THE PREVALENCE, DISTRIBUTION AND ECONOMIC IMPORTANCE OF FASCIOLOSIS IN CATTLE, SHEEP AND GOATS IN KENYA

BY

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

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DEDICATION

This project report is dedicated to my loving parents:

Mr. Peter Kithuka and Mrs. Zipporah Kathome.

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ABSTRACT

Fasciolosis is a trematode zoonotic disease of public health and economic importance. The disease in humans is hardly recognized by medical doctors and is rarely considered as a differential diagnosis among other parasitic infections. In humans it leads to hepatic damage hence occasioning the cost of hospitalisation and loss of human working hours. In animals it leads to mortalities, growth retardation, drop in production in livestock and condemnation of the infected livers at post mortem meat inspection (Meat control act, 1972).

There has been a systematic and well co-ordinated effort in documenting the prevalence of fasciolosis in livestock in several countries of the world. However not much has been done in recent years in Kenya. No recent studies on the prevalence of fasciolosis in various species of domestic animals in the various provinces and districts of the country have been carried out, yet information from such studies is important in the planning and implementation of fasciolosis control programmes. It is particularly important in identifying the regions of the country to be given priority and species of animals to be targeted.

Little effort has been put into determining the economic losses occasioned by fasciolosis in livestock in most countries of the world, Kenya included. The economic losses may be due to various factors, particularly important is the economic losses occasioned by the condemnation of liver fluke infected livers at slaughter. Lack of recent information on the prevalence and economic importance of fasciolosis in cattle, sheep and goats in Kenya necessitated the studies reported in this report.

Using the post-mortem meat inspection records available in the Department of Veterinary Services, Kabete, a retrospective abattoir survey was carried out to determine the prevalence of fasciolosis in cattle, sheep and goats in Kenya, covering a period of ten years (1990-1999). The prevalence was calculated for all districts and then for each of the seven provinces of Kenya. The national prevalence was calculated from the pooled provincial data.

A total of 5,421,188 cattle were slaughtered in Kenya during the 1990-1999 period. Out of these 427,931 had fasciolosis giving a national fasciolosis prevalence of 7.9%. Western province recorded the highest (16.1%) prevalence with 126,660 cattle found to be infected out of the 785,873 slaughtered. This was followed in a descending order by Eastern province (11.3%) with 599,900 cattle slaughtered and 67,881 infected, Nyanza province (8.9%) with 159,814 cattle slaughtered and 14,237 infected, Rift Valley province (8.3%) with 731,438 cattle slaughtered and 60,634 infected, Central province (6.1%) with 1,834,301 cattle slaughtered and 111,576 infected, Nairobi province (3.9%) with 314,758 cattle slaughtered and 12,248 infected and Coast province (3.5%), where 995,104 cattle were slaughtered and 34,695 infected.

A total of 1,700,281 sheep were slaughtered in Kenya over the ten-years' period, out of which, 61,955 were infected giving a national prevalence of 3.6%. Western province recorded the highest (10.1%) prevalence with 19,554 sheep found to be infected out of the 194,251 slaughtered. This prevalence was followed, in a descending order, by Nyanza province (8.7%) where 40,735 sheep were slaughtered and 3,560 had *Fasciola* infection, Eastern province (4.8%) where 168,207 sheep were slaughtered and 8,150 had *Fasciola* infection, Central province (3.5%) where 483,481 sheep were slaughtered and

16,852 had *Fasciola* infection, Rift valley province (2.6%) where 407,319 sheep were slaughtered and 10,704 had *Fasciola* infection, Nairobi province (0.9%) where 57,960 were slaughtered and 532 had *Fasciola* infection and Coast province (0.7%) where 348,328 were slaughtered and 2,603 had *Fasciola* infection.

A total of 2,062,828 goats were slaughtered in Kenya from 1990-1999. Out of these, 48,889 were infected with *Fasciola* giving a national prevalence of 2.4%. The highest prevalence of 9.1% was recorded in Western province where 125,621 goats were slaughtered and 11,383 were infected. This was followed by Nyanza province (4.7%) where 72,686 goats were slaughtered and 3,428 had *Fasciola* infection, Central province (4.4%) where 211,325 goats were slaughtered and 9,351 had *Fasciola* infection, Eastern province (2.7%) where 499,266 goats were slaughtered and 13,475 had *Fasciola* infection. In the Rift Valley province, a total of 283,635 goats were slaughtered and 6,755 (2.4%) were infected, in Coast province 764,627 goats were slaughtered and 3,929 (0.5%) were infected and lastly in Nairobi province 105,668 goats were slaughtered and 568 (0.5%) were found to be infected.

A cross-sectional survey was carried out in the outskirts of Nairobi's Dagoretti slaughterhouses where routine post-mortem meat inspection was done. All the liver flukes detected in cattle, sheep and goats were collected and transported to the laboratory for analysis to determine their species by observing their size and morphology. Out of the 1,584 cattle inspected, 147 (9.3%) had liver flukes. All the liver flukes collected from the 147 livers were identified as *F. gigantica*. Livers from a total of 989 sheep were inspected, out of which 8 (0.8%) had liver flukes. Livers from a total of 954 goats were inspected, out of which 4 (0.4%) had liver flukes. All the liver flukes collected in Dagoretti from the three livestock species were identified as *F. gigantica.*

The economic importance of fasciolosis in livestock was determined by calculating the loss, in monetary terms, occasioned by condemnation of infected livers. The data collected from the meat inspection records provided the number of livers condemned due to fasciolosis in cattle, sheep and goats slaughtered from 1990-1999. A monetary value was calculated for the livers condemned by multiplying the quantity (Kg) with the average market prices for the livers of the three livestock species. This revealed that, a total of Kshs. 201,436,470 was lost nationally due to condemnation of *Fasciola* infected livers. This represented a loss of Kshs. 192,568,950, Kshs. 4,956,400 and Kshs. 3,911,120 due to condemnation of cattle, sheep and goat livers respectively. The study observed a general down ward trend of the economic loss over the period 1990-1999, from Kshs. 21,557,520 in 1990 to Kshs. 16,221,530 in 1999.

These results indicated that cattle had the highest prevalence of fasciolosis, followed by sheep and goats in a descending order. Western province had the highest prevalence of fasciolosis for cattle, sheep and goats, while Coast province had the lowest prevalence for all the species.

The high prevalence of fasciolosis in livestock in Kenya, coupled with its economic and public health importance, calls for concerted control measures to be implemented in this country. The regions of the country showing the highest fasciolosis prevalence such as Western, Nyanza, Central and Eastern Provinces, should be given more attention when implementing the fasciolosis control programmes.

Salvaging the residue value of condemned livers by using them to process pet foods after sterilisation can also reduce the heavy economic loss, revealed in this study. In addition, control of fasciolosis in livestock will lower the prevalence of the disease in slaughtered animals and therefore reduce the number of livers condemned at slaughter due to presence of *Fasciola spp.*

CHAPTER 1. INTRODUCTION.

Fasciolosis is a worldwide parasitic liver infection of wild and domestic ruminants, caused by trematodes of the genus *Fasciola*. The disease is caused by two species of *Fasciola*, namely *Fasciola gigantica* and *Fasciola hepatica* (Mitchell, 1968, Bitakaramire, 1969, Preston and Castelino, 1977, Gracey and Collins, 1992). These two species are known to cause the disease in domestic ruminants in Kenya, with *F. gigantica* being the most important species (Froyd, 1959, Bitakaramire, 1969, Ogambo-Ongoma, 1969).

Adult worms of this genus parasitize the liver bile ducts of various definitive hosts, mainly ruminants of both domestic and wild animals (Soulsby, 1986, Blood *et al.*, 1994). *F. gigantica* has been found in either the bile duct or gall bladder of approximately 50% of the African buffalo (Birdernagel, 1972) and livers of the Indian rhinoceros (Bhattacherjee and Halder, 1971).

The intermediate hosts for *Fasciola spp* are various species of snails. The most important snail intermediate host for *F. hepatica* is *Lymnaea truncatula in* Europe and *Galba bulimoides* and *G. techella* in the United States of America. In New Zealand, *L. tormentosa* and *L. truncatula* have occurred without fasciolosis becoming a major disease. But with the introduction of *L. columella* the prevalence of this disease markedly increased (Harriss and Charleston, 1980). In Kenya the intermediate hosts for *F. gigantica* and *F. hepatica* are *L. natalensis* and *L. truncatula* respectively, *F. gigantica* is thought to be the most important species in ruminants in Kenya (Bitakaramire, 1969), but *F. hepatica* is also known to occur. The relative occurrence of the two species has however, not previously been determined.

The snails that act as intermediate hosts of *Fasciola spp* are infected by miracidia, which are ciliated larvae that hatch from the flukes' eggs, shed in the faeces of definitive host feaces. The miracidia develop into cercariae in the snails, which are later shed and encyst as metacercariae on vegetation. These metacercariae are relatively resistant to environmental extremes (Ogambo-Ongoma, 1970), which enables them to survive for several months on pastures. When grazing, definitive hosts ingest the metacercariae, which migrate to the liver, mature into adult flukes and begin to release eggs (Simpson and Kunkle, 1985).

Climatic factors play an essential role in the occurrence and distribution of fasciolosis, but the relationship is not absolute. The important environmental factors influencing the life cycle of the free-living stages are temperature and soil moisture (Meek and Morris, 1979, Brumpy and Gryseel, 1985). Temperature affects the rate of advancement throughout the life cycle and hence the infection rate (Ollerenshaw, 1974). Soil moisture acts as the limiting factor on the life cycle and hence influences both the seasonality of the infection and its intensity (Meek and Morris, 1979).

Fasciolosis is a biologically complex disease with varying prevalence and distribution from country to country as well as within countries (Blood *et al.*, 1994). Previous surveys carried out in Kenya by Cheruiyot (1983) and Anon (1986) indicated a decrease in prevalence of fasciolosis when compared to Bitakaramire (1969). The investigators attributed this decrease to possible increase in the use of antihelmintics against *Fasciola* in the country. The report by Anon (1986) indicated a slight change in distribution and an increase in the liver fluke associated liver condemnations, compared to those reported by Bitakaramire in 1969. Since 1986, no surveys have been carried out to determine the prevalence of fasciolosis in Kenya. With climatic changes that have occurred in the country in the recent past such as the prolonged drought, flooding and the *El Nino* rains, the prevalence of the disease may have changed. In addition to the above changes, livestock farmers are more enlightened and better management and diseases control measures are in place than they were when the last studies were carried out. These changes are likely to have an impact on the prevalence of the disease, and there was therefore need to re-assess the situation with regard to fasciolosis in cattle, sheep and goats in Kenya.

Fasciolosis causes economic losses in livestock through mortalities, abortions, growth retardation, drop in meat production, drop in milk yield, condemnation of infected livers and sometimes condemnation of emaciated carcasses due to liver fluke infections and cost of animal treatment (Gracey and Collins, 1992). Infections with *Fasciola spp* also predispose animals to other infections (Huges, 1978, Ogunrinade and Ogunrinade, 1980). In Kenya, Anon (1986) reported an annual economic loss of Kshs. 320 million in the livestock industry due to fasciolosis, while Cheruiyot, (1983) reported a loss of Kshs. 800, 000 per year at the Kenya Meat Commission (K.M.C.) and Bitakaramire, (1969) reported a loss of Kshs. 567,000 annually at the K.M.C.

The importance of carrying out estimates on economic losses due to fasciolosis, over a period of time, is to assess whether any change in weather conditions, management practices or disease control measures have had an impact on the importance of the disease in the livestock industry. The estimates also help to point out the importance of the disease in the livestock sector, so that it can be given the attention it deserves when instituting control measures. It is important to assess the economic impact of a disease before a decision on the institution of control measures can be made. No recent studies on the economic losses due to fasciolosis have been undertaken in Kenya and there was need to make new estimates so as to establish the current situation of the disease in the country.

The objectives of this study were:

(1) To determine the trends in the prevalence of fasciolosis in cattle, sheep and goats over a ten year period (1990-1999) and to assess the distribution of fasciolosis in Kenya.

(2) To estimate the economic losses resulting from condemnation of organs infected by *Fasciola* trematodes at post–mortem meat inspection for the period 1990-1999.

(3) To determine the relative occurrence of the two species of *Fasciola* (*F. gigantica* and *F. hepatica*) at post mortem meat inspection, through an examination of the morphology of the parasites collected at Dagoretti slaughterhouses, Nairobi.

CHAPTER 2. REVIEW OF LITERATURE.

2.1. Aetiology of fasciolosis

Fasciolosis is a parasitic disease caused by digenic trematodes of the genus *Fasciola* namely *Fasciola gigantica* and *Fasciola hepatica* (Preston and Castelino, 1977). *F. hepatica* has been shown to be of economic importance only in sheep and cattle, while *F. gigantica* is more common in Africa and India where it occurs commonly in cattle, sheep, goats and buffaloes. In Kenya *F. gigantica* is the most important species, although both species occur (Froyd, 1959, Bitakaramire, 1968, Ogambo-Ongoma, 1969, Preston and Castelino, 1977, Ogeto, 1993).

F. hepatica is leaf shaped, broader anteriorly than posteriorly with an anterior cone shaped, projection that is followed by a pair of broad- shaped shoulders. It is greyish brown in colour, changing to grey when preserved in 75% alcohol (Soulsby, 1986). *F. gigantica* resembles *F. hepatica* but is readily recognised by its large size being 25-75 mm in length and up to 12 mm in breadth. The anterior cone is smaller than that of *F. hepatica*, the shoulders are not as prominent and the body is more transparent (Soulsby, 1986).

2.2. Intermediate hosts for *F. gigantica* and *F. hepatica*.

Snail vectors of *Fasciola* parasites are limited to the species of *Lymnaea* and *Galba*. The important snail intermediate host for *F. hepatica* is mud snail, *L. truncatula* in Europe and *G. bulimoides* and *G. techella* in USA (Kendall, 1965, Gracey and Collins, 1992). In New Zealand *L. tormentosa*, *L. columella* and *L. truncatula* have been reported as possible intermediate hosts. The two snail species have led to an increase in prevalence of fasciolosis in New Zealand (Harris and Charleston, 1980).

In Kenya the important snail intermediate host for *F. gigantica* is *L. natalensis*. The occurrence of this snail was reported in Ghana by McCullough (1965). In Kenya the occurrence of fasciolosis depends on the prevalence of the infected snails and the seasonal rainfall and temperature. In Malawi, snail infections are high in April and May, with the release of most cercariae occurring in August and October (Mzembe and Chaudhry, 1981). Outside Africa, other species of *lymneid* snails have been identified as intermediate host for *F. gigantica* and their geographical distribution was reviewed by Over (1982). Kendall, (1965) presented a comprehensive review of the relationship between various species of *Fasciola* and their snail intermediate hosts. Cross infections by *F. gigantica* and *F. hepatica* in some species of *Lymnaea* have been reported (El Harith, 1980). *L. truncatula* and *L. natalensis* prefer low-lying swampy areas with slow moving water. Land with small streams should also be considered as a favourable habitat for the snails (Blood *et al.*, 1994). Land that is frequently irrigated is also suitable for the snails, since they burrow into the soil in between irrigation and release a large number of cercariae when free water is available (Blood *et al.*, 1994). The two snails are aquatic and live in large permanent water bodies that contain abundant vegetation, although slow moving or still and clear waters provide the most satisfactory habitat (Soulsby, 1986).

2.3. Life cycle of *F. gigantica* and *F. hepatica*

The eggs of *F. hepatica* and *F. gigantica* enter the duodenum from the liver with the bile and leave the vertebrate host in faeces. The rate of development of the eggs depends on the ambient temperature with optimum temperature for development being 15-24°C (Christiansen and Nansen, 1976). Eggs hatch in about 10-12 days, producing the first larval stage, the miracidia. The miracidia are broad anteriorly with small, ciliated, papiliform protrusions for their survival. The miracidia must find a suitable snail host within 24-30 hours after hatching. The miracidia actively penetrate available snails, cast off their ciliated ectoderm and are transformed into an oblong sac known as sporocyst (Dawes, 1960, Gracey and Collins, 1992). Dawes (1960) studied the penetration of *F. hepatica* into *L. truncatula* and *F. gigantica* into *L. natalensis* and demonstrated that the final stage of penetration into snails was not performed by the miracidia but by the young sporocyst. In addition, the study revealed that the miracidia adhered to the epithelial cells of the snail by suction. The sporocysts then penetrate into the apical organ of the gut of the snail and cast off their ciliated epithelia so that the final penetration into the snail is effected by the unciliated young sporocysts. Temperatures above 10°C are necessary before the snails breed or before the sporocysts develop within the snail (Dinnik and Dinnik, 1959, Sewell, 1966). According to these workers, the miracidia infect the snails and develop into cercariae within 5-8 weeks. The snails release cercariae, which encyst on vegetation and become metacercariae. These are ingested by the definitive hosts when grazing or drinking infected water. The survival of metacercariae depends on the climate of the area. In Kenya, seasonal low temperatures delay larval development (Dinnik and Dinnik, 1959). In general infection with metacercariae is greatest when animals are forced to feed in swampy areas particularly during the dry season (Blood *et al.*, 1994). Development of miracidia within the snails ceases in winter but resumes as the environmental temperatures rise in the spring and summer. Winter infection is less important than the spring infection, possibly due to the mass mortality of the infected snails in winter (Reid, 1973).

Huges (1978), studied metacercariae excystation and reported that excystation could be induced by treating metacercarial cysts with acid and pepsin, followed by treatment with trypsin and bile. Huges (1978) further confirmed the necessity for pre-treatment with both acid and pepsin and obtained excystation in an artificial juice composed of trypsin, pancreatin, sodium taurocholate and cholesterol. This worker reported that excystation could occur with cysts no more than two days of age.

The immature flukes penetrate the gut wall into the peritoneal cavity and then migrate towards the liver. A small number penetrate the blood vessels and reach the liver via the blood circulation. The blood route of migration to the liver may often be misdirected and many immature flukes can be found in the lungs. Following invasion of the liver, the young flukes freely migrate tortuously through the liver parenchyma before following a more directed migratory pattern prior to entering the bile ducts (Dow and Todd, 1986). Migration into the liver occurs 5-6 weeks post infection and at seven weeks the liver flukes begin to enter the main bile ducts. From then onwards an increasing number enter the bile ducts and reach sexual maturity, beginning to lay eggs 10-12 weeks after infestation (Blood *et al.*, 1994).

In his study on the pathogenesis of fasciolosis caused by *F. gigantica* in calves, Bitakaramire (1969) reported that the minimum time taken by the young flukes to reach the bile ducts ranged from 12 to 14 weeks. In the Philippines it was reported that metacercariae of *F. gigantica* are able to exist on almost any kind of grass, particularly rice plants, and thus feeding of rice straw during dry season spreads the infection (Dumag *et al.*, 1976).

At 20°C and 12% relative humidity, metacercariae could be destroyed after 6 minutes on the infected straw (Kimura *et al.*, 1980). In laboratory studies, the effect on infectivity of metacercariae was tested at different freezing temperatures (Boray and Enigk, 1964). In hot dry regions, metacercariae die quickly. In North Victoria in Australia, the area is dry and thus infections are usually due to recent contamination (Meek and Morris, 1979). In the United Kingdom, massive levels of metacercariae can accumulate during summer (Ross and Todd, 1970).

Adult cattle act as carriers of *Fasciola* parasites for many years because of the longevity of the individual mature flukes in the bile ducts. Pre-natal infections may occur in cattle. Rees and Richard (1975) suggested that these pre-natal infections may impair the ability of the cattle to develop resistance and therefore these animals may play an important role in the epidemiology of the parasite.

2.4. Distribution of fasciolosis

Dinnik and Dinnik (1959) showed that *F. gigantica* is a liver fluke that is widespread throughout Africa. This fluke is solely responsible for fasciolosis in cattle. The prevalence of *F. gigantica* in various African countries was summarised by Malek (1980). In West Africa major outbreaks of bovine fasciolosis have been related to the distribution of *L. natalensis* and rainfall (Schillhorn van Veen, 1980). As an example of the high rate of infection between 1973 and 1977, the incidence was 65.4% in cattle, with the highest incidence occurring during and just after the rainy season (Schillhorn van Veen, 1980, Fabiyi and Adeleye, 1982). In Southern Nigeria, Ogunrinade and Ogunrinade (1980), reported a prevalence of 2.5% bovine fasciolosis based on parasitological examination of the faeces. They further reported a mortality rate of 1% and a liver condemnation rate of 7% from abattoir records from 1971 to 1976 (Ogunrinade and Ogunrinade, 1980). Variations in the prevalence of fasciolosis in trade cattle in Eastern Nigeria were reported by Ikeme and Obioha (1973). They suggested that these could be due to differences in meat inspection as well as the quality of abattoir records.

In Zambia, a survey of bovine fasciolosis, using livers condemned due to *F. gigantica* and *F. hepatica* infection over a number of years, showed that the prevalence ranged between 80-90% (Silangwa, 1973). In Malawi, the prevalence, based on abattoir data, varied from 10-60% from one district to another, while in Kenya, Ogeto (1993), reported district prevalences ranging from 7.3% in Kajiado to 43.7% in Nyandarua, based on faecal samples from cattle.

The spread of fasciolosis to new areas depends upon the snail intermediate hosts or infected ruminants. The snails may be infected and spread the disease without movement of the ruminant hosts (Wamae *et al.,* 1990). Major studies of bovine fasciolosis in Kenya carried out by Bitakaramire (1968,1969,1973), Castelino and Preston (1979), Cheruiyot (1983), Anon (1986) and recently Waruiru *et al* (1997), established that the occurrence of fasciolosis is related to the mean annual rainfall. In addition these studies have indicated that the highest prevalence occurs in areas harbouring high snail populations.

Bitakaramire (1973) and Preston and Castelino (1977) showed that the prevalence of bovine fasciolosis also varied with the breed of the animal, with the exotic breeds, e.g. the Holstein, Friesian, Ayrshire and Jerseys having the higher prevalence as compared to the indigenous breeds e.g., the small East African Zebu. Castelino and Preston (1979) also showed that boran cattle had lower prevalence than the exotic breeds such as the Aberdeen Angus and Friesians.

Several investigators have reported seasonal variation in the prevalence of fasciolosis in snails. In Uganda, Ogambo-Ongoma (1970) showed that infections of snails with *F. gigantica* fluctuated with rainfall. The number of infected snails harbouring mature cercariae increased as the rainfall increased and decreased as the rainfall decreased. The reverse was true of the snails harbouring rediae. Hyera (1984) found out that the prevalence of fasciolosis based on the condemnation of bovine livers was high during the dry season in Iringa District of Tanzania. But the differences between prevalence during the dry and wet season were not statistically significant. Similar observations were earlier made by Mahlau, (1970) and Ecimovic and Mahlau (1973) in Iringa and Mbeya areas respectively. An epidemic of fasciolosis always follows a wet summer in England and Wales, Ollerenshaw (1971,1974). Using rainfall data for the month of June, Ollerenshaw (1974) was able to predict an epidemic of fasciolosis.

2.5. Environmental factors affecting the occurrence and distribution of fasciolosis.

At temperatures below 10 °C, no development of the *Fasciola* eggs occurs. However from 10-26°C, an increasing rate of development is observed (Soulsby, 1986). In Britain, Ollerenshaw (1974) demonstrated that under field conditions, eggs are unlikely to hatch in less than three weeks. Eggs may survive for sometime at low temperatures and under field conditions, while accumulation of unhatched eggs may occur in winter. However, these eggs are subjected to adverse conditions, and those that survive until spring do not cause a significant contribution to infections of snails as those which are passed by infected animals in spring (Ollerenshaw, 1974). Temperatures affect rate of advancement through the life cycles and hence influence infection intensities (Ollerenshaw, 1974; Gracey and Collins, 1992).

Soil moisture, plays a significant role in determining the distribution of snails whose growth and reproduction rates are dependent on the availability of wet environmental conditions (Simpson and Kunkle, 1985). Thus, soil moisture acts as a limiting factor on the life cycle and hence influences both the seasonality and intensities of *Fasciola* infections (Meek and Morris, 1979).

2.6. Pathogenesis and clinical manifestation of fasciolosis.

Bitakaramire (1969) observed two manifestations of fasciolosis in cattle in Kenya. The first was a sub clinical form, which causes a gradual loss of condition in animals and an observable drop in milk production. In this form a fluke burden of 380-500 was recorded from the livers of each animal at necropsy. The second was a severe clinical fasciolosis. Cattle suffering from this form of the disease were thin, had sub-mandibular oedema, pale mucous membranes, and staring coats, reduced appetite, drop in milk production and produced firm faeces. No jaundice was observed and the body temperature remained normal. These animals had 620-850 flukes per liver. This is probably the commonest form of fasciolosis in Kenya.

Acute and chronic fasciolosis is caused by different stages of *Fasciola* species in the liver. The acute form occurs 5-6 weeks after ingestion of large numbers of metacercariae and may be due to the sudden invasion of the liver by masses of young flukes (Blood *et al,* 1994). Sufficient liver parenchyma may be destroyed to cause acute hepatic insufficiency. In addition to this, haemorrhage into the peritoneal cavity may occur (Boray and Enigk, 1964).

Hypoalbuminaemia occurs due to reduced albumin synthesis and expanded plasma volume due to liver damage (Dargie and Berry, 1978). Reid (1973) showed that immature flukes were tissue feeders but may accidentally ingest some blood. Due to this, a minor degree of anaemia that develops in the first 4-5 weeks of infection probably reflects the loss of blood as a result of the young flukes. Migration may occur more rapidly in pregnant sheep as compared to cattle, and it has been suggested that this may be analogous to the peri-parturient rise in egg counts that occurs in *Ostertagia* and *Haemonchus* infections (Sinclair, 1972).

Chronic fasciolosis develops slowly and is due to activity of the adult flukes in the bile ducts. The flukes cause cholangitis, biliary obstruction, and destruction of hepatic tissue, fibrosis and anaemia. The anaemia seen in chronic fasciolosis is caused by the blood sucking activity of the flukes and the continuous drain of iron reserves (Reid, 1973). Later work, suggests that a substance produced by the flukes, possibly proline, may contribute to the development of the anaemia (Craig and Richard, 1980). Hypoalbuminaemia is more marked in the chronic disease mainly due to the increased protein plasma leakage into the gut. Chronic infection has been shown to limit growth rate and feed conversion efficiency in growing heifers (Oakley *et al.*, 1978). It has also been shown that *F. hepatica* infections increase the susceptibility of cattle to *Salmonella dublin* infection and predisposes them to prolonged infection and faecal excretion.

Infected ewes have shown reduced fertilities, body growth rates and wool weight which are proportional to the number of flukes present (Meek and Morris, 1979). Boray, (1969) demonstrated that the number of metacercariae ingested determines to a large extent the forms in which bovine fasciolosis is manifested. He showed that the prepatent period is shorter with smaller numbers of metacercariae, whereas large numbers lead to hepatic damage and fibrosis, which retards migration of the young flukes.

The number of metacercariae ingested at any one time is probably not the only factor that determines whether acute or chronic fasciolosis occurs or whether the pathogenesis is related chiefly to hepatic parenchymal damage or to biliary tract obstruction (Dow and Todd, 1986). Ross and Todd (1970) showed that previous exposure to infection appears to inhibit migration of the flukes. Migration of young *F. hepatica* through hepatic tissue containing quiescent spores of *Clostridium novyi* may cause the development of infectious necrotic hepatitis in cattle. The migration is also thought to stimulate occasional cases of bacillary haemoglobinuria.

Bitakaramire (1969), investigated experimental infection in calves, but did not attempt to correlate production indices with infection. He estimated the prepatent period to be 13 weeks. In this experiment, all calves aged 8 months, given 10,000 *metacercariae* died. Only one of the 4 calves given 1,000 *metacercariae* died while all others survived 27 weeks post-infection. Bitakaramire (1969) demonstrated 3 stages of development of the liver lesions. During the first stage, the migrating immature flukes caused damage to the liver parenchyma, blood vessels and bile ducts. The second stage was characterized by the proliferation of bile ducts and fibroblasts on the portal triad and surrounding the liver fluke tracks, which resulted in a scar tissue formation. In the third stage, the epithelia of the bile ducts became denuded and the walls became thickened, fibrotic and later calcified.

2.7. Necropsy findings and clinical pathology.

Acute hepatic fasciolosis is characterised by extensive damage of the liver. The capsule shows small perforations and sub-capsular haemorrhages. The parenchyma exhibits tracts of damaged tissue and is more friable than normal. The peritoneal cavity may contain an excess of bloodstained serum (Ross and Todd, 1970). In acute fasciolosis, severe normochromic anaemia, eosinophilia and a severe hypoalbuminaemia occurs, but eggs will not be present in the faeces (Blood *et al.*, 1994).

The chronic form is characterised by the presence of large leaf-shaped flukes in grossly enlarged and thickened bile ducts. Calcification of the bile duct walls is a common finding. Liver function tests are not significantly affected. One of the important facets of a necropsy examination is to estimate the duration of infection from the length of the flukes. This may help to locate the habitat of the snails and may be an important factor in a control programme (Ross and Todd, 1970; Sinclair, 1962). Sub-mandibular oedema and ascites is a common finding in the chronic form (Reid, 1973). Serum levels of *plasma glutamate dehydrogenase* and *gamma-glutamyl transpeptidase* enzymes are elevated when the young flukes enter the bile ducts, reaching base levels by 8-10 weeks post-infection (Schillhorn van Veen and Buys, 1970).

2.8. Economic importance of fasciolosis.

Fasciolosis causes economic losses due to mortalities, abortions, retardation of growth, drop in milk and meat production and condemnation of both infected livers and emaciated carcasses (Anon, 1986). Huges, (1978) and Ogunrinade and Ogunrinade (1980), showed that animals with severe acute fasciolosis die either directly due to fasciolosis or indirectly due to pre-disposition to other diseases.

Large losses have been recorded in the East African region by Coyle, (1958). Hammond (1956) recorded mortalities of 71.8% in cattle, in mainland Tanzania. Sewell, (1966) demonstrated that 20,000 *metacercariae* gave rise to about 7,000 young flukes and took 11 weeks to cause death due to sub-acute fasciolosis in a 2 year old Zebu steer.

With regard to retardation of growth, Sewell (1966) demonstrated that each fluke reduced weight gain by 198 gm per month in cattle infected with *F. gigantica*. In another study on the economic importance of *F. gigantica* in beef cattle, Chick (1980) demonstrated that the liver flukes significantly reduced body weight gain changes in cattle during the first 12 weeks post-infection. During this period there was significance between the effects of nutritional deficiency and flukes on the body weight changes, thus supporting the hypothesis that the overall effects of liver fluke infection is positively potentiated if there is a concurrent nutritional stress. In Kenya this consideration is of particular importance since nutritional stress is common. In the same study, Chick (1980) showed that a superimposed infection with 1,200 *metacercariae* of *F. gigantica* in cattle depressed the growth rate by 11.7% when compared to the naturally infected group. Chick (1980) working on production effects caused by *F. gigantica* in beef cattle found that growth rate was depressed by 14.1% to 14.7% in steers receiving a superimposed artificial infection of 1,200 *metacercariae* with stocking rates of 3.54 to 4.39 beasts per hectare. A maximum of 315 flukes per cattle were recorded at slaughter.

Similarly, a superimposed artificial infection rate of 600 metacercariae with a recovery rate of 262 flukes per animal at slaughter depressed growth by 20% and 3.5% in high and low nutritional regimes respectively. The timing and severity of the body weight loss were dependent upon the total fluke burden and the quality of the diet available. Hope (1984) demonstrated that *F. gigantica* infection resulted in less efficient feed utilisation.

According to Ross and Todd, (1970), low-grade infection of about 100 flukes in cattle resulted in an 8% loss in meat and milk production, infection with 250-300 flukes resulted in a 16% loss and heavy infection with over 500 flukes resulted in a 23% loss in production. Oakley *et al.*, (1978) demonstrated that *F. hepatica* infection in growing dairy heifers has a limiting effect on growth and impairs efficiency of feed conversion since infected animals consume more feed to achieve the same or lower performance than non-infected calves. The effect on growth rate was more marked when animals had access to reasonably high plane of nutrition. Oakley *et al.*, (1978) therefore stated that a low plane of nutrition masks this effect on growth but not on feed conversion efficiency.

Hope (1984) examined live weight gains, dry matter and energy intakes in relation to two levels of infection and to super infection in cattle. He demonstrated that sub-clinical infection derived from 600 *metacercariae* which gave an estimated average infection of 54 flukes per animal, 26 weeks after infection, reduced the weight gain by 8% over the first 6 months of infection. After this period, the infection had little effect on performance. Higher levels of infection (1,000 *metacercariae)* reduced the weight gain by 28% over the same period and caused appearance of clinical signs in some animals. The superimposed infection generally did not cause a marked reduction in performance at the same level of infection in previously infected animals. Poor performance appeared to be due to impaired feed conversion efficiency, while at higher infection level, inappetance also contributed to losses.

The economic losses attributable to the chronic form of fasciolosis in cattle have been calculated on the basis of reduction of milk yield and quality, depression of feed conversion efficiency and lengthening of fattening time to reach slaughter weight. Norman and Allen (1975) demonstrated that liver fluke infection lowered the quality and quantity of milk produced in dairy cattle. Milk from treated animals had higher percentages of total solids and butterfat content than from untreated animals.

Routine treatment of dairy cattle infected sub-clinically with *F. hepatica* resulted in significant increase in milk yields. Other workers in Holland, Germany, Italy, Yugoslavia, Britain and Japan [reviewed by Froyd and McWilliam (1975)] have estimated that fluke infection can depress milk yields by some 5-50% with even light to moderate infections.

Froyd and McWilliams (1975) assessed economic losses resulting from fasciolosis in the United Kingdom. Estimates were made of the number of animals likely to be at risk based on survey data and direct information from individual abattoirs in the areas not covered by the survey. Realistic estimates of the cost of productivity and depression resulting from sub-clinical and chronic fasciolosis were made. They calculated that the annual loss in the livestock industry in the United Kingdom exceeded 2 million pounds in liver losses and another 5 million pounds in weight gain losses and lowered carcass quality. In the Netherlands, Pekelder (1975) estimated that *F. hepatica* infection causes losses amounting to a minimum of 125-150 million guilders per year, although these figures differ from year to year depending on the weather conditions. Hyera (1984) estimated an annual monetary loss of United States $ 9,608.7 to 16,556 in Tanzania as a result of condemnation during meat inspection of bovine livers infected with liver flukes.

In Kenya, it has been estimated that the Kenya Meat Commission alone lost Kshs 800,000 annually for the period between 1954-1966 from liver condemnation due to bovine fasciolosis (Bitakaramire, 1969). A later survey carried out by Preston and Castelino (1977), gave an estimated loss of about Kshs. 240,000 annually from liver condemnation due to bovine fasciolosis during the period 1972-1974. Animals receiving adequate treatment against liver flukes had a calving interval, which was shorter by about 20 days compared to the untreated. This difference represents a substantial gain from milk yields (Hope, 1984).

In an attempt to compare economic losses resulting from condemnations of livers due to stilesiasis and fasciolosis in sheep and goats for a period of five-years (1974-1978), Cheruiyot, (1983) estimated that fasciolosis resulted in an average loss of Kshs 332,800 annually. Similarly, a survey by the Agricultural Research Foundation (Anon, 1986) on the distribution and economic impact of liver fluke in Kenya estimated an annual loss of Kshs 326 million due to liver fluke infection in cattle, sheep and goats.

2.9. Diagnosis of fasciolosis.

In the tropics, common occurrence of fasciolosis and haemonchosis in cattle causes diagnostic problems. In endemic areas, for fasciolosis most cases of chronic ill health in cattle should be considered as a possible consequence of the disease. To support the diagnosis there should be fluke eggs in the faeces and the hepatic lesions characteristic of the disease at necropsy. The detection of the characteristic operculated fluke eggs in the faeces is diagnostic of bovine fasciolosis. The eggs are thin walled, yellowish brown in colour, (Happich and Boray, 1969) and it is the commonly used method in the diagnosis of fasciolosis. The eggs are floated in zinc sulphate solution of specific gravity of 1.364 (MAFF, 1986). Though the faecal examination is the commonest method in diagnosis, it lacks sensitivity since eggs do not appear during the acute or chronic forms of the disease. For these reasons serodiagnosis is an alternative for detecting *Fasciola* infection (Hillyer, 1981).

Several serological techniques are potentially better alternative for routine diagnosis of fasciolosis in cattle. These techniques, which include the Enzyme Linked Immunosorbent Assay (ELISA), Immunodiffusion, Immunoelectrophoresis and Counter-electrophoresis, have been useful in the detection of antibodies in humans and experimental animals infected with *F. hepatica* (Reddington *et al.*, 1984). Hillyer (1985) demonstrated that both ELISA and gel diffusion gave reliable results when compared to other serological tests in detecting primary bovine fasciolosis and recommended development of other tests with purified antigens. In a study comparing Double Immunodiffusion, Indirect Fluorescent Antibody Test (IFAT) and ELISA for diagnosis of bovine fasciolosis, Ogunrinade (1983), observed the sensitivities and specificities to be, Double Immuno Diffusion (54%, 100%), IFAT (72%, 95%) and ELISA (100%, 100%), respectively. Hence ELISA was recommended as a better test for field serodiagnosis of fasciolosis.

The ELISA test has been shown to be sensitive and useful in the diagnosis of fasciolosis in a wide variety of animals e.g., cattle, sheep and goats (Zimmerman *et al.*, 1982). However, there have been reports of cross reactivity in the ELISA test between common helminths infections, particularly fasciolosis and *Taenia saginata*, cysticercosis (Craig and Rickard, 1980).

Chromatographic techniques have been employed to isolate and characterise potential specific somatic or excretory secretory antigens for use in these serological tests

(Reddington *et al.*, 1984, Hillyer, 1986). Given these comparative studies and the relative ease of the test, the ELISA technique has been commonly used for diagnosis of fasciolosis (Hillyer, 1985, 1986, Khalil *et al.*, 1990, Kamal *et al.*, 1992).

Hillyer (1985), used cleaner excretory/secretory products, which showed an added advantage in that they were easier to process. Humans, rabbits, cattle and sheep infected with *F. hepatica* all develop antibodies to a 17KD polypeptide antigen as detected by the Enzyme-Linked Immuno-Electro Transfer Blot (EITB), suggesting that these may be useful markers to detect infections.

2.10. Control of fasciolosis.

The control of fasciolosis may be achieved using one or a combination of the following methods (Roberts and Suhardono, 1996):

(a) Molluscicide application.

(b) Treatment of infected animals using anthelmintic drugs.

(c) Land drainage or fencing off marshy areas where practicable.

Control of infection by excluding grazing animals from habitats known to be infected is in practice in some areas of Tanzania, but is impracticable in most others as it involves avoiding good pastures or wasting scarce fodder (Fabiyi, 1987). Attempts to control fasciolosis in cattle and sheep have predominantly been based on the administration of anthelmintics, which are used strategically or during out-breaks of the disease (Gracey and Collins, 1992). By treating experimentally infected calves, Bitakaramire (1969), observed that there was improved weight gains. He therefore suggested that to achieve effective control of fasciolosis, chemotherapeutic treatment should be combined with molluscicide application in snail habitats.

As for the use of molluscicides, carbon tetrachloride, hexachloroethane and hexachlorophen were used extensively during the early part of this century. Widespread use of molluscicides presents practical difficulties, which include the topographical nature of the endemic areas and lack of trained workers. In addition there are costs coupled with environmental concerns due to the toxic effects associated with molluscicides. In Kenya, Preston and Castelino (1977), obtained encouraging results with the minimum use of molluscicides and recommended their use in carefully selected snail habitats. The work of Wamae *et al.*, (1990), though limited to only ranches, recommended application of molluscicides when infected snails abound and before flooding of the habitats. They also suggested that treatment of animals be done at the same time and again 10 weeks later to eliminate maturing infections. Immunization of cattle using prepared antigen as a measure to control fasciolosis has been tried, with encouraging results. (Spithill and Dalton, 1998).

According to Fabiyi (1987), control measures are most effective if directed against the developing flukes before they mature and reach egg-laying stage. Anthelmintic treatment is the chief method of reducing *F. gigantica* infection in the tropics, but in most areas, the drugs are applied haphazardly (Fabiyi and Adeleye, 1982).

The dry season treatment is mainly used as a tactical approach. In most areas, patterns of infection have not been adequately studied, and there is little knowledge on which to base dosing programmes. Such areas have relied on the prepatent period of 3 months of the parasites. Thus treatments are commonly recommended at quarterly intervals in order to ensure the destruction of the developing flukes which may have gained access into the animals since the last treatment and before they have reached the egg laying stage (Tongston, 1978).

Using a restricted programme of strategic dosing with triclabendazole, Fawcett (1990) observed that the percentage of ewes passing fluke eggs dropped from 49% to less than 1% after a 5-year period without the reappearance of clinical fasciolosis. This program was suggested to offer an effective and practical means of controlling fasciolosis, (Stansfield *et al.* 1987; Maes *et al.*, 1990; Waruiru et al, 1994). Regular treatment with triclabendazole may lead to the development of resistance to the drug by *Fasciola hepatica* (Overend & Bowen, 1995; Lammert *et al.*, 2000).

CHAPTER 3. MATERIALS AND METHODS

This study was carried out in two phases. In phase one, the prevalence and economic importance of fasciolosis in cattle, sheep and goats in seven provinces of Kenya over a period of ten years was calculated from meat inspection records. In the second phase of the study, liver flukes recovered from cattle, sheep and goats slaughtered at Dagoretti slaughterhouse were examined to determine the occurrence of *F. hepatica* and *F. gigantica*.

3.1. Data collection from meat inspection records.

Meat inspection records for cattle, sheep and goats slaughtered in seven provinces of Kenya over a period of ten years (1990 - 1999) that were available at the Kenya Veterinary Department, Kabete were used in this study. Records from thirty-eight districts in seven out of eight provinces were analysed. The records were used to determine the number of livers condemned in the slaughterhouses and slaughter-slabs during the routine post-mortem meat inspection as a result of the presence of *Fasciola spp*, and the total number of animals slaughtered for each of the three species in every district. The records were used to calculate the annual and overall provincial and national prevalences and economic importance of fasciolosis in cattle, sheep and goats in Kenya over the 10-year period. Records from North Eastern province were not available at the Veterinary Department because the department had not taken over meat inspection in this province from the Ministry of Health. North Eastern province was therefore omitted from the analysis.

3.1.1. Calculation of the prevalence of fasciolosis.

The prevalence of fasciolosis was calculated as a percentage of the number of animals infected with *Fasciola spp* and their livers therefore condemned out of the total number slaughtered. For each species of livestock, prevalence was calculated for each district for every month and for every year. All the data from districts in a province were then pooled to determine the prevalence of fasciolosis in that province. Prevalence of fasciolosis in cattle, sheep and goats for the entire country during each of the 10 years was then calculated from the pooled provincial data.

3.1.2. Calculation of economic losses due to condemnation of *Fasciola* infected livers.

The economic losses due to fasciolosis in cattle, sheep and goats were determined by putting a monetary value to the condemned livers for the ten-year period (1990-1999). For each of the livestock species, data on the number of livers condemned was tabulated by district and province for each year. The average weight of livers for each species was estimated and the current market price per Kilogram (Kshs./ Kg) given. The total quantity in kilograms of livers condemned was calculated by multiplying the total number of livers condemned with the average liver weight for each species. The economic loss was determined by multiplying the total quantity condemned for each species with the current market price (Ksh / Kg) of liver for that species. The annual and total economic losses for the whole country during the 10-year period were calculated.

3.2. Post-mortem examination of livers at Dagoretti slaughterhouses.

In the second phase of the study, the relative occurrence of the two species of *Fasciola* i.e. *F. hepatica* and *F. gigantica* in cattle, sheep and goats slaughtered at Dagoretti slaughterhouses in Kenya was determined. Dagoretti slaughterhouses are the largest slaughterhouses in Kenya and the animals slaughtered there come from almost every part of the republic of Kenya. To determine the relative occurrence of the two species of liver flukes, liver flukes from infected livers of the three livestock species were collected and differentiated into species using their size and morphology. The abattoir prevalence of fasciolosis in the three livestock species was also determined using information obtained during the visits to the slaughterhouses.

Visits were made to Dagoretti slaughterhouses to collect samples of liver flukes from cattle, sheep and goats, where the livers of all the slaughtered animals were thoroughly inspected for the presence of *Fasciola spp*. Livers were sliced using a sharp knife and liver flukes picked using a blunt forceps. A minimum of 6 liver flukes were picked from every infected liver except where the liver had less than 6 liver flukes. This was to help in finding out if one animal could be having a mixed species infection and also to ensure that the real species of the liver fluke is correctly identified. The flukes were preserved in universal bottles containing 70% alcohol and transported to the laboratory at the University of Nairobi, Kabete campus for further analysis. Details that were recorded during meat inspection for each sample collected included:

1. Species of the livestock from which the *Fasciola spp* were collected.
2. Age of the animal.
3. Sex of the animal infected with *Fasciola spp.*

4. Origin of the animal.

5. Number of liver flukes present in an infected liver.

6. The extent of the liver damage (categorised as none, medium, extensive and very extensive) depending on gross morphology.

The species, age, sex and origin of the animal were collected to find the distribution of the *Fasciola species* in animals. From the universal bottles containing 70% alcohol, the flukes were transferred to petri dishes and spread on the table placing them on a clean white paper. The flukes were characterized by their size and morphology. Their sizes were then marked using a pencil and a ruler. The ruler was used to determine the exact sizes of the liver flukes by marking their length and width on the white paper and then recording it. Liver flukes that measured less than 40 mm in length, leaf-shaped, very broad shoulders, pointed at the posterior end and were grey in colour when preserved in 70% alcohol were classified as *F. hepatica.* Those that measured over 40 mm in length, were transparent when preserved, more elongate, leaf-shaped with sloping shoulders that were relatively narrow, and had a rounded posterior were classified as *F. gigantica.*

3.3. Statistical data analysis.

The data were analysed statistically using repeated measures of Analysis of Variance (ANOVA) as described by Huitema, (1980), to test for the significant differences in the provincial, species and annual prevalences. The level of significance used was $p \leq 0.05$. The difference in the overall national prevalence of fasciolosis for the three livestock species was also compared using the analysis of variance.

CHAPTER 4. RESULTS.

4.1. THE PREVALENCE OF FASCIOLOSIS IN CATTLE, SHEEP AND GOATS IN THE PERIOD 1990-1999.

4.1.1. Prevalence of fasciolosis in cattle

Over the period of 10 years, a total of 5,421,188 cattle were slaughtered in the seven provinces. Out of these, 427,931 (7.9%) were found to be infected with *Fasciola spp.* Western province had the highest prevalence (16.1%) of fasciolosis. Out of the 785,873 cattle slaughtered in this province, 126,660 were found to be infected. This was followed by Eastern province with a prevalence of 11.3%. Out of 599,900 cattle slaughtered in this province, 67,881 were found to be infected with *Fasciola spp.* Nyanza province had a prevalence of 8.9%, Rift Valley province had a prevalence of 8.3%, Central province had a prevalence of 6.1% and Nairobi province had a prevalence of 3.9 %. Coast province had the lowest prevalence (3.5%). The overall mean provincial prevalences were significantly different (p= 0.0035). This information is summarized in Table 1, which shows the number of cattle slaughtered in each of the seven provinces of Kenya during the period 1990 - 1999, the number found to be infected with *Fasciola spp* at post mortem meat inspection and the calculated percentage prevalence of fasciolosis. The information is also tabulated in Appendix 1, which shows the data for the total number of cattle slaughtered in each province by district, those infected with *Fasciola spp* and the prevalence of fasciolosis. For ease of overview, the calculated overall percentage prevalence of fasciolosis in the seven provinces is summarized in Figure 1.

The annual and overall mean provincial prevalence of bovine fasciolosis in each of the seven provinces in Kenya and the mean national prevalence for each of the years 1990 to 1999 are shown in Table 2. In Appendix 2, data on the number of cattle slaughtered in each of the seven provinces during each of the 10 years, the number whose livers were found to be infected with *Fasciola spp* and the calculated prevalence of fasciolosis are shown. Cases of fasciolosis in cattle were recorded in all provinces throughout the ten-year period covered in this study. The trend in the prevalence of bovine fasciolosis over the 10 years period in the seven provinces mirrored the overall observations in Table 1 and Figure 1. Western province recorded the highest prevalence of fasciolosis (range of 14.7% to 20.6%), during 9 out of the 10 years, the exception being 1991 when the province recorded the third highest prevalence of 8.6% after Eastern province (11.5%) and Nyanza province (10.1%). As in the overall provincial prevalence recorded in Table 1 and Figure 1, the high prevalence of fasciolosis in Western province during each of the 10 years, was followed in the majority of instances by that recorded in Eastern, Nyanza and Rift Valley provinces in that order. There was a slight increase in the prevalence of fasciolosis in all provinces during the 10-year period, except in Coast province where prevalence remained low and in Nyanza province where there was a drop in prevalence from 1993 onwards, compared to the previous years.

Table 1. The total number of cattle slaughtered in each of the seven provinces of Kenya during the period 1990 – 1999, the number found to be infected with *Fasciola spp* at post mortem meat inspection and the calculated overall percentage prevalence of fasciolosis.

Province	Number of cattle slaughtered	Total infected With *Fasciola spp*	Prevalence of fasciolosis (%)
Western	785,873	126,660	16.1
Eastern	599,900	67,881	11.3
Nyanza	159,814	14,237	8.9
Rift Valley	731,438	60,634	8.3
Central	1,834,301	111,576	6.1
Nairobi	314,758	12,248	3.9
Coast	995,104	34,695	3.5
Total	5,421,188	427,931	7.9

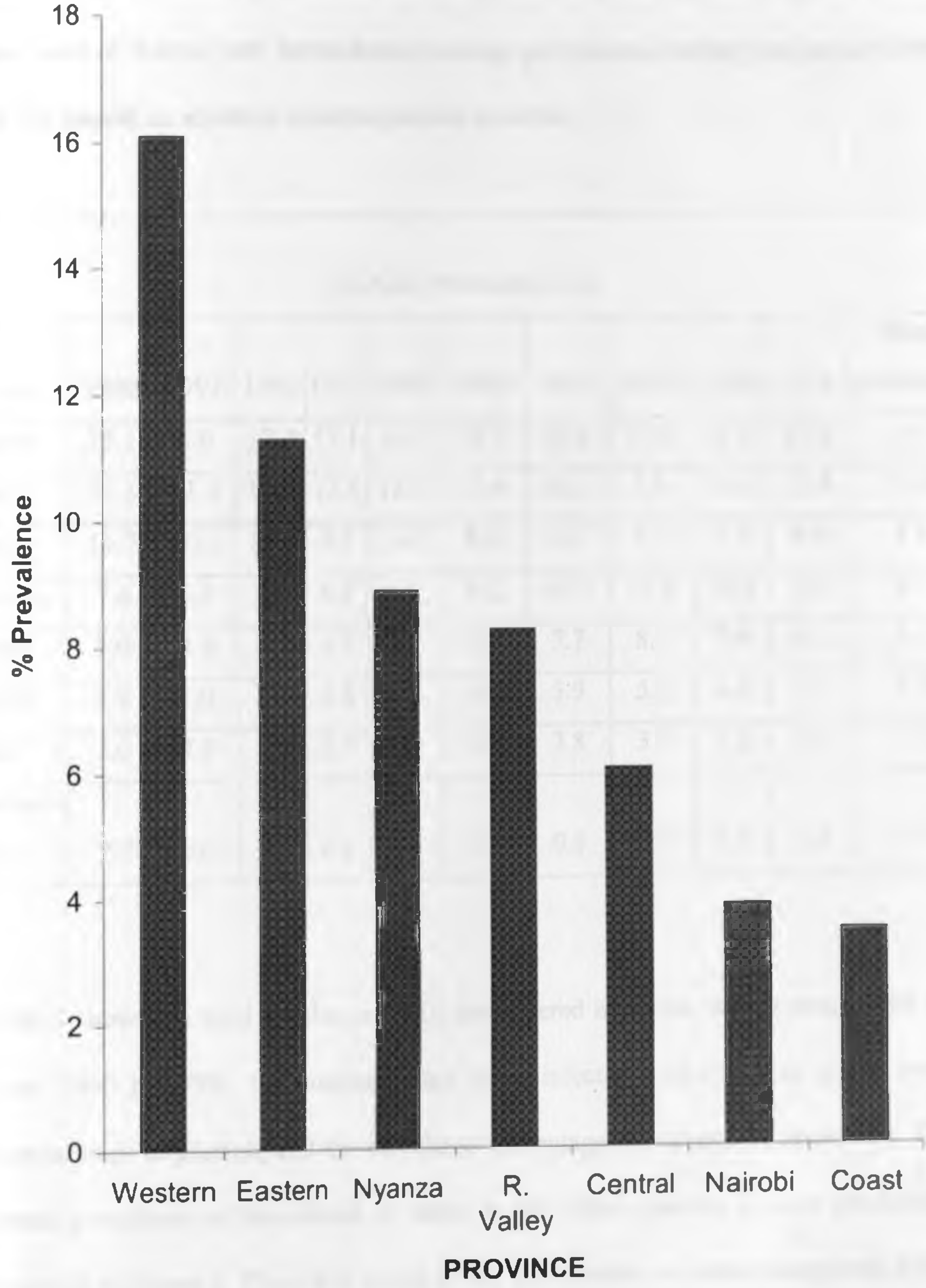

Figure 1. Prevalence of fasciolosis in cattle in the seven provinces of Kenya during the period 1990 - 1999 based on abattoir meat inspection records.

Table 2. The annual prevalence of fasciolosis in cattle in each of the seven provinces of Kenya and the national average prevalence, during the period 1990 – 1999, based on abattoir meat inspection records.

	YEARS (Prevalence %)										
Province	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Mean prevalence
Western	15.1	8.6	17.0	17.1	14.7	19.7	20.6	17.8	18.5	17.1	16.1
Eastern	11.3	11.5	10.3	12.5	12.8	15.4	15.3	5.8	13.5	12.8	11.3
Nyanza	11.7	10.1	13.0	9.7	14.0	8.4	4.6	5.3	7.7	8.9	8.9
R. Valley	7.4	6.2	6.0	6.3	9.6	9.2	10.3	10.8	10.9	9.0	8.3
Central	5.0	4.4	4.5	4.7	6.1	6.8	7.7	8.4	7.4	9.7	6.1
Nairobi	2.8	2.0	3.4	2.6	2.8	4.3	5.9	5.5	4.3	5.1	3.9
Coast	3.0	3.8	3.5	2.9	4.3	3.7	3.8	3.3	3.2	3.5	3.5
National Mean	7.3	6.0	7.4	6.6	8.2	9.3	9.8	7.9	8.9	9.2	7.9

Table 3 shows the total number of cattle slaughtered in Kenya during each of the 10 years (1990 to 1999), the number found to be infected with *Fasciola spp* at post-mortem meat inspection, and the calculated percentage prevalence of fasciolosis. The annual prevalence of fasciolosis in cattle in the entire country is also graphically presented in Figure 2. There was a drop in the total number of cattle slaughtered in the entire country from 1994 to 1999. The calculated prevalence of fasciolosis in cattle in the entire country was 7.3% in 1990, it dropped to 6.0% in 1991, rose again to 7.4% in 1992 and then dropped to 6.6% in 1993. This was followed by a gradual increase in prevalence from 8.2% in 1994 to an overall high of 9.9% in 1997. A slight decrease in prevalence occurred in 1998 when a prevalence of 8.9% was recorded, but rose again to 9.2% in 1999. As observed in majority of the provinces in Table 2, there was an overall increase in the prevalence of fasciolosis in the country between 1990 and 1999, especially over the last six years.

Table 3. The number of cattle slaughtered in Kenya annually during the period 1990 – 1999, the number found to be infected with *Fasciola spp* at post mortem meat inspection and the calculated annual prevalence.

Year	Number of cattle slaughtered	Total infected with *Fasciola spp*	Prevalence (%)
1990	623,748	45,480	7.3
1991	645,831	38,543	6.0
1992	673,425	49,806	7.4
1993	615,411	40,503	6.6
1994	553,322	45,698	8.2
1995	487,876	45,340	9.3
1996	472,282	46,281	9.8
1997	513,056	40,581	7.9
1998	459,123	40,990	8.9
1999	377,114	34,709	9.2
Total	5,421,188	427,931	7.9

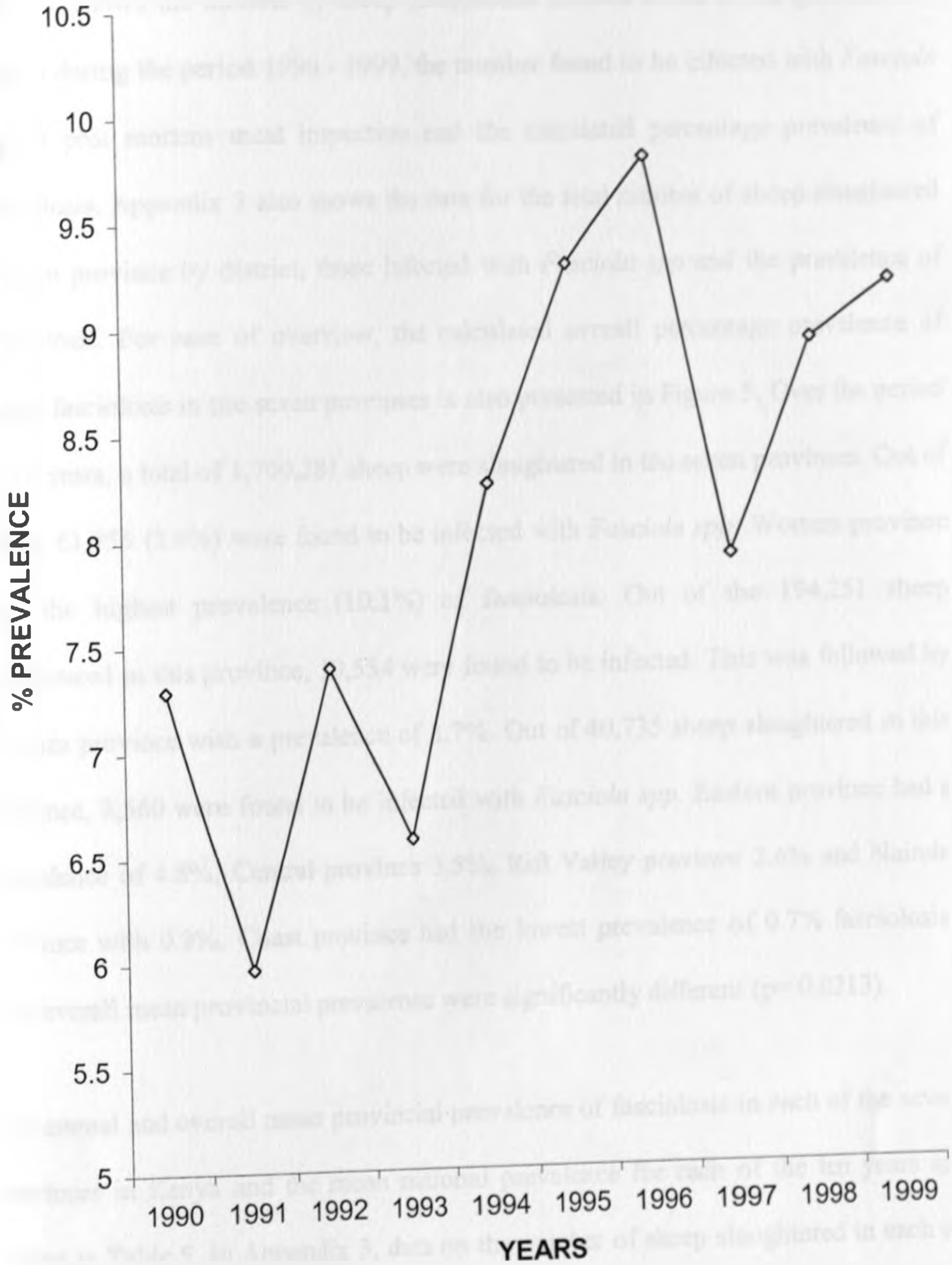

Figure 2. Trends in the prevalence of bovine fasciolosis in Kenya over the period 1990 - 1999 based on abattoir meat inspection records.

4.1.2. Prevalence of fasciolosis in sheep.

Table 4 shows the number of sheep slaughtered in each of the seven provinces of Kenya during the period 1990 - 1999, the number found to be infected with *Fasciola spp* at post mortem meat inspection and the calculated percentage prevalence of fasciolosis. Appendix 3 also shows the data for the total number of sheep slaughtered in each province by district, those infected with *Fasciola spp* and the prevalence of fasciolosis. For ease of overview, the calculated overall percentage prevalence of sheep fasciolosis in the seven provinces is also presented in Figure 5. Over the period of 10 years, a total of 1,700,281 sheep were slaughtered in the seven provinces. Out of these, 61,955 (3.6%) were found to be infected with *Fasciola spp.* Western province had the highest prevalence (10.1%) of fasciolosis. Out of the 194,251 sheep slaughtered in this province, 19,554 were found to be infected. This was followed by Nyanza province with a prevalence of 8.7%. Out of 40,735 sheep slaughtered in this province, 3,560 were found to be infected with *Fasciola spp.* Eastern province had a prevalence of 4.8%, Central province 3.5%, Rift Valley province 2.6% and Nairobi province with 0.9%. Coast province had the lowest prevalence of 0.7% fasciolosis. The overall mean provincial prevalence were significantly different ($p = 0.0213$).

The annual and overall mean provincial prevalence of fasciolosis in each of the seven provinces in Kenya and the mean national prevalence for each of the ten years are shown in Table 5. In Appendix 3, data on the number of sheep slaughtered in each of the seven provinces during each of the 10 years, the number whose livers were found to be infected with *Fasciola spp* and the calculated prevalence of fasciolosis are shown. Cases of fasciolosis in sheep were recorded in all provinces throughout the ten-year period covered in this study. The trend in the prevalence of fasciolosis over the 10 year period in the seven provinces mirrored the overall observations in Table 4 and Figure 3. Western province recorded the highest prevalence of fasciolosis (range of 5.8% to 23.8%) during 5 out of the 10 years, followed by Nyanza province, which had the highest prevalence during the other 5 years. Nyanza province however, recorded very low prevalence of 1.6% and 2.0% in 1990 and 1999 respectively. As in the overall provincial prevalence recorded in Table 4 and Figure 3, the high prevalence of fasciolosis in Western province and Nyanza province during each of the 10 years, was followed in the majority of instances by that recorded in Eastern, Central and Rift Valley provinces in that order. There was a slight decrease in the prevalence of fasciolosis in Nairobi, Coast, Central and Rift Valley provinces during the ten-year period. In Western province the prevalence remained high (5.8% and 23.8%), In Eastern province the prevalence remained nearly the same ranging between 3.7% to 6.4%, while in Nyanza province the prevalence was 1.6% in 1990 and then it rose to a high of 18.4% in 1996 and later dropped to 9.9% in 1999.

Table 4. The number of sheep slaughtered in each of the seven provinces of Kenya during the period 1990 – 1999, the number found to be infected with *Fasciola spp* at post mortem meat inspection and the calculated overall prevalence of fasciolosis.

Province	Number of sheep slaughtered	Total infected with *Fasciola spp*	Percent prevalence of fasciolosis
Western	194,251	19,554	10.1
Nyanza	40,735	3,560	8.7
Eastern	168,207	8,150	4.8
Central	483,481	16,852	3.5
R. Valley	407,319	10,704	2.6
Nairobi	57,960	532	0.9
Coast	348,328	2,603	0.75
Grand total	1,700,281	61,955	3.6

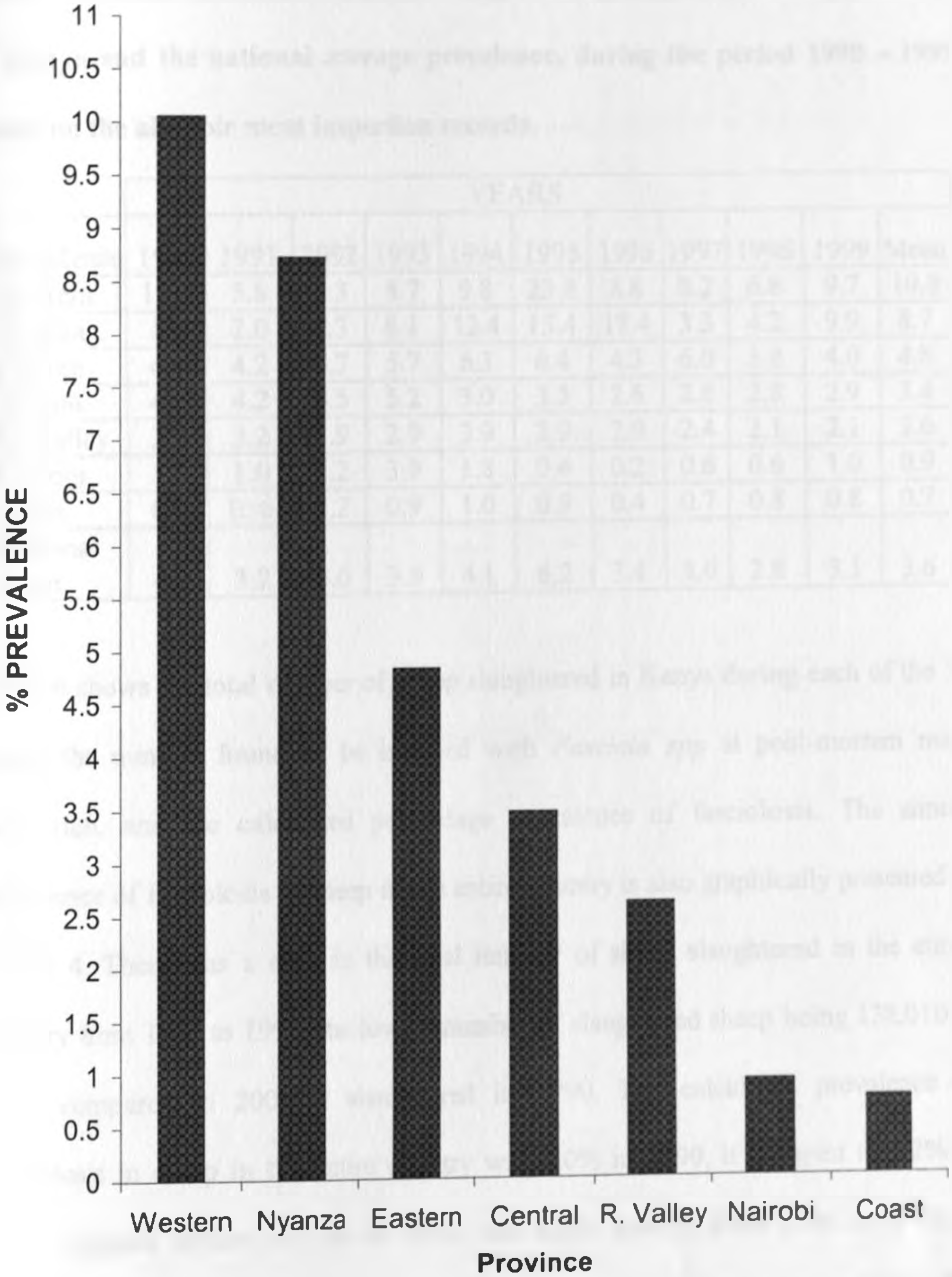

Figure 3. Prevalence of fasciolosis in sheep in the seven provinces of Kenya during the period 1990 - 1999 based on meat inspection records.

Table 5. Annual prevalence of fasciolosis in sheep in each of the seven provinces of Kenya and the national average prevalence, during the period 1990 – 1999, based on the abattoir meat inspection records.

	YEARS										
Prevalence	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Mean
Western	12.2	5.8	6.3	8.7	9.8	23.8	8.8	8.2	6.8	9.7	10.0
Nyanza	1.6	2.0	7.3	8.1	12.4	15.4	18.4	3.3	4.2	9.9	8.7
Eastern	4.4	4.2	3.7	5.7	6.3	6.4	4.3	6.0	3.8	4.0	4.8
Central	4.2	4.2	3.5	5.2	3.0	3.3	2.6	2.8	2.8	2.9	3.4
R. Valley	3.2	3.2	1.9	2.9	3.9	2.9	2.0	2.4	2.1	2.1	2.6
Nairobi	1.0	1.0	1.2	3.9	1.8	0.4	0.2	0.6	0.6	1.0	0.9
Coast	0.2	0. 6	1.2	0.9	1.0	0.9	0.4	0.7	0.8	0.8	0.7
National mean	4.0	3.2	3.0	3.9	4.1	6.2	3.4	3.0	2.8	3.1	3.6

Table 6 shows the total number of sheep slaughtered in Kenya during each of the 10 years, the number found to be infected with *Fasciola spp* at post-mortem meat inspection, and the calculated percentage prevalence of fasciolosis. The annual prevalence of fasciolosis in sheep in the entire country is also graphically presented in Figure 4. There was a drop in the total number of sheep slaughtered in the entire country from 1990 to 1999, the lowest number of slaughtered sheep being 138,010 in 1999 compared to 200,257 slaughtered in 1990. The calculated prevalence of fasciolosis in sheep in the entire country was 4.0% in 1990, it dropped to 3.2% in 1991, dropped further to 3.0% in 1992, rose again steadily from 3.9% in 1993, to 4.1% in 1994 and 6.2% in 1995. The prevalence then dropped to 3.4% in 1996, 3.0% in 1997, to 2.8% in 1998 and then rose to 3.1% in 1999. As observed in majority of the provinces in Table 5, there was an overall slight decrease in the prevalence of fasciolosis in the country between 1990 and 1999, with a slight increase in the last two years.

Table 6: The total number of sheep slaughtered in Kenya annually during the period 1990 – 1999, the number found to be infected with *Fasciola spp* at post mortem meat inspection and the calculated annual prevalence of fasciolosis.

Year	Number of sheep slaughtered	Total infected With *Fasciola spp*	Percent Prevalence
1990	200,257	7,998	4.0
1991	199,872	6,438	3.2
1992	199,386	5,905	3.0
1993	149,000	5,856	3.9
1994	162,702	6,734	4.1
1995	150,222	9,327	6.2
1996	169,878	5,685	3.4
1997	177,486	5,422	3.0
1998	153,468	4,261	2.8
1999	138,010	4,329	3.1
TOTAL	1,700,281	61,955	3.6

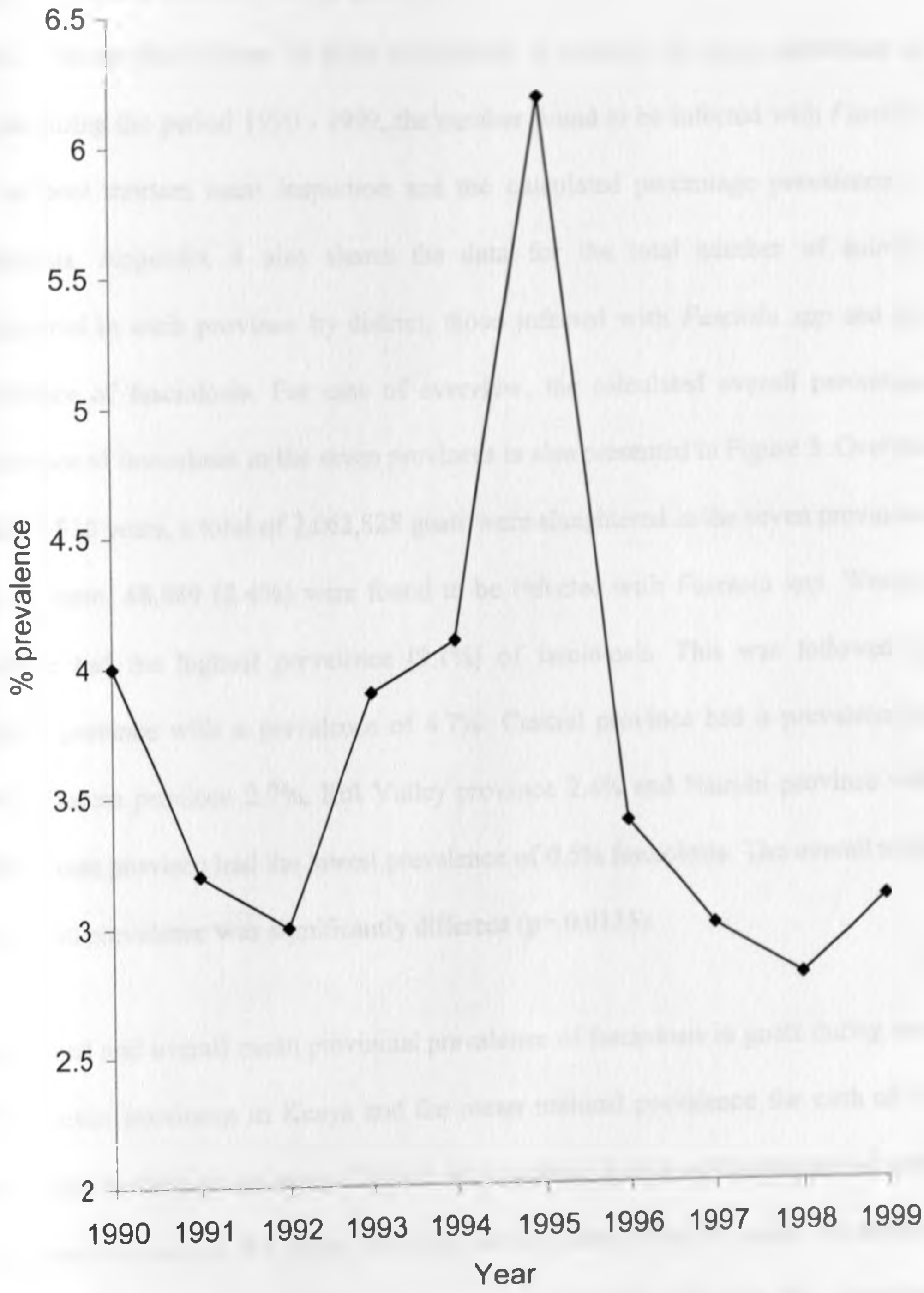

Figure 4. Trends in the prevalence of fasciolosis in sheep in Kenya over the period 1990 - 1999 based on meat inspection records.

4.1.3. Prevalence of fasciolosis in goats

Table 7 shows the number of goats slaughtered in each of the seven provinces of Kenya during the period 1990 - 1999, the number found to be infected with *Fasciola spp* at post mortem meat inspection and the calculated percentage prevalence of fasciolosis. Appendix 4 also shows the data for the total number of animals slaughtered in each province by district, those infected with *Fasciola spp* and the prevalence of fasciolosis. For ease of overview, the calculated overall percentage prevalence of fasciolosis in the seven provinces is also presented in Figure 5. Over the period of 10 years, a total of 2,062,828 goats were slaughtered in the seven provinces. Out of these, 48,889 (2.4%) were found to be infected with *Fasciola spp*. Western province had the highest prevalence (9.1%) of fasciolosis. This was followed by Nyanza province with a prevalence of 4.7%. Central province had a prevalence of 4.4%, Eastern province 2.7%, Rift Valley province 2.4% and Nairobi province with 0.5%. Coast province had the lowest prevalence of 0.5% fasciolosis. The overall mean provincial prevalence was significantly different (p= 0.0135).

The annual and overall mean provincial prevalence of fasciolosis in goats during each of the seven provinces in Kenya and the mean national prevalence for each of the years 1990 to 1999 are shown in Table 8. In Appendix 5, data on the number of goats slaughtered in each of the seven provinces during each of the 10 years, the number whose livers were found to be infected with *Fasciola spp* and the calculated prevalence of fasciolosis are shown. Cases of fasciolosis in goats were recorded in all provinces throughout the ten-year period covered in this study except for Coast province where prevalence of 0% was recorded in 1992. The trend in the prevalence of fasciolosis over the 10-year period in the seven provinces mirrored the overall observations in Table 7 and Figure 5. Western province had the highest prevalence of fasciolosis (range of 1.5% to 20.6%), during 9 out of the 10 years, the exception being 1991 when the province had the sixth highest prevalence of 1.5% and in 1993 when it ranked 3rd highest with 5.0% prevalence (Table 8). As in the overall provincial prevalence recorded in Table 7 and Figure 5, the high prevalence of fasciolosis in Western province during each of the 10 years, was followed in the majority of instances by that recorded in Nyanza followed by Central province. There was a steady increase in the prevalence of fasciolosis in all provinces during the first 5 years. Later the prevalence started going down from 1996 to 1999.

Table 7. The total number of goats slaughtered in each of the seven provinces of Kenya during the period 1990 – 1999, the number found to be infected with *Fasciola spp* and the calculated overall prevalence of fasciolosis.

Province	Number of goats slaughtered	Total infected With *Fasciola spp*	Prevalence (%)
Western	125,621	11,383	9.1
Nyanza	72,686	3,428	4.7
Central	211,325	9,351	4.4
Eastern	499,266	13,475	2.7
R. Valley	283,635	6,755	2.4
Nairobi	105,668	568	0.5
Coast	764,627	3,929	0.5
Grand total	2,062,828	48,889	2.4

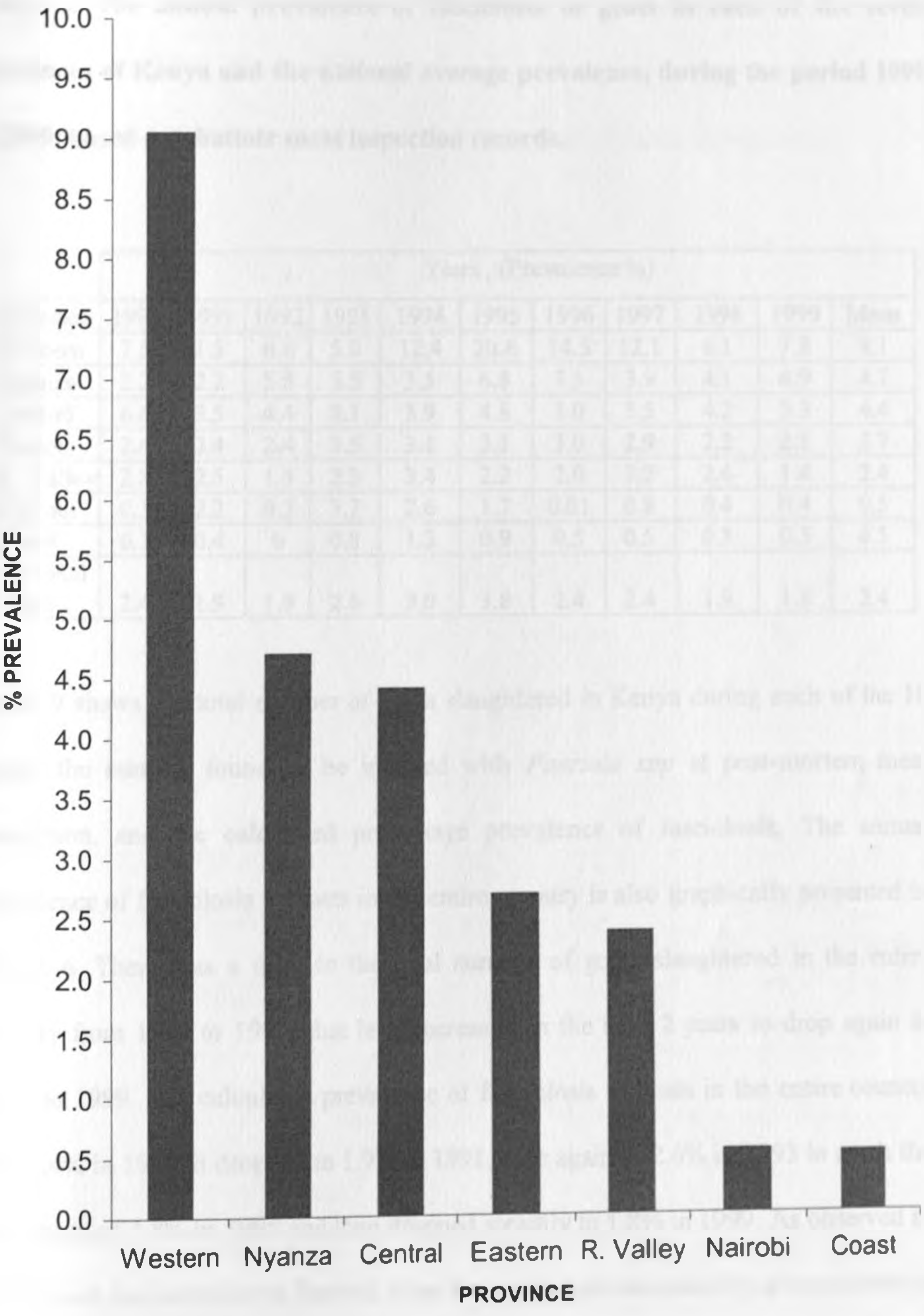

Figure 5. Prevalence of fasciolosis in goats in the seven provinces of Kenya during the period 1990 - 1999 based on meat inspection records.

Table 8. The annual prevalence of fasciolosis in goats in each of the seven provinces of Kenya and the national average prevalence, during the period 1990 – 1999, based on abattoir meat inspection records.

	Years (Prevalence %)										
Province	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Mean
Western	7.5	1.5	6.8	5.0	12.4	20.6	14.5	12.1	6.1	7.8	9.1
Nyanza	2.2	2.2	5.8	5.5	3.5	6.8	7.3	3.9	4.1	4.9	4.7
Central	6.6	3.5	4.4	8.1	3.9	4.8	3.0	3.5	4.2	3.3	4.4
Eastern	2.4	2.4	2.4	3.5	3.1	3.1	3.0	2.9	2.2	2.1	2.7
R. Valley	2.8	2.5	1.5	2.3	3.4	2.2	2.0	3.2	2.6	1.4	2.4
Nairobi	0.3	2.2	0.3	3.7	2.6	1.7	0.01	0.8	0.4	0.4	0.5
Coast	0.1	0.4	0	0.8	1.3	0.9	0.5	0.5	0.3	0.3	0.5
National mean	2.4	1.9	1.9	2.6	3.0	3.8	2.4	2.4	1.9	1.8	2.4

Table 9 shows the total number of goats slaughtered in Kenya during each of the 10 years, the number found to be infected with *Fasciola spp* at post-mortem meat inspection, and the calculated percentage prevalence of fasciolosis. The annual prevalence of fasciolosis in goats in the entire country is also graphically presented in Figure 6. There was a drop in the total number of goats slaughtered in the entire country from 1990 to 1995, that later increased in the next 2 years to drop again in 1997 to 1999. The calculated prevalence of fasciolosis in goats in the entire country was 2.4% in 1990, it dropped to 1.9% in 1991, rose again to 2.6% in 1993 to reach the maximum of 3.8% in 1995 and then dropped steadily to 1.8% in 1999. As observed in majority of the provinces in Table 8, there was an overall increase in the prevalence of fasciolosis in the country between 1990 (2.4%) and 1995 (3.8%), and then a drop from (3.8%) in 1995 to (1.8%) in 1999.

Table 9. The total number of goats slaughtered in Kenya annually during the period 1990 – 1999, the number found to be infected with *Fasciola spp* at post mortem meat inspection and the calculated overall prevalence of fasciolosis.

Year	Number of goats slaughtered	Total infected With *Fasciola spp*	Prevalence (%)
1990	239,076	5,646	2.4
1991	208,597	4,004	1.9
1992	236,082	4,466	1.9
1993	176,260	4,609	2.6
1994	195,641	5,893	3.0
1995	164,161	6,159	3.8
1996	219,633	5,351	2.4
1997	242,437	5,809	2.4
1998	198,906	3,750	1.9
1999	182,035	3,202	1.8
TOTAL	2,062,828	48,889	2.4

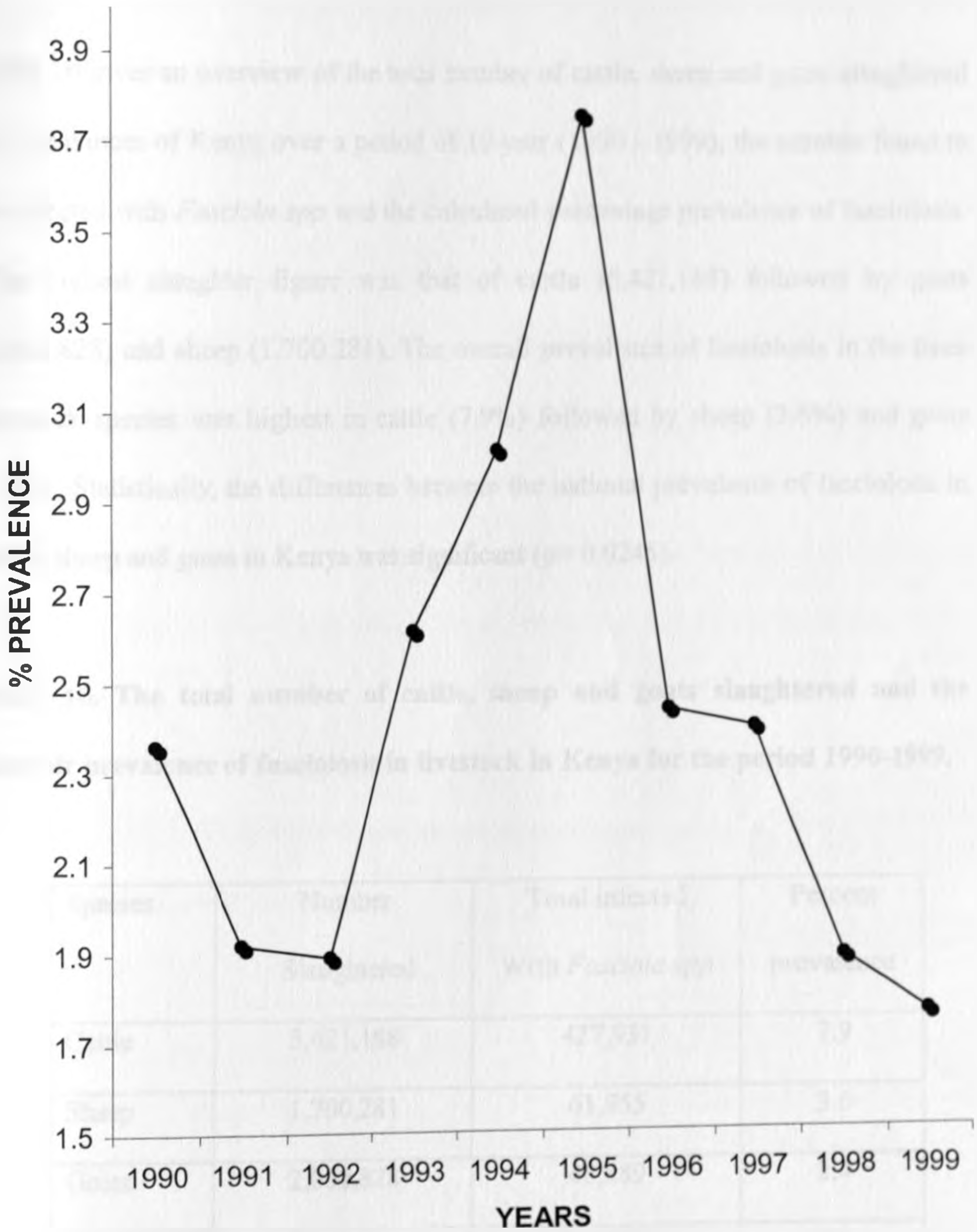

Figure 6. Trends in the prevalence of fasciolosis in goats in Kenya over the period 1990 - 1999 based on meat inspection records.

4.1.4. A comparison of the results on the abattoir prevalence of fasciolosis in cattle, sheep and goats for the period 1990-1999.

Table 10 gives an overview of the total number of cattle, sheep and goats slaughtered in 7 provinces of Kenya over a period of 10 year (1990 - 1999), the number found to be infected with *Fasciola spp* and the calculated percentage prevalence of fasciolosis. The highest slaughter figure was that of cattle (5,421,188) followed by goats (2,062,828) and sheep (1,700,281). The overall prevalence of fasciolosis in the three livestock species was highest in cattle (7.9%) followed by sheep (3.6%) and goats (2.4%). Statistically, the differences between the national prevalence of fasciolosis in cattle, sheep and goats in Kenya was significant (p= 0.0245).

Table 10. The total number of cattle, sheep and goats slaughtered and the abattoir prevalence of fasciolosis in livestock in Kenya for the period 1990-1999.

Species	Number Slaughtered	Total infected With *Fasciola spp*	Percent prevalence
Cattle	5,421,188	427,931	7.9
Sheep	1,700,281	61,955	3.6
Goats	2,062,828	48,889	2.4
Total	9,184,297	538,775	5.9

Table 11 gives an overview of the annual prevalence of fasciolosis in cattle, sheep and goats slaughtered in 7 provinces of Kenya over a period of 10 year (1990 - 1999). The highest prevalence of fasciolosis in cattle was in 1996 (9.8%) followed by 1995 (9.3%), while the lowest prevalence in the same animal species was in 1991 (6.0%). The prevalence of fasciolosis in cattle was uneven throughout the ten years and so the pattern can be described as an up and down trend. This is also demonstrated in Figure 8. In sheep the highest prevalence of 6.2% was recorded in 1995, and then dropped to 4.1% in 1994. The lowest prevalence in sheep was 0.6% and this was recorded in 1997. Prevalence of fasciolosis in goats was lower than in cattle and sheep and the highest prevalence in goats was 3.6% in 1995 followed by a prevalence of 3.0% of 1994. The lowest prevalence was 1.8% recorded in 1999. An increase in prevalence of fasciolosis was noted in all the three species between 1993 and 1996 relative to the other years.

Table 11. The overall annual prevalence of fasciolosis in cattle, sheep and goats over the period 1990 – 1999.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Mean
Cattle	7.3	6.0	7.4	6.6	8.3	9.3	9.8	7.9	8.9	9.2	7.9
Sheep	4.0	3.2	3.0	3.9	4.1	6.2	3.3	3.0	2.8	3.1	3.6
Goats	2.4	1.9	1.9	2.6	3.0	3.6	2.4	2.4	1.9	1.8	2.4

Table 12 shows the mean prevalence of fasciolosis in cattle, sheep and goats slaughtered in 7 provinces of Kenya over a period of 10 years (1990 - 1999). The table shows that the prevalence of fasciolosis in all three species of livestock was highest in Western province. For cattle, this was followed by Eastern, Nyanza and Rift Valley provinces. The second, third and fourth highest prevalence of fasciolosis in sheep and goats was recorded in Nyanza, Eastern and Central Province, respectively. Coast province and Nairobi province had the lowest prevalence of fasciolosis in all the three species. While the prevalence of fasciolosis in cattle and sheep was higher in Eastern province than Central province, the prevalence of fasciolosis in goats is higher in Central province. When comparing Nairobi and Coast province, the prevalence in all the three livestock species is nearly the same, but with Nairobi province having a slightly higher prevalence than Coast province. Figure 7 compares prevalence in all the three livestock species in various provinces, while Figure 8 compares the prevalence trends in the three livestock species over the ten-year period. The difference between the mean provincial prevalence of fasciolosis in cattle, sheep and goats was statistically significant (p= 0.0124). The difference between the districts prevalence of fasciolosis in cattle, sheep and goats was significant (p= 0.0154).

Table 12. A comparison of the prevalence of fasciolosis in cattle, sheep and goats slaughtered in seven provinces of Kenya.

	Nairobi	Western	Coast	Eastern	Central	R. Valley	Nyanza	Mean
Cattle	3.9	16.1	3.5	11.3	6.1	8.3	8.9	7.9
Sheep	0.9	10.1	0.7	4.8	3.5	2.6	8.7	3.6
Goats	0.5	9.1	0.5	2.7	4.4	2.4	4.7	2.4

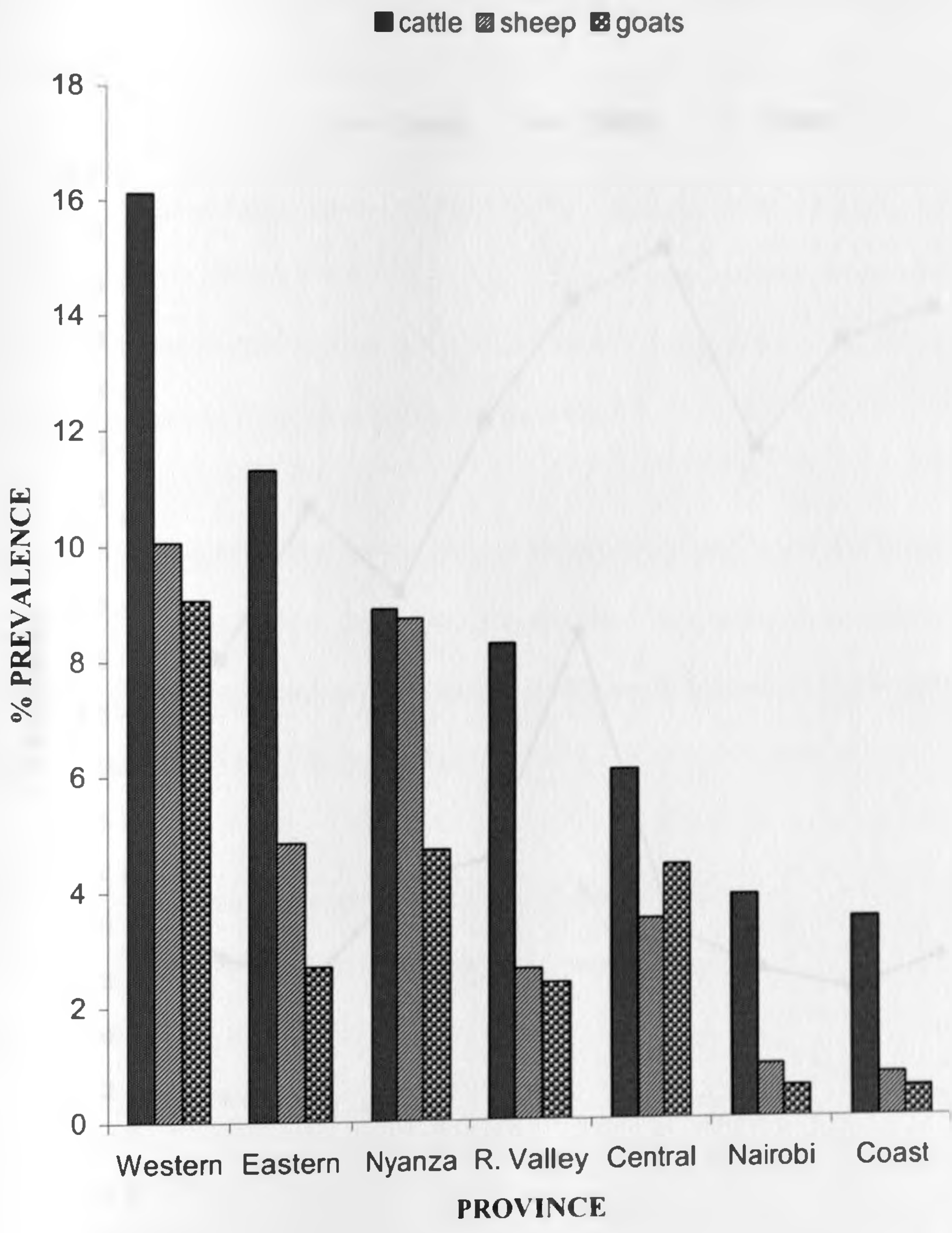

Figure 7. The overall prevalence of fasciolosis in cattle, sheep and goats in the seven provinces of Kenya in the period 1990-1999 based on meat inspection records.

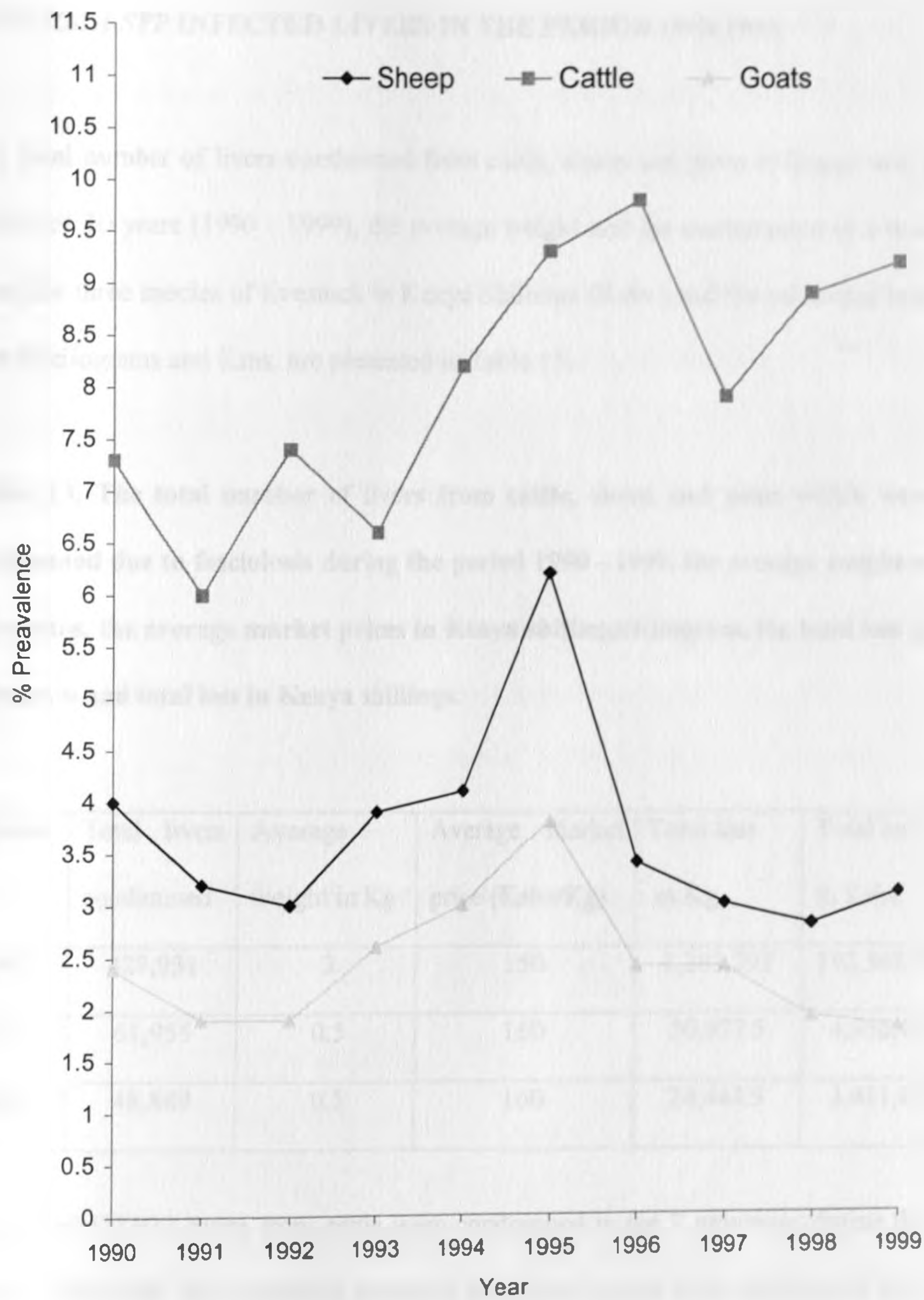

Figure 8. Trends in the prevalence of fasciolosis in cattle, sheep and goats in Kenya over the period 1990-1999 based on meat inspection records.

4.2. THE ECONOMIC LOSSES OCCASIONED BY CONDEMNATION OF *FASCIOLA SPP* INFECTED LIVERS IN THE PERIOD 1990-1999.

The total number of livers condemned from cattle, sheep and goats in Kenya over a period of 10 years (1990 - 1999), the average weight and the market price of a liver from the three species of livestock in Kenya Shillings (Kshs.) and the calculated total loss in kilograms and Kshs. are presented in Table 13.

Table 13. The total number of livers from cattle, sheep and goats which were condemned due to fasciolosis during the period 1990 - 1999, the average weight in kilograms, the average market prices in Kenya shillings/Kilogram, the total loss in Kilogram and total loss in Kenya shillings.

Species	Total livers condemned	Average weight in Kg	Average market price (Kshs/Kg).	Total loss in Kg	Total loss in Kshs.
Cattle	427,931	3	150	1,283,793	192,568,950
Sheep	61,955	0.5	160	30,977.5	4,956,400
Goats	48,889	0.5	160	24,444.5	3,911,120

A total of 427,931 livers from cattle were condemned in the 7 provinces during the period 1990-1999. The calculated economic loss from bovine livers condemned over this period, using the average current market price of Kshs.150 / Kg and an average weight of 3 kg for bovine livers, was Kshs. 192,568,950. The average annual loss was calculated to be Kshs. 19,256,895.

A total of 61,955 livers from sheep were condemned due to fasciolosis during the same period. The total economic loss for the ten years period, calculated using an average current market price of Kshs.160 / Kg and average weight of 0.5 Kg per liver was Kshs. 4,956,400. The average annual loss was Kshs. 495,640.

For goats, 48,889 livers were condemned due to fasciolosis. The total economic loss resulting from this, calculated using an average current market price of Kshs.160 / Kg and the estimated average weight of 0.5 Kg per liver was Kshs. 3,911,120. On average the annual loss was calculated to be Kshs. 391,112.

The total economic loss from the three animal species was Kshs. 201,436,470 (approx. US $ 2,685,819.6). The highest economic loss resulted from condemnation of *Fasciola*-infected livers from cattle followed by sheep and goats. Appendix 1, 3 and 5 show losses per district and province for cattle, sheep and goats, respectively. Annual losses in cattle, sheep and goats are also shown in Table 14, while in Table 15 the total losses in cattle, sheep and goats in the seven provinces are shown.

Table 14. Annual losses as a result of condemnation of *Fasciola spp*-infected livers from cattle, sheep and goats during the period 1990 –1999 in Kshs.

YEAR	CATTLE	SHEEP	GOATS	Total
1990	20,466,000	639,840	451,680	21,557,520
1991	17,344,350	515,040	320,320	18,179,710
1992	22,412,700	472,400	357,280	23,242,380
1993	18,226350	468,480	368,720	19,063,550
1994	20,564,100	538,720	471,440	21,574,260
1995	20,403,000	746,160	492,720	21,641,880
1996	20,826,450	454,800	428,080	21,709,330
1997	18,261,450	433,760	464,720	19,159,930
1998	18,445,500	340,880	300,000	19,086,380
1999	15,619,050	346,320	256,160	16,221,530
TOTAL	192,568,950	4,956,400	3,911,120	201,436,470

As shown in Table 14, the total annual economic losses in the country as a result of condemnation of *Fasciola*-infected livers ranged from approximately 16 million to 23 million. The highest loss was recorded in 1992 when Kshs. 23,242,380 was lost, and lowest in 1999 when Kshs.16,221,530 million was lost from all the three livestock species. The highest loss in cattle was noted in 1992 when Kshs. 22,412,700 was lost, while in goats the highest loss was in 1995 when Kshs. 492,720 was lost and in sheep it was in 1995 when Kshs 746,160 was lost. Individually the lowest losses were in 1999, being Kshs. 15,619,050 in cattle, Kshs. 256,160 in goats and Kshs. 340,880 in 1998 in sheep.

Table 15. The total losses in Kenya shillings for cattle, sheep and goats slaughtered in seven provinces of Kenya during the period 1990 - 1999 as a result of condemnation of *Fasciola*-infected livers.

	Nairobi	Western	Coast	Eastern	Central	R. Valley	Nyanza	TOTAL
Cattle	5511600	56997000	15612750	30546450	50209200	27285300	6406650	192568950
Sheep	42560	1564320	208240	652000	1348160	856320	284800	4,956,400
Goats	45440	910640	314320	1078000	748080	540400	274240	3911120
Total	5599600	59471960	16135310	32276450	52305440	27844340	6965690	201436470

The highest economic losses due to fasciolosis was recorded in Western province, followed by Nairobi, Central, Eastern, Rift Valley, Coast and finally Nyanza province which recorded the least losses. In cattle the province that lost the highest amount of money was Western province, where Kshs. 56,997,000 was lost within the ten years. The province that lost the lowest amount of money was Nairobi province where Kshs. 5,511,600 was lost. Similarly in sheep, the province that lost the highest revenue was Western province (Kshs. 1,564,320) within the ten years, while the province that recorded lowest loss in revenue from sheep, due to fasciolosis was Nairobi (Kshs. 42,560). The total loss from liver condemnation in goats was Kshs. 3,911,120 from all the provinces. Eastern province took the lead in revenue loss, with a loss of Kshs. 1,078,000 within the ten years. The lowest loss in goats due to fasciolosis was recorded in Nairobi province (Kshs. 45,440). The total loss from all the three livestock species was highest in Western province (Kshs. 59,471,960), followed by Central province (Kshs. 52,305,440), Eastern province (Kshs. 32,276,450), Rift Valley province (Kshs. 27,844,340), Coast province (Kshs. 16,135,310), Nyanza province (Kshs.

6,965,690) and lastly Nairobi province (Kshs. 5,599,600). The highest national economic loss due to condemnation of *Fasciola*-infected livers was recorded in cattle (Kshs. 192,568,950), followed by sheep (Kshs. 4,956,400) and then goats (Kshs. 3,911,120).

4.3. THE PREVALENCE AND TYPES OF *FASCIOLA SPECIES* IN CATTLE, SHEEP AND GOATS BASED ON SAMPLES COLLECTED DURING POST-MORTEM MEAT INSPECTION AT DAGORETTI ABATTOIRS.

4.3.1. Cattle

During post mortem meat inspection at Dagoretti slaughter house, details of the age, sex and origin of cattle, sheep and goats found to be infected with *Fasciola spp*, the number of liver flukes found in the livers and the size and species of the liver flukes identified from the three livestock species were recorded. During the post mortem meat inspection, livers from a total of 1,584 cattle from five provinces of Kenya were inspected. Out of the 1,584 cattle inspected 1,273 (80.4%) were from Rift Valley province, 41 (2.6%) were from Western province, 119 (7.5%) were from Central province, 134 (8.5 %) were from Eastern province and 17 (1.1%) were from North Eastern province. No cattle from Nairobi Province, Coast Province and Nyanza Province were inspected. Out of the 1,584 cattle inspected, 147 (9.3%) had liver flukes. Of these, 6 (4.1%) had chronic and very extensively damaged livers, 4 of these were from Kiambu District and 2 from Thika District in Central Province. A total of 30 of the infected livers (20.0%) were extensively damaged, 90 (61.2%) had medium damage, while 19 (12.9%) had no visible liver damage. Among the 147 cattle with fasciolosis, 76 (51.7%) were males, whereas 71 (48.3%) were females. Among the 147 cattle with fasciolosis 80 (54.4%) originated from Rift Valley province, 34 (23.1%) from Central province, 24 (16.3%) from Eastern province, 3 (2.0%) from North Eastern province, while 6 (4.1%) were from Western province. All the liver flukes collected from the 147 livers were identified as *F. gigantica*.

Table 16. Number of cattle slaughtered in Dagoretti abattoirs during the study period, provinces of origin, the number found to be infected and their prevalence.

	N. Eastern	Central	Nairobi	Western	R. Valley	Eastern	Coast	Nyanza	Total
Origin	17	119	0	41	1,273	134	0	0	1584
Infected (%)	3 (17.6%)	34 (25.6%)	0	6 (14.6%)	80 (6.3%)	24 (17.9)	0	0	147 (9.3%)
F. gigantica	3	34	0	6	80	24	0	0	147
F.hepatica	0	0	0	0	0	0	0	0	0

4.3.2. Sheep

During the post mortem meat inspection, livers from a total of 989 sheep were inspected, out of these 8 (0.8%) had liver flukes. No visible damage was detected, in the livers of infected sheep. All the flukes collected from infected livers were *F. gigantica*. Out of the 989 sheep inspected 156 (15.8%) came from North Eastern, 5 (0.5%) came from Central province, 73 (7.4%) came from Eastern province, while Rift valley contributed 755 (76.3%) as shown in Table 17. None of the examined sheep came from

Nairobi, Coast, Western and Nyanza province. Among the 8 sheep with fasciolosis 5 (62.5%) were males, whereas the other 3 (37.5%) were females. Seven (87.5%) of the infected sheep originated from Rift Valley province and 1 (12.5%) from Central province. Other provinces did not record any infected sheep.

Table 17. Number of sheep slaughtered in Dagoretti abattoir during the study period, province of origin and the number found to be infected and their prevalence.

	N. Eastern	Central	Nairobi	Western	R. Valley	Eastern	Coast	Nyanza	Total
Originating	156	5	0	0	755	73	0	0	989
Infected (%)	0	1 (0.2%)	0	0	7 (0.93%)	0	0	0	8 (0.81%)
F. gigantica	0	1	0	0	7	0	0	0	8
F. hepatica	0	0	0	0	0	0	0	0	0

4.3.3. Goats

During the post mortem meat inspection, livers from a total of 954 goats were inspected, out of which 4 (0.4%) had liver flukes. No visible liver damage was detected in any of the infected livers. Of the 954 goats inspected 230 (24.1%) came from North-Eastern, 8 (0.8%) came from Central province, 82 (8.6%) came from Eastern province, while Rift valley contributed 634 (66.5%). None of the examined goats came from Nairobi, Coast, Western and Nyanza provinces as shown in Table 18.

All the liver flukes collected from infected goats were *F. gigantica*. Among the 4 goats with fasciolosis 2 were males, whereas the other 2 were females and all originated from Rift Valley province. Other provinces did not record any infected goat.

Table 18. Number of goats slaughtered in Dagoretti abattoirs during the study period, provinces of origin and the number found to be infected and their prevalence.

	North Eastern	Central	Western	Nairobi	Rift Valley	Eastern	Coast	Nyanza	Total
Origin	230	8	0	0	634	82	0	0	954
Infected (%)	0	0	0	0	4 (0.6%)	0	0	0	4 (0.4%)
F. gigantica	0	0	0	0	4	0	0	0	4
F. hepatica	0	0	0	0	0	0	0	0	0

CHAPTER 5. DISCUSSION AND CONCLUSIONS.

5.1. DISCUSSION.

Fasciolosis is the most common trematode infection in domestic ruminants throughout the world and is of great economic importance (Blood *et al.* 1994). The current study sought to investigate, using retrospective post-mortem meat examination records, the burden of fasciolosis disease and subsequent economic impact in the livestock industry. In addition, the study investigated infection by *Fasciola* spp within 3 species of meat animals, cattle, sheep and goats. The results from the post mortem meat inspection records helped in mapping of the disease in livestock in Kenya, by determining the prevalence of livestock fasciolosis within the seven provinces of Kenya. North Eastern province was the only province whose prevalence was not determined since there were no records from that region. The records were unavailable because the Veterinary Department had not taken over the meat inspectorate services from the Ministry of Health in this province.

The prevalence of fasciolosis observed in this study in various provinces of Kenya was similar to what Fabiyi and Adeleye, (1982) and Ogunrinade (1983) observed in Nigeria, with areas that receive high rainfall having higher prevalence than the dry areas. In this study, Western province of Kenya was found to have the highest prevalence of fasciolosis in cattle, sheep and goats. Western province recorded high prevalence probably because of the high annual rainfall 1200-2200 mm in the region (Kenya Atlas, 1991) and the high presence of *Lymnaea natalensis* (Brown, 1980), *L. natalensis* is the snail intermediate host for *F. gigantica* in Kenya (Cheruiyot; 1983). The association of a high incidence of livestock fasciolosis with high rainfall areas of

Kenya indicates that *L. natalensis* snails, the intermediate hosts of *F.gigantica* are most plentiful in wetter regions of Kenya. This does not mean that *L. natalensis* snails do not exist in low rainfall areas. The evidence available for the occurrence of *L. natalensis* in drier districts is that there is a low incidence of the disease in these districts (Bitakaramire, 1973, Ogunrinade, 1981). The other possible explanation for the high prevalence of livestock fasciolosis in Eastern, Nyanza and Western province is the high population of livestock (Kenya Atlas, 1991), which helps in perpetuation of the disease. Livestock in these provinces are also kept under extensive production systems, where they are grazed outdoors and taken to drink water at the wells, springs, accumulated water masses and rivers. This increases the contact between the *Fasciola spp* eggs and the snails. In addition it provides a good environment for egg hatching and later ingestion of the metacercariae by the livestock as they drink water and feed on the watercress (Bitakaramire, 1973, Lammert *et al.*, 2000). Coast province recorded the lowest prevalence in the three livestock species. Hardly is *L. natalensis* found in the coastal region (Brown, 1980). There are also few if any water masses that accumulate in this region. The other probable reason is the high temperatures experienced in Coast province, which do not favour the development of *Fasciola* eggs to cercariae. Bitakaramire (1973) demonstrated that in dry areas, *L. natalensis* snails might survive in dry mud for about 6 months and start multiplying again when wet conditions return. But in the driest regions, i.e. with a mean annual rainfall of less than 250 mm like some parts of coastal region there is apparently no sufficient moisture to maintain snail life for the continual propagation of fasciolosis in these areas, again the evaporation rate is too high.

The prevalence of fasciolosis in cattle in Kenya has been reported by several authors (Bitakaramire, 1969, Cheruiyot, 1983, Waruiru *et al.*, 1992, Ogeto, 1993, Githigia, *et al.* 1995) but only limited information on epidemiology is available on fasciolosis in sheep (Maingi et al, 1997). In this study, the national prevalence of fasciolosis in goats was found to be 2.4% and that of sheep to be 3.6%.

The overall national prevalence of fasciolosis in cattle, sheep and goats in Kenya reported in this study were slightly lower than those reported by most of the previous authors. For example, Bitakaramire (1973) reported a national prevalence of 13-21% in cattle, Cheruiyot, (1983) reported a national prevalence of 10-13% in cattle, and Ogeto, (1993) reported a national prevalence of 13% in cattle. However, compared to the current study, the report by Bitakaramire (1973) and that by Cheruiyot (1983) were based on slaughterhouse (K.M.C) data while that by Ogeto (1993) was based on V. I. L and serological results. The low prevalence recorded in this study could partly be due to the type of data used compared to the other studies and possible extensive use of anthelmintic/flukicides against liver flukes and molluscicides to kill snails. The low prevalence may also have been contributed by the stoppage of the Kenyan Government in offering clinical veterinary services to livestock farmers. This task has been taken over by private veterinary practitioners who may be providing more efficient services in mostly the high potential areas they set their practices.

Improved systems of reporting and better meat inspection procedures in most slaughterhouses and slaughter slabs in Kenya observed in the recent years (Ndirangu, 2001) may have enlightened many farmers on the economic importance of fasciolosis, leading them to improve on the deworming / parasite control in their livestock. Low prevalence rate recorded in this study could also be linked to improved animal husbandry techniques as observed by Olusi (1996) in Maiduguri, Borno state, Nigeria.

From the post mortem meat inspection records kept for cattle, sheep and goats slaughtered in seven provinces of Kenya during the period 1990-1999, cattle had the highest prevalence of fasciolosis followed by sheep and goats in that order. This was true both at national level and in all provinces except Central province. Similar results were reported by Anon (1986). The low prevalence recorded for goats and sheep may partly be explained by the fact that the exposure time to fasciolosis is shorter for sheep and goats (Olusi, 1996). This is partly because of their feeding habits. Also it is thought that, the lesions in sheep and goats require experience to diagnose as the bile ducts are enlarged without much thickening (Olusi, 1996), so that the meat inspectors with limited experience of the disease in goats and sheep may miss it. Furthermore the life cycle of *F.gigantica* tends to favour infection of grazing animals than browsing animals like goats (El Sahouri *et al,* 1987, Roundelaud *et al.,* 2001). Sheep and goats are often confined by their owners and are hand-fed. This greatly reduces their chances of acquiring fluke infection (Olusi, 1996). According to Schillhorn van Veen (1980) cattle harbour chronic infections for long periods and such infections are only revealed at post-mortem meat inspection. Small ruminants on the other hand succumb to fasciolosis and never reach slaughter slabs and this could be a possible reason why sheep and goats had lower prevalence than cattle despite coming from same region. Goats are reared in drier areas than sheep and cattle. Goats are also known to develop resistance to fasciolosis (Doy and Hughes, 1984, Harouni and Yagi, 1985, El Sahouri *et al.* 1987; Harouni *et al.*

1989), which does not occur in sheep and cattle because Harouni and Yagi (1985) showed that a primary infection with *F. gigantica* in goats stimulates resistance to homologous and future challenge.

The prevalence of fasciolosis in cattle found in the abattoir records is lower than the 10-13% revealed by similar studies in Kenya (Bitakaramire, 1969), 36.5% reported in Uganda (Magona *et al.* 1999) and 21% reported in Ethiopia by Tegene (1994) who used slaughterhouse data. The prevalence calculated from post-mortem inspection was higher than what was calculated from the records; such a higher prevalence can be explained by the special efforts made during inspection. In routine inspection the inspectors avoid mutilating liver by cuts, which may reduce the sale value of the organ. Bitakaramire, (1973) also noted this.

No sex relationship was established between the prevalence of fasciolosis in any of the livestock species in this study and the conclusion made was that all sexes have equal chances of being infected. All slaughtered animals were adults and their age did not influence the extent of liver fluke infection.

From all the 147 liver flukes collected from infected cattle at Dagoretti slaughterhouse it was found out that all were *F. gigantica*. Mitchell, (1968) reported that Kenya and Uganda are inhabited solely by *F. hepatica* while Tanzania is exclusively a *F. gigantica* territory. But Bitakaramire (1968) reported that in Kenya, fasciolosis of cattle is mainly due to *F. gigantica*. Ogambo-ongoma (1969) reported the incidence of *F. hepatica* in Kenyan cattle as being slight and confined to the highlands, while the vast majority of cases of fasciolosis, whether in highlands or at lower altitudes being due to *F.gigantica*. In Kenya, although there has been reference to the presence of *F. hepatica*, by Froyd (1959) and Mitchell, (1968), the most important species causing fasciolosis in cattle, sheep and goats is *F.gigantica*. This species is endemic in most districts of Kenya, as was supported by the findings of this study where all the liver flukes detected in animals from various districts at Dagoretti slaughterhouses were *F. gigantica* and none was *F. hepatica*.

The monthly disease incidences in the districts as determined from the abattoir records indicate a peak incidence during the months of July to October. Maingi and Mathenge (1995) had obtained similar results. This seasonal incidence observed in monthly records may be explained in terms of the seasonal migration in search of water and fodder during dry season. Because of the reduction in water level at this time, cattle are able to graze in the affected areas and thus acquire an infection (Ogunrinade, 1983). The annual variation in the incidence of fasciolosis may be associated with climatic changes, which affect field conditions that influence multiplication and transmission of the parasite and the frequency of cattle and water contact (Blood *et al*, 1994).

The survey has revealed that huge amount of revenue was lost in Kenya during the period 1990-1999, due to condemnation of *Fasciola*-infected livers. The total loss was estimated to be Ksh. 206 million (approx. US $ 2,575,000). The highest economic loss resulted from condemnation of *Fasciola*-infected livers of cattle. Bitakaramire (1969) reported that the Kenya Meat Commission lost Kshs. 567,000 yearly due to fasciolosis, while the ARF report (Anon, 1986) indicated that the livestock industry in Kenya looses about Kshs. 321 million annually due to fasciolosis. The economic loss reported in this study is lower than what the Anon (1986) reported mainly because it is only the condemned livers that were examined. But the figure reported here is larger than what Bitakaramire (1969) and Cheruiyot (1983) reported possibly because the number slaughtered was larger and also because of the prices used. Although Central province had a low prevalence it lost more revenue mainly because it slaughtered a lot of animals and this also underlines the importance of carrying out estimates of economic losses, rather than relying on prevalences alone to establish the importance of a disease.

This study has demonstrated that fasciolosis is an important disease in ruminants in Kenya, which causes major economic losses as has been reported previously by other investigators. There is therefore need to intensify control measures for the disease in order to minimize these losses. There is also need to educate the public on the importance of this disease as a starting point to controlling it. The human medical doctors should also be enlightened on this disease so that they may consider it as a differential diagnosis in all liver insufficiency conditions especially in this era of HIV/AIDS. Fasciolosis may be a debilitating condition in human beings.

5.2. CONCLUSIONS

1. Fasciolosis is present in cattle, sheep and goats in Kenya. During the 10 years covered in this study, cattle had the highest prevalence of the disease, followed by sheep and goats.

2. Fasciolosis was recorded in cattle, sheep and goats from all provinces in Kenya, but the prevalence was highest in Western province for all the three species of livestock. The lowest prevalence of fasciolosis was recorded in Coast province. The high prevalence of fasciolosis recorded in Western province is probably because of the high rainfall, high livestock density and presence of the snail intermediate host in the area.
3. *Fasciola gigantica* was the only species of *Fasciola spp* recovered from infected livers from all three species of livestock, examined at Dagoretti slaughterhouses. The occurrence of *F. hepatica* in cattle, sheep and goats in Kenya is minimal or none.
4. Fasciolosis in cattle, sheep and goats is of great economic importance in Kenya. The large amount of money lost due to condemnation of liver fluke-infected livers indicates this. Average annual national economic losses of Kshs. 19,256,895 (approx. US $ 240,711), Kshs. 987,024 (approx. US $ 12,338) and Kshs. 391.112 (approx. US $ 4,889) were recorded in cattle, sheep and goats respectively, during the 10 years period.
5. The prevalence of fasciolosis infection of 7.8 % in mostly traditionally managed cattle at a productive age is high. There is need for urgent attention of establishing a programme for instituting appropriate control measures to prevent production losses, given that farmers keeping cattle under such management do not currently practise any routine control measures against *Fasciola spp* infection.

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7.0. APPENDICES

Appendix 1. Distribution by District of the number of cattle slaughtered, number infected with *Fasciola spp*, prevalence and economic losses in each of the 7 provinces of Kenya in the period 1990-1999.

Province	District	Total slaughtered	No. Infected	Prevalence.	Economic Loss
Nairobi	Nairobi	314758	12248	3.9	5511600
Western	Lugari	8972	1605	17.9	722250
	Vihiga	58738	8281	14.1	3726450
	Busia	77916	21811	28.0	9814950
	Kakamega	504554	72191	14.3	32485950
	Mt. Elgon	3959	635	16.0	285750
	Teso	9548	1706	17.9	767700
	Bungoma	122186	20431	16.7	9193950
Total		**785873**	**126660**	**16.2**	**56997000**
Coast	Mombasa	258604	4930	1.9	2218500
	Malindi	16647	1	0.01	450
	Kwale	348963	16357	4.7	7360650
	Kilifi	276978	4040	1.5	1818000
	Taita Taveta	86350	9275	10.7	4173750
	Lamu	7562	92	1.2	41400
TOTAL		**995104**	**34695**	**3.5**	**15612750**
Eastern	Kitui	19988	3098	15.5	1394100
	Mbeere	5238	489	9.3	220050
	Machakos	223472	37027	16.6	16662150
	Embu	124141	10024	8.1	4510800
	Meru	147696	7358	5.0	3311100
	Makueni	79365	9885	12.5	4448250
TOTAL		**599900**	**67881**	**11.3**	**30546450**
Central	Thika	35543	4372	12.3	1967400
	Kirinyaga	121400	21577	17.8	9709650
	Nyandarua	82795	9964	12.0	4483800
	Nyeri	144508	14091	9.8	6340950
	Maragua	20167	2904	14.4	1306800
	Kiambu	1310977	42947	3.3	19326150
	Muranga	118911	15721	13.2	7074450
TOTAL		**1834301**	**111576**	**6.1**	**50209200**
R. Valley	Nakuru	202107	18849	9.3	8482050

	Kericho	60718	9181	15.1	4131450
	Kajiando	270181	12027	4.5	5412150
	Laikipia	72004	6972	9.7	3137400
	T. Nzoia	29144	5479	18.8	2465550
	U. Gishu	95388	7958	8.3	3581100
	Koibatek	1896	168	8.9	75600
TOTAL		**731438**	**60634**	**8.3**	**27285300**
Nyanza	Homa Bay	19336	1020	5.3	459000
	Kisii	24762	2129	8.6	958050
	Siaya	14490	1510	10.4	679500
	Kisumu	101226	9578	9.5	4310100
TOTAL		**159814**	**14237**	**8.9**	**6406650**

Appendix 2. The number of cattle slaughtered annually in each of the 7 provinces of Kenya during the period 1990 - 1999, the number found to be infected with *Fasciola spp*, and the calculated percentage prevalence of fasciolosis.

	1990			1991			1992			1993			1994		
Province	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%
Nairobi	23767	676	2.8	25526	509	1.9	24087	822	3.4	37405	982	2.6	41102	1136	2.7
Western	105022	15813	15.0	109455	9384	8.5	113090	19219	16.9	63841	10920	17.1	88828	13025	14.6
Coast	105548	3189	3.0	122629	4708	3.8	127777	4509	3.5	134306	3968	2.9	86209	3716	4.3
Eastern	58398	6587	11.2	62372	7170	11.4	70638	7316	10.3	60376	7577	12.5	53714	6874	12.7
Central	241065	12012	4.9	221977	9854	4.4	233153	10593	4.5	220828	10300	4.6	196720	11989	6
R. Valley	78100	5818	7.4	91798	5703	6.2	91977	5498	5.9	82512	5189	6.2	72172	6914	9.5
Nyanza	11848	1385	11.6	12074	1215	10.0	12703	1649	12.9	16143	1567	9.7	14577	2044	14
Mean	623748	45480	7.2	645831	38543	5.9	673425		7.3	615411	40503	6.5	553322	45698	8.2

	1995			1996			1997			1998			1999		
Province	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%
Nairobi	36256	1568	4.3	28641	1682	5.8	30053	1657	5.5	32801	1405	4.2	35120	1811	5.1
Western	75642	14917	19.7	70955	14644	20.6	55958	9965	17.8	66086	12231	18.5	36996	6342	17.1
Coast	84533	3138	3.7	83702	3173	3.7	95053	3123	3.2	94145	2994	3.1	61202	2177	3.5
Eastern	48235	7419	15.3	46649	7127	15.2	114990	6706	5.8	41985	5652	13.4	42543	5453	12.8
Central	162965	11050	6.7	164801	12688	7.6	131268	11024	8.3	143784	10638	7.3	117740	11428	9.7
R. Valley	65966	6051	9.1	59831	6154	10.2	64289	6972	10.8	59132	6431	10.8	65661	5904	8.9
Nyanza	14279	1197	8.3	17703	813	4.5	21445	1134	5.2	21190	1639	7.7	17852	1594	8.9
Mean	487876	45340	9.2	472282	46281	9.7	513056	40581	7.9	459123	40990	8.9	377114	34709	9.2

Key:
Sld. = Number of cattle slaughtered

Inf. = Number found to be infected with *Fasciola spp* at post mortem meat inspection.

% = Calculated prevalence of fasciolosis

Appendix 3. Distribution by District of the number of sheep slaughtered, number infected with *Fasciola spp*, prevalence and economic losses in each of the 7 provinces of Kenya in the period 1990-1999.

Province	District	Total slaughtered	Infected livers	Prevalence	Economic losses
Nairobi	**Nairobi**	**57960**	**532**	**0.9**	**42560**
Western	Lugari	2731	104	3.8	8320
	Vihiga	3537	170	4.8	13600
	Busia	8080	1656	20.5	132480
	Kakamega	112509	12286	10.9	982880
	Mt. Elgon	3160	68	2.2	5440
	Teso	5100	153	3	12240
	Bungoma	59134	5117	8.7	409360
Total		**194251**	**19554**	**10.1**	**1564320**
Coast	Mombasa	116928	896	0.8	71680
	Malindi	691	0	0	0
	Kwale	184961	1311	0.7	104880
	Kilifi	29131	95	0.3	7600
	Taita Taveta	14099	285	2.0	22800
	Lamu	2518	16	0.6	1280
TOTAL		**348328**	**2603**	**0.7**	**208240**
Eastern	Kitui	1572	23	1.5	1840
	Mbeere	3016	0	0	0
	Machakos	73528	2795	3.8	223600
	Embu	32519	636	2.0	50880
	Meru	33738	2686	8.0	214880
	Makueni	23834	2010	8.4	160800
TOTAL		**168207**	**8150**	**4.8**	**652000**
Central	Thika	2919	364	12.5	29120
	Kirinyaga	9969	760	7.6	60800
	Nyandarua	118273	5802	4.9	464160
	Nyeri	175852	6478	3.7	518240
	Maragua	462	52	11.3	160
	Kiambu	162246	2221	1.4	177680
	Muranga	13760	1175	8.6	94000
TOTAL		**483481**	**16852**	**3.5**	**1348160**
R. Valley	Nakuru	226659	5884	2.6	470720
	Kericho	20431	507	2.5	40560
	Kajiando	103407	2967	2.9	237360
	Laikipia	45646	449	1.0	35920
	T. Nzoia	5780	557	9.6	44560
	U. Gishu	2895	222	7.7	17760
	Koibatek	2501	118	4.7	9440
TOTAL		**407319**	**10704**	**2.6**	**856320**
Nyanza	Homa Bay	1885	110	5.8	8800
	Kisii	11428	637	5.6	50960
	Siaya	272	53	19.5	4240
	Kisumu	27150	2760	10.2	220800
TOTAL		**40735**	**3560**	**8.7**	**284800**

Appendix 4. The number of goats slaughtered annually each year in each of the 7 provinces of Kenya during the period 1990 - 1999, the number found to be infected with *Fasciola spp*, and the calculated percentage prevalence of fasciolosis.

Province	1990			1991			1992			1993			1994		
	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%
Western	15648	1176	7.5	16973	260	1.5	15685	1069	6.8	10623	526	4.9	11989	1487	12.4
Eastern	63649	1555	2.4	60563	1483	2.4	61222	1487	2.4	40175	1390	3.4	48576	1487	3.0
Nairobi	5622	121	2.1	6545	147	2.2	7665	443	5.7	5755	316	5.4	7728	272	3.5
R. Valley	29362	817	2.7	33072	821	2.4	32411	491	1.5	27240	620	2.2	24662	834	3.3
Central	27977	1852	6.6	26792	937	3.4	21649	962	4.4	13177	1063	8.0	16951	669	3.9
Nyanza	10584	32	0.3	5554	121	2.1	4336	14	0.3	1008	37	3.6	951	25	2.6
Coast	86234	93	0.1	59098	235	0.3	93114	0	0	78282	657	0.8	84784	1119	1.3
Mean	239076	5646	2.3	208597	4004	1.9	236082	4466	1.8	176260	4609	2.6	195641	5893	3.0

Province	1995			1996			1997			1998			1999		
	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%
Western	11779	2427	20.6	11711	1700	14.5	11733	1422	12.1	12286	752	6.1	7194	564	7.8
Eastern	45307	1393	3.0	46823	1405	3.0	51328	1490	2.9	40586	919	2.2	41037	866	2.1
Nairobi	6993	475	6.7	8632	629	7.2	8195	321	3.9	7746	320	4.1	7805	384	4.9
R. Valley	23995	529	2.2	29031	594	2.0	31401	1011	3.2	25042	642	2.5	27419	396	1.4
Central	16956	808	4.7	21915	649	2.9	25098	878	3.4	19364	815	4.2	21446	718	3.3
Nyanza	1692	29	1.7	28923	3	0.01	22741	190	0.8	14279	53	0.3	15600	64	0.4
Coast	57439	498	0.8	72598	371	0.5	91941	497	0.5	79603	249	0.3	61534	210	0.3
Mean	164161	6159	3.7	219633	5351	2.4	242437	5809	2.3	198906	3750	1.8	182035	3202	1.7

Key:
Sld. = Number slaughtered
Inf. = Number infected with *Fasciola spp*
% = Calculated prevalence of fasciolosis.

Appendix 5. Distribution by District of the number of goats slaughtered, number infected with *Fasciola spp*, prevalence and economic losses in each of the 7 provinces of Kenya in the period 1990-1999.

Province	District	Total slaughtered	Infected Livers	Prevalence	Economic Losses
Nairobi	**Nairobi**	**105668**	**568**	**0.5**	**45440**
Western	Lugari	339	13	3.8	1040
	Vihiga	5973	286	4.8	22880
	Busia	14088	1889	13.4	151120
	Kakamega	72488	6477	8.9	518160
	Mt. Elgon	1832	25	1.4	2000
	Teso	7059	159	2.3	12720
	Bungoma	23842	2534	10.6	202720
Total		**125621**	**11383**	**9.1**	**910640**
Coast	Mombasa	213862	117	0.1	9360
	Malindi	11586	2	0.01	160
	Kwale	405042	3198	0.8	255840
	Kilifi	64057	262	0.4	20960
	Taita Taveta	58947	848	1.4	67840
	Lamu	11133	54	0.5	4320
TOTAL		**764627**	**3929**	**0.5**	**314320**
Eastern	Kitui	18256	789	4.3	63120
	Mbeere	39605	296	0.7	23680
	Machakos	166826	5067	3.0	405360
	Embu	112575	1032	0.9	82560
	Meru	56290	3242	5.8	259360
	Makueni	105714	3049	2.9	243920
TOTAL		**499266**	**13475**	**2.7**	**1078000**
Central	Thika	9162	197	2.2	15760
	Kirinyaga	44039	3148	7.1	251840
	Nyandarua	25274	1158	4.6	92640
	Nyeri	60735	2356	3.9	188480
	Maragua	5266	191	3.6	15280
	Kiambu	41220	718	1.7	57440
	Muranga	25629	1583	6.2	126640
TOTAL		**211325**	**9351**	**4.4**	**748080**
R. Valley	Nakuru	121958	3513	2.9	281040
	Kericho	19219	387	2.0	30960
	Kajiando	116612	1972	1.7	157760
	Laikipia	15376	127	0.8	10160
	T. Nzoia	4764	441	9.3	35280
	U. Gishu	2884	249	8.7	19920
	Koibatek	2822	66	2.4	5280
TOTAL		**283635**	**6755**	**2.4**	**540400**
Nyanza	Homa Bay	9180	174	1.9	13920
	Kisii	17638	863	4.9	69040
	Siaya	598	97	16.2	7760
	Kisumu	45270	2294	5.7	183520
TOTAL		**72686**	**3428**	**4.7**	**274240**

Appendix 6. The number of sheep slaughtered each year in each of province 7 provinces of Kenya during the period 1990 - 1999, the number found to be infected with *Fasciola spp*, and the calculated percentage prevalence of fasciolosis.

	1990			1991			1992			199[illegible]	
Province	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%	Sld	I[illegible]
Western	23641	2905	12.2	22608	1320	5.8	24675	1554	6.2	10204	8[illegible]
Eastern	20041	889	4.4	19768	825	4.1	23353	864	3.6	16843	9[illegible]
Nyanza	3280	54	1.6	3692	73	1.9	2574	188	7.3	3427	2[illegible]
R. Valley	45315	1459	3.2	43435	1373	3.1	40314	771	1.9	34938	10[illegible]
Central	60254	2546	4.2	63549	2554	4.0	54196	1880	3.4	45016	23[illegible]
Nairobi	8151	81	0.9	7704	73	0.9	7672	89	1.1	1537	6[illegible]
Coast	39575	64	0.1	39116	220	0.5	46602	559	1.1	37035	3[illegible]
Total	200257	7998	3.9	199872	6438	3.2	199386	5905	2.9	149000	58[illegible]

	1995			1996			1997			199[illegible]	
Province	Sld	Inf	%	Sld	Inf	%	Sld	Inf	%	Sld	[illegible]
Western	21050	5020	23.8	21258	1880	8.8	20340	1659	8.1	19580	1[illegible]
Eastern	15119	969	6.4	16792	716	4.2	15511	923	5.9	11886	[illegible]
Nyanza	4737	728	15.3	4832	891	18.4	4800	157	3.2	4437	1[illegible]
R. Valley	34276	993	2.8	45384	896	1.9	48025	1134	2.3	41667	[illegible]
Central	40949	1341	3.2	44847	1171	2.6	45926	1267	2.7	41406	1[illegible]
Nairobi	3342	13	0.3	5859	12	0.2	9933	60	0.6	4805	
Coast	30749	263	0.8	30906	119	0.3	32951	222	0.6	29687	[illegible]
Total	150222	9327	6.2	169878	5685	3.3	177486	5422	0.6	153468	4[illegible]

Key:
Sld. = Number slaughtered
Inf. = Number infected with *Fasciola spp*
% = Calculated prevalence of fasciolosis.