled (16 and 14, respectively).

5.3.4 Grazing management

The grazing management practices on the study farms are shown in Table 5.1. Cattle were reared under two grazing systems, namely, free-grazing and zero-grazing.
The vast majority 82% (115/140) of the surveyed farms (Table 5.1) practiced free-grazing. Zero-grazing was not common with only 5.7 (8/140) of the farms practicing it. It was however more commonly practiced in Kathome sub-location 62.5% (5/8) of the surveyed farms) and by only 9.5% (3/33) of the surveyed farms in Katine and Ndunduni sub-locations.

Insert Tables 5.2 and 5.3 here

Table 5.1 Farm characteristics of the 140 farms on which cattle were bled to assess the prevalence of tick-borne diseases in the four divisions of Machakos District, 2007.

Division	Sublocation	No of farms in each Sublocation	Average cattle herd size	Sex (No of animals)		Breed (No of animals)		Age (No of animals)			Grazing management (No of farms)			Tick control frequency (No of farms)		Disease History* (No of farms)		
				Male	Female	Indigenous	Crosses	Calves	Yearlings	Adults	Free	Semi free	Zero	Regular	Irregular	ECF	A	B
Ndithini	Kiatineni	21	8.3	34	38	72	0	10	20	42	19	2	0	6	15	11	3	1
	Milani	13	16.5	16	14	30	0	0	10	20	13	0	0	4	9	7	3	1
Matungulu	Kalandini	21	11.1	18	37	55	0	9	37	9	19	2	0	9	12	14	3	5
	Katine	11	6.3	13	28	9	32	8	7	26	7	3	1	5	6	3	0	0
Kangundo	Ndunduni	22	3.8	17	58	46	29	18	18	39	12	8	2	17	5	6	0	0
	Kathome	8	4.3	5	15	4	16	2	9	9	2	1	5	4	4	1	0	0
Athi River	Katani	23	24.2	19	39	49	9	14	15	29	22	1	0	16	7	28	5	0
	Ngelani	21	16.5	10	38	48	0	8	14	26	21	0	0	11	10	12	1	0
Total		140		132	267	313	86	69	130	200	115	17	8	72	68	82	15	7

Table 5.2 Herd sizes and breed of sheep and goats in the study sub-locations

Division	Sublocation	Average herd sizes for the small ruminants		Breeds	
		Sheep	Goats	Sheep	Goat
Ndithini	Kiatineni	7.4	7.0	Red head	The small East African Goat
	Milani	6.4	20.0	Red head	The mall East African Goat
Matungulu	Kalandini	1.1	4.9	Red head	The mall East African Goat
	Katine	6.3	3.6	Red head	The small East African Goat
Kangundo	Ndunduni	0.79	1.3	Red head	The mall East African Goat
	Kathome	0.75	4.1	Red head	The mall East African Goat
Athi River	Katani	13.5	16.3	Red head	The small East African Goat
	Ngelani	8.7	19.3	Red head	The mall East African Goat

5.3.5 Tick control and tick-borne diseases

Regular tick control by acaricide application was reportedly practiced in approximately half of 51%(72/140) the surveyed farms (Table 5.1) but there were differences by sub-locations. About 43% (60/140) of the farms practiced regular tick control on all three livestock species (cattle, goats and sheep). Ndunduni sub-location had the highest proportion 77% (17/22) of the farms that practiced regular tick control while in Katani and Ngelani sub-locations, regular tick control was practiced on 70% (16/23) and 52% (11/21) respectively of the surveyed farms. Tick control was irregular in Kiatineni and Kalandini sub-locations.

About 74% (104/140) of the survey farms with cattle reported treating at least one or more clinical cases of tick-borne diseases in the previous 12 months prior to the survey (Table 5.1). Overall 79% (82/104) of the farmers reported treating at least one clinical case of East Coast fever, and 14% (15/104) and 7% (7/104) reported treating cases of anaplasmosis and babesiosis, respectively. Katani, Kalandini and Ngelani sub-locations had the highest proportion of farms that had had clinical cases of ECF in the previous 12 months; 78% (18/23), 67% (14/21) and 57% (12/21), respectively. Kathome, Katine and Ndunduni had the lowest proportion of farms that had reported clinical ECF; 4% (1/23), 14 % (3/21) and 29% (6/21), respectively.

Cases of anaplasmosis were reported in Katani sub-location by 22% (5/23) of the survey farms and in one farm in Ngelani sub-location. The disease was not reported in other sub-locations.

Clinical cases of suspected babesiosis in the last 12 months were mainly reported in Kalandini sub-location by 24% (5/21) of the farmers. One farm each in Kiatineni and Milani reported the disease. No cases of babesiosis were reported in the other sub-locations.

5.3.6 Sero-prevalence of tick borne-diseases in cattle

A total of 399 cattle serum samples collected from cattle were screened for each of the TBDs infections, namely, *Theileria parva*, *Anaplasma marginale* and *Babesia marginale*. Antibodies to the three TBDs infections were detected in all the sub-locations and farms sampled. Overall, theileria antibodies were detected in 58.9% (235/399) of the samples while those to babesia and anaplasma were detected in 41.1% (164/399) and 35.0% (140/399) of the samples, respectively (Table 5.3). The highest seroprevalence rates for ECF were estimated in Katani 87.9% (51/58), Milani 85.7% (36/42) and Ngelani 77.1% (37/48). The lowest seroprevalence 14.7% (11/75) was estimated in Ndunduni sub-location. A similar pattern of seropositivity was also observed for anaplasmosis. However, the seropositivity pattern for babesiosis was different with the highest prevalence rates estimated in Katine 56.4% (22/39), Kiatineni 46.7% (28/32), Katani 46.5% (27/58) and Ngelani 45.8% (22/48) (Table 5.3).

Overall, the seroprevalence of *T. parva* was significantly ($p<0.05$) higher than that of *B.bigemina* and *A.marginale* but there was no significant difference between the seroprevalence rates of *A.marginale* and *B. bigemina* in the County.

Table 5.4: Distribution of antibodies to Theileria, Anaplasma and Babesia in cattle sera by division and sub-location in Machakos County, 2007**.**

		Tick-borne diseases						
		East Coast fever			Anaplasma		Babesiosis	
Division	Sub-location	No. of samples tested	No. Positive	(proportion) % Positive	No. Positive	(Proportion) % positive	No positive	(Proportion) % positive
Ndithini	Kiatineni	60	32	53.3	23	38.3	28	46.7
	Milani	42	36	85.7	22	52.4	9	21.4
Matungulu	Kalandini	57	37	64.9	15	26.3	29	50.1
	Katine	39	25	64.1	17	43.6	22	56.4
Kangundo	Ndunduni	75	11	14.7	4	5.3	22	29.3
	Kathome	20	6	30.0	2	10.0	5	25.0
Athi River	Katani	58	51	87.9	33	56.9	27	46.5
	Ngelani	48	37	77.1	24	50.0	22	45.8
Total/ Average		399	235	58.9	140	35.0	164	41.1

5.3.6.1 *Univariate analysis of factors associated with the seroprevalence rates of tick-borne diseases*

As shown in Table 5.4 there were significant ($p< 0.05$) differences in the seroprevalence rates of *T.parva* across the divisions with Kangundo Division having the lowest rate (17.9%) and Athi River Division the highest rate (83%). Cattle from Athi River Division were 25 times (OR=0.04) more likely to test positive to *T. parva* relative to cattle from Kangundo. Other factors associated with seropositivity to *T. parva* included age, breed, grazing system and tick infestation (Table 5.4). Calves had the lowest prevalence rate (50.1%) and adult cattle the highest (65.5%). The difference was statistically significant ($p < 0.05$). Indigenous cattle had a significantly ($p < 0.05$) higher seropositivity to *T. parva* compared to exotic crosses and were three times (OR=0.35) more likely to test positive to *T. parva* relative to exotic cattle. Cattle reared under a free grazing system were eleven times (OR=0.09) more likely to test positive to *T. parva* relative to cattle reared under a zero grazing system. Cattle that were infested with *Rhipicephallus appendiculatus* at the time of the survey were twice (OR=2.15) more likely to test positive to *T. parva* than non-infested cattle. Sex of the animals and frequency of tick control on the farms were not associated with testing positive for *T. parva* infection.

Age of animal, tick infestation, grazing system and division were all positively associated with testing positive to *A.marginale* infection. Calves had the lowest prevalence rate (34.8%) and adult cattle the highest (61.5%) (Table 5.4). The difference was statistically significant ($p < 0.05$). Adult cattle were thrice (OR=0.33) more likely to test positive to *A.marginale* than calves.

Cattle that were infested with *R.appendiculatus* at the time of the survey had a significantly ($p<0.05$) higher prevalence rate (64.4%) of antibodies to *A. marginale* than cattle that were not infested (46.3%) and twice (OR=2.1) more likely to test positive to *A. marginale* than cattle that there were not infested. Similarly, cattle that were free-grazed had a significantly ($p< 0.05$) higher seropositivity (47.6%) to *A. marginale* than cattle that were zero-grazed (22%) and were four times (OR=0.23) more likely to test positive to *A. marginale* than cattle that were zero-grazed. There was significant ($p<0.05$) difference in the seropositivity to *A .marginale* between the four divisions (Table 5.4). Cattle in Athi River Division were twice (OR=0.53) and four times (OR=0.24) more likely to test positive to *A. marginale* than cattle in Matungulu and Kangundo, respectively.

Adult cattle had a significantly ($p< 0.05$) higher prevalence (49%) of antibodies to

B.bigemina than calves (29%) (Table 5.4). Adult cattle were twice (0.42) more likely to test positive to *B.bigemina* than calves. Also cattle that were free-grazed had a significantly ($p< 0.05$) higher (45.5%) prevalence of antibodies to *B.bigemina* than zero-grazed (19.5%) cattle.

Division was also associated ($p<0.05$) with seropositivity to *B.bigemina*. Cattle in Athi River Division were one and half (OR=0.66) times and twice (OR=0.46) more likely to test positive to *B.bigemina* than cattle in Ndithini and Kangundo Divisions, respectively. However, cattle in Matungulu Division were about one and half times (OR=1.4) more likely to test positive to *B.bigemina* than cattle in Athi River Division.

Table 5.5 Risk factors of testing positive to TBDs obtained in univariate analysis in Machakos County, Kenya (to be inserted)

Table 5.4 Univariate analysis of factors associated with testing positive to the tick-borne diseases infections in cattle sampled in Machakos District, Kenya ,2007.

Category			*T. parva*			*A. marginale*			*B. bigemina*		
Animal-level factors	Level	No.of animals	Prevalence (%)	OR [95% CI]	*p-value*	Prevalence (%)	OR [95% CI]	*p-value*	Prevalence (%)	OR [95% CI]	*p-value*
Breed	Cross	86	35.1	0.35 [0.22, 0.58]	0.000	46.5	0.77 [0.48, 1.24]	0.28	43.0	1.1 [0.67, 1.77]	0.72
	Indigenous	313	64.9	1		53.0	1		40.9	1	
Age	Calf	69	50.7	0.54 [0.31, 0.94]	0.04	34.8	0.33 [0.19, 0.59]	0.0001	29.0	0.42 [0.24, 0.77]	0.005
	Yearling	130	54.6	0.63 [0.40, 0.99]		45.4	0.52 [0.33, 0.81]		36.2	0.52 [0.37, 0.93]	
	Adult	200	65.5	1		61.5	1		49.0	1	
Sex	Male	132	63.6	1.3 [0.85, 2.00]	0.22	57.6	1.4 [0.94, 2.18]	0.09	37.9	0.81 [0.53, 1.23]	0.32
	Female	267	57.3	1		48.7	1		43.1		
Disease history	Present	*	63.1	1.4 [0.91, 2.03]	0.13	56.9	1.3 [0.73, 2.24]	0.38	50.0	1.4 [0.09, 22.9]	0.80
	Absent	*	55.7			50.7	1		50.0		
Tick infestation	Present	118	69.5	1.9 [1.17, 2.92]	0.007	64.4	2.1 [1.35, 3.28]	0.0009	35.6	0.71 [0.46, 1.11]	0.13
	Absent	281	55.2	1		46.3	1		43.8	1	
Farm-level factors											
Tick control	Regular	248	59.3	0.99 [0.65, 1.49]	0.95	54.0	1.3 [0.86, 1.93]	0.22	40.7	0.93 [0.62, 1.41]	0.74
	Irregular	151	59.6	1		47.7	1		42.4		
Grazing system	Zero	41	14.6	0.09 [0.04,0.23]	0.0000	22.0	0.23 [0.11,0.50]	0.0000	19.5	0.31 [0.14,69]	0.003
	Free	358	64.7	1		47.6	1		37.5	1	
Area-level factor											
Division	Kangundo	95	17.9	0.04 [0.02, 0.09]	0.000	28.4	0.24 [0.13, 0.43]	0.000	28.4	0.46 [0.26, 0.83]	0.0015
	Matungulu	96	66.7	0.41 [0.21, 0.79]		46.9	0.53 [0.30, 0.94]		54.2	1.37 [0.79, 2.39]	
	//Ndithini	102	66.7	0.41 [0.21, 0.79]		66.7	1.21 [0.69, 2.14]		36.3	0.66 [0.38, 1.15]	
	Athi River	106	83.0	1		62.3	1		46.2	1	

*Disease history values for each infection are different: Respectively, present and absent values are 198 and 201 (*T. parva*), 58 and 341 (*A. marginale*), 8 and 361 (*B. bigemina*).

5.3.6.2 *Multivariate analysis of factors associated with the seroprevalence of tick-borne diseases*

Four factors (age, division, grazing system and tick infestation) were significantly (p<0.05) associated with the risk of *T. pava*. The variable cattle breed that was significant in univariate analysis was not retained in the multivariate analysis suggesting that it was a potential confounder. Cattle were at a higher risk of exposure to *T.parva* infection if they came from Athi River Division than if they were from any of the other three divisions (Table 5.5). Kangundo Division had the least risk (OR=0.05) of exposure to *T. parva* followed by Ndithini Division (OR=0.19). Similarly, adult cattle, cattle reared under free-grazing system, and presence of ticks on cattle were twice, three times, and twice as likely to test positive to *T.parva* infection relative to calves, zero-grazed cattle and cattle without ticks, respectively.

Only two factors were significantly (p<0.05) associated with the risk of *A. marginale* (Table 5.5). Tick infestation (with *R .appendiculatus*) and grazing system that were initially significant in the univariate analysis were not significantly associated with testing positive to *A. marginale* in multivariate analysis suggesting that the two variables were potential confounders. Cattle had a higher risk of exposure to *A. marginale* if they came from Athi River Division compared to the other three divisions. Similarly, adult cattle were twice and three times more likely to test positive to *T .parva* relative to yearlings and calves, respectively.

All three factors (age, grazing system and division) that were signficantly associated with the sero-prevalence of *B.bigemina* in the univariate analysis remained signficant in the multivariate analysis. This suggested that none of the three factors was a potential confounder.

Table 5.6: Multivariate analysis output of factors associated with the seropostivity of

tick-borne diseases in Machakos County, 2007.

Tick-borne disease	Variable	Level	OR	OR 95% CI	*p*-value
Theileria parva					
	Age	Adult	1	-	0.012
		Yearling	0.50	[0.29, 0.85]	
		Calf	0.45	[0.23, 0.89]	
	Tick infestation	Present	2.15	[1.02, 4.53]	0.04
		Absent	1	-	
	Grazing system	Free	1	-	0.02
		Zero	0.33	[0.12,0.91]	
	Division	Athi	1	-	0.000
		Kangundo	0.05	[0.02, 0.11]	
		Matungulu	0.44	[0.22, 0.88]	
		Ndithini	0.19	[0.08,0.47]	
Anaplasma marginale					
	Age	Adult	1	-	0.0005
		Yearling	0.52	[0.32, 0.83]	
		Calf	0.34	[0.19, 0.63]	
	Division	Athi	1	-	0.000
		Kangundo	0.23	[0.12, 0.42]	
		Matungulu	0.57	[0.32, 1.02]	
		Ndithini	1.09	[0.6,1.96]	
Babesia Bigemina					
	Age	Adult	1	-	0.0006
		Yearling	0.36	[0.2, 0.67]	
		Calf	0.49	[0.3, 0.79]	
	Grazing system	Free	1	-	0.013
		Zero	0.36	[0.15, 0.88]	
	Division	Athi	1	-	0.002
		Kangundo	0.61	[0.32, 1.16]	
		Matungulu	1.63	[0.91, 2.91]	
		Ndithini	0.60	[0.33, 1.03]	

5.3.6.3 *Multivariate analyses without variable "division" for tick-borne diseases*

The variable "division" was significantly associated with seropositivity to the three TBDs. Since divisional boundaries are administrative in nature, it was necessary to investigate other attributes in the County for their importance in explaining the TBD seroprevalence variations in the County. Thus, multivariate models without the variable "division" were built with all the significant univariate variables. The purpose of this was to investigate any (additional) significant effects, which could have been masked by effects of "division". The outputs of these models are shown in Table 5.6.

For *T. parva* seroprevalence age and grazing system remained significant but the variable "breed" turned significant ($p < 0.05$) while the variable "tick infestation" was insignificant ($p > 0.05$) suggesting that division was a potential confounder in the association of the two variables with testing positive to *T. parva.* The same applied to tick infestation and grazing system for *A.marginale*. No variable was masked by the effects of division for *B. bigemina*.

Table 5.7: Multivariable analysis ($p \leq 0.05$) for exposure to the three tick-borne diseases infections without the variable “division” in cattle sampled from Machakos County, Kenya.

Variable	Level	OR	95% CI	*p*-value
Theileria parva				
Age	Adult	-	-	0.03
	Yearling	0.52	[0.3, 0.94]	
	Calf	0.58	[0.37, 0.94]	
Breed	Indigenous	-	-	0.006
	Crosses	0.47	[0.27, 0.81]	
Grazing system	Free	-	-	0.000
	Zero	0.11	[0.05, 0.28]	
Anaplasma marginale				
Age	Adult	-	-	0.0003
	Yearling	0.53	[0.33, 0.83]	
	Calf	0.35	[0.19.0.63]	
Tick infestation	None	-	-	0.033
	Present	1.64	[1.03,2.62]	
Grazing system	Free			0.0002
	Zero	0.24	[0.11,0.54]	
Babesia Bigemina				
Age	Adult	-	-	0.004
	Yearling	0.59	[0.37, 0.93]	
	Calf	0.42	[0.23, 0.76]	
Grazing system	Free	-	-	0.002
	Zero	0.30	[0.14, 0.68]	

5.3.7 Tick Challenge

A total of 155 cattle, 167 goats and 121 sheep were sampled for ticks from 106, 109 and 90 of the survey farms, respectively. The tick challenge was high in all the study sub-locations except in Ndunduni and Kathome. *Rhipicephalus appendiculatus* was the commonest tick species found on cattle, sheep and goats in all the sub-locations (Table 5.7). The other common tick species observed were *Boophilus decoloratus, Rhipicephalus evertsi, Rhipicephalus pulchellus and Amblyomma variegatum. Boophilus decoloratus* was prevalent in all sub-locations except Ndunduni, while *Amblyomma variegatum* was observed on animals in four of the study eight sub-locations (Kiatineni, Milani, Kalandini and Katani). *Rhipicephalus evertsi* was only prevalent in Milani, Ndunduni and Katani sub-locations while *Rhipicephalus pulchellus* was only prevalent in Katani and Ngelani sub-locations of Athi River Division.

Table 5.8: Tick species and level of tick challenge on cattle, sheep and goats in the selected farms in Machakos County, 2007.

Sub – location	No. of farm on which animals were sampled for ticks			Species and No. sampled			Species and No. with ticks			Tick challenge	Prevalent tick species
	Cattle	Goats	Sheep	Cattle	Goats	Sheep	Cattle	Goats	Sheep		
Kiatineni	11	13	10	26	24	20	22	13	11	High	*R. appendiculatus A.variegatum, B.decoloratus*
Milani	13	10	11	19	34	24	16	26	18	High	*R. appendiculatus, A.variegatum, R. evertsi B.decoloratus*
Kalandini	15	20	15	22	20	15	21	15	10	High	*R. appendiculatus A. variegatum, B. decoloratus*
Katine	11	10	10	11	16	10	11	10	7	High	*R. appendiculatus. B. decoloratus*
Ndunduni	12	9	6	14	9	7	2	0	1	Low	*R.appendiculatus R. evertsi*
Kathome	8	6	0	17	6	0	6	2	0	Medium	*R. appendiculatus B. decoloratus*
Katani	16	20	18	16	26	22	15	14	16	High	*R. appendiculatus, A.variegatum, R.evertsi B.decoloratus R.pulchellus*
Ngelani	20	21	20	30	32	23	30	21	16	High	*R. appendiculatus, B.decoloratus R.pulchellus*
Total	106	109	90	155	167	121	123	101	79		

5.3.8 Diseases diagnosed during the farm visits

During the survey, 14 cattle were clinically sick with elevated temperatures of greater than 39.4^{o}C. Five of the cattle were found to be infected with *Trypanosoma vivax*, one with ECF while the other 8 animals were infected with what was suspected to be bacterial infections. The ECF case was diagnosed on one of the farms in Kiatineni sub-location. All the 5 cases of trypanosomiasis were diagnosed in Milani sub-location. Four suspected bacterial infections were diagnosed in Milani while 2 cases were diagnosed in Ngelani. One case each of suspected bacterial infection were diagnosed in Katani and Kiatineni sub-locations.

5.4 DISCUSSION

This study was the first to provide a population-based assessment of serum antibodies prevalence to *Theleria parva*, *Anaplasma marginale* and *Babesia bigemina* infections in Machakos County. Variability was observed in serum antibody prevalence to the three tick-borne diseases, degree of tick infestation across the divisions, grazing systems and age of animals. In the absence of re-challenge, it has been demonstrated that antibodies to *Theileria parva* decline by six months (Lawrence *et al*., 2004) after infection. During this study, the relatively high prevalence of the tick-borne diseases suggested recent or continuous infection by the parasites.

As expected, older animals were at an elevated risk of testing positive to antibodies to the TBDs because of the longer duration of exposure to infected ticks. Similarly, cattle on free- grazing systems were continuously exposed to the infected ticks. This was confirmed when tick counts on cattle were enumerated; high tick challenges was found in three of the study divisions that practised free-range grazing system. The prevalence estimates of 58.9%,35.0% and 41.1% for *T.parva*, *A. marginale* and *B.bigemina* respectively robtained in this study were in general agreement with estimates reported for TBDs by Latif *et al*. (1994) in western Kenya, Maloo *et al*. (2001a) in the Coastal region of Kenya and Okuthe and Buyu (2006) in the western highlands of Kenya. The varying prevalence rates of the TBDs and tick challenge suggest the existence of different epidemiological states for the three tick-borne diseases. Endemically stable states characterized by among other factors high antibody prevalence (>70%) and a constant tick challenge (Norval *et al*.,1992; Deem *et al.*, 1993; Perry and Young, 1995; Gitau, 2000; Kivaria *et al*., 2004) appear to exist for ECF in Katani and Ngelani sub-locations of Athi River Division and in Milani sub-location of Ndithini Division. On the other hand, a state of endemic instability characterized by low antibody prevalence of < 30% appeared to exist in Kangundo and Matungulu Divisions. A low antibody prevalence pattern observed for anaplasma and babesia suggested endemic instability in all the study divisions.

Apparently, more cattle were exposed to *T. parva* compared to the other TBD infections. This was not surprising as *R. appendiculatus*, the vector tick of *T. parva* was the commonest tick species observed in all the sub-locations. These results were similar to results reported by Muraguri (2000) in the Coastal lowlands of Kenya. However, the sero-prevalence to *T. parva* was much higher than that observed by Gachohi *et al.* (2010) in neighbouring Mbeere County. The high level of exposure to ticks observed indicates a high a risk of ECF in Machakos County. The sero-prevalence results to the three TBDs were consistent with the number of clinical cases of the three TBDs recorded by the farmers in the 6-12 months period that preceded the current study. East Coast fever was reported more frequently than anaplasma and babesiosis by the farmers.

Although the tick vectors for anaplasmosis and babesiosis were common in all sub-locations, the sero-prevalence for the two infections was low. This state of endemic instability was not supported by data because of the few clinical cases recorded by farmers. However, it was possible that the recorded cases were an underestimate of the true incidence of the two diseases in the area probably due to problems of diagnosis or even recall. The concept of endemic stability/ instability is best investigated through longitudinal studies where factors such as seasonal abundance of ticks, morbidity and mortality could be evaluated (Perry *et al*., 1992). Thus, further studies need to be undertaken to establish the true endemic state of the two diseases in the study area.

Kathome and Ndunduni sub-locations had low sero-prevalence rates for all the three TBDs. This may have been attributed to the fact that most farmers in the two sub-locations practiced zero grazing. In addition, most farmers in the two sub-locations kept exotic crossbreeds of cattle and they applied acaricides on a regular basis. The farmers were apparently aware that these cattle breeds were more susceptible to tick-borne diseases than the indigenous breeds and thus applied tick control more rigorously. On the other hand, the sero-prevalence of ECF was significantly higher in Athi River Division (Katani and Ngelani sub-locations) than in other divisions. The two sub-locations also had relatively higher sero-prevalence rates of anaplasma and babesia than the other sub-locations. This may have been attributed to poor tick control practices reported in the two sub-locations. Although most farmers in the two sub-locations indicated that they undertook tick control on a regular basis, it was observed that a few applied the acaricides as recommended as ticks could still be found attached on animals that had been sprayed as late as a day or two prior to the farm visit. Poor tick control was also documented in smallholder cattle production systems in western Kenya in a study carried out by Okuthe and Buyu (2006). Improper application of acaricides especially the use of under strength acaricides can result in ticks developing widespread resistance. This is an aspect that needs further investigation. Indeed, no association was found between frequency of tick control on the farms and the risk of testing positive to the TBDs. There is need for enhanced extension services to educate farmers on proper methods of acaricide application Delivery of veterinary services in Athi River Division was found to be poor relative to the other divisions.

Small ruminants were found to be important alternative hosts for ticks for farms where more than one ruminant species was kept. These results were consistent with the observations by Wesonga *et al*. (2006) that goats and sheep played an important role in maintaining tick populations on a ranch. It is therefore important that tick control at farm level should target all livestock species in order to reduce tick burdens on the pastures. On farms that practice zero-grazing, small ruminants on the same farms that are freely-grazed could be a source of tick infestation on cattle if tick control on the small ruminants is not undertaken on a regular basis (Maloo *et al*., 2001c).

There was no association between cattle breeds and testing positive to anaplasma. This may be due to the alternative means of transmission of the disease other than ticks. The disease is also transmitted by biting flies and contaminated needles (Scole *et al.*, 2008). There was a high probability of transmission by needles in divisions such as Athi River and Ndithini where there was poor access to veterinary services. As a result, most of the farmers treated their sick animals and often used unsterilised needles. Biting flies were also common in all the sub-locations and therefore their role in the transmission of the disease needs to be studied.

Rhipicephalus appendiculatus was the commonest tick species in all the sub-locations. This may explain the relatively higher sero-prevalence of *Theileria parva* compared to *Anaplasma marginale* and *Babesia bigemina.* With the exception of Kathome and Ndunduni sub-locations where tick control was generally good, there was likely to have been challenge by *R. appendiculatus* throughout the year in the other sub-locations. As a consequence of continuous tick challenge, most calves (≤ 6 months) were exposed to a low but continuous *T. parva* challenge leading to a state of endemic stability (Kivaria *et al*., 2004). A typical ECF endemic stability state is characterized by rare clinical disease with low mortality rates that are limited to young stock. This state is found in a few localized parts of the country where the local Zebu cattle are maintained under extensive management conditions with little or no efficacious acaricide application and where *R. appendiculatus* can undergo at least two generations annually (Perry *et al*., 1994). Under such circumstances, greater numbers of cattle are reservoirs of *T. parva* at low levels of parasitaemia and thus ticks bear low infection rates. Calves born in these areas become immune through natural infection before they are three months old (Moll *et al*., 1986) and therefore little or no clinical disease occurs. Parameters used to characterize endemic stability are the antibody prevalence of calves (Deem *et al.*, 1993) and age-specific morbidity and mortality rates (Norval *et al.*, 1992). This state of endemic stability appeared to occur in Athi River and Ndithini divisions but was absent in Kangundo and Matungulu Divisions.

Amblyomma variegatum, the vector of *Ehrlichia ruminantium* (heartwater) was one of the common tick species in the study area. Blood samples collected from the three livestock species were not screened due to problems with the standardization of the ELISA kits used in the screening of Cowdria (*Ehrlichia ruminantium*,), the main tick-borne disease of small ruminants in Eastern Africa (Dolan, 1991). It will be necessary to screen the sera for *Ehrlichia ruminantium* once the problem with the kits is resolved so as to obtain a clearer picture of the sero-prevalence of all the major TBDs in the study area as at the time of the survey. *Ehrlichia ruminantium* has previously been isolated (Ngumi *et al*., 1997) from a sub-location adjacent to the study site.

Generally, the high tick challenge in the study area could largely be attributed to a break down in tick control services formerly supported by the government not only in the County, but in the rest of the country. Despite the enactment of the Cattle Cleansing Act (GoK, 1976) which led to the initiation of a national tick control programme, adequate control of ticks and TBDs is still far from being achieved. The structural adjustment programm as advocated by the World Bank in the late 1980s and the escalating costs of acaricides, relevant infrastructure and monitoring services for the intensive tick control strategies advocated by the Cattle Cleansing Act led to the inability of the government services to sustain the program. Just like in other parts of the country, poor management of dips by local committees in the County virtually led to the collapse of the tick control facilities. As a result, most farmers depend on hand sprays to apply acaricides on the animals (personal observation).

In conclusion, introduction of exotic breeds, which are highly susceptible to TBD, should be undertaken with strict tick control. However, inspite of the high level of tick challenge in the County, it is possible to introduce improved cattle breeds if an integrated approach to the control of tick-borne diseases is adopted that will lead to the development of endemic stability. This is feasible with ECF, if a policy of strategic dipping, in combination with other strategies such as immunization against the disease is adopted. A similar approach can be eventually adopted with the other TBDs subject to further studies being conducted on which combination of strategies is most effective.

CHAPTER 6

MORBIDITY AND PRODUCTIVITY ESTIMATES IN SMALLHOLDER LIVESTOCK FARMS IN MACHAKOS COUNTY

6.1 INTRODUCTION

A few epidemiological and socio-economic studies aimed at assessing the risk of TBDs have been conducted in the Coast, Central and Western regions of Kenya (Maloo, 1993; Maloo *et al.,* 1994). In Machakos County, and indeed in much of the eastern region of the country, such data are largely lacking. These data would be invaluable in the design of appropriate and targeted control programmes of TBDs known to have negative impact on livestock productivity arising from morbidity and mortality (Minjauw and McLeod, 2003). Data from other regions of the country cannot be extrapolated to the situation in Machakos County due to differences in climatic and cattle production systems. Longitudinal studies incorporating intensive monitoring are best suited to reliably evaluate the risk and impact of these diseases.

In this Chapter, the incidence of ECF and other diseases affecting livestock productivity in both cattle and small ruminants are assessed.

6.2 MATERIALS AND METHODS

6.2.1 Study implementation

6.2.1.1 *Selection of farms for the longitudinal study*

The study was carried out in seven sub-locations (Kiatineni, Kalandini, Katine, Ndunduni, Kathome, Katani and Ngelani). Milani sub-location in Ndithini Division was omitted because of inaccessibility during the rainy season. Four farms from each of the three divisions (Kangundo, Matungulu and Athi River) and two from Ndithini Division were randomly selected for the study from a sampling frame described in Chapter 4. Using random number tables, two farms per study sub-location were randomly selected from the list of farms that participated in the cross-sectional survey. Milani sub-location was omitted from the list of selected sub-locations due to concerns about accessibility during the rainy seasons. Thus, fourteen herds were selected for the study.
The selected farms were then followed up for 12 months.

6.2.1.2 *Recruitment of study animals*

All young animals (calves, lambs and kids) found on the 14 farms at the time of the first farm visits in January 2008 were recorded and ear-tagged for ease of identification. Other young animals (calves, kids and lambs) were recruited as they entered the study population mainly through births.

6.2.2 Monitoring of animal health and productivity

6.2.2.1 *Data collection*

A notebook was issued to all the study farmers for keeping simple farm records such as livestock births, deaths, sales and milk production. All the farms were followed- up on monthly basis for 12 months. During each of the farm monitoring visits, a short questionnaire (Appendix 6.1) was used to collect and record both farm and animal level data. The information sought included:

- Birth weights.
- Occurrence of diseases.
- Herd dynamics (births, mortality, culling rates, sales).
- Weaning weights and ages.
- Fertility and breeding female management.
- Milk production of cows calving during the observation period.
- Tick challenge. On every visit all selected animals (cattle, sheep and goats) on the farms were observed for presence of ticks and categorized as described in Chapter 5.
- Tick control. Tick control was categorized as follows:

Regular= acaricide (dip, spray or pour- on) applied according to anufacturers'instructions at 1-2 weeks interval. Irregular= acaricide (dip, spray or pour- on) applied according to manufacturers' instructions only at times of high tick challenge.

None= no tick control measures used.

- Other information recorded during the monthly visits were:

Veterinary interventions and farm management practices undertaken (such as treatments, castrations, dehorning, vaccinations and deworming) between visits. Details of the date(s) when the interventions were undertaken as well as the costs were recorded.

The questionnaires were administered to the designated head of the household or the person in charge of the management of the farm. For each of the administrative sub-locations, the local animal health assistant was recruited as an enumerator to perform the interviews in the local Kikamba language.

6.2.2.2 *Disease diagnosis and reporting*

Besides monthly visits by the principal investigator, occurrence of disease on the selected farms was monitored on a daily basis by the livestock owner. Farmers were instructed to report all suspected cases of disease to either the animal health assistant or the principal investigator to enhance data collection and recording. In three of the sub-locations (Katine, Ndithini and Ndunduni), the local animal health assistants were recruited to monitor the occurrence of diseases. Other farms relied on mobile phone communication to notify the chief investigator of disease occurrences who then visited such farms within a period of not more than 24 hours. The animal health assistants were also instructed to notify the principal investigator of disease conditions of which they could not make a diagnosis.

To avoid losing any of the recruited animals particularly calves to TBDs, the livestock owners were also trained in early recognition of clinical signs of TBDs, namely, ECF, anaplasma, cowdriosis (heartwater) and babesiosis. To enhance reporting and confirmation of diseases, all clinical cases of TBDs in cattle on the study farms were treated free of charge throughout the trial period.

Cases of ECF were tentatively diagnosed in the field based on clinical assessment. The key clinical signs of the disease included malaise, lachrymation or corneal opacity, petechiael haemorrhages on gums and tongue, anorexia, acute respiratory distress, parotid and pre-scapular lymph node enlargement and a fever (rectal temperature of more than 39.4^{o}C). For anaplasmosis the signs were high fever (40.5^{o}C) progressive anaemia, jaundice and in some cases passing of hard faeces, and for babesiosis the clinical signs were an acute onset of high fever (41^{o}C), jaundice and dark red to brown urine. Cowdriosis was suspected in the event of sudden death and nervous signs being observed particularly in small ruminants.

A thin and thick blood smear and a lymph node biopsy smear were made from all reported cases before treatment. Definitive diagnoses were done following examination of Giemsa-stained samples at the veterinary research laboratories, Muguga. Arrangements were made to deliver samples that needed to be examined in the laboratory soon after fixing in alcohol. This was usually done within 24 hours of clinical diagnosis.

Acceptable animal welfare standards were taken into consideration in this study. Hence, study animals were not unduly left to die in order to monitor mortality. All cattle that were diagnosed with ECF were treated using buparvaquone (Butalex®, Scheling-Plough Animal Health, UK) at a dose of 2.5 mg/kg.

6.2.2.3 *Confirmation of tick-borne infections*

The stained thin blood smears were used for examination of haemoparasites either for general assessment of the prevalence of TBDs or to confirm suspected disease cases. Each smear was examined for theilerial piroplasms, anaplasma and babesia parasites in the red blood cells using the oil immersion x 100 objective of the light microscope. At least three fields were thoroughly examined for each smear. Detection of specific parasites in blood smears was confirmatory for anaplasmosis, and babesiosis and ECF by detection of macroshizonts in the lymphocytes on stained lymph node smears (Figures 6.1 and 6.2). Only positively confirmed cases of TBDs were included in the analysis. In case of death, a postmortem was carried out whenever possible. All information was recorded in a field sheet.

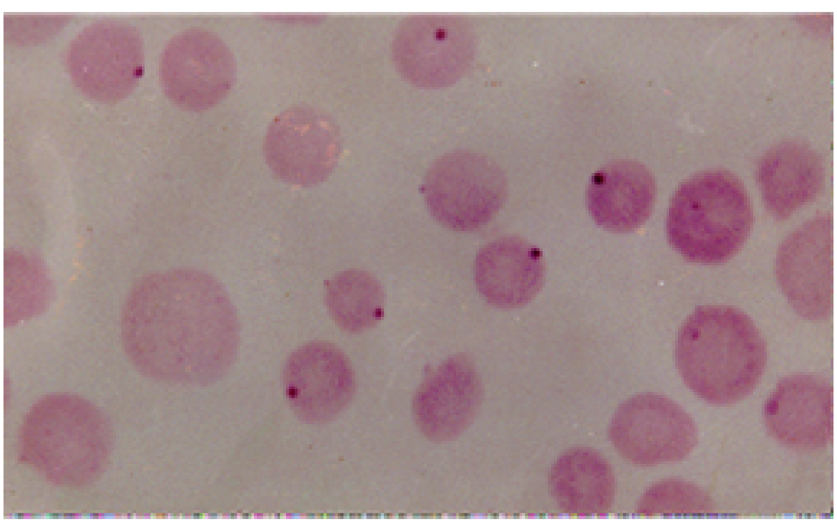

Figure 6.1: *Anaplasma marginale* bodies in red blood cell.

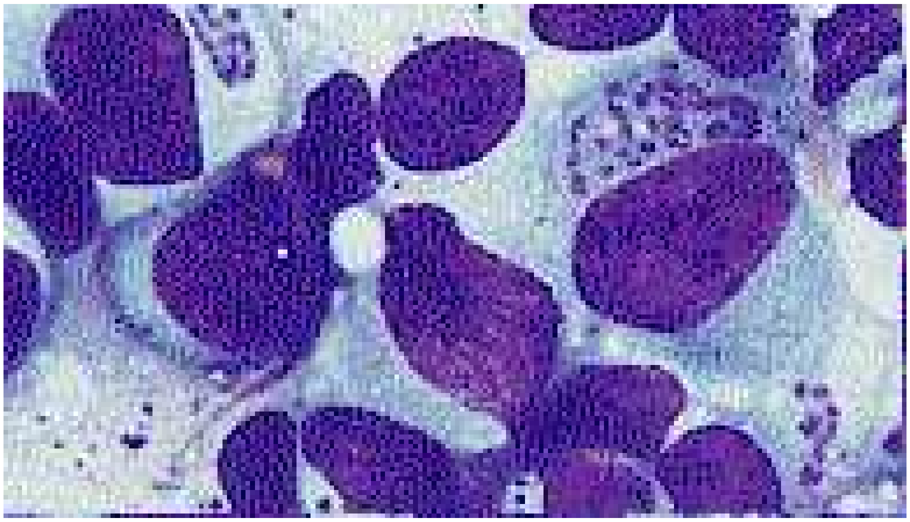

Figure 6.2: Macroschizonts in lymphocytes.

6.2.2.4 *Diagnosis and confirmation of other common infections*

General bacterial infections were confirmed on the basis of response to antibiotic treatment reported by the farmers, three to four days after the treatment.

Mange and mycotic infections were confirmed from the observed lesions and microscopic examination. Areas of thickened skin in obviously itchy animals were very suggestive of mites, particularly if there was no evidence of lice. Skin scrapings were taken from the thickened sections for examination under a microscope in the laboratory.

Helminth infections were confirmed through examination of faecal samples using the quantative McMaster floatation method (Souslby, 1982) for detection of nematode eggs and cestode eggs and coccidian oocysts. A simple sedimentation method was used for detection of trematode eggs. Animals with faecal nematode egg counts of up to 100,000 eggs per gram of faeces (epg) were categorized as suffering from acute nematode infection while those with faecal egg counts of 2,000 or less were considered to be suffering from chronic nematode infection (Allonby and Urquhart, 1975; Nginyi, 1999). Diagnosis of helminthosis was done in conjunction with clinical signs such as anemia, edema in the mandibular region, weakness, unthriftness and emaciation.

The symptoms on which diagnosis of malnutrition was based included weakness with protrusion of bones of the shoulders, ribs, backbone and hips, sunken eyes and tucked up abdomens. On postmortem, it was diagnosed based on lack of fat under the skin, very little body fat around the heart, kidneys and other organs and within the bone marrow, reduced muscle mass, and shrunken body organs.

6.2.2.5 *Collection of data on animal productivity and herd dynamics*

The farmers were requested to record in the notebooks births, deaths and animals sold or brought into the farm. Farmers with lactating animals were asked to record the daily milk production. In the three sub-locations where AHAs were available, they were asked to make regular visits to the farms to ensure that farmers made the required entries into the notebooks. The live weight of all calves was estimated and recorded by the same person (the chief investigator) using a weight band (Dalton supplies) during the monthly visits. Live weights of kids and lambs were taken using a spring weigh scale (Hanson® Model 21). Farmers were asked to report animal births (and hence date of calving) as soon as possible to enable birth weights to be taken. Records were also taken of when calves, lambs and kids were weaned. Data on cases of infertility in cows and breeding management were also recorded.

6.2.3 Estimating productivity parameters

6.2.3.1 *Productivity rate*

The productivity rates and the formula used to derive them are summarized in Table 6.1. The rates were based on the twelve- month follow up period. Data on female infertility and management were also obtained. Infertility was defined as diminished or lack of capacity to produce viable offspring.

6.2.3.2 *Birth weights, weight at weaning and age at weaning*

Birth weights, weight at weaning and age at weaning were obtained for calves, kids and lambs born during the 12-month observation period. The mean birth weights were derived only for the animals whose records were taken within 24 hours of birth.

6.2.3.3 *Estimation of milk production*

Farmers kept records of daily milk output from all cows that calved and those that were already lactating during the observation period. Measurements were done in litres using calibrated 1 litre plastic cups, beer bottles (0.5 litres) or soda bottles (0.3 litres). Two milk production parameters; mean daily yield per cow and annual lactation yield were estimated. The production estimates were made for three periods categorised as peak (1 to 90 days), declines (91 to 180 days) and late (181 to 365 days) phases of lactation.

Table 6.1: Definition of productivity parameters estimated during the longitudinal study of smallholder farms in Machakos County, 2007.

Parameter	Definition
Bull / cow ratio	$\frac{\text{Number of mature bulls}}{\text{Number of cows}}$
Parturition rate	Number of parturitions per female per year
Off-take rate	$\frac{\text{Sales/exits x 100}}{\text{Herd size}}$

6.2.4 Incidence rates

Disease incidence rates were calculated as the ratio of the number of observed events per unit time to the population at risk (Putt *et al*., 1987). True rates were calculated to define the speed of occurrence of TBDs or productivity parameters. The specific rates are defined in the relevant sections. Generally, the incident rates (IR) for the various diseases were computed as described in Martin *et al*. (1987):

$$IR = \frac{\text{Number of events during observation period}}{\text{Animal months at risk}}$$

The monthly rates were subsequently converted into annual rates

In order to calculate the true incidence rates of the disease events, the entry and exit points for the animals was determined. The denominator for estimating incidence was the number of animal-months between the dates the longitudinal phase of the study began (or date of recruitment for those animals introduced into the study after commencement) and detection of infection, withdrawal from the study, or end of the study.

Incidence rates of the various diseases recorded during the observation were computed.

In addition, age- specific rates were also computed. Cattle were categorized as calves (from birth to 12 months of age), yearlings (13-24 months) and adults (over 2 years of age). Goats and sheep were categorised as kids/ lambs (less than 6 months), weaners (6 months to less than 1 year) and adults (1 year and above). The categorization of goats and sheep is as described by SR-CRSP (1992), Abegaz and Awgichew (2009) and Schoenian (2012). Under this categorization, on average goats and sheep naturally wean by 6 months and attain sexually maturity by 1 year of age.

6.2.5 Meteorological data

The main meteorological station nearest to the longitudinal sites was Katumani, close to Machakos town. Rainfall figures, daily minimum and maximum temperatures for the period of the longitudinal study (Jan 2008 to May 2009) were derived from records kept at the station. The mean monthly values were then calculated from the daily values.

6.3 Data management and analysis

Three separate dataset files for cattle, sheep and goats were designed in Microsoft Access (Microsoft Corporation, USA) to store data on individual animal variables (animal number, age, sex, breed) visit variables (animal number, entries, exits, diseases, tick counts, applied methods of disease control) and farm level variables (division, location, farm code). After screening the files for errors, they were exported to STATA Version 10 (StataCorp, 2007) program for analysis. Risk periods for calculation of incidence rates for various disease events were calculated in Microsoft Excel program (Microsoft Corporation, USA) after exporting the relevant data files from the Access program.

6.4 RESULTS

6.4.1 Meteorological Data

The mean monthly rainfall was 1.25mm (Figure 6.1). A maximum of 4.31 mm was received during the traditional long rain period of March to June. Hardly any rainfall was received between May and October.

No major temperature fluctuations were recorded during the study period with the temperature generally within the normal annual range of 18-25^{o} C for the County (Figure 6.2).

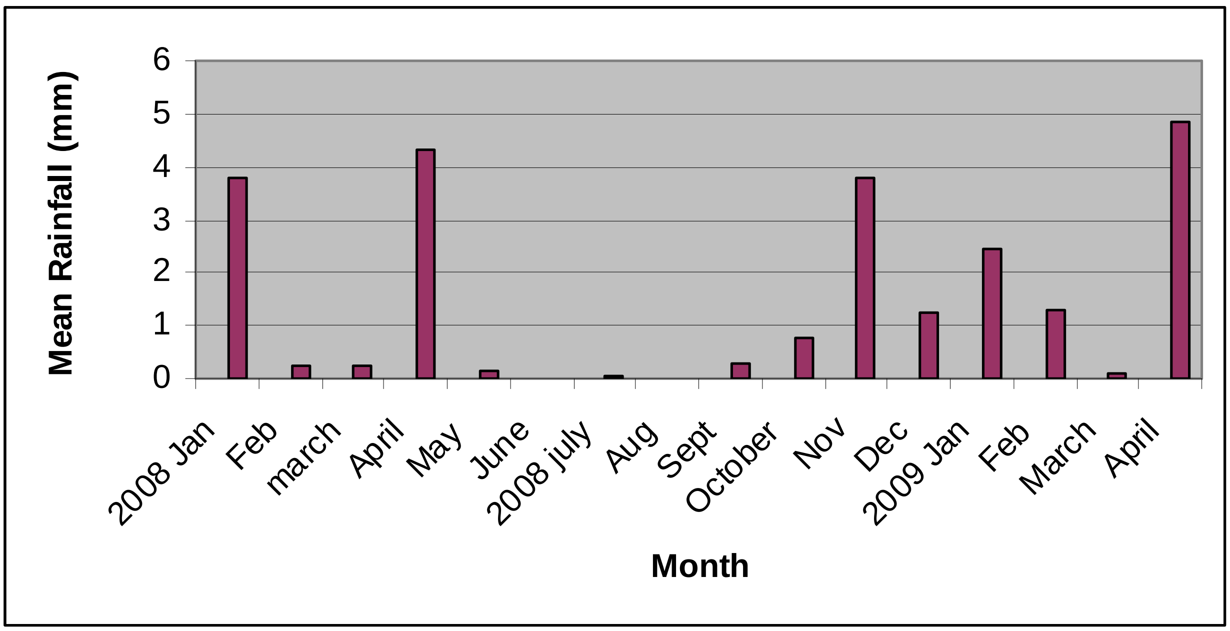

Fig 6.3: Distribution of rainfall in the study area during the monitoring period (Jan 2008-April 2009).

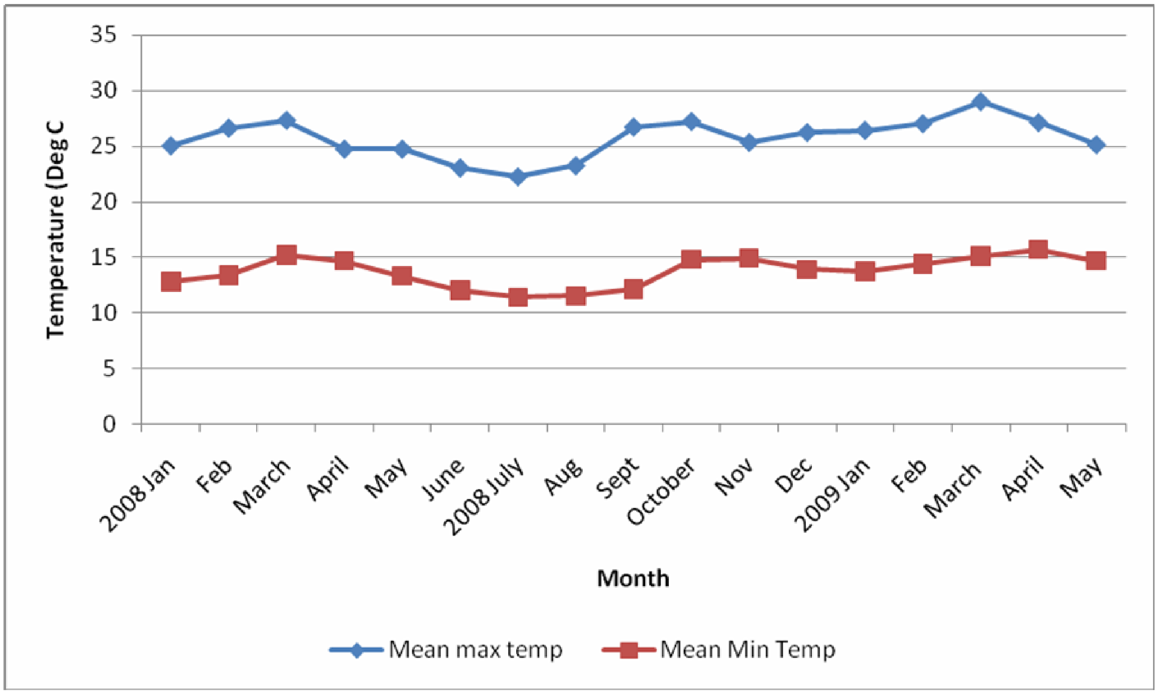

Figure 6.4: Mean maximum and minimum monthly temperature in the study area during the monitoring period (Jan 2008-April 2009).

6.4.2 Characteristics of the study farms

The characteristics of the 14 study farms are summarized in Table 6.2. The average size of the farms was 18.9 acres (range 1.5 to 72). All the farms practiced mixed farming. The average number of cattle was 15.8 (range 4-47). Only 14.2% (2/14) of the farms (all in Kangundo Division) had improved (indigenous zebu/ exotic crosses) dairy cattle that were zero-grazed. Cattle on the remaining 12 farms (85.7%) were reared under the free grazing system.

Sheep were the least common species of livestock on the study farms. The average number of sheep on the farms was 6 (range 0-24) while the average number of goats was 12.1 (range 0-50). The breeds of sheep and goats found on the farms were indigenous breeds of sheep (red Maasai) and goats (the small East African goat).

The housing for calves, goats and sheep consisted of simple grass thatched or galvanised sheets roofs supported by gum or eucalyptus poles. The walls consisted of widely spaced eucalyptus poles designed to keep the animals confined and keep predators away.

Table 6.2: Farm characteristics of the 14 farms that participated in the longitudinal study in Machakos County in 2008 to 2009.

Division	Farm code	Farm size (acres)	No of cattle	No of sheep	No of goats
Athi River	ATH/07	25	20	5	0
	ATH/17	15	14	0	12
	NGE/08	70	47	24	43
	NGE/11	72	40	15	50
Kangundo	KAN/05	9	5	3	0
	KAN/15	1.5	5	0	2
	KAT/01	10	20	0	26
	KAT/08	2	4	0	2
Matungulu	KAL/04	20	30	15	10
	KAL/21	4	12	6	0
	KNE/05	7	4	12	2
	KNE/08	8	4	4	3
Ndithini	ND/11	18	8	0	20
	ND/13	3	8	0	0
Total		264.5	221	84	170
Average		18.9	15.8	6	12.1

6.4.3 Cohort dynamics

6.4.3.1 *Cattle cohort dynamics*

Initially, 17 calves and 7 yearlings with birth and disease history records were recruited (Table 6.3). These calves and yearlings were found on 13 of the farms. Calf entries resulted mainly from births within the study farms. Out of a total of 65 new entries observed, 56 (86.2%) were from births with male calves contributing 29 (51.7%) of the births. No calving took place in one of the farms throughout the study period. Six calves and 3 yearlings entered the farms from other farms as gifts or entrustments. Of the 9 calves and yearlings that were transferred into the selected farms during the study, 6 were female and 3 were male. Sixty (92.3%) of the new entries were indigenous (zebu) while 5 five (7.7%) were exotic. A total of 26 calves that contributed to the follow–ups exited from the study cohort before the end of the study due to deaths, sales, theft or transfer out of farms as gifts or entrustments. Of the exits, 16 (61.5%) were female and the other 10 were male. Twenty-three (88.4%) of the exits were calves or yearlings of indigenous (Zebu) breed. Fourteen (53.8%) of the exits came from Athi River, Kangundo 5 (19.2%), Ndithini 2 (7.7%) and 5 (19.2) from Matungulu Division.

No adult cattle were brought into the any of the recruited farms during the study period. However, five animals, all cows exited during the study period. Three cows died during the observational period while 1 cow each was given out as a present or sold. No cow or breeding bull was culled during the study period.

Table 6.3: A cohort of calves/ yearlings monitored for 12 months and reasons for exit from the study.

Entries since precious visit				Withdrawals since previous visit					
Visit Number	Births	Transfers	Total	Deaths	Sales	Transfers	Theft	Total	No. calves/yearlings observed
Initial				N/A	N/A	N/A	N/A	N/A	24
1	6		6	0	0	0	0	0	30
2	6	1	7	2	0	0	0	2	35
3	7	5	12	1	0	3	1	5	42
4	2	1	3	2	2	0	1	5	40
5	3		3	1	2	0	0	3	40
6	2		2	0	0	1	0	1	41
7	4		4	1	0	2	1	4	41
8	7		7	0	0	0	0	0	48
9	3	2	5	1	0	0	0	1	52
10	6		6	1	2	0	0	3	55
11	5		5	0	1	1	0	2	58
12	5		5	0	0	0	0	0	63
Total	56	9*	65	9	7	7	3	26	

* Three of the transfers into the study farms were yearlings

6.4.3.2 *Kids and lambs dynamics on the study farms*

Twenty-eight lambs/kids and 7 weaners were originally recruited into the study (Table 6.4). The kids and lambs were recruited from each of the selected farms while the weaners were found on 35.7% (5/14) of the farms. The 12 monitoring visits resulted into 632 individual observations for goats and sheep. New entries resulted mainly from births within the farms. Of the 43 new entries, 79.0% (34/43) were from births. Female kids/ lambs contributed 70.5 % (24/43) of the new births.

Eight goats and sheep (4 weaners and 4 adults) were bought and brought into the farms during the study. One goat (a male adult) entered one of the farms as a gift. Of the new entries that entered the farms through purchasing or as gifts, 5 were male while 4 were female.

Twenty one (48.8%) of the new entries were recorded in Athi River Division. Five (11.6%) new entries were recorded in Kangundo Division. Ndithini had 14.0% (6/43) while Matungulu Divisions had 25.6% (11/43) new entries.

A total of 14 exits were recorded during the study due to deaths, sales, theft or transfer out of the farms as gifts or entrustments (Table 6.4). Five of the exits were a result of death from disease, 4 animals were sold, another 4 were transferred to other farms while 1 animal was stolen from one of the farms.

Table 6.4: A cohort of goats and sheep followed up for 12 months in Machakos County, 2008 to 2009 reasons for exit from the study.

	Entries since precious visit				Withdrawals since previous visit					
Visit Number	Births	Purchase	Transfers	Total	Deaths	Sales	Transfers	Theft	Total	No. kids/lambs observed
Initial	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	28
1	2	0	0	2	0	0	2	0	2	28
2	2	1	0	3	0	0	0	0	0	31
3	1	0	0	1	1	0	0	0	1	31
4	4	0	0	4	1	0	0	0	1	34
5	1	0	0	1	1	1	0	1	3	32
6	2	4	1	7	0	0	1	0	1	38
7	6	1	0	7	1	0	0	0	1	44
8	5	0	0	5	0	0	1	0	1	48
9	4	0	0	4	0	0	0	0	0	52
10	2	2	0	4	0	0	0	0	0	56
11	1	0	0	1	1	2	0	0	3	54
12	4	0	0	4	0	1	0	0	1	57
Total	34	8	1	43	5	4	4	1	14	

6.4.4 Morbidity rates

6.4.4.1 *Incidence of East Coast fever*

Table 6.5 shows the true annualized incidence rates of confirmed ECF cases distributed according to both farm and animal level factors. Twenty-six (26) cases of ECF were confirmed only in the indigenous zebu cattle in the 14 farms during the one-year follow-up period. This converted to an overall incidence rate of 2.6% per calf-month. The rate was significantly ($p < 0.05$) higher in calves (64.1%) than in yearlings (0%) and adults (6.20%) (Table 6.5). Indeed, adults were 10 times (IRR=0.1) less likely to develop ECF relative to calves. Similarly, significantly ($p<0.05$) more cases of ECF occurred in animals on farms where there was no tick control (incidence rate =60.86%) compared to farms where tick control was practiced (incidence rate of 9.95%). There was a close relationship between the incidence of ECF and frequency of acaricide application as shown by the drastic decrease in the incidence as the frequency increases (Table 6.5). Season was associated with the occurrence of ECF with significantly ($p<0.05$) more cases reported in the rainy season (incidence rate 45.93%) than in the dry season (incidence rate 20.03%). Division was associated with disease as significantly ($p<0.05$) more cases were recorded in Athi River Division compared to the other 3 study divisions (Table 6.5).

Table 6.5: The incidence of ECF in Machakos County categorized by animal and farm level factors (Jan 2008 to Jan 2009).

Variable	Levels	No. of cases	Animal months-at-risk	Incidence rate (%) per cow month (95% CI)	Annual incidence rate[1]	Incidence rate ratio (IRR)	p-value
Division	Ndithini	1	133	0.7 (0.0, 4.2)	9.02[a]	0.14	0.02
	Kangundo	1	212	0.4 (0, 2.6)	5.66[a]	0.09	0.05
	Matungulu	3	288	1.0 (0.2, 3.0)	12.5[a]	0.19	0.01
	Athi	21	384	5.5 (3.4, 8.4)	65.63[b]	1.00	-
Breed	Indigenous	26	926	2.8 (1.8, 4.1)	33.70	-	
	Exotic	0	91	0	0	-	
Age	Yearling	0	181	0	0	-	-
	Adult	2	387	0.5 (0.0, 1.9)	6.20[a]	0.10	0.02
	Calf	24	449	5.3 (3.4, 8.0)	64.14[b]	1.00	
Sex	Female	18	661	2.7 (1.6, 4.3)	32.68[a]	1.22	0.64
	Male	8	356	2.2 (0.9, 4.4)	26.96[a]	1.00	
Tick levels	Low	5	305	1.6 (0.5, 3.8)	19.68[a]	0.84	0.78
	Moderate	5	202	2.5 (0.8, 5.8)	29.70[a]	1.27	0.69
	High	10	203	4.9 (2.4, 9.1)	59.14[a]	2.53	0.07
	None	6	307	2.0 (0.7, 4.3)	23.45[b]	1.00	
Tick control	Yes	5	603	0.8 (0.2, 1.9)	9.95[a]	0.16	0.00
	No	21	414	5.1 (3.1, 7.8)	60.86[b]	1.00	
Tick challenge	No	6	307	2.0 (0.7, 4.3)	23.45[a]	0.69	0.42
	Yes	20	710	2.8 (1.7, 4.4)	33.80[a]	1.00	
Season	Wet (Rainy)	16	418	3.8 (2.2, 6.2)	45.93[a]	2.30	0.04
	Dry	10	599	1.7 (0.8, 3.1)	20.03[b]	1.00	
[2]Dipping frequency	>8	3	334	0.9 (0.2, 2.6)	10.78[a]	0.41	0.17
	0-4	10	82	12.2 (5.8, 22.4)	146.4[b]	5.66	0.00
	5-8	13	601	2.2 (1.2, 3.7)	26.4[c]	1.00	

[1]Rates followed by a different superscripts are statistically different ($p<0.05$)

[2] Key to dipping frequency: Categories 0-4, 5-8 and >8 refer to the total number of times that tick control was practiced at farm level during the entire observation period

6.4.4.2 *Incidence of other diseases and conditions*

In the course of the follow-up period, 4 cases of anaplasmosis were confirmed converting to an annual incidence of 4.26% per cow- year. Of the 4 cases, 2 were in calves and 2 in yearlings equivalent to annual incidence rates of 4.44% per cow-year and 1.11% per cow-year, respectively.

Other conditions/ infections observed in cattle included malnutrition (13 cases), mange (*Chorioptes bovis*) (9 cases), mycosis (*Trichophytan bovis*) (7 cases) and diarrhoea (7 cases). Malnutrition was found in three of the study divisions and the annual incidence rate ranged from a high of 26.3% in Matungulu Division to 14.5 % per cow-year in Athi River and 9.2% per cow-year in Ndithini Division (Table 6.6). These rates were not significantly different at 5% significance level. All the cases of malnutrition were diagnosed in indigenous cattle and equally in all the age categories and sexes. There was no association (p>0.05) between malnutrition and season (wet/dry) and any of the other variables considered (Table 6.6).

Table 6.6: The incidence of malnutrition in Machakos County categorized by animal and farm level factors (Jan 2008 to Jan 2009).

Variable	Levels	No. of cases	Animal months-at-risk	Incidence rate (%) per cow month (95% CI)	Annual Incidence rate	Incidence Rate Ratio (IRR)	P-value
Division	Ndithini	1	131	0.8 (0, 4.3)	9.17	0.76	0.80
	Kangundo	0	223	0	0	0	-
	Matungulu	6	274	2.2 (0.8, 4.8)	26.28	1.46	0.58
	Athi	6	498	1.2 (0.4, 2.6)	14.45	1.00	-
Breed	Indigenous	13	1035	1.3 (0.7, 2.1)	15.06	-	-
	Exotic	0	91	0	0	-	-
Age	Yearling	2	216	0.9 (0.1, 3.3)	11.11	1.26	0.79
	Adult	6	370	1.6 (0.6, 3.5)	11.11	1.47	0.59
	Calf	5	540	0.9 (0.3, 2.2)	19.46	1.00	
Sex	Female	9	761	1.2 (0.5, 2.2)	13.15	1.93	0.40
	Male	4	365	1.1 (0.3, 2.8)	14.40	1.00	
Season	Wet	6	469	1.3 (0.5, 2.8)	15.35	2.11	0.25
	Dry	7	657	1.1 (0.4, 2.2)	12.78	1.00	

Mange was diagnosed in all the 4 divisions with the highest incidence rate (12.12% per cow-year) recorded in cattle in Kangundo Division (Table 6.7). However, the rates were not significantly different between the divisions at 5% significance level. Although the incidence rates were not significantly different in the three age categories, it was higher in calves than in yearlings and adults. Of all the variables that were considered only the variable "tick control" was associated with mange (Table 6.7). Mange was significantly ($p<0.05$) higher on farms where tick control was not practiced (incidence of 14.17 per animal year) compared to farms where tick control was practiced (incidence of 2.61 per animal year). This was an indication that the acaricides used for tick control were also effective on mites.

Table 6.7: The incidence of mange in Machakos County categorized by animal and farm level factors (Jan 2008 to Jan 2009).

Variable	Levels	No. of cases	Animal months-at-risk	Incidence rate (%) per cow month (95% CI)	Annual incidence	Incidence rate ratio (IRR)	p-value
Division	Athi	4	502	0.7 (0.2, 2.0)	9.56	1.00	
	Ndithini	1	134	0.7 (0.4, 4.2)	8.95	0.94	0.95
	Kangundo	2	198	1.0 (0.1, 3.6)	12.12	0.62	0.67
	Matungulu	2	301	0.7 (0, 2.4)	7.97	0.84	0.84
Breed	Indigenous	9	1044	0.9 (0.4, 1.6)	10.34	-	
	Exotic	0	91	0	0	-	
Age	Calf	7	521	1.3 (0.5, 2.8)	16.12	1.00	
	Yearling	1	216	0.5 (0, 2.6)	5.56	0.35	0.32
	Adult	1	398	0.3 (0, 1.4)	3.21	-	
Sex	Male	2	381	0.5 (0, 1.9)	6.30	0.66	0.61
	Female	7	754	0.9 (0.4, 1.9)	11.14	1.00	
Tick control	Yes	1	458	0.2 (0, 1.2)	14.17	0.10	0.02
	No	8	677	1.2 (0.5, 2.3)	2.61	1.00	
Season	Wet	2	468	0.4 (0, 1.5)	5.13	0.48	0.36
	Dry	7	667	1.0 (0.4, 2.2)	12.6	1.00	

* Key to dipping frequency: Categories 0-4, 5-8 and >8 refer to the total number of times that tick control was practiced at farm level during the entire observation period.

Cases of non-specific diarrhoea were recorded in Athi River, Kangundo and Ndithini Divisions and none in Matungulu (Table 6.8). Of all the factors considered, only breed and season were associated with diarrhea. Exotic cattle were approximately 9 times (RR=9.19) more likely to have diarrhea relative to indigenous cattle. Similarly, diarrhea was 8.7 times more likely during the wet season than in the dry season (Table 6.8).

Table 6.8: The incidence of diarrhea in Machakos County categorized by animal and farm level factors (Jan 2008 to Jan 2009).

Variable	Levels	No. of cases	Animal months-at-risk	Incidence rate (%) per cow month (95% CI)	Annual incidence rate[1]	Incidence rate ratio (IRR)	p-value
Division	Ndithini	1	124	0.8 (0, 4.5)	9.68	1.33	0.80
	Kangundo	3	213	1.4 (0.3, 4.1)	16.90	2.26	0.32
	Matungulu	0	312	0	0	-	
	Athi	3	494	0.6 (0.1, 1.8)	7.29	1.00	
Breed	Exotic	3	81	3.7 (0.8, 10.8)	44.44[a]	9.19	0.00
	Indigenous	4	1062	0.4 (0.1, 1.0)	4.52[b]	1.00	
Age	Yearling	0	227	0	0	-	
	Adult	4	367	1.1 (0.3, 2.8)	13.08	2.01	0.36
	Calf	3	549	0.5 (0.1, 1.6)	6.56	1.00	
Sex	Male	3	378	0.8 (0.2, 2.3)	9.52	1.50	0.60
	Female	4	765	0.5 (0.1, 1.3)	6.27	1.00	
Season	Wet	6	470	1.3 (0.5, 2.8)	15.32[a]	8.66	0.05
	Dry	1	673	0.1 (0, 0.8)	1.78[b]	1.00	

[1]Rates followed by a different superscripts are statistically different ($p<0.05$).

Mycosis was observed in Athi River, Kangundo and Matungulu divisions. Kangundo Division had the highest annual incidence rate (17.83%) of the disease during the observation period (Table 6.9). However, the incidence of the disease was not significantly different between the three divisions ($p>0.05$). No case of the disease was observed in Ndithini Division. The incidence was significantly ($p<0.05$) higher in exotic crosses than in the indigenous zebu cattle and was detected only in calves and yearlings. No association (>0.05) was found between mycosis and the other factors that were considered (Table 6.9).

Table 6.9: The incidence of mycosis in Machakos County categorized by animal and farm level factors (Jan 2008 to Jan 2009).

Variable	Levels	No. of cases	Animal months-at-risk	Incidence rate (%) per cow month (95% CI)	Annual incidence rate[1]	Incidence rate ratio (IRR)	p-Value
Division	Ndithini	0	135	0	0	-	
	Kangundo	3	202	1.5 (0.3, 4.3)	17.83	2.55	0.25
	Matungulu	1	311	0.3 (0, 1.8)	3.86	0.56	0.61
	Athi	3	521	0.6 (0.1, 1.7)	6.90	1.00	
Breed	Exotic	3	70	4.3 (0.9, 12.5)	51.45[a]	11.35	0.00
	Indigenous	4	1099	0.4 (0, 0.9)	4.37[b]	1.00	
Age	Yearling	1	222	0.5 (0, 2.5)	5.41	0.40	0.40
	Adult	0	413	0	0	-	
	Calf	6	534	1.1 (0.4, 2.4)	13.48	1.00	
Sex	Male	2	391	0.5 (0, 1.8)	6.14	0.79	0.78
	Female	5	778	0.6 (0.2, 1.5)	7.71	1.00	
Tick control	Yes	6	691	0.9 (0.3, 1.9)	10.42	4.13	0.19
	No	1	478	0.2 (0, 1.2)	2.51	1.00	
Season	Wet	5	486	1.0 (0.3, 2.4)	12.34	3.52	0.13
	Dry	2	683	0.3 (0, 1.1)	3.51	1.00	

[1]Rates followed by a different superscripts are statistically different ($p<0.05$)

6.4.5 Mortality rates

Eleven cattle died during the follow-up period converting to an overall crude mortality rate of 11.6% per cow-year. Of the 11 that died, 8 were calves and 3 were adults.

Three calves died of ECF, 4 calves died suddenly of a disease condition that could not be established and 1 calf died of diarrhoea.

The cause specific annual mortality rates for ECF, non-specific disease condition and diarrhoea were 6.56%, 8.74% and 2.19% respectively per cow year. One cow each died of milk fever, malnutrition and injuries as a result of falling into a deep pit. This converted to a cause specific annual mortality rate of 3.27% per cow year for each of the three conditions.

6.4.6 Morbidity in sheep and goats

A variety of diseases/ conditions were observed in both sheep and goats during the follow-up period. The cases were too few to enable the computation of true rates as was done for cattle diseases. However, helminthosis had the highest number of cases (8) detected in both species followed by 7 suspected cases of Contagious Caprine Pleuropneumonia (CCPP) (Table 6.10). The helminths identified were *Trichostrongylus colubriformis*. Pneumonia, diarrhea due to bacterial infections, severe flea infestations and mange were the other diseases detected in small ruminants. The 7-suspected cases of CCPP were reported in Ngelani sub-location of Athi River Division. All the goats died despite attempts by the farmer to treat with antibiotics. Confirmation of diagnosis was not done as the farmers did not report the outbreak immediately it occurred. The suspected source of the CCPP outbreak were goats reportedly sourced from North Eastern Kenya.

Table 6.10: Distribution of cases of disease /conditions in sheep and goats during a one-year follow-up period in Machakos County, 2008 -2009.

Species	Disease/ Condition							
	Helminthosis	Pneumonia	Fleas	Mange	Diarrhea	CCPP (suspected)	Injuries	Non specific diagnosis
Sheep	3	1	0	0	1	0	1	2
Goats	5	3	3	1	3	7	1	1
Total	8	4	3	1	4	7	2	3

6.4.7 Estimates of productivity parameters

6.4.7.1 *Mean daily milk yield*

A total of 44 lactating cows were monitored from February 2008 to March 2009 (Table 6.11). The mean daily milk yield was significantly ($p<0.05$) higher for the exotic breeds (6.22 litres) than for the indigenous (1.86 litres) zebu breeds.

Table 6.11: Comparison of the mean daily milk yield between exotic crosses and indigenous breeds of cattle, in Machakos County.

Breed	No. of lactating cows	Mean milk yield (litres)	95% CI	
			Lower	Upper
Exotic crosses	7	6.22	6.17	6.27
Indigenous breed	37	1.86	1.85	1.87
Overall	44	1.97	1.98	1.96

6.4.7.2 *The annual lactation curves*

The decline of milk yield was more pronounced for exotic breeds but was more gradual for indigenous cattle (Figure 6.3). The milk yield for the exotic breeds was higher than for the indigenous breeds for the entire follow-up period. A sharp fall in milk yield was observed for exotic crosses between the first and sixth month of lactation that coincided with the onset of a prolonged dry period.

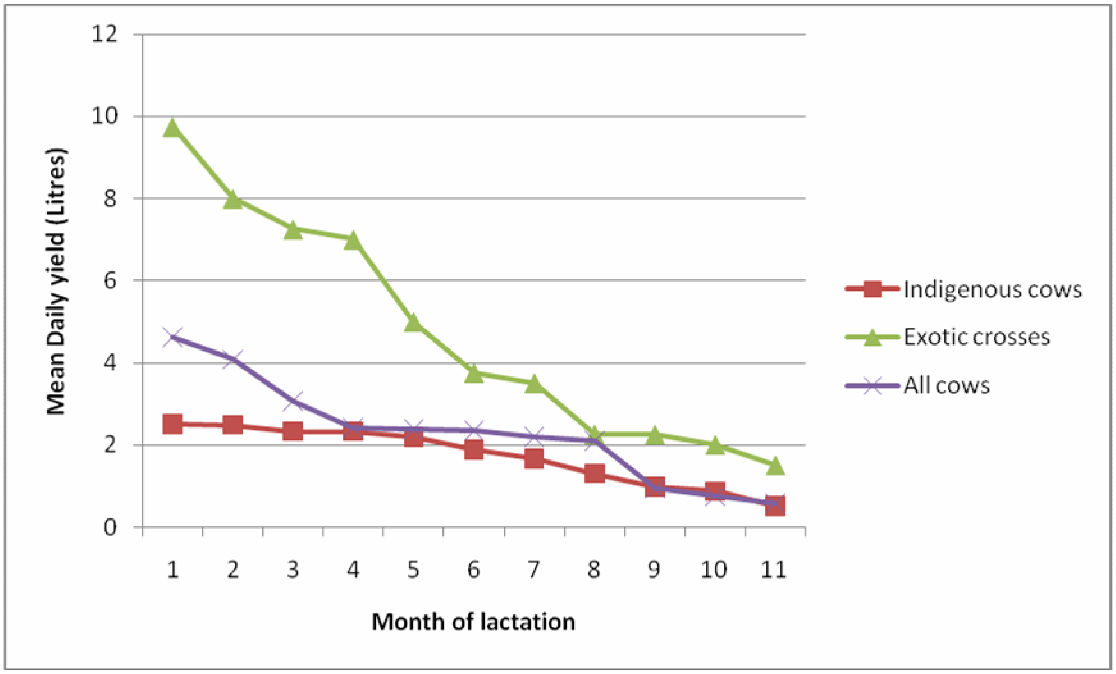

Figure 6.5: Comparative annual lactation curves for exotic cross breeds, indigenous zebu and all cows (combined) monitored in the four divisions of Machakos County in 2008 to 2009.

6.4.7.3 *Birth weights and age at weaning*

A total of 51 calves and a combied total of 34 lambs and kids were recorded within 24 hours of birth (Tables 6.12 and 6.13). The overall estimated mean birth weight for the calves was 27.45kg (range 18-43). However, the mean birth weights were higher for exotic cross calves (37 kg) than for the indigenous calves (26kg) and female calves (29 kg) on average weighed more than male calves (26 kg) (Table 6.12). The highest mean birth weights were recorded for calves in Kangundo Division (32.8kg) and the least in Matungulu Division (21.8kg). The overall mean birth weight for sheep and goats was 3.73kg (range 2- 6) (Table 6.13). Male goats and sheep (3.97kg) on average weighed more than female goats and sheep (3.54 kg). The highest mean birth weights were recorded in Kangundo Division (4.25 kg) and least in Ndithini (2.00kg).

Table 6.12: Distribution of calf birth weights by division, sex and breed in Machakos County, 2008-2009.

Level	Variable	No of calves	Mean birth weight in Kg (range)
Division	Athi River	28	27.50 (20-38)
	Kangundo	9	32.78 (24-43)
	Matungulu	8	21.75 (18-28)
	Ndithini	6	26.83 (21-32)
Sex	Male	24	25.67 (18-35)
	Female	27	29.03 (20-43)
Breed	Indigenous	46	26.41 (18-38)
	Exotic	5	37.0 (34-43)
Overall			27.5 (18-43)

Table 6.13: Distribution of kid and lamb birth weights by division and sex in Machakos County, 2008 to 2009.

Variable	Level	No of sheep and goats	Mean birth weight in kg	(range)
Division				
	Athi River	18	3.61	2-6
	Kangundo	4	4.25	3-6
	Matungulu	10	3.91	2-6
	Ndithini	2	3.54	2-6
Sex	Male	10	3.97	2-6
	Female	24	3.54	2-6
Overall			3.73	2-6

6.4.7.4 *Weaning age*

The overall mean weaning age for calves in the study sites was 101.24 days (Table 6.14). Athi River Division had the lowest mean weaning age (76.2 days) while Kangundo had the highest mean weaning age (140 days). Male calves were weaned at a significantly ($p<0.05$) earlier age than the female calves. There was no significant ($p>0.05$) difference in the mean weaning age between the indigenous and exotic crossbreeds of cattle. Calves in Ndithini Division had the highest mean weaning weight (89.2kg). The average mean weaning weight for the indigenous calves was higher than that of the exotic cross calves.

Table 6.14: Distribution of weaning age and weight by division, sex and breed in Machakos County, 2008 -2009.

Variable	Level	Mean age (days) at weaning	Mean weight in kg (range)
Division	Athi River	76.15 (3-361)	67.57 (23-134)
	Kangundo	140.00 (11-328)	79.63 (24-154)
	Matungulu	116.93 (4-537)	58.46 (18-143)
	*Ndithini	-	-
Sex	Male	83.42 (3-361)	70.52 (18-23)
	Female	117.69 (7-537)	72.33 (23-143)
Breed	Exotic Cross	102.40 (11-283)	67.14 (34-143)
	Indigenous	100.95 (3-537)	70.95 (18-154)
Overall		101.24 (3-537	70.52 (18-154)

* Only one calf was weaned on the selected farms during the study period

The average weaning age for goats and sheep was 143 days (Table 6.15). The lowest weaning age for the small ruminants was recorded in Matungulu Division (122 days) and the highest in Kangundo Division (163 days). Male goats and sheep were weaned at a lower mean age (137 days) than the female goats and sheep (155 days).

Goats and sheep were weaned at a mean weight of 12.25kg. The lowest mean weaning weight was recorded in Matungulu Division (11.09kg) and the highest in Ndithini (16.00kg). Female goats and sheep were weaned at a higher mean weight 13.34kg compared to the male animals (11.71kg).

Table 6.15: Goat and sheep weaning age and weight in the four divisions of Machakos County during the observational study.

Variable	Level	Mean age (days) at weaning (range)	Mean weight (kg) at weaning (range)
Division	Athi River	138.42 (28-248)	12.34 (3-20)
	Kangundo	163.06 (30-248)	11.97 (3-16)
	Matungulu	122.00 (28-235)	11.09 (2-19)
	Ndithini	160.33 (128-218)	16.00 (13-16)
Sex	Male	136.75 (28-248)	11.71 (3-20)
	Female	154.54 (30-248)	13.34 (2-20)
Overall		143.23 (28-248)	12.25 (2-20)

6.4.7.5 *Bull to cow ratio*

The number of mature bulls and breeding females was 47 and 70, respectively, equivalent to a bull/ cow ratio of 1:1.5. However, approximately 50% of the bulls were castrated and thus the breeding bull/ cow ratio was 1:3.0. The two farms that kept exotic crosses relied on artificial insemination services for breeding. Most of the farms that reared indigenous cows shared one bull that they considered to be of "superior genetic" make up. The choice of the suitable breeding bull was based on physical characteristics such as body size, hump size or "skin" colour.

6.4.7.6 *Female fertility and management*

Four cases of infertility were reported during the study period, two in Kathome sub-location and 1 case each in Kalandini and Ndunduni sub-locations. The common practice was to serve cows 4-5 months after calving. Calves were allowed to suckle up to 2-3 months before cows calved. Goats and sheep on average kidded / lambed once a year.

6.4.7.7 *Livestock off-takes*

Livestock off-take was defined as the proportion of animals annually leaving the total herd/flock due to slaughters, sales or other transactions such as exchanges, gifts and loans. Death was excluded from the definition.

The total number of cattle, sheep and goats on each of the study farms are shown in Table 6.2. The number of cattle that exited the study farms in Athi River, Kangundo, Ndithini and Matungulu Divisions was 7, 4, 2 and 3 respectively. This converted into off-take rates of 5.79%, 11.76%, 12.50% and 6.00% respectively.

The corresponding number of sheep and goats that exited the study farms in the four divisions was 3, 3, 0 and 2 respectively. This converted into off-take rates of 2.01%, 9.10%, 0% and 3.85% respectively.

6.5 DISCUSSION

There was a consistently higher entry rate to the study herd compared to the exit rate resulting into an increase of the originally recruited (calf, kid and lamb) cohorts. Births contributed the majority of the entries. These results were similar to observations made by Muraguri (2000) in Kwale and Kilifi Countys in the Coast Province. Majority of the surveyed farmers had high regard for calves, lambs and kids as they regarded them as future replacement stock. Generally, good care was taken of the young animals. For instance in Ndithini and Ngelani sub-locations, the young of all species were housed in specially constructed units to protect them from predators.

Although farmers often sold adult small ruminants to meet their immediate financial needs, cattle were rarely sold even during severe dry spells as was the case during the second half of the study (August 2008 to March 2009) as they were used for long-term investment options. Similar observations were made by Ngategize (1989) in a review of livestock farming systems in Sub-Sahara Africa, Little *et al.* (2001) in northern Kenya and southern Ethiopia, and Maichomo (2008) in the pastoral Masaai community of Kajiado County. Small stocks were useful in cushioning against the effects of drought due to their fast multiplication compared to cattle. The reluctance to sell cattle even when pastures were inadequate resulted in severe malnutrition and starvation to death of animals on some farms. The rearing of livestock in the study area is not entirely a commercial enterprise as may be expected but a combination of source of livelihood and a status symbol. A similar observation was made by Maichomo (2008) in a study carried out in Kajiado County. This is an issue that needs to be addressed if livestock production is to be improved in the County.

Concurrent rearing of cattle, sheep and goats can be used to diversify risks associated with the different species as advocated by Little *et al*. (2001). This becomes important especially during prolonged dry spells because it is known that different livestock species adapt differently to drought (McCabe, 2009). For instance, small ruminants survive on poor quality forbs and browse, which is the only available foliage during severe droughts.

The rate of multiplication for small ruminants is also faster than that of cattle. Thus, a herd of small ruminants recovers from losses incurred during droughts faster than for cattle. The resilience of smallstock in the face of drought has been reported in Tanzania by Mtenga *et al*. (1986), Connor *et al*. (1990), Njombe (1986) and Njombe (1993). Small ruminants are more easily sold compared to cattle during drought events enabling farmers to liquidate their herds to avoid further losses.

Misdiagnosis or unconfirmed cases of disease can lead to biased estimates of disease risk. The current study combined clinical signs and microscopic examination of biopsy smears as the basis for diagnosis of TBDs. The approach is most suitable for confirmation of current infections (Irvin and Mwamachi, 1983) and it may have helped to minimise the incidences of misdiagnosis often associated with the diagnosis of TBDs (O'Callaghan, 1998).

The ability to effectively confirm ECF, as well as other blood parasites on microscopic morphology depends largely on good sampling and skills of the operator (FAO, 1984) as was the case in the current study. The intensive monitoring of the study animals and free treatments offered for the TBDs enhanced both the rate and speed of reporting by the farmers. The incidence of ECF in calves (28.3%) was similar to what Muraguri (2000) and Okuthe and Buyu (2006) estimated in calves in the Coastal lowlands and western highlands of Kenya (23.1% and 32.1%, respectively) but much higher than the 3.57% observed by Swai *et al*. (2009) in the Tanga region of Tanzania.

Calves had a significantly higher incidence of ECF than adults. This was expected as susceptibility is known to significantly decrease with age particularly among indigenous breeds of cattle (Swai *et al.*, 2005; Muraguri *et al.*, 2005; Rubaire-Akiiki *et al.*, 2006; Swai *et al.*, 2009; Phiri *et al*., 2010; Gachohi *et al*., 2012).

There was no significant difference ($p > 0.05$) in the incidence of ECF between female animals and male cattle. This may be because the management of both sexes was observed to be relatively similar. Minjauw and McLeod (2003) made similar observations in India and eastern and southern Africa.

No case of ECF was confirmed in exotic cattle presumably because all the exotic cattle were zero-grazed and therefore under low tick challenge. In addition, it was observed that farmers keeping the breeds tended to apply acaricides more regularly than farmers with indigenous cattle. Exotic cattle are known to be more susceptible to TBDs (Norval *et al.,* 1992; Ndungu *et al.*, 2005; Gachohi *et al*., 2012) and apparently the farmers were aware of this fact.

The incidence of ECF was higher in Athi River Division compared to the other three divisions. These results were consistent with those from the cross-sectional survey carried out earlier whereby the division also had the highest prevalence of the disease. These differences could be attributed to the different environmental conditions since the distribution of the TBD vectors is influenced by ecological, geographical and climatic factors (Swai *et al.,* 2006; Bazarusanga *et al*., 2007; Gachohi *et al.,* 2012). Most farms in

Athi River Division experienced high tick challenge throughout the observation period especially by *Rhipicephalus appendiculatus* unlike Kangundo Division where most farmers zero-grazed their animals.

Only three calves died of ECF during the study period. During the earlier cross-sectional survey, 226 calves were reported to have been treated on 81 of the farms, 12 months prior to the study. It was observed during the longitudinal study that a number of farmers in the County, including some recruited into the study, used herbs to treat ECF. This suggested that the provision of free treatments offered during the trial, could have resulted into a lower mortality rate due to ECF. The other reason could have been an exaggerated diagnosis of ECF in anticipation for support given that ECF treatment is expensive.

There were only four confirmed clinical cases of anaplasmosis and no case of babesiosis in spite of the fact that *Boophilus decoloratus*, a major vector of the two diseases was prevalent in three of the study divisions. These results are similar to those of a study carried out by Swai *et al*. (2009) in the Tanga region of Tanzania. Despite concerns with respect to misdiagnosis of the two diseases, it appeared that many cases of the diseases are routinely reported to the local veterinarian officials (Chapter 3) and there is a need for further epidemiological investigation to be carried out.

Non-specific diarrhea and tick infestations were the most common causes of morbidity in cattle. This finding was similar to that of a study carried out by Phiri *et al*. (2010) in Zambia. Sheep and goat diseases diagnosed most commonly included helminthosis and pneumonia. Pneumonia was particularly a problem in goats. Although only 4 cases were diagnosed on the study farms during the observation period, farmers insisted pneumonia was the commonest disease problem in small ruminants particularly during the cold period of the year (May to August). Indeed, all the cases during the observation period were diagnosed during this period. This may perhaps be due to the poor design of housing for the small stock leading to exposure to cold conditions during the night. The houses were designed to keep away predators or prevent thefts.

Fleas were a serious problem particularly in Kathome sub-location where farmers complained of their persistence despite application of acaricides regularly. They applied amitraz, pyrethroid or organophosphate compounds for fleas control but all were apparently ineffective. Control of fleas appears to be a problem in Kenya as reported in a survey conducted in Kajiado County (Mugambi *et al*., 2012). A plan of action on the control of fleas in the country needs to be drawn up by the Department of Veterinary Services to enable farmers deal with the growing menace. Extension messages in the country on the control of ectoparasites mainly focus on ticks (DVS, personal communication; KARI, 2012) and largely ignore other ectoparasites some of which are of public health importance. Livestock harbour fleas which cause dermatitis, allergies or jiggers in human beings. Some species of bovine fungal and mite infestations can also infect human beings. Thus, the control of livestock ectoparasites needs to be comprehensive in the interest of public health and should not be primarily directed at the control of TBDs.

Contagious Caprine Pleuropneumonia is not known to be endemic in the study area. However, the outbreak of suspected cases of the disease underlies the problem of uncontrolled livestock movements between different parts of the country. Although there is a shortage of veterinary personnel who are tasked with monitoring livestock movement in the study area, the fact that the animals were transported more than 300 kilometres from the North Eastern Province into the County without any valid documentation exposes serious weakness with regard to enforcement of laws governing livestock movement in the country. If the country is to successfully establish the proposed disease free zone (GoK, 2009), which will enable the country to access the lucrative European Union market under vision 2030, then the act (CAP 354) governing livestock movement needs to be strictly enforced. Successful implementation of the disease free zones is expected to have a spin-off effect that will spur livestock development especially in the marginal areas such as the study area.

A spell of drought was experienced during the study period. Though much of the County can be described as being semi arid, the amount of rainfall received was far below the annual average of 500 mm. In arid and semi arid lands of Kenya, drought is the most important hazard encountered by households (Huho *et al*., 2011). Indeed, drought has been increasing in frequency, especially in Northern Kenya from once every 10 years in 1970 to currently once in every 2-3 years in (Howden, 2009). Prolonged droughts can lead to gradual changes in rangelands vegetation from palatable to non-palatable species with the overall effect of diminishing pasture quantity and quality (Huho *et al.*, 1990). The drought weather spell that was experienced during the study period was the cause of malnutrition observed on some of the farms.

The average daily milk production was low compared to that reported for high potential areas in the central region of the country. Although the drought weather conditions adversely affected milk production especially among the exotic crossbreed of cows, the overall average daily milk production (1.98 litres) was less than a third of the average daily milk production of 7.2 litres recorded in the central highlands of Kenya (Staal *et al*., 1997; Karanja *et al*., 2002). The low milk production could be attributed to the predominantly poor breeds of indigenous cattle kept in County, which are not suitable for a dairy cattle enterprise (Thorpe *et al*., 1995).

Previous studies in Kiambu County on factors influencing milk production reported inadequate feeds and poor reproduction management as the key factors (Omore *et al*., 1994). Lack of adequate feed was one of the constraints to livestock production that was ranked highly by the farmers during the rapid appraisal study (Chapter 3). This was further aggravated by the drought conditions experienced during the last three months of the study.

Farmers with exotic crosses of cattle had very limited access to artificial insemination services and relied on "shared" bulls, often of low genetic potential. The resulting offspring were often of lower genetic potential than the dams. This may have contributed to the lower than expected milk production on the farms that kept the exotic crosses. Crossbreeding between suitable *Bos Taurus* breeds and local breeds can be used to improve the genetic potential of the local breeds in the study area.

Although the average weaning age for calves was within the recommended range of 3 to 7 months, calves on some farms were allowed to suckle up to 2 months prior to calving. Studies have shown that cows not being suckled have increased fertility (Larson, 2007). When artificial insemination is used, the pregnancy rate increases by 63% in cows that are weaned at 80 days compared to 54% in cows weaned at 215 days (Larson, 2007). In addition, cows with calves that had been weaned early conceived on average 7 days earlier than those cows with calves that were not weaned early. In small ruminants early weaning enables breeding ewes and does to regain condition faster resulting in higher conception rates (MLA, 2011; Geotsch *et al*., 2011). Early weaning can also help improve the throughput (rate of giving birth) of calves, lambs and kids and therefore further improving livestock productivity. It is also advantageous during drought to avoid rapid deterioration of the body condition of female animals. Livestock productivity in the study area was found to be unsatisfactory but can substantially be improved by adoption of good breeding management and animal husbandry practices.

Although the birth weights of calves seemed not to be adversely affected by the sub-optimal genetic potential of the cattle breeds in the study region, the growth performance as at the time of weaning was low compared to the performances recorded for dairy cattle (Trail and Gregory, 1981) and for beef and dual-purpose cattle (Radostitis *et al*., 1994). Despite the birth weight of the exotic crosses (37kg) being higher than the 23.7 kg recorded by Muraguri (2000) in the Coastal lowlands and Omore *et al*. (1994) in Kiambu County, the weaning weights for calves weaned at 8 months (143-154kg) were less than average weight of 170 kg those recorded by Trail and Gregory (1981) for Boran and Sahiwal calves of similar age. Apart from breed differences, factors that are associated with daily weight again of calves include pasture condition, season, distance to the pastures, watering frequency, initial body weight and infection with TBDs (Gitau *et al*., 2001; Karimi *et al*., 2002). The drier climatic conditions in the study area could have been responsible for the relatively lower average weight attained by the calves at the time of weaning compared to those recorded in higher potential areas of the country.

Productivity of the small ruminants in the study area was sub-optimal. Under good breeding management, goats and sheep are expected to give birth on average twice a year (Schoenian, 2011). None of the breeding ewes or does gave birth more than once during the study period. On all farms, goats and sheep were allowed to mate naturally and this could have been the main cause of the relatively long inter kidding or lambing intervals. However, the birth weights for lambs and kids were comparably to those of other studies (Kiriro, 1986; Goetsch *et al.*, 2011).

Livestock off-take rates were low in all the four study divisions. The off-take rates for cattle were similar to those recorded by Arasio (2004) in Turkana County (1.30% - 12.00%) while the off-take rates for small ruminants were much lower than the 25% recorded in the same study. The off-take rates were also much lower than those recorded by Njoka and Kinyua (2006) on commercial ranches in Machakos (28.7% for cattle and 15.3% for small ruminants) and the average off-take rate of 25% for cattle and small ruminants in the commercial sector in Africa (Musemia *et al.*, 2006). The off-take rates for small ruminants in the four divisions were not consistent with those of the socio-economic study (Chapter 4), whereby farmers indicated that sheep and goats were frequently sold to cater for short falls in the family incomes. Indeed the off-take rates were less than those recorded for cattle. This was probably due to drought conditions experienced at the time of the survey. The farmers were apparently aware of the fact that small ruminants had a better chance of survival compared to cattle under such conditions and hence were reluctant to sell or dispose off the animals.

No culling of livestock that were either infertile or past their peak performance with regard to milk production took place during the study period. Despite the fact that reproduction is not a highly heritable trait (Miller, 2010), it is important to remove genetic material (infertile animals) from the herd so as not to proliferate females that are difficult to breed.

CHAPTER 7

EFFICACY OF EAST COAST FEVER VACCINE AND COST ANALYSIS OF IMMUNIZING CATTLE AGAINST THE DISEASE IN MACHAKOS COUNTY

7.1 INTRODUCTION

East Coast Fever (ECF) is the most economically important disease of livestock in East and Central Africa (Norval *et al*., 1992). The disease puts the lives of more than 25 million cattle at risk in the 11 countries of sub-Saharan Africa where it is endemic (ILRI, 2010) and endangers a further 10 million animals in regions such as southern Sudan, where it has been spreading at a rate of more than 30 kilometres a year. While decimating herds of indigenous cattle, East Coast fever is an even greater threat to improved exotic cattle breeds and is therefore limiting the development of livestock enterprises, particularly dairy, which often depend on higher milk-yielding crossbred cattle (Muraguri *et al*., 2005; Okuthe and Buyu, 2006; Chenyambuga *et al*., 2010; Gitau *et al*., 2010). In Zebu (*Bos indicus*) calves kept under pastoral management system, ECF is responsible for annual mortality rates of 40-80% (Homewood *et al.*, 2006; Di Guillo *et al*., 2009). It is estimated that an effective ECF vaccine for cattle could save the affected countries at least a quarter of a million US dollars a year (ILRI, 2010).

An experimental vaccine against East Coast fever was first developed more than 30 years ago at the Kenyan Agricultural Research Institute (KARI). Cattle were vaccinated using the ‘infection-and-treatment method’(ITM), so-called because the animals were infected with live *Theleiria parva* parasites and simultaneously treated with a long- acting tetracycline to stop development of the disease. The resulting immune response coupled with sub-lethal natural challenge protected the animals against the disease for the rest of their lives (Mutugi *et al.,* 1989; Tumusiime, 2007; Di Guillo *et al*., 2009; McKeever, 2009).

The *T. parva* Marikebuni stock was isolated and characterized by Irvin *et al*. (1983) from the Coast Province of Kenya. Field studies carried out in Coast, Central and Rift Valley provinces of Kenya have shown that the stock significantly reduces the incidence of ECF in immunized cattle (Wesonga *et al*., 2000; Maloo, 2001c; Wanjohi *et al.,* 2001). The efficacy of *T. parva* Marikebuni has not been evaluated in Eastern Province of Kenya.

Disease control, especially of the TBDs is a major constraint to livestock production in the County. If shown to be efficacious, then the use of the infection and treatment method to control ECF in the County can significantly reduce treatment and tick control costs (Mukhebi *et al*., 1989; Muraguri, 1998) and thereby improve farmers' income (McLeod, 1997) upon adoption of the technology.

Loss in productivity, hence profit, arising from infectious and parasitic diseases reduces the efficiency of conversion of inputs (water, feed, drugs, labour, land capital and management) into outputs (meat, milk, skin, manure and traction power) in ruminants (Tambi and Maina, 1999; Nwafor, 2004). In a livestock production system, disease can have either direct or indirect effect in the form of additional cost or revenue foregone. Diseases also affect herd structure, limits access to better markets and lead to suboptimal use of production technology (Tambi and Maina, 1999; Benett, 2003).

Use of animal health economics to support the decision making process is increasingly gaining importance in the livestock production sector. Economics of livestock production involves making decisions based on rational choices in the allocation of scarce resources against competing alternatives (Ackello-Ogutu and Waelti, 1990; Ørskov and Viglizzo, 1994). Numerous economic analysis studies have been undertaken on different farming systems in Kenya. These include cost analysis of immunization against East Coast fever on smallholder dairy farms in Central Kenya (Muraguri,1998), a study on the effect of vector borne diseases on productivity of smallholder cattle in the Coastal lowlands (Muraguri, 2000), and analysis of productivity of Orma/ Zebu cattle crosses in a pastoral production system (Maichomo, 2008). Results from studies carried out in Zambia to assess the impact and financial implications of ITM in traditionally managed Sanga cattle (crosses between *Bos indicus* and *Bos Taurus*) cattle showed that it is a cost effective strategy for ECF control (Minjauw *et al*., 1999).

The main objective of this phase of the study was to assess the efficacy of ECF vaccination in a Dual Purpose Cattle Small Scale (DPCSS) production system in the context of disease incidence and economic analysis. The vaccine strain was the *T. parva* Marikebuni stock 316.

7.2 MATERIALS AND METHODS

7.2.1 Design of vaccination trial

7.2.1.1 *Farm and animal selection and sample size determination*

The minimum age of calves selected for immunization was 1 month (Maloo *et al.*, 2001b). Only calves and yearlings were selected as they are the most susceptible age groups to East Coast fever (Swai *et al.*, 2009; Phiri *et al*., 2010). Besides, the cost of administering the vaccine significantly increases with animal size (Muraguri *et al.*, 1998). In addition, the dosages of the long acting tetracylines that are administered concurrently with the vaccine are computed on the basis of animal body weight and therefore the smaller the animal, the cheaper the cost of immunisation.

7.2.1.2 *Selection of farms for the trial on the efficacy of the ECF vaccine*

A list of all farms that had relatively good records on disease history in the seven sub-locations selected for the longitudinal study was prepared. For a farm to be selected for the immunisation trial, it had to have at least 2 calves that were at least one month of age (Maloo *et al.*, 2001b). Only calves and yearlings not previously treated against ECF were recruited into the trial. Milani sub-location in Ndithini Division was omitted due to concerns about accessibility during the rainy seasons. Using random number tables, four farms were randomly selected from each of the seven sub-locations. Based on this selection criterion, a total of 28 farms with 178 calves were recruited into the trial.

To block the effects of farm, control calves and yearlings were selected from the same farms as the vaccinated calves/yearlings. Each farm was then given a code and all recruited animals tagged. Calves and yearlings that entered the herds in the course of the one-year follow-up period and met the selection criteria were recruited into both groups.

The minimum number of calves that needed to be immunised by the end of the study (assuming that immunising against ECF will result in 50% reduction in incidence of ECF) was derived from the formula in Dohoo *et al.* (2003):

$n= [Z_{\alpha} (2PQ)^{1/2} - Z_{ß} (P_eQ_e + P_cQ_c)^{1/2}]^2 / (P_e - P_c)^2$

Z_{α} = Value of Z (1.96) which provides α/2 in each tail of a normal curve for a two- tailed test.

$Z_{ß}$ = Value of Z (-0.84) which provides ß in lower tail of a normal curve (Zß is negative if ß < 0.5).

P_e= Estimate of response rate in vaccinated group assuming prevalence of ECF to be (40%) (Ngumi *et al.*, 2005) = (20%).

P_c = Estimate of response rate in non-vaccinated group (40%)

$P= P_e+P_c /2 = (0.30)$

$Q=1-P \quad = (0.70)$

The minimum number of animals for the vaccine trial was

$$= \frac{[1.96\ (2 \times 0.30 \times 0.70)^{1/2} + 0.84\ (0.20 \times 0.80 + 0.40 \times 0.60)^{½}]^2}{(0.20- 0.40)^2}$$

$$(1.270 + 0.563)^2 / 0.20^2 = 81$$

Thus, a minimum of 81 animals needed to be immunised with 81 controls.

7.2.1.3 *Immunisation procedure*

Farmers were once again asked about the disease history of eligible calves and yearlings for the last 1-3 months. A stratified random method was used to allocate cattle to the treatment and control groups. The study population was stratified by herd and within each herd the calves and yearlings were randomly (using a random number table) allocated to each of the two treatment groups.

Clinical examination of the animals was undertaken just prior to the inoculation of the vaccine. Animals with a rectal temperature > 39.4^0 C were excluded. Irrespective of whether the body temperature was normal or not, animals with enlarged superficial lymph nodes were excluded on suspicion of having been recently infected with ECF. Animals that appeared malnourished (weakness with protrusion of bones of the shoulders, ribs, backbone and hips and sunken eyes) were also excluded from the trial.

Based on this criterion, a total of 100 calves and yearlings were initially vaccinated against ECF while 78 others served as controls.

The immunization procedure was carried out using the method described by Radley (1978). The *T. parva* (Marikebuni) stabilate was stored in 0.5ml aliquots in plastic straws kept under liquid nitrogen canisters. The straws were rapidly thawed by rubbing between the palms and their contents dispensed into universal bottles. A 1:40 dilution of the stabilate was done using Eagles Minimum Essential Medium with 3.5% w/v bovine plasma albumin and 7.5% glycerol. After 30 minutes of equilibration, the stabilate was inoculated subcutaneously in front of the pre-scapular lymph node. A 30% long acting oxytetracylines (Tetroxy L.A, Bimeda) was administered at a dosage rate of 30 mg per kg body weight by deep intramuscular injection. Any immunised animal developing clinical signs of ECF with fever and macroshizonts in lymph node smears for at least three days was designated as an "ECF reactor" (Wanjohi *et al*., 2001). However, inspite of using the 30% oxytetracylines formulation, there was regular communication with the farmers just in case of the odd reactors.

7.2.1.4 *Surveillance of East Coast fever*

Surveillance of ECF in both the vaccinated group and controls was by determination of antibody titres and the incidence rate of the disease. Since the tick vector of *Theleria parva* had been observed to be prevalent in the study area during the cross-sectional study, it was expected that some of the calves were already exposed to *Theileria parva* by the time they were one month old. Under this scenario, the Indirect Fluorescent Antibody Test (IFAT) is ideal in monitoring the immune response as it is possible to record the change in antibody levels for animals that were already exposed to *Theleria parva* at the time of immunization. Although immunity to ECF is cell-mediated (McKeever, 2007), sero-conversion following immunisation can be used as a tool to monitor the viability of the ECF vaccine. Thus, it is necessary to determine seropositivity to *T.parva* on the day that the animals were immunised (day 0) and on the 35^{th} day (day 35) post immunisation.

The IFAT test was carried out as described by Burridge and Kimber (1972). Schizont antigens were prepared as described by Cakmak (1990). Briefly, cultures containing schizont antigens were centrifuged at 200g for 20 minutes at 4^0C.The supernant fluid was removed and the cell pellet was resuspended in 100ml of phosphate buffered saline (PBS) at 4^0C (PH 7.2 to 7.4). This was followed by centrifugation at 200 g for 20 minutes. The washing procedure was repeated three times. After the final wash, the cells were resuspended in PBS. Thin layers of the cell suspension were spread on Teflon-coated multisport slides (Glaxo-Welcome, UK) using a 100µl pipette. The slides were dried and fixed in acetone for 10 minutes. Pre-vaccination and post-vaccination sera were tested at serial antigen dilutions of 1:40 up to 1:2560. Twenty (20) µl of each serum dilution were transferred to the antigen (schizont) wells. This was followed by incubation at 37^0C for 30 minutes. Serum samples were removed from antigen wells by immersing in two consecutive jars containing PBS for 10 minutes each time. Twenty (20) µl of diluted anti–bovine immunoglobulin fluorescein isothiocyanate conjugate at a dilution of 1:100 was added. Evans blue at a concentration of 0.01% was added as a counterstain and incubated at 37^0C for 30 minutes. This was followed by washing three times in PBS. Known positive and negative sera were used as controls. The slides were read under a fluorescent microscope. An animal was considered exposed (positive) if its serum reacted at titres of 1:160 (Burridge and Kimber, 1972).

Animals were followed for a period of 12 months post vaccination. Each farm was visited on a monthly basis and the infection status of each animal determined by clinical and laboratory examination of blood and lymph node smears. Clinical surveillance was kept on all the cattle in both treatment groups on daily basis. In three of the sub-locations (Ndithini, Katine and Ndunduni), the local animal health assistants (AHA) were recruited to monitor the occurrence of disease. In the rest of the sub-locations, farmers were asked to report by phone all suspected cases of disease to the principal investigator. To ensure rapid reporting of diseases, all clinical cases of TBDs and other infectious disease conditions in cattle on the selected farms were treated free of charge throughout the trial period. Early signs of ECF looked for included pyrexia, enlargement of superficial lymph nodes and dyspnoea. Blood smears and needle biopsies were made from prescapular lymph nodes of all animals reported ill especially when accompanied by a rectal temperature of $\geq 39.4^{o}$ C. The smears were fixed in methanol and taken to the laboratory at the Veterinary Research Centre, Muguga for staining in Giemsa and examination under a light microscope. The lymph node smears were examined for the presence of schizonts and the blood smears for *Theileria parva* piroplasms, anaplasma and babesia. Animals found to be suffering from ECF were treated with buparvaquone (Butalex®, Pitman Moore, UK) and supportive antibiotic drugs while cases of anaplasma were treated with either imidocarb diproponiate® (Pitman, Moore, UK) or a long acting tetracycline. Tick challenge was assessed as described in Chapter 5.

7.2.1.5 *Data Collection*

The parameters recorded soon after immunization and during the regular monthly visits were:

- Pre and post-immunization serological status.
- Tick challenge levels.
- Cases of ECF and other TBDs.
- Treatments against TBDs.

- Mortality due to ECF and other TBDs.
- Expenditure on acaricides.
- Expenditure on disease treatment.

7.2.2 Data management and analysis

Data were entered into an access file. The incidence rates for various disease events were calculated in Microsoft Excel program (Microsoft Corporation, USA) after exporting the relevant data files from the Access program. After thorough screening for errors, the files were exported to STATA Version 10 (StataCorp.2007) statistical program for analysis.

Multivariate analyses were conducted using Poisson regression models that incorporated general estimating equations to correct for repeated measures in time for antibody titre determination. Only the first cases of ECF and other TBDs were considered in the analyses. Animal-level factors taken into consideration included breed, sex, age, tick challenge/level. The farm level factors included dipping frequency, tick control, and herd-size. Division and season of the year were also taken into consideration. Dipping frequency was transformed into a categorical variable with 3 classes (level 1: 0-4 times; level 2: 5-8 times and level 3: over 8 times) before being fitted in the multivariable model.

7.2.2.1 *Estimation of ECF incidence and vaccine efficacy*

The incidence rate (IR) of ECF was computed as described in Dohoo *et al*. (2003):

$$IR = \frac{\text{Number of events during observation period}}{\text{Animal-months at risk}}$$

The denominator for estimating incidence was the number of animal-months between the dates the intervention (immunization) study began (or date of recruitment for those animals introduced into the study after commencement) and detection of infection, withdraw from the study, or end of the study.

Vaccine efficacy was calculated as described by Babo Martins *et al.* (2010):

$$\text{Efficacy of vaccination} = \frac{(\text{Incidence rate in control group - Incidence rate immunised in group})}{\text{Incidence rate in control group}}$$

7.2.2.2 *Estimation of the cost of application of acaricides and treatment of East Coast fever*

On each visit during the study, information was recorded on disease treatments, the cost of each treatment (including professional charges if any) undertaken, number of times acaricides had been applied on the animals since the previous visit and expenditure on acaricides. The figures derived from these records were used to compute the annual cost of application of acaricides and ECF treatments. The annual cost of acaricide application was computed as described by Muraguri (2000) as:

TC = MA * NA (PM) * 12

Where,

TC= Total cost,

MA= Mean application cost per animal, and

NA (PM) = mean number of application cost per month.

The mean annual cost of ECF treatment per animal was derived from the formula:

M (AT) = TC (D) /NC

Where, M (AT) is the mean cost of treatment per animal,

TC (D) = Total treatment cost for the disease, and

NC = Number of cases of the disease recorded during the study period.

7.2.2.3 *Cost of immunisation per herd*

The total cost of immunization per herd ($Y_{(h)}$) was estimated as described by *et al*. (1997):

$(Y_{(h)}) = V + M + \alpha (D + B + C)$

Where

V= Veterinary proffesional charges

M= Mean cost of monitoring (transportation and labour) per herd.

α = Mean number of animals per herd.

D= Cost of vaccine per animal (one dose).

B= Cost of the blocking drugs per animal.

C= Mean cost of consumable items per animal.

The detailed figures used to compute the cost of immunization in the trial were based on the costs of immunizing against ECF derived from Muraguri (1998), Babo Martins (2010) and VRC (2011).

7.2.2.4. *Economic analysis*

Partial farm budget analysis was used to estimate the profitability level of herd immunisation against ECF by the infection and treatment method (ITM) in the County. Partial budgeting provides a simple economic description and comparison of different disease control measures (Dijkhuizen *et al.*, 1995).

The components and parameters used and the partial budget framework are as shown in Tables 7.1 and 7.2, respectively.

Table 7.1: Partial farm budget framework.

1. Additional returns
2. Costs no longer incurred
3. Subtotal: 1 + 2
4. Foregone returns
5. Additional costs
6. Subtotal: 4+5
7. Difference: 3 – 6: Derived net return. If net return is negative, then the procedure is not recommended and vice versa.

Table 7.2: Parameters and components considered in Partial Budget Analysis of the financial benefits of East Coast Fever immunisation using the infection and treatment method in Machakos, County.

Parameters	Components considered
Additional returns	Extra Calves Sold =ECS x (CP NI Group- CP I Group)
Additional costs incurred	1.Cost of vaccination = VC x NoA I Group 2.Cost of treatment of reactors= TC x (R x NoI) 3.Cost of treatment of infected calves= TC x ECFInc group I x No animals group I 4. Tick control (NI Group and I Group)
Costs No longer incurred	1.Costs with treatment of diseased calves= TC x ECFInc Group NI x No animals Group NI 2. Tick control. It is envisaged that tick control costs will be reduced by 50% among immunised animals (GPI).
Foregone returns	None since calves that died had no salvage value

Key: CP= Cost per head; ECFInc= East Coast fever Incidence; ECS =Extra calves sold;
I = immunised group; NI= Non-immunized group; NoA= Number of calves
R= percentage of reactors to vaccination; TC= Treatment cost; VC = Vaccine cost

7.2.2.5 *Assumptions of the analysis*

Only calves and yearlings were selected for immunization to avoid production losses associated with milk withdrawn for human consumption following injection with long acting oxytetracylines. It was assumed that as a consequence of ECF vaccination, immunized calf price/trade would increase (Homewood *et al.*, 2006) and calves would command a 50% higher price in the market (Di Giulio *et al.,* 2009). The analysis was performed on assumption that the subsequent immunization in the County would be carried out by a private veterinarian in line with the government policy of delivery of the technology by private veterinary practioneers; hence a professional charge of USD 13.33 per farm was included in the analysis. It was also assumed that the veterinarian travelled on average 50km to supervise the immunization. The analysis was done for the year 2008-the year the immunisation trial was carried out. All the prices and costs are therefore in 2008 terms when the mean market conversion rate was Ksh.75 to the USD.

7.2.2.6 *Determination of association between vaccination and incidence of East Coast Fever*

Attributable Risk (AR): Since the disease is often observed among vaccinated cattle not all disease in the non-vaccinated cattle could be attributed to the being non-vaccinated. The rate of disease in the non-vaccinated group which was attributed to being non-vaccinated was obtained from the difference in rate of disease among the non-vaccinated and vaccinated cattle as described by Martin *et al*. (1987): p(D+/V-) - p(D+/V+) where p(D+/V-) is the rate of disease among the non-vaccinated cattle and p(D+/V+) is the rate of disease among the vaccinated cattle.

Attributable Fraction (AF): The proportion of disease in the non-vaccinated cattle that was due to being non-vaccinated was computed as follows: AR/p (D+/V-).

Population Attributable Risk (PAR): is the increase in risk of disease in the entire population that is attributable to being non-vaccinated. This was computed as the overall observed risk (combining vaccinated and non-vaccinated groups) in the study population minus the baseline risk (risk in the vaccinated group): p(D+) - p(D+/V+) where p(D+) is the rate or proportion of diseased animals in the population and p(D+/V+) is the rate of disease among the vaccinated cattle.

Population Attributable Fraction (PAF): Indicates proportion of disease in the whole population that is attributable to being non-vaccinated and can be avoided if all animals were vaccinated. This was was computed as described by Martin *et al*. (1987) and Gachohi *et al*. (2013):

7.3 RESULTS

7.3.1 Study population

Initially, 178 calves/ yearlings were recruited into the study from the 28 study farms (Table 7.3). One hundred (57.6%) calves were immunized against ECF while 78 (42.4%) served as controls. Calves born on the farms during the twelve-month follow-up period were progressively recruited into the study at the age of 1 month. An additional 34 calves were born or brought into the study farms during the study period. A total of 29 calves/

yearlings were lost to the study through deaths, sales or transfers. By the end of the study, there was a total of 183 calves and yearlings (Table 7.3).

Table 7.3: Division and farm distribution of calves and yearlings in the controlled immunization trial against East Coast fever in Machakos County, 2008-2009.

		No of calves/yearlings present			
		Start of study		End of study	
Division	No of farms	Immunised	Control	Immunised	Control
Athi River	7	58	44	79	45
Kangundo	7	11	12	16	13
Matungulu	9	16	13	19	13
Ndithini	5	15	9	15	12
Total	28	100	78	129	83

7.3.2 Sero-conversions following immunization against ECF

The highest proportion (93.7%) of cattle that sero-converted 35 days post immunization was recorded in Athi River Division while Kangundo Division had the lowest proportion (87.5%) (Table 7.4). None of the 13 cattle in the control group in Kangundo Division sero-converted while Matungulu Division had the highest proportion (15.4%) of control cattle that sero-converted. Overall, 92.2% of the calves and yearlings sero-converted after immunisation compared to only 6% that sero-converted in the control group; the difference was statistically significant ($p<0.05$). No “reactors” were observed among the vaccinated animals.

Table 7.4: Serological reactions of cattle in the immunised and control groups in the immunization trial against East Coast fever in Machakos County, 2008- 2009.

Division	No. of cattle		No. of cattle with post- immunization antibody titres > 1:160		Proportion of immunized cattle that sero-converted	Proportion of control cattle that sero-converted
	Immunised	Control	Immunised	Control		
Athi River	79	45	74	2	93.7	4.4
Kangundo	16	13	14	0	87.5	0
Matungulu	19	13	17	2	89.4	15.4
Ndithini	15	12	14	1	93.3	8.3
Total	129	83	119	5	92.2	6.0

7.3.3 Incidence of tick-borne diseases

A total of 35 clinical cases of ECF were recorded during the one-year study period. Of these, 9 were in the immunised group and 26 in the control group (Table 7.5). The annual incidence rate (42.7%) of ECF in the control group was significantly ($p<0.05$) higher than the rate in the immunised group (7.8%). Calves and yearlings in the control group were apparently 6 times more likely to develop ECF relative to those in the immunised group (Table 7.5). Other factors significantly ($p< 0.05$) associated with incidence of ECF included age, sex, tick control on farm, tick challenge, season and dipping frequency (Table 7.5). After adjusting for effects of confounding in multivariate analysis, only three variables of the seven that were significant in univariate analysis were retained in the final model, i.e., immunization, age and sex (Table 7.6). Division, which was not significant in univariate analysis was significant in the final model indicating that its effects were confounded by the other variables. This effect was more pronounced in

Matungulu Division where the IRR changed from 1.42 (1/0.7, Table 7.5) in univariate analysis to 3.14 (1/0.32, Table 7.6) in the final model indicating that cattle in the division were approximately 3 times less likely to develop ECF relative to cattle in Athi River. The effects of immunisation were not confounded as the IRR changed minimally in the univariate analysis from 5.5 to 5 (1/0.2, Table 7.6) in multivariate analysis.

The efficacy of the vaccine was 81.7% indicating that the vaccine reduced the incidence of ECF in vaccinated calves and yearlings by 82%.

Table 7.5: Univariate analysis for exposure to *Theileria parva* infection in a controlled Immunization trial against East Coast fever in Machakos County, 2008-2009.

Variable	Levels	No. of ECF cases	Animal months-at-risk	[1]Incidence rate (%) per cow month (95% CI)	[2]IRR (95% CI)	Annual Incidence rate	p-value
ECF immunization	Yes	9	1,391	0.6 (0.3 - 1.2)	1.00	0.078	
	No	26	730	3.5 (2.3 - 5.2)	5.50 (2.58 – 11.74)	0.427	0.00
Division	Athi	23	1,224	2.0 (1.3 – 3.1)	1.00	0.225	
	Ndithini	5	258	1.9 (0.6 – 4.5)	1.03 (0.39 – 2.71)	0.233	0.95
	Kangundo	2	256	0.8 (0.1 – 2.8)	0.42 (0.10, 1.76)	0.094	0.23
	Matungulu	5	382	1.3 (0.4 – 3.1)	0.70 (0.26 – 1.83)	0.157	0.46
Breed	Indigenous	31	1,605	1.9 (1.3 – 2.7)	1.00	0.232	
	Exotic	4	517	0.8 (0.0 – 3.2)	0.22 (0.03 – 1.83)	0.093	0.13
Age	Calf	29	1,290	2.2 (1.5 – 3.2)	1.00	0.270	
	Yearling	5	723	0.7 (0.2 – 1.6)	0.31 (0.12 – 0.79)	0.083	0.02
	Adult	0	105	0	0	0	0.99
Sex	Male	18	658	2.7 (1.6 – 4.3)	1.00	0.328	
	Female	17	1,463	1.2 (0.7 – 1.9)	0.42 (0.22 – 0.82)	0.139	0.01
Tick control	Yes	15	1,643	0.9 (0.5 – 1.5)	1.00	0.110	
	No	19	472	4.0 (2.4 – 6.3)	4.50 (2.35 – 8.98)	0.483	0.00
Tick challenge	Yes	28	1,123	2.5 (1.7 – 3.6)	1.00	0.299	
	No	7	998	0.7 (0.3 – 1.4)	0.28 (0.12 – 0.64)	0.084	0.00
Season	Wet	21	905	2.3 (1.4 – 3.5)	2.01 (1.03 – 3.96)		0.04
	Dry	14	1,216	1.1 (0.6 – 1.9)	1.00	0.138	
Dipping frequency	0 - 4	12	277	4.3 (2.2 – 7.6)	3.35 (1.57 – 7.15)	0.520	0.00
	5 - 8	8	685	1.2 (0.5 – 2.3)	0.90 (0.38 – 2.12)	0.140	0.81
	> 8	15	1159	1.3 (0.7 – 2.1)	1.00	0.155	

[1]IRR Incidence Rate Ratio
[2]CI Confidence Interval

Table 7.6**:** Multivariable analysis for exposure to*Theileria parva* infection in cattle in a controlled immunization trial against East Coast fever in Machakos County, 2008-2009.

Variable	Level	[1]IRR	95% [2]CI	Std. Err.	p-value
Immunization	Control	0.20	0.09-.44	0.08	0.00
	Vaccinated	1.00			
Division	Kangundo	0.26	0.06-1.19	0.20	0.08
	Matungulu	0.32	0.11-0.91	0.17	0.03
	Ndithini	0.81	0.29-2.24	0.42	0.68
	Athi	1.00			
Age	Yearling	0.27	0.10-0.73	0.14	0.01
	Adult	0.00	0.00	0.00	0.99
	Calf	1.00			
Sex	Female	2.18	1.09-4.36	0.77	0.03
	Male	1.00			
Season	Wet	2.00	0.99-4.02	0.71	0.05
	Dry	1.00			

[1]IRR Incidence Rate Ratio
[2]CI Confidence Interval

7.3.4 Association between vaccination and incidence of East Coast fever

The attributable risk and attributable fractions were 0.24 (24%) and 0.77 (77%) respectively. Thus, 24% of the incidence of the disease in the non-vaccinated group was attributed to non-vaccination while 77% of the cases of ECF in the non-vaccinated cattle were due to non-vaccination against the disease.

The increase in the risk of the disease in the entire population (from which the trial animals were selected) that was attributable to being non-vaccinated was 0.14 (14%) (PAR) while the proportion of disease in the whole population (PAF) that was attributed to being non-vaccination was 0.58 (58%).

7.3.5 Cost of immunization

The mean herd size was 20.8 animals comprising of 13.2 adults, 2.5 yearlings and 5.1 calves. However, only calves and yearlings were considered in the estimation of the cost of the ECF vaccine. The mean number of calves and yearlings on the trial farms was 7.3. The immunization costs are as shown in Table 7.7. The consumable items included syringes, hypodermic needles, microscopic slides and staining reagents.

The estimates of the cost of an immunising dose of stabilate were based on the current production costs of 100,000 doses at VRC Muguga. The current total cost of producing the stabilate (100,000 doses) is USD 113,300. This included the cost of quality control processes (cross-immunity trials, titration and screening for pathogens).

The total cost of a dose of the vaccine (inclusive of all costs) was 6.96 USD (Table 7.7) (equivalent to Ksh. 522 at the average exchange rate Ksh.75 to the dollar at the time of the trial in 2008).

Based on the data collected from the 28 trial farms, the average cost of treating a calf (up to 12 month of age) for ECF was Ksh.258 while average annual cost of application of acaricides per animal was Ksh.205.9 (Table 7.8). East Coast fever was mainly treated by use of long acting tetracyclines.

Table 7.7: Estimated cost of the various components in ECF immunization in Kenya, 2008.

Item	Category*	Cost in USD.		Percentage of total cost
		Per farm	Per animal	
Stabilate production	Variable	8.25	1.13	16.23
Blocking drugs	Variable	3.50	0.48	6.90
Consumable items	Variable	11.68	1.60	22.99
†Labour (monitoring)	Fixed	-	-	-
Transportation	Fixed	1.83	0.25	3.59
Professional charges	Fixed	25.55	3.50	50.29
Total		50.81	6.96	

*Parameters costed per animal (animal-dependent) were termed as “variable” while those costed per whole farm were termed as fixed.
†No reactors are expected when 30% oxytetracylines formulation is used. This eliminates the need for monitoring.

Table 7.8: Inputs used in partial farm budget analysis of the financial benefits of East Coast Fever immunisation by the infections and treatment method in Machakos County, 2007.

Parameter	Value		Source
	Immunized	Non immunized	
No of calves (NoA)	129	83	Study data
Market value of a calf (CP)	*Ksh.6,347	Ksh.6,347	Study data
ECF cumulative incidence (CumInc)	7.76	42.74	Study data
ECF cumulative mortality (CumMort)	0	5	Study data
Vaccine Cost (Ksh) VC	Ksh.522		Market price
Cost of treatment (Ksh) TC	Ksh.258	Ksh.258	Market price
Percentage of reactors to vaccination (R)	0	Study data	Market price
Cost of tick control Annual basis per animal (TCA)	Ksh.205.9	Ksh.205.9	Study data

*Based on field data from elsewhere, the price of immunised calves is expected to increase by at least 50%

Immunization of calves against East Coast fever generated a net output of Ks 559,257.90 which translated into a mean marginal return of Ksh.2, 638.00 per vaccinated calf (Table 7.9).

Table 7.9: Net return of immunization against ECF in Machakos County.

Parameter
Additional returns: N/B accurate records of extra calves sold as a result of immunization not available
Additional costs Cost of vaccination Ksh.67,338.00 Cost of treatment of infected calves-immunised group Ksh. 258,268.30 Tick control Ksh.43,650.80
Costs no longer incurred Treatment of diseased cattle Ksh.915,234.4 (Non-immunized calves) Tick control Ksh. 13,280.60 Net return = Ksh (915,234.4 + 13,280.6) –(67,338.0 +258,268.3 + 43,650.8) = 559,257.90 Average net return per calf = Ksh. 2,638.00

The number of animals immunized per farm had a major influence on the mean cost per animal, with the total cost of immunization decreasing as the number of cattle per herd increased (Figure 7.1). In this analysis, the cost of monitoring, the professional fees and transportation costs were termed as fixed costs, since they were charged uniformly, irrespective of the number of animals on the farm. These cost contributed 54.9% of the total cost, hence the high cost when few animals were immunised on the farm.

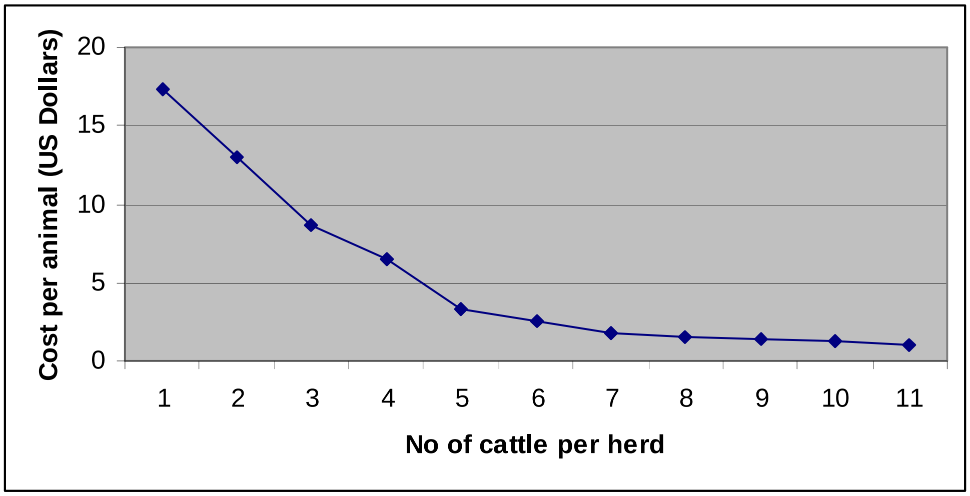

Figure 7.1: The trend of the total cost per animal on sensitivity analysis of the total number of animals immunized per farm

7.4 DISCUSSION

East Coast fever in cattle is mainly controlled by the frequent application of acaricides. However, the use of acaricides to control the tick vectors of the disease is unsustainable due to increasing costs of acaricides, poor maintenance of dips or sprays, water shortages, tick resistance to the acaricides, illegal cattle movements, and contamination of the environment or food with toxic residues, and availability of alternative tick hosts (mainly ungulates) (Wesonga *et al.*, 2006; Ocaido *et al.*, 2008; Mendes *et al*, 2011). Thus, immunization against ECF appears attractive as it is expected to reduce the risk of the disease and reliance on the use of acaricides. The result would be an increase in productivity.

It is estimated that the ECF vaccine can save affected countries, mainly in sub-Sahara Africa, up to 315 millionUSD a year in both losses due to mortality and control costs

(ILRI, 2010). In herds kept by the pastoral Masaai people, for example, the disease kills from 20% to over 50% of all unvaccinated calves (DFID, 2009). In a study carried out in Zambia (Berkvens *et al*., 1987), ECF incidence rates of 70% to 80% were recorded in calves less than one year old with corresponding fatality rates of 30-40%. This scenario makes it difficult and often impossible for the herders to plan for the future, to improve their livestock enterprises and thus raise their standard of living.

In endemic areas where there is continuous challenge with the infected ticks (*R. appendiculatus*), animals only need to be immunised once in their life (Radley *et al.*, 1975; Mutugi *et al*., 1989). Calves, the most susceptible age group, can be immunised as early as 1 month after birth (Maloo *et al.,* 2001b). The technique is growing in popularity in the East African region with Tanzania taking the lead. For instance, more than 500,000 cattle have been immunised against ECF in the country since 1998 (ILRI, 2010). It is estimated that calf mortality can be reduced by up to 95% following immunization (ILRI, 2010).

A number of studies have been conducted to establish the efficacy of the ECF vaccine in the Central, Coastal, South and North Rift Valley regions of Kenya and in the Ngorongoro region of Tanzania (Young *et al*., 1981; Radley, 1981; Mutugi *et al*., 1989; Mutugi *et al*., 1991; Wesonga *et al*., 2000; Wanjohi *et al.*, 2001; Babo Martins *et al.,* 2010). All these studies demonstrated a significant difference between the number of cases of ECF observed among immunised cattle compared to the non-immunised ones. Apart from the study undertaken by Babo Martins *et al*. (2010) in the Ngorongoro region of Tanzania, none of the studies evaluated the incidence of the disease among the immunised and non-immunised animals as a criteria for computing the efficacy of the vaccine. This was the first trial to test the efficacy of the vaccine in the eastern region of the country.

A high proportion (93.7%) of the cattle sero-converted following immunization. This rate was within the range (85% to 100%) considered acceptable for a viable vaccine (Muraguri *et al*., 2003). The sero-conversion rates were similar those observed in similar studies (Wesonga *et al*., 2000; Wanjohi *et al.,* 2001; Oura *et al.,* 2004; Babo Martins *et al.,* 2010). However, antibody response following natural infection with *T. parva* or immunisation does not correlate with immunity to the disease as immunity against *T. parva* is cell-mediated (Emery *et al*., 1981; Morzaria *et al*., 2000; McKeever, 2007).

The efficacy of the vaccine in this study was (82%) which is lower than the 95% reported by ILRI (2010) or 97% reported by Babo Martins *et al*.(2010). This could probably be attributed to differences in tick challenge between the study sites, differences in the vector tick infection rates with the *T. parva* parasite, and environmental factors. It has been shown that high tick challenge could precipitate immunosuppression (Bock and De Vos, 2001; Rashid *et al.*, 2009) in the infested animals resulting into clinical ECF. In addition, high tick infection rates with *Theileria parva* can result in exposed animals particularly calves, developing the disease before the vaccine could have had time to stimulate the body's immunity (James, 1999; Rashid *et al.*, 2009). It is also known that tick infection rates with T. parva are greatly influenced by environmental factors such as climate (Ochinda *et al*., 2003; Olson and Patz, 2010)and that the parasite thrives in the tick vector within the environmental temperature range of 18-28^{o}C (Ochonda *et al*., 2003). The sporozoite stage of the parasite multiplies rapidly within the salivary glands of the tick vector under high environmental temperatures. An important implication of this is that the efficacy of the ECF vaccine could be influenced by the prevailing weather conditions. Thus, there is need to conduct further investigations on the effects of high tick challenge and *T. parva* tick infection rates on the efficacy of the ECF vaccine.

The efficacy of the vaccine could have been further affected by the adverse drought conditions during the trial period as this could have been a major source of stress. Stress conditions such as drought and poor livestock management practices are known to have adverse effects on the efficacy of vaccines (Clement *et al.*, 2004; Rashid *et al.,* 2009).

In the study, only 77% of the cases of ECF in the non-vaccinated cattle were attributed to non-vaccination against the disease. This does suggest that there are indeed other factors responsible for the occurrence of the disease even among the immunised cattle.

Nevertheless, the results of the immunisation trial in the study area do indicate that the vaccine had a significant protective effect. The vaccine reduced the incidence of ECF by 82%. Indeed, vaccination of all calves/yearlings in the study area would have reduced the overall incidence of the disease by 58%. This study does provide evidence that the vaccine can be used to control the disease in Machakos. Indeed the high number of clinical cases of ECF that were observed during the study (Chapter 6) was a stong indicator that the disease is an important constraint to livestock production in the County. Use of the vaccine in the County can greatly improve livestock productivity as has been the case in other parts of the country where there has been a roll out of the vaccine

(Muraguri and Peeler, 1996; Ndua *et al.,* 1999). Concerns on the possibility of introduction of vaccine strains following immunization against ECF was one of the reasons the Department of Veterinary Services introduced the policy of gradual roll out of the vaccine. Under this policy, commercial use of the vaccine was only permitted in Coast, Kiambu County and ironically Machakos County where no trials on vaccine had been carried out.

However, in the last five years, there has been a shift in government policy regarding the use of the live ECF vaccine. The Department of Veterinary Services is no longer cautious about the use of the vaccine outside the regions where the initial trials on the vaccine were carried out. Currently there are no restrictions on where the vaccine can be used in the country. This has largely been the effect of recent research findings that have allayed fears over the role of the live ECF vaccine with regard to the introduction of new *Theileria parva* strains (Oura, 2004; Oura, 2007; McKeever, 2007). These studies do confirm that elements of the vaccine establish a carrier state in vaccinated animals and alleles associated with vaccine strains emerge in co-grazing non-vaccinated cattle. However, the epidemiological impact of these observations could be tempered by extensive recombination of co-ingested strains in the tick vector. Besides, widespread livestock movement, both legal and illegal, probably plays a bigger role in the introduction of new *Theileria parva* strains. Ticks with “new” strains of *Theileria parva* can also be introduced through fodder or hay brought from other parts of the country particularly during the drier periods of the year.

In view of change in policy on the use of the live vaccine, the “greater” Machakos County is bound to benefit from the uptake of the technology since the vaccine was efficacious in the trial and none of the farmers raised any safety concerns that could be attributed to the vaccine. The vaccine will greatly contribute to the preservation of the livelihoods of the resource poor farmers in the region as it will greatly reduce the mortality of calves. Calves are an importance asset as they are the future replacement stock of the cattle herds.

Apart from reduced mortality from the disease, the other benefits of immunising against the disease include reduced costs associated with treatment and reduction in acaricide usage. Tick control in the County following immunisation against ECF was not addressed by the study. However, previous studies by Wesonga *et al*. (2000) and Wanjohi *et al.* *(*2001) established that depending on the level of tick challenge, tick control frequency can be reduced to just once every three or four weeks on farms where all animals are immunised against the disease without significant increase in the incidence of other tick-borne diseases.

Studies by Mukhebi *et al.* (1990), Nyangito *et al.* (1994), Mukhebi *et al*. (1995) and Muraguri *et al.* (1998) established the cost/ benefits of immunizing against ECF. A similar study carried out in Zambia to assess the impact and financial implications of ITM in traditionally managed Sanga cattle (cross between *Bos indicus* and *Bos Taurus* cattle) showed that it is a cost-effective strategy for the control of ECF (Minjauw *et al.*, 1999).

Immunisation of cattle against ECF in the Coast Province of Kenya was found to reduce economic losses by 24–40% in indigenous zebu cattle populations and by 40–70% in genetically improved grade cattle (Thornton and Odero, 1998). In the study, it was estimated that immunisation would yield increases in net income of 24–100%, depending on the alternative control strategy employed. On the basis of cost-benefit ratio, immunisation at a cost of Ksh 544 (USD 25, in 1990 values) per animal would be financially profitable in grade but not in zebu cattle. For the new strategies to be as financially profitable for zebu cattle, the cost of immunisation would have to be in the range of Ksh 230–415 per animal, or the farm-gate price of milk would have to increase by at least 80%. Other studies have estimated the cost of immunisation per animal to range from USD 2.50 to USD 20 (Radley, 1978; Kiltz, 1985, Mukhebi *et al.*, 1990; Babo Martins *et al.*, 2010).

The results of the current study fall within this range (USD 6.96) per animal and are similar to those of a recent study carried out by Babo Martins *et al.* (2010) in Tanzania where the cost of immunisation was 6 USD per animal. The relative low cost of immunisation per animal in the two studies compared to some of the earlier studies is attributed to the selection of calves and yearling for ITM as opposed to adult cattle. The other factor that resulted into lower immunisation costs was the use of the 30% formulation of oxytetracylines as the blocking agent. The higher concentration of the oxytetracylines (30mg/kg) compared to the conventional (20mg/kg) oxytetracylines has been observed to have a negligible “reactor” rate (Di Giulio *et al*., 2009). Treatment of reactors is a major cost if oxytetracylines formulations of a lower concentration are used accounting for up to 16% of the total cost (Muraguri, 1998). The cost of the vaccine may seem to be too high for the smallholder farmers in the County. Despite the cost, calves are only immunised once in their lifetime as the immunity lasts a lifetime if there is continuous tick challenge. On the other hand, farmers spend between Ksh.220 and Ksh.500 in treating each indigenous calf and up to Ksh. 4,000 for adult exotic cattle. Thus farmers who immunise their cattle against the ECF stand to make big savings on treatment costs.

Partial budgeting provides a simple economic description and comparison of different disease control measures (Dijkhizen *et al*., 1995). Partial budget is used to decide whether it is economically worthwhile to introduce a new technology/change in an enterprise. The decision is taken if the net returns are positive. Positive net returns are good indicators of profitability of a new technology. From the results of the study, ITM technology is financially profitable even when the extra calves sold as a result of reduced mortality and the expected increase in the price of immunised calves were not taken into consideration. The ITM realized a net return of Ksh.2, 638.00 per immunized calf. This was significant in the study area since the average price of a calf was relatively low (Ksh.6, 347.00). High net returns are indicators of high profitability of immunisation. Thus, it can be concluded from the study that it is economically worthwhile to immunise calves against ECF in the Machakos County.

If immunization against the disease is integrated with reduced acaricide usage, then accrued returns are even much higher. If the tick control frequency is reduced to once every two weeks, this will result into a 50% reduction in acaricide costs. The annual cost of tick control per animal (cattle) would drop from Ksh.206 to Ksh. 103.

Another benefit that can be derived from immunisation is the increased value of the immunised cattle. For instance, among the Masaai pastoralists of Tanzania immunised calves are sold at a price 50% higher than the non-immunised calves (Babo Martins, *et al.,* 2010).

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CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

8.1.1 Constraints limiting livestock production

A combination of qualitative and quantitative methods were used in identifying farmers' constraints to livestock production in the four study divisions of Machakos County. Qualitative techniques involved rapid appraisal techniques while quantitative methods included cross-sectional surveys to evaluate the risks of the prevalent tick-borne diseases of cattle in the County. The longitudinal study was used to further quantify the incidence of the tick-borne diseases, assess animal health and productivity. Using rapid appraisals, it was possible to identify and quantify not only the major livestock diseases but also the other factors that constrained livestock production in Machakos County. The main constraints identified in order of importance were livestock diseases (mostly tick-borne diseases), poor access to livestock and livestock product markets, poor veterinary infrastructure and inadequate feed. In addition, the qualitative techniques unmasked problems that otherwise would have been missed out if only quantitative methods were used. For instance, it was possible to identify reasons why poor livestock breeds (indigenous) have been kept for so long in the County. Rearing of livestock in the County was not undertaken primarily for commercial reasons but was also a status symbol. The other reason was the fear of adopting new or unfamiliar animal husbandry practices such as keeping the more disease prone but improved cattle breeds.

Predation was also identified as a major constraint to livestock production in one of the study divisions (Ndithini Division). Such information is usually not found in the County or Department of Veterinary Services annual reports.

The main advantages of applying qualitative data collection methods were the relatively shorter periods for completion and the prompt feedback of results to the farmers. Within a period of a month and using an average of 4 personnel (author, facilitator, local veterinarian or AHA and one recorder), it was possible to gather data on all major constraints, disease risk and control strategies. The prompt feedback of results to the farmers was particularly useful for continued collaboration as costly incentives were not necessary. It also helped to gain farmer confidence during the subsequent cross-sectional surveys. Thus, the informal data collection tools were important in the initial collection of data and facilitation of researcher entry into the study area.

The main disadvantages of quantitative studies were the high costs and the need for specialized personnel and equipment during the serological evaluations. The longitudinal study was also time-consuming. Costly incentives in terms of free veterinary services, continuous reassurance and feedback were necessary to sustain the study. It costs the equivalent of 2.5US$ to screen for *Theileria parva*, *Anaplasma marginale* and *Babesia bigemina*, using the ELISA serological kit. Besides, many disposable and capital items of equipment were required. Although quantitative study was expensive and time consuming, it yielded estimates of various animal health and productivity parameters, and management. Both methods (qualitative and quantitative) complemented each other very well in this study. The study further demonstrated the need to involve farmers in assessing constraints or problems affecting livestock production. Though farmers' perceptions on key problems that limit livestock production in a particular farming system cannot be entirely relied on, their views can expose issues that otherwise would have been neglected (Omiti *et al*., 2007). Such issues could be of great significance in designing appropriate mitigation measures against specific constraints limiting livestock development or improvement.

8.1.2 Seroprevalence of tick-borne diseases in Machakos County

8.1.2.1 Risk of tick-borne diseases

Tick-borne diseases especially ECF were the main constraints to livestock production in the study area. Antibodies to the three TBDs infections were detected in all the selected farms. The overall estimates of *T. parva, A. marginale* and *B. bigemina* antibodies in the County were 58.9% [95% CI: 56.5%, 62.3%],, 35.0% [95% CI: 31.9%,38.8%] , 41.1% [95% CI: 38.9%,41,4%] respectively. Based on the findings of the cross-sectional survey, a state of endemic stability characterized by high seroprevalence rates and few clinical cases was found to possibly exit for ECF in two of the study divisions (Athi River and Ndithini) while anaplasma and babesia appeared to exist in a state of endemic instability characterized by low seroprevalnce and high number of clinical cases in all the study divisions. However, these results were at variance with the findings during the longitudinal phase of the study as only a few clinical cases of the two diseases were documented.

Although *Amblyomma variegatum,* the vector of *Ehrlichia ruminantium* (heartwater) was one of the commonest tick species in the study area, no case of the disease was documented during the observational period. These findings are different from those made by Ngumi *et al*. (1997) which confirmed the presence of the disease in Machakos County. Tick challenge was high in three of the study divisions namely, Athi River, Matungulu and Ndithini. R. appendiculatus, the vector for *T. parva* was the commonest tick species observed in the study site. Only 43% of the study farms that kept both cattle and small ruminants practiced tick control on all the three livestock species. During the regular visits to the farms small ruminants were often found to be infested with ticks. Thus, on farms that practice zero-grazing for cattle and also keep small ruminants on free ranging, the latter could act as important sources of tick infestation to cattle

8.1.3 Socio-economic and demographic characteristics of the livestock farmers

8.1.3.1 Livestock and crop enterprises

One- hundred-and-eighty seven (93.5%) of the 200 study farms practiced mixed farming. This indicated diversification of sources of income in the drought prone County, in order to better manage risks associated with either crop or livestock enterprises. Mixed farming in the County is therefore important as it enhances food security. However, it was noted during the study that farmers took full advantage of mixed farming to maximize on crop production as the two enterprises are interdependent. Livestock manure can be used to supplement fertilizers to enhance crop production and improve on food security. The majority (84%) of the 200 farmers used manure on their farms. Surplus manure was sold to provide an extra source of income.

Although cattle were kept as the main source of family income, sheep, goats and chicken also played important roles such as catering for short falls in family incomes. Thus, all livestock species played a significant role in the social and economic lives of the smallholder farmers in the County.

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8.1.4 Morbidity and productivity estimates in smallholder livestock farms in Machakos County

East Coast fever was the commonest disease diagnosed on the study farms during the longitudinal study. Twenty-six (26) cases of ECF were confirmed on 14 farms converting to an annual incidence rate of 30.7% per calf-year. The risk factors of *T. parva* infection in cattle were the administrative divisions where the farms were located (there were more infections in Athi River and Ndithini divisions), age of animal (more in calves), tick control on the farm (more on farms where tick control was irregular) and season of the year (more in the rainy seasons).

Malnutrition, mange, mycosis and diarrhoea were the other conditions or infections observed in cattle. Malnutrtion was not associated with any animal or farm level variables. Tick control was the only variable that was associated with mange. Mange was significantly higher on farms where tick control was not practiced compared to farms where tick control was practiced. Thus, it can be concluded that the acaricides used for tick control were also effective on mites.

Breed was associated with the incidence of non-specifc diarrhoea and mycosis. The incidence of the two conditions was significantly ($p<0.05$) higher among the exotic crosses of cattle (44.4% per cow- year) compared to the indigenous breed (4.5% per cow-year).

The commonest causes of morbidity in sheep and goats were helminthosis and pneumonia while diarrhoea due to bacterial infections, severe flea infestations and mange were the other diseases detected in small ruminants.

Livestock productivity in the study area was found to be sub-optimal. The mean daily production of milk, in cattle was 1.98 litres which was less than a third of the average daily milk production recorded in the high potential areas of the country. Milk production and sales in the four divisions of the County were very low at the time of the survey. This was mainly attributed to the small number of farmers who keep improved dairy cattle breeds, inadequate veterinary extension services and poor marketing of milk in the County due to under developed co-operative societies.

One of the main hindrances to the improvement of livestock production in the study area is the failure by farmers to fully embrace livestock keeping as a commercial enterprise. There is therefore need for change in attitude for farmers to adopt new farming practices and technologies.This can be achieved by provision of extension services to the farmers on the viability of keeping improved higher producing dairy cattle or goat breeds that will produce enough milk for both domestic consumption and sale.

The breeding intervals for goats and sheep was once every 12 months instead of the optimal interval of once every 6 months. The mean off- take rates for cattle and small ruminants were 9% and 4%, respectively.

8.1.5 Efficacy of the East Coast fever vaccine

8.1.5.1 *Immunization against ECF*

The vaccine against ECF was found to be efficacious against the disease in the study area as it reduced its incidence by 82% which is lower than the 95% reported by ILRI (2010) or 97% reported by Babo Martins *et al*.(2010). The differences in efficacy can be explained by differences in tick challenge, differences in the vector tick infection rates with the *Theileria parva* parasite, and environmental factors.

8.1.5.2. *Association of immunisation with incidence of ECF*

Twenty four (24) per cent of the incidence of ECF in the non–vaccinated group was attributed to non-vaccination (Attributable Risk) while 77% of the disease in the non –vaccinated cattle was due to non –vaccination (Attributable Fraction). The increase in the risk of ECF in the population that was attributable to being non- vaccinated was 14% (Population Attributable Risk) while the proportion of the disease in the population that was attributable to non-vaccination (Population Attributable Fraction) was 58%.

8.2 RECOMMENDATIONS

8.2.1 Veterinary infrastructure

Since only one functional dip was operational during the study, it is recommended that the Veterinary Department provides partial financial support and technical assistance in reviving the dips. In addition, the farmers should take the responsibility of managing the dips. Dip management committees should be streamlined to ensure that the right people are selected to manage them in order to avoid mismanagement. To ensure sustainable operation of the dips, farmers need to be sensitized on the concept of cost sharing. However, there should be a level of subsidization possibly with the use of Constituency Development Funds (CDF). This will lessen the financial burden on the farmers and encourage regular dipping of the animals. The veterinary department should assist with extension and supervision services. For instance, the department could assist with provision of dip attendants.

In the meantime, extension services are necessary to assist farmers who still rely on hand sprays to control ticks on the right choice of acaricides as well as how to effectively apply the hand spray technique as it is not as reliable as dips.

8.2.2 Acaricide application

Farmers need to be made aware of the importance of applying acaricides on all livestock species on their farms in order to reduce tick burdens on the pastures. The information is of particular importance to farmers who zero-graze cattle while small ruminants on the same farms were free-grazing.

8.2.3 Formation of co-operatives

Farmers need to be encouraged to form groups or associations as a way of enhancing chances of accessing credit or loans from financial institutions. This will also need participation of co-operative development officers to advice the farmers on how to organize themselves into co-operatives. Access to finance will then assist farmers upgrade livestock as well as expand both livestock and crop production. By being in organised groups, the farmers will hopefully be able to overcome bottlenecks caused by brokers in the marketing of livestock, as they will have direct access to markets at better prices.

8.2.4 Livestock improvement

A shift from keeping indigenous breeds of cattle to keeping improved breeds of livestock is a prerequisite for improved livestock productivity in the study area. The poor animal genetic resources cannot sustain an effective dairy cattle production system in the County. There is a misguided fear of keeping improved cattle breeds in particular. The perception is that grade animals easily succumb to hot weather conditions and diseases. Thus, there is need for education on the benefits of keeping improved cattle breeds. The veterinary and animal production departments as well the local administration officials need to work together on this. The best approach is to keep improved breeds such as Friesian crosses that are well adapted to the local conditions. Exchange visits with farmers from neighbouring Countys who are already experienced with regard to keeping such breeds will be of great benefit.

8.2.5 Artificial insemination services

The farmers should also be actively involved in addressing the issue of provision of artificial insemination (AI) services, which are the pillar of improving genetic potential. At the moment, availability of these services in the County is unreliable as they have to be sourced from Nairobi. The problem can be solved by the farmers coming together to form co-operatives which can sponsor locally sourced students to be trained at certificate or diploma level in the field of artificial insemination. In the long run, the farmers should be able to recoup the money invested in the training. The trainees could be bonded to serve the community for an agreed period of time. If the farmers opt to use bulls then they need to be involved in breeding management so as to avoid inbreeding and spread of sexually transmitted diseases.

8.2.6 Rearing of small ruminants

Rearing of small ruminants should be encouraged as they are better adapted to the climatic conditions in the County and are a means of diversification of income and spreading of risks. Improved sheep (e,g Dorper) and goat breeds (German Alpine and Galla goats) would translate into improved household incomes. Since sheep, goats and chicken play an important role in the livelihoods of the smallholder farmers, it is recommended that studies on livestock in smallholder livestock production systems should be designed to include all livestock species.

8.2.7 Fodder preservation

Farmers also need to be trained on storage and preservation of fodder. However, emphasis should be placed on drought resistant crops such as sorghum, cassava and millet as the study area has a semi arid climate. A variety of forage seeds are available that are suitable for the semi arid climate in the County. The fodder should be planted during the rainy period in preparation for the drier months. This could be practiced as a drought mitigation practice. Farmers should also be encouraged to construct dams to harvest water during the rainy seasons. The water could be used to irrigate fodder and hay.

It was noted during the study that education was lacking on the recommended stocking rates on the farms for the available feed resources. The stocking rates did not take into consideration availability of feed especially during the dry seasons. The average stocking rate was 4.7 adult cattle and 2 sheep/goats per hectare. The recommended stocking rate for zebu cattle and indigenous goats and sheep is 0.6 ha/TLU or 0.6 ha/250 kg (Jaetzold and Schmidt, 1983). This is equivalent to approximately 2 adult cattle or 17 sheep/goats per hectare. To address the problem it is recommended that farmers in the County should be trained on the importance of keeping smaller but more productive animals.

8.2.8 Further studies

Findings from the cross-sectional survey suggesteds a state of endemic instability for anaplasmosis and babesiosis in the study area. However, the findings of the longitudinal study did not support these results. Thus, further studies need to be undertaken to establish the true endemic state of the two diseases.

8.2.9 Efficacy of ECF vaccine

Although the ECF vaccine was found to have a significant protective effect and can be used to control the disease in Machakos County, the efficacy of the vaccine was lower than that observed in other parts of the country. In view of these findings, further investigations need to be conducted on the effect of factors such as climate, level of tick challenge and *T. parva* tick infection rates on the efficacy of the ECF vaccine.

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Appendix 4.1: Socio-economic questionnaire

Section 1: Farm indentification

1) Name of farmer ………………………………………………………………
2) Farm code ………………………………………………………………
3) Location ………………………………………………………………
4) Date of interview ………………………………………………………………
5 Interviewer ………………………………………………………………

Section 2: Household characteristics and labour

6) How many people are there in the household? ………………………………………
7).How many members of your family presently live on the farm………………………?

8) Other than farming, do you engage in other income generating activities ?
    1) No
    2) Yes

9) If yes, how many hours on average does he/ she work on the farm?...................hours per day.

10) In the absence of the farm owner, who is responsible for farm labour and management?
    1) Wife
    2) Son
    3) Daughter
    4) Employee
    5) Other (specify)………………..

11) Do you employ non-family members on the farm?
    1) No
    2) Yes

12. Which period of the year do you hire this labour?
    1) Not applicable
    2) All year round
    3) Harvest season only
    3) Other (specify) ………………………………………………………………

13. How many people on average do you hire for labour during this period?
    None/ not applicable Number……………………………………………….

14. Which are the main crops that you grow and what area of the farm does each cover?
    1)……………………………………Acres/Hectares……………………………
    2) ………………………………Acres/Hectares………………………………
    3) ………………………………Acres/Hectares……………………………….

4) …………………………………Acres/Hectares……………………………….
5) …………………………………Acres/Hectares……………………………….

15. For those crops that you normally grow, please estimate the fraction that is sold per year?

Crop (1)…………………..
Crop (2)…………………..
Crop (3)…………………..
Crop (4) ………………….
Crop (5)

16. Do you rent any land for agriculture? If yes, how big is the land you rent?

1) No
2) Yes, ……………………………………………Acres

17. Which time of the year do you normally rent the land?

1) N/A, land not rented
2) All year round
3) Rainy season only
4) Dry season only
5) Other ……………………………………………………

Section 2. Farm inputs.

18. Do you ever purchase fertilizer for farm use?

(1) Yes (2) No

19. If yes, which crops do you apply it?
1) All crops
2) Cash crops only
3) Cattle forage
4) Other: Specify …………………………………………………………….

20. Do you ever apply manure to your crops? (1) Yes (2) No

21. If yes, to which crops do you apply?

2) All crops
3) Cash crops only
4) Cattle forage
5) Other: Specify …………………………………………………………………

22. If manure is ever applied, are there occasions that you buy it from other farms

23. How much do you normally buy per year?

24. State how much you spend on it.

25. Do you ever purchase forage from outside your farm? (1) Yes (2) No.

26. If Yes which forage is purchased---------------?

27. Which period of the year do you normally buy the forage?
1) N/A
2) All year round
3) Rainy season only
4) Dry season only
5) Other…………………………………………………………………

28. How much forage on average do you buy per year---------------?

How much do you spend on it per year-------------------?

29. Do you feed concentrates to your cattle/sheep/goat?
Cattle (1) Yes (2) No
Sheep (1) Yes (2) No
Goat (1) Yes (2) No

30. If yes, to which animals do you offer it?
1) N/A
2) All cows
3) Lactating cows, throughout lactation
4) Lactating cows, early lactation only
5) Dry cows only
6) Weaned heifers
7) Weaned bulls
8) Un-weaned calves
9) Other Specify (…………………………………)*indicate here if given to sheep or goats.

31. If yes, which concentrates do you normally offer?
1) Not offered
2) Specify …………………………………………………………

32. How much feed concentrates do you give per animal per day?
Specify ……………………………………………………Kg/day

33. When are the feed concentrates fed to cattle?
1) N/A
2) All year round

3) During the dry season only.
4) When cows have calved
5) Other …………………………………………………………………

34. What is the source of the concentrates you feed?
1) N/A
2) Purchased from local retailers
3) Home grown and mixed
4) Other …………………………………………………………………

35. Do you offer your animals any nutritional supplements? If yes, which ones?
1) None
2) Molasses
3) Salt lick
4) Mineral and salt mix
5) Other (specify…………………………………………………………………)

36. If you feed nutritional supplements, to which animals do you feed them?
1) N/A
2) All cows
3) Lactating cows, throughout lactation
4) Lactating cows, early lactation.
5) Weaned heifers
6) Weaned bulls
7) Unweaned calves
8) Other specifies. (…………………)* indicate here if given to sheep or goats

37. When are the nutritional supplements fed to the cattle?
1) N/A
2) All year round
3) During the dry season only.
4) Other (………………………)*indicate here if given to sheep or goats

Section 3: Veterinary Practises

38. Do you normally deworm your cattle/ sheep/goats?
Cattle (1) Yes (2) No
Sheep (1) Yes (2) No
Goats (1) Yes (2) No

39. If yes, which animals do you normally deworm?
1) No deworming done.
2) All animals (cattle/sheep/goats)
3) Only adults (specify species………………….)
4) Only weaned animals (specify species……………..)
5) Only calves/lambs/kids (specify……………….)

6) Other ………………………………………………………………..

40. If yes, what product (dewormer) did you use during the last deworming?
…………………………………………………………………

41. If yes, how often do you normally deworm?

1) Once a year (Specify for each species……………….)
2) Twice a year (Specify for each species……………….)
3) Three times a year (Specify for each species……………….)
4) Four times a year (Specify for each species……………….)
5) Other…………………………………………………………………

42. If yes, does your frequency of deworming vary between the adults and calves/lambs/kids?

1) Not differ
2) Differs, describe…………………………………………………………………

43. In the last 12 months, which vaccinations have been offered to your cattle? How much were you charged for it?

	Against which disease	*Cost per animal*
Vaccine 1	----------------------------	------------------------
Vaccine 2	-----------------------------	------------------------
Vaccine 3	-----------------------------	------------------------

44. Which other veterinary practices have you carried out on your cattle in the last 12 months.

	Species	Cost per Animal
(1) Dehorning	------------	------------------
(2) Caesarian	-------------	------------------
(3) Castration	--------------	------------------
(4) Artificial Insemination	---------------	-------------------
(5) Other ---------------(specify)	---------------	--------------------

45. **Section 4. Livestock commodity prices**

Are you a member of any co-operative dealing with livestock production activities

1) No
2) Yes, Name of Co-operative…………………………………………………………………

46. How many cows are you milking presently?

1) None
2) Cows in milk…………………………………………………………………

47. Do you ever sell milk? If yes, how much on average do you sell per day

1) No milk sold
2) ……………………………………………litres/ bottles sold per day.

48. If you sell milk, to whom do you sell?

1) No milk sold (N/A)
2) Local Co-operative
3) Neighbours/ local consumers
4) Other ………………………………………………………………

49. For how much are you currently selling the milk per Litre/Bottle (tick)………………?

50. Does the price of milk change at any period or season of the year?

(1)Yes 2) No (If yes specify when-----------------------)

51. If an animal dies on the farm, what do you normally do with the carcass?

1) Buried- no salvage value
2) Skinned and hide sold
3) Other (specify) ………………………………………………………………

52. If the skin is sold, how much on average is it worthy according to the age of the animal?

Calf………………………………………………………………
Weaned cattle……………………………………………………
Adult cattle………………………………………………………
Kid……………………………………………………………….
Weaned goat………………………………………………………
Adult goat………………………………………………………...
Lamb…………………………………………………………...
Weaned sheep……………………………………………………..
Adult sheep……………………………………………………….

53 Have you sold any animals in the last one year? (1) Yes (2) No

54. If yes, give animal species sold

(1) Cattle…………………… No. sold…………………………..
(2) Sheep…………………… No sold…………………………...
(3) Goat…………………… No sold………………………….....

55 Reasons for selling…………………………………………………

1) Pay school fees………………………………
2) Daily needs…………………………………..
3) Others (specify)

56. Price range for each species…………………………..

(1) Cattle…………………………………………….
(2) Sheep…………………………………………….

Goats…………………………………

Appendix 5.1: Cross-sectional survey questionnaire

Section 1: Farm identification

1a Name of interviewer			
1b contact address			
2. Date			
3. Division			
4. Location			
5. Sublocation			
6.GPS reading	South (S) East (E) Altitude		Format S00.01217 Format E35.22283 Format 2489 m

7. Name of farmer

8. Sex of respondent Male □ Female □

9. Relation of respondent to the household head

Section 2 Farm characteristics and livestock production

10. Total acreage of farm-----------------------------------

11. Would you characterize your farming activities as?

(1) Mainly livestock □ (2) Mixed livestock/crop □ (3) Mainly crop □

12. For how long have you have been keeping cattle? --------------------years.
(1) 1-5 years (2) 6-10 years (3) over 10 years

13. Which of the following livestock do you keep? How many do you have presently?

Livestock	**Number**
(1) Cattle	-------------
(2) Sheep`	-------------
(3) Goats	-------------
(4) Camels	-------------
(5) Donkeys	-------------
(6) Chicken	-------------
(7) Pigs	-------------
(8) Other (Specify______________)	-------------

14. For cattle, which of the following types do you keep?
(1) Improved (exotic or crosses) dairy cattle only.
(2) Only local (indigenous) cattle.
(3) Both improved and indigenous (local zebu).

15. How do your cattle get access to forage (grazing system)?
(1) Cut/purchased feeds transported to animals (zero grazing)-----specify source.
(2) Free grazing on pasture
(3) Combination of grazing and stall-feeding (Semi zero-grazing)

16. If your cattle are on pasture, do they ever graze off farm (away from farm)?
1) No
2) Sometimes
3) Always.

Section 3: Animal Health
17. Which problems do you face when keeping animals?

Rank the disease (**1 Most important and 5 least important**).

	Cattle	Sheep	Goat
1)Disease			
2)Lack of feeds and water			
3)Poor type of cattle breeds			
4)Lack of credit facilities			
5)Other (specify----------)			

18. Which are the most important diseases affecting your animals (in terms of economic loses)?
Rank the diseases (**1 Most important and 3 least important**).

Cattle	Sheep	Goat

19. Who normally treats your animals when they are sick?
1) The farmer or other family member
2) The local government veterinarian
3) The local animal health assistant
4) Private veterinarian
5) Community Animal Health Worker (CAHW)
6) Other (specify__________________________)

20. In the last 12 months, did any of your cattle get ECF (Ngai)?
1) No
2) Yes

21. If yes, which age groups were affected and how many cases were encountered?
1) Calves (cases---------------------------)
2) Weaners (cases-------------------------)
3) Adults (cases---------------------------)

22. Which of the cases of ECF that occurred on your farm were treated?
1) None
2) All cases
3) Affected calves only
4) Affected weaners only
5) Affected adults only
6) Other (_________________)

23. Did you lose any animal from ECF (Ngai) in the last 12 months?
1) No
2) Yes (how many________________)

24. Approximately how much money do you have to spend per treatment of a case of ECF?

____Ksh.

25. In the last 12 months, did any of your cattle get Anaplamosis (Ndigana)?
1) No
2) Yes

26. If yes, which age groups were affected and how many cases were encountered?
1) Calves (cases______________________)
2) Weaners (cases______________________)
3) Adults (cases________________________)

27. Which of the cases of anaplasmosis that occurred on your farm were treated?
1) None.
2) All cases
3) Affected calves only.
4) Affected weaners only
5) Affected adults only
6) Other (________________)

28. Did you lose any animal from anaplasmosis (Ndigana) in the last 12 months?
1) No
2) Yes (how many?____________)

29. Approximately how much do you have to spend per treatment of a case of anaplasmosis?
_________________________________Ksh.

30 In the last 12 months, did any of your cattle get Babesiosis?

31. If yes, which age groups were affected and how many cases were encountered?
1) Calves (cases__________________)
2) Weaners (cases ____________________)
3) Adults (cases______________________)

32. Which cases of babesios that occurred on your farm were treated?
1) All cases
2) Affected calves only.
3) Affected weaners only
4) Affected adults only
5) Other (________________)

33. Did you lose any animal from Babesiosis in the last 12 months?

1) No
2) Yes (how many____________)

34. Approximately how much do you have to spend per treatment of a case of Babesiosis?
_________________________________Ksh.

35. In the last 12 months, did any of your cattle/ sheep/ goats get heartwater?

1) No
2) Yes (how many?____________)

36. If yes, which age groups were affected and how many cases were encountered?
1) Calves/Lambs/Kids (cases__________________)
2) Weaners (cases ____________________)
3) Adults (cases______________________)

37. Did you lose any animal from heartwater in the last 12 months?

1) No
2) Yes (how many____________)

38.. Approximately how much money do you have to spend per treatment of a case heatwater?

____Ksh.

Section 4: Tick Control

38. Do you control ticks on your farm?
1) No
2) Yes

39. If yes, which method do you use?
1) Dipping, private dip
2) Dipping, communal dip
3 Hand spraying
4) Spray race
5) Hand dressing
6) Other (specify________________)

40. If yes, in which livestock do you regularly control (once or twice a month?
1) Cattle
2) Sheep/ Goats
3) Donkeys
4) Camels
5) Other: specify________________________

41. If yes for cattle, which types (breed) of cattle do you normally treat?
1) All animals
2) Grade only
3) Local breeds only
4) Other: specify____________

42. At what age do you start tick control on calves/lamb/kids?

Frequency of tick control	**calves**	**lambs**	**kids**
1) Below two weeks			
2) Two weeks to 1 month			
3) Over1 month			
4) Other (specify________)			

43. How often do you normally control for ticks for each species (cattle/sheep/goat)

Frequency of tick control	**calves**	**lambs**	**kids**
1) Twice a week			
2) Once a week			

3) Once per two weeks			
4) Once every 3 weeks			
5) Once a month			
6) Other (specify--------)			

44. Are there times that you change this frequency?
1) No
2) Yes

45. If yes, what time of the year do you control ticks?
1) Wet season
2) Dry season
3) Other: specify___________________

46. If yes, what is the reason for changing frequency?
1) Cannot afford all the time.
2) Unavailability at times
3) No tick problems
4) Other: specify_______________________

47. Which chemicals do you use for tick control?
1) Triatix
2) Almatix
3) Tikfix
4) Supadip
5) Other: Specify____________

48. Do you ever change the acaricides at times?
1) No.
2) Yes

49. If you have ever changed acaricides, what were the reasons for changing?
(____)

Section 5: Constraints to livestock production.

49. Ask the farmer about factors that he/she feels are constraints to current livestock production. Read the list of constraints
at least twice, then ask respondent if there are others he or she would wish to add. Score the following constraints to live stock production from 5 to 0 (5=very important, 0=completely unimportant). Constraints not listed can be added. Elaboration of the constraints will be noted in the “probing check list”. The responses to the probing should be recorded on a separate sheet of paper attached to the questionnaire.

Constraints	**Cattle**	**Sheep**	**Goats**	**Probing check list**
Disease				Specify the diseases
Feed				(i)What time of the year is when feed is unavailable (ii) Quality of feed and sources.
Water				(i) Sources and reliability of the supply. (ii) Quality.
Low genetic potential				(i) Time taken to weaning (ii) Age at weaning weights (iii) Breeding practices A.I or bull? (iv) Selection qualities
Poor fertility				(i) Heat detection-method used (ii) Effect of availability of feed. (iii) In breeding (iv) Tracking of sires if natural mated (v) In breeding
Marketing of livestock and livestock products				(i) Availability of market (ii) Long distance to market (iii) Low prices (iv) Unreliable customers (v) Constraints in the marketing of meat, milk hides an skins and honey.
Lack of access to livestock services(including vet services)				(i) What kind of services are available (ii)If not available why? Distance? Terrain? Cost?
Finance				(i) Sources (ii) How accessible are the finances (iii) Guarantees/ security on borrowing

51. Interest in vaccination.

If you could obtain a vaccine against any disease of cattle, which disease would you want to vaccinate your cattle against?

____
____

Appendix 5.2: Cross sectional survey: Individual animal data sheet

Name of farmer		**Farm code**		**Sub-location**	
District		**Division**		**Recorder**	
Date of visit		**Location**			

Animal ID	Age[1] Calf =1 Yearling=2 Adult=3	Sex Female=1 Male=2	Breed, Bos Taurus=1 Bos indicus=2 Mixed=3	Weight (Kg)	Temp (°c)	Body score Very poor=1 Fair=2 Good=3 Very good=4	Disease history ECF=1 Anap=2 Babesiosis=3 Heartwater=4	Tick infestation[1] No ticks=0 Low=1 (<10) Moderate=2 (10-20) High=3(>20)	Serum blood taken (Tick)	Thin blood smear(tick)	Lymph node biopsy (tick)

[1] Indicate the main tick species beside the tick infestation level.

Appendix 5.3: Disease Translation

Disease	Local Name	Direct translation	Interpretation
Anaplasmosis	Kithatia/ Nthiana	*Kithatia* refers to hardened feaces often observed in the animals with anaplasmosis. *Nthiana* is generally used to refer to the disease by the community	Though this is not a pathognomic sign of the disease (hardened faeces), the field veterinary personnel who attended the interviews confirmed that in most instances cattle reported to have this as one of the key symptoms were often positive for anaplasmosis.
Anthrax	Ndulu	Something that kills very fast associated with oozing of blood from body orifices.	Translated directly to mean anthrax.
Babesiosis	Kumaa Nthakame	Kumaa Nthakame. Means to urinate blood.	Haematuria is one o f the key symptoms of the disease. The community derived the name of the disease from the symptom. Though mentioned, it was not ranked
Black quarter	Ikene	A swelling	Swelling associated with disease areas such as upper parts of affected limbs, brisket and psoas muscle. Rapid onset and high mortality reported by the farmers.
Brucellosis	Kuvuna	Abortion	Abortion, a symptom associated with the disease in late pregnancy. Infertility was reported to follow the abortion. Local veterinarians verified that sporadic cases do occur.
ECF	Ngai	Lymph node	Term used in central Kenya and parts of eastern Kenya to refer to enlarged lymph nodes, one of the key signs of ECF. Normally the term directly refers to ECF.
Eye worm	Kiinyu Kya Yiitho	Worm of the eye	The term refers to infection of the eye whereby the farmers describe a worm like organism in the eye.
Foot and Mouth Disease	Muthingithu / Kuvu	*Muthingithu* means wobbling movement/unsteady gait. *Kuvu* means rot between	The wobbling or unsteady gait is as result of the lameness caused by the vesicles on feet (in the cleft) and painful swelling of the coronet. Farmers were also able to describe other symptoms such lesions in the mouth and abundant

		toes	salivation. Outbreaks invariably confirmed by vet department whenever disease outbreak is suspected. Disease known for the quarantine measures put in place following confirmation
Heartwater	Muthyuuku	Move in circles (circling)	Name associated with circling; one of the main symptoms of heartwater. Circumstantial evidence provided by description of excess “water” in the thorax and in a sac around the heart (Hydrothorax / hydropericardium)
Lumpy Skin Disease (LSD)	Nthunthua wa Kikonde	Skin or hide lumps	Multiple nodules on the skin, one of the key symptoms of LSD. Rapid spread described as a feature of the disease.
Mastitis	Uwau wa Mikami or Uwau wa nondo	Disease of udder or teats	Inflammation of the mammary gland irrespective of the cause.
Mites	Mbanguule		Translated directly to mean mites.
Pneumonia	Mavui	Lungs	Disease affecting lungs. Reported to be associated with difficulty in breathing, coughing and most common during the cold months. Occurrence confirmed by local vet personnel
Rabies	Mung’ethya	Open mouth in readiness to bite or snarl	A symptom of rabies whereby infected animal bite objects. Farmers reported other key symptoms like aggressiveness. Disease is known to be endemic in the district.
Trypanosomiasis	Uwau wa matungua (or Kisiko)	Disease caused by tsetse flies	Disease transmitted by tsetse flies.
Worms	Minyoo	Swahili word for helminths	Universally used word referring to helminth infection in livestock

Appendix 6.1: Longitudinal study monthly farm/animal monitoring form

Section 1

Farm ID

Name of farmer	
Farm code	
Location	
Date of visit	
Name of Enumerators	

Exits since last visit (cattle/sheep/goats removed from herd)
(Specify the species____________________)

Animal No.	Died (tick)	Sold	Slaughtered on farm (tick)	Given out/ transferred out (tick)	Date of exit

Entries since last visit (cattle added into the herd)

Age/category			Sex	Purchased	Transfer into farm	Other ,specify	Date	No. given
C	Y	A						
C	Y	A						
C	Y	A						
C	Y	A						

C=Calves, Y=Yearlings, A=Adults.

Entries since last visit (sheep/ goats added into the herd)

Age/category			Sex	Purchased	Transfer into farm	Other ,specify	Date	No. given
<6months	6months-1yr	>1yr						
<6months	6months-1yr	>1yr						
<6months	6months-1yr	>1yr						
<6months	6months-1yr	>1yr						

Births since last visit (animals must be tagged, check last no. on list (specify the species)

No of female calved	Date of calving/lambing	Given tag No.	Sex (male or female)

Diseases since last visit

Animal No.	Diseases	Date detected	Treated? Y/N	Treated by	Drugs administered	Outcome died/recovered

Farm management practices since last visit (cattle)

Activity	NO/YES	Date(s) of activity	Animals covered			Brand (chem.)used
Tick control			C	Y	A	
Dewormings			C	Y	A	
Other (__________)			C	Y	A	

C=Calves, Y=Yearlings, A=Adults.

Farm management practices since last visit (sheep/goats)

Activity	NO/YES	Date(s) of activity	Animals covered			Brand (chem.)used
Tick control			<6months	6months-1yr	>1yr	
Dewormings			<6months	6months-1yr	>1yr	
Other (_______)			<6months	6months-1yr	>1yr	

Cattle vaccination since last visit

VACCINATION	No/Yes	Date of Vacc	Animals covered (tick	Cost per animal (Sh)
FMD				
RINDERPEST				
Other (________)				

C=Calves, Y=Yearlings, A=Adults.

Section 2.

For all cattle calving within the study period, administer this section every visit until the end of the study.

Milk offtake

Cow No.	Date of calving if after last visit	Morning yield Kgs/bottle	Evening yield/Kgs/ bottle	Total yield per day Kgs/bottles

Section 3:

For all calves/lambs/kids less than 1 year examine thoroughly and sample as follows

Weight and samples

Animal no.	Date of birth if borne after last visit	Weaned? Yes /No	Weight (nearest 0.5kg)	Blood sample(tick when taken)	Tick challenge/species