PREVALENCE AND INTENSITY OF INFECTION WITH GASTROINTESTINAL PARASITES IN THOMSON'S GAZELLES ON MARULA RANCH IN KENYA

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DECLARATION

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

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DEDICATION

I dedicate this thesis to my dear husband Dr. Paul Guthiga and my lovely children Angela and Nathan Maina.

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ABSTRACT

Thomson gazelles are an important part of wildlife in Kenya. Gastrointestinal (GIT) parasites may, however, be a limiting factor to their management. Gazelles also act as reservoir hosts for helminth infections, and any attempts to limit helminthosis in domestic ruminants in mixed grazing may be thwarted by the presence of the gazelles. Studies on the epidemiology of GIT parasites in wildlife in order to establish sustainable control strategies are therefore important. The objective of this study was therefore to determine the prevalence and intensity of infection with GIT parasites in Thomson's gazelles on the ranch, in relation to weather factors, the age and sex of the host.

The study was carried out in two phases. In phase I worm counts and nematode eggs per gram (epg) of feaces was determined. Rectal fecal samples were collected from gastrointestinal tracts of 6 and 19 male gazelles slaughtered at the ranch during the month of June and September 2003, respectively. Worms from the gastrointestinal tract were recovered and counted as described in the MAFF manual. Nematode eggs per gram (epg) of faeces, presence of fluke eggs, cestode eggs and coccidian oocysts was then determined. In phase II, 31 male and female gazelles (consisting of 3 young males, 6 young females 19 adult females and 3 male adults) were captured during the month of October 2003 and rectal fecal samples collected. Nematode epg, presence of fluke eggs, cestode eggs and coccidian oocysts were then determined from each sample.

Strongyle-type nematode eggs were found in 23 out of the 25 (92%) slaughtered gazelles, while 9 (36%) and 8 (32%) gazelles, were shedding *Trichuris* eggs and coccidian

oocysts, respectively. All the 31 captured gazelles were shedding Strongyle-type nematode eggs and coccidian oocysts. *Trichuris* eggs were found in 1 out of 3 fecal samples from the captured young males and in none of the samples from 6 captured young females and 22 adult gazelles. Mean Strongyle-type nematode epg for gazelles slaughtered in June and September were 497 and 2220 respectively, while that for the captured gazelles was 2672. This difference in mean epg between samples collected in June and September and October was statistically significant ($p<0.05$). There was a significant difference ($p<0.05$) in the mean epg for all 25 slaughtered males (1550) and the 19 captured adult females (3056). Fluke eggs and cestode eggs were not observed in any of the samples. Fecal cultures revealed predominance of *Haemonchus*, *Gazellostrongylus* and *Trichostrongylus* in fecal samples from the slaughtered gazelles and captured gazelles.

Haemonchus, *Gazellostrongylus* and *Trichostrongylus* were isolated in the abomasa of 16 (64%), 17 (68%) and 9 (36%) of the 25 slaughtered gazelles, respectively. The mean worm burdens for *Haemonchus* were 10 with Standard deviation (Sd) of ± 16, 49 and Sd of ± 54 for gazelles slaughtered in June and September, respectively. The mean worm burdens for *Gazellostrongylus* was 100 with a Sd of ± 127, 25 and a Sd of ± 62 for gazelles slaughtered in June and September, respectively. The mean worm burdens for *Trichostrongylus* was 29 with Sd of ± 66, 26 and a Sd of ±51 for gazelles slaughtered in June and September, respectively. For *Haemonchus* and *Trichostrongylus*, the worm burdens were significantly higher ($p<0.05$) in guts collected in September than in June, while the reverse was true for *Gazellostrongylus*.

Trichostrongylus, *Cooperia* and *Nematodirus* were isolated from the small intestines of 24 (96%), 15 (60%) and 5 (20%) of the gazelles, while *Trichuris* was isolated from the large intestines of all slaughtered gazelles. The Mean worm burdens for *Trichostrongylus* were 195 with a Sd ± 162, 852 and a Sd of ± 690 for gazelles slaughtered in June and September, respectively. The mean worm burdens for *Nematodirus* were 16 and a Sd of ± 27, 28 and a Sd of ± 120, for gazelles slaughtered in June and September, respectively. The mean worm burdens for *Cooperia* were 85 with a Sd of ± 127, 200 and a Sd of ± 220 for gazelles slaughtered in June and September, respectively. The worm burdens for *Trichuris* were 48 and a Sd of ± 24, 43 and a Sd of ± 40 for gazelles slaughtered in June and September, respectively. Worm burdens for *Trichostrongylus* were significantly higher ($p<0.05$) in September.

In the abomasa of 13 of the 25 (52%) slaughtered gazelles, characteristic lesions were found. These consisted of nodules ranging in diameter from 3-4cm, which contained numerous adult male and female *Gazellostrongylus* worms and pus- like material. The worms were large in size protruding from orifices in the middle of the nodules. The worms were dark red in color, due to what appeared like blood ingested from the host.

Correlation analysis was performed to determine the relationship between worm burdens and the fecal eggs counts and the relationship between the worm burdens and the weighs of the gazelles. Results showed that there was a negative correlation (-0.34) between the total worm burdens in the abomasums and the body weights of the gazelles, additionally there was a negative correlation (-0.2) between worm burdens and the fecal egg counts

for gazelles slaughtered in June while there was a positive correlation (0.46) between worm burdens and fecal egg counts in those slaughtered in September.

Results from this study indicate that GIT nematodes are prevalent in all age groups of Thomson gazelles on Marula Ranch during the dry and wet seasons. The egg counts were quite high with most of the gazelles having epg higher than 2000. Relatively high numbers of adult *Trichostrongylus* were recovered than any other species. Some of the predominant genera such as *Haemonchus* and *Gazellostrongylus* are voracious bloodsuckers, which poses a serious threat to the health and productivity of the gazelles. *Haemonchus* and other nematodes found in the gazelles are also transmissible to domestic ruminants on the ranch. Control of these parasites is therefore necessary.

CHAPTER 1

1.0 INTRODUCTION

Diseases of wildlife are important because they cause morbidity and mortality in affected animals leading to reduced productivity or spread of diseases to domestic animals and /or to human beings. Zoonotic diseases are of concern when wildlife is utilized (Cooper, 1985). Transmission of diseases to humans can occur when the animals are handled, when carcasses of slaughtered wildlife are processed, when meat and offals are consumed and when by-products are distributed widely. Processors, handlers and the consumers are all potentially at risk. This danger can be eliminated through proper carcass inspection and adequate precautionary measures in meat inspection. There is scarcity of knowledge on zoonotic gastrointestinal parasite infections of wildlife which is necessary for accurate assessments at game meat inspection. Sound public health and conservation procedures are necessarily for the investigation and reporting on the prevalence and intensity of gastrointestinal infections in wildlife.

Diseases have had considerable negative impact on the meat industry in Kenya. The magnitude in the wildlife sector is not known. Some species of wildlife are relatively tolerant to certain diseases but the complex relationship between microorganisms, their hosts and the environment has changed drastically in recent years. For example wildlife and domestic animals are in many instances grazing together. Supplementary feeding of wildlife is now practiced and intensive or high populations of wildlife are kept in relatively small areas. The balance that is assumed to have existed in the past is now disturbed and as a consequence, diseases appear to be more common in wild populations (Kock, 1995).

A report by the World Commission on Environment "Our common future"(I.U.C.N 1980) calls for concerted efforts by all nations "to begin managing resources to ensure both sustainable human progress and human survival". The world conservation strategy stresses the conservation of natural resources for sustainable development. The need to ensure these natural resources of the world are conserved and used with great efficiency is emphasized. Diseases affecting wildlife are likely to hamper performance and utilization of this natural resource. Such diseases include gastrointestinal worm infections, which have been reported in various game ranching systems (Wambwa and Ogara, 2002). The problem of endo-parasites in Kenya is widespread in the ranches (Waruiru *et al*., 1995), which may be attributed to the way game ranches are run. There are for instance no helminth control strategies for the wildlife in the ranches. The system in most ranches involves keeping and grazing livestock and wildlife in the same ranch. This system encourages cross-infection of endo-parasites between wild and domestic animals. Because the wild animals are not regularly dewormed and they act as reservoirs for the parasites, they constantly keep contaminating the grazing areas and maintaining high levels of herbage infectivity. It is well established that Thomson's gazelles act as reservoir hosts in fenced situations and any attempt to limit helminthosis in the domestic ruminants on such ranches by regular anthelmintic treatments would be thwarted by the presence of the gazelles (Allonby, 1981).

Despite these challenges, it can be argued that the development of wildlife utilization will benefit many communities. The value of wildlife and tourism to the economy of Kenya is

undisputable: Tourism is the second largest sector of Kenya's economy, it accounts for 21 per cent of total foreign exchange earnings and 12 per cent of GDP (KWS, 2013). Further planned consumptive use of the resources will increase wildlife's contribution to the country's economy, reduce wildlife/people conflict and help to conserve wildlife and habitat (Kock, 1995). If on the other hand wildlife utilization is not carried out, there is a risk that even the protected areas system will prove unsustainable, tourism will decline and in consequence the economy will suffer. This in turn will result in further exploitation of resources as communities seek ways of survival (Kock, 1995). More than 80% of the total land surface in Kenya comprises of rangelands which are generally less suitable for cultivation, but with vast potentials for wildlife keeping and livestock husbandry (Kock, 1995). The rangelands are fragile and often subject to unsustainable use, through crop cultivation and livestock husbandry systems, which threatens the destruction of wildlife habitats and the degradation of the environment in the areas.

Waruiru *et al.,* (1995) and Ngatia *et al.,* (1996), reported parasitic infection in the Thomson's gazelles in Athi River, Kajiado District. Studies carried out in domestic ruminants have shown that weather factors have significant influence on the level of infection with parasites, particularly with gastrointestinal nematodes. Studies to establish the relationship between levels of infection and the weather factors are therefore important in the design and implementation of control strategies. Majority of the studies carried out to determine occurrence and distribution of GIT parasites in wild ruminants are based on abattoir surveys. Majority of the animals slaughtered in these abattoirs are however adult males and these studies may therefore not give a true picture of the

prevalence and levels of infection in the entire population. This project was therefore designed with the following objectives:

1.1 Objectives

The overall objective was to determine the prevalence and intensity of infection with gastrointestinal parasites in Thomson's gazelles in relation to weather factors, age and sex of the host

Specific Objectives:

i. To determine the prevalence of infection with gastrointestinal parasites in Thomson's gazelles in relation to weather factors, age and sex of the host.
ii. To determine the intensity of infection with gastrointestinal parasites in Thomson's gazelles in relation to weather factors, age and sex of the host

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Gazelles

Gazelles are medium-sized antelopes that have long-ringed horns. They are the most common of all antelopes; occurring not only throughout the dryer parts of Africa but also in the Middle East, and across Asia to Siberia and China. All gazelles are extremely elegant and are characterized by pale, sandy-colored coats and ribbed, S-shaped horns. There are 16 different species of gazelle allocated among 3 subgenera, Gazella, Trachelocele, and Nanger. Thomson's gazelle belongs to the sub-genus Gazella (Arthur *et al*., 1999).

2.1.1 Thomson gazelle (Gazella thomsonii)

Thomson gazelles are small mammals. The adult females weigh between 16 and 21kg and the males weigh between 20 and 25 kg. A newborn gazelle weighs about 2.6 Kg (Arthur *et al*., 1999). These gazelles have slender bodies and long legs. Both sexes have horns. Males have long, slightly S- shaped, annulated (ringed) horns. Females have shorter, thinner horns that are sometimes broken or deformed. This species has a pale fawn marking on its back and a white stomach. This two toned coloration enables Thomson gazelles to blend into their environment. They also have characteristic black stripes on their sides and a black mark on their nose (Arthur *et al*., 1999).

Thomson gazelles are migratory herbivores. They can be found in different types of groups: all males, all females and mixed herds of 60-70 individuals. These herds can

reach 1000 individuals when they are migrating. They feed on short grasses that other species cannot or do not eat (Ogara, 1991).

Female Thomson gazelles are sexually mature within nine months from birth, while males take 18 months to achieve sexual maturity. The life expectancy for Thomson's gazelles is 10 years. Once mature, the females go into estrus about twice a year producing one kid per pregnancy (Arthur *et al*., 1999).

Thomson gazelles migrate annually from woodlands to short-grass steppe. In Kenya this migration corresponds to the short rains in November and the long rains in May (Arthur *et al*., 1999). They occupy tropical scrub forest, savannah and grasslands. Gazelle meat is a good source of food for humans in areas where the species are found. Gazelles are also a good source of food for wild predators that may otherwise attack domestic animal herds (Arthur *et al*., 1999).

2.2 Game ranching

Game ranching is defined as the use of rangelands for the maintenance of wild animal populations for subsequent cropping and sale of meat and by-products (Ebedes, 1993). Game ranching is most successful in relatively well-developed economic systems where wildlife management is practiced to an advanced level. In, Kenya wild animals still share much of the land with people but with the rapid growth of human population, redistribution of land and damage to natural resources (e.g. cutting of forests for timber or for fuel wood) many species and populations are threatened. This phenomenon is not

unique to Kenya and has been reviewed (IUCN/ UNEP/WWF, 1991; Kirkwood, 1994). In Kenya, statistics (Kinyua *et al*, 2000), indicate that up to 60% of wildlife in rangelands is outside protected areas. Approximately 8% of the total land area of Kenya is set aside for nature conservation (Kinyua *et al*, 2000). One of the major threats facing Kenya is the loss of biological diversity (Draft Wildlife policy, 2012). Land use changes favoring agriculture and rural and urban development have led to the reduction and modification of wild habitats, resulting in the extinction of or threat of extinction to wildlife species and natural areas which serve as its habitat.

Most of the game animals in East Africa are found in semi-arid marginal areas where rainfall is inadequate for crop production but sufficient for ranching purposes. There is increasing conflict between human interests and wildlife conservation due to the urgent need to increase food production for a fast-growing human population in Kenya. One way of trying to resolve this conflict is to support wildlife utilization to become a more profitable form of land use, which is not merely on tourism (Watson, 1965). The advantages of utilizing game meat for alleviating the food shortage experienced in many third world countries, including Kenya, have been well stated by Watson (1965), Ledger *et al.,* (1967), Schindler *et al.,* (1969) and Skinner (1970). Tolbert (1966) and Reul (1981) discussed the potential for ranching African ungulates on the rangelands with or without livestock. It is pointed out that cropping of game on the Savannah is biologically productive and can support a variety of ungulates, which can produce high biomass per unit area.

Some ranches are well advanced towards a multi-species management system, and for others, the incentive has been a decline in the value of beef industry and restrictions on the use of more lucrative export markets due to inadequate disease control programs in the country (Kock, 1995). Disease issues, which have already had considerable impact on the meat industry in Kenya, could also lead to problems in the wildlife sector.

2.3 Parasitic infections in wild gazelles

Some species of wildlife are relatively tolerant to certain diseases but the complex relationship between microorganisms, their hosts and the environment has changed dramatically in recent years. We can no longer say, "Let nature take its course" because we have changed the environment and so modified the freedom of the wild animals such that, mother nature is no longer with us! Diseases rarely have one cause. Nutritional deficiencies and problems of over-population, over-use of habitat, or soil contamination by the constant presence of animals, may allow parasites to build up in numbers (Chema, 1980). When the number of parasites greatly increases or when the animal is stressed, the growing parasitic burden will reduce the resistance of the host to infection, and the parasites may become pathogenic (Sachs and Debbie, 1969).

2.3.1 Parasitic infections in tissues

Parasitic infections that may occur in tissues and organs of Thomson's gazelles include *Sarcocystis*, cysts of tapeworms such as *Echinococcus* and spargana with Thomson's gazelles acting as intermediate hosts (Grootenhuis, 1999).

Stilesia hepatica, a tapeworm occurring in the bile ducts of ruminants may also be found in the liver. Ruminants become infected with the parasite through ingestion of infected herbage. The parasite occurs in animals of all ages. This parasite is considered to be non pathogenic, and no clinical signs are associated with it even with heavy infections. Affected livers may have lesions of mild cirrhosis with some thickening of the bile ducts. The economic importance of this infection results from the condemnation of affected livers at meat inspection (Hansen and Perry, 1994).

Sarcocystis species are cyst-forming sporozoa with a two-host cycle. The parasite occurs in two forms in meat, as a visible macroscopic cyst and as an invisible microcyst. The macrocysts can be present at high infestation rates and render carcasses unattractive for human consumption (Grootenhuis, 1999). These parasites are common within skeletal and cardiac muscle fibres of aquatic birds and most mammals particularly herbivores including Thomson's gazelles. In addition, the parasites have also been observed in the brain of sheep (Kaliner *et al.*, 1971, 1974). The parasite in muscle represents intermediate stages of intestinal coccidia of carnivores. Thomson's gazelles acquire infection with *Sarcocystis* by ingesting sporulated oocysts of the parasite from the ground with feed. The oocysts are deposited by carnivores e.g. hyenas which act as the definitive hosts in which the parasites multiply in the small intestines (Soulsby, 1982).

Hydatidosis or larval echinococcosis is the cystic stage of *Echinococcus granulosus*, this parasite has a cosmopolitan distribution and is very common in parts of Africa, Latin America and some countries of Southeast Asia (Hansen and Perry, 1994). There are

several types of life cycles involving different mammalian species. One cycle involves domesticated ruminants and dogs; another cycle involves wildlife species, for example the warthog-lion cycle in Africa. Other cycles involve domesticated animals and wildlife, such as the dromedary camel-jackal cycle in some regions of sub-Saharan Africa (Hansen and Perry, 1994).

The gravid segments of the *E. granulosus* tapeworm are excreted in the feces of dogs and the eggs released from the segments are highly resistant to adverse climatic conditions. They may be carried by wind in dust or be mechanically transported by flies. Following ingestion of the eggs by the intermediate hosts, which include man, domesticated animals and numerous wild animals like Thomson gazelles the embryos emerge and migrate to the blood stream through which they are carried to various organs and tissues in which the hydatid cysts develop. The final host acquires the infection by eating viscera containing fertile hydatid cysts (Hansen and Perry, 1994). Hydatid cysts are of major public health importance. The cysts can occur in man after ingestion of the parasite eggs from wild or domestic carnivores infested with the adult parasites through consumption of meat with the cysts (Soulsby, 1982).

Results of a study carried out by Ngatia *et al.*, (1996), on a game ranch at Athi River in Kenya, showed that the most common lesions in the wild animals surveyed were found to be those associated with or caused by parasites especially helminths. These and other non-specific lesions found in slaughtered ruminants resulted in the condemnation of the organs and hence an economic loss as most of the animals were cropped and slaughtered

for sale. Macroscopic *Sarcocystis* were only found in the Grants gazelle, while intermediate stages (cysticercoids) of tapeworms were found in Thomson's gazelle. Thomson gazelles were also infected with *Stilesia spp*, hydatid cysts in the liver and peritoneal cysts (*Cysticerus spp*) (Ngatia *et al.*, 1996). Although no clinical signs have been associated with these types of parasites in wild animals, they can lead to economic losses due to condemnation of carcasses or infected organs.

During a pilot game-cropping scheme from 1964-67 outside Serengeti National Park in Tanzania, meat inspection was carried out on 500 antelopes including Thomson gazelles, and other wild animals (Sachs, 1970). Three forms of tapeworm larvae were identified in the wild herbivore hosts:

- Cysticerci- larva form of *Taenia*
- Echinococcus cysts- larva form of *Echinococcus*
- Spargana- larva form of *Diphyllobothriidae*

Meat infected with cysticerci is condemned primarily because of the associated risk of infection of man. However, even if it could definitely be established that game animal cysticerci are not a risk to man, infected carcasses should not be sold, because of aesthetic reasons (Dinnik and Sachs, 1969).

From results of a pilot scheme carried out in the Serengeti area, it was estimated that the game meat liable to be rejected as a result of parasite infection would be equivalent to 15-20% of the carcass yield (Schindler *et al.*, 1969).

2.3.2 Parasitic infections in gastro-intestinal tract

Gastrointestinal parasites probably cause the greatest economic losses to domestic livestock and game animals worldwide, not so much because they cause a debilitating disease, but because they cause malnutrition and thus lower the productivity of animals (Allonby, 1981).

In general, wild ruminants including Thomson gazelles are susceptible to infection by the nematodes found in domestic livestock, especially those that invade the respiratory system and alimentary canal. The most, and widely prevalent nematodes are the *Trichostrongyle* group (*Haemonchus, Ostertagia, Trichostrongylus, Cooperia* and *Nematodirus*), *Oesophagostomum* and *Bunostomum*. The life cycles of most Trichostrongyles, *Oesophagostomum* and *Bunostomum* are similar: the cycles are direct, that is, these nematodes do not require intermediate hosts to complete their life cycles.

Grootenhuis (1999) reported that Thomson's gazelles carry the following nematodes; *Cooperia hungi, verrucosa, yoshidai,; Cooperioides antidorca, Gazellostrongylus lerouxi, Haemonchus bedfordi, contortus; Impalaia tuderculata, Longistrongylus sabie, Paracooperia daubneyi, serrata; Trichostrongylus axei, colubriformis, minor, probolurus* and *Trichuris spiricolis.*

On the basis of taxonomic criteria, it has been estimated that about 20-40% of the parasites commonly recorded in wild ruminants are also found in domestic animals (Sachs *et al.,* 1973; Prestwood *et al.,* 1976; Woodford, 1976). However, of these species,

those likely to be of most economic significance are: *Haemonchus* spp, *Trichostrongylus* spp, *Impalaia* spp, *Cooperia* spp, *Nematodirus* spp, *Oesophagostomum* spp, *Trichuris* spp and *Gazellostrongylus* spp, (Grootenhuis, 1999).

In a study carried out by Waruiru *et al.*, (1995) in a game ranch at Athi River in Kenya, all Thomson gazelle's examined were found to be heavily infected with intestinal worms. Thomson gazelles counts of nematode eggs per gram (epg) of feces were higher than 2000. They were also found to have a notably higher intestinal worm burden than any other antelope examined.

In another study carried out by Khalil and Ingram (1981), 20 out of 26 Thomson gazelles and 14 out of 60 Grants gazelles from Kajiado District, Kenya, were infected with *Gazellostrongylus lerouxi*. The parasite occurs mainly in nodules up to 4cm in diameter in the abomasum and most animals have 3 nodules but there may be up to 5 of such. Most of the nodules contain adult male and female worms and many eggs. Up to 24 worms may be present. Sometimes the nodules have a small sinus opening to the abomasal lumen from which dark red worms protrude. Adults are never found free in the abomasal contents. Some smaller nodules without a sinus contain disintegrating parasites (Khalil and Ingram, 1981).

To assess the economic significance for domestic animals of gastrointestinal parasites in wild ruminants, it is necessary to know to what extent the wild ruminants contribute to overall pasture larval contamination and what additional effect this produces on the

domestic stock. Furthermore, as is now being recognized, the sub-clinical effects of nematodiosis are much greater than had been previously thought. The role of wild ruminants as reservoir hosts is likely to assume more importance and greater consideration will have to be given to their role in this important disease (Allonby, 1981). The fact that all the animals graze together on the same pastures suggests that cross-transmission may occur as has been demonstrated artificially (Preston *et al*., 1979). From studies on artificial infection, it has been found that *Haemonchus contortus* in sheep was larger and heavier than that in gazelles. This has been confirmed under natural conditions. It can be concluded that under existing methods of control the gazelles probably do not play a significant role in the epidemiology of sheep helminthosis. However Thomson gazelles act as reservoir hosts in a fenced situation and any attempt to limit helminthosis in domestic stock by regular anthelmintic treatments would be thwarted by the presence of the gazelles (Waruiru *et al*., 1995).

Domestic livestock and wild ruminants share common range in much of East Africa increasing the potential for cross infection with endoparasites among these ruminants (Beaudion *et al.,* 1970). Prestwood and Pursglove (1981) reported that 32 species of gastrointestinal nematodes have been recorded in wild ruminants, several of which also infect livestock (Anderson, 1962; Prestwood *et al*., 1973, Prestwood *et al*., 1975, Prestwood *et al*., 1976; Davidson *et al*., 1980; McGhee *et al*., 1981; Conti and Howerth, 1987). Livestock management often utilizes some control programme against gastrointestinal parasites and several drugs have been demonstrated to be effective in the treatment of gastrointestinal parasites in domestic ruminants (Fraser, 1986). Free-ranging

wild ruminants could potentially serve as a reservoir for gastrointestinal nematodes (Dunn 1968, McGhee *et al.* 1981) and lead to reinfection of treated livestock (Davidson *et al*., 1980).

2.3.3 Nematode life cycle

The life cycles of most *trichostrongylid* nematodes such as *Haemonchus, Trichostrongylus, Cooperia, Nematodirus, Ostertagia, Oesophagostomum* and *Bunostomum* are similar and direct. Adult nematodes inhabit the gastrointestinal tract and the females lay eggs that are passed out in faeces into the environment. The eggs hatch and release the first-stage larvae (L_1). These then molt to the second-stage larvae (L_2), shedding their protective cuticle in the process. The L_2 molt into the infective third stage larvae (L_3) but retain the cuticle from the previous molt. Under optimal conditions of humidity and temperature this development process takes about 7 to 10 days. The parasitic phase of the life cycle begins with the ingestion of L_3 on pastures by the host. The L_3 then penetrate the gastrointestinal mucosa (*Haemonchus* and *Trichostrongylus*) or enter gastric glands (*Ostertagia*) and ex-sheath the extra cuticle in the process. The L_3 then molt to the fourth stage larvae (L_4) and remain in the mucous membrane or gastric glands for 10 to 14 days. They then emerge and molt into young adults (L_5), mature and start egg production in about 3 week's post-infection (Hansen and Perry, 1994; Vlassoff *et al*., 2001). The development of infective larvae ingested by an animal during adverse environmental conditions may be temporarily arrested (hypobiosis) in the abomasal or intestinal mucosa.

There are some exceptions to the general pattern described as in *Nematodirus* where the development to the L_3 occurs entirely within the egg. These larvae then hatch and become infective to the host. The parasitic part of the lifecycle of *Oesophagostomum* requires six weeks to complete. The infective L_3 penetrate the lamina propria of the intestine and the host responds by surrounding it in fibrous nodules. The larvae emerge into the intestinal lumen after two weeks and mature in the next 4 weeks. In hosts with previous infections, their stay in the intestinal wall nodules may be prolonged to 3-5 months. Eventually most of the larvae die and the nodules may be calcified (Hansen and Perry, 1994).

Host infection with *Bunostomum* is by ingestion or skin penetration of the L_3. The larvae that penetrate the skin are then carried in the venous blood to the lungs, enter the alveoli, are coughed up then swallowed. Larvae entering through both routes then pass to the small intestines, molt and mature 8-9 weeks post-infection. The infective larval stage of *Trichuris* is contained within the egg and is released following ingestion of the egg by the host. Infection by *Strongyloides* occurs through oral ingestion of infective third-stage larvae, through milk or penetration through the skin. Development into the adult stage occurs in the small intestines (Hansen and Perry, 1994).

2.3.4 Factors influencing the levels of infection

According to Hansen and Perry (1994) and Barger (1999) the size of any gastrointestinal parasite infection in grazing animals depends on several interacting factors. These factors include the number of infective larvae ingested by the host, host immunity, livestock production systems and the control methods used.

Rate of infection

The major epidemiological factor influencing the worm burdens of grazing animals is the infection rate (Barger, 1999). Fluctuations in the number and availability of the infective larvae on the pastures are in turn influenced by factors that affect contamination of the environment with nematode eggs. Such factors include the stocking density and the intrinsic multiplication rates of the nematode species present and by the translation process of development, survival and dissemination of the free-living stages (Armour, 1980; Hansen and Perry, 1994; Barger, 1999).

Development and survival of free-living stages

The development of nematode eggs to the infective larval stage and the survival of these larvae on pastures are influenced by several environmental factors and biological agents. These include temperature, moisture, humidity, sunlight, oxygen supply, soil structure, herbage growth and composition, size and consistency of feces, predaceous fungi in the soil and fecal pats, dung-burying beetles and earthworms (Hay *et al*, 1997; Larsen, 2000; Vlassoff *et al*., 2001). However, the principle factors are temperature and moisture (Waller and Donald, 1970; Gibson and Everett, 1976) and vary in different parts of the world. In most of tropical and subtropical areas, little variations in temperatures occur and are permanently favorable for larval development in the environment (Ikeme, Iskander and Chong, 1987; Hansen and Perry, 1994). Variation in rainfall is the major factor governing the survival and development of the pre-parasitic stages (Altaif and Yakoob, 1987; Banks *et al*., 1990; Onyali, Onwuliri and Ajayi, 1990; Nginyi *et al*., 2001). The ideal temperature and relative humidity for larval development of many

species in the microclimate of the tuft of grass or vegetation is between 22^{o}C and 26^{o}C and 100% (minimum 85%) respectively. Development can also occur at a slower rate at temperatures as low as 5^{o}C and at over 30^{o}C, but with a high larval mortality (Hansen and Perry, 1994).

The survival of larvae in the environment depends upon adequate moisture and shade. Desiccation from lack of rainfall kills eggs and larvae, and is the most rapidly lethal of all climatic factors. The larvae may be protected from desiccation for a time by the crust of the fecal parts in which they lie or by migrating into the soil (Hansen and Perry, 1994). The pre-parasitic stages of nematodes differ in their response to the environmental conditions especially temperature, moisture and sunlight. Generally, the L_3, which have a protective sheath and embryonated eggs, are the most resistant, followed by the un-embryonated eggs, L_1 and L_2 in that order (Soulsby, 1982). Variations in the response to the above stimuli also occur in nematode species. The pre-parasitic stages of *Nematodirus*, which develop within the egg until hatching, are more resistant to the adverse environmental effects than most trichostrongylid nematodes (Soulsby, 1982). The embryonated eggs and the third stage larvae of *Trichostrongylus colubriformis* are resistant to desiccation and some degree of water deprivation may enhance its survival (Andersen and Levine, 1968) while those of *Haemonchus* are very susceptible (Waller and Donald, 1970).

Migration of infective larvae

For the infective larvae to be ingested by the ruminant host, they have to migrate or be transported from the feces in which they were deposited to any nearby herbage. Suitable

conditions for this migration occur when rainfall or moisture disintegrates the crust of fecal material and the larvae are washed onto the herbage or transported by invertebrates such as the dung beetles and earthworms (Hansen and Perry, 1994; Hay et al., 1997; Larsen, 2000; Hein, *et al*, 2001). However, excessive moisture or sustained torrential rainfall adversely affects development of eggs and pasture larval density through rapid disintegration of feces and washing of eggs and larvae (Ikeme *et al*., 1987).

Once on the herbage, infective larvae migrate up and down the blades of grass according to the amount of moisture on the grass (Hansen and Perry, 1994). During the rains and when dew is on the grass, the larvae migrate to the top of the herbage. Following evaporation the larvae migrate to the base of the herbage and even down into the soil (Rose, 1963; Michael, 1976; Hansen and Perry, 1994). The rate of migration of the infective larvae also depends primarily on the microclimate in the herbage, which in turn is influenced by the soil type (Michael, 1976).

Seasonal patterns of larval development and host infection

The development and survival patterns of infective larvae in the environment and host infections differ according to the climate. The humid tropical climate provides a more or less permanently favorable environment for the development and survival of parasitic larvae. Therefore, several larval peaks and generations of parasites develop in the pastures and animals all the year round (Ikeme *et al*., 1987; Romjali *et al*., 1997).

The arid tropical climate is often unfavorable for parasitic larval survival. However, short periods of rain or irrigation can rapidly transform the environment into a favorable one. The host infection and transmission of parasites in such areas is restricted to the wet season (Ogunsusi, 1979a; Charles, 1989). The only means to carry-over infection from one rainy season to the other is through animals harboring adult worms and / or hypobiotic larvae (Chiejina, *et al*, 1988; Macpherson, 1994).

The savannah-type tropical and subtropical climate has long dry seasons. As the dry season progresses, the environment for the development and survival of larvae changes from unfavorable to hostile. The population of surviving larvae declines rapidly in the open pastures, but more slowly in the wooded areas. Host infections during the dry season are therefore minimal. At the start of the rains, the environment is rapidly transformed into a favorable one. During the rainy season, there is a continuous cycle of infection between the host and the pastures larval densities. Worm population in the animals fluctuates considerably throughout the rainy season (Ogunsusi, 1979a).

2.4 Control of helminth infections in Wildlife

Gastrointestinal tract infection by strongylate nematodes is a common cause of clinical and sub-clinical disease in non-domestic ungulates (Boyce *et al*., 1991). Effective nematodes control programme have been developed for domestic livestock

Studies in domestic ruminants have demonstrated that anthelmintic control programmes for strongyle nematodes are most likely to succeed if they are strategic in nature and

focus on preventing pasture contamination. Pasture contamination occurs when adult parasites in the host produce eggs that are passed to the environment with the feces, ultimately resulting in an accumulation of infective larvae on pasture. The objective of strategic treatment is to eliminate worms within animals during those periods when harsh climatic conditions prevent the survival of larvae on pasture. This preventative approach reduces the populations of parasites within the host and on the pasture, and minimizes re-infection. It also reduces morbidity and mortality with a minimal number of treatments, thereby decreasing the selective pressure for the development of anthelmintic resistance (Boyce *et al*., 1991).

Most species of gastrointestinal nematodes are nonpathogenic or mildly pathogenic in free-ranging wild ruminants under normal circumstances (Prestwood and Pursglove 1981). However, heavy infection combined with malnutrition lead to morbidity of wild ruminants.

Eradication of gastrointestinal nematodes of ruminants is not practical and generally, such a course is not required (Brunsdon, 1980). The aim of control is to ensure that parasite populations do not exceed levels incompatible with economic production. This can be achieved through three interrelated approaches: by use of anthelmintics, by grazing management and by dependence on the acquisition of immunity. Potentially, the most efficient control requires the complete integration of all the three facets (Brunsdon, 1980).

At present, most parasite control in domestic ruminants in Kenya is based almost entirely on the regular use of anthelmintics. While usually affording protection against serious disease and mortality, such treatments are frequently not effective in preventing the exposure of animals to high levels of pasture infestation. In the humid tropical zones in Africa for example, where *H. contortus* is predominant and weather conditions conducive for development and survival of infective larvae almost throughout the year, anthelmintic treatments need to be made at rather short intervals if mortalities are to be eliminated and satisfactory weight gains achieved (Allonby and Urquhart, 1975; Schillhorn van veen and Brinskman, 1975). Consequently, production losses still occur as a result of reinfection in the interval between treatments.

Control of gastrointestinal parasites in wildlife can be achieved using anthelmintics incorporated into the feed or mineral blocks such as the urea molasses blocks recently developed by KARI (KARI, 1999) or controlled burning of pastures. Madzingira *et al.*, (2002) reported that 54% of ranches having both domestic and wild animals in Zimbabwe dewormed both cattle and antelopes. Antelopes were dewormed using albendazole and fenbendazole medicated supplimentaly feed blocks.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was carried out on the Thompson's gazelles in Marula Game ranch in the semi-arid area of Naivasha. Marula Game ranch is located in Nakuru County and situated on the eastern floor of the Great Rift Valley, bounded approximately by latitude 0^{o}-009'S and 0^{o} -55'S, and by longitudes 35^{o} 50"E and 36^{o} 42'E. Figure 3.1 shows the location of Nakuru County and Marula game ranch.

Figure 3.1 Map of Kenya Showing the location of Nakuru County and Marula Game Ranch

Various ranches and hills surround the ranch. Lakes Naivasha, Oloidien, Sonacchi and Elementaita including large parts of their catchments also border the ranch. The study area is semi-arid and lies largely within eco-climatic zones 4 and 5, characterized partly by open savannah grassland, dense but scattered Leleshwa shrubs (*Tarchonanthus camphoratu*), and sparsely distributed acacia (*Acacia Senegal*) woodland. The mean annual rainfall is 620 mm.

The Game Ranch measures some 30,000 acres in size. It is the third largest ranch in Nakuru, after Kedong and Soysambu. Combined livestock and wildlife ranching is a key economic activity in the ranch. At the time of the study there were 10, 000 cattle in the ranch, for beef and milk production, 2000 goats for meat, and different species of wild animals as shown in Table 3.1. According to a census carried out in September 2003, there were approximately 3087 Thompson's gazelles, which was the largest population of wild animals on the ranch.

The ranch employs about 50 game scouts and security personnel to prevent subsistence poaching of wildlife and fence vandalizism. Wildlife cropping earns the ranch more than Kshs. 2 million per year. The ranch is a member of the Nakuru Wildlife Conservancy, a local wildlife management institution that draws its membership from all ranch owners within Nakuru County.

Table 3.1: Species of wildlife found in Marula Ranch in September 2003

Species	Total Number
Zebra	1666
Thomson gazelle	3087
Impala	2687
Eland	524
Buffalo	882
Water buck	312
Warthog	789
Grants gazelle	71
Jackal	130
Baboon	754
Dikdik	210
Steinbuck	33
Reedbuck	36
Hippopotamus	115
Duiker	14
African hare	86
Sykes monkey	59
Colobus monkey	19
Vervet monkey	119
Serval cat	1
Mongoose	5
Hyena	1
Leopard	2
Fox	8
Bush buck	6

This ranch and other ranches in Naivasha area continue to play an important role in the management of wildlife, because the wildlife habitats in most of the ranches are still intact. The ranches are important buffer zones for wildlife particularly from Hell's Gate National Park.

3.2 Sample collection and analysis

The study was carried out between June 2003 and September 2003, and was done in two phases. The first phase involved collection of gastrointestinal tracts from slaughtered male gazelles for worm recovery, enumeration and determination of nematode eggs per gram (epg) of feces. The second phase involved capture of male and female gazelles of various age groups and collection of rectal fecal samples for determination of nematode epg and the presence of fluke eggs, tapeworm eggs and coccidian oocysts.

3.2.1 Collection of gastrointestinal tracts

The goals of cropping are to kill animals efficiently with minimal disturbance to the wildlife herd, which is not only important for the sustainability of the cropping operation but also for the multiple use of wildlife e.g. tourism and sport hunting. At the time of the study game cropping had not been burned by KWS.

Cropping of the gazelles that were used in this study was done at night. On location of a herd of Thomson gazelle a halogen spotlight mounted on a vehicle was used to dazzle the animals that were killed using a 30.06 caliber rifle aiming for a head or neck shot. This cropping operation was carried out by rangers employed by the ranch owner. The gazelles were selectively culled; they were judged to be of adult size and discrimination was made on sex. The ranch manager was a licensed cropper, and guided the selection. Only males were culled. The shot animals were subsequently transported to the ranch slaughterhouse.

At the slaughterhouse, the carcasses were weighed and their weights recorded, heads were removed and the carcass flayed, eviscerated and then hung on rails. Meat inspection was conducted early in the morning and the meat taken to the designated market outlets. Collection of gastro intestinal tracts was done on two different dates (19th June and 19th September 2003). The number of samples to be collected was determined by order of gazelles (game meat) by various hotels, therefore all animals slaughtered were used as samples. Each sampled carcass was sexed, aged, numbered (Tg1-Tg26) and weighed, gazelle Tg 7 was omitted from the analysis due to missing information. The gastrointestinal tracts (stomachs and intestines) were labeled and transported to the Parasitology laboratory, Department of Veterinary Pathology, Microbiology and Parasitology, Faculty of Veterinary Medicine, University of Nairobi for processing. The dates on which gastro intestinal tracts were collected from Marula Ranch, reference number; sex, age group and the carcass weight are shown in Appendix I.

3.2.2 Worm recovery and identification

The worms from the gastrointestinal tract were recovered as described in the MAFF (1986) manual and by Hansen and Perry (1994). The abomasa, small intestines, caecum and the colon were double ligated with a string at their extreme ends and separated. The abomasum was then opened through the greater curvature and the contents released into a bucket. The mucosa was thoroughly washed under running tap water and the washings collected in the same bucket. The bucket contents were further cleaned through a fine mesh sieve of 150µm aperture and preserved in 70% alcohol until recovery of worms was undertaken. At the time of examination, the abomasal contents were put in calibrated beakers and water added to make 500ml. After thorough stirring, a sub-sample of 100ml

was drawn; all worms present were recovered under a dissecting microscope and preserved in 70% alcohol.

The small intestines were slit longitudinally, the contents collected and processed as described for the abomasum. The large intestine contents were washed into a bucket then passed through a course meshed sieve (500μm), all worms present were then recovered, counted and identified as described in the MAFF (1986) manual.

The worms were put in separate petri dishes, depending on the part of the gastro intestinal tract they were recovered from. Individual worms were then fished out and mounted on microscope slides for identification to genus level based on morphological characteristics described in MAFF (1986) manual. The total number of worms of each genus in each sub-sample was then recorded. The total number of worms in the gazelle was calculated using the dilution factor of the sub-sample. Photographs of the parasites showing characteristic morphological features were taken. During examination for worms in the abomasum nodules with worms were encountered. These were measured, photographs taken and the worms identified. Worms were identified to genus level based on available literature for domestic ruminants, as no literature for wild ruminant parasites was available.

3.2.3 Processing of fecal samples

Fecal samples (3-5gm) were collected directly from the rectal portion of the gastro intestinal tract of the slaughtered gazelles into fecal pots for fecal worm egg count. The samples were stored at 4^{o}C until they were examined. The number of nematode eggs per gram of feces (epg) and the presence of tapeworm eggs and coccidia oocysts were determined for each sample using a modified McMaster technique with a lower limit of detection of 100 eggs (Whitlock, 1948). Saturated sodium chloride was used as the flotation solution. A sedimentation technique as described by Hansen and Perry (1994) was used to detect the presence of *Fasciola* eggs in the fecal samples. The presence or absence of coccidian oocysts and tapeworm eggs was noted.

3.2.4 Fecal cultures, recovery and identification of larvae

Fecal samples were pooled for all gazelles, slaughtered on each sampling day, incubated at 27^{0} C for 10 days and nematode larvae recovered and identified to genus level using cuticular morphology and size as described in the MAFF (1986) manual.

3.2.5 Capture and collection of fecal samples from Thomson's gazelles

Capture of Thomson gazelles was done on 9/10/2003 in Marula Ranch and fecal samples collected from them for analysis of parasitic infections. This was done for comparison purposes because all the slaughtered animals collected from the ranch for fecal sampling and worm recovery in June and September 2003 were adult males which were selectively culled for game meat. The gazelles were captured and fecal samples collected directly from the rectum of individual gazelle for fecal worm egg count. The gazelles were aged, sexed and numbered (S1-S31) before fecal samples were taken. The age of the gazelles

was classified into young males, young females, adult males and females. The reference number, age group and sex of the captured animal are shown in Appendix II.

The capture of gazelles and collection of fecal samples was carried out by eleven (11) members of the Kenya Wildlife Service (KWS) and five (5) members from the University of Nairobi. For this exercise, a good site free from physical barriers was selected to ensure that the speed and direction of flight of the animals chased was not affected. Once a suitable capture site was identified the capture net was assembled as shown in Figure 3.2. The net was made of 6-8mm woven nylon rope, with a natural green color for camouflage purposes. The capture net was enclosed with nets, supported by poles except for the main entrance, which was funnel shaped. The entrance to the net funnel was approximately 400m wide. The depth of the net was 400m, the end of the site consisted of a round corral with a diameter of 20-30m, fiber cord (flexible) cable, (1200m, 6.5mm) cut into 100m lengths was used to support the nets. Ten manual winches with an 800kg capacity were used to tension the cables used to support the nets. Approximately 50 metal pipes, each 2.5m high and 50mm in diameter were used. Fifty 1.5m steel mine drill bits were driven into the ground to support the metal pipes and 30 fencing standards, each 1.8m long, were used to anchor the cables supporting the metal poles and nets.

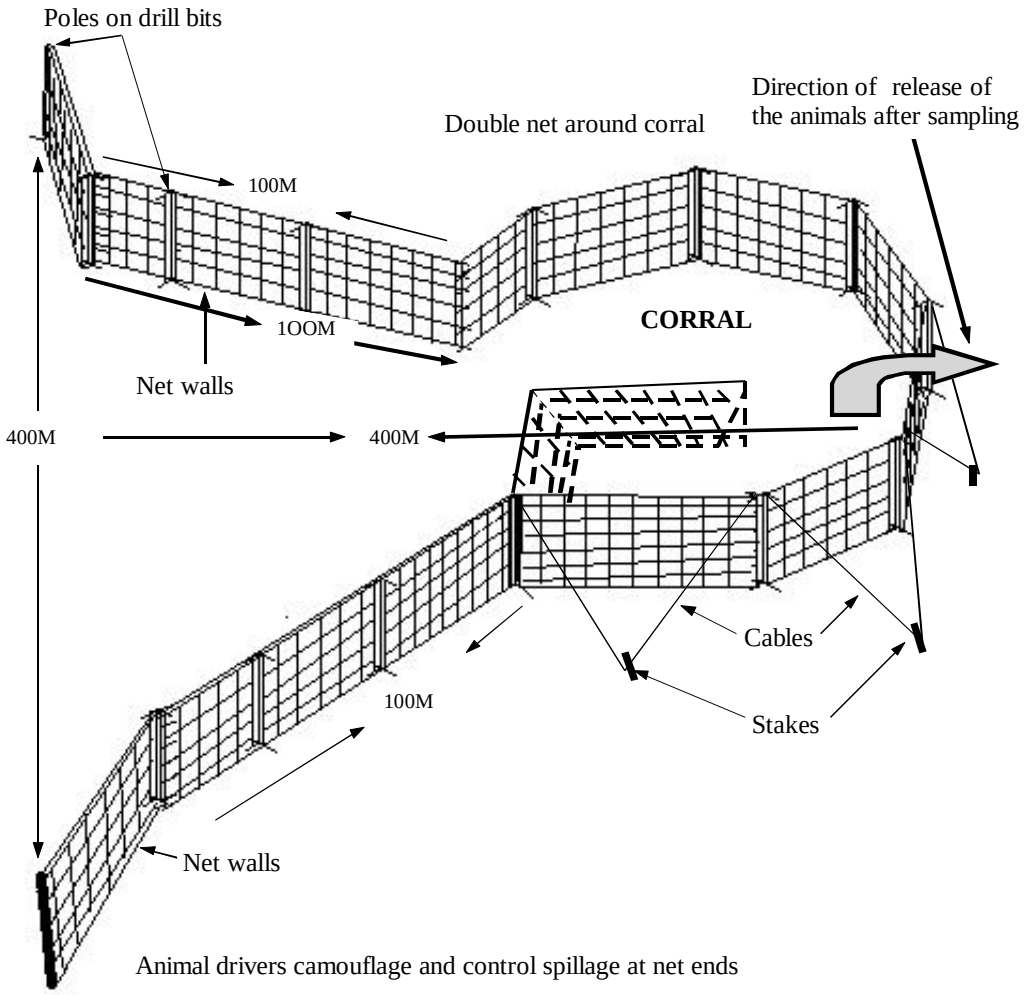

Figure 3.2 The capture net.

Once the construction was complete the personnel positioned themselves. The capture team members were divided into groups and positioned strategically in camouflage

around the net to assist drive in, and restrain the captured animals. Three vehicles driven at high speed were used to drive in the animals into the capture site. Once the Thomson gazelles were trapped inside the corral, the assistants entered the corral by detaching a small section of the net from the bottom cable around the corral. The assistants then restrained the trapped Thomson gazelles by hand as shown in Figure 3.3, while others took fecal samples directly from the rectum of individual animals using moistened index fingers. The number of animals sampled was not predetermined, all captured gazelles were sampled. The samples were placed in labeled plastic pots and transported to the laboratory for examination. Number, age and sex of every gazelle captured were recorded. Every gazelle captured was safely and efficiently handled to avoid injuries. After taking the fecal samples, the animals were then released and driven away beyond the net to avoid rejoining the herds that were not sampled.

3.2.6 Processing of fecal samples

Fecal samples were processed for enumeration of nematode eggs and examined for tapeworm eggs and coccidia oocysts using the McMasters technique as in 3.2.2. The presence or absence of coccidian oocysts and tapeworm eggs was noted. Fecal samples remaining after epg determination were pooled and divided into two portions. One portion was used for culture and larvae identification. The second portion was used for oocyst sporulation. Fecal cultures were also prepared and larvae identified to genus level using cuticular morphology and size as described in the MAFF (1986) manual and as outlined in 3.2.3.

3.2.7 Sporulation of coccidian oocysts

Fecal samples from all the captured gazelles were pooled together and the coccidian oocysts isolated using a floatation technique. In this procedure, the fecal samples were crushed and magnesium sulphate solution added, causing the oocysts to float. The sample was allowed to stand for 15 minutes and the supernatant was decanted. The magnesium sulphate solution was removed from the supernatant by dilution and repeated centrifugation to give clean oocyst sediment. This sediment was suspended in a solution of potassium dichromate (25% w/v) and transferred into clean covered Petri dishes, which were incubated at room temperature with constant aeration for seven days, after which the oocysts had not sporulated. They were then incubated for further three days and still did not sporulate. The solution was then discarded and therefore the oocysts were not identified.

Figure 3.3 Restraining of Thomson's gazelle for fecal sample collection.

3.2.8 Meteorological data

Data on mean monthly rainfall for the period of the study and the long-term means collected at the Marula station was obtained from the Meteorological Department Headquarters in Nairobi.

3.2.9 Data analysis

Worm burdens for the strongyle nematodes and egg counts were logarithmically transformed [log (x+10)] to normalize their distribution. Descriptive data was generated and analysis of variance (ANOVA) and a paired t-test performed in Microsoft Excel Program (2001). The means of egg counts were compared between age and sex of the host and the dry and wet months. Means of worm burdens were compared between gazelles captured in June and September. The term prevalence was defined as the percentage of samples found positive for helminth eggs or coccidia oocysts (Margolis *et al*., 1982). A value of $p<0.05$ was considered significant. Correlation analysis was carried out to examine the relationship between egg counts and worm burdens, and worm burdens and body weights of the slaughtered gazelles.

CHAPTER 4

4.0 RESULTS

4.1 Rainfall distribution

The long-term (1961-1999) mean monthly rainfall (mm), the monthly total rainfall (mm), and the number of rainy days recorded in the study area between November 2002 and October 2003, are shown in Figure 4.1. During this period, a total of 757mm of rainfall was recorded. This was higher than the long-term mean of 680 mm of rainfall. The amount of rainfall recorded during the short rains of October to December 2002 (193.1mm) was higher than the long-term mean (173.5mm), and also the total rainfall recorded during the long rains of May to June 2003 (351.1mm) was higher than the long-term mean (245.3). The highest amount of total monthly rainfall recorded during this period (135mm) occurred in May, while the lowest amount of total monthly rainfall recorded during this period (2.5mm) occurred in February. The amount of rainfall received during the study months (June, September and October) was 87.6mm, 16mm and 101mm, respectively. The long-term mean monthly rainfall for the months of June, September and October was 57.1mm, 35mm and 53.4mm, respectively. The amount of rainfall received during the months of June and October was higher than the long-term mean monthly rainfall, while that of September was lower than the long-term mean monthly rainfall. The number of rainy days recorded in the months of June, September and October were ten, five and fifteen, respectively.

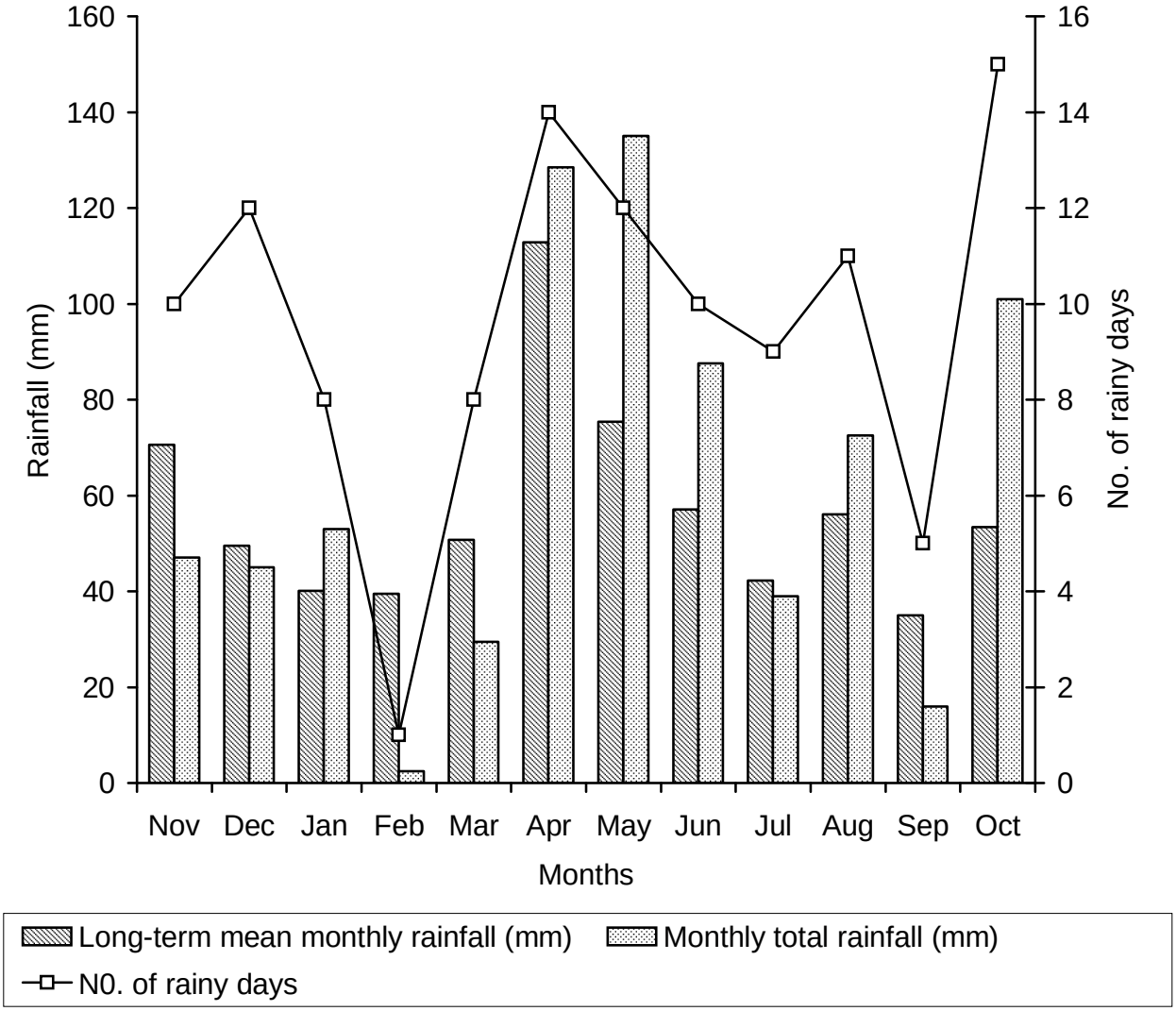

Figure 4.1 The long-term mean monthly rainfall in mm (1961-1999) and the monthly total rainfall (mm) and number of rainy das per month recorded at Marula Ranch between November 2002 and October 2003.

4.2 Worm burdens in slaughtered gazelles

Worm burdens were determined in a total of 25 male gazelles slaughtered on the ranch in June (6 gazelles) and September (19 gazelles). These gazelles ranged in body weight from 16Kgs to 25Kgs (June) and from 21Kgs to 27Kgs (September). The mean body weights for gazelles slaughtered in June and September were 21.5Kgs and 23.7Kgs respectively. Statistical comparison between the two means indicated that there was a

significant difference ($P<0.05$) in the body weights between male gazelles slaughtered in June as compared to those slaughtered in September. Table 4.1 shows the genera of nematodes isolated in the abomasa of gazelles slaughtered in June and September, the mean and range of worm burdens and prevalence while appendix III shows the total number of worms isolated in the abomasum of each gazelle.

In the abomasum, *Haemonchus*, *Gazellostrongylus* and *Trichostrongylus* were isolated. These parasites could be distinguished using their size and characteristic morphological features. For *Haemonchus* these features included the shape of the bursa, gubernaculum and spicules, which have hook-like spines in the male (Figure 4.2a) and the anterior papillae (Figure. 4.2b). For *Gazellostrongylus*, the characteristic morphological features used included the brownish-red coloration, shape of the bursa and spicules and crisscrossing longitudinal striations (Figure 4.3a, b and c).

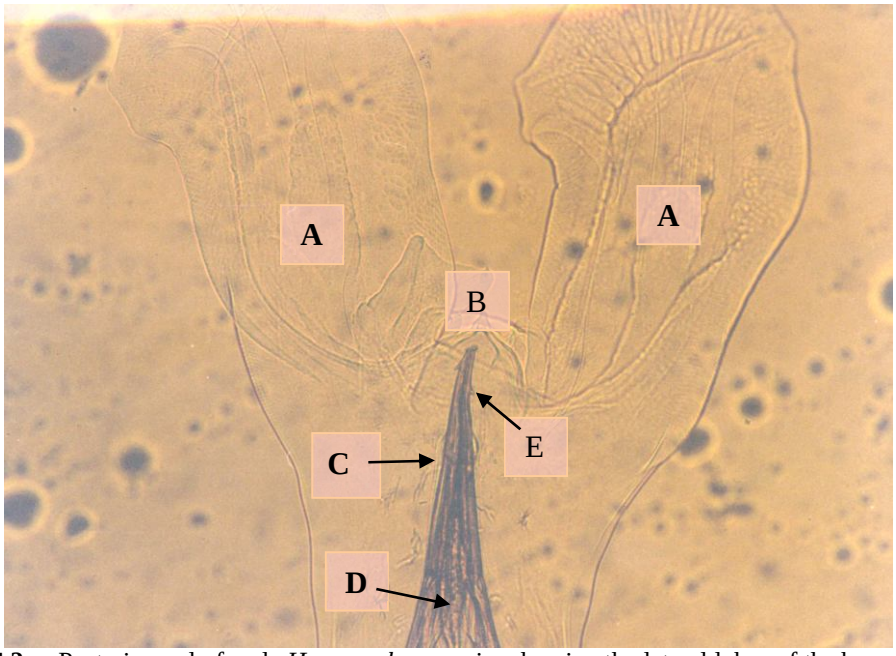

Figure 4.2 a: Posterior end of male *Haemonchus* species showing the lateral lobes of the bursa (A), small dorsal lobe (B), spicules (C), gubernaculum in the middle (D) and hook-like spines on the spicules (E).

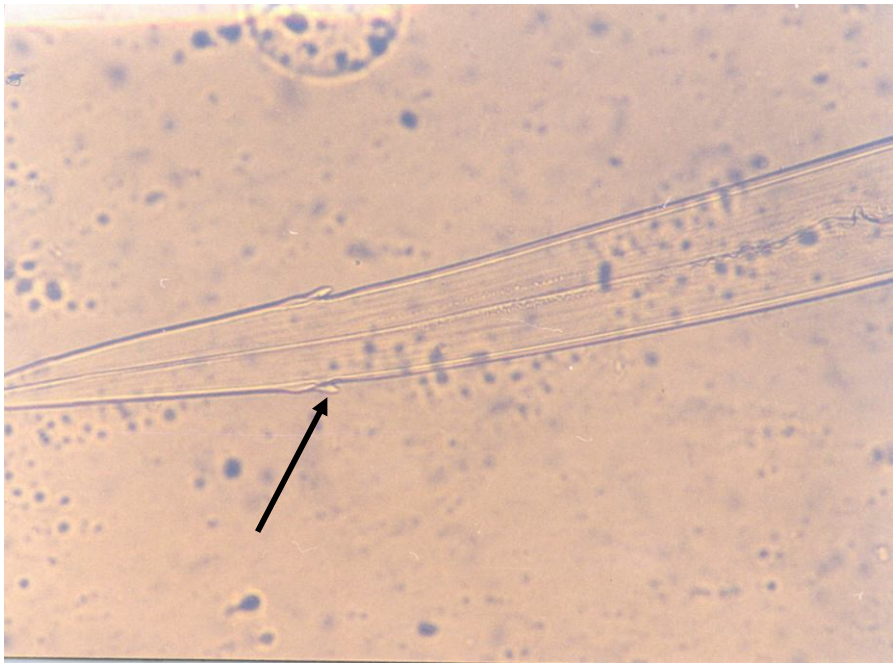

Figure 4.2 b: Anterior end of *Haemonchus* species showing the papillae indicated by an arrow

Figure 4.3a: Anterior end of *Gazellostongylus* showing crisscrossing longitudinal striations.

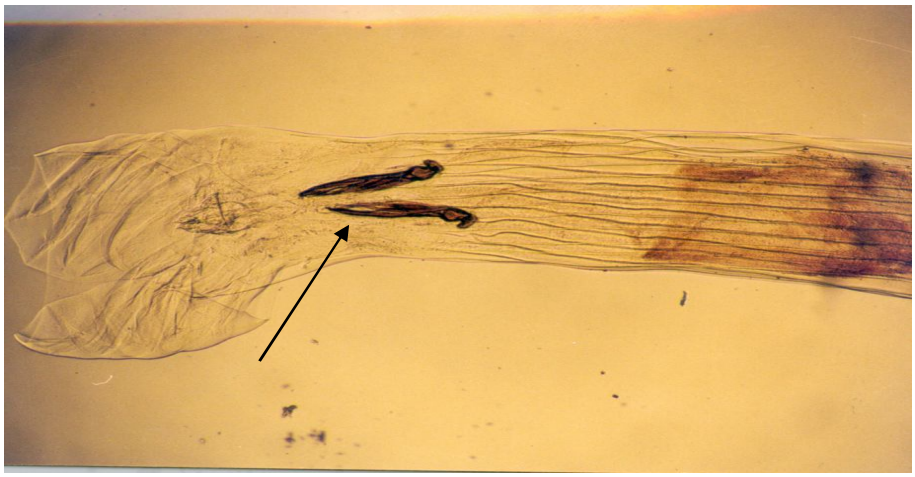

Figure 4.3b: Posterior end of male *Gazellostrongylus* showing the bursa, spicules, and brownish-red coloration

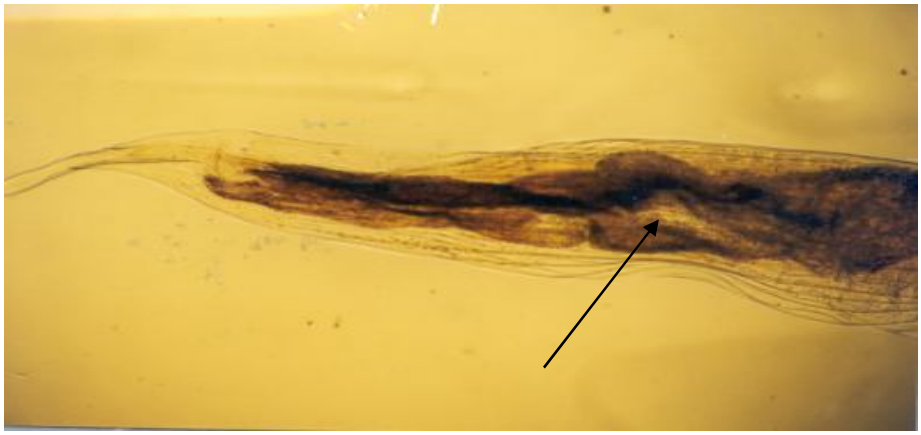

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Figure 4.3c: Posterior end of female Gazellostrongylus showing longitudinal striations and red brownish coloration

Table 4.1:The genera of nematodes isolated in the abomasa of gazelles slaughtered in June and September 2003, the mean, range and standard deviation (sd) of worm burdens and the prevalence (%).

Organ	**Genera**	**June**		**September**	
		Mean (Range)	Prevalence (%)	Mean (Range)	Prevalence (%)
Abomasum	*Haemonchus*	10 (0-35) Sd ± 16	33	49 (0-203) Sd ± 54	95
	Gazellostrongylus	100 (15-350) Sd ± 127	100	25 (0-249) Sd ± 62	37
	Trichostrongylus	29 (0-175) Sd ± 66	17	26 (0-207) Sd ± 51	58

Gazellostrongylus was found in all 6 gazelles (100%) slaughtered in June, and in 7 out of 19 (37%) of the gazelles slaughtered in September. The highest prevalence of *Haemonchus* was recorded in September with 18 out of 19 (95%) gazelles having the parasites. Similarly, gazelles slaughtered in September had higher burdens of *Trichostrongylus* (58%) compared to those slaughtered in June (17%) as shown in Table 4.1.

The mean worm burdens for *Haemonchus* in the gazelles slaughtered in June and September were, 10 with Sd of ± 16, 49 with Sd of ± 54 respectively. Statistical

comparison between the two means indicated that there was significant difference ($P<0.05$) of the worm burdens between animals in June as compared to worm burdens in September. Mean worm burdens for *Gazellostrongylus* in June and September were 100 with Sd of ± 127, 25 with Sd of ± 62 respectively. These means were statistically significant ($P<0.05$). Mean worm burdens for *Trichostrongylus* in June and September were 29 with Sd of ± 66, 26 with Sd of ± 51 respectively. Statistical comparison between the two means indicated that there was no significant difference ($P>0.05$) of the worm burdens between animals slaughtered in June and September.

Lesions were found in the abomasum of 13 out of the 25 (52%) gazelles slaughtered in both June and September that were infected with *Gazellostrongylus*. The lesions consisted of nodules (Figure 4.4a) in the inner walls of the abomasum, which measure between 3 and 4cm in diameter. Majority of the animals had four nodules but there were up to five nodules in a few cases. The nodules had an orifice in the middle from which adult male and female worms that were large and dark red in color protruded into the lumen of the abomasum. The nodules were found in the fundic region on the lesser curvature of the abomasum, and when palpated, were soft and flocculating like they contained some fluid inside. On opening up these nodules, there was a fluid inside which was found to be pus-like and creamish in color. When cut open, some of the worms got cut in the process of opening up the nodules and a red blood like fluid gushed out (Figure 4.4b).

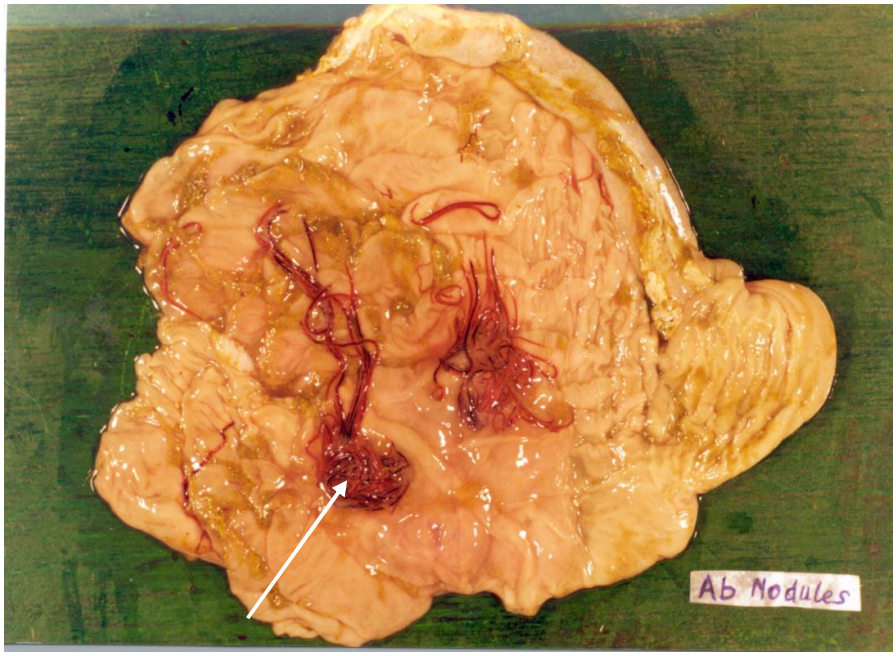


Figure 4.4 a: Abomasum of a gazelle infected with *Gazellostrongylus*, showing 3-4 cm nodules indicated by an arrow.

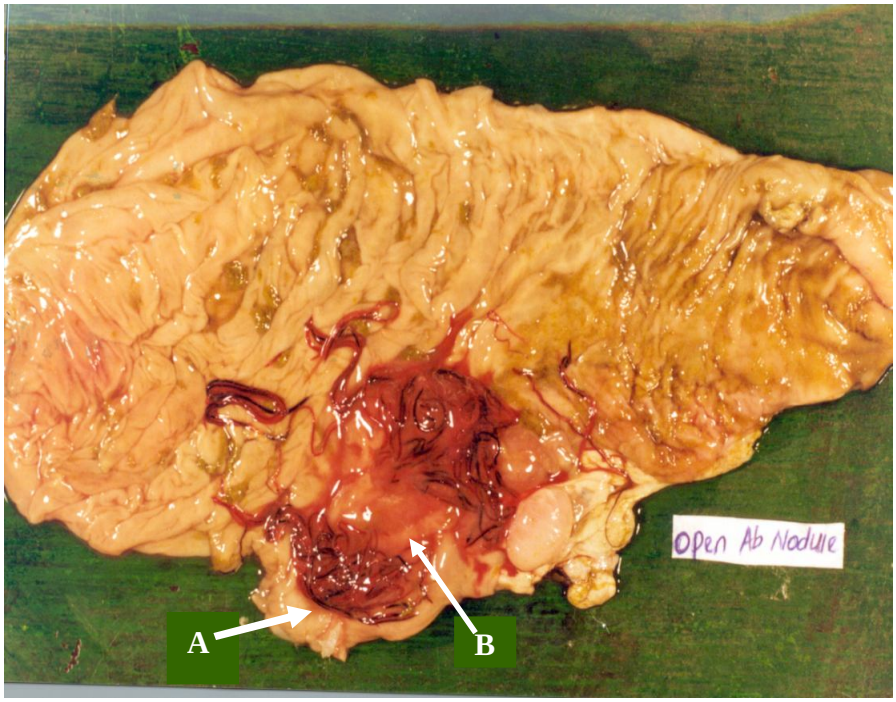


Figure 4.4 b: Abomasum of a gazelle infected with *Gazellostrongylus* showing worms (A) and reddish cream pus-like material (B) from open nodules.

Table 4.2 shows the genera of nematodes isolated from the small intestine and large intestines of gazelles slaughtered in June and September, the mean worm burdens, range and the prevalence. In appendix IV and V, the total numbers of worms isolated from the small and large intestines of each gazelle respectively are shown.

In the small intestines, *Trichostrongylus*, *Nematodirus*, and *Cooperia* were isolated, while *Trichuris* was isolated in the large intestine. These parasites were distinguished using their sizes and characteristic morphological features. These features included two long spicules and a bursa with two large elongated lateral lobes (Figure 4.5) for *Nematodirus*. For *Cooperia* two different species were identified using the shape of the bursa and spicules as shown in Figure 4.6a (branched spicules) and Figure 4.6b (wing like expansion on the middle of spicules). Striations on the anterior end of *Cooperia* are also shown in Figure 4.6c. Those of *Trichostrongylus* included dark brown colored spicules, which were short and stumpy with twisted gloves (Figure 4.7a) and the excretory pore at the anterior end (Figure 4.7b).

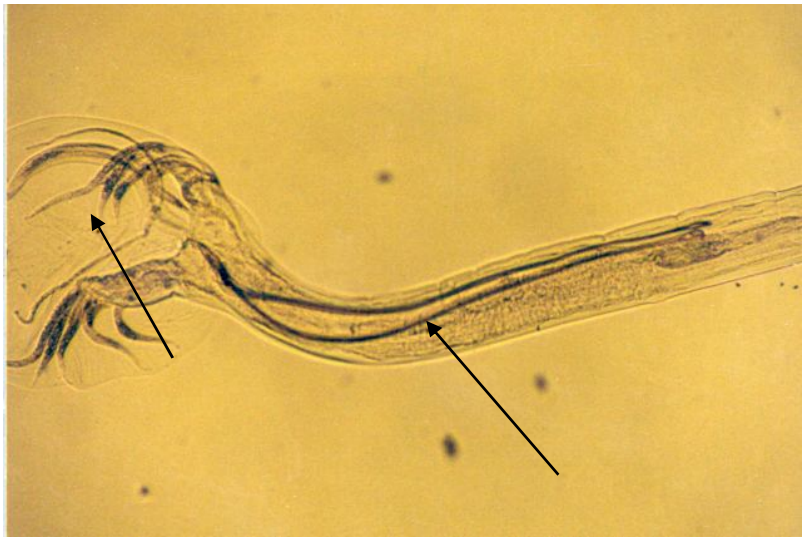


Figure 4.5: Posterior end of male *Nematodirus* species showing two long spicules and a bursa with two large elongated lateral lobes.

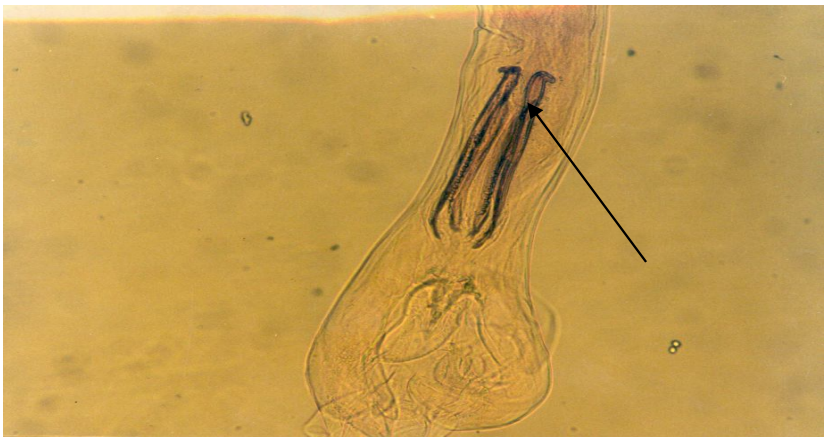


Figure 4.6a: Posterior end of a male *Cooperia* species showing spicules with branched posterior ends.

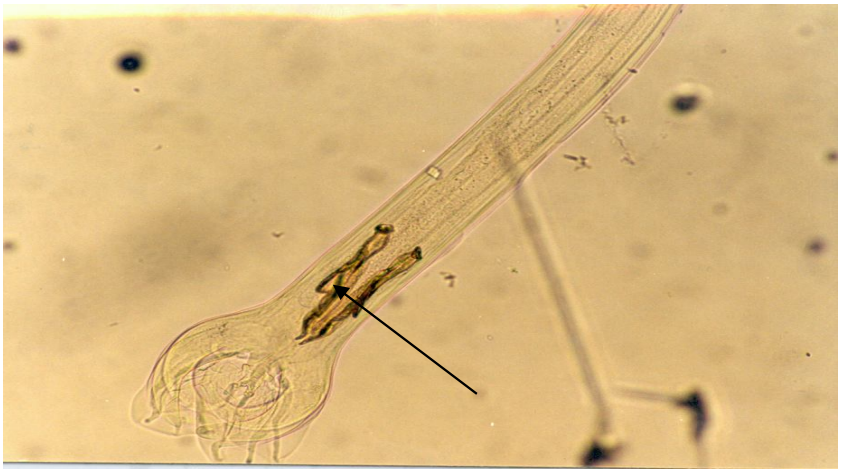


Figure 4.6 b: Posterior end of a male *Cooperia* species showing wing like expansion in the middle of spicules

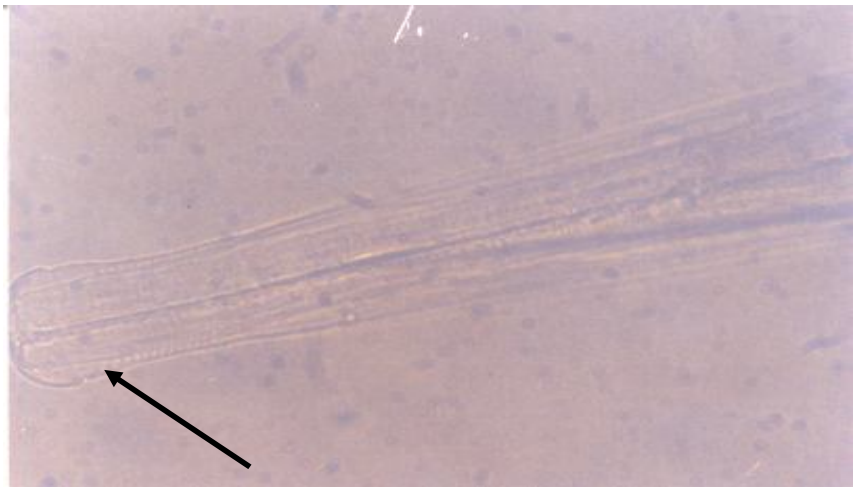


Figure 4.6 c: Anterior end of *Cooperia* species showing transverse striations indicated by an arrow

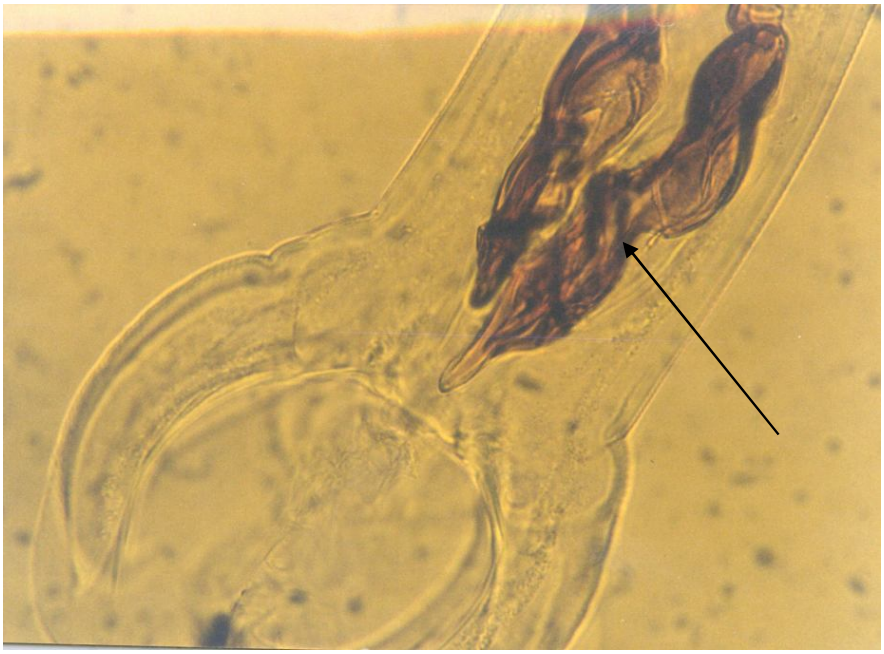


Figure 4.7a: Posterior end of a male *Trichostrongylus* species, showing dark brown colored spicules which are short and stumpy with twisted gloves.

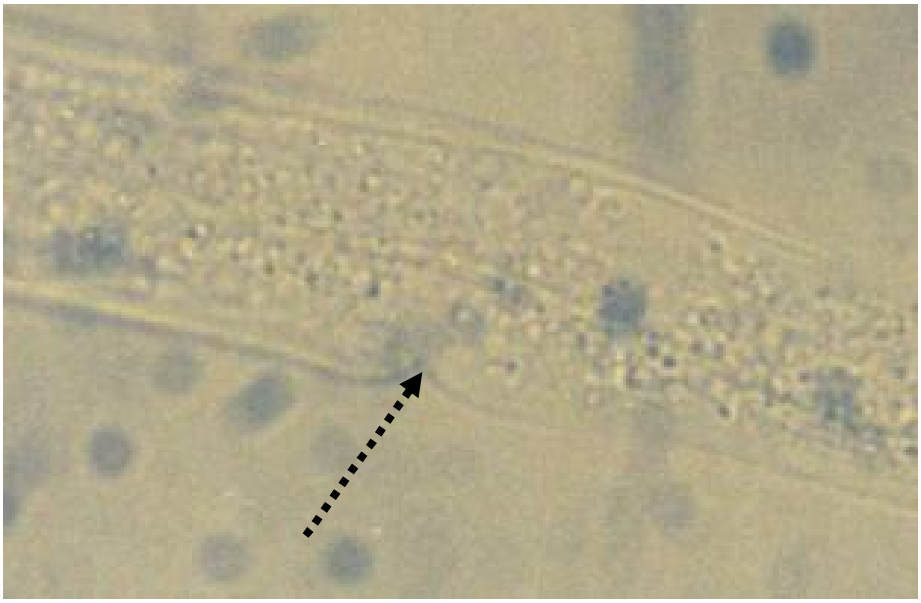


Figure 4.7b: Anterior end of *Trichostrongylus* species showing the excretory pole indicated by an arrow.

Trichostrongylus was found in all 6 gazelles (100%) slaughtered in June, and in 18 out of 19 (95%) of the gazelles slaughtered in September. The prevalence of *Nematodirus* in June was 33% with 2 out of 6 gazelles having the parasite and the prevalence recorded in September was (5%) with 1 out of 19 gazelles having the parasite. However, the highest prevalence of *Cooperia* was recorded in September with 14 out of 19 (74%) gazelles infested and the lowest prevalence recorded in June with 3 out of 6 (50%) gazelles having the parasite. In the large intestine, *Trichuris* was found in all the gazelles slaughtered (100%) in June and in September.

The mean worm burdens for *Trichostrongylus* in the gazelles slaughtered in June and September were 195 with Sd of ± 162, 852 with Sd of ± 690 respectively. Mean worm burdens for *Nematodirus* in June and September were 16 with Sd of ± 27, 28 with Sd of ± 120 respectively. Mean worm burdens for *Cooperia* in June and September were 85 with

Sd of ± 127, 200 with Sd of ± 220 respectively. Finally the mean worm burdens for *Trichuris* in June and September were 48 with Sd of ± 24, 43 with Sd of ± 40 respectively. Statistical comparison between the two means indicated that there was a significant difference ($P<0.05$) of the worm burdens for *Trichostrongylus* between animals slaughtered in June and September. However, for *Nematodirus* and *Cooperia* results indicated that the means were not statistically different ($p>0.05$).

Table 4.2: Genera of nematodes isolated from the intestines of gazelles slaughtered in June and September 2003, mean worm burdens, range, Standard deviation (Sd) and prevalence (%).

Organ	Genera	June		September		P value
		Mean (Range)	Prevalence	Mean (Range)	Prevalence	
Small intestines	*Trichostrongylus*	195 (65-475) Sd± 162	100	852 (0-2150) Sd± 690	95	0.019
	Nematodirus	16 (0-65) Sd ± 27	33	28 (0-525) Sd±120	5	0.42
	Cooperia	85 (0-325) Sd± 127	50	200 (0-750) Sd± 220	74	0.266
Large Intestines	*Trichuris*	48 (15-80) Sd± 24	100	43 (3-152) Sd± 40	100	0.411

Correlation analysis showing the relationship between the log worm burdens in the abomasum and intestines and the mean body weights for the 25 gastrointestinal tracts examined in June and September 2003 are shown in Fig 4.8a and b. Fig 4.9a and b show

the plots of the relationship between body weights and the log worm burdens for *Haemonchus* and log total worm counts for *Gazellostrongylus* respectively. Fig 5.1a shows plots of the relationship between body weights and the total log worm burdens while Fig 5.1b shows the relationship between log worm burdens for *Haemonchus* and *Gazellostrongylus*. The correlation analysis for the relationship between worm burdens and body weights indicated both positive and negative linear correlations. There was a negative correlation between total worm burdens in the abomasum and body weights (-0.34) as shown in Figure 4.8a while there was a positive correlation between total worm burdens in the intestines and body weights (+0.404) as shown in Figure 4.8b. There was a positive correlation between body weights of the gazelles and the log worm burdens for *Haemonchus* +0.095 as shown in Figure 4.9a and a negative correlation for *Gazellostrongylus* (-0.499) as shown in Figure 4.9b. There was a positive correlation between body weights of the gazelles and the total log worm burdens for *Haemonchus* (+0.39) as shown in Figure 5.1a, while there was a negative correlation between total log worm counts and total log worm counts for *Gazellostrongylus* (-0.42) as shown in Figure 5.1b.

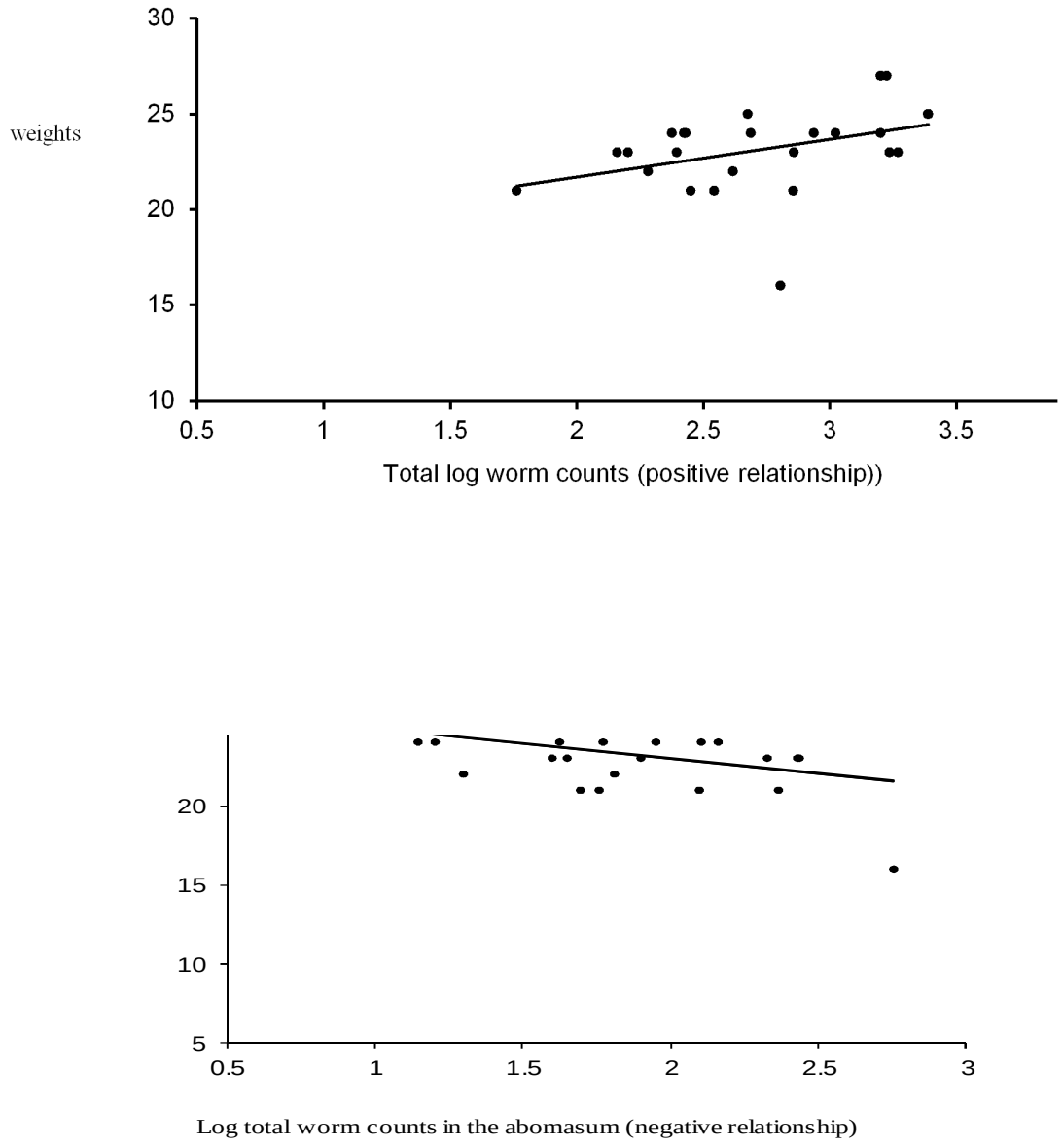
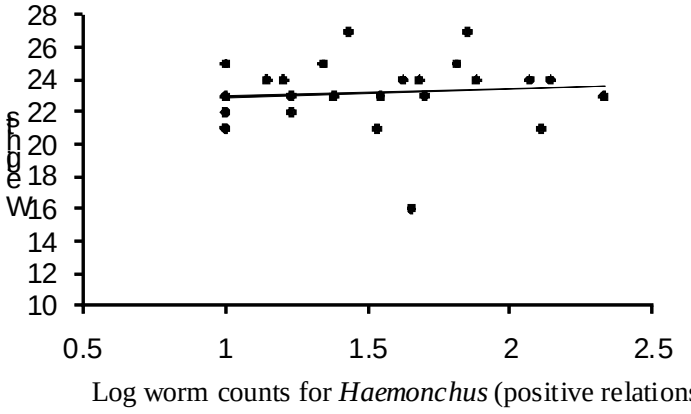


Figure 4.8 a & b: Plots of the relationship between body weights of gazelles and the log worm burdens in the abomasum (a) and body weights and log worm burdens in the intestines (b) for 25 gastrointestinal tracts examined in June and September 2003.



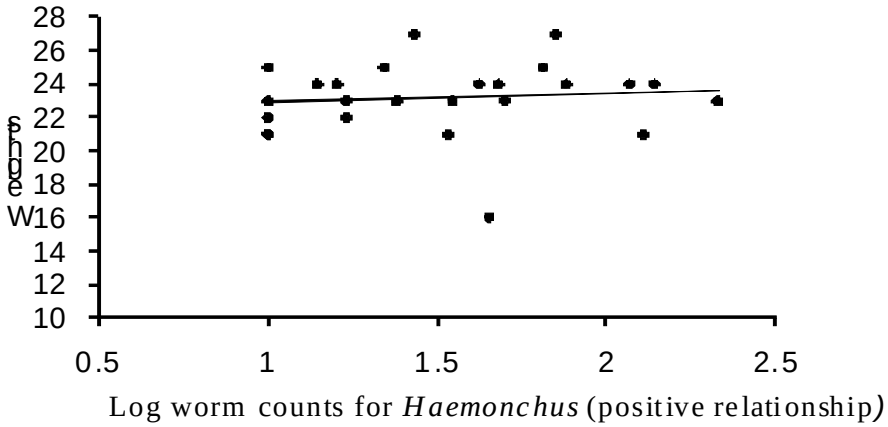


Figure 4.9 a &b: Plots of the relationship between body weights of gazelles and the log worm burdens for *Haemonchus* (a) and *Gazellostrongylus* (b) for 25 gastrointestinal tracts examined in June and September 2003.

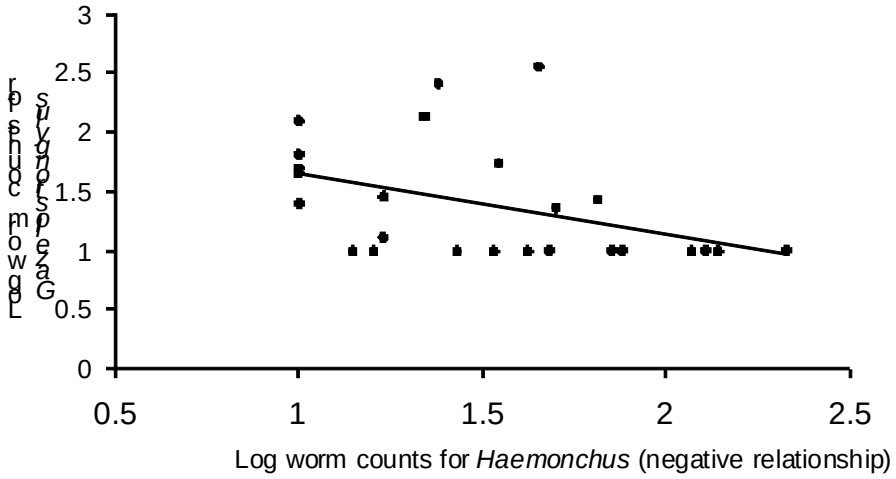


Figure 5.1:Plots of the relationship between body weights of gazelles and the total log worm burdens in the abomasums (a) and the relationship between log worm burdens for *Haemonchus* and for *Gazellostrongylus* (b) for 25 gastrointestinal tracts examined in June and September 2003.

4.3 Fecal egg counts and coccidian oocysts in slaughtered and captured gazelles

Figure 5.2 shows the ccurrence (%) of the Strongyle-type nematode eggs and coccidian oocysts in fecal samples from gazelles slaughtered at Marula ranch in June and September 2003. Out of the 6 gazelles slaughtered in June, 5 (83%) were shedding Strongyle-type nematode eggs, but none were shedding *Trichuris* eggs or coccidian oocysts. All the19 gazelles slaughtered in September were shedding Strongyle-type nematode eggs, 7 (37%) were shedding *Trichuris* eggs and6 (32%) coccidia oocysts.

Figure 5.3 shows the occurrence (%) of the Strongyle-type nematode eggs, *Trichuris* eggs and coccidian oocysts in young and adult, male and female gazelles captured at the ranch in October 2003. All the 31 gazelles captured, were shedding Strongyle-type nematode

eggs and coccidian oocysts, while only 1 (3%) was shedding *Trichuris* eggs. The prevalence of Strongyle-type nematode eggs was 100% in the young and adult male and female gazelles captured in October. *Trichuris* eggs were found in only 1 fecal sample out of the 3 (33%) young males examined, but in none of the samples from the young females and all the adults examined. The prevalence for coccidian oocysts was 100% for all the age groups and sexes of gazelles captured.

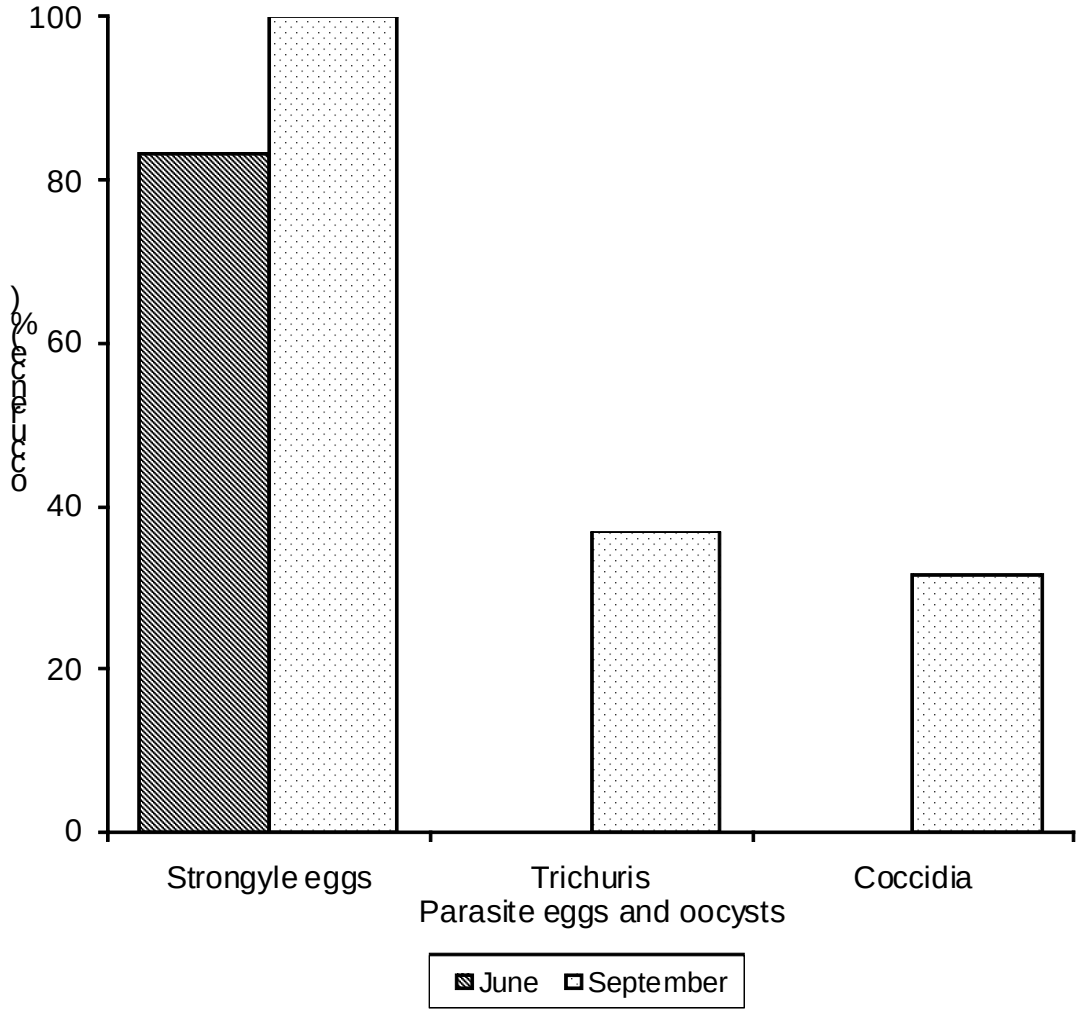


Figure 5.2: The occurrence (%) of the Strongyle-type nematode eggs, *Trichuris* eggs and coccidian oocysts in 25 gazelles slaughtered in June and September 2003.

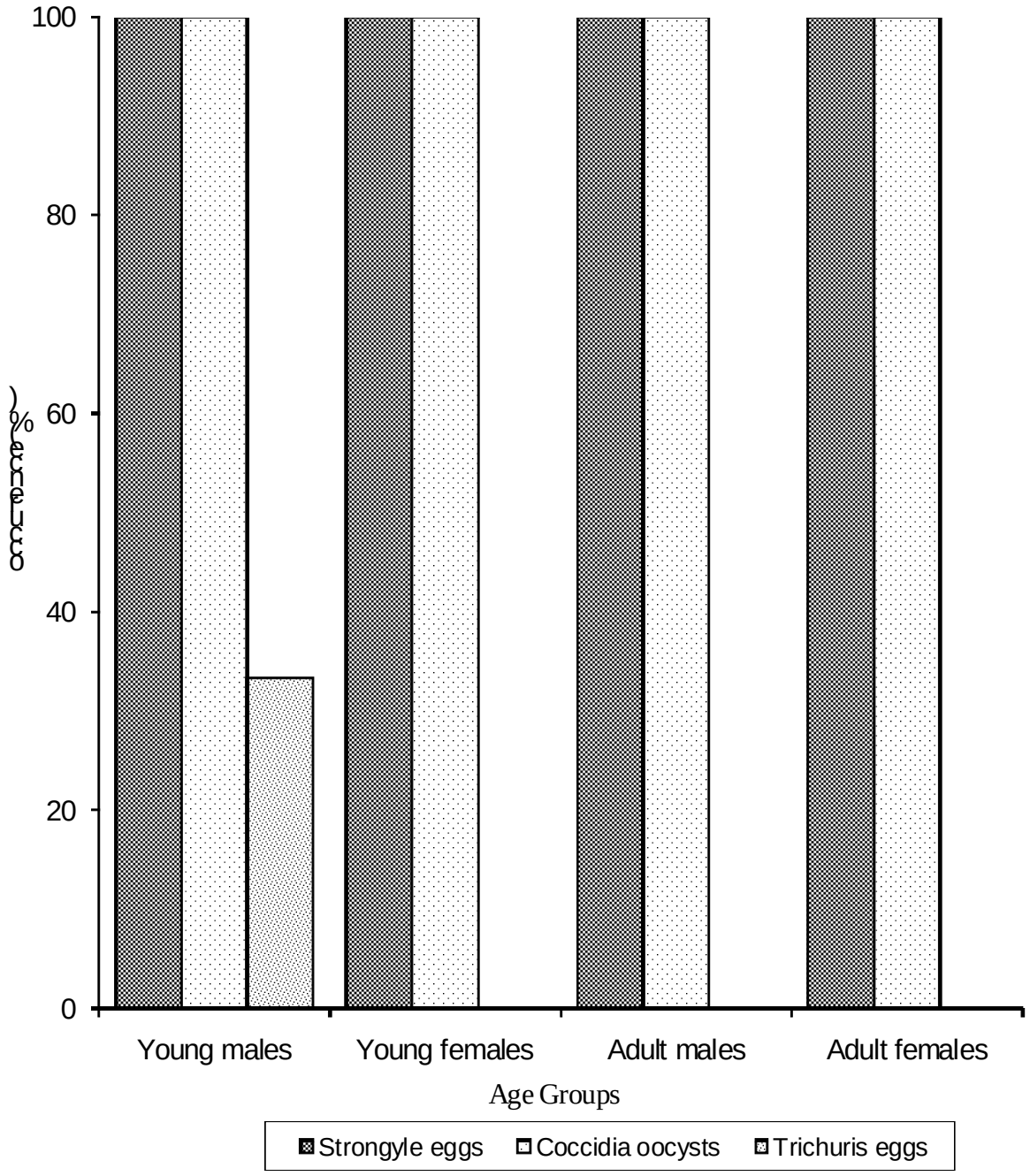


Figure 5.3: The percent occurrence of the Strongyle-type nematode eggs, *Trichuris* eggs and coccidian oocysts in young and adult, male and female gazelles captured at the ranch in October 2003.

Table 4.3 shows the number of gazelles slaughtered in June and September and those captured in October, the geometric mean Strongyle-type nematode egg counts and results

of statistical comparisons between the means. The mean for Strongyle-type nematode eggs was highest for the gazelles captured in October (2670) and lowest in gazelles slaughtered in June (497). Statistical comparison between the two means indicated that there was a significant difference between mean counts in June and September (P value = 0.017) and between mean counts in June and October (P value = 0.00094). However there was no significant difference between mean counts for samples collected from slaughtered gazelles in September and those captured in October.

Table 4.3: The number of gazelle's slaughtered in June and September and those captured in October 2003, the geometric mean of Strongyle-type nematode egg counts and results of statistical comparisons.

Months compared	Number	Geometric mean	P Value
June September	6 19	497 2220	0.017
September October	19 31	2220 2670	0.453
October June	31 6	2670 497	0.00094

Table 4.4 shows the number of slaughtered male gazelles and captured males and females, the geometric mean of Strongyle-type nematode egg counts and results of statistical comparisons.

Table 4.4: The number of slaughtered males and captured male and female gazelles, the geometric mean Strongyle-type nematode egg counts and results of statistical comparisons

Age and sex of gazelles	Number	Geometric mean Strongyle-type EPG	P Value
Slaughtered males Captured (all age groups)	25 31	1550 2670	0.09
Slaughtered males Captured adults	25 22	1550 2935	0.051
Slaughtered males Captured young	25 9	1550 2119	0.45
Slaughtered males Captured males	25 3	1550 2202	0.25
Slaughtered males Captured adult females	25 19	1550 3056	0.04
Captured Adults Captured young	22 9	2935 2119	0.35
Captured adult females Captured adult males	19 3	3056 2269	0.27
Captured adult males Captured young males	3 3	2138 2269	0.82
Captured adult females Captured young females	19 6	3056 2110	0.49
Captured young males Captured young females	3 6	2138 2110	0.98

The geometric mean Strongyle-type nematode EPG for slaughtered male gazelles was compared with those of all the gazelles captured; males and females, young and adults. Statistical comparison between the two means indicated that there was a significant difference (P value=0.041) between the captured females and the slaughtered males. However, there was no significant difference between all the other groups.

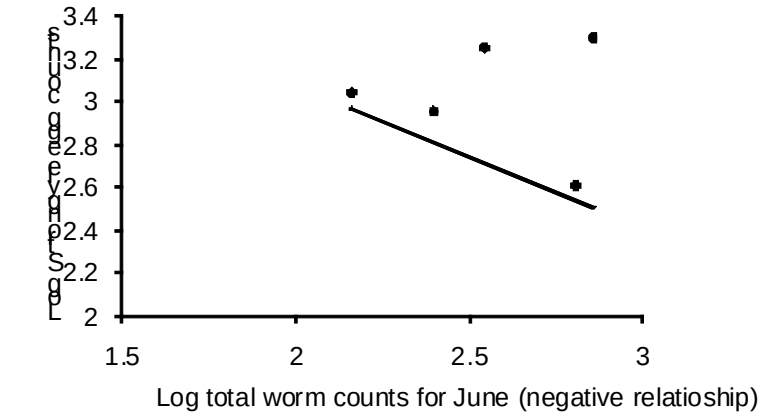
The regression plots showing the relationship between the log Strongyle-type egg counts and the worm burdens recorded for the gastrointestinal tracts examined in June and September are shown in fig 5.4a and b respectively. Fig 5.5 shows the regression plot for the relationship between log Strongyle-type egg counts and the combined worm burdens in all the 25 gastrointestinal tracts. The regression analysis for the relationship between

gazelles slaughtered in June and for those slaughtered in September indicated both positive and negative liner correlations. The r value for the relationship between log Strongyle-egg counts and worm burdens for the gazelles slaughtered in June (fig 5.4a) was –0.201 while that for the gazelles slaughtered in September (fig 5.4b) was +0.457. The r value for the relationship between log Strongyle-type egg counts and the combined worm burdens in all the 25 gastrointestinal tracts (fig 5.5) was +0.27.

4.4: Results of fecal cultures from slaughtered and captured gazelles

Figure 5.6 shows the distribution of genera of gastrointestinal nematodes from fecal cultures of gazelles slaughtered in June and September 2003. *Gazellostrongylus, Haemonchus* and *Trichostrongylus* were recovered from cultures in both June and September. *Gazellostrongylus* had the highest occurrence (52% and 44%) for June and September respectively. The lowest occurrence was for *Haemonchus* (22%) in June and the lowest in September was for *Trichostrongylus* (17%).

The mean distribution of genera of gastrointestinal nematodes in fecal cultures from gazelles captured in October 2003 is shown in Figure 5.7.



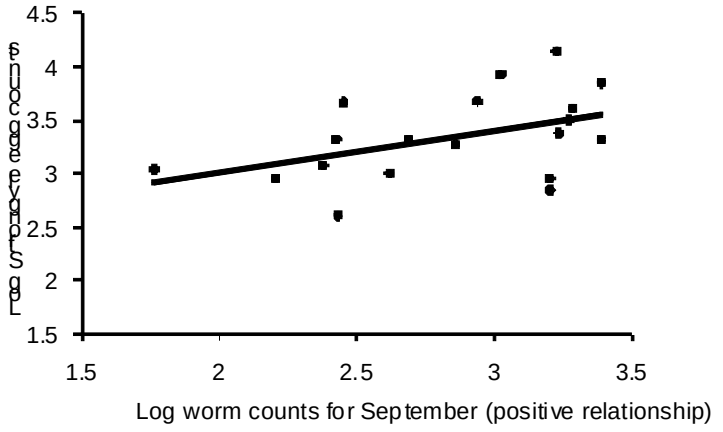


Figure 5.4: Plots of the relationship between the log Strongyle-type egg counts and the log worm burdens recorded for the gastrointestinal tracts examined in June (a) and in September (b) 2003.

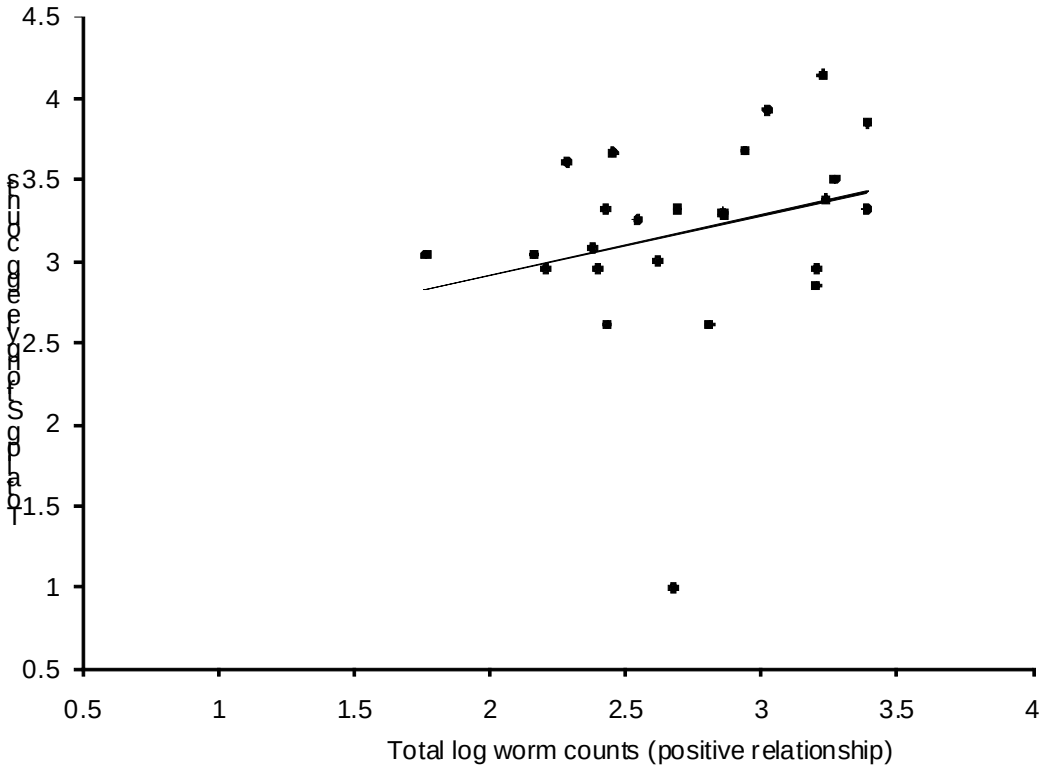


Figure 5.5: The overall total log Strongyle-type egg counts and total log worm burdens for June and September.

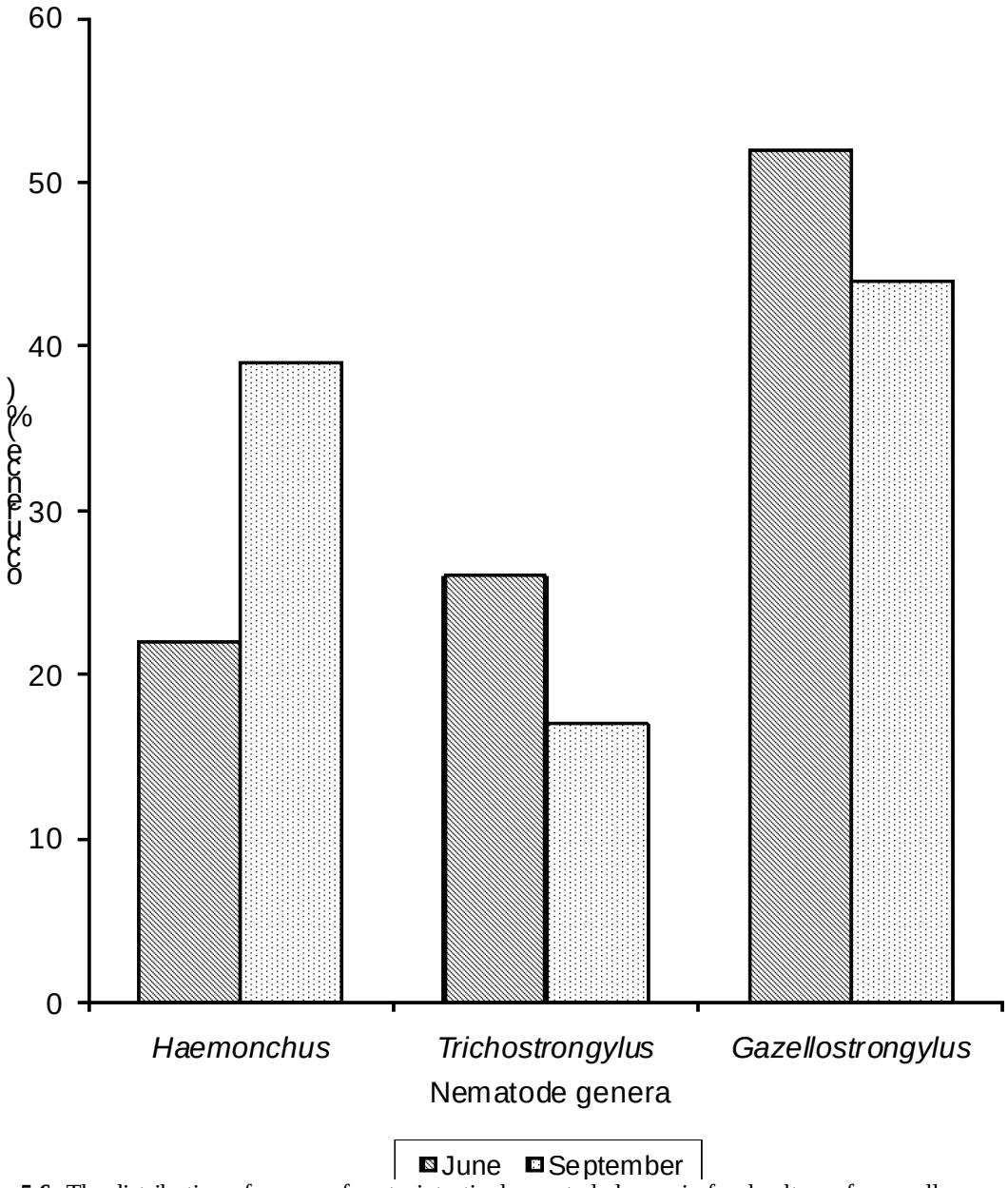


Figure 5.6: The distribution of genera of gastrointestinal nematode larvae in fecal cultures for gazelles slaughtered on Marula ranch in June and September 2003.

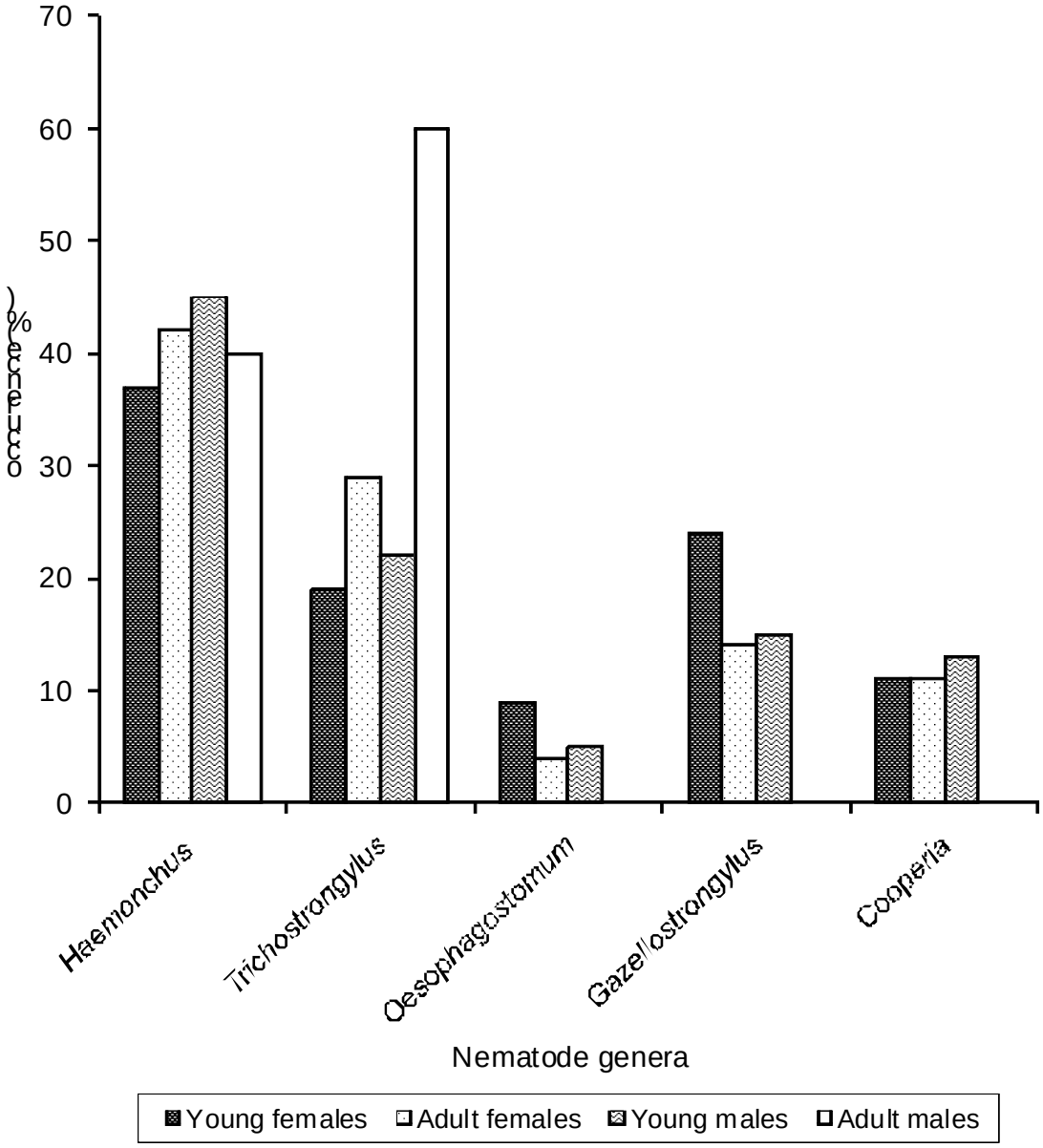


Figure 5.7: The distribution of genera of gastrointestinal nematode larvae in fecal cultures for young and adult, male and female gazelles captured at the ranch in October 2003.

Haemonchus, Trichostrongylus, Oesophagostomum, Gazellostrongylus and *Cooperia* were recovered from fecal cultures of 31 gazelles captured at the ranch in October 2003. The occurrence for *Haemonchus* was 45% in young males, 40% in adult males, 37% in

young females and 42 % in adult females. Adult males had the highest percentage occurrence for *Trichostrongylus.* Larvae of *Oesophagostomum*, *Gazellostrongylus* and *Cooperia* were not encountered in fecal cultures from adult males. *Oesophagostomum* had the lowest occurrence in fecal cultures from all age groups. In young males, *Oesophagostomum* accounted for 5% occurrence, while it was in young females and 4% in the adult females. Cultures from young females had the highest percent occurrence for *Gazellostrongylus* (24%), followed by young males (15%) and then adult females (14%). Fecal cultures from young males had the highest occurrence for *Cooperia* (13%), while the young and adult females had 11% occurrence.

CHAPTER 5

5.0 DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

Data on the occurrence of gastrointestinal nematodes from this study clearly shows that the parasites are prevalent in Thomson gazelles within the study area. Greater numbers of these worms occurred in the abomasum and small intestines with relatively fewer parasites in the large intestines of the gazelles. This observation is similar to that of Waruiru *et al.,* (1995), who recorded similar genera of gastro-intestinal nematodes in Thomson gazelles slaughtered at the Wildlife Ranching and Research (WRR) Ltd. near Athi-River, a semi-arid area of Kenya. The results on the occurrence of the various genera of nematodes based on differential worm counts in the present study showed that mixed nematode infections occurred in Thomson's gazelles in the study area, with *Haemonchus, Gazellostrongylus* and *Trichostrongylus* being the most prevalent species. This observation was also confirmed by the results of fecal cultures and identification of larvae, which showed that *Haemonchus, Gazellostrongylus* and *Trichostrongylus* were the most abundant nematodes.

It has been known that on the basis of taxonomic criteria, wild ruminants and domestic ruminants share a proportion of their nematode fauna. However, studies on cross-infection between the two groups have been performed experimentally only on a limited scale and even less is known about the extent to which this occurs naturally in the field. Inevitably therefore, any assessment of the role of wild ruminants in nematodiasis must at this stage be based largely on knowledge of the disease in domestic animals and certain

hypothesis regarding the expected degree and influence of cross-infection. On the basis of taxonomic criteria it has been estimated that about 20-40% of the nematode species commonly recorded in wild ruminants are also found in domestic animals (Sachs *et al.,* 1973; Prestwood *et al.,* 1976; Woodford, 1976).

In general, ruminants are susceptible to infection by most of the nematodes found in domestic livestock, especially those that invade the respiratory system and alimentary canal. Stomach worms such as species of *Haemonchus*, *Ostertagia*, and *Trichostrongylus* have been reported in variety of species of wild ruminants (Prestwood *et al.,* 1976). *Haemonchus* is a voracious bloodsucker, which pose a serious threat to the health and productivity of domestic ruminants (Allonby and Urquhart, 1975; Allonby, 1976; Soulsby, 1982). *Trichostrongylus* can also cause clinical disease, which may result in death and loses due to reduced productivity. Nematode infections in gazelles, as established by the study may therefore potentially be a major constraint to gazelle production in the study area, requiring the establishment of cost-efficient and sustainable control programs.

Results obtained from this study show that *Gazellostongylus* was a common nematode in the abomasum of gazelles found on Marula Ranch in Nakuru County. This observation is in contrast with that of Urquhart, *et al*., (1960) and that of Kibichori (1990), who indicated that the worm appeared to have a specific geographical distribution. They indicated that the worm was found in Athi-River since all the gazelles examined in their studies were from Athi-River and had *Gazellostrongylus*. These studies however did not

examine gastrointestinal tracts of gazelles from other areas and their conclusions therefore appear to have been based on assumptions and restricted to populations in the study area

Despite the apparent heavy infection with *Gazellostongylus* in some gazelles in the present study, the seemed to be healthy. This is in agreement with observations made by Kibichori (1990) in Athi-River, where *Gazellostrongylus* was recovered in high proportions, but the health of the gazelles did not seem affected. However, heavy infestation of the abomasum would definitely interfere with normal physiological functions of this organ probably in the same way *Ostertagia* spp are known to do (Bwangamoi, 1970). This indeed is a problem in game ranching where there is restricted grazing which would promote a hyper-endemic situation where infection could be quite high. The aesthetic effects of the nodules could also be of concern during the sale of meat for human consumption. Control of these parasites is therefore necessary.

Urquhart *et al*., (1960) indicated that *Gazellostrongylus* worms were whitish in color. Observations made during this study showed that the worms were dark red in color and when broken, a red blood-like fluid gushed out of their guts. However, when the worms were fixed in formalin they acquired a whitish color. This observation is in agreement with that of Kibichori, (1990). It is therefore possible that Urquhart *et al*., (1960) did not observe fresh specimens or obtained fresh worms prior to sucking blood.

The observations made in this study indicated presence of lesions in the abomasum of gazelles slaughtered in both June and September that had *Gazellostrongylus*. The lesions consisted of nodules that measure between 3 and 4cm in diameter. Majority of the animals had four nodules but there were up to five nodules in a few cases. These observations are in agreement with those of Khalil and Ingram (1981) in a study in Kajiado District, Kenya. Results from the current study are however in contrast with those of Kibichori (1990) who found up to 30 nodules in the abomasum. It is not easy to explain why there is such a significant variation. However, one of the possible explanations may be related to the age of the animal. It is possible that the parasites are acquired over a long period of time accumulating in the abomasum. The acquisition may also be higher during certain periods of the year and may be related to weather factors that would influence larval development and survival on pastures.

In the present study, the mean worm counts for *Haemonchus* and *Gazellostrongylus* in the abomasum and *Trichostrongylus* in the small intestine showed a significant difference between the months the animals were slaughtered. The mean worm burden for *Haemonchus* and *Trichostrongylus* were higher in September, which was a dry month, compared to June, while the mean worm burden for *Gazellostrongylus* was higher in June, which was a wet month. Relatively high numbers of adult *Trichostrongylus* were recovered and this was higher than any other species. Similar observations were made in Northern Nigeria where high proportions of adult *Trichostrongylus* species were recovered in sheep during the long dry season (Ogunsusi, 1979b). The results obtained

here therefore confirm that *Trichostrongylus* species are capable of surviving unfavorable environmental conditions as an adult population in the hosts.

The results of the study on the relationship between the worm burdens and the weights of the gazelles slaughtered in Marula Ranch indicated that the heavier the gazelle was, the more *Haemonchus* species it had, and the lesser the *Gazellostrongylus* species. One of the factors that may have contributed to the current observation would be that *Haemonchus* is the resident parasite in the abomasum, and its occurrence causes displacement of *Gazellostrongylus*.

Data on the Strongyle egg counts and the prevalence of gastrointestinal parasites, clearly shows that the Strongyles, especially *Haemonchus*, *Gazellostrongylus* and *Trichostrongylus* are the most common parasites in Thomson gazelles within the study area. The egg counts for the animals examined were quite high with most of the animals having eggs per gram (e.p.g) higher than 2000. These observations are in agreement with those of Waruiru *et al*., (1995) who recorded fecal egg counts (e.p.g) higher than 2000 in Thompson gazelles in a game ranching farm in Athi-River, Kenya. In small domestic stock, Strongyle e.p.g of 600-2000 counts indicate a severe infection with intestinal parasites, depending on the species of worms present, and treatment of lambs and kids is advisable when Strongyle e.p.g of 1000 or more are found (Soulsby, 1982). In cattle, an output of Strongyle e.p.g of 300-600 count is considered severe and de-worming measures should be instituted to reduce the worm burdens when levels are above Strongyle epg of 300 (Soulsby, 1982). Despite the high egg counts recorded in both the

captured and slaughtered gazelles all the animals examined were apparently healthy. This evidence should, however not be accepted as an indication of the non-pathogenicity of parasites in wild animals. When the number of parasites greatly increases, or when the animal is stressed, the growing parasitic burden will reduce the resistance of the infested host and the parasite may become pathogenic (Sachs and Debbie, 1969). Differences in the susceptibility of breeds of sheep to gastrointestinal nematodes infections have been demonstrated in different parts of the world (Abbott *et al*., 1985; Courtney *et al*., 1985; Baker, 1995; Amarante *et al*., 1999). In Kenya, the Red Maasai sheep has been observed to be more tolerant to infection with *Haemonchus* i.e. have less worm burdens than the exotic breeds (Preston and Allonby, 1979b; Bain *et al*., 1993; Baker, 1995). This observation may apply to the gazelles because despite the high egg counts, all the gazelles examined were apparently healthy. However the worm burdens were low, the gazelles may have acquired few worms but they could not regulate their egg production. Results of this study indicate low worm burdens compared to what would be observed in sheep and gastrointestinal tracts that have never received anthelmintic treatment. This observation may be due to the way the gazelles feed. They are grazers as well as browsers and if feeding on scrub high enough, they could avoid most of the infective larvae. The plants the gazelles eat may also have medicinal effect to the gazelles. The grazing land is also vast, which leads to dilution of infective larvae on the herbage and therefore less levels of infection. The environment is harsh, killing most of the larvae on the pastures.

The prevalence and intensity of infection with gastrointestinal nematodes in grazing livestock is greatly influenced by the weather pattern. In most of the tropic and the subtropics, variation in rainfall is the major factor that influences the development and survival of the pre-parasitic stages on pastures and therefore the infection rates (Altaif and Yakoob, 1987; Banks *et al*., 1990; Waruiru, 1998). In Kenya, reports on the prevalence and intensity of infection with Strongyles in small ruminants indicate that higher counts were recorded during the wet than the dry seasons in Naivasha (Gatongi, 1995), Nyandarua (Maingi, 1996), Makuyu (Githigia, 2000) and in Kajiado (Chege, 2002). Higher counts were recorded during the dry than the wet seasons in Embu (Ulvund *et al*., 1984) and in Muguga (Wamae and Ihiga, 1990). In the present study, the egg counts were significantly higher ($p<0.05$) during the dry months (September to October) than the wet month (June). Similar observations were made by Omara-Opyene (1985) in Marsabit and Gatongi *et al*., (1998) in Naivasha. Several factors may have contributed to the current observations. The gazelles were grazing in a vast area of land, which does not allow for very heavy contamination of pastures by the animals. There was also less competition for food from other animals therefore there was availability of enough pastures for the gazelles and the level of nutrition might have been high. These results may however be biased because only 6 gazelles were examined in June compared to 19 gazelles examined in September.

In the semi-arid region of Naivasha, Gatongi (1995) reported that fecal egg counts was a good measure of worm burdens during the wet but not the dry season. Maingi (1996) and Chege (2002) working in the high rainfall area of Nyandarua District, and the semi arid

area of Kajiado District respectively, reported positive correlation between worm burdens and fecal egg counts in small ruminants during both the dry and the wet seasons. In the present study results on the relationship between worm burdens and fecal egg counts in gazelles revealed a positive correlation in September with a correlation coefficient of 0.46, which was a dry month, and a negative correlation in June with a correlation coefficient of -0.2, which was a wet month. However, due to the small number of gazelles examined in June the observations made during the present study should not be considered conclusive. A more detailed study on the relationship between worm burdens and fecal egg counts in gazelles is required before any definite conclusions can be made.

In domestic ruminants, age influences the susceptibility of animals to helminth infections (Berger, 1993). Lambs are more susceptible to infections due to immunological hypo-responsiveness (Watson and Gill, 1991; Colditz *et al*., 1996). As the animals grow older, immunity develops which results in a decline in levels of infection in adults (Dobson, *et al* 1990). It is also well recognized that previously acquired immunity to nematode infection tends to be lost in late pregnancy and in lactation in domestic ruminants (Berger, 1993). The present study showed that gastrointestinal nematodes are prevalent in all age groups and sexes of Thomson gazelles on Marula ranch and there was no significant difference in the mean Strongyle-type nematode E.P.G between the captured adult and young gazelles. This could be explained by the failure of gazelles of all ages to regulate egg production in the parasites. The immune response to parasites is demonstrated in many ways, by egg production, by establishment of worms in gastrointestinal tract and by the size of the worms. It is possible that although gazelles

acquire few worms they cannot regulate egg production and they do not acquire immunity to helminth infections with age as in domestic animals.

Data on the occurrence of coccidia oocysts clearly shows presence of coccidia oocysts in fecal samples of gazelles examined in September and October 2003. However all the gazelles examined in June were not infected with coccidia. Although attempts to sporulate oocysts from the gazelles to facilitate identification failed, the obviously different sizes and structures of the oocysts indicated that various species of coccidia were present. The clinical signs of infections are the same as those seen with domestic cattle: diarrhea that may be bloody, anorexia, depression, anemia and death. No significant seasonal fluctuations in prevalence or intensity of infection were observed, which is in accord with observations in sheep in Kenya (Maingi and Munyua, 1994), in Senegal (Vercruysse, 1982) and Australia (O'Callaghan *et al*., 1987) and in goats in a semi-arid region of Kenya (Waruiru *et al*., 1991). Poult (1969) reported that high percentage of oocysts are destroyed by complete dryness, exposure to direct sunlight or high temperatures. Omara-Opyne (1985) also observed that the highest frequency of coccidiosis and oocysts counts in calves in the arid Marsabit District of Kenya occurs during the wet season. Changes in the weather conditions in the study area may not have been severe enough to cause a significant difference in oocysts counts. The above results may be biased because only 6 gazelles were examined in June, which was a wet month.

5.2 Conclusions and Recommendations

GIT nematodes are prevalent in all age groups, of Thomson gazelles on Marula Ranch during the dry and wet seasons. *Haemonchus*, *Trichostrongylus* and *Gazellostrongylus* occurred in most of the gazelles, while *Nematodirus*, *Cooperia* and *Trichuris* occurred in a few of the gazelles examined at the ranch. Some of the predominant genera such as *Haemonchus* and *Gazellostrongylus* are voracious bloodsuckers, which poses a serious threat to the health and productivity of the gazelles especially where game ranching is an enterprise. *Haemonchus* and other nematodes found in the gazelles are probably also transmissible to domestic ruminants on the ranch.

Control programs for these parasites in wild animals are necessary e.g. by use of mineral blocks or by incorporating anthelmintics into the feed, monitoring the potential for pasture contamination and determining the efficacy of control drugs. There is also need to determine the cross-infection of various nematodes between the gazelles and domestic livestock.

Further research to establish the epidemiology of *Gazellostrongylus* and development of the nodules in the gazelles should be carried out since a number of facts about *Gazellostrongylus* are unknown; for example, it's life cycle and epidemiology and its relationship with other abomasal parasites. Further a more detailed study on the relationship between worm burdens and fecal egg counts in gazelles is required before any definite conclusions can be made.

6.0 REFERENCES

Abbott, E.M., Parkins, J.J. and Holmes, P.H., (1985). Influence of dietary protein on the es tablishment and pathogenesis in Finn Dorset and Scottish Blackface lambs given a single moderate infection of *Haemonchus contortus*. Research in Veterinary Science. **38**: 6-13

Allonby, E.W. and Urquhart, G.M., (1975). The epidimiology and pathogenic significance of *Haemonchus* in a Merino flock in East Africa. Veterinary Parasitology. **1**:129-143

Allonby, E.W. (1976). Annual report of sheep development project, East African Veterinary Research Organization (EAVRO), Kenya. Pp. 50

Allonby, E.C. (1981). The role of wild ruminants in the epidemiology of nematodiasis in Kenya. In: Wildlife Disease Research for Economic Development. Eds. L Karstad, B. Nestel, M Graham, Published by IDRC, Ottawa, Canada, 46-47

Altaif, K.I. and Yakoob, A.Y., (1987). Development and survival of *Haemonchus contortus* larvae on pastures in Iraq. Tropical Animal Health and Production. **19**:88-92

Amarante, A.F.T., Graig, T.M., Ramsey, W.S., El-Sayed, N.M., Desouuki, A.Y. and Bazar, F.W., (1999). Comparison of naturally acquired parasite burdens among Florida Natives, Rambouillet and crossbreed ewes. Veterinary Parasitology. **85**: 61-69

Anderson, R.C., (1962). The parasites (helminthes and arthropods) of white-tailed deer. White-tailed Deer Disease Symposium. **1**:162-173

Andersen, F.L. and Levine, N.D., (1968). Effect of desiccation on survival of the free-living stages of *Trichostrongylus colubriformis*. Journal of Parasitology. **54**: 117-128

Armour, J., (1980). The epidemiology of helminth disease in farm animals. Veterinary Parasitology.**6**:7-46

Arthur L., Buikema. JR. and John Wiley. (1999). Bioinquiry: Thomson Gazelle. John Wiley and sons, inc. New York. Pp. 36-40

Bain, R.K., Wanyangu, S.W., mugambi, J.M., Ihiga, M.A., Duncan J.L. and Stear, M.J., (1993). Genetic resistance of Red Maasai to *Haemonchus contortus*. Proceeding of the 11th Scientific Workshop of Small Ruminant Collaborative Research Support Programme, 3-4 March 1993, Nairobi, Kenya.

Baker, R.L., (1995). Genetics of disease resistance in small ruminants in Africa. In: Breeding for resistance to Infectious Diseaes of Small Ruminants (Gray, G.D., Woolaston, R.R. Eaton, B.T. eds.). Australian Centre for International Agricultural Research (ACIAR). Monogragh No. **34,** Canberra, Australian, Pp. 120-138

Banks, D.J.D., Singh, R., Barger, I.A., Pratap, B. and Le Jambre, L.F., (1990). Development and survival of infective larvae of *Haemonchus contortus* and *Trichostrongylus colubriformis* on pastures in a tropical environment. International journal for Parasitology **20**:155-160.

Berger, I.A., (1993). Influence of sex and reproductive status on susceptibility of ruminants to nematode parasitism. International Journal for Parasitology.**23**: 463-469.

Barger, I.A., (1999). The role of epidemiological knowledge and grazing management for helminth control in small ruminants. International Journal for Parasitology. **29**: 41-47.

Boyce, W., Allen, J., Himmelwright, C., Elliott, L., Mikolon, A., Mazet, J. and Gardner, I., (1991). Implementation and evaluation of a strategic parasite control program from captive exotic ungulates. Journal of American Veterinary Medicine Association. **198**: 1972-1976.

Brunsdon, R.V., (1980). Principles of helminth control. Veterinary Parasitology. **6**:185-215.

Bwangamoi, O., (1970). *Gazellostrongylus* (*paracooperia*) *lerouxi*, the cause of large nodules in the abomasum of gazelles in Kenya. Bulletin of Epizootic and Diseases. Africa. **18**: 351-354.

Charles, T.P., (1989). Seasonal prevalence of gastrointestinal nematodes in goats in Peraruhuco State, Brazil. Veterinary Parasitology. **30**:335-343

Chege, J.N., (2002). Epidemiology and control of gastrointestinal helminth infections in sheep in semi-arid area of Kajiado District, Kenya. Ph.D. Thesis. University of Nairobi, Nairobi Kenya.

Chema, S. (1980). Wildlife Disease Research and Economic Development. Proceedings of a workshop held on 8 and 9 Sep. 1980 in Kabete. Pp. 12

Chiejina, S.N.; Fakae, B.B. and Eze, B.O., (1988). Arrested development of gastrointestinal trichostrongylids in goats in Nigeria. Veterinary Parasitology. **28**: 103-113.

Conti, J.A. and Howerth, E.W. (1987). Osteragiosis in a white-tailed deer due to *Ostertagia ostertagia*. Journal of Wildlife Disease. **23**: 159-162.

Colditz, I.G., Watson, D.L., Gray, G.D. and Eady, S.J., (1996). Some relationships between age, immune responsiveness and resistance to parasites in ruminants. International Journal for Parasitology. **26**: 869-877.

Cooper, J.E. (1985). Medico-Veterinary Collaboration. A review of its importance and relevance, especially in the tropics. Tropical Doctor **15**: 187-191.

Courtney, C.H., Parker, C.F., McClure, K.E. and Herd, R.P., (1985). Resistance of exotic and domestic lambs to experimental infections with *Haemonchus contortus*. International Journal of Parasitology. **15**: 101-109.

Davidson, W.R., McGhe, M.B., Nettles, V.F. and Chappell, L.C., (1980). Haemonchosis in white-tailed deer in the southeastern United States. Journal of Wildlife Disease. **16**: 499-508.

Dinnik, J.A., and Sachs, R., (1969). Cysticercosis, Echinoccosis and Sparganosis in wild herbivores in East Africa. Veterinary Medicine Review. **2**: 11-114.

Dobson, R.J., Waller, P.J. and Donald, A.D., (1990). Population dynamics of *Trichostrongylus colubriformis* in sheep: The effect of host age on the establishment of infective larvae. International Journal for Parasitology. **20**:353-357.

Dunn, A.M., (1968). The wild rumunant as reservoir host of helminth infection. Symposium of Zoo Society, London. **24:**221-248.

Ebedes, H. (1993). Game ranching in South Africa. In**:** Zoo and Wild Animal Medicine Current Therapy 3. (M.E. Fowler, ed.) Philadelphia:W.B. Saunders and C. Pp.163

Fraser, CM., Ed. (1986). The Merck Veterinary Manual, sixth edition. Merck and Co., Inc., Rahway, N.J.

Gatongi, P.M., (1995). The epidemiology and control of gastrointestinal nematodes of small ruminants in a semi-arid area of Kenya with emphasis on hypobiosis of *Haemonchus contortus*. Ph.D. Thesis, Mc Gill University, Montreal. Canada

Gatongi, P.M., Prichard, R.K., Ranjan, S., Gathuma, J.M., Munyua, W.K., Cheruiyot, H. and Scott, M.E., (1998). Hypobiosis of *Haemonchus contortus* in natural infections of sheep and goats in a semi-arid area of Kenya. **Veterinary Parasitology**. **77:** 49-61.

Gibson, T.E. and Everett, G., (1976). The biology of the free-living stages of *Haemonchus contortus*. British Veterinary Journal. **132**:50-59.

Githigia, S.M., (2000). The epidemiology and impact of gastrointestinal nematodes infections in goats in Kenya and biological control on gastrointestinal nematodes of sheep in Denmark. Ph.D. Thesis. University of Nairobi, Nairobi Kenya.

Grootenhuis, J.G. (1999). 25 years of wildlife disease research in Kenya. Published by the Kenya Agricultural Research Institute, Nairobi, Kenya. Pp. 80

Hansen, J., and Perry B., (1994). The Epidemiology, Diagnoses and Control of Helminth Parasites of Ruminants. ICLAD, Nairobi Kenya.pp.171

Hay, F.S., Niezen, J.H.; Miller, C.; Bateson, L. and Robertson, H., (1997). Infestation of sheep dung by nematophagous fungi and implications for control of free-living stages of gastro-intestinal nematodes. Veterinary Parasitology. **70**: 247-254.

Hein,W.R., Shoemarker C.B. and Heath, A.C.G., (2001). Future technologies for control in sheep. New Zealand Veterinary Journal. **49**: 247-251.

Ikeme, M.M., Iskander, F. and Chong, L.C., (1987). Seasonal changes in the prevalence of *Haemonchus* and *Trichostrongylus* hypobiotic larvae in tracer goats in Malaysia. Tropical Animal Health and Production. **19**:184-190.

International Union for the Conservation of Nature (IUCN). (1980). *World conservation Strategy*. Gland: IUCN: New York. Pp.104

International Union for the Conservation of Nature (IUCN) / United Nations Environment Program (UNEP)/ World Wide Fund for Nature (WWF) (1991). *Caring for the earth: a strategy for sustainable living*. Gland: IUCN, UNEP and WWF. Pp. 92-95

Jarrett, W.F.H., Jennings, F.W., McIntyre, W.I.M., and Sharp, N.C.C. 1960. Resistance to *Trichostrongylus colubriformis* produced by x-irradiated larvae. Veterinary Record. **72**:884

Kaliner G., Grootenhuis, J.G., Protz, D., (1974). A survey for sarcosporidial cysts in East African game animals. Journal of Wildlife Diseases. **10**: 237-238.

Kaliner, G., Sachs, R., Fay, L.D. and Schiemann, B., (1971). Presence of Sarcocystis in East African game animals. Tropenmed. Parasitology. **22**: 156-164.

Kenya Agricultural Research Institute (KARI) (1999) Technical Note No. 2 on Integrated Helminth Control. Pp. 55

Khalil, L.F. and Ingram, P.L., (1981). *Gazellostrongylus lerouxi* Yeh, 1956 from Thomson and Grant's gazelles in Kenya. In: Wildlife Diseases of the Pacific Basin and other countries. Proceedings of the 4th International Conference on the Wildlife Disease Association, Sydney, Australia. August 25-28, 1981. Eds. Murray, E.F. Pp.132-136.

Kibichori, L.W., (1990). The Pathology of *Gazellostrongylus lerouxi* in the abomasa of gazelles and its possible cross-infectivity to sheep. A dissertation. Kenya Polytechnic. Nairobi Kenya. Pp. 22-40.

Kinyua P.D., Van Kooten G.C, and Bulte E.H., 2000. African wildlife policy: protecting wildlife herbivores on private game ranches.

Kirkwood J.K., (1994) Veterinary education for wildlife conservation health and welfare. Veterinary Record. **135**: 148-151.

Kock, R.A. (1995). Wildlife Utilization: Use it or lose it- a Kenyan perspective. Biodiversity and conservation. **4**: 241-256.

Larsen, M., (2000). Prospects of controlling animal parasitic nematodes by predacious micro-fungi. Parasitology. **120**:S121-S131.

Ledger, H.P., Sachs, R. and Smith, N.S. (1967). Wildlife and food production (with special reference to the semi arid areas of tropics and sub tropics). World review of Animal Production.**3**: 13-37.

Macpherson, C.N.L., (1994). Epidemiology and control of parasites in nomadic situations. Veterinary Parasitology. **54**: 87-102.

Madzingira, O., Mukaratirwa, S., Pandey, V.S. and Dorny, P. (2002). A survey of the management and use of anthelmintics in cattle and game on mixed farming systems in Zimbabwe. Proceedings of the 10th International Conference of the Association of Institutions of Tropical Veterinary Medicine, Copenhagen 2002.

MAFF (1986). Ministry of Agriculture fisheries and food. Manual of Veterinary Parasitological Techniques. Technical Bulletin. No.**18**. HSMO, London. Pp. 131.

Maingi, N. and Munyua, W.K., (1994). The prevalence and intensity of infection with *Eimeria* species in sheep in Nyandarua district of Kenya. Veterinary Research Communications. **18** (1), 19-25

Maingi, N., (1996). Anthelmintic resistance, epidemiology and control of gastrointestinal nematodes in small ruminants in Nyandarua District, Kenya and in Denmark. Ph. D. Thesis. University of Nairobi, Nairobi Kenya.

Margolis, L., Esch, G.W., Holmes, J.C., Kuris, A.M., and Schald, G.A. (1982). The use of economic terms in parasitology (Report of an ad hoc committee of the American Society of Parasitologists). Journal of Parasitology. **68**: 131-133.

McGhee, M.B., Nettles, V.F., Rollor, E.A., Prestwood A.K. and Davidson, W.R., (1981). Studies in cross-infection and pathogenicity of *Haemonchus contortus* in white-tailed deer, domestic cattle and sheep. Journal of Wildlife Disease.**17**: 353-364

Michael, J.F., (1976). The epidemiology and control of some nematode infections of grazing animals. Advances in Parasitology. **14**: 355-397.

Ngatia, T. A., Mbuthia, P.G., Waruiru, R.M., Njiro, S.M., Kanyari, P.W., Munyua, W.K., Weda, E.H., and Ngotho, J.W. (1996). Gross lesions encountered in slaughtered wild and domestic ruminants in a game ranching farm in Kenya. Bulletin of Animal Health Production. Africa. **44**: 101-104.

Nginyi, J.M., Duncan, J.L., Mellor, D.J., Stear, M.J., Wanyangu, S.W., Bain, R.K. and Gatongi, P.M., (2001). Epidemiology of parasitic gastrointestinal nematode infections of ruminants on smallholder farms in Central Kenya. Research in Veterinary Science. **70**: 33-39.

O'Callaghan, M.G., O'Donoghue, P.J. and Moore, E., 1(987) Coccidia in sheep in South Australia. Veterinary Parasitology. **24**:175-183.

Ogara, W.O., (1991). The ecology and biology of Saiga (*Saiga Tatarrica Linneaus*) found in the Precaspian Steppe of Kalmyiky. The Kenya Veterinarian. Vol.**15**: 81-83.

Ogunsusi, R.A., (1979a). Pasture infectivity with trichostrongylid larvae in the Northern Guinea savanna of Nigeria. Research in Veterinary Science.**26**: 320-323.

Ogunsusi, R.A., (1979b). Termination of arrested development of trichostrongylids in Northern Nigeria. Research inVeterinary Science. **26**: 189-192.

Omara-Opyene, A.L. (1985). A survey of gastrointestinal parasitism in cattle under nomadic management in Marsabit, Northern Kenya. Bulletin of Animal Health and Production, Africa. **33**:107-112.

Onyali, I.O., Onwuliri, C.O.E. and Ajayi, J.A., (1990). Development and survival of *Haemonchus contortus* larvae on pasture at Vom, plateau state, Nigeria. Veterinary Research Communications. **14**: 211-216.

Poult, J.P. (1969). Coccidiosis of sheep. Veterinary bulletin. **39**: 609-618.

Preston, J.M., Karstad, L., Woodford, M.H. and Allonby, E.W., (1979). Experimental transmission of gastro-intestinal nematodes between sheep (*Ovis aries*) and Thompson's gazelle (*Gazella thomsonii*). Journal of Wildlife Diseases. **14**: 305-308.

Preston, J.M. and Allonby, E.W., (1979). The influence of hemoglobin phenotype on the susceptibility of sheep to *Haemonchus contortus* infection in Kenya. Research in Veterinary Science. **26**:140-144.

Prestwood, A.K., Hayes, F.A., Eve, L.H. and Smith, J.F., (1973). Abomasal helminthes of white-tailed deer in the Southeastern United States, Texas, and the Virgin Islands. Journal of American Veterinary Medicine Association. **163**: 556-561.

Prestwood, A.K., Kellogg, F.E., Pursglove, S.R. and Hayes, F.A., (1975). Helminth Parasitisms among intermingling insular populations of white-tailed deer, feral cattle and feral swine. Journal of American Veterinary Medicine Association. **166**: 787-789.

Prestwood, A. K., Purseglove, S. R. and Hayes, F. A. (1976). Parasitism among white-tailed deer and domestic sheep on common range. Journal of Wildlife Diseases.**12**: 380-385.

Prestwood, A.K. and Pursglove, S.R., (1981). Gastrointestinal nematodes. Pp. 318-350. In: Davidson, W.R., Hayes, F.A., Nettles, V.F. and Kellogg, F.E. (eds). Diseases and parasites of white-tailed deer. Tall Timbers Res. Sta. Misc. Pub.7, Tallahassee, Fla.

Reul, H.R. (1981). The potential of wild animals in the tropics. **The courier**. No. **65** Jan-Feb. 1981.

Romjali, E. Dorney, P. Batubara, A. Pandey, V.S. and Gatenby, R.M., (1997). Peri-parturient rise in fecal strongyle egg counts of different genotypes of sheep in North Sumatra, Indonesia. Veterinary Parasitology. **68**: 191-196.

Rose, J.H., (1963). Observations on the free-living stages of the stomach worm Haemonchus contortus. Parasitology. **53**: 469-481.

Sachs, R., and Debbie, J.G. (1969). A field guide to the recording of parasitic infestations of game animals. East African Wildlife Journal. **7**: 27-36

Sachs, R. (1970). Cysticercosis of East African game animals. Journal of South African Veterinary Medicine Association. **41**: 79-85

Sachs, R., Gibbons, L. M., and Lweno, M.F. (1973). Species of Haemonchus from domestic and wild ruminants in Tanzania, East Africa, including a description of H. dinniki (new species). Z., Tropenmed. Parasitology. **24**: 467-475.

Schillhorn van Veen, T.W. and Brinskman, T.W., (1975). An evaluation of anthelmintic drenching schemes for lambs on wet season grazing. Samaru Agricultural Newsletter. **17:** 151-156.

Schindler, R., Sachs R., Hilton, P.I., and Watson R.M., (1969). Some veterinary aspects of the utilization of African game animals. Bulletin of Epizootic and Diseases. Africa. **17**: 215-221.

Skinner, J .D., (1970). Game ranching in Africa as a source of meat for local consumption export. Tropical Animal Health and Production. **2**: 151-157.

Soulsby, E.J.L. (1965). Textbook of Veterinary Clinical Parasitology, Oxford, Blackwell Scientific Publication.

Soulsby, E.J.L., (1982). Helminths, Arthropods and Protozoa of Domestic Animals. 7th edition. Bailliere Tindall, London, Lea and Febiger, Philadelphia. Pp.212-258.

Tolbert, L.M. (1966). Comparison of the efficiency of wildlife animals and domestic livestock in utilization of East African Rangeland. I.U.C.N, New York, Sept. publication: Pp. 329-333.

Ulvund, M.J., Maina, E. and Mararo, J., (1984). Fecal egg counts in ewes and their lambs in Embu, Kenya during a one-year period. Kenya Veterinarian. **8**:9-13.

Urquhart, G.M., Hay, D., Zaphiro, D.R.P. and Spinage, C.A., (1960). Some internal parasites of game animals in Kenya. Journal of Wildlife Diseases.**26**: 11-20.

Vercruysse, J., (1982). The coccidia of sheep and goats in Senegal. Veterinary Parasitology. **10**: 297-306.

Vlassoff, A., Leathwick, D.M. and Heath, A.C.G., (2001). The epidemiology of nematode infections in sheep. New-Zealand Veterinary Journal. **49**:213-221.

Waller, P.J. and Donald, A.D., (1970). In. Altaif, K.I. and Yakoob, A.Y. (eds). Development and survival of *Haemonchus contortus* larvae on pastures in Iraq. Tropical Animal Health and Production. **19**:88-92.

Wamae, L.W. and Ihiga, M.A.K., (1990). Seasonal fecal egg counts changes in Kenyan goats through a one-year period. Bulletin of Animal Health Production in Africa. **38:**1-4.

Wambwa, E.N. and Ogara, W.O., (2002). A point prevalence study of gastrointestinal parasites in Burchell's Zebra at Lewa Downs Ranch, Isiolo District, Kenya. The Kenya Veterinarian. Vol. **25** (2002).

Waruiru, R.M., Githigia, A.M. and Nginyi, J.M., (1991). The prevalence of coccidia of goats in OL' Magogo farm in Kenya. Bulletin of Animal Health and Production in Africa. **39**: 247-249.

Waruiru R.M., Mbuthia P.G., Njiro S.M., Ngatia T A., Weda E.H., Ngotho. J.W., Kanyari P.W., and Munyua W.K. (1995). Prevalence of gastrointestinal

parasites and lungworms in wild and domestic ruminants in a game ranching farm in Kenya. Bulletin of Animal Health Production, Africa. **43**: 253

Watson, R.M. (1965). Game utilization in Serengeti: Preliminary investigations part 1. British Veterinary Journal **121:** 540-545.

Watson, D.L. and Gill, H.S., (1991). Post natal ontogeny of immunological responsiveness against in Merino sheep. Research in Veterinary Science. **51**: 88-93.

Western, D. (1989). Conservation without parks. In: Wildlife in the Rural Landscape. D. Western and M.C. Pearl (eds.). New York. Oxford University Press. Pp: 158-165

Whitlock, H.V. (1948). Some modifications of the McMaster helminth egg counting technique and apparatus. Journal of Council of Science and Industrial Research. **21:** 177-180

Woodford, M.H. (1976). A survey of parasitic infestation of wild herbivores and their predators in the Ruwenzori National Park, Uganda. Thesis: Pp. 81

7.0 APPENDICES

Appendix I: Reference numbers, sex, age group and weight of Thompson's gazelles slaughtered at Marula Ranch on two different days.

Date	Reference	Sex	Age Group	Carcass Weight (undressed)
19/06/03	Tg1	M	Adult	16kgs
	Tg2	M	Adult	23kgs
	Tg3	M	Adult	25kgs
	Tg4	M	Adult	21kgs
	Tg5	M	Adult	23kgs
	Tg6	M	Adult	21kgs
19/09/03	Tg8	M	Adult	24 kgs
	Tg9	M	Adult	23 kgs
	Tg10	M	Adult	24 kgs
	Tg11	M	Adult	21 kgs
	Tg12	M	Adult	24 kgs
	Tg13	M	Adult	24 kgs
	Tg14	M	Adult	27 kgs
	Tg15	M	Adult	25 kgs
	Tg16	M	Adult	21 kgs
	Tg17	M	Adult	27 kgs
	Tg18	M	Adult	23 kgs
	Tg19	M	Adult	23 kgs
	Tg20	M	Adult	22 kgs
	Tg21	M	Adult	23 kgs
	Tg22	M	Adult	24 kgs
	Tg23	M	Adult	25 kgs
	Tg24	M	Adult	24 kgs
	Tg25	M	Adult	22 kgs
	Tg26	M	Adult	24 kgs

Appendix II: Reference number, age group and sex, of Thompson's gazelles captured at Marula ranch on 9/10/03

Reference number	Age group	Sex
S1	Young	M
S2	Young	F
S3	Adult	F
S4	Young	F
S5	Adult	F
S6	Young	F
S8	Adult	M
S9	Adult	F
S10	Adult	M
S11	Adult	F
S12	Adult	F
S13	Adult	F
S14	Adult	F
S15	Young	M
S16	Young	F
S17	Adult	F
S18	Young	M
S19	Adult	F
S20	Adult	F
S21	Adult	F
S22	Young	F
S23	Adult	F
S24	Young	F
S25	Adult	F
S26	Adult	M
S27	Adult	F
S28	Adult	F
S29	Adult	F
S30	Adult	F
S31	Adult	F

Appendix III: Mature worm counts from the abomasas of Thompson's gazelles slaughtered at Marula Ranch in June and September 2003.

	Haemonchus			*Gazellostrongylus*			*Trichostrongylus*		
No	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**
Tg1	35	5	30	350	85	265	175	150	25
Tg2	25	15	10	45	5	40	-	-	-
Tg3	-	-	-	15	10	5	-	-	-
Tg4	-	-	-	115	80	35	-	-	-
Tg5	-	-	-	35	15	20	-	-	-
Tg6	-	-	-	40	10	30	-	-	-
Tg8	38	22	16	-	-	-	11	4	7
Tg9	7	6	1	19	7	12	4	1	3
Tg10	66	33	33	-	-	-	14	3	11
Tg11	24	13	11	-	-	-	24	6	18
Tg12	107	57	50	-	-	-	11	2	9
Tg13	128	70	58	-	-	-	8	2	6
Tg14	17	8	9	-	-	-	63	7	56
Tg15	55	4	51	17	2	15	19	2	17
Tg16	118	48	70	-	-	-	105	21	84
Tg17	61	14	47	-	-	-	9	2	7
Tg18	40	10	30	13	1	12	207	96	111
Tg19	14	2	12	249	96	153	-	-	-
Tg20	-	-	-	55	15	40	-	-	-
Tg21	203	94	109	-	-	-	-	-	-
Tg22	32	13	19	-	-	-	-	-	-
Tg23	12	1	11	127	76	51	-	-	-
Tg24	6	5	1	-	-	-	-	-	-
Tg25	7	2	5	3	1	2	-	-	-
Tg26	4	3	1	-	-	-	-	-	-

Appendix IV: Mature worm counts from the small intestines of Thompson's gazelles slaughtered at Marula Ranch in June and September 2003.

No	*Trichostrongylus*			*Nematodirus*			*Cooperia*		
	Total	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**
Tg1	70	10	60	-	-	-	-	-	-
Tg2	65	25	40	-	-	-	-	-	-
Tg3	125	10	115	30	10	20	325	180	145
Tg4	475	130	345	65	15	50	120	70	50
Tg5	135	50	85	-	-	-	70	50	20
Tg6	300	15	285	-	-	-	-	-	-
Tg8	210	60	150	-	-	-	-	-	-
Tg9	120	10	110	-	-	-	-	-	-
Tg10	765	15	750	-	-	-	200	150	50
Tg11	-	-	-	-	-	-	-	-	-
Tg12	90	20	70	-	-	-	20	10	10
Tg13	120	30	90	-	-	-	-	-	-
Tg14	1150	150	1000	-	-	-	350	100	250
Tg15	1940	40	1900	-	-	-	400	150	250
Tg16	1600	250	1350	-	-	-	450	250	200
Tg17	1450	450	1000	-	-	-	150	50	100
Tg18	1350	250	1100	-	-	-	100	50	50
Tg19	450	50	400	-	-	-	-	-	-
Tg20	250	50	200	-	-	-	100	50	50
Tg21	900	50	850	-	-	-	750	250	500
Tg22	950	150	800	-	-	-	600	450	150
Tg23	2150	100	2050	-	-	-	150	50	100
Tg24	550	50	500	-	-	-	300	250	50
Tg25	1750	100	1650	-	-	-	150	50	100
Tg26	400	100	300	525	375	150	75	25	50

Appendix V: Mature worm counts from the large intestines of Thompson's gazelles slaughtered at Marula Ranch in June and September 2003.

No	*Trichuris*		
	Total	**Male**	**Female**
Tg1	80	40	40
Tg2	55	25	30
Tg3	70	5	65
Tg4	35	10	25
Tg5	15	5	10
Tg6	35	5	30
Tg8	26	6	20
Tg9	52	13	39
Tg10	96	24	72
Tg11	16	4	12
Tg12	48	12	36
Tg13	56	14	42
Tg14	29	7	22
Tg15	42	10	32
Tg16	41	11	30
Tg17	122	31	91
Tg18	152	38	114
Tg19	12	3	9
Tg20	26	4	12
Tg21	19	5	14
Tg22	18	5	13
Tg23	36	9	27
Tg24	6	1	5
Tg25	32	8	24
Tg26	3	1	2