UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

EFFECTS OF ARTHROPOD ECTOPARASITE INFESTATIONS ON LIVESTOCK PRODUCTIVITY IN THREE DISTRICTS IN SOUTHERN GHANA

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BY

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DECLARATION

I do hereby declare that apart from references to the work of other investigations which I duly acknowledged, the work presented in this thesis is original and it was carried out under the joint supervision of Dr. Fred Aboagye-Antwi and Dr. Delphina A. M. Adabie-Gomez.

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ABSTRACT

Livestock are vital to subsistence and economic development, providing food, income, employment, manure and savings for Sub-Saharan African farmers. Diseases and arthropod ectoparasite infestations often impact negatively on livestock production and productivity. This study assessed the effects of arthropod ectoparasite infestations on the productivity of three ruminant (cattle, sheep and goats) livestock species in three Districts of Southern Ghana around the Volta River. A total of nine (9) communities were purposely sampled. In all, 37 questionnaires (20 in Lower Manya Krobo, 9 in Dangbe West and 8 in North Tongu) were administered to livestock farmers and, 368 ruminants (209 cattle, 53 sheep and 106 goats) were randomly sampled for arthropod ectoparasites. Majority of farmers (76 %, n = 28) practiced semi-intensive management system. All cattle kraals were either moved or cleaned once a year at most, sometimes after three to five years, unlike small ruminant pens which received more frequent cleaning. Eighty-seven percent (n = 32) responded positively to being aware of and encountering arthropod ectoparasites. Livestock kept under poor husbandry conditions coupled with less frequent use of pesticides were found with more arthropod ectoparasites, which were manifested by the high percentage (83.3 %) of the farmers that use pesticides. Over sixty percent (62.2 %) of farmers complained of poor veterinary services, which was manifested by a high percentage (73 %) of farmers carrying out self-treatment of their animals. A total of 4283 arthropod ectoparasites (537 lice, 3442 ticks, 296 fleas and 8 mites) from 8 genera (Lice: *Linognathus*, *Haematopinus*, *Bovicola*; Ticks: *Amblyomma*, *Rhipicephalus*, *Hyalomma*; Fleas: *Ctenocephalide;* and Mites: *Sarcoptes)* were collected, which included *Rhipicephalus microplus* an invasive species reported for the first time in Ghana. Approximately eighty percent (79.9 %) of the sampled ruminants were found to be positive for at least one arthropod ectoparasite and 13.6 % were infested with at least two arthropod ectoparasites. These parasites affected the livestock negatively, causing wounds, lesions, anorexia and blood loss eventually contributing to weight loss and loss of income. The current results of high ectoparasite infestation in livestock, poor husbandry practices and the presence of an invasive tick species highlights the need for an up-scaling of ectoparasite control efforts and improved veterinary services towards boosting production and productivity.

DEDICATION

I dedicate this work to The Almighty Allah, my father Momodou Bah (late), uncle Saidou Jallow (late), mother Ramata Jallow, my lovely wife Fatou Bah, all my siblings (Muhammed, Omar, Mariama, Abdoulie, Ebrima and Aminata), cousins Abdoulie Jawo, Buba Sowe and Yero Bah, my in-laws and the entire family in Dutabullu whose support, patience and encouragement have been very vital during the course of my study.

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LIST OF ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research
ARPPIS	African Regional Post Graduate Programme in Insect Science
CERSGIS	Centre for Remote Sensing and Geographic Information Services
CBPP	Contagious Pleura Pneumonia
DABCS	Department of Animal Biology and Conservation Sciences
DAAD	Deutscher Akademischer Austausch Dienst (German exchange programme)
DFID	Department for International Development
DNA	Deoxyribonucleic acid
EPM	Economic Policy Management
FAO	Food and Agriculture Organization
GAPS	Ghana Agricultural Production Survey
GDP	Gross Domestic Product
GPS	Global Positioning System
GSS	Ghana Statistical Services
IDL	Institute of Distance Learning
IDS	Institute of Development Studies
ILCA	International Livestock Centre for Africa
ILRAD	International Laboratory for Research on Animal Diseases
ILRI	International Livestock Research Institute
IPM	Integrated Pest Management
KSIREC	Kpong Soil and Irrigation Research Centre

MOFA	Ministry of Food and Agriculture
PCR	Polymerase chain reaction
SME	Small and Medium Enterprise
SRID	Statistics, Research and Information Directorate
SP	Synthetic Pyrethroids
TBDs	Tick-borne diseases
UGBS	University of Ghana Business School
VSD	Veterinary Services Department
WAD	West African Dwarf

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Livestock systems in the agriculture sector occupy about thirty percent (30 %) of the planet's terrestrial surface area that is free from ice, and this sector is increasingly organized in long market chains employing approximately 1.3 billion people globally and directly supporting the livelihoods of 600 million small-holding farmers in the developing countries (Thornton, 2010).

The livestock sector is vital to subsistence and economic development in Sub-Saharan Africa. The farm animals provide a flow of essential food products throughout the year and are a major source of government revenue and export earnings. The employment and income of millions of people in rural areas, draught energy and manure provided by livestock for crop production help in improving food security for many Africans (Chambers and Conway, 1992) and reduce drudgery and money spent on buying of fertilizer. Sale of livestock and their products often constitutes the only source of cash income in most rural areas, and hence the only way in which subsistence farmers can buy consumer goods and procure the improved seeds, fertilizers and pesticides needed to increase crop yields (Sansoucy, 1995). This livestock capital provides livelihood opportunities and food security for millions of smallholders, mainly women. Ruminant livestock plays a major role in the socio-cultural life of the farming communities as a partial determinant of wealth and payment of dowry (Bettencourt *et al.*, 2014). It also acts as a bank and insurance in times of difficulty. Sheep and goats are often slaughtered for various occasions and functions such as births, funerals and marriages as well as religious ceremonies like the Muslim feast of Idul Adha (Jabbar, 1998).

In Ghana, livestock including poultry, are kept by about 1.54 million households and is estimated that about 12 million people depend on livestock for their livelihood (Ashley and Annor-Frempong, 2004). The sector is thus a major feature in Ghana's agriculture and contributes largely towards meeting food needs, providing draught power, manure to maintain soil fertility and structure and cash income. The livestock sector contributes in direct products, about seven percent (7 %) of agricultural GDP (SRID, 2001) excluding manure and draught power that are provided to the crop sector. The contribution of agricultural sector to national GDP had experienced a decline from 2009 to 2013 in the following order: 2009, 31.89 %; 2010, 29.8 %; 2011, 25.3 %; 2012, 23 % and 2013, 22 %. The contribution of livestock to this sector also showed a similar declining trend: 2009, 20 %; 2010, 20 %; 2011, 1.8 %; 2012, 1.6 % and 2013, 1.5 % (GSS, 2014).

However, the extensive nature of the production systems and the high incidence of devastating endemic and trans-boundary animal diseases as well as arthropod ectoparasites infesting the animals ensure productivity remains low and the sector is unable to satisfy the growing needs of increasing populations for animal products (Angyiereyiri *et al.*, 2015). As a result, food security and development have been compromised in/under such conditions in the developing world. Diseases and parasites are among the most severe factors that impact on livestock production and productivity. Arthropod ectoparasite infestations have a major impact on husbandry, productivity and welfare of domestic animals (Colebrook and Wall, 2004).

Arthropod ectoparasitisms are among those that pose serious threat to both animals and humans all over the world. The painful bites of parasites could be a great nuisance, leading to loss of volumes of blood (Natala *et al.*, 2009) and animal disturbance, lead to reduced time spent on grazing and ruminating. The biting behaviour of ectoparasites may indirectly cause increased levels of irritation, itching, and rubbing, and in some cases results in self-wounding (Hussein, 1979; Wall, 2007; Kaufman *et al.*, 2009; Natala *et al.*, 2009).

Arthropod ectoparasites are vectors of numerous human and animal diseases. Ticks are capable of transmitting several important protozoans, rickettsial, bacterial, fungal and viral diseases to animals and humans. This leads to great economic loss and impart negatively on human health (Allan, *et al.*, 2003). For example, *Rickettsia prowazekii* which causes typhus fever is transmitted in lice faeces and hard ticks in the genera *Dermacentor* and *Amblyomma* (Parola and Raoult, 2001), while *Rickettsia mooseri (typhi)* causes fleaborne (endemic or murine) typhus. The disease is transmitted to man by Oriental rat fleas of the species *Xenopsylla cheopis* with the rats serving as reservoir of the pathogens (Bitam, *et al.*, 2010). Ticks are also vectors of Lyme disease which may have long-term severe, chronic and disabling effects on humans (Feder Jr *et al.*, 2007). Ectoparasitic flies such as tsetse flies and tabanids may be found feeding directly on the blood of livestock in their adult stages or screwworms, bot and warble flies that may be parasitic on the living tissues causing myiasis. Biting mites are also capable of transmitting a host of rickettsial and viral diseases to livestock and humans, apart from the allergic reactions shown by some people when exposed to their saliva during their feeding process (Pratt, 1963).

Few studies have assessed the effects of arthropod infestation on livestock productivity. These previous works include a general survey of arthropod ectoparasites on domestic animals in military operational areas in Thailand (Changbunjong, *et al.*, 2009); the effects of ectoparasites on small ruminants in Ethiopia (Tesfaye, *et al.*, 2012; Kebede, 2013); and a study on the prevalence of small ruminant ectoparasites and associated risk factors in the Tigray Region of Ethiopia (Abebe, *et al.*, 2011). Another surveyed the use of acaricide in the control of ectoparasites by livestock farmers in Ghana (Nkegbe, 2014). Ntiamoa-Baidu *et al.*, (2004) did an updated list of the ticks of Ghana and an assessment of the distribution of the ticks of Ghanaian wild mammals in different vegetation zones.

More recently, a survey on arthropod ectoparasites on goats and domestic fowls was conducted in Vunania, Navrongo, Ghana, that assessed the types and degree of ectoparasite infestation and distribution on body parts of goats and domestic fowls (Angyiereyiri *et al.*, 2015). These previous works were mainly on the prevalence, effects, control and update of arthropod ectoparasites. These works notwithstanding, huge gaps in knowledge exist especially in assessing the effects of these ectoparasite infestations on livestock productivity.

1.2 Problem Statement

The average Sub-Saharan African farmers without livestock are highly vulnerable to malnutrition and poverty because of their inability to purchase protein-rich foodstuffs like meat and meat products. Coupling crop farming with livestock provides an avenue for meeting their nutritional needs as well as generates extra income to supplement their meager income. However, livestock farming is perennially plaqued with infestation of ectoparasites. Livestock is affected by infestation of different arthropod ectoparasites, but little has been documented on their effects on productivity in Ghana, which may serve as guide to most appropriate and sustainable control methods of arthropod ectoparasites infestation on ruminant livestock.

1.3 Justification

For many smallholder farmers, livestock is the only ready source of cash to buy inputs for crop production - seeds, fertilizers and pesticides (Chaminuka *et al.*, 2014). Livestock income also goes towards buying things the farmers cannot make for themselves. And that includes paying for school fees, utilities, medicine and taxes (Schiere *et al.*, 2002). Income from cropping is highly seasonal. In contrast, small stock, with their high rates of reproduction and growth, can provide a regular source of income from sales. So can milk and milk products like ghee, butter and cheese. Larger animals such as cattle are a capital reserve (Padjung and Natsir, 2005), built up in good times to be used when crop yields are poor or when the family is facing large expenses such as the cost of a wedding or hospital bills. Livestock production constitutes a very important component of the agricultural economy of developing countries, (Sansoucy, 1995), a contribution that goes beyond direct food production to include multipurpose uses, such as skins, fibre, fertilizer and fuel, as well as capital accumulation (Padjung and Natsir, 2005). Furthermore, livestock are closely linked to the social and cultural lives of several million resource-poor farmers for whom animal ownership ensures varying degrees of sustainable farming and economic stability (Sansoucy, 1995). They contribute substantially and directly to food security and human health. For poor and under-nourished people, particularly children, the addition of modest amounts of livestock products to their diets can have substantial benefits for their physical and mental health (Thornton, 2010).

The importance of ruminants (i.e., cattle, sheep and goats) to the socioeconomic wellbeing of people in developing countries in the tropics (Sansoucy, 1995), in terms of nutrition, income and intangible benefits such as savings, an insurance against emergencies, cultural and ceremonial purposes cannot be overemphasized. Ruminants also play a complementary role to other livestock in the utilisation of available feed resources, while providing one of the practical means of using vast areas of natural grassland in regions where crop production is impractical (Maitima, *et al.*, 2009).

The contribution of this sector to Agricultural GDP over the years (2009 to 2013) has shown a steady reduction as indicated above. Despite the declining nature of the contribution of livestock in the Agricultural GDP and low contribution (7 %) to Ghana's agricultural GDP (SRID, 2001), the sector continues to play a major role in the socio-cultural life of farming communities as well as provide protein in the form of milk and milk products for the most vulnerable (women and children) in the society. Domestic livestock meat production in Ghana is low and amounted to about 66,283 tonnes in the year 2000, of which beef contributed about twenty-seven percent (27 %), mutton about eighteen percent (18 %), goat and pig meat about seventeen percent (17 %) each, and poultry meat about twenty-one percentage (21 %) (SRID, 2001).

According to Ghana's Ministry of Food and Agriculture, total meat imports rose from 97,719 metric tonnes in 2012 to 183,949 metric tonnes in 2013, registering an increase of 88 per cent. Currently, Ghanaians consume an average of 225,000 metric tonnes of meat annually however the domestic production constitutes only 30 per cent of meat production, while poultry import alone constitutes 80 per cent of the total meat imports (Boadi, 2015). Thus, highlighting the need to identify factors such as ectoparasites infestation that negatively affect meat production in order to have informed decisions on proper control measures towards boosting livestock production.

Anything, including arthropod ectoparasite infestations, poor farm management, poor awareness of farmers and poor animal health extension services, may all hamper the productivity of the livestock sector. Stopping or reducing these negating factors requires an investigation of the presence and effect of these arthropod ectoparasites on livestock productivity. This is urgently needed in order to come up with effective control measures that will reduce their associated social and economic burden (Fuehrer *et al.*, 2012), as well as the risk factors associated with the improper use of inputs like pesticides (acaricides and insecticides) and poor husbandry practices.

Arthropod ectoparasitism can pose a serious threat to livestock and humans all over the world. The painful bites of parasites could be a great nuisance, leading to loss of volumes of blood and reduced body weight (Walker, 2007; Natala *et al.*, 2009). *Rhipicephalus microplus* (formerly *Boophilus microplus*) is a hard tick that can be found on many hosts including cattle, buffalo, horses, donkeys, goats, sheep, deer, pigs, dogs and some wild animals. Heavy tick infestations on animals can decrease production and damage hides (Kebede, 2013). *Riphicephalus microplus* can also transmit babesiosis caused by the protozoan parasites *Babesia bigemina* and *Babesia bovis,* and anaplasmosis which is caused by *Anaplasma marginale* (Brian *et al.*, 2002).

The entire southern part of West Africa covering Southern Nigeria, Benin, Togo and Ghana features high climate suitable for *R. microplus* (De Clercq *et al.*, 2013), as such could serve as a region of potential epidemic episodes of tick-borne diseases coupled with its attendant consequences. *Rhipicephalus microplus* has been reported in Benin and La Côte d'Ivoire (De Clercq *et al.*, 2013; Madder *et al.*, 2012). These countries share border with Ghana and some pastoralists from those countries enter Ghana to graze their livestock. Generally, there has been limited research work on the effects of arthropod ectoparasite infestations on livestock productivity in Ghana, without which proper and sustainable control methods will be difficult if not impossible to achieve.

Therefore, it is relevant to determine the prevalence rate of these ectoparasites and their effect on livestock productivity in the present study. This will engender well informed decisions to be taken on the most sustainable control measures against these ectoparasites that have the least effect on the environment and non-target organisms including man and natural enemies, especially when synthetic chemicals are used. Ultimately, this will contribute toward increasing production and productivity in the livestock subsector, which will in turn have positive impact on the livelihood of the rural farmer in terms of protein-rich food (particularly for the most vulnerable in society: women and children), cash, savings, fertilizer (organic) and reduced farm drudgery. More importantly, unlike crops, livestock is ready cash to the farmer. To the government, reduced meat and chemical importation and usage will serve as an improvement on the health of the farmers and consumers as well as improve the country's gross domestic product (GDP).

The knowledge gained on investigating the prevalence and effect of arthropod ectoparasites on livestock productivity could provide voucher specimen of the arthropod ectoparasites of livestock in Ghana, and also serves as a bench mark for the development of better control measures.

1.4 Objective of the Study

1.4.1 Main objective

To assess the effects of arthropod ectoparasite infestations on livestock productivity and their potential as vectors of zoonotic diseases.

1.4.2 Specific objectives

1. To determine the relationship between husbandry practice and arthropod ectoparasite infestations prevalence on livestock.

2. To assess farmers awareness on arthropod ectoparasites.

3. To assess farmers perception on the effects of arthropod ectoparasite infestation on ruminant livestock productivity.

4. To determine the prevalence of arthropod ectoparasites on common livestock (cattle, sheep and goats) in three districts in Southern Ghana.

5. To identify at the molecular level the potential zoonotic pathogens borne by arthropod ectoparasites of livestock.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Livestock/Ruminant Production

Agriculture, which includes both crop and livestock production remains the single largest source of income and livelihoods for rural households in the developing world, normally providing more than fifty percent of household income (Jayne *et al.*, 2003; Otte and Chilonda, 2003). The livestock sector of Ghana is a diverse mix of small and large-scale systems, with most of the rural population remaining reliant on smallholder farms. Mixed farming with cash crop activities dominate farm priorities, however livestock (cattle, small ruminant, pigs and poultry) are becoming increasingly important for many smallholder farmers (Peeling and Holden, 2004).

Livestock production is done under three main systems. These are the intensive, semi-intensive and extensive systems. The extensive system is practiced in the rural areas whereas the intensive system is mainly practiced by commercial farmers, particularly those engaged in commercial poultry production, while the extensive system is normally practiced in rural communities where land is more available (Adzitey, 2013).

2.1.1 Types of ruminants reared in Ghana

Livestock production is an important and integral part of Ghana's agriculture economy (Diao, 2010), involving the rearing of both ruminant and non-ruminants, the former comprising of cattle, sheep and goats and the latter comprises of pigs, poultry (domestic fowls, guinea fowls, turkeys and ducks) and rabbits though grasscutters, snails, bees are increasing (Adzitey, 2013). However, the most indigenous are sheep, goats, cattle, pigs and poultry (Angyiereyiri, 2015).

A survey conducted in a peri-urban area in Ghana indicated that livestock kept by farmers include cattle, sheep, goats, and poultry (Guinea fowl, turkey, chicken, and duck), cattle being the only species milked (Okantah, *et al.*, 1999), cattle (large), sheep and goats (small) being the only ruminants. The small ruminants comprise of Djallonke sheep, Sahelian sheep and goats, West African Dwarf goats and crossbreds; while the large ruminants include Ghana Short Horn, Zebu, Sanga, N'dama, and crossbreds (Okantah *et al.*, 1999).

2.2 Ruminant production in Ghana: Importance, Prospects and Challenges

Livestock production in Ghana continues to be a small-scale, unorganised rural activity (Ocloo *et al.*, 2014). The roles of men, women, children and the elderly in livestock husbandry vary from region to region in Ghana and are determined by traditional farming system and an array of socio-economic variables, however small ruminants are generally owned and taken care by women and children, but decisions on their disposal (sale, slaughter, transfer) are commonly taken in consultation between male and female household members, irrespective of ownership (Tangka, *et al.*, 2000). Most cattle kraals within the smallholder farmer contain animals which belong to several owners either from the same family, extended family members, and/or friends and are cared for by one household or a herder (usually a Fulani herdsman) (Turkson, 2003). Livestock have always played significant role on the livelihood of Sub-Saharan rural people. Survival of people depend not only on their financial resources, but also on the assets that they have at their disposal (Chambers, 1995) and for the rural farmer livestock is the major asset, serving as a walking bank to many.

2.2.1 Importance of ruminant production

Livestock production constitutes a very important component of the agricultural economy of developing countries, a contribution that goes beyond direct food production to include multipurpose uses, such as skins, fibre, fertilizer and fuel, as well as capital accumulation. Furthermore, livestock are closely linked to the social and cultural lives of several million resource-poor farmers for whom animal ownership ensures varying degrees of sustainable farming and economic stability (Sansoucy, 1995). Livestock, particularly ruminant livestock is important to man and the environment. They are capable of converting vegetation from non-arable land, crop residues, by-products from processing units and organic waste that would go unexploited into human food of high nutrient density and nutritional quality which contribute directly to food security (FAO, 2012).

According to Ashley and Annor-Frempong (2004), livestock including poultry are kept by more than one and a half million households in Ghana, and about twelve million people depend on livestock for their livelihood. The Sub-sector is estimated to contribute about 9 % to the nation's agricultural gross domestic product (GDP) and is a source of income for several rural farm households, especially in the northern part of the country.

Livestock is capable of providing food in the form of meat, milk and eggs which are significant livelihood benefits. The sector also compliments cropping activity through the provision of manure to improve crop yield, draught power for cultivation and transport of people and agricultural produce (Pender *et al.*, 2004). This brings in another important dimension of integrated crop-livestock farming which is the predominant system of production and subsistence in essentially all communal farming systems to which the majority of rural livestock farmers in Ghana belong.

Within the household, livestock is capable of contributing to nutrition improvement, particularly for the most vulnerable in the society (women and children) (Vlassoff, 2007) in three ways: (i) through occasional direct consumption of milk, eggs or meat; (ii) the use of the income earned from sales of livestock and its products to buy food and pay school fees when crops are not matured for harvesting. On average small ruminants (sheep and goats) have an annual revenue of GH¢55.54 ($14.50) and cattle GH¢257.66 ($67.27) each in Ghana (Osei-Akoto *et al.*, 2014); and (iii) by increasing crop production as a result of mixed farming (Tangka *et al.*, 2000; Neumann *et al.*, 2000; Otte *et al*., 2005). Many rural farmers use livestock money to buy good seeds, fertilizer and farm implements which boost their crop production. The use of livestock as draft animals reduces the drudgery in crop cultivation, transport of farm produce and people. The livestock in Sub-Saharan Africa is far from meeting the populace demand and gives opportunity for livestock farmers to increase production with progress (Thornton, 2010).

2.2.2 Prospects of ruminant production

According to Thornton (2010), the demand for livestock products is projected to grow substantially in the coming decades, due to rapid population growth, increasing urbanization and income growth, which is an opportunity for livestock farmers to progress. Demand for meat and milk in developing and emerging economies will double and that for poultry meat triple, while demand for cereals will increase by just a third between 2010 - 2050 (Alexandratos and Bruinsma, 2012). This growing demand and the surge in food prices, estimated at 4 % annually for quality animal products such as meat, milk and eggs in West Africa, can be translated into opportunities for local producers to increase production (Peeling and Holden, 2004).

Meat demand in Ghana exceeds its supply which justifies the import of live animals (especially ruminants) from neighboring countries like Ivory Coast and meat from either Europe or America (Adzitey, 2013) and is also a net importer of dairy products (Okantah *et al.*, 2005). This also shows that local supply is less than demand, therefore livestock farmers can increase their production level and still find market. There is also the opportunity of readily available land and grass/herbs. The useable land size of Ghana, coupled with human population ensures that vast land is available for animal production and other agriculture activities. Most part of this land has enough coverage of grass and other plants which animals depend on as feed. Most breeds also have better resistance to local diseases and the harsh environmental conditions because they have adapted to the local conditions. The breeds have the ability to survive the free range system, scavenge on their own and experience minimal ill-health problems (Adzitey, 2013). Despite these factors which serve as opportunity for increased benefit and prospects of livestock production, the sector is faced with numerous challenges.

2.2.3 Challenges of ruminant production

Livestock production in Sub-Saharan Africa, including Ghana, is faced with various challenges which may have direct bearing on the producer, the government and funding bodies. These challenges include feed shortage during the dry season, which constitutes the greatest challenge when it comes to quality and quantity. Poorly fed livestock is more vulnerable to diseases and arthropod ectoparasites since their immune system is compromised and has poor grooming abilities which can lead to heavy infestation, which in turn leads to low productivity (Rony *et al.*, 2010). Majority of Sub-Saharan livestock farmers do not practice good grazing methods, and hardly conserve feed for the lean season, despite the availability of adequate feed during the rainy season of the year. This poor grazing practice also add to the poor quality and quantity of feed which serves as a major limitation to meeting the nutrient requirements of grazing livestock for most of the year (Sertse and Wossene, 2007).

The unavailability of or inadequate water is another major challenge confronting livestock production in Sub-Saharan Africa. Water constitutes up to eighty percentage of the animal body weight and its deprivation leads to reduced feed intake (Alemayehu *et al.*, 2012). In some areas, animals trek long distances to get to drinking points. At times, such drinking points have insufficient or poor quality water. All these have negative impact on the animals. Walking long distances may lead to weigh loss and, insufficient and poor quality (muddy) water could lead to low intake. All these may contribute to low productivity. The unavailability of water is mainly experienced when the livestock's need is most, particularly during the dry season when the highest percentage of the feed they consume is dry. Sometimes watering points are limited, resulting in large numbers of livestock coming together at a single watering hole which can lead to increased chances of spreading diseases and arthropod ectoparasites as well as land degradation. Due to limited funds from governments' animal production services, the provision of watering facilities for the livestock industry is hardly thought about in Sub-Saharan Africa (Peeling and Holden, 2004).

Another challenge is that governments fail to provide veterinary health services to the livestock farmers (Peeling and Holden, 2004) or inadequate or poor veterinary support (Holden, 1999), which affects production negatively. This has resulted in some untrained livestock farmers buying veterinary drugs and conducting treatment of their animals themselves. Such practices may lead to major problems like drug resistance, consumers being exposed to chemical residues in livestock products such as meat and milk, post treatment complications due to unsterile needles, wrong route of drug administration, improper drug dilution and over dosing. The use of locally trained community animal health workers has succeeded in some countries like Indonesia and Ethiopia (Peeling and Holden, 2004). Such personnel reside within the community and are almost always accessible. Funding agents have a vital role to play in these areas by providing funds to government veterinary services to improve the veterinary extension officer/farmer ratio, by employing more trained personnel, and improving on extension worker mobility.

Other challenges include poor husbandry or management practices (Turkson and Naandam, 2003), low soil fertility for forage production, and weak market chains for livestock and livestock products. According to Masikati (2011), these challenges are within farmers' capacity to mitigate in terms of crop production, but for grazing lands, the intervention and support of government and funding bodies are paramount. Poor husbandry practices include poor housing which exposes livestock to the hot African sun and / or rains and dust, poor breeding practices, poor arthropod ectoparasites control methods, poor tethering or grazing practices, and lack of livestock health calendar. These are all within management techniques that affect livestock production and productivity (Turkson, 2003).

Low soil fertility for forage production obviously leads to production of poor quality forage which negatively affects the benefiting livestock. In Sub-Saharan Africa most of the grazing lands are community owned which is mostly dominated by crop farmers. Increased human and livestock populations have resulted in increased competition for resources including productive land and water. This has contributed significantly to inter- and intra-communal conflicts especially between pastoralists and crop farmers. Crop farmers complain that livestock farmers let their livestock trample and feed on their crops whiles searching for water and pasture. On the other hand, livestock farmers argue that crop farmers cultivate their plants on paths and grazing lands. These conflicts sometimes result in clashes and at times loss of lives. For example in 2000, 38 farmers were killed by pastoralists and in 2008, 8 people were killed, several houses set alight and livestock stolen in Tanzania (Makoye, 2016). Good road network and storage facilities will also improve the livestock marketing system.

A survey carried out in five districts in Ghana in 1998 revealed that skin diseases, tick infestation, digestive diseases (such as diarrhoea) and trypanosomosis were the four most important problems affecting livestock production in that order (Okantah *et al.*, 1998). Skin diseases are mainly associated with the presence of arthropod ectoparasites such as ticks and mites. In an extensive cross border study conducted by Chenyambuga *et al*. (2010) in three districts around Lake Victoria at Kisumu (Kenya), Kiruhura (Uganda) and Tarime (Tanzania) to assess the farmers' perceptions on tick-borne diseases (TBDs) and resistance of their local cattle breeds to TBDs, it was revealed that livestock diseases were the most important constraint to cattle production and tick-borne diseases ranked higher than other diseases.

The Veterinary Services Departments (VSD) of most countries have been mandated to improve and maintain livestock health (Turkson, 2003), which are generally the demands for livestock farmers. Many a time the veterinary service fails to reach these expectations particularly for the poor smallholder farmers, generally in Sub-Sahara to which Ghana belong (Umali *et al.*, 1992). The end result of this inability to deliver the proper services at the right time which may be due to inadequate resources like mobility, drugs and enough trained personnel, paves the way for livestock owners to opt for self-medication of their livestock (Turkson and Brownie, 1999). The poor husbandry practices, diseases and arthropod ectoparasites generally results in poor livestock productivity. The lack of livestock extension and the unwillingness of banks to provide credit facilities for cattle farming were identified as other factors hampering the growth of the dairy industry in Ghana during a research on the characterization of peri-urban dairy production in Ghana (Okantah *et al.*, 1998).

With the increase in adoption of effective vaccines and advances in the development of vaccines, pandemic diseases have become less problem to livestock production (Peeling and Holden, 2004), instead parasites, respiratory problems and production factors have become key issues that affect production and productivity (Perry *et al.*, 2002).

2.3 Arthropod ectoparasites

The name “Arthropoda” is from the Greek, meaning “jointed foot.” Possession of jointed appendages is the primary feature distinguishing arthropods from other phyla. This phylum is the most diverse assemblage, only small fraction is parasitic to domestic animals but their harm is quite enormous (Thorp, 2009). Some are pests in their own right, whiles majority of them act as mechanical or biological transmitters for many pathogenic viruses, bacteria, protozoa and helminthes from one animal to another including man, hence are arthropods of medical and veterinary importance (Wall and Shearer, 2001). According to Urquhart *et al.*, (1996), there are two major classes of arthropods of veterinary importance, namely the lnsecta (Orders: Diptera (flies), Phthiraptera (lice), Siphonoptera (fleas) and Hemiptera (bedbugs)) and Arachnida (Acarina (soft and hard ticks and mites)) (Walker *et al.,* 2013). Arthropod ectoparasites of veterinary importance can be grouped by intimacy of their association with the host. This association range from permanent ectoparasites to ones that contact the vertebrate briefly once every few days (Mullens, 2009).

Arthropod ectoparasites like all ectoparasites are threat to livestock production and productivity because they are found to affect livestock directly and indirectly (Natala *et al.*, 2009). Arthropods are diverse assemblage of invertebrates, containing over eighty percent of all known animal species and occupy almost every known habitat (Yakhchali and Hosseine, 2006). They are covered by a hard chitinuos exoskeleton divided by sutures into sclerites. Segmented body and jointed apodemes (ingrowth or internal ridges of arthropods) allow movement and extensive specialization.

Arthropod ectoparasitisms are among those that pose serious threat to both animals and humans all over the world. As a result of their activity, arthropod ectoparasites may have direct and indirect effects on their hosts. Direct effects they may cause include blood loss, myiasis, skin inflammation and pruritus (itching), disturbance, toxic, allergic response and social nuisance. Indirect effects are self-wounding, alopecia and as vectors of pathogens such as Babesia and Anaplasma which have negative impact on livestock production (Wall, 2007). Insects, mites and ticks are among parasitic arthropods that have a significant impact on the health, wellbeing and productivity of their vertebrate animal hosts (Walker, *et al.*, 2013).

2.4 Arthropod ectoparasite infestations on ruminant livestock

Two major groups of arthropods are parasitic to mammals and birds and are important to humans, influencing the wellbeing and productivity or acting as vectors for viral, bacterial, protozoan or metazoan (helminth) disease agents. These same groups of arthropods impact livestock species often inducing significant stress and altering behaviours related to feeding and movement. Although most mites are free-living predacious or plant-feeders, there is a small Sub-group that are parasites to animals. In contrast, all ticks are parasites, feeding primarily on blood of their hosts and acting as vectors for numerous serious pathogens (Jongejan and Uilenberg, 2004).

The painful bites of arthropod ectoparasites could be a great nuisance, leading to loss of volumes of blood (Natala *et al.*, 2009). The behaviour of ectoparasites may also cause harm indirectly, causing the direct effects, and this leads to reduced time spent on grazing or ruminating and in some cases to self-wounding (Hussein, 1979; Wall, 2007). Some of these ectoparasites may also act as vectors of viruses, rickettsia, bacteria, protozoa, cestodes and nematodes, including vectors of zoonotic diseases in humans (Parola *et al*, 2003; Petney *et al*, 2007). Ticks alone transmit several important protozoans, rickettsial, bacterial and viral diseases to animals and humans, thereby causing great economic loss, and imparting negatively on human health (Petney *et al*, 2007). The four members of the insect orders considered as ectoparasites are: all members of the Phthiraptera (chewing and sucking lice), all members of the Siphonaptera (fleas), some members of the Hemiptera (true bugs) and vast majority of free living Dipteran species which are important blood feeders as well as vectors for protozoan diseases. In addition, there are several taxa of Dipteran insects whose larval stages (maggots) feed on the living tissues of hosts causing various forms of myiasis

(Natala *et al.*, 2009).

2.5 Insecta (Insects)

Insects belong to the Phylum Arthropoda and the body of the adult is divided into three distinct parts; the head, thorax and abdomen. They have a single pair of sensory antennae, mandibulate mouthparts and a pair of compound eyes on the head; and three pairs of legs on the thorax (Chapman, *et al.*, 2013).

2.5.1 Diptera (flies)

The *Diptera*, or "true flies," are one of the largest and most diverse order of insects, morphologically, biologically and ecologically. Diptera means "two-winged" which refers to the fact that they have one pair of wings (Hall and Gerhardt, 2002). Traditionally, the Diptera have been divided into two: Nematocera ("lower" Diptera) and Brachycera ("higher" Diptera), with the latter sometimes divided further into the Orthorrhapha and Cyclorrhapha (Courtney and Keiper, 2009).

2.5.1.1 Brief description of Dipterans

The insect head generally comprises of six fused segments, mandibulate mouthparts comprising of a labrum, pair of mandibles, pair of maxillae, a hypopharynx and a labium, with a single pair of antennae. There is great variation in the mouthparts, depending on the feeding habits, with adaptation for biting-chewing, sponging or piercing and sucking (Urquhart *et al.*, 1996). The pro-, meso- and meta-thorax each bears a pair of jointed legs. The thorax of many insects also bears two pairs of wings, but in the Diptera, only one pair is functional, the other is reduced and is known as halteres and has a balancing function. The abdomen is made of up to eleven segments with terminal modification that carry the reproductive organs. In insects, the sexes are separate and after fertilization the female produces either eggs or larvae (Courtney and Keiper, 2009).

2.5.1.2 Life cycle Dipterans

Insect development may be holometabolous as in fleas, where fertilized eggs hatch into larvae which undergo three or more larval stages followed by formation of pupae before the final adults emerge; or hemimetabolous as in lice, where fertlilized eggs hatch to nymphs which resembles the adult but differing mainly in the absence of genitalia. The nymphs undergo several nymphal stages or instars before forming adults without pupal stage (Mullen, 2009).

2.5.2 Phthiraptera (lice)

Lice belong to the order Phthiraptera or as two orders namely, Anoplura (sucking lice) and Mallophaga (chewing/biting lice). They are known to be wingless insects, purely obligatory, lifelong ectoparasites of mammals and birds. Lice show high rate of host specificity, spending their entire life on one host and are not able to survive away from their hosts for three to seven days (Urquhart, *et al.*, 1996). Specializations in the diet of lice underpin their major taxonomic divisions that make it possible to separate them into those that feed on skin debris, feathers and fur, and those that have specialized in blood feeding (Mullens, 2009). All Anoplura (sucking lice) parasitize mammals and feed on their blood, whiles the Mallophaga (biting lice) feed on skin, hair and feather debris of either mammals or birds but sometimes feed on blood oozing from bite site (Barker, *et al.*, 2003). Although the number of lice species is not so much, heavy infestation of sucking lice can cause severe loss of blood resulting to anaemia particularly on young livestock, while both sucking and biting lice are capable of being a source of irritation and skin damage which may lead to a loss of production and damage to hides and skin. Horses, cattle, sheep, goats and pigs may be heavily infested with sucking lice. *Haematopinus* and *Linognathus*, are key sucking lice of livestock (Urquhart *et al.*, 1996). Transmission of lice largely occurs opportunistically when hosts are in close contact with each other, particularly as during breeding, or in overcrowded conditions (Faries, 2005).

2.5.2.1 Brief description Phthirapterans

Lice are wingless ectoparasitic insects that have a dorsoventrally flattened head and body. The Mallophaga have mandibles for chewing whereas the Anoplura have the mouthparts modified for piercing and sucking. Lice are variable in size (0.4 - 10 mm in the adult stage), and colour (grayish white or tan). Most are blind, but a few species have primitive eyes which are merely photosensitive spots. Their antennae are capitate with three to five segments. The legs terminate in claws, the lice of mammals having one claw on each leg, while those of birds have two claws on each leg.

Four species of lice feed on cattle; the most common is the little red chewing louse *Bovicola bovis* which is recognized by its broad head and reddish brown coloration. The remaining three lice are blood sucking lice: the *Linognathus vituli,* the *Haematopinus eurysternus/quadripertusus* and the *Solenopes capillatus.* Although there is variation among them, they can reach a maximum length of 30 millimetres (Geden *et al.*, 1989).

2.5.2.2 Life cycle Phthirapterans

The lice life cycle is hemimetabolous. On average the life cycle takes about 2 - 3 weeks depending on the environment and is composed of three stages (egg, nymph and adult) as illustrate on Figure 1. Adult louse lays eggs in their shells (nits) which are easier to detect than the adult louse. A female louse lays several eggs daily throughout her life time of about 30 days. Eggs are cemented near the base of the hair and hatch in 1 to 2 weeks. Once the egg hatches, the nymphal louse, which resembles a small adult louse, experiences two additional moults before becoming an adult. The developing chewing lice feed on tissue debris whiles those of the sucking lice feed on blood in a sucking manner like a mosquito (Urquhart, *et al.*, 1996)

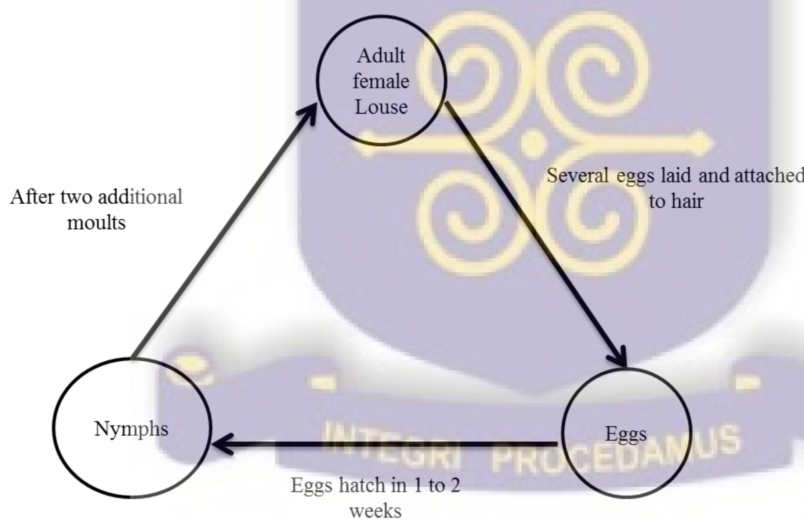


Figure 1: Life cycle of Pthiraptera (lice)

2.5.3 Siphonaptera (fleas)

Fleas are apterous insects and belong to the order *Siphonaptera*. They have mouthparts modified for piercing and sucking. Fleas are tiny bloodsucking parasites that attack dogs, cats and many other domestic mammals (cattle, sheep and goats), wild mammals and birds.

They can be found everywhere in the world, regardless of climatic conditions. In regions with cold winters, the flea populations show a seasonal pattern with peaks during the summer. Over 2000 species have been described worldwide. Fleas have higher affinity to sheep than in goat and have serious economic impact particularly on lambs due to their nuisance behavior, and the high volume of blood they consume which may result to anaemia. Their control cannot be fully met by animal treatment alone (Fagbemi, 1982).

2.5.3.1 Brief description of Siphonapterans

Fleas are holometabolous small, light yellow to almost black wingless insects with laterally flattened body and short mouthparts modified for piercing and sucking, measuring between 1.0 to 8.5 mm in length (Chapman *et al.*, 2013; Hastriter and Whiting, 2009). They generally have varying number of bristles and short antenna with three segments lying in deep grooves on either side of the head which assist during mating (Chapman *et al.*, 2013). Their heavily sclerotized integument have a glossy surface and makes movement through hairs and feathers quite easy. Fleas are not easily removed by preening or grooming due to the presence of backward pointing combs or ctenidia (Figure 2) found on the pronotal or/and genal borders, which are very important features in species identification. They generally avoid light by burrowing in animal hair or in dark crevices. Fleas are apterygota but have well developed hind legs (Figure 18) for jumping which is mostly mistaken by many as flying.

The females have an abdomen that points down unlike the male which has its abdomen pointing upward. Despite having host preferences, casual feeding is not uncommon and most will feed on a wide range of mammals and birds. Both adult males and females are obligate haematophagous ectoparasites of mammals and birds and are capable of causing dermatitis; transmitting plague (*Yersinia pestis*), murine typhus (*Rickettsia*) and tapeworms to human (Hastriter and Whiting, 2009).

2.5.3.2 Life cycle of fleas (Siphonaptera)

Fleas breed close to the resting and sleeping places of their hosts, in dust, dirt, cracks in floors or walls, livestock pens and birds' nests. Development stages require high humidity. The life cycle of fleas is a holometabolous type, undergoing four stadia; egg, larva, pupa and adult (Figure 2). Females require blood for the development of eggs, and continue to lay eggs as long as they take blood meals. They lay eggs which have smooth surfaces either on the ground or host from where they drop to the ground. These eggs may hatch in two days or two weeks depending on the surrounding temperatures and humidity. The maggot-like larvae have a coat of bristles with chewing mouthparts and feeds on debris and faeces of the adult fleas which contain blood. They are four to ten millimetres long though apodous, they are very mobile. They spin a cocoon (pupal stage), a form of wooly puparium which is well camouflaged because it is sticky when newly spinned and soon becomes covered with dust, sand and other fine particles. The flea pupae can remain in the bedding without hatching for up to 6 months as *pre-emerging* adults. Once animals come close such fleas detect their body heat, movements, pressure caused by footsteps, and increased carbon dioxide (CO_2) that stimulate their emergence, which can take place more or less simultaneously. The adult emerges after undergoing two moults. Both moulting and pupation depend on ambient temperatures; the life cycle may be completed in three weeks in warm conditions, whereas it may be extended for two years in low temperatures.

Fleas spend most of their life cycle away from the host, not only the eggs, larvae and cocoons, but also the adults which can spend up to six months between feeds. The usual life span of fleas is one to two years (Lance *et al.*, 2002).

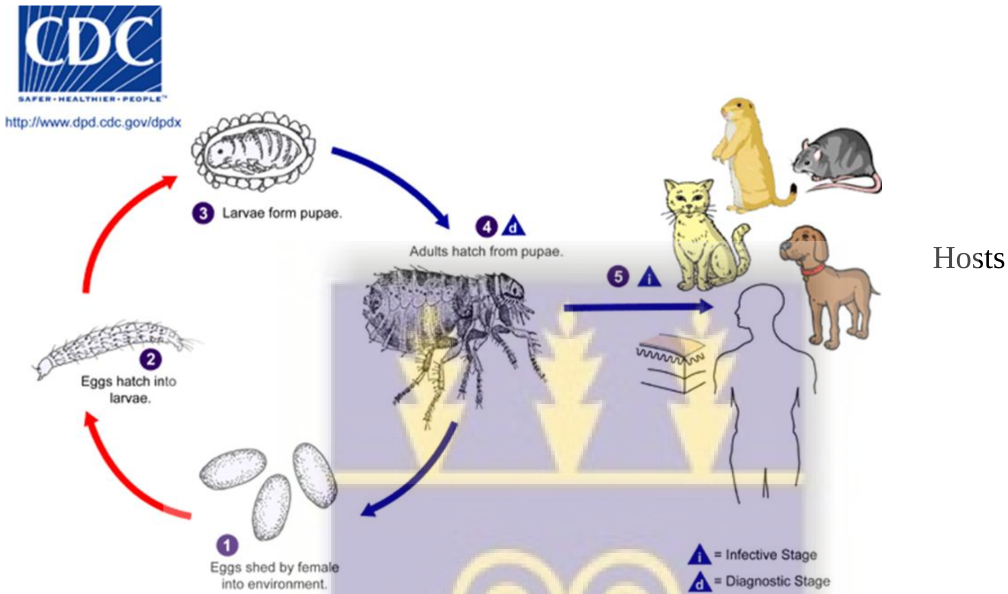


Figure 2: Life cycle of Siphonoptera (Juli, 2016)

2.6 Arachnida

Unlike insects, instead of head, thorax and abdomen like in insects, the arachnid body is ancestrally divided into the prosoma or cephalothorax (the first fused six body segments) and the opisthosoma or abdomen (the remaining body segments). The Arachnida include the ticks, mites, spiders and scorpions, but those of considerable veterinary importance are the ticks and mites. The adult has four pairs of legs on the abdomen unlike insects. There are no antennae, and the mouthparts are greatly modified and carry hypostome in the middle, a pair of chelicerae and pair of outer palps on both sides. These structures are borne on the basis capituli or false head (Walker *et al.,* 2013). The legs are jointed and articulate with the body via the coxae. Larvae are easily recognized by the presence of only three pairs of legs, whereas nymphs and adults have four pairs of legs. The absent of genital aperture on nymphs differentiates them from adults. The pulvillus and a pair of claws found on each tarsus of most species is absent in argasid nymphs and adults. An organ found on the dorsal surface of the tarsus of leg I in all stages of ticks, consisting of an anterior pit and a posterior capsule is an odor-detecting sensory apparatus. Functions like gustatory, thermosensory and mechanosensory have been associated with this Hallers organ. It also used for distinguishing genera and species (Sonenshine *et al.*, 2002).

2.6.1 Ticks

Ticks are from two families, the first family is Ixodidae often called hard ticks because of the presence of a rigid chitinous scutum which covers the whole dorsal surface of the adult male but covers only a small area behind the head of the female and nymphal stages. These ticks are found throughout the year (Yakhchali and Hosseine, 2006). The second is the Argasidae also called soft ticks because they lack the hard scutum.

2.6.1.1 Brief description of ticks

The Ixodids are obligate haematophages known to be important vectors of protozoan, bacterial, viral and rickettsial diseases which have direct bearing on animal and human health. The ixodids spend relatively short time on their hosts to feed, hence are temporal parasites, despite being obligate parasites. They are either one-host, two-host or three host ticks depending on the number of animals they get attached to during their life cycle, hence their greater ability to transmit disease causing agents to livestock.

Livestock contribute to natural, financial, human, physical and social capital in different ways and to different degrees within smallholder dairy, crop–livestock and livestockdependent systems. All of these production systems are at risk from ticks and tick-borne diseases (TBDs) (Mandell, 2000).

According to Mandell (2000), ticks are second to only mosquitoes as vectors of human diseases. They also represent one of the most important threats to the livestock industry in the tropics. They may impair livestock health hence affect production and productivity. When ticks attach to the host, they cause irritation of the skin with subsequent ulceration, and sometimes secondary bacterial infections may result. Wounds caused by ticks may become infested by screw-worms or other agents of myiasis, and are also associated with the spread of bovine dermatophilosis caused by *Dermatophilus congolensis*. All of these decrease production and damages hides or skins. Heavy infestations of ticks can result in anaemia, particularly in small and older animals, and the restlessness caused by the presence of large numbers of ticks can lead to a significant loss of weight and condition (Pegram and Osterwijk, 1990). *Amblyomma*, *Hyalomma* and *Rhipicephalus* are genera recognized for such direct and indirect effects. Some ticks are capable of causing toxicosis to livestock which causes progressive, ascending, afebrile paralysis, which can be relieved by quickly removing the tick, if not removed animal can die of it.

The mouth parts of ticks are borne on the basis capituli (Figure 9), which have different shape structures depending on the species. Mouthparts consist of a median hypostome, a pair chelicerae lateral to hypostome with mobile digits adapted for cutting, and a pair of sensory palps lateral to the chelicerae. The hypostome has recurved teeth for maintaining position and are very significant for species identification. It also bears a dorsal groove to permit the flow of saliva and blood during feeding.

The mouthparts borne on the capitulum are anterior and visible from the dorsal surface for Ixodidae unlike Argsidae that have the ventrally and cannot be seen from above.

There are series of grooves on the scutum and body and row of notches called festoons on the posterior border of the body, and chitinous plates on the ventral surface of males all of which serve as distinguishing features. The genital opening is found in the ventral mid-line with the anus posterior. Some ticks are ornates with enamel-like areas on their body. The adults have a pair of spiracle behind the fourth pair of coxae. Some coxae have spurs depending on the tick species. Eyes are situated on the outside margin of the scutum when present (Urquhart *et al.*, 1996). Argasidae are flattened and covered by small marginal discs. Eyes occur on folds lateral to coxae when present (Sonenshine *et al.*, 2002).

2.6.1.2 Life cycle of ticks

Majority of hard ticks require three hosts (Figure 3) to complete their life cycle and during this development they go through four stages. These stages are egg, larva (also called seed tick); nymph and adult without a pupa, hence are hemimetabolous. Adult ticks mate after feeding. The gravid female drops from the host and lay thousands of eggs on the ground. The eggs hatch into larvae or seed ticks which quest for a host. After feeding they leave the host and moult to nymphs, which also look for a host to feed after which they moult to adults' (Figure 3). The adults feed, mate and the cycle is repeated.

Because ticks are obligate haematophagous and feed on different hosts, they are good vectors capable of transmitting disease causing agents from one animal to the other (Knipling and Steelman, 2000). Argasids take several small blood meals and lay small batches of eggs unlike ixodids that take large blood meal once and lays more eggs. Most argasids also have two or more nymphal instars in their life cycle, each of which most consume blood and moulting occurs off the host in crevices, crack or beneath debris. (Sonenshine *et al.*, 2002).

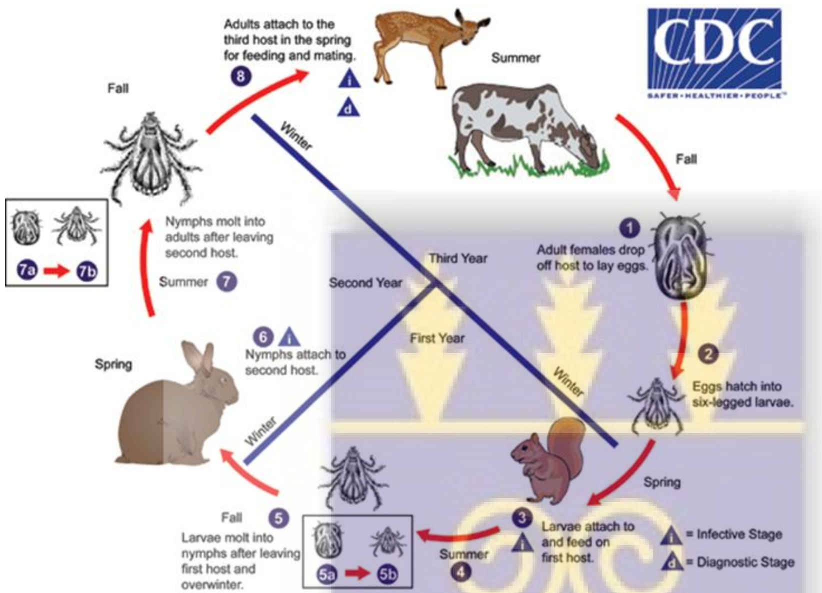


Figure 3: Three year life cycle of ticks (Web retrieved)

2.6.1.3 Some tick-borne diseases

The most damaging effect of ticks is their ability to transmit diseases, some of which can be fatal to the livestock According to Kaufman *et al.* (2009), the tick-borne diseases of importance to the livestock industry can be classified as follows:

Anaplasmosis: This group of diseases is caused by rickettsia-like organisms of the genus *Anaplasma*, which are usually transmitted by ticks, but which may also be transmitted mechanically by biting Diptera (e.g. Tabanidae and *Stomoxys*). Anaplasmosis affects domestic and wild ungulates and is widespread throughout the tropics.

Babesiosis: This group is widespread throughout the tropics, causing heavy losses in non-resistant livestock. It is caused by protozoan parasites transmitted by ticks of the genera *Boophilus* and *Rhipicephalus*. Without treatment, mortality rates are very high (30 % for *Babesia bigemina*, 70 - 80 % for *B. bovis*). Babesiosis or "cattle fever" was eradicated from the United States between 1906 and 1943, by eliminating its vectors *Rhipicephalus microplus* and *Rhipicephalus annulatus*. Before its eradication, babesiosis cost the U.S. an estimated millions in direct and indirect annual losses (Jongejan and Uilenberg, 2004).

As with anaplasmosis, babesiosis tends to be more important in non-resistant exotic animals, although *B. bovis* infections are very severe and even local breeds of cattle can be greatly affected by *B. bigemina* under conditions of poor health or nutrition. Animals that recover from babesiosis become carriers for life and can develop the disease again if subjected to stress. The entire southern part of West Africa (covering Southern Nigeria, Benin, Togo and Ghana), features high climate suitability for *R. microplus* (De Clercq *et al.*, 2013), such could serve as a region of potential epidemic episodes of diseases coupled with its attendant consequences. *R. microplus* has been reported in Benin and La Côte d'Ivoire before 2011 and Burkina Faso and Togo after 2011 (Adakal *et al., 2013;* De Clercq *et al.*, 2013; Madder *et al.*, 2012). La Côte d'Ivoire, Burkina Faso and Togo all share border with Ghana and some pastoralists from these countries enter Ghana to graze their livestock which may serve as a vehicle to introduce this species in Ghana.

Heartwater: is an infectious, non-contagious, disease of domestic and wild ruminants (Walker and Koney, 1999). This disease also called cowdriosis is caused by the rickettsial organism *Ehrlichia* (formerly *Cowdria*) *ruminantium.* The disease is transmitted by ticks of the genus *Amblyomma* and the species *variegatum* being the most widespread vector which is most prevalent in the Caribbean and all over Sub-Saharan Africa except certain areas of

Southern Africa (Uilenberg, 1983). It is specific to cattle, sheep, goats and some wild ruminants. Heartwater or cowdriosis is most severe in small ruminants, but also causes heavy losses in exotic cattle, which are more susceptible than indigenous breeds. However, indigenous cattle can also be affected if poor conditions weaken their immune system, or if animals are moved from an area free of heartwater to an area in which it is endemic (Wikel, 1999).

Theileriosis: This disease is caused by species of the protozoan *Theileria*, transmitted by ticks of the genera *Rhipicephalus, Hyalomma* and *Amblyomma*. *Amblyomma* is one of the ticks known to be present throughout the year due its ability to strive in different climatic and weather conditions (Natala *et al.*, 2009). *Theileria* is responsible for the most pathogenic tick-borne diseases of cattle. Theileriosis represents one of the most important threats to livestock production in the tropics; mortality levels may reach 90 % in endemic situation and in susceptible animals, hence it is a major constraint on the livelihoods of millions of rural farmers (Mukhebi, 1992).

Lyme disease caused by the bacterium *Borrelia burgdorferi*, and **Relapsing fever** caused by *Borrelia spp*. The former is transmitted by the relatively slow-feeding ixodid (hard) ticks of the genus *Ixodes* and the latter by the fast-feeding argasid (soft) ticks of the genus *Ornithodoros*. Relapsing fever is also transmitted through the bite of lice (*Pediculus humanus*) (Schwan and Piesman, 2002).

2.6.2 Mites

Mites are closely related to ticks, but are obligate parasites that live on the surface of the skin of livestock and feed on the lymph. Mites are found on different parts of livestock, causing marked irritation, which makes the animal to kick, scrub and bite the infested parts in the case of dogs and cats. Infested animal body parts show lesions with exudative dermatitis, pustule formed and hard crusts on skin. Most mites are free-living and harmless. Other mites are parasitic, and those that infest livestock animals cause many diseases that are widespread, reduce production and profit for farmers, and are expensive to control (Mullens, 2009).

Some mites have been found to be the intermediate host of tapeworms that infest domestic animals such as cattle, sheep and goats. Young animals are more susceptible than older animals to the tapeworms (Allred, 1954).

2.6.2.1 Brief description of mites.

The body of mites is divided into two major parts or regions; the anterior gnathosoma bearing the mouthparts which consist of a median hypostome, a pair of chelicerae and a pair of pedipalps, and the idiosoma, which forms the rest of the body where the legs and eyes (when present) are found. The pedipalps generally have five segments but may be greatly reduced and highly modified in various mite groups. They are primary sensory appendages with chemical and tactile sensors which are significant to the mite in finding food and perceiving environmental cues. The pedipalps may also be modified as raptorial structures for capturing prey or as attachment devices to facilitate clinging to hosts. Each chelicera is three-segmented and terminates in a chela or pincer, which is composed of a fixed digit and a movable digit designed for seizing or grasping. Unlike ticks, mites do not have Haller's organ, their hypostome is toothless and generally smaller than ticks (Mullen and Oconnor, 2002).

The anterior part of the idiosoma bearing the legs is the podosoma and the posterior section behind the legs is the opisthosoma. The portion of the idiosoma bearing the first and second pairs of legs is the prodosoma and the hysterosoma extends from just behind the second pair to the posterior end of the body. These designations are helpful in locating specific setae and other structures.

Mites like ticks have four pair of legs as nymphs and adults, but three pairs in larvae. The legs are divided into coxa, trochanter, femur, genu, tibia, tarsus and the pretarsus which commonly bears a pair of claws, a single empodium, and in certain groups, a membranous pulvillus. These structures aid in movement or in clinging to various surfaces, including hosts.

Mites feed differently depending on the groups they belong to; Psoroptic mites feed superficially at the stratum corneum; Sarcoptic mites feed by burrowing within the living layers of the epidermis, mainly stratum spinosum; Demodectic mites feed between the epidermis and the hair shaft in hair follicles; Dermanyssid and trombiculid mites feed by piercing the skin with their chelicerae or a stylostome feeding tube and feeding on blood and body fluid; and other mites feeding using their chelicerae to scrape either at the skin surface, or at base of feather example the shaft and calabus, or to penetrate and scrape at internal tissue.

In cattle, chorioptic mange commonly occurs on the base of the tail, the perineum, and the back of the udder. The hooves may also be affected, resulting in lameness. Heavy infestations can cause loss of condition, which can lead to emaciation and damage to hides (Walton and Currie, 2007).

2.6.2.2 Life cycle of mites

Mites undergo hemimetabolous life cycle in three weeks involving egg, prelarva, larva, protonymph, deutonymph, tritonymph and adult. In some groups one or more stages may be suppressed, resulting in a wide range of life-history patterns (e.g., chiggers). Mites may either deposit eggs externally or retain them in the uterus until hatching. The prelarva is a nonfeeding, quiescent stage unlike the larva which is active and moults to produce nymph which usually resemble the adult except for their small size, pattern of sclerotization and chaetotaxy (arrangement of bristles) (Mullen, 2009).

2.7 Factors influencing arthropod ectoparasite infestations in livestock

The arthropod ectoparasites discussed above are influenced by various challenges and factors that may affect their reproduction, survival and spread from one host to another. Rainfall, temperature, vegetation, competing species and management/husbandry practices are key environmental factors that influence arthropod infestation in livestock. Husbandry practices where livestock from different communities are grazed together have a key influence in general on the spread of arthropod ectoparasites (Asmaa *et al.*, 2014). Ideal temperature and availability of moisture are key factors for the life cycles of most arthropod ectoparasites (DeClercq, *et al.*, 2013), as they regulate development and the mortality rates of the complete life cycle during the time spent away from the host (off-host). Temperature has potential influence during moulting periods (Sonenshine *et al.*, 2006), a process which arthropods undergo to allow increase in size. According to Angyiereyiri (2015), rainfall influences the development, survival and activity of ectoparasites particularly ticks, which was supported by Mohammad and Ali (2006) and Hall (2006), all found that when there is increase in moisture and decrease in temperature, arthropod ectoparasite (ticks, lice and fleas) infestations also increase. According to Asmaa *et al.,* (2014), breed, age and sex are key host factors that influence tick infestation in livestock. The tick prevalence is higher in indigenous cattle breed than crossbred and infestation is higher during summer when temperature has high influence on tick population (Kabir *et al.,* 2011). Tick infestation is highest in cattle, followed by sheep and then goats in terms of species with the udder and genitalia as the most ideal predilection sites.

These parasites do not only parasitize livestock but also humans particularly those who work in close contact with infested livestock (Angyiereyiri, 2015), hence the importance of having information on their prevalence and an estimate of the economic losses caused by these parasites. This study therefore, assessed the effects of arthropod ectoparasites infestation on livestock productivity with a view to generating a dataset that could help in formulating strategies for ectoparasites control in the area and its environs.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

A cross-sectional study was done in three Districts (Lower Manya Krobo, Shai Osu Doku and North Tongu) located in three administrative regions (Eastern, Greater Accra and Volta respectively) in Southern Ghana. The study was conducted in nine (9) different communities namely Teye Kwame, Mueter, Akuse, Narhkorpe, Adzakatsekorpe, Kpong Soil and Irrigation Research Centre, Adzagonokorpe, Meiykpor and Afuakakorpe (Figure 4). Eight of the communities can be seen on the map. The ninth community is Adzaktsekorpe which is very close to Kpong SIREC, though not indicated on the map.

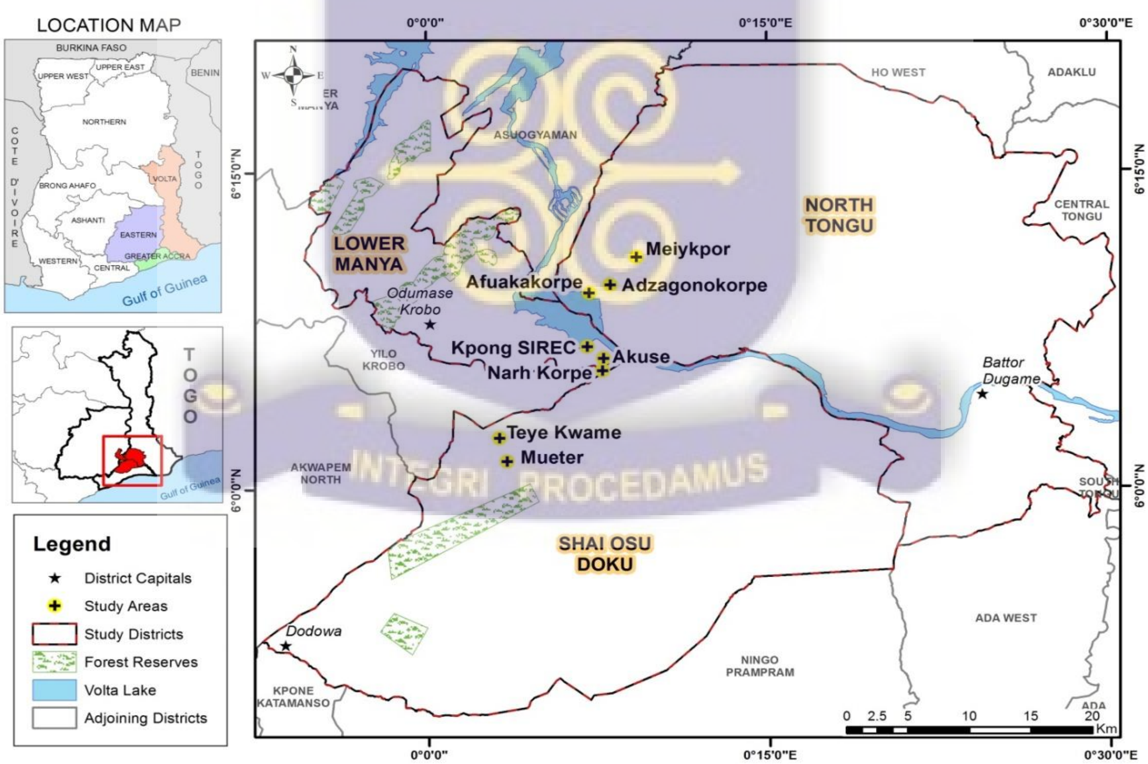


Figure 4: Map of study area

The area is part of the Accra plains and has coastal savannah vegetation. The vegetation cover of Lower Manya Krobo and Greater Accra districts is more of savannah sparsely covered with Neem trees or shrubs with more grass coupled with mango plantations. North Tongu is covered with more trees, more forest-like compared to the other two districts.

The major ethnic groups in Lower Manya District are Krobos, Ewes and Akans; in the Shai Osu Doku District are Brongs, Ashantis and Akans and in North Tongu District are Ewes, Guans and Akans (GSS, 2014). But in all the three districts majority of the herders were Fulani from neighbouring countries (La Cote d'Ivoire and Mali).

The area is characterized by bimodal rainfall, the major rainy season peaks in June and the minor season in October. The total rainfall from January 2015 to June 2016 was 1430.3 mm, with an average temperature of 30.8 ^{o}C and average relative humidity of 75.3 % (Appendix D). Table 1 shows the GPS coordinates and land elevation of the study localities as captured using Garmine e Trex 20 hands held device.

Table 1: Study communities with their GPS coordinates and land elevation.

COMMUNITY	NORTH	EAST	ELEVATION (metres)
Greater Accra Region			
Teye Kwame	06^0 02.646'	000^0 03.009'	71
Mueter (old water works)	06^0 01.087'	000^0 02.302'	76
Eastern Region			
Akuse	06^0 05.503'	000^0 05.840'	43
Narhkorpe	06^0 06.117'	000^0 05.501'	51
Adzakatsekorpe	06^0 07.278'	000^0 05.108'	45
Kpong Soil and Irrigation Research Centre	06^0 07.741'	000^0 04.297'	28
Volta Region			
Adzagonokorpe	06^0 09.646'	000^0 08.069'	26
Meiykpor	06^0 10.969'	000^0 09.220'	54
Afuakakorpe	06^0 09.279'	000^0 07.124'	30

3.2 Study Design

The research involved field and laboratory work. At the field level, questionnaire administration to livestock farmers, parasitological work on ruminant livestock and general observation and discussion with livestock farmers were conducted. The questionnaires were administered purposely to 37 (20 Eastern, 9 Greater Accra and 8 Volta Regions) selected livestock farmers in the three study Regions, and the parasitological survey involved the examination of the whole bodies of sampled ruminants (cattle, sheep and goats) and the arthropod ectoparasites found were collected and preserved until identification.

The laboratory work involved morphological identification of all collected arthropod ectoparasites to genera level where possible to species level, and molecular identification of some vector-borne pathogens harboured by ticks.

3.3 Sampling procedure and Questionnaire administration

Thirty-seven (37) households were purposely sampled because of their willingness to participate in the study both by accepting to respond to the questions in the questionnaire, and assisting in the parasitological work such as restraining the animals for the collection of arthropod ectoparasites from the livestock.

Questionnaires with 42 closed-ended and one open-ended questions were written in English (Appendix A) and administered to individual farmers to assess their knowledge on arthropod infestation on livestock, their husbandry practices, and their expenditure and gains from the livestock. More information on the types of pesticides, methods of application/administration, knowledge on dilution, and their storage were gathered through further discussion and interactions. Where the respondents did not understand English, an interpreter translated it into a language that the respondents understood (Figure 5).

3.4 Parasitological survey

3.4.1 Collection of parasitic arthropods

Collection of arthropod ectoparasites was done on 368 ruminants (209 cattle, 53 sheep and 106 goats) from 27 kraals of cattle and 18 flocks of small ruminant (6 flocks with sheep only, 7 with goats only and 5 flocks having sheep and goats mixed). The animals were humanely restrained and their body surfaces examined (Figure 6). Arthropod ectoparasite collection was done using a modification of the collection method described in Knopf *et al.* (2002). Ticks were searched for by passing hand through animal's body coat and ticks found were collected using blunt forceps. They were collected from the anogenital, dewlap, front or hind legs, neck, udder, scrotums and tail parts of the animal and put in separate Eppendorf tubes (Figure 7) to ease identification. Much care was undertaken to collect more male ticks to ease identification (Madder *et al.,* 2012).

Clinical examination for lice and fleas was done by multiple hair partings and the parasites were collected using forceps. For fleas, either water or ethanol was applied on the animals' coat to immobilize fleas before removal.

Animal coat and hooves were examined for other parasites such as myiatic larvae, while areas with crusts or lesions suspected to be mange were deep scraped with oil smeared scalpel blade (Hendrix, 1998) as cited in Yakhchali and Husseine, 2006).

Figure 5: Researcher interviewing seated Muhammed Hachim, a prominent livestock farmer and a cattle dealer

Figure 6: Cattle humanly restrained by farmer during arthropod ectoparasites collection by researcher

3.4.2 Preservation of parasitic arthropods

Collected ticks, lice and fleas were put in individual 1.5 ml Eppendorf tubes (Figure 7) that contained 70 % ethanol. Scrapings were also put in 1.5 ml Eppendorf tubes containing 5 % formalin. The tubes were appropriately labelled. Both samples and field recorded data (Appendix B) were transported to the Department of Animal Biology and Conservation Sciences Parasitology laboratory for further processing and analyses.

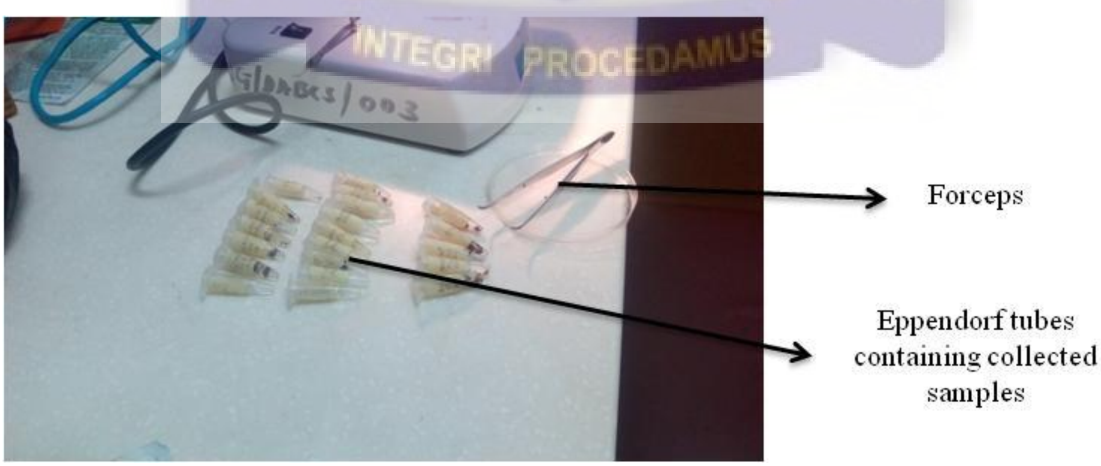


Figure 7: Eppendorf tubes containing collected arthropod ectoparasites next to a dissecting microscope

Modified Battini *et al.* (2015) body condition scoring was adopted; poor body condition score was given to ruminants with extremely thin to smooth and less prominent spinous process as well as those having moderate depth of loin muscle. Good body condition score was given to those in which the spinous process only stickup and prominent, with smooth, rounded and well covered transverse process. Keen observation of the livestock kraals, pen types, watering and feeding practices were taken note throughout the study. Farmers were also questioned during and after sampling about their relationships with other livestock owners and crop farmers.

3.4.3 Morphological identification of collected arthropod parasites

Lice, ticks and fleas were directly examined under Leica EZ4 HD® dissecting (8X - 40X) and Leica icc50 HD® compound microscopes (10X and 40X) to morphologically identify specimens.

Skin scrapings were digested in 10 % Potassium hydroxide (KOH) at 60 - 80 ^{o}C for 15 minutes, centrifuged at 1500 - 2000 revolutions per minute (rpm) for 5 minutes (AL-Kardi, 2013) before viewing under the compound microscope at 100 X magnifications.

3.4.3.1 Identification of Ticks

The identification of the tick species was done based on their morphological characteristics (Latif and Walker, 2004; Walker *et al.*, 2013) such as the presence of scutum and alloscutum for females, conscutum for males as a hard plate on the dorsal surface plus the shape of their margins and the punctuations distribution on these hard plates, presence or absence of festoons and or grooves, shape of eyes (convex or concave if present), coloration of legs, position (whether anterior or posterior) and length of mouthparts, shape of lateral margins of basis capituli, length of palp article and presence or absence of spurs, and ventrally number of spurs on coxae if present and which coxae, size and shape of spiracles with or without sparse or dense setae, presence or absence of ventral (adanal and subanal) plates and shape (U or V) of anal groove. *Rhipicephalus* morphological characters like hypostomal dentition, presence of seta on palp articles one (1), presence or absence of caudal appendage (Figure 8), distinct or indistinct ventral plate spurs, and presence or absence of spurs on coxae 2 and 3 were used for identification to species level (Madder, 2016).

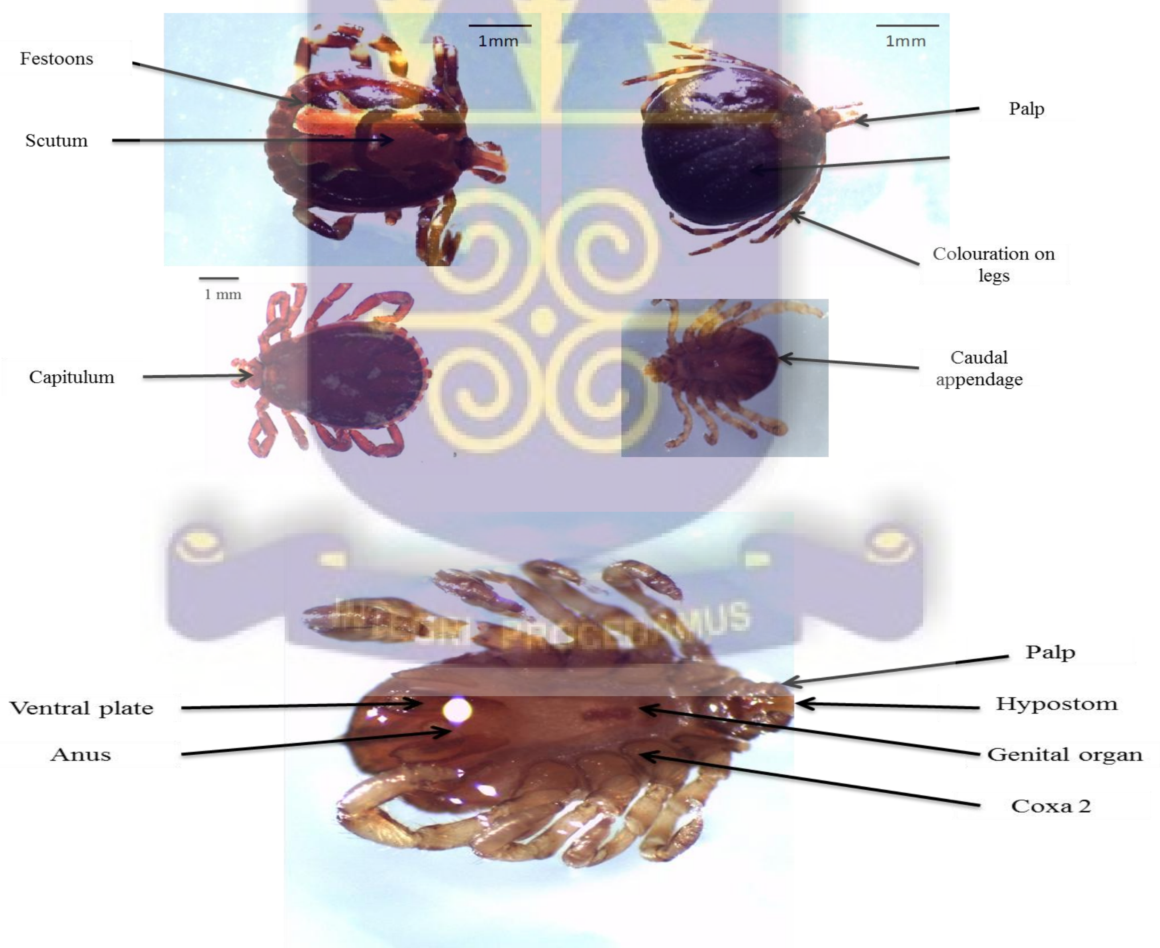


Figure 8: Some identification features of ticks.

3.4.3.2 Identification of Fleas

Morphological features like number of spines of genal comb (figure 9) and presence or absence of eyes, orientation (vertical or horizontal) of genal comb, shape (blunt or pointed) of spines, ratio of head length to height and difference in length of spines I and II of the genal comb were used for fleas (Mathison and Pritt, 2014).

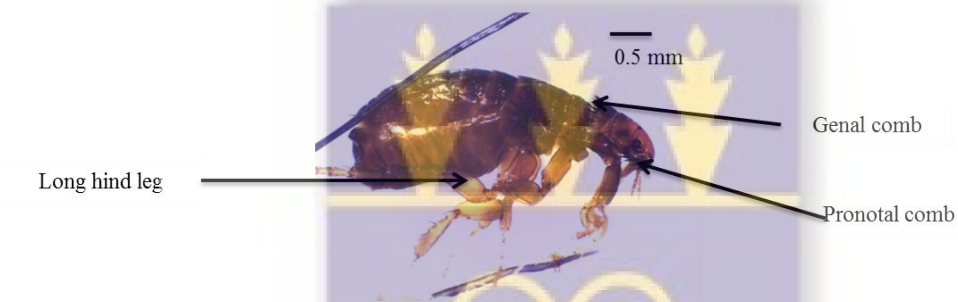


Figure 9: Some identification features of flea.

3.4.3.3 Identification of Lice

Presence or absence of eyes, length and width of thoracic sternal plates when present, shape (blunt rounded or acute and long) of thoracic sternal plates with median projections, sternal pits on or off plate, head length at ocular points compared to its width, length of antennae compared to length of head at ocular points (Figure 10), as well as shape of head (expanded or not,) behind the antennae and shape (rounded or acutely conical) of fore head were used for lice (Mathison and Pritt, 2014).

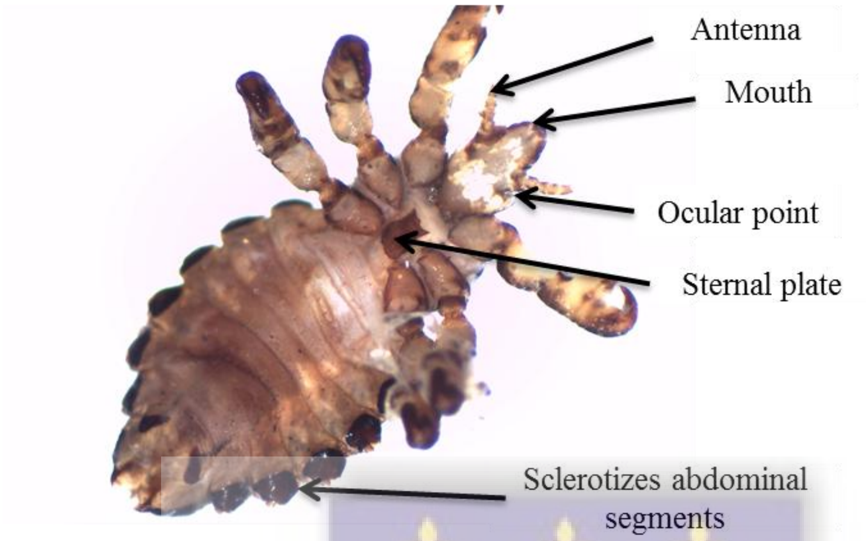


Figure 10: Some features of *Haematopinus* louse

3.4.3.4 Identification of Mites

Length of legs and presence of hair between bases of first and second pairs of legs, presence or absence of setae on cephalothorax, presence or absence of fattened scales on body, length of body (either prolonged behind or ballon-shaped), position of anal opening, and shape (pointed or blunt) of scales and spines were the morphological features used for mite identification (Pratt, 1963).

3.4.4 Molecular identification of tick-borne pathogens

3.4.4.1 Tick DNA extraction methods

DNA extraction was done on 9 adult ticks (6 *Rhipicephalus*, 2 *Amblyomma* and 1 *Hyalomma*) and some *Amblyomma* eggs. Both ticks and eggs were cleaned using modified Halos *et al.* (2004) washing method where they were first washed in sterile water bath, rinsed in absolute ethanol bath, before drying on filter paper. Two methods were applied in crushing the ticks. In one of the methods, the whole tick was crushed in 5 ml Eppendorf tube using a sterile pestle. The second method was used on engorged ticks where a sterile scalpel blade was used to remove the exoskeletons and the internal organs and blood were put in the Eppendorf tubes and crushed. Eggs were also put in Eppendorf tubes and crushed. The following were added to the samples (whole tick, eggs or ticks without exoskeleton) before mechanically crushing:

- Distil water 95 µL
- 2 x Digestion Buffer 95 µL
- Proteinase K 10 µL
- Beta-mercapto ethanol 3.5 µL

DNA extraction was performed using the modified method of Qiamp DNA extraction kit for tissue protocol (Qiagen, Hilden, Germany) (Appendix C).

3.4.4.2 Polymerase chain reaction (PCR)

For the PCR, a total volume of 25 µL was used containing 14.05 µL water, 1 µL $MgCl_2$, 0.2 µL dNTPs, 5 µL 5 x Buffer 0.75 µL Taq, 1 µL for each of the primers (forward and reverse) and 2 µL extracted DNA were added to each PCR reaction.

For *Babesia bigemina*, PCR assays were performed using Applied Biosystems 2720 Thermal Cycler under the following conditions: an initial denaturation at 96 ^{o}C for 60 seconds (s), 35 cycles followed with denaturation at 96 ^{o}C for 15 s, annealing at 60 ^{o}C for 60 s (1 min.) and a final extension step at 72 ^{o}C for 1 min.

For *Anaplasma*, PCR assays were performed using BIO RAD i thermal Cycler under the following conditions: an initial denaturation at 96 ^{o}C for 60 seconds (s), 35 cycles followed with denaturation at 96 °C for 15 s, annealing at 53 °C for 60 s (1 min.) and a final extension step at 72 °C for 1 min.

3.5 Assessment of Potential Risk Factors for Ectoparasite Infestation

Potential risk factors for ectoparasite infestation like age, species, sex, breed, body condition, weight and measurement of right shank of sampled animal were recorded (Hassan, *et al.*, 2011) on a data scoring form (Appendix B). The age of the animals was determined using their dentition as described by Aiello and Mays (1998) with the help of the owner or herder. Animals were divided into two groups based on their age; cattle less than 2 years were categorized as young and those more than two years considered as adults; for sheep and goats (small ruminants), the young group referred to those less than a year old and adults, more than one year. Cattle weight was taken using a weight band, and small ruminants were weighed using digital clock phase scale, and the weight was recorded in kilogrammes (Kg). The right shank of each sampled animal was measured in centimetres using tailor's tape.

3.6 Data Analysis

All data (both questionnaire and sampling scoring format) were entered in SPSS version 20. Data from sampling scoring format (Appendix B) was also entered in Excel spread sheet. Questionnaires were analysed using descriptive statistics.

Assessment of farmers' awareness of arthropod ectoparasites, farmers perception on effects of arthropod ectoparasite infestations on ruminant livestock productivity, determination of the relationship between husbandry practices and prevalence of arthropod ectoparasite infestations on livestock and effects of arthropod ectoparasite infestation on livestock output were done using descriptive statistic.

The prevalence of infestation was calculated using the method of Gebreselama *et al.* (2014). The prevalence of infestation was calculated by dividing the proportion of animals positive with arthropod ectoparasites by the total number of animals sampled for the parasites, all multiplied by 100. Significant level was determined using Chi square.

$$\textbf{Prevalence of arthropod ectoparasites} = \frac{\text{No. of animals positive}}{\text{Total No. of animals sampled}} \times 100$$

CHAPTER FOUR

4.0 RESULTS

4.1 Livestock structure

Collection of arthropod ectoparasites was done 368 ruminants (209 cattle, 53 sheep and 106 goats) from 27 kraals of cattle and 18 flocks of small ruminant (6 flocks with sheep only, 7 with goats only and 5 flocks having sheep and goats mixed).

In total, 27 kraals and 18 pens (27 kraals with cattle only, 6 pens with sheep only, 7 pens with goat only and 5 pens with sheep and goat combined) were sampled during the study. Out of the 27 sampled kraals, majority (74 %) of them had 50 to 100 cattle and only 26 % had between 100 and 500 cattle. Four of the questionnaire respondents had between 100 and 500 cattle but were divided into two kraals for easy management. Three of the sampled pens kept both cattle and small ruminants. About sixty-seven percent (66.7 %) of the six sheep pens sampled had less ten sheep. Three of the seven sampled goat pens had between 10 and 50 goats, and three of the five sampled sheep and goat mixed pen had more than ten ruminants. The dominant cattle breeds were Sanga, other cattle breeds found were N'Dama, Sokoto Goudali and Zebu as well as Njallonke sheep and West African Dwarf (WAD) goats. There were also cross breeds of cattle, being mixes of at least two or all the three main breeds.

4.2 Income and expenditure

Approximately eighty-seven percent (86.5 %) of farmers kept the livestock for sale, while only 10.8 % kept them for consumption.

About forty-six percent (45.9 %) of the livestock farmers said they pay herdsmen to herd their animals. The form of payment for herders was in the form of a heifer provided to them by the owners every three years they herded the animals.

Approximately 35.1 % of the respondents revealed that they spent one hundred to five hundred Ghana cedis (GH¢ 100 - 500) ($25.64 - $128.21) on treatment of diseases for the 6 months preceding this study, and the same percentage also spent more than GH¢ 500 ($128.21) during that time. Cattle farmers spent more compared to small ruminants which were not a surprise considering the average sizes of these animal. 45.9 % of the respondents sell milk. 27 % earn less than 100 Ghana cedis and 16.2 % earned GH¢ 100 - 500. Respondents said they do not milk the small ruminants but rather left it for lambs and kids. 83.8 % of the respondents acknowledged that they sell livestock and on average 43.2 % earned more than GH¢ 1500 ($384.62) annually. 27 % of the respondents reported that they spent less than GH¢100, 35.1 % spent GH¢100 – 500, 35.1 % spent more than GH¢500 and only 2.7 % did not spent on treating their livestock six months preceding this study. Those who did not spend were new in the business with their first stock. More importantly, farmers who keep both small and large ruminants were found to be more willing to spend on large ruminants (cattle) than the small ruminants (sheep and goats) during treatment.

There was a strong positive correlation (Appendix E) between the weight of livestock and the shank width of sampled animals which translates that more meat could be obtain from animals with better weight and would fetch more kilos of meat.

4.3 Husbandry practices

4.3.1 Management practices

Figure 12 illustrates that majority (75.7 %, n = 28) of the livestock farmers in the three study regions in Southern Ghana practiced semi-intensive system and only few (2.7 %) farmers used the extensive management system, whiles 21.6 % practice intensive system.

In the semi-intensive management system, during the day the cattle are tethered or taken for grazing and watering by a herder. At night the cattle are kept in the kraals which are open with no roof, but fenced with sticks. Because of the docile nature of the dominant cattle breed (Sanga) even where the kraal was wide and had enough space for them to spread, they always keep close to each other at all times even where there is enough space (Figure 13).

Some (33.3 %) of the small ruminant pens are roofed with grass or corrugated iron sheets and fenced with sticks, few (22.2 %) had corrugated iron fence, and few (16 %) had no roof. The floor was dry and more hygienic compared to that of the cattle kraals. The sheep like the Sanga cattle, were also found mostly crowded close to each other, unlike the goats which were found sparsely spread (Figure 13).

Approximately 21.6 % practiced intensive management system (Figure 11), whereby the animals are housed, stall fed and watered (zero grazing). This was found in Kpong Soil and Irrigation research Centre only. This was due to the continuous cropping practiced in the area and limited time of these people as most of them are staffs in the research centre.

Only 2.7 % (i.e. one flock) practiced extensive where the animals are left on their own to fend for themselves and only come home at their own time with less attention from the farmer/owner (Figure 11). Less attention was given, no housing or shelter was provided, feed supplement and proper watering were also absent.

All the 27 sampled cattle kraals and majority (55.6 %, n = 10) of the small ruminant flocks were kept under semi-intensive system and only seven were managed intensively. Most (72.22 %) of the small ruminant pens were roofed and cleaned once, twice a week or every two weeks. The cattle kraals were all without roofs and the ground turn muddy when it rains.

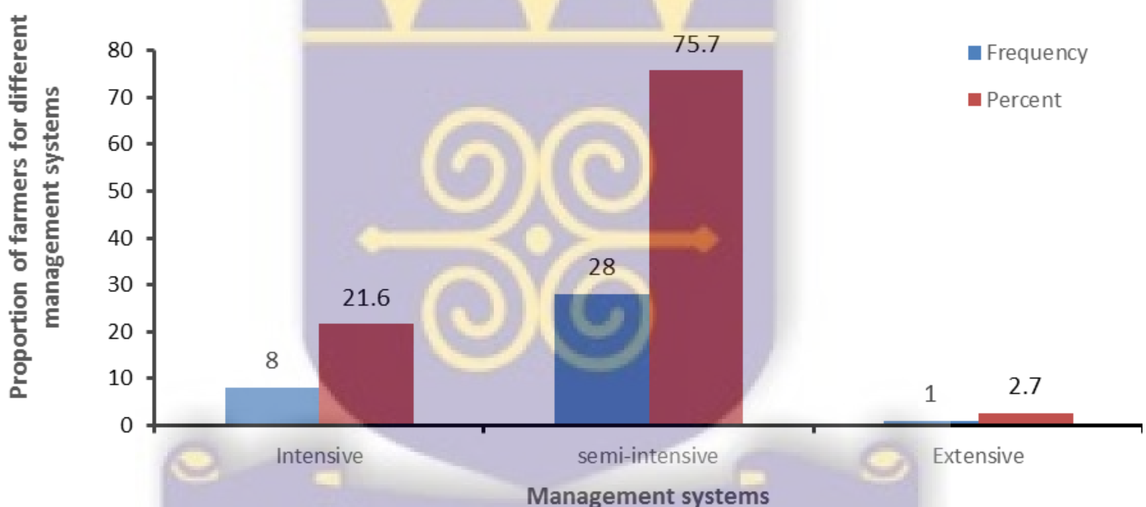


Figure 11: The three ruminant management systems practiced in the study area

Only few (8, 21.6 %) small ruminant farmers supplement feed with cassava and plantain peels and trimmings and lopped *Leuceana leucocephala* leaves. Both ruminants kept under the semi-intensive system were watered once or twice a day before herded in the morning and when they returned and before housed.

Ninety percent (90 %) of the herd of cattle were released for grazing between 4 am and 6 am. They were brought back at 12 pm or 1 pm for short break and milking after which they were released again at 3 pm and come back home at 7 pm. The small ruminants were grazed from 2 pm or 3 pm to 6 or 7 pm.

The cattle were found sheltered in an enclosure fenced by sticks which were closed arranged leaving an entrance where a two forked stick one at each side and a long straight one put across. All (27) the kraals had no roof to prevent the cattle from rain, dew or the heat from the sun. The sampled pens (18) of small ruminants were generally fenced with sticks and or corrugated iron sheets and roofed with either grass or corrugated iron sheets only few (16.7 %) of the sampled pens were without roof. The doors were properly made either with sticks alone or with corrugate to contain both adult and young ones.

Among the kraal owners, only those 54 % of the farmers that utilize the droppings of cattle as farm yard manure clean their kraals twice a year (the major and minor seasons), the others (46 %) only move or clean their kraals once every 3 - 5 years. Kraals with less frequent cleaning and use of pesticides were more heavily infested with arthropod ectoparasites. Small ruminant pens were found to be more regularly cleaned, once, twice a week or every two weeks once.

None of the respondents use cattle as draft animal. Throughout the field work no draft animal, either bovine or equine, was seen yet some were asking for the government to provide them with tractors.

4.3.2 The relationship between husbandry practices and prevalence of arthropod ectoparasite infestations on ruminant livestock

Table 2 shows that semi intensive management system had the highest number of animals infested with arthropod ectoparasites and the least infested animals were found in the extensive management system.

Table 2: Management system practiced and number of ruminant livestock infested with arthropod ectoparasites.

Management system	**Number of ruminants positive of different arthropod ectoparasites**			
	Lice	Ticks	Fleas	Mites
Intensive	11	17	16	0
Semi intensive	34	225	32	0
Extensive	0	0	0	1

Correlation was significant between management system practiced and arthropod ectoparasites interactions ($p < 0.01$), but there were no significant difference ($p < 0.05$) between the intensive and semi intensive management systems and the number of ruminants infested with arthropod ectoparasites.

Livestock which were owned and monitored directly by household head or ones which have owners frequently visiting them were found with better body condition and less arthropod ectoparasite infestations.

4.4. Herd/Flock health

4.4.1 Farmers awareness on arthropod ectoparasites

Eighty-seven percent (87 %, n = 32) of the respondents acknowledged being aware of arthropod ectoparasite infestations on their livestock. This was clearly manifested by the high percentage (73 %, n = 27) of farmers using acaricides on their livestock, with the majority (73 %, n = 27) reporting that the infestation was more severe during the rainy season. According them, during the dry season when the sun is very hot there are few ticks seen.

Measuring the direct and indirect effects of arthropod ectoparasite infestations on livestock productivity would need more time, hence the study investigated the perception of farmers on this issue. It was found that farmers (73 %) perceived that arthropod ectoparasite infestations cause weight loss to livestock which indirectly affects milk yield, meat quality and quantity and this reduces their income. According to the farmers the ticks are more abundant when there is more milk, that is during the rainy season but because of their indirect effects (wounds, bruises) on the teats or udder, some animals are not milked. Approximately eleven percent (10.8 %) revealed that many wounds and lesions (Figure 12) on livestock are as a result of arthropod ectoparasite infestations which they attributed mainly to tick and flea infestations. Some of the remaining 16.2 % perceived that arthropod ectoparasite infestations transmit diseases, 6.3 % said they have less knowledge on the effects on livestock, and others (4.5 %) perceived that the infestations of these parasites on their livestock cause livestock deaths.

Approximately 7.6 % of the sampled livestock had bruises and majority of these were infested with fleas. In addition, 4.3 % and 2.7 % had wounds and lesions respectively most of them were infested with ticks particularly the *Amblyomma variegatum* (Figure 12). Most of these skin problems were found on the armpits, anogenital areas, inside ears, and teats. Majority (85.3 %) of the sampled animals showed none of these but skin conditions like stairy coats, loosing of hair and weakness were observed on some (8 %) of these. The stairy coat was found on goats infested with *Linognathus* sucking lice (Figure 16), while the loosing of hair was found on sheep infested with *Mallophagan* chewing lice *Bovicola* spp. (Figure 17). Most of the kids infested with lice had poor body condition.

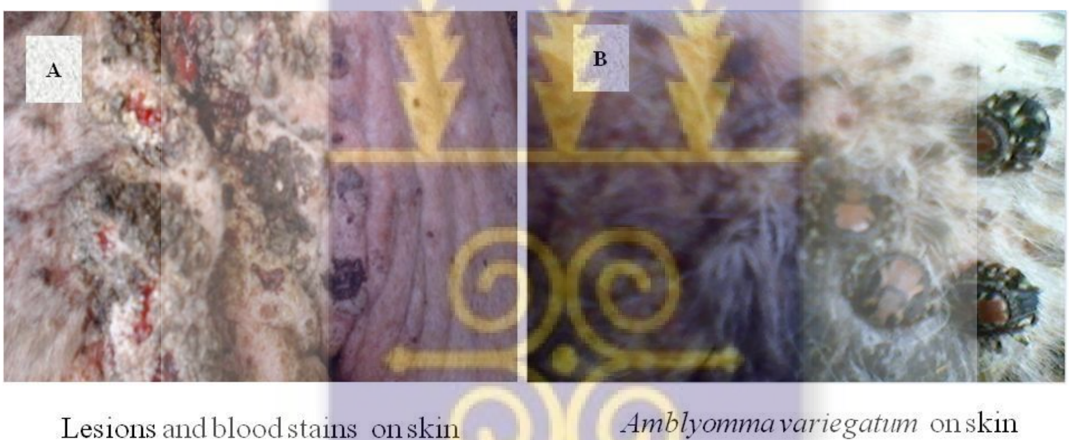


Figure 12: Skin of cattle illustrating lesions and blood stains after removing ticks (A), and skin infested with *Amblyomma variegatum* (B) both on the anogenital areas.

About fifty six percent (55.6 %) of the twenty-seven sampled kraals had more than five cattle deaths six months preceding this study, 18.5 % had 5 – 10 deaths, and 7.4 % had more than ten deaths. Out of 18 sampled flocks, 33 % had more than five small ruminant deaths, only 16.7 % had 5 - 10 deaths. Farmers attribute sudden high deaths to poisoning by crop farmers.

Approximately 62 % (n = 23) complained about poor veterinary services (Table 3), manifested by the high percentage (73 %) who conduct treatment of their animals themselves. 89.2 % (n = 33) reported that they use conventional medicines for treatment. Two post-treatment problems which have resulted in wounds at injection sites were observed on a buck and sheep. Seventy percent (70 %, n = 26) of the respondents also said they do not get advice from the Veterinary Service Department of the Ministry of Food and Agriculture (MoFA).

Only 29.7 % reported that they isolate new animals for at least a week. This was found to be purely for the animals to become familiar to the new place (not for disease or arthropod ectoparsite control or prevention) so that after grazing they will come home to the new place instead of the old place. Lactating calves were separated from their mothers (also not for disease or arthropod ectoparsite control or prevention) purely to prevent them from suckling depriving the herder from getting his share of the milk.

About thirty percent (29.7 %, n = 11) (Table 3) of farmers complained of inadequate grazing area and the conflict they have with crop farmers. One female livestock farmer has stopped small ruminant production to reduce conflict between her and crop farmers. According to her, she has been summoned to court by a crop farmer because of her small ruminants which trespassed into the crop farm.

Table 3: Constraints faced by livestock farmers in the study area

Constraints	Frequency	Percent
Poor veterinary services	23	62.2
Inadequate grazing land	11	29.7
Others	3	8.1
Total	37	100.0

4.5 The prevalence of arthropod ectoparasites on common livestock (cattle, sheep and goats) in Southern Ghana

A total of 368 ruminant livestock (cattle, 57 %, n = 209; sheep, 14 %, n = 53; and goats, 29 %, n = 106) were examined for the presence of arthropod ectoparasites from the three regions, as shown in Table 4. There were more animals sampled from Eastern Region among the regions and more cattle among the three ruminant species as shown in Table 4. This was due to willingness of the farmers to participate in the study and accessibility of the areas.

Table 4: Number of ruminants in each region examined for presence of arthropod ectoparasites

Regions	Number of Ruminant Livestock			
	Cattle	Sheep	Goats	Total
Eastern	101	42	93	236
Greater Accra	43	11	8	62
Volta	65	0	5	70
Total	209	53	106	368
Dominant Breeds	Sanga	Njallonke	West African Dwarf (WAD)	Ruminant Livestock

Figure 13 illustrates the three dominant breeds of ruminant species under the study. The cattle were resting under the shade of a Neem tree during the short break. The sheep are in their pen, whiles the goats inside the fence where their pen is located. The cattle and sheep were found to have more direct contact to each other compared to the goats which frequently butt each other. The closeness to each other allows easy transmission of ectoparasites from one animal to the other.

Figure 13: Dominant ruminant species: Sanga cattle (A), Njallonke sheep (B) and West African Dwarf goat (C)

Note the resting positions of the cattle and direct contacts that may encourage transfer of ectoparasites among the animals.

The arthropod ectoparasites collected were lice, ticks, fleas and mites (Tables 4 and 5). Table 5 shows that eastern Region had the highest prevalence of arthropod ectoparasites and tick prevalence was the highest among the four arthropod ectoparasites collected.

Though Eastern Region had the highest prevalence of arthropod ectoparasites, statistically it was not significant ($p < 0.05$).

Table 5: Number of ruminants positive for arthropod ectoparasites from the three study regions of Southern Ghana

Region	Animal breed	No. of animals examined (sampled)	No (%) of arthropod ectoparasites collected				
			Lice	Ticks	Fleas	Mites	Total
Eastern	Cattle	101 (27.4)	46 (1.1)	1800 (42.0)	0 (0)	0 (0)	1846 (43.1)
	Sheep	42 (11.4)	36 (0.8)	100 (2.3)	174 (4.1)	8 (0.2)	318 (7.4)
	Goats	91 (24.7)	32 (0.7)	115 (2.7)	122 (2.8)	0 (0)	269 (6.3)
	Sub-Total	234 (63.6)	114 (2.7)	2015 (47.0)	296 (6.9)	8 (0.2)	2433 (56.8)
Greater Accra	Cattle	43 (11.7)	348 (8.1)	713 (16.6)	0 (0)	0 (0)	1061 (24.8)
	Sheep	11 (3.0)	6 (0.1)	38 (0.9)	0 (0)	0 (0)	44 (1.0)
	Goats	10 (2.7)	28 (0.7)	36 (0.8)	0 (0)	0 (0)	64 (1.5)
	Sub-Total	64 (17.4)	382 (8.9)	787 (18.4)	0 (0)	0 (0)	1169 (27.3)
Volta	Cattle	65 (17.7)	41 (1.0)	639 (14.9)	0 (0)	0 (0)	680 (15.9)
	Sheep	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Goats	5 (1.4)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)
	Sub-Total	70 (19.0)	41 (1.0)	640 (14.9)	0 (0)	0 (0)	681 (15.9)
	Total	368 (100)	537 (12.5)	3442 (80.4)	296 (6.9)	8 (0.2)	4283 (100)

The study also revealed that cattle were more (83. 2 %) infested with arthropod ectoparasites than the other two ruminant species as shown on Table 6. Statistically the difference was significant ($p < 0.01$). One lamb found positive with mites (*Sarcoptes scabieis*).

Table 6: Overall arthropod ectoparasites collected from the three ruminant livestock species

Ruminant species	Lice	Ticks	Fleas	Mites	Total No.	%
Cattle	428	3132	0	0	3560	83.1
Sheep	44	150	174	8	376	8.8
Goats	65	160	122	0	347	8.1
Total	537	3442	296	8	4283	100.0

4.5.1 Predilection sites of arthropod ectoparasites

Ticks were found on all parts of the animal body. *Amblyomma* (Figure 14) were found in all the ruminant species and found on anogenital areas, udder or scrotums, ears, dewlap, under tail and tail switch, eye lashes firmly cemented.

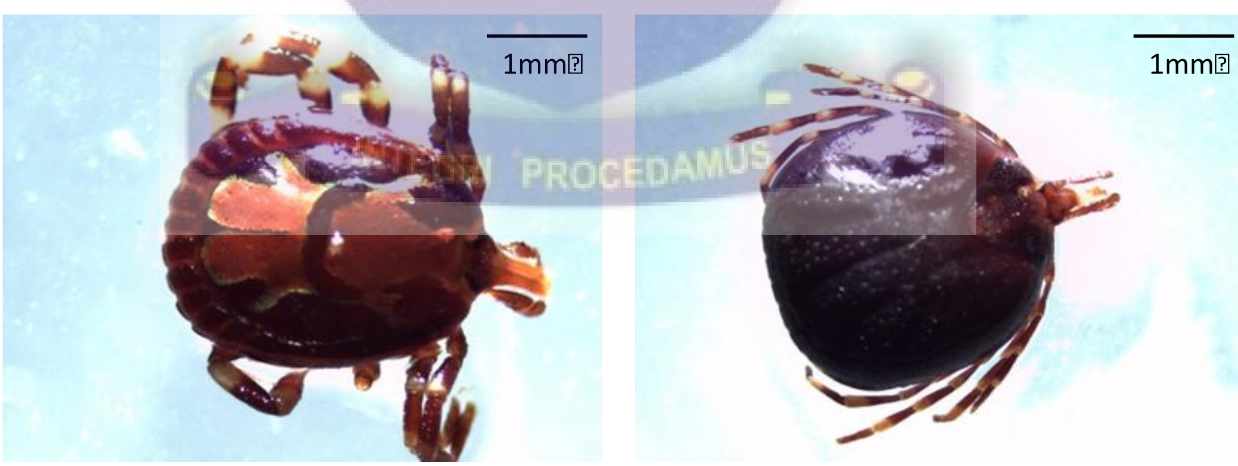
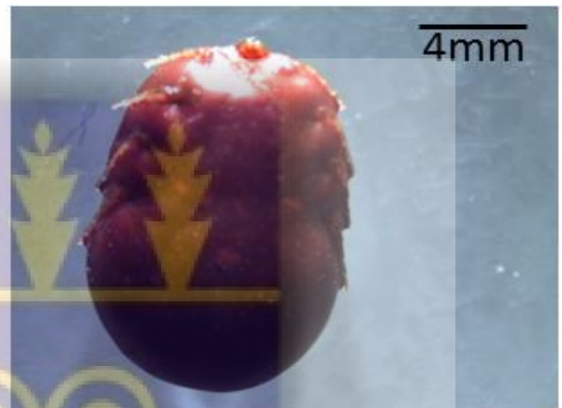


Figure 14: Male (left) and female (right) of *Amblyomma* tick

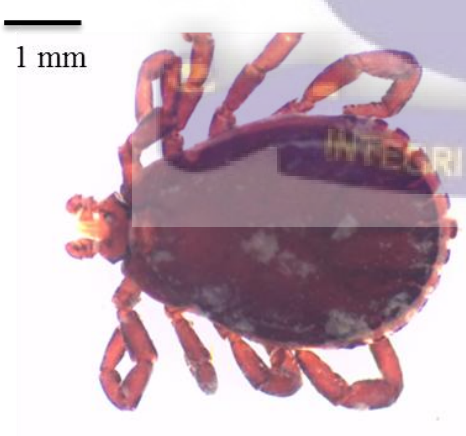
The *Rhipicephalus* (* First report of this invasive *R. microplus* in Ghana) were mainly found on cattle and on the shoulders, dewlap and anogenital areas. *Rhipicephalus sanguineus* were found on both cattle and sheep under the tail or close to the anus or vagina covered by the tail.

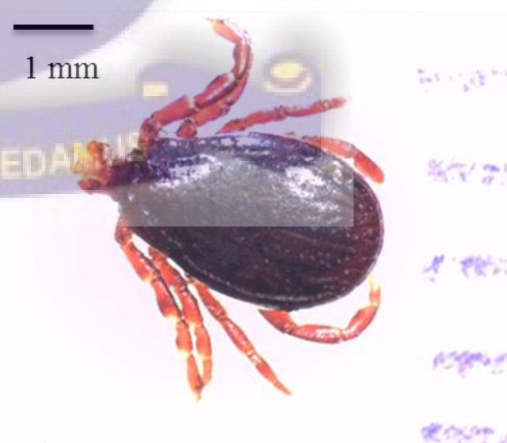
The *Hyalomma* (Figure 15) was collected from dewlap and tail area.



*Male *Rhipicephalus microplus* tick   Engorged female *Rhipicephalus microplus* tick

* First report of this invasive *R. microplus* in Ghana.





Rhipicephalus sanguineus   *Hyalomma* spp

Figure 15: *Rhipicephalus* and *Hyalomma* species of tick found on ruminants in the study area

Sucking lice (Anoplura) of the genera *Haematopinus* and *Linognathus* (Figure 16) were predominantly found on cattle tail switches, ears and eye lashes, where hairs are longer and sparse, as well as on goats with stairy coats. *Haematopinus* spp. were found mainly on the tail switches, eye lashes and edges of cattle ears (Figure 16) where the hair is long and sparse. The ones with sternal plates with median projections (*H. quadripertsp*) (cattle tail louse) were mainly found on cattle switch.

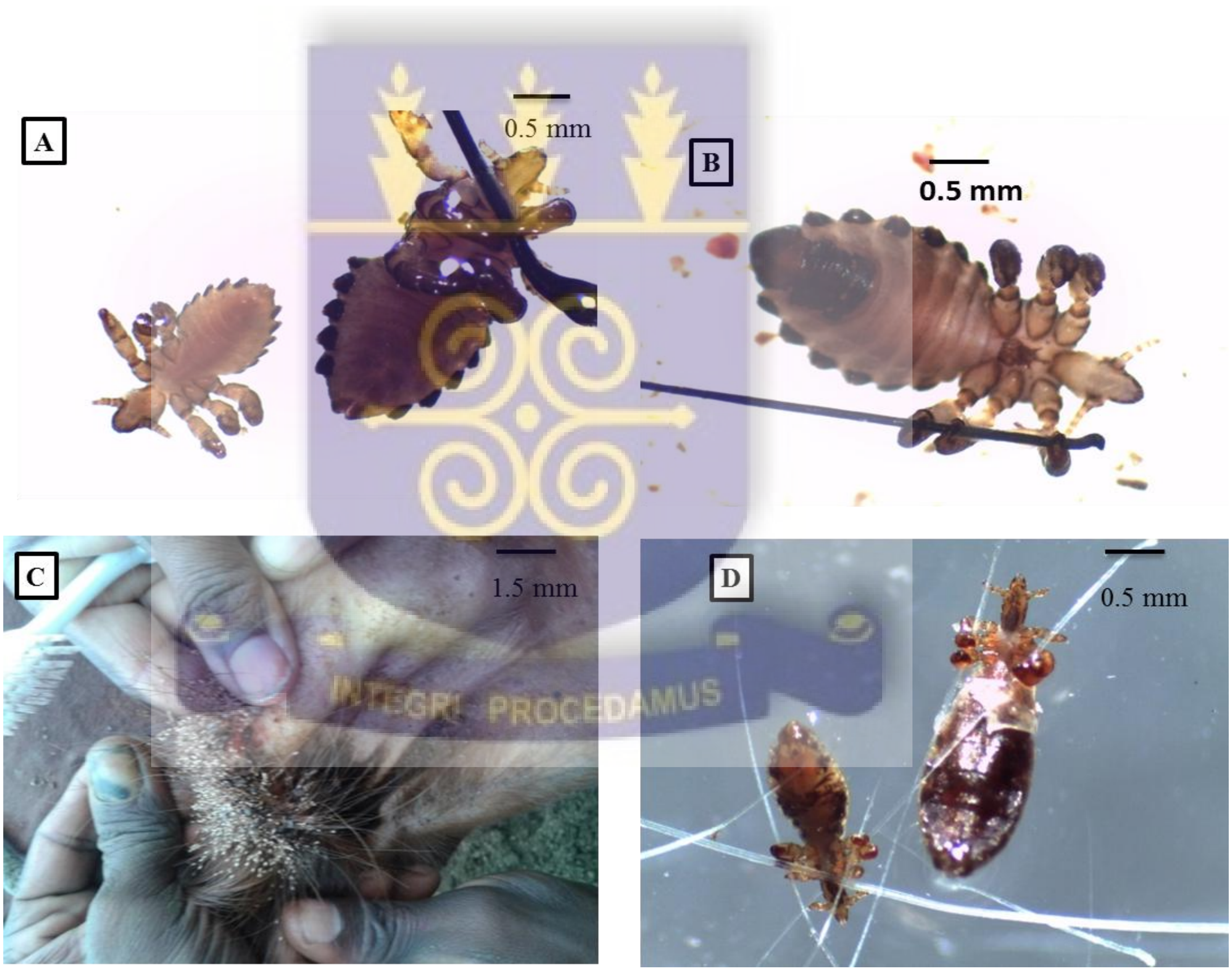


Figure 16: Ventral view of sucking lice: (A) *Haematopinus* spp without sternal plate; (B) *Haematopinus* spp with sternal plate; (C) Cattle ear infested with *Haematopinus* lice, *Bovicola* (chewing) louse; and (D) *Linognathus* spp

The mallophagan louse *Damalinia* (*Bovicola*) spp. (Figure 17) was found on the dorsal parts of sheep with tick closely packed wool and on back and the *Linognathus* was collected mainly from neck of goats.

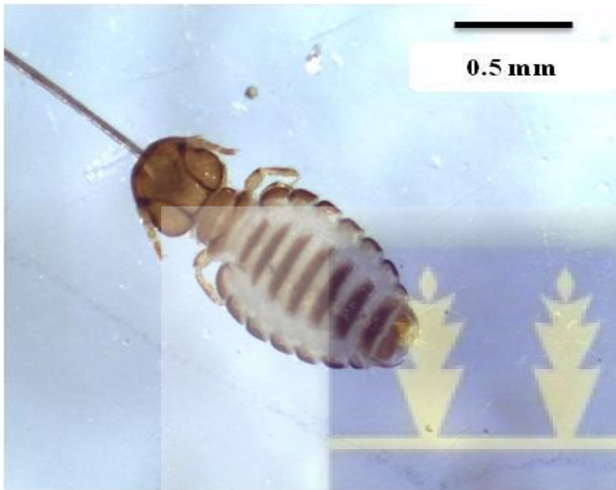


Figure 17: Chewing louse, *Damalinia* (*Bovicola*) spp.

Fleas (Figure 18) were predominantly found on the small ruminants only and most abundant in those housed with proper roofs, and at times with fence limiting the movement of the animals. The only species collected was the dog flea *Ctenocephalides canis*.

Figure 18: *Ctenocephalides canis* (dog flea), the only flea species collected during the study

Seventy-nine percent (79 %, n = 294) of the sampled ruminants were positive for at least one arthropod ectoparasite and 20 % (n = 74) negative. Fourteen percent (14 %, n = 50) had mixed infestation as shown in Table 7 which also shows that only 20.1 % (74) ruminant livestock of the 368 sampled had no arthropod ectoparaite collected from them and animals positive of arthropod infestation formed the majority approximately eighty percent (79.9 %) (Table 7).

Table 7: Proportions of single and mixed infestation of arthropod ectoparasites collected from 368 sampled ruminant livestock

Arthropod ectoparasites	Frequency	Percent
Lice	6	1.6
Fleas	37	10.1
Ticks	201	54.6
Lice and ticks	35	9.5
Lice and fleas	4	1.1
Fleas and ticks	10	2.7
Ticks and mites	1	0.3
No ectoparasites	74	20.1
Total	368	100.0

Table 8 shows data on the different arthropod ectoparasites collected, their numbers, percentage and the mean or the average number of arthropod ectoparasites collected per animal from the three ruminants. A total of 4,283 arthropod ectoparasites consisting of 537 (12.5 %) lice; 3,442 (80.4 %) ticks; 296 (6.9 %) fleas and 8 (0.2 %) mites were collected from the three ruminant livestock in the three districts. Among the ticks the genus *Amblyomma* formed the majority, followed by *Rhipicephalus* (*R. sanguineus* and *R. microplus* were identified to species level) and *Hyalomma* spp.

Table 8: The identification of the different arthropod ectoparasites and their distribution in sampled ruminant livestock from the study areas

Ruminant Host (Number examined)	Ectoparasite species identified	Animals with ectoparasites No. (%)	Ectoparasites collected No. (%)	Mean ectoparasites collected per host
Cattle (n = 209)	*Amblyomma variegatum*	162 (77.5)	1013 (32.3)	6
	Rhipicephalus spp.	161 (77.0)	2011 (64.2)	12
	Hyalomma spp.	43 (20.6)	115 (3.7)	3
	**Rhipicephalus microplus*	57 (27.3)	241 (7.7)	4
	Rhipicephalus sanguineus	23 (11.0)	48 (1.5)	2
	Haematopinus quadripertusus	27 (12.9)	428 (100.0)	16
Sheep (n = 53)	*Amblyomma variegatum*	20 (37.7)	70 (46.7)	4
	Rhipicephalus spp.	13 (24.5)	57 (38.0)	4
	Hyalomma spp.	3 (5.7)	11 (7.3)	4
	Rhipicephalus sanguineus	10 (18.9)	43 (28.7)	4
	Ctenocephalide canis	18 (34.0)	174 (100.0)	10
	Bovicola ovis	5 (9.4)	44 (100.0)	9
	Sarcoptes scabiei	1 (1.9)	8 (100.0)	8
Goats (n = 106)	*Amblyomma variegatum*	13 (12.3)	83 (51.9)	6
	Rhipicephalus spp.	13 (12.3)	71 (44.4)	5
	Hyalomma spp.	3 (2.8)	6 (3.8)	2
	Rhipicephalus sanguineus	8 (7.5)	32 (20.0)	4
	Ctenocephalides canis	31 (29.2)	122 (100.0)	4
	Linognathus africanus	6 (5.5)	49 (75.4)	8
	Bovicola caprae	6 (5.5)	16 (24.6)	3

*First report of this invasive tick species in Ghana.

The study revealed that more arthropod ectoparasites were collected from female adult cattle than their male counterparts with a prevalence of 72.13 % (female) and 68.62 % (male), but this difference was not statistically significant ($p < 0.05$).

Cattle with good body condition had more (72.27 %) of arthropod ectoparasites compared to those with poor body conditions. This difference was also not statistically significant ($p < 0.05$).

More arthropod ectoparasites were collected from young sheep than their adult counterparts with a prevalence of 56.79 % (young) and 43.21 % (adult), but this difference was not statistically significant ($p < 0.05$). Arthropod ectoparasites collected from sheep with good body condition were more than their counterparts with poor body condition with a prevalence of 89.13 % and 10.87 % respectively. Statistically the difference in percentage of infestation was significant ($p < 0.05$).

Goats with good body condition were more infested 55.33 %, than those with poor body condition. Statistically the difference in percentage of infestation was significant ($p < 0.01$). Female goats were more infested 54.47 %, than their male counterparts. Statistically the difference in percentage of infestation was highly significant ($p < 0.01$). Young goats were more infested 69.74 %, than adult ones. Statistically the difference in percentage of infestation was significant ($p < 0.05$).

4.6 Potential zoonotic pathogens borne by arthropod ectoparasites of livestock

PCR identification was successful for all eleven ticks and eggs samples.

A 2 % agarose gel electrophoregram of PCR amplified rDNA sequence of ticks and eggs. Lane M = 1 Kilo bp ladder, Lane 1 = positive control, Lanes 2, 3, 7, 8, 9, and 10 = *Rhipicephalus*, Lanes 4 and 5 = *Amblyomma*, Lane 6 = *Hyalomma*, and Lanes 11 and 12 = Eggs of *Amblyomma* (Figure 19 and Figure 20)

All were identified as *Babesia bigemina* (Figure 19) and *Anaplasma* (Figure 20) as illustrated by the 1 kilo base pair (bp) band sizes.

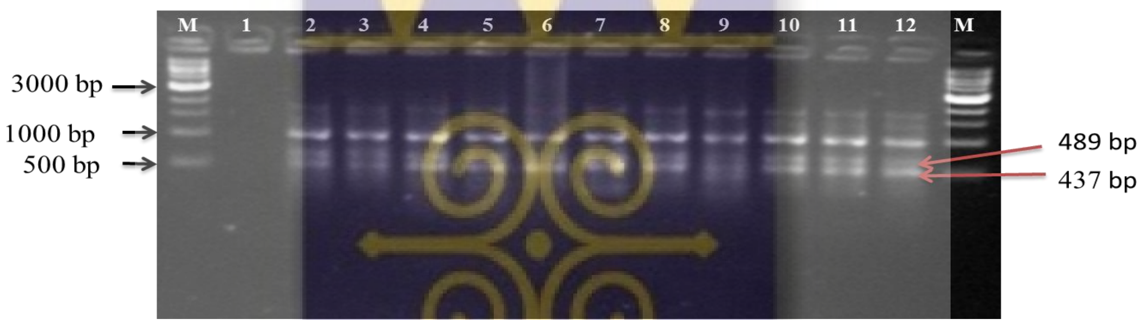


Figure 19: Ethidium bromine-stained 2 % agarose gel electrophoregram of *Babesia bigemina* obtained from the analysis of ticks and eggs rDNA - PCR product

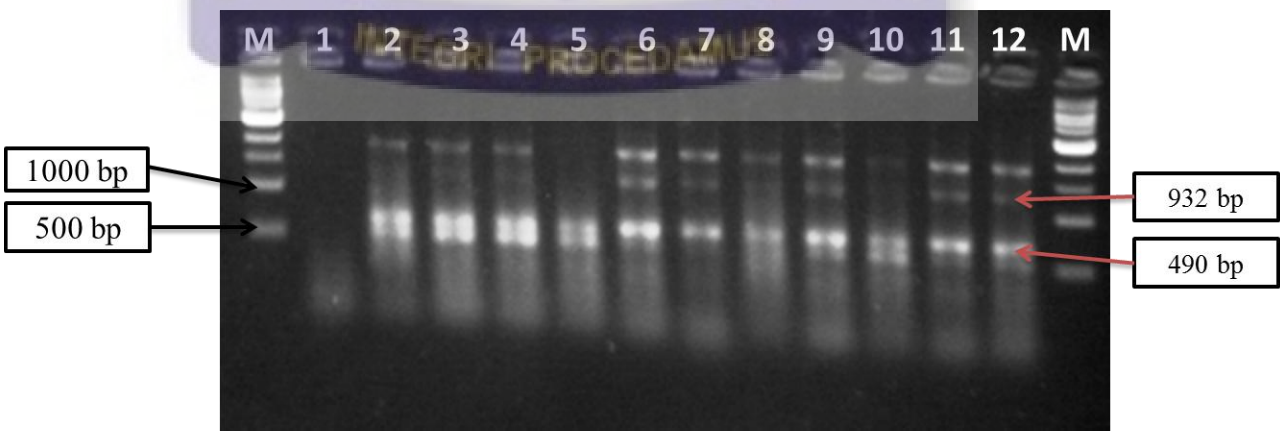


Figure 20: Ethidium bromine-stained 2 % agarose gel electrophoregram of *Anaplasma* obtained from the analysis of ticks and eggs rDNA - PCR product

CHAPTER FIVE

5.0 DISCUSSION

5.1 Livestock structure

The study revealed that the livestock structure was generally not large, on average the cattle were 50 - 100 per kraal and small ruminants were 10 - 50 per pen. These were the numbers of animals that could be easily managed by one or two herders. The study also revealed that the cattle management system was mainly semi-intensive. This is in line with the findings of Turkson and Naandam (2003) on the assessment of veterinary needs of ruminant livestock owners in three districts in Ghana, where they found that the production system practiced was mainly semi-intensive. Only few small ruminant farmers in Kpong Soil and Irrigation Research Centre in Lower Manya District practiced the intensive system within the study area. This could be explained by the frequent interaction of these ruminant owners with researchers and continuous cropping activity in the area, coupled with their higher level of formal education.

5.2 Management systems practiced

The husbandry practices in the area seem to favour arthropod ectoparasite infestations, considering the less frequent cleaning or moving of cattle kraal, the close contact of the livestock and the length of grazing times. This probably accounted for the high pesticide usage. Although only 24 % (n = 7) of farmers isolated their new stock, this was not done for the purposes of disease or ectoparasite control but for the new stock to become familiar to their new environs. Farmers did so to ensure that when new stock are introduced to the herd during grazing it will always find its way back to the new place and not stray away.

Turkson (1998) reported that Ghanaian veterinarians attributed the ignorance of farmers on management skills to be due to their poor attitudes to livestock care as well as poor knowledge seeking behaviour. This was experienced first-hand during this study as some of the livestock farmers were reluctant to participate in this research. Majority of those who participated were first time livestock farmers venturing into small ruminant and cattle production. Some cattle farmers with small ruminants diplomatically refused to catch these animals for sampling by saying they cannot restrain them. Some of these cattle owners did not stay in the same place with the herders; as a result the herders had to consult them whenever there was need for treatment. This agrees with the findings of Turkson and Naandam (2003) who reported that herdsmen were the immediate people responsible for the animals' upkeep, although they cannot take major decisions like payment of veterinary services, which are often referred to the owners who live in towns and are sometimes not easily reached. This delay in decision making, according to the same authors, causes more serious problems, which could have been solved rapidly. A similar condition was observed during the study in the North Tongu District, Volta Region where the herders and owners were not staying in the same community. However, where livestock were owned by household heads who took decisions on the health of animals, or where livestock owners regularly visit herders, such livestock were found with fewer infestations and had better body condition. This could be due to regular or timely application of pesticides since they are the decision makers and are regularly present.

Largely, the husbandry practices could be described as poor, increasingly contributing to the susceptibility of the animals to ectoparasite infestation as demonstrated by Asmaa *et al.* (2014), who reported that poor husbandry practices of small holder farmers was found to be a determinant in making the animals more prone to tick infestation in a study conducted in Beni-Suef District in Egypt.

5.3 Prevalence of arthropod ectoparasites

Although a high percentage of farmers acknowledged being aware of and having experienced ectoparasite infestations on their animals, this was found to be mainly so for tick infestations. This may be the reason why their main concern was the control of these ticks, which corroborates the findings of Turkson and Naandam (2003) who investigated traditional veterinary knowledge and practices among farmers in the Northern Region of Ghana. These authors reported that when farmers identified signs of diseases on their livestock, they promptly sought help to rectify the situation.

Only a few farmers (13.5 %) acknowledged seeing fleas but had little or no concern for them being on their livestock. This agrees with Angyirereyiri *et al.* (2015) who stated that livestock farmers do not take ectoparasite infestations seriously. They recommended that veterinary extension officers intensify their outreach activities in order to succeed in the control of ectoparasites in the Kassena-Nankana East Municipality of the Upper East Region of Ghana.

Farmers in the study area generally perceived that arthropod ectoparasite infestations on their ruminant livestock caused nuisance to the animals, increase skin ailments like bruises, wounds and also caused diseases. These parasites were also perceived to cause reduction in milk yield. Generally, farmers believed infestations on livestock involved more investment on production since more money was likely to be spent on pesticides and or babecidals and antibiotics.

The presence of lice was a surprise to most farmers, particularly the cattle farmers who were frequently using pesticides. This could be due to a flaw in the mode of pesticide application, aimed at targeting areas where ectoparasites are observed only (spot application method).

Most of them complained about poor response of ticks to cypermetrine acaricide treatment and some had switched to using Ivermectin injectable, which was not quite affordable to many. The mode of application of the injectable also requires possession of specialized skills, though some farmers were administering it themselves. The poor response of ticks to cypermetrine could be associated to poor drug handling, inappropriate method of application (Walton, 2011), drug resistance and/or due to the quality of the drug, as some farmers complained that they were not sure of the potency of the drugs.

Majority of the small ruminants had lower tick infestation but higher flea infestation, unlike the cattle which had high tick and louse infestation rates. In the small ruminants, this could be due to their low interaction with other flocks as well as the improved husbandry practice in terms of regular pen cleaning (Kusiluka *et al*., 1998) and use of injectable Ivermectin to control these parasites.

The high rate of tick infestation in cattle could be attributed to the husbandry practices considering the grazing time, cattle are on the field when temperatures are low and sequestering ticks are quite active. Biu *et al*., (2012), in a study on the effects of temperature and relative humidity on the egg laying pattern of *Rhipicephalus sanguineus* infesting sheep in semi-arid region of Nigeria found that the ovipositional behaviour of *Rhipicephalus* *sanguinues* could be influenced by temperature and humidity changes. During the short break the cattle crowd under trees away from the sun and at night, they are kept in the congested kraals. These conditions are convenient for the arthropod ectoparasites to survive and get transmitted to other animals. Additionally, the unhygienic conditions of kraals make it suitable for ectoparasite infestations to thrive and may partly account for the high tick infestation found among the cattle (Kusiluka *et al.*, 1998; Biu *et al.*, 2012).

Most farmers who applied acaricides topically used mostly spot acaricide application method (applying the chemical only where they see ticks) with the help of either a knapsack or small portable hand sprayers despite the fact that they always use the word “dipping” as their method of acaricide application. Some farmers applied these acaricides on all body parts as long as there were ticks without considering open wounds, and lesions which may allow systemic penetration of the chemical to the livestock and which could have a negative effect on the animals.

The study also revealed heavy arthropod ectoparasite infestations among domestic ruminants. This is in line with findings of Angyirereyiri *et al.* (2015) regarding arthropod ectoparasites infested domestic livestock in Vunania in the Upper Region of Ghana. The high infestation in the study area was not surprising, considering the poor husbandry practices employed in the area and the weak relationship between livestock farmers and the Veterinary Services Department of Ministry of Food and Agriculture (MoFA). This concurred with the study conducted by Turkson and Naandam (2003), who reported that poor management techniques of farmers were very important factors affecting livestock production. The high rate of tick infestation in cattle could also be due to the poor husbandry practices; overcrowding of animals, poor grazing management, poor hygiene and delays in controlling the parasites. Kusiluka *et al.,* (1998) in a study on the causes of morbidity and mortality in tethered, stall-fed and pastoral goats carried out in the tropical highland and semi-arid areas of Morogoro District, Tanzania showed that management factors such as confinement in houses, grazing systems and house hygiene, to a variable extent, influence the prevalence of diseases in animals in Tanzania. The same authors reported that increased warmth and humidity favoured proliferation of the parasites.

The presence of fleas on small ruminants kept in pens could be attributed to their biology of these particular insects. Unlike lice they feed at intervals and after feeding, they leave the host and hide in dark places (corners or crevices); as such where the spot acaricide application to animals is carried out, it does not affect the fleas as observed in the present study.

Ticks were more widely spread on the body of cattle than the small ruminants; they were found almost on all parts of the body, but more abundant on the anogenital areas, dewlap, neck, armpits udder and teats, scrotums and tail. Ticks were mainly found in ear lobes, undersides of the limbs and tail of sheep and goats, while fleas were commonly located on the back, neck and abdomen of goats. Angyirereyiri *et al.* (2015) also observed in their study that the ears and underside of the limbs were the most preferred body part for infestation by ticks and mites, while fleas were common around the neck and back regions of the body of goats. The anogenital areas, udder, scrotum areas, and armpits had high infestation of *A. variegatum* as well as skin disruptions with bruises or wounds. According to Koney *et al.* (1993), *Amblyomma* spp. facilitates dermaphilosis, which could be associated with the cement layer on the skin the ticks use to glue themselves on the animal's body. Engorged ticks of the genera *Rhipicephalus* and *Amblyomma* which formed the majority of the ticks collected in this study (Table 7 Figure 14) may be 3 to 4 times larger in size than their unfed ones (Figure 16); the ingestion of blood from the host lead to anaemia in heavily infested animals (Walker *et al.*, 2013) as observed in the current study.

Contrary to observation of Angyiereyiri (2015), lice were found on goats, which support findings of Mohammad and Ali (2006), Hall (2006) and the present study. This could be attributed to the small size of the lice and colours of host hair which renders the lice difficult to be seen under poor light. During the study the collected chewing lice, *Bovicola* (presently called *Damalinia)* were found mainly at dorsal part of sheep where the hair was dense, whiles sucking lice, (*Linognathus spp* and *Haematopinus* spp) were found mainly on the body of goats, and the ears, the tail switch and the eye lashes of cattle which have sparse hairs respectively. Del Rosario and Manuel (1989) reported in their study on Philippine swamp buffalo that in the order of decreasing frequency of *Haematopinus tuberculatus* was found mostly on the ear, neck, shoulder, elbow, vulva and thigh. This shows a decreasing length of the hair on the buffalo.

Kids and lambs infested with fleas and lice were seen grooming their legs and parts of the body they can reach, every two to three minutes, at times scratching their bodies against fixed objects. Adults were observed using the latter approach more often to relieve the discomfort caused by these ectoparasites. This behaviour was presumed to contribute to the many bruises on the legs and other parts of the body of the animals, some of which developed secondary infections that resulted in festering sores. These parasites affected the livestock negatively, causing wounds, lesions, reducing grazing and reduced ruminating time, as well as blood loss. All these are factors that are very likely to contribute to weight loss and loss of income during post-mortem inspection when carcasses are totally or partially condemned and also increase the input on medication.

A cow was observed with loss of appetite and was losing weight continuously; the owner suspected Contagious Bovine Pleuro Pneumonia (CBPP) but sold it. When it was slaughtered, no pathological changes in the lungs were observed during post-mortem examination to ascertain the possibility of CBPP infection. This was done because there was an outbreak of the disease in some parts of the country (Hachim, 2016: pers. com. - Muhammed Hachim is a livestock businessman who owns cattle kraals). However, the symptoms of loss of appetite and continuous weight loss could have been due in part to parasitic infections and infestations, although this was not confirmed in the present study.

The presence of *R. sanguineus* (dog tick) on some of the ruminants was not surprising because dogs were present in those areas where the farmers use them for security to minimise livestock theft in the study area. Additionally, other studies have previously reported *R. sanguineus* on ruminants (Sarani, *et al*., 2014).

Due to the presence of *B. bigemina* and *Anaplasma*, the existence of the diseases Babesiosis and Anaplasmosis among livestock in the study area could be inferred. Both diseases are known to have negative effect on livestock production/productivity.

5.3.1 An invasive tick species *Rhipicephalus microplus*

For the first time, the study revealed the presence of an invasive tick species *R. microplus* (Figure 16) in Ghana, which had previously been discovered in Benin in 2008. It is the second West African country to report this infestation, after its initial confirmation in Ivory

Coast in 2007 (Madder *et al.,* 2012). This confirms De Clercq *et al.* (2013)'s assertion that the entire southern West Africa region (covering southern Nigeria, Benin, Togo and Ghana) is suitable for this tick species. According to Adakal *et al.*, (2013), this tick has been confirmed in Burkina Faso, Mali and Togo after 2011 and its prevalence is associated to the ability of the tick to establish itself and spread far across vast distances. This rapid spread could be attributed to the transhumance of cattle. It is likely that this could be the possible route for the entry of the species into Ghana as most of the Fulani herdsmen interviewed in this study came from the neighbouring countries like Burkina Faso and from Mali.

Rhipicephalus microplus is a one-host tick and has the following advantages over the indigenous *R. decoloratus*: the ability to produce more eggs and has a shorter life cycle hence the ability of replacing *R. decoloratus*. *Rhipicephalus microplus* is capable of transmitting bovine babesiosis caused by *Babesia bovis* and *B. bigemina* hence poses more threat than *R. decoloratus*. *Rhipicephalus microplus* can also transmit bovine anaplasmosis caused by *A. naplasma marginale* and Sporochaetosis caused by *Borrelia theilleri*. The other importance of this tick species is its resistance to synthetic pyrethroids (SP) (Lovis *et al.*, 2012), a major group of acaricides used in the study area.

CHAPTER SIX

6.0 CONCLUSION, RECOMMENDATIONS AND LIMITATIONS

6.1 Conclusion

The study revealed that livestock farmers in the Eastern, Greater Accra and Volta Regions- around the Volta Lake- are more aware of tick infestation and their effects on their production than the other arthropod ectoparasites detected on their ruminants. They perceived arthropod ectoparasites to affect livestock productivity. It was found that poor husbandry practices had a bearing on the presence and spread of arthropod ectoparasites.

The study also revealed high prevalence of arthropod ectoparasites on ruminant livestock, such as lice, ticks and fleas, in this area. There was more production input on ruminants infested with arthropod ectoparasites, most of which were also having skin diseases, wounds and bruises; ruminants managed under poor husbandry practices were the most affected. The present study has revealed for the first time the presence of an invasive tick species (*R. microplus*).

Finally it could be concluded that arthropod ectoparasite infestations lowered the body condition, increased production cost as confirmed by the farmers and lowered ruminant livestock output in the study area, which negatively affected the productivity and income of the farmers. There is the need for an up-scaling of ectoparasite control efforts and improved veterinary services towards boosting production and productivity.

There is also an urgent need to further investigate the entry point and spread of the *R. microplus* ticks (a major vector for babesiosis and anaplasmosis) into Ghana, in order to implement appropriate measures to contain this pest or avoid its spread which can adversely affect the livestock industry in Ghana.

6.2. Recommendations

The recommendations suggested fall into two categories:

1. Further research into ectoparasite control
2. Education of livestock farmer on husbandry practices

6.2.1 Recommendation for further research and communication of research results

There is the need for an up-scaling of ectoparasite control efforts and improved veterinary services towards boosting production and productivity. Additionally, there is the need to further investigate the entry point and spread of the *R. microplus* ticks (the vector for babesiosis and anaplasmosis) into Ghana, especially along the route of transhumance.

A need assessment of veterinary service for farmers will also help promote the development of effective interventions towards boosting productivity and improving farmer livelihoods.

Prompt communication to farmers of research findings should be enhanced to build trust and confidence between researchers and farmers, as this will encourage farmers to participate in future research activities aimed at improving their productivity.

6.2.2 Recommendations to livestock farmers

It is recommended that the farmers in the study area release their cattle for grazing at 8 am and bring them back at 5 – 6 pm to reduce the chances of questing ticks from climbing on to the animals.

The direct and frequent robbing of livestock should be minimized by proper monitoring, more frequent cleaning of pens and the use of pesticides when necessary.

Kraals and sheep pens should be kept in a hygienic condition.

6.3 Limitations

Morphological identification of all the collected arthropod ectoparasites to species level was not possible because of the unavailability of a dissecting microscope with magnification of 80X or 100X to help determine morphological markers accurately.

Due to financial constraints, the molecular characterization of the ticks and isolation of specific vector-borne pathogens like *Babesia bovis* and *Anaplasma marginale* from the collected arthropod ectoparasites was not actualized.

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APPENDICES

Department of Animal Biology and Conservation Science, University of Ghana, Legon.

Effects of arthropod ectoparasite infestations on livestock productivity in three districts in Southern Ghana.

This research seeks to assess the effects of arthropod ectoparasite infestations on livestock output, in terms of milk or meat yield or both as well as body quality of animals. As part of this study, I will ask you questions about how you keep your animals and whether your animals get infested or not, as well as how the infestation affects your earnings from the animals.

The findings of this study will contribute towards developing effective ways of controlling ectoparasite infestation on livestock which will eventually lead toward boosting productivity. I would be very grateful if you will take part in this research work.

Participation in this work is completely voluntary and you are at liberty to opt out whenever you feel so. The study is being carried out for academic purposes only and as such, confidentiality will be ensured. Your responses shall not be divulged to anyone other than what the study is meant for and your anonymity will be ensured.

Effects of arthropod ectoparasite infestations on livestock productivity in three districts in Southern Ghana.

Appendix A: Individual Questionnaire

Fill space and circle or tick the appropriate option

General Information

Enumerator:…………………………..…Serial No.:……….…..…. Date:……………..……

A. Background

1.1 Administrative District………………………………….... 1.2 Region:……………………..…

1.3 Name of Village:…………………………………………………………….………

1.4 Name of farm/farmer:……………………………….…Tel.:…………………

1.5 Sex: (a) Male (b) Female

1.6 Educational level: (a) Tertiary (b) Senior School (c) Primary School (d) others (please specify..

1.7 Age (years): (a) less than 20 (b) 20-50 (c) more than 50

1.8 Marital status: (a) married (b) divorced (c) single (d) widowed (e) separated

1.9 Why are you keeping livestock?

(a) Consumption (b) sale (c) fertilizer (d) others (please specify)……….

1.10 How did you get your initial stock?

(a) inherited (b) purchased (c) others (please specify)……………..

1.11 Source of family income: (a) sale of livestock (b) sale of livestock product (c) both ‘a’ and ‘b’ (d) others (please specify).

B. Livestock Structure

	Number of Livestock kept				
Livestock species	**< 10**	**10-50**	**50-100**	**100-500**	**>500**
2.1 Cattle					
2.2 Sheep					
2.3 Goats					

C. Husbandry practices

3.1 What management system are you practicing?

(a) Intensive (b) semi-intensive (c) Extensive (d) others (please specify)………

3.2 Do you isolate new stock? Yes No

3.4 When do you release your animals for grazing?

(a) Before 8 am (b) 8-10 am (c) after 10 am (d) Others (please)……...

3.5 When do they come back from grazing? (a) Before 4 pm (b) 4-6 pm

(c) after 6 pm (d) Others (please)………………..

3.6 How often do you **move/clean** the holding ground? Underline the applicable one.

(a) Once in a month (b) twice in a month (c) others (please specify)………

3.7 Do you use pesticides (Insecticides and/or Acaricides)? Yes (b) No

D. Income and Expenditure

4.1 Do you pay a herder? (a) Yes (b) No …………Skip to Q 4.2

4.1.1 How much do you pay him/her per month?

(a) less than GH□ 500 (b) GH□ 500 to 1000 (c) more than GH□ 1000

4.2 Do you sell milk? (a) Yes (b) No ………… Skip to Q4.3

4.2.1 How much do you get from selling milk monthly?

(a) Less GH□ 100 (b) GH□ 100 to GH□ 500 (c) more than GH□ 500

4.3 Do you sell livestock? (a) Yes (b) No …… Skip to Q4.4

4.3.1 How much do you earn from livestock sales annually?

(a) less than GH□ 500 (b) GH□ 500 to 1500 (c) more than GH□ 1500

4.4 Do you use farm yard manure on your farms? (a) Yes (b) No

4.5 Do you have cattle as draught animals? (a) Yes (b) No

4.6 How much did you spend on livestock treatment for the past 6 months?

(a) less than GH□ 100 (b) GH□ 100 to 500 (c) more than GH□ 500

E. Herd/flock Health

5.1 Do you encounter ectoparasites problems on your livestock? (a) Yes (b) No...Skip to Q 5.6

5.2 Which ectoparasites? (a) Lice (b) ticks (c) fleas (d) others (please specify)

5.3 What time of the year do you mostly have this problem?

(a) Rainy season (b) dry season (c) others (please specify)…………

5.4 What effects do these ectoparasites have on your livestock?

(a) Loss of weight (b) wounds (c) Mastitis (d) others (please specify)..

5.5 Who treats these ectoparasites on your livestock?

(a) Call a veterinarian (b) do it by myself (c) others (please specify)…

5.6 What type of medication do you use on your livestock?

(a) Local herbs (b) conventional medicine (c) others (please specify)…

5.7 How many ruminant livestock have you lost in the past 6 months?

Cattle (a) less 5 (b) 5 to 10 (c) more than 10

Sheep (a) less 5 (b) 5 to 10 (c) more than 10

Goats (a) less 5 (b) 5 to 10 (c) more than 10

5.8 What signs and symptoms did you observe on them before they died?

(a) Scratching (b) limping (c) loss of weight (d) Others (please specify)…………

5.9 How did you dispose of the carcass (es)?

(a) Bury them (b) throw them (c) Burn them (d) others (please specify)…………

5.10 Do you receive advice from veterinarians? (a) Yes (b) No

5.11 What are the most serious constrains facing ruminant production in your area (here)?

(a) poor veterinary services (b) inadequate grazing land (c) Others (please specify)…

5.12 What type of support do you think will help to improve ruminant livestock production/productivity in this area? (a) Improved veterinary services (b) availability of veterinary drugs (c) availability of grazing land (d) Others (please specify)…………

5.13 Do you have any question or comment?.......................................……………………………………

THANK YOU.

Appendix B: Arthropod ectoparasites Sampling Questionnaire/Data scoring form on potential risk factors for ectoparasite infestation

Enumerator:…………………..………………………..Serial No:………………Date:………………….

Administrative/Region…………………..   Name of Village:……..……...…………..………

Name of Farmer:……………………...   Farmer's Contact No:..………………...……..…

S/N	L/stock species	Breed	Age	Body Condition	Type and number of arthropod ectoparasites (Infestation)					Effects of arthropod parasites on Skin				Weight (Kg)	Width of Right Shank (cm)
					Lice	Ticks	Fleas	Mites	Myiatic Larvae	Bruises	Lesions	warbles	Wound		

Keys:

- Species: S = sheep, C = cattle, G = goat
- Body condition: g = good, p = poor
- Skin effects: N/S = not serious, S = serious, V/S = very serious
- Breed: Sa = Sanga, Z = Zebu. N = N'Dama, J = Njallonke, WAD = West African Dwarf, SG = Sokoto Gudali
- Age: Adult or Young

Appendix C: DNA Extraction

DNA Extraction protocol - ZR Genomic DNATM – Tissue MiniPrep

1. Put whole tick or tick without exoskeleton or eggs in an Eppendorf tube add a solution of

- Distil water (H_2O) 95 µL
- 2X Digestion buffer 95 µL
- Proteinase K 10 µL
- Beta-mercapto ethanol 3.5 µL

Then using a pestle crush until solution colour changes.

2. Incubate tube with mixture at 55 ^{o}C for 1 – 3 hours.

3. Add 700 µL Gnomic Lysis Buffer to the tube and mix thoroughly by vortexing. Centrifuge at 10,000 x g for one minute to remove insoluble debris.

4. Transfer the supernatant to a Zymo-Spin^{TM} IIC Column in a collection tube. Centrifuge at 10,000 x g for one minute.

5. Add 200 µL of DNA Pre-wash buffer to the spin column in a new collection tube. Centrifuge at 10,000 x g for one minute.

6. Add 400 µL of g-DNA wash buffer to the spin column. Centrifuge at 10,000 x g for one minute.

7. Transfer the spin column to a clean microcentrifuge tube. Add 50 µL DNA Elution buffer or water to spin column. Incubate 2-5 minutes at room temperature, then centrifuge at top speed for 30 seconds to elute the DNA. Add another 50 µL and repeat process. The eluted DNA can be used immediately for molecular based applications or stored =< 20 ^{o}C for future use.

Appendix D: Weather Report

Total rainfall, average monthly temperatures and relative humidity figures retrieved from Akuse metrological station through Ghana Metrological Agency East Legon, Accra July 15, 2016.

2015	Rainfall (mm)	Average T °C	Average R/H (%)	2016	Rainfall (mm)	Average T °C	Average R/H (%)
Jan.	34.9	28.0	64	Jan.	16.9	29.3	60
Feb.	31.4	30.0	75	Feb.	10.3	31.1	64
Mar.	96.6	29.8	76	Mar.	83.7	31.1	74
Apr.	170.0	29.6	79	Apr.	27.1	31.0	75
May	40.0	29.6	78	May	174.0	30.8	79
June	126.4	27.6	84	June	243.6	29.8	85
July	134.4	26.9	84				
Aug.	10.1	27.2	79				
Sept.	30.2	28.5	77				
Oct.	169.2	28.7	81				
Nov.	30.8	29.2	80				
Dec.	0.3	28.2	61				

Appendix E: Correlation output

Table 9: Correlation output of livestock weight with respect to the width of its right shank

Correlations

			Weight of livestock	width of right arm of livestock
Spearman's rho	Weight of livestock	Correlation Coefficient	1.000	.952**
		Sig. (2-tailed)	.	.000
		N	368	368
	width of right arm of livestock	Correlation Coefficient	.952**	1.000
		Sig. (2-tailed)	.000	.
		N	368	368

**. Correlation is significant at the 0.01 level (2-tailed).