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The prevalence of helminths in warthogs, bushpigs and some antelope species in Limpopo Province, South Africa

by

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ABSTRACT

The aim of the study was to describe the helminth parasites of the common game species in the Limpopo Province, focusing on the northern and western parts where the climate is harsh and dry, with a large area considered to be semi-arid. In total 36 animals were examined which included ten impala, *Aepyceros melampus*, eight kudu, *Tragelaphus strepsiceros*, four blue wildebeest, *Connochaetes taurinus*, two black wildebeest, *Connochaetes gnou*, three gemsbok, *Oryx gazella*, one nyala, *Tragelaphus angasii*, one bushbuck, *Tragelaphus scriptus* and one waterbuck, *Kobus ellipsiprymnus,* as well as six warthogs, *Phacochoerus aethiopicus,* and a single bushpig, *Potamochoerus porcus*.

New host records for species include *Trichostrongylus deflexus* in the blue wildebeest, *Agriostomum gorgonis* in the black wildebeest, *Stilesia globipunctata* in the waterbuck, and *Fasciola hepatica* in the kudu. The only known zoonotic helminth recovered was one hydatid cyst of an *Echinococcus* sp. from the lungs of a warthog.

The total burdens and species variation of the helminths in this study were all consistently low compared to other studies done in areas with higher rainfall. This has practical implications when animals are translocated to areas with higher rainfall and higher prevalence of helminths.

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INTRODUCTION

More than a third of the 14 million hectare comprising the Limpopo Province is dedicated to nature conservancies and game farms. Game ranching forms a significant part of the land use practices and game is an important resource for both commercial farmers and local consumers.

To utilize game as a natural resource, it is imperative to know more of the natural mechanisms which control the size and density of their populations. Parasites play an important role in regulating host populations in a natural environment (Anon. 2000). Farming with game creates an unnatural system and disrupts the balance between parasite and host. For instance, confinement predisposes animals to high parasite loads because of high stocking rates, mixed species populations, and restricted movement, which causes high stress levels that suppress their immunity to these parasites (Malan, Horak, De Vos & Van Wyk 1997). In a stressful environment animals can become diseased or even die from parasite loads that they would have survived under natural conditions. Carcass condemnation due to macroscopic pathology caused by the parasites can lead to even further financial losses. Knowledge about the helminth infections of game in an area is therefore important.

The internal parasites of wildlife have been extensively described for the eastern Limpopo Province, including the Kruger National Park. However, less work has been done in the northern and western parts of the Province, and, as the climate and vegetation differ significantly from that of the east of the Province, this should have bearing on the prevalence of helminths in these areas.

Because of the extensive interface between game and domestic livestock in the Province, the presence of helminths in wildlife can also affect domestic stock and it is an important consideration in the evaluation of parasite control programmes. The transmission of helminths between wildlife and domestic stock is a regular occurrence, although it appears that antelope tolerate the helminths of sheep and cattle better than domestic stock tolerate the helminths of antelope (Boomker 1990a). Furthermore, zoonotic infections can potentially be acquired by human consumers. Investigations into the helminth infections of game are therefore necessary from both a scientific and a public health point of view.

The objectives of this study were to firstly determine which helminths are prevalent in game species in the study area, focusing on the more common antelope species, warthogs and bushpigs, and secondly to determine whether known zoonotic helminths are present in game species that are used for venison production, including *Taenia solium*, *Taenia saginata* and *Echinococcus* spp. To this effect the organs and intestinal tracts of 37 animals from various localities were examined during the hunting season of 2006 and 2007.

CHAPTER 1

LITERATURE REVIEW

2.1 THE PREVALENCE OF HELMINTH PARASITES

Wildlife appears to be capable of living with high parasite loads without any apparent ill-effect on their health. A common evolutionary history between indigenous hosts and their parasites in a specific habitat has led to the reduction or cessation in detrimental effects of parasites on their hosts (Malan *et al.* 1997). The association between host, parasite and environment are more stable the more complex and diverse the components of the association are (Malan *et al.* 1997).

A review on the aggregation of parasite populations revealed that overdispersion of parasites is the rule rather than the exception (Waid, Pence & Warren 1985). This implies that most individuals in a population have a few parasites, while a few individuals have a high parasite burden. Reasons for overdispersion include the host's ability to reduce or limit parasite burdens, the host's behaviour, physical condition, age and sex (Waid *et al.* 1985), variation within the habitat, and the distribution of infective eggs in the host's environment, for example in dung pats (Anon. 2000).

Parasites play an important role in the regulation of wildlife populations by having a density-dependent harmful effect on their hosts. The density-dependent process is likely to be most apparent with helminths with a direct life cycle (Henke, Pence & Bryant 2002). The regulatory role parasites play most often functions in combination with other biotic and abiotic factors. For instance, during drought, dormant parasites may flare up to cause disease in an already compromised animal.

Therefore, the prevalence of helminths are dependent on intrinsic factors related to the parasite itself, or extrinsic factors related to the host, both intermediate and definitive, or environmental factors. Human intervention, such as translocation of livestock and fencing, can also influence the prevalence of helminths.

Parasite-related factors

a. Biotic potential

One factor that is considered to play a role is the capacity of helminths to produce a high number of eggs. A single host of nematodes may harbour thousands of reproductively active female nematodes. Female nematodes with egg outputs that are considered very high include

Oesophagostomum and *Haemonchus* with daily egg outputs between 5 000-10 000 (Anon. 2006). A parasite load of 100 – 1 000 adult *Haemonchus contortus* in sheep cause chronic clinical signs, whereas a parasite load of up 35 000 cause hyperacute death (Reinecke 1983).

b. Egg availability

The availability of eggs on pasture or veld will depend on both the definitive host's defaecation habits and the feeding habits of the intermediate host. It is known that grazers usually harbour higher numbers of internal parasites than browsers (Horak 1980). A definitive host that makes use of a latrine will play a lesser role in disseminating eggs compared to a host that defaecates indiscriminately (Boomker, Horak & Flamand 1991c). Several agents have been suggested to play a role in the dispersal of helminth eggs, namely birds, the wind, rainfall, arthropods, earthworms, animal feet and blowflies (Gemmell 1997; Raether & Hänel 2003).

c. Viability of larval stages

When comparing the prevalence of the parasites in different hosts and between hosts in different locations, it is evident that the biotic potential and hence the transmission dynamics of parasites vary between different ecological regions and climatic zones. Climatic factors play an important role in the survival of helminth eggs or free-living stages in the environment. Nematode eggs and larval stages are dependent on optimal conditions for the hatching and survival. Even the migrations of the larvae are determined by environmental conditions (Reinecke 1983). Similarly, miracidia of trematodes must find a suitable intermediate host within hours after hatching before further development can take place. Their environmental requirements are also strict as the eggs must be deposited in water or desiccation will kill off the eggs or the miracidia (Reinecke 1983). The eggs of the *Taenia* spp., on the other hand, are known to be highly resistant to certain environmental conditions, although desiccation does kill them (Theis & Schwab 1992). Mares (1987) found that in the former Transkei (now part of the Eastern Cape Province), " the overgrazing, the periodic droughts and the erosion give the parasites as hard a time as they do the livestock".

Parasites themselves have several mechanisms to overcome and survive adverse environmental conditions. Hypobiosis is the arrested development of the free-living stages of a nematode and is triggered by stimuli such as temperature and photoperiod which results in the inhibited development in a subsequent stage of the life cycle (Reinecke 1983). Non-specific arrested development is caused by factors in the immediate environment of the parasite, such as host- and parasite-related factors (Reinecke 1983).

d. Host-specificity

Host specificity is a fundamental characteristic of parasites, yet it is seldom absolute and to a variable degree it is relative (Cameron 1964, cited by Horak 1981). According to Horak (1980) parasites can be considered as definitive, occasional or accidental parasites of their respective hosts. *Definitive parasites* have a high prevalence in the specific host population and the population has a high mean intensity of the respective parasite. The parasite can reproduce and survive for long periods in these hosts. *Occasional parasites* have a significant variance in the number of parasites per host. The parasite may be capable of reproduction, but survival is for only a limited period. *Accidental parasites* have a low prevalence in the host population. The parasite may not be able to develop in the host and adult parasites may not be able to reproduce. A short survival period in the host is likely. The above categories of parasites mainly refer to nematodes with direct life cycles. The presence of helminths with an indirect life cycle is merely an indication of the abundance of the intermediate host (Boomker 1990a).

Helminth parasites of antelope are not very host specific. Antelope appear to tolerate each others helminths, which indicate a well-developed and long-standing relationship between host and parasite (Boomker, Horak & De Vos 1986). Especially ruminants with a common ancestor are likely to harbour parasites from the same family or genus. Cross-transmission will occur provided the hosts are fairly closely related and intrinsic determinants in the new hosts allow a viable association to develop (Horak 1980).

e. Cross-transmission

Fencing has interfered with animal movement and, with the exclusion of predators, has lead to overstocking, particularly in small game reserves and game ranches. A variety of animals that do not naturally occur together are also kept in high numbers on game farms. Overstocking goes hand-in-hand with overgrazing and overbrowsing. Excessive high stocking rates together with the deterioration of veld leads to increased parasitism and disease (Malan *et al*. 1997). Animals are more likely to harbour accidental parasites when different hosts are kept in the same limited area (Horak 1980).

There has been a long association between domestic stock and impala, *Aepyceros melampus,* on farms in South Africa. Therefore it is not surprising that there is considerable overlapping of the helminth fauna of sheep, cattle and impala (Horak 1978). The practice of either introducing livestock into wildlife regions or reintroducing wildlife into areas that are used for livestock rearing has lead to the introduction of parasites of both groups to each other and cross-infection took place. The host range of some parasites has increased in this way. Many helminth species that infect wild ruminants do not occur in domestic ruminants (Horak 1980). However, antelope appear to be often accidentally infected with helminths from domestic ruminants. When hosts are immunologically naive to parasites there is a potential to cause morbidity in the host.

2.2 THE ECOLOGY AND HELMINTHS OF HOSTS

The prevalence of parasites is closely linked to the ecology of their hosts, which includes the host's distribution, feeding behaviour, social organization and habitat preference. These aspects all play a role in the exposure rate of the host to parasites. Intrinsically, the host's susceptibility to infection will also influence the parasite burdens of the animal. Some general aspects of host ecology are firstly discussed, followed by the ecology of the specific hosts examined. A parasite list is provided for each host species.

a. Host distribution

The distribution of parasites of domestic stock is generally mainly influenced by climatic factors. The parasites of free-ranging antelope will be influenced by climate, but also by the biogeographical distribution of their hosts. Within the hosts range, the prevalence will differ as the climate differs (Horak 1980).

b. Feeding behaviour

The feeding behaviour of the host determines the level of exposure of an animal to the infective stage of a parasite. Grazing antelope include blue wildebeest, *Connochaetes taurinus*, black wildebeest, *Connochaetes gnou*, blesbok, *Damaliscus dorcas phillipsi*, and bontebok, *Damaliscus dorcas dorcas*. In general their helminths are very similar (Anon. 2000). Nyala, *Tragelaphus angasii,* and kudu, *Tragelaphus strepsiceros,* are both browsers and thus share similar feeding habits. Grazers usually harbour higher numbers of internal parasites than browsers (Horak 1980). In a study done on various artiodactylids from nature reserves in South Africa, twenty browsers surveyed had a mean helminth burden of 887, compared to five grazers with 1 390 and six mixed feeders with a mean burden of 4 063 (Boomker *et al.* 1986). Firstly, browse is more nutritious compared to grass, therefore browsers consume less than grazers and secondly, infective stages occur on the ground or grass. Mixed feeders like impala, springbok, *Antidorcas marsupialis*, and grysbok, *Raphicerus melanotis*, utilize a mixture of browse and grazing, with the result that they have worm burdens intermediate between those of grazers and browsers (Anon. 2000).

c. Habitat preference

The habitat preference of the host is also important in determining its parasite load. In Uganda, buffaloes, *Syncerus caffer,* utilize grass in low moist areas and around wallows, and this has been said to be the reason for the higher prevalence of *Fasciola gigantica* in buffaloes compared to kob, *Kobus kob,* and Jackson's hartebeest, *Alcelaphus buselaphus jacksoni,* in the same district in Uganda (Bindernagel 1972).

d. Social behaviour

Wildlife hosts have evolved many mechanisms to enable themselves to live productively with a parasite load, of which one is evasive habits like seasonal migration (Malan *et al*. 1997). Animals that occur singly or in pairs are also unlikely to contaminate their environment to a significant degree (Boomker *et al.* 1986). Blue duikers, *Cephalophus monticola,* have very selective feeding habits and are exclusive browsers. This together with the fact that they are solitary for most of their lives is why they neither have a large helminth burden nor a large variety of helminths (Boomker, Booyse & Keep 1991a).

e. Host susceptibility

The host's immune reaction to internal parasites is varied and is influenced in itself by many factors. An animal may be capable of protecting itself against reinfection, but can also rid itself of its worm burden. An animal's immune response can also cause retarded growth and development of certain stages of helminths. Horak (1978) compared the marked seasonal larval inhibition of *Cooperia* spp. in impala to the lack of inhibition in cattle on irrigated pasture. He attributed it to the fact that the impala were continuously exposed to infection, whereas the cattle referred to were kept worm-free until exposure on the pasture for a relatively short time before slaughter. He concluded that the impala developed immunity as a result of the continual challenge and this likely played a role in inhibiting larval development in the impala. Browsing animals' immunity is unlikely to eliminate entire worm burdens since the burdens in browsers are never large enough to elicit an immune response (Boomker *et al*. 1986).

The immune system of animals can be compromised in unnatural conditions, such as translocation and confinement. Translocating animals has the risk of at the same time transporting parasites into an area where they might not have previously occurred and thus increasing its distribution, and the risk of introducing naive individual animals that are already stressed to local parasites that are foreign to them. These immunocompromised animals suffer form high parasite loads and thus act as a reservoir to all the animals in the area (Anon. 2000).

Impala

Impalas are one of the most numerous antelope species in the Limpopo Province. They have considerable commercial value for hunting, cropping, commercial game farming and tourism (Horak 1978). Exporting of impala meat is increasing in popularity.

Impala are medium sized antelope with males reaching 75-92 cm (Estes 1991). Impala are considered an intermediate or mixed feeder. Although they predominantly graze while grasses are green, they also browse on foliage, forbs, shoots and seedpods (Estes 1991). This gives them an unusually varied, abundant and reliable food supply and also enables them to lead a sedentary existence and to reach high densities. They can thrive in areas where the natural vegetation has degenerated because of overgrazing or bush encroachment (Estes 1991). Impala are seasonally or perennially territorial and gregarious. In the dry season they are rarely found more than a few kilometers from water, but when ample green vegetation is available they can go without drinking (Estes 1991).

Impala and their parasites have been extensively studied by several authors and in addition to those listed by Round (1968), some significant contributions has been made by Mönnig (1933); Heinichen (1973); Horak (1978, 1980, 1981) and Anderson (1992). Because of its feeding ecology, impalas are exposed to the helminths of both browsers and grazers. Impala also share pastures with domestic livestock on many game ranches in South Africa and considerable overlapping of the helminth fauna in sheep, cattle and impala occurs (Horak 1978). This is reflected in the long list of helminth parasites that have been recovered from these antelope (Table 2.1).

Table 2.1 Helminth parasites of impala

Helminth species	References
Bunostomum trigonocephalum	Horak (1980)
Cooperia connochaeti	Horak (1980)
Cooperia fuelleborni	Heinichen (1973); Horak (1980)
Cooperia hungi	Heinichen (1973); Horak (1978, 1980)
Cooperioides hamiltoni	Heinichen (1973); Horak (1978, 1980); Anderson (1992)
Cooperioides hepaticae	Heinichen (1973); Gibbons (1978); Horak (1978, 1980); Anderson (1992)
Gaigeria pachyscelis	Heinichen (1973); Horak (1980)
Gongylonema pulchrum	Horak (1978, 1980)
Haemonchus bedfori	Heinichen (1973); Horak (1980)
Haemonchus krugeri	Heinichen (1973); Horak (1980)
Haemonchus placei	Horak (1978, 1980)
Impalaia nudicollis	Heinichen (1973); Boomker (1977); Horak (1980)
Impalaia tuberculata	Heinichen (1973); Boomker (1977); Horak (1978, 1980)
Longistrongylus sabie	Heinichen (1973); Gibbons (1977); Horak (1978, 1980)
Muellerius capillaris	Heinichen (1973); Horak (1980)
Oesophagostomum columbianum	Heinichen (1973); Horak (1978, 1980)
Pneumostrongylus calcaratus	Heinichen (1973); Horak (1980)
Strongyloides papillosus	Horak (1978, 1980)
Trichostrongylus axei	Horak (1978, 1980)
Trichostrongylus colubriformis	Heinichen (1973); Horak (1978, 1980)
Trichostrongylus falculatus	Horak (1978, 1980)
Trichostrongylus thomasi	Heinichen (1973); Horak (1980)
Trichuris globulosa	Heinichen (1973); Horak (1980)
Avitellina sp.	Heinichen (1973); Horak (1980)
Moniezia benedeni	Heinichen (1973); Horak (1980)
Moniezia expansa	Heinichen (1973); Horak (1978, 1980)
Stilesia hepatica	Heinichen (1973); Horak (1980)
Thysaniezia giardi	Heinichen (1973); Horak (1980)
Cysticercus sp.	Heinichen (1973); Young & Wagener (1968)
Calicophoron calicophorum	Heinichen (1973); Horak (1980)
Fasciola gigantica	Horak (1978, 1980)
Paramphistomum sp.	Horak (1980)
Schistosoma mattheei	Heinichen (1973); Horak (1980)

Kudu

Kudus are gregarious antelope, occurring in small herds of 1-4 females with their offspring. They are relatively large antelope, with males up to 1,3 m in shoulder height (Skinner & Smithers 1990). Their preferred habitat is savanna woodland and riparian woodland with thickets (Skinner & Smithers 1990). Kudus roam considerably. In the Kruger National Park their home ranges were recorded to be 3-25 km^2 (Skinner & Smithers 1990).

Kudus are predominantly browsers, but may eat grass at times. They are also known to eat seed pods off the ground (Skinner & Smithers 1990). In the Kruger National Park female groups spent 50-58% of a 24-hour day foraging of which 45% was done at night (Estes 1991). Browsing animals harbour lesser burdens of parasites compared to grazers and mixed feeders (Boomker, Horak & De Vos 1989a). Because of their feeding habits they are less exposed to the infective free-living stages of parasites (Boomker *et al.* 1989a). As browsers, kudus also do not normally eat much aquatic vegetation and therefore relatively few are infested with trematodes (Condy 1972). Trematodes that have been described to occur in kudu are *Schistosoma mattheei, Fasciola gigantica* and amphistomes (Condy 1972). Kudu appear to be very susceptible to infection with *Fasciola* and mortalities have been described (Condy 1972).

According to the criteria of Horak (1980) *Haemonchus vegliai, Cooperia neitzi, Cooperia acutispiculum, Elaeophora sagittus* and *Trichostrongylus deflexus* are definitive parasites of kudus in the Kruger National Park (Boomker *et al.* 1989a) and in the Eastern Cape (Boomker, Horak & Knight 1991d). The amphistomes, *Schistosoma mattheei, Moniezia benedeni, Taenia* larvae, *Impalaia tuberculata, Agriostomum gorgonis* and *Strongyloides papillosus* are considered occasional parasites (Boomker *et al.* 1991d).

Kudus are known to harbour parasites from other species. Kudus in Addo Elephant National Park harboured *Nematodirus helvetianus* and *Dictyocaulus* sp., thought to originate from cattle in the area (Boomker *et al.* 1991d). Cross-infection due to a higher number of antelope species in Etosha is thought to be the reason for the higher number of helminth species recovered from kudus in Etosha compared to kudus from the Eastern Cape with a similar mean parasite burden (Boomker *et al.* 1991d). *Cooperioides hamiltoni*, a parasite described in impala, is considered an occasional parasite of kudus (Boomker, Anthonissen & Horak 1988).

Table 2.2 Helminth parasites of kudus

Helminth species	**References**
Agriostomum cursoni	Round (1968); Boomker *et al.* (1989a)
Agriostomum gorgonis	Round (1968); Boomker *et al.* (1989a)
Cooperia acutispiculum	Boomker *et al.* (1989a)
Cooperia fuelleborni	Boomker *et al.* (1991d)
Cooperia hungi	Boomker e*t al*. (1988, 1989a)
Cooperia neitzi	Round (1968); Boomker *et al.* (1988, 1989a)
Cooperia pectinata	Round (1968); Boomker *et al.* (1989a)
Cooperia punctata	Boomker e*t al*. (1988, 1989a)
Cooperia rotundispiculum	Boomker *et al.* (1991d)
Cooperia yoshidai	Boomker *et al.* (1989a)
Cooperioides hamiltoni	Boomker e*t al*. (1988)
Elaeophora sagittus	Mönnig (1926); Round (1968); Boomker e*t al*. (1988, 1989a)
Dictyocaulus sp.	Boomker *et al.* (1991d)
Gaigeria pachyscelis	Round (1968); Boomker *et al.* (1989a)
Haemonchus contortus	Round (1968); Boomker *et al.* (1989a)
Haemonchus vegliai	Round (1968); Boomker e*t al*. (1988, 1989a)
Impalaia tuberculata	Boomker e*t al*. (1988, 1989a)
Impalaia nudicollis	Boomker *et al.* (1988)
Nematodirus helvetianus	Boomker *et al.* (1991d)
Oesophagostomum walkeri	Round (1968)
Onchocerca sp.	Round (1968); Boomker e*t al*. (1988)
Ostertagia circumcincta	Round (1968)
Ostertagia ostertagi	Boomker *et al.* (1991d)
Parabronema sp.	Boomker *et al.* (1989a)
Paracooperia devossi	Boomker e*t al*. (1988, 1989a)
Setaria africana	Round (1968); Boomker *et al.* (1989a)
Strongyloides papillosus	Boomker *et al.* (1989a)
Thelazia rhodesii	Round (1968)
Trichostrongylus deflexus	Boomker *et al.* (1989a)
Trichostrongylus falculatus	Boomker a*t al*. (1988, 1989a)
Trichostrongylus thomasi	Boomker a*t al*. (1988)
Trichuris sp.	Boomker *et al.* (1989a)
Amphistomes	Boomker *et al.* (1989a)

Cotylophoron cotylophorum	Round (1968)
Fasciola gigantica	Condy (1972)
Schistosoma mattheei	Boomker *et al.* (1989a)
Avitellina sp.	Boomker *et al.* (1989a)
Echinococcus sp. larvae	Boomker *et al.* (1989a)
Moniezia benedeni	Boomker *et al.* (1989a)
Taenia spp. larvae	Boomker *et al.* (1989a)

Kudus occur widely in southern Africa and, despite their habitat preference, occur in a wide range of climatic zones. Therefore the number of parasites that have been recorded to occur in kudu is relatively extensive and well studied. A host-parasite list has been compiled by Round (1968), but has been amended (Table 2.2) by other authors, including Condy (1972) and Boomker *et al*. (1988, 1989a, 1991d).

Bushbuck

Bushbuck, *Tragelaphus scriptus,* is a medium-sized forest antelope (Estes 1991). The males reach a height of 70-100 cm (Estes 1991). This antelope is predominantly a browser but also selects new growth of grass. They are solitary, non-territorial and sedentary (Estes 1991).

The helminth parasites of bushbuck are listed in Table 2.3.

Nyala

Nyala have similar traits to bushbuck but are bigger. Males can reach up to 112 cm (Skinner & Smithers 1990). The females are distinctly smaller, with shoulder heights up to 97 cm (Skinner & Smithers 1990). Nyalas are confined in low-lying, densely wooded areas, generally near water. According to Skinner & Smithers (1990), nyalas are mixed feeders, shifting from grazing in the summer rainy season to browse in the dry season. Nyalas are gregarious, non-territorial and sedentary (Estes 1991).

The helminth parasites of nyala are listed in Table 2.4.

Table 2.3 Helminth parasites of bushbuck

Helminth species	References
Cooperia neitzi	Boomker *et al.* (1986)
Dictyocaulus viviparus	Boomker *et al.* (1986)
Elaeophora sagittus	Boomker *et al.* (1986)
Gongylonema sp.	Boomker *et al.* (1984, 1987)
Haemonchus vegliai	Boomker *et al.* (1986, 1987)
Longistrongylus spp.	Boomker *et al.* (1986)
Oesophagostomum sp.	Boomker *et al.* (1987)
Ostertagia harrisi	Boomker *et al.* (1984, 1986, 1987)
Paracooperia devossi	Boomker *et al.* (1984, 1986, 1987)
Pneumostrongylus calcaratus	Boomker *et al.* (1986)
Setaria africana	Boomker et al. (1987)
Setaria scalprum	Boomker *et al.* (1984)
Trichostrongylus falculatus	Boomker *et al.* (1986)
Trichostrongylus instabilis	Boomker *et al.* (1986)
Taenia sp.	Boomker *et al.* (1984, 1986)

Blue wildebeest

Blue wildebeest are highly gregarious occurring in herds that range from 20 to thousands of animals. An adult male stands at about 1,5 m at the shoulder with a mass of about 250 kg (Skinner & Smithers 1990). Although they are famous for their annual migrations, populations are either mobile aggregations or dispersed in sedentary resident herds. Their social organization is finely adjusted to the prevailing conditions (Estes 1991).

Blue wildebeest are almost exclusively grazers. They are anatomically adapted to close, rapid bulk feeding on short grasses. They need to drink daily, or at least every other day, and this limits them to pastures within commuting distance of water, calculated at 10-15 km (Estes 1991). Wildebeest observed in Etosha during one annual cycle revealed that the populations spent 53% of the total time resting, 33% grazing, 12% in moving and 1-2% in social interactions (Estes 1991).

The feeding ecology of blue wildebeest is reflected in the parasite list (Table 2.5), typical of a grazing animal. The tendency of wildebeest to migrate would also affect the exposure rate and

Table 2.4 Helminth parasites of nyalas

Helminth species	References
Camelostrongylus harrisi	Boomker *et al*. (1996)
Cooperia hungi	Boomker *et al*. (1996)
Cooperia rotundispiculum	Boomker *et al*. (1991c, 1996)
Dictyocaulus viviparus	Boomker *et al*. (1991c)
Elaeophora sagittus	Boomker *et al*. (1991c, 1996)
Gaigeria pachyscelis	Boomker *et al*. (1991c, 1996)
Gongylonema verrucosum	Boomker *et al*. (1996)
Haemonchus vegliai	Boomker *et al.* (1986, 1991c, 1996)
Impalaia tuberculata	Boomker *et al*. (1991c, 1996)
Oesophagostomum sp.	Boomker *et al*. (1991c, 1996)
Onchocerca sp.	Boomker *et al*. (1996)
Ostertagia harrisi	Boomker *et al*. (1991c)
Paracooperia horaki	Boomker *et al*. (1991c, 1996)
Setaria africana	Boomker *et al*. (1996)
Setaria labiatopapillosa	Boomker *et al*. (1996)
Strongyloides papillosus	Boomker *et al*. (1996)
Teladorsagia trifurcata	Boomker *et al*. (1996)
Trichostrongylus deflexus	Boomker *et al*. (1991c, 1996)
Trichostrongylus falculatus	Boomker *et al*. (1991c, 1996)
Moniezia benedeni	Boomker *et al*. (1996)
Stilesia hepatica	Zieger *et al.* (1998)
Taenia sp.	Boomker *et al.* (1991c)
Thysaniezia sp.	Boomker *et al.* (1991c)
Calicophoron calicophorum	Round (1968)
Cotylophoron cotylophorum	Round (1968)
Paramphistomum microbothrium	Boomker *et al*. (1996)
Schistosoma mattheei	Boomker *et al*. (1991c, 1996)

thus the seasonal abundance of the parasites. The seasonal patterns of several parasites of wildebeest from KNP have been attributed to either climatic influences or a combination of climatic factors and migratory patterns of the wildebeest in the Park (Horak, De Vos & Brown 1983b). In small game farms animals will have limited migration patterns and therefore increased chances of becoming reinfected from the contaminated pastures.

Table 2.5 Helminth parasites of blue wildebeest

Helminth species	References
Agriostomum gorgonis	Le Roux (1923); Round (1968); Horak *et al*. (1983b); Bain (2001)
Cooperia connochaeti	Boomker *et al*. (1979); Gibbons (1981); Horak *et al*. (1983b)
Dictyocaulus viviparus	Round (1968); Bain (2001)
Gaigeria pachyscelis	Horak *et al*. (1983b)
Haemonchus bedfordi	Round (1968); Bain (2001)
Haemonchus contortus	Round (1968); Gibbons (1979); Bain (2001)
Oesophagostomum sp.	Horak *et al*. (1983b)
Oesophagostomum columbianum	Round (1968); Bain (2001)
Protostrongylus etoshai	Round (1968); Bain (2001)
Strongyloides sp.	Round (1968)
Trichostrongylus axei	Horak *et al*. (1983b)
Trichostrongylus colubriformis	Horak *et al*. (1983b); Round (1968)
Trichostrongylus falculatus	Horak *et al*. (1983b)
Trichostrongylus thomasi	Horak *et al*. (1983b)
Trichostrongylus rugatus	Round (1968); Bain (2001)
Trichuris sp.	Horak *et al*. (1983b)
Avitellina sp.	Horak *et al*. (1983b)
Moniezia benedeni	Round (1968); Bain (2001)
Moniezia expansa	Round (1968); Bain (2001)
Stilesia hepatica	Round (1968); Bain (2001)
Cysticercus regis	Horak *et al.* (1983b)
Cysticercus tenuicollis	Round (1968)
Echinococcus granulosus	Round (1968)
Calicophoron calicophorum	Round (1968); Bain (2001)
Fasciola gigantica	Round (1968); Bain (2001)
Fasciola hepatica	Bain (2001)
Schistosoma margrebowiei	Round (1968)
Schistosoma mattheei	Round (1968)

Black wildebeest

Black wildebeest are smaller than blue wildebeest with males being 111-121 cm in height and 140-157 kg. They are plains animals as well but are better adapted to temperate climates than the blue wildebeest. They are endemic to the Southern African subregion (Skinner & Smithers 1990). They are more common in the colder regions of the country (Boomker, Horak, Watermeyer & Booyse 2000) and occur in the Highveld grasslands and the arid Karoo, mostly south of the Orange River (Estes 1991). Black wildebeest have been translocated to farms in the Limpopo Province and have not occurred here naturally.

In comparison to the blue wildebeest, the black wildebeest is a mixed feeder and is known to take up to 37% foliage of karroid bushes and shrubs in its diet (Estes 1991). Their social organization and behaviour are very similar to that of blue wildebeest.

The helminths of black wildebeest have received little attention (Boomker *et al.* 2000). They appear to be fairly resistant to parasitic infections as animals from Golden Gate Highlands Park and Rietvlei Reserves harboured relatively low burdens of only a small number of helminth species when compared to blue wildebeest from the Kruger National Park (Horak *et al.* 1983b). A black wildebeest from the Mountain Zebra National Park harboured a single *Taenia* sp. larva, 26 *Haemonchus* spp. females and one *Haemonchus* spp. larva (Boomker *et al.* 2000). Neither of two black wildebeest from the Karoo National Park harboured any worms (Boomker *et al*. 2000). Table 2.6 presents a list of helminth parasites in black wildebeest.

Gemsbok

Gemsbok, *Oryx gazella,* are actually relatively common but do not occur naturally in Limpopo Province and have been translocated by game farmers. They are desert-adapted large mammals. Males stand at 115-125 cm with an average weight of 176 kg (Estes 1991). Gemsbok are gregarious, nomadic and occur in mixed herds. Although gemsbok feed mainly on short grass, they are known to browse and to dig for roots, bulbs and tubers. They consume cucumbers and wild melons in their natural habitat where water is scarce (Estes 1991). Gemsbok also have anatomical and behavioural adaptations to survive in an arid habitat (Estes 1991). A list of their helminths is presented in Table 2.7.

Table 2.6 Helminth parasites of black wildebeest

Helminth species	References
Cooperia connochaeti	Bain (2001)
Cooperia curticei	Round (1968); Bain (2001)
Haemonchus bedfordi	Round (1968); Bain (2001)
Haemonchus contortus	Round (1968); Bain (2001)
Oesophagostomum columbianum	Round (1968); Bain (2001)
Strongyloides sp.	Bain (2001)
Trichinella spiralis	Bain (2001)
Trichuris sp.	Horak *et al.* (1983b)
Trichostrongylus rugatus	Round (1968); Bain (2001)
Avitellina sp.	Bain (2001)
Moniezia benedeni	Bain (2001)
Taenia sp. larva	Horak *et al.* (1983b)
Cysticercus tenuicollis	Round (1968); Bain (2001)
Thysaniezia sp.	Horak *et al.* (1983b)
Calicophoron calicophoron	Round (1968); Bain (2001)

Waterbuck

Waterbuck, *Kobus ellipsiprymnus,* is a common antelope in Southern Africa. As one of the heaviest antelopes, males attain a mass of 236 kg and a shoulder height of up to 127 cm (Estes 1991). It is a grazer that has to drink often and its distribution is limited to grassland within a few kilometres of water. It is possibly the most water-dependent of the antelopes (Estes 1991). Waterbuck are sedentary and are most dispersed in the wet season. During the dry season they spend most of their time in open grasslands near water (Estes 1991). Waterbuck feed on a variety of grasses, preferably of medium and short length (Estes 1991). The parasites that have been recorded from waterbuck reflect its ecology of being a grazer and being water-dependent (Table 2.8).

Table 2.7 Helminth parasites of gemsbok

Helminth species	References
Agriostomum equidentatum	Boomker *et al*. (1986)
Agriostomum gorgonis	Round (1968)
Cooperia curticei	Round (1968)
Bronchonema magna	Boomker *et al*. (2000)
Haemonchus bedfordi	Round (1968)
Haemonchus contortus	Round (1968)
Impalaia nudicollis	Boomker *et al*. (1986)
Longistrongylus curvispiculum	Boomker *et al*. (2000)
Longistrongylus meyeri	Boomker *et al*. (1986)
Nematodirus spathiger	Round (1968); Boomker *et al*. (2000)
Oesophagostomum columbianum	Round (1968)
Paracooperia serrata	Boomker *et al*. (1986)
Ostertagia ostertagi	Boomker *et al*. (2000)
Protostrongylus etoshai	Round (1968)
Setaria hornbyi	Round (1968); Watermeyer, Boomker & Putterill (2004)
Strongyloides sp.	Boomker *et al*. (1986)
Trichostrongylus colubriformis	Round (1968)
Trichostrongylus deflexus	Boomker *et al*. (2000)
Trichostrongylus falculatus	Boomker *et al*. (2000)
Trichostrongylus pietersei	Boomker *et al*. (2000)
Trichostrongylus rugatus	Round (1968); Boomker *et al*. (2000)
Trichostrongylus thomasi	Boomker *et al*. (2000)
Trichuris globulosa	Round (1968)
Trichuris sp.	Round (1968)
Avitellina centripunctata	Round (1968)
Moniezia expansa	Round (1968)
Thysaniezia giardi	Round (1968)
Cysticercus tenuicollis	Round (1968)
Taenia multiceps larva	Verster & Bezuidenhout (1972)
Paramphistomum cervi	Round (1968)

Table 2.8 Helminth parasites of waterbuck

Helminth species	**References**
Bunostomum cobi	Round (1968)
Cooperia curticei	Round (1968)
Cooperia fuelleborni	Round (1968); Boomker *et al*. (1986)
Cooperia hungi	Round (1968); Boomker *et al*. (1986)
Cooperia verrucosa	Round (1968)
Cooperia yoshidai	Boomker *et al*. (1986)
Dictyocaulus sp.	Zieger *et al.* (1998)
Haemonchus bedfordi	Round (1968); Boomker *et al*. (1986)
Haemonchus contortus	Round (1968)
Haemonchus yoshidai	Boomker *et al*. (1986)
Impalaia nudicollis	Round (1968)
Impalaia tuberculata	Boomker *et al*. (1986)
Longistrongylus schrenki	Round (1968)
Microfilaria sp.	Round (1968)
Oesophagostomum columbianum	Round (1968); Boomker *et al*. (1986)
Parabronema sp.	Boomker *et al.* (1986)
Setaria hornbyi	Round (1968); Watermeyer *et al*. (2004)
Setaria labiatopapillosa	Round (1968)
Trichostrongylus colubriformis	Round (1968)
Trichostrongylus rugatus	Round (1968)
Cysticercus tenuicollis	Round (1968)
Moniezia expansa	Round (1968)
Stilesia globipunctata	Round (1968)
Stilesia hepatica	Round (1968); Boomker *et al*. (1986); Zieger *et al.* (1998)
Calicophoron sp.	Zieger *et al.* (1998)
Carmyerius papillatus	Bain (2001)
Carmyerius parvipapillatus	Bain (2001)
Carmyerius spatiosus	Bain (2001)
Cotylophoron cotylophorum	Bain (2001)
Fasciola gigantica	Bain (2001); Hammond (1972); Zieger *et al.* (1998)
Fasciola hepatica	Hammond (1972)
Paramphistomum cervi	Bain (2001)
Paramphistomum microbothrium	Bain (2001)

Warthogs and bushpigs

Pigs are highly social animals with the basic social unit made up of a sow with her litter. They are gregarious, non-territorial and live in sounders within definite, overlapping home ranges. Bushpigs, *Potamochoerus porcus,* are largely nocturnal, whereas the warthogs, *Phacochoerus aethiopicus,* are strictly diurnal (Estes 1991).

Dense cover and water are essential requirements for bushpigs and they only occur where these conditions pertain (Skinner & Smithers 1990). They occur in sounders of four to six, sometimes up to 12. Warthog's sounders are made up of an adult female with her offspring and an adult male. Maternity groups are formed. Their ranges vary from 64 to 374 ha (Estes 1991).

Pigs are omnivorous and roots, bulbs and fallen fruit are consumed. They use their snouts to locate and uncover food. In the wet season warthogs graze, whereas in the dry season they specialize on the underground rhizomes of perennial grasses and sedges, bulbs and tubers. Unlike other pigs, warthogs graze and root while kneeling. Warthogs and bushpigs will on hot days wallow daily. Bushpigs are known to readily eat carrion and excrement, and also kill small mammals and birds (Estes 1991).

Warthogs are the only pigs adapted for grazing and savanna habitats (Estes 1991). Bushpigs occur in wooded habitats. They are serious agricultural pests that are on the increase in farming areas.

Adult warthog boars stand at about 70 cm with a mass of up to 100kg (Skinner & Smithers 1990). Bushpigs are slightly bigger with males up to 80 cm and weighing up to 115kg (Estes 1991).

The helminths of warthogs in southern Africa have been described by several authors, including Ortlepp (1964b); Horak, Biggs, Hanssen & Hanssen (1983a); Horak, Boomker, De Vos & Potgieter (1988) and Boomker, Horak, Booyse & Meyer (1991b). The helminth parasites of warthogs as listed by Round (1968) includes parasites from all of Africa and is quite extensive. However, many helminths occur only in certain regions as is evident from the work of the Ortlepp (1964b); Horak *et al*. (1983a, 1988) and Boomker *et al.* (1991b). Table 2.9 presents a list of helminth parasites of warthogs.

Little work on the helminth parasites of bushpigs has been done. They are difficult to sample because of their largely nocturnal activity and their relatively limited distribution in forested areas. Ortlepp (1964b) examined material from Mozambique and the northern Transvaal which are included in the list of helminth parasites of Round (1968). Table 2.10 presents the helminth parasite list of bushpigs.

2.3 HELMINTH ZOONOSES

There is a public health risk associated with the consumption of venison. Several zoonotic taeniids have been identified in a variety of game species. The occurrence of Cysticercus bovis in African game species has been reported (Sachs 1970). Cysticercus cellulosae has been reported in wild boar, *Sus scrofa,* (Eslami & Farsad-Hamdi 1992) and warthogs (Bain 2001).

Although hydatid material of human origin studied in Sub-Saharan Africa all conform to the sheep strain (MacPherson & Wachira 1997), this does not prove non-infectivity of other *E. granulosus* strains to humans. Because of the seriousness of *Echinococcus* spp. infection, one should always take the necessary precautions when handling wild carnivores (Young 1975).

Other possible zoonotic helminth infections from wildlife include *Trichinella spiralis*, *Toxocara* and *Toxascaris*, and *Schistosoma. Trichinella spiralis* occurs in pigs and wild boar in Europe and *Trichinella nelsoni* in wild pigs in Africa (Boomker pers. comm.). Infection in humans occurs with the consumption of meat (Eslami & Farsad-Hamdi 1992; OIE 2005).

Table 2.9 Helminths parasites of warthogs

Helminths species	References
Ascaris lumbricoides	Round (1968)
Ascaris phacochoeri	Ortlepp (1964b); Round (1968); Horak *et al.* (1988); Boomker *et al.* (1991b)
Ascaris suum	Round (1968)
Cooperia hungi	Boomker *et al.* (1991b)
Haemonchus krugeri	Boomker *et al.* (1991b)
Hyostrongylus sp.	Round (1968)
Impalaia tuberculata	Horak *et al.* (1988); Boomker *et al.* (1991b)
Microfilaria sp.	Round (1968)
Murshidia hamata	Daubney (1923); Ortlepp (1964b); Round (1968); Horak *et al.* (1988); Boomker *et al.* (1991b)
Murshidia pugnicaudata	Daubney (1923); Ortlepp (1964b); Round (1968); Horak *et al.* (1988); Boomker *et al.* (1991b)
Necator sp.	Round (1968)
Odontogeton phacocoeri	Round (1968)
Oesophagostomum aethiopicum	Round (1968)
Oesophagostomum eurycephalum	Round (1968)
Oesophagostomum goodeyi	Round (1968)
Oesophagostomum mocambiquei	Ortlepp (1964b); Round (1968); Horak *et al.* (1988); Boomker *et al.* (1990b, 1991b)
Oesophagostomum mpwapwae	Round (1968)
Oesophagostomum mwanzae	Round (1968); Horak *et al.* (1983a, 1988); Boomker *et al.* (1991b)
Oesophagostomum oldi	Round (1968)
Oesophagostomum roubaudi	Round (1968)
Oesophagostomum santosdiasi	Round (1968)
Oesophagostomum simpsoni	Round (1968)
Oesophagostomum yorkei	Round (1968)
Phacochoerostrongylus pricei	Round (1968)
Physaloptera joyeuxi	Round (1968)
Physocephalus sexalatus	Round (1968); Horak *et al.* (1983a, 1988); Boomker *et al.* (1991b)
Probstmayria vivipara	Round (1968); Horak *et al.* (1983a, 1988); Boomker *et al.* (1991b)
Setaria castroi	Round (1968)
Strongyloides sp.	Horak *et al.* (1988); Boomker *et al.* (1991b)
Trichostrongylus colubriformis	Horak *et al.* (1983a)

Trichostrongylus deflexus	Boomker *et al.* (1991b)
Trichostrongylus falculatus	Horak *et al.* (1988)
Trichostrongylus instabilis	Horak *et al.* (1988)
Trichostrongylus thomasi	Horak *et al.* (1988); Boomker *et al.* (1991b)
Trichuris spp.	Horak *et al.* (1988); Boomker *et al.* (1991b)
Cysticercus cellulosae	Round (1968)
Cysticercus tenuicollis	Round (1968)
Echinococcus granulosus larva	Horak *et al.* (1988); Boomker *et al.* (1991b)
Moniezia benedeni	Round (1968)
Moniezia mettami	Ortlepp (1964b); Boomker *et al.* (1991b)
Paramoniezia phacochoeri	Ortlepp (1964b); Round (1968)
Taenia crocutae	Horak *et al.* (1988); Boomker *et al.* (1991b)
Taenia hyaenae	Horak *et al.* (1988); Boomker *et al.* (1991b)
Taenia regis	Horak *et al.* (1988); Boomker *et al.* (1991b)
Gastrodiscus aegyptiacus	Round (1968)
Schistosoma sp.	Horak *et al.* (1988); Boomker *et al.* (1991b)

Table 2.10 Helminth parasites of bushpigs

Helminth species	**References**
Ascaris lumbricoides	Round (1968)
Ascarops strongylina	Ortlepp (1964b); Round (1968)
Diplogaster parasiticus	Round (1968)
Globocephalus longemucronatus	Round (1968)
Globocephalus versteri	Ortlepp (1964b); Round (1968)
Gnathostoma hispidum	Round (1968)
Morgascaridia sellsi	Round (1968)
Oesophagostomum aethiopicum	Ortlepp (1964b); Round (1968)
Physocephalus sexalatus	Ortlepp (1964b); Round (1968)
Rhabditis sp.	Round (1968)
Setaria congolensis	Ortlepp (1964b); Round (1968)
Setaria castroi	Ortlepp (1964b); Round (1968)
Trichinella spiralis	Round (1968)
Cysticercus tenuicollis	Round (1968)
Echinococcus sp. larva	Round (1968)
Gastrodiscus aegyptiacus	Ortlepp (1964b); Round (1968)

CHAPTER 3

MATERIALS AND METHODS

Survey localities

The survey was mainly done in the northern parts of Limpopo Province, in the area around the Soutpansberg and Musina, and the western parts, near Lephalale. Around the Soutpansberg the vegetation is Mixed Bushveld with parts falling in the mist belt on the escarpment. The northern parts towards Musina are semi-arid and the vegetation type varies between Thornveld to Mopani veld (Acocks 1988). Rainfall is strictly confined to the summer and ranges between 250-400 mm per annum. The rainfall recorded for the year July 2006 to June 2007 for the Soutpansberg area and Musina was 300-500mm but was concentrated in short intervals (South African Weather Service 2007). The climate is very hot during summer and cool during winter with occasional frost.

The western parts are also semi-arid and the vegetation type is Sweet Bushveld to Mixed Bushveld (Acocks 1988). The annual rainfall varies between 450 to 550 mm per annum (Acocks 1988). The recorded rainfall for the year July 2006 to June 2007 for the Lephalale area was 100-200mm (South African Weather Service 2007). The summers are also hot and the winters cool (Acocks 1988).

The study area and collection data are given in Table 3.1.

Study animals

The antelope species examined include ten impalas, eight kudus, four blue wildebeest, two black wildebeest, three gemsbok, one nyala, one bushbuck, one waterbuck, six warthogs and one bushpig, that were culled or hunted during the hunting seasons May to September 2006 and May to September 2007.

Since only a few organ samples from the gemsbok from Kerneels Young Trust were submitted to the Louis Trichardt Veterinary Laboratory for post mortem examination, a complete parasite collection was not possible.

The carcasses of several warthogs at a meat processing plant were examined for *Trichinella* spp. As only the eviscerated carcasses were available, only samples from the diaphragm and the intercostal muscle could be collected and examined.

Table 3.1 The collection data for the various animals examined

Species	**Ñ**	**Date**	**Locality**	**Farm**	**GPS**
Impala	3	Jun 06	Musina	Musina Research Station	22°40.645 S 29°48.895 E
	1	Jul 07			
	1	Jun 06	Musina	Kerneels Young Trust	22°40.645 S 29°48.895 E
	2	Jul 06	Lephalale	Bushman’s Safaris	23°10.086 S 28°05.189 E
	3	Aug 07	Soutpansberg	Nwanedi Nature Reserve	22°56.129 S 29°55.003 E
Kudu	3	May 07	Soutpansberg	Langgedachte	23°19.985 S 29°48.075 E
	2	Jul 07	Musina	Musina Research Station	22°40.645 S 29°48.895 E
	1	Jun 06	Musina	Kerneels Young Trust	22°40.645 S 29°48.895 E
	1	Jul 07	Lephalale	Bushman’s Safaris	23°10.086 S 28°05.189 E
	1	Aug 07	Soutpansberg	Nwanedi Nature Reserve	22°56.129 S 29°55.003 E
Bushbuck	1	Aug 07	Soutpansberg	Last Post	23°17.557 S 29°54.593 E
Nyala	1	Sep 07	Soutpansberg	Uitvlught	23°02.903 S 29°46.035 E
Blue wildebeest	3	May 07	Soutpansberg	Langgedachte	23°19.985 S 29°48.075 E
	1	Jul 06	Lephalale	Bushman’s Safaris	23°10.086 S 28°05.189 E
Black wildebeest	2	Jul 07	Lephalale	Bushman’s Safaris	23°10.086 S 28°05.189 E
Gemsbok	2	Jul 07	Musina	Musina Research Station	22°40.645 S 29°48.895 E
	1	Jun 06	Musina	Kerneels Young Trust	22°40.645 S 29°48.895 E
Waterbuck	1	Jul 07	Soutpansberg	Last Post	23°17.557 S 29° 54.593 E
Warthog	2	Aug 06	Lephalale	Bushman’s Safaris	23°10.086 S 28°05.189 E
	2	Aug 07			
	1	Jun 06	Musina	Kerneels Young Trust	22°40.645 S 29°48.895 E
	1	Jun 07	Musina	Alldays	22°45.639 S 29°48.523 E
Bushpig	1	Oct 07	Soutpansberg	Soekmekaar	23°17.557 S 29°54.593 E

Collection and preservation of parasites

The carcasses of the culled animals were first visually inspected for the presence of *Taenia* or *Echinococcus* metacestodes on cut surfaces and the pericardium, heart, diaphragm and liver (OIE 2005). In addition, when permitted, the freed tongue was examined visually and palpated. Only single metacestodes were collected and the specimens were preserved in 70% alcohol.

Carcasses in this study that were destined for export purposes were not skinned until they reached the abattoir, therefore muscle incisions of these carcasses were not made, except for the masseter muscle and the diaphragm. The heads and capes of animals hunted for trophies were preserved, therefore no incisions of the masseter muscles or tongues were made.

Further collection of helminths in the antelopes was as described by Boomker *et al.* (1989a). Depending on the size of the animal, aliquots of 1/4th, 1/10th or 1/25th of ingesta of the various parts of the intestinal tracts were made. The abomasal content of the bushbuck was examined *in toto*. No digests of the abomasal or intestinal mucosae were done.

The helminths of warthogs and bushpig were recovered as described by Boomker *et al*. (1991b). In addition, muscle samples were taken from the diaphragm, intercostal and masseter muscles, crushed between glass plates and examined under a stereoscopic microscope for the presence of *Trichinella* spp. (OIE 2005).

Faeces were collected from the rectum for quantitative egg counts using the modified McMaster method (Reinecke 1983).

Parasite counts and identification

Aliquots of ingesta and organ washings were fixed and preserved in 70% ethyl alcohol. These were transported back to the laboratory, where they were examined under a stereoscopic microscope and all helminths removed. The nematodes were cleared in lactophenol, identified under a standard microscope with the aid of the description of the authors listed in Tables 2.1-2.10, and counted. Male nematodes were identified to the species level, whereas female nematodes, especially where two or more species occurred in a single host, were identified only to the generic level. Fourth stage larvae were also only identified to the generic level.

If adult cestodes were still alive at the time they were collected, they were first relaxed in water in Petri dishes. After all movement had ceased, they were fixed in 5% formalin for 24 h. As preservative, 70% alcohol was used (Loos-Frank 2000).

Scoleces of the metacestodes were dissected out and mounted *en face* in Berlese’s fluid under slight pressure from a cover slip. This is the preferred method for viewing and measuring rostellar hooks (Loos-Frank 2000).

Data analysis

Sampling was not truly random and to an extent dependent on external persons. Therefore the significance of the results could not be compared statistically. However, descriptive statistics, such as mean intensity and prevalence (Anon. 2006) were used in those cases where they could be applied.

Terminology

For the purpose of this study, the following definitions as mentioned by Boomker (1990a) are used:

- Abundance or abundant refers to the mean nematode burden of each of the helminth species recovered from all the individuals examined. The helminth species that is most numerous is considered the most abundant.

- Prevalence or prevalent refers to the percentage of individual animal species infected with helminth species at a study location. The helminth species present in the largest number of animals examined is considered the most prevalent.

CHAPTER 4

RESULTS

Impala

Twelve helminth species of which ten are nematodes and two cestodes were recovered from impala in this study. The total helminth burden of each impala is presented in Table 4.1.

Multiple eosinophilic granulomata were found in the lungs of two impala, but no parasites could be recovered from these lesions.

Cooperia hungi (Figure 4.1) was most prevalent and was recovered from nine of the ten impala from all localities where impala were sampled. *Impalaia tuberculata* and *Oesophagostomum columbianum* were recovered from five impala from three localities. *Trichostrongylus deflexus* (Figure 4.2) was recovered from four individual impalas from two localities.

Cooperia hungi also had the highest intensity with 500 worms per individual. One impala had an adult worm burden of 450 together with a burden of 200 4th stage *Cooperia* larvae. The mean intensity of *C. hungi* for all 10 animals was 253 worms per animal.

Haemonchus krugeri (Figure 4.3) was recovered from two impalas from Bushman’s Safari’s with the second highest intensity of 350 and 400 in each impala.

Table 4.1 The total helminth burdens of impala examined

Species	Lephalale area			Musina area				Soutpansberg area			Mean burden (ñ=10)	Prevalence (%)
	BI1	**BI2**	**BI3**	**MI1**	**MI2**	**MI3**	**YI1**	**NwI1**	**NwI2**	**NwI3**		
Cooperia fuelleborni						75					7	10
Cooperia hungi	150	100		75	500	25	450	475	475	275	253	90
Cooperia L4							200				20	10
Cooperioides hamiltoni	200	75									28	20
Cooperioides hepaticae								10		20	3	20
Haemonchus krugeri	350		400								75	20
Haemonchus L4	25			25							5	20
Impalaia tuberculata		75					225	325	25	50	71	50
Impalaia L4	225										23	10
Longistrongylus sabie						50					5	10
Oesophagostomum columbianum	125	25	250		25			25			5	50
Oesophagostomum L4								225			23	10
Trichostrongylus colubriformis									150	25	18	20
Trichostrongylus deflexus	25	25		50		75					18	40
Moniezia expansa					5						1	10
Stilesia hepatica										7	1	10
Total burden	1 100	300	650	25	550	250	875	1 100	650	377	589	

L4 = 4th stage larvae

Kudu

Five nematode species and one trematode were recovered from kudu in this study. The total worm burden of the kudu is summarized in Table 4.2.

The kudu with the highest total helminth burden had 2 460 worms, of which 2 425 were *Haemonchus contortus*. Excluding this kudu, the mean burden for the other seven kudus was 82 worms per individual. The lowest burden in these kudus was 6 worms. The mean helminth burden of the sampled animals was 403 worms per individual.

Haemonchus contortus (Figure 4.3) was also the most prevalent worm and were recovered from six of the eight kudus sampled, followed by *Elaeophora sagittus* that was recovered from three of the kudu sampled.

Bushbuck

No parasites were recovered from this animal.

Nyala

The nyala bull was submitted to the Louis Trichardt Veterinary Laboratory for a post mortem in October 2007. *Clostridium novyi* was diagnosed as the cause of death. No parasites were recovered from this animal.

Blue wildebeest

Five nematode species were recovered from blue wildebeest in this study. The helminth burdens of the four wildebeest are summarized in Table 4.3.

The highest total burden in an animal was 550 worms. Then mean helminth burden of the four blue wildebeest was 407 worms.

The worm with the highest intensity was *H. contortus* with 500 per individual, followed by *Haemonchus bedfordi* with 375 per individual.

Table 4.2 The total helminth burdens of kudu examined

Helminth species	Soutpansberg area				Lephalale	Musina area				
	VK1	**VK2**	**VK3**	**NwK1**	**BK1**	**YK1**	**MK1**	**MK2**	**Mean burden (ñ=8)**	**Prevalence (%)**
Agriostomum gorgonis			25						3	12.5
Cooperia neitzi			240						30	12.5
Elaeophora sagittus				4			85	1	12	37.5
Haemonchus contortus	50	275	2 425		50		50	25	359	75
Oesophagostomum L4						25			3	12.5
Fasciola hepatica				2					0	12.5
Total burden	**50**	**275**	**2 690**	**6**	**50**	**25**	**135**	**26**	**407**	

L4 = Fourth stage larvae

Table 4.3 The total helminth burdens of blue wildebeest examined

Species	**VWB1**	**VwB2**	**VwB3**	**BwB1**	**Mean burden (ñ=4)**	**Prevalence (%)**
Cooperia connochaeti	75	175		125	94	75
Haemonchus bedfordi				375	94	25
Haemonchus contortus	100	175	500		194	75
Oesophagostomum columbianum				50	12	25
Trichostrongylus deflexus	25		25		12	50
Moniezia benedeni			fragments			25
Total burden	200	350	525	550	407	

Black wildebeest

Three nematode species were recovered from the two black wildebeest.

The one black wildebeest (BSw2) had a markedly higher total burden compared to the other black wildebeest (BSw1). Three helminth species were recovered from BSw2 in contrast to only one from BSw1. *Haemonchus bedfordi* is the only helminth recovered from both black wildebeest and also had the highest intensity with a mean of 488 individual worms per animal.

The helminth burdens of the two black wildebeest are summarized in Table 4.4.

Table 4.4 The total helminth burdens of two black wildebeest examined

Species	**BSw1**	**BSw2**	**Mean burden**
Agriostomum gorgonis		50	25
Haemonchus bedfordi	100	875	488
Oesophagostomum columbianum		150	75
Total burden	100	1 075	588

Gemsbok

Two nematode species and the larval stages of two cestode species were recovered from the gemsbok. The helminths recovered from the gemsbok are summarized in Table 4.5.

One specimen of *Setaria hornbyi* (Figure 4.6) was recovered from one gemsbok from Musina. Three calcified specimens of *Setaria* spp. were recovered from one gemsbok from Kerneels Young Trust. In this case, identification to the species level was not possible.

The larval stage of *T. hydatigena* (Figure 4.7), Cysticercus tenuicollis, was found attached to the mesenterium and liver of all three of the gemsbok. One gemsbok from Musina had two cysticerci of *T. hyaenae* (Figure 4.8) in the triceps muscles and one in the heart muscle. Species identification was made on the number and sizes of rostellar hooks (Table 4.6a and b).

Table 4.5 The helminths recovered of gemsbok examined

Species	MG1	MG2	YG1
Cooperia hungi	350		
Setaria hornbyi	1		
Setaria spp.			3
Taenia hydatigena larvae	7	6	2
Taenia hyaenae larvae		3	
Total burden	358	9	*

* Total helminth burden could not be determined.

Table 4.6a Numbers and measurements of the rostellar hooks of larval *Taenia hydatigena*

	YG1 Mesenterium	**MG1 Mesenterium**	**MG2 Mesenterium**	**Cysticercus tenuicollis** (After Verster 1969)
Number of hooks	31	29	28	28-36
Large hooks mean size (µm)	193	199	203	191-218
Small hooks mean size (µm)	137	139	141	118-143

Table 4.6b Numbers and measurments of the rostellar hooks of larval *Taenia hyaenae*

	MG2 (skeletal muscle and heart)	**Cysticercus of *T. hyaenae*** (After Verster 1969)
Number of hooks	30	28-36
Large hooks mean size (µm)	213	202-242
Small hooks mean size (µm)	130	128-159

Waterbuck

Five helminth species were recovered from the waterbuck. The total burdens of each nematode are presented in Table 4.7.

The total nematode burden was 2 150, with *Cooperia curticei* (Figure 4.1) having the highest intensity of 2 075.

Table 4.7 The total helminth burdens of the waterbuck examined

Helminth species	**Intensity**
Cooperia curticei	2 075
Oesophagostomum columbianum	25
Trichuris sp.	50
Total nematode burden	2 150
Avitellina sp.	Fragments
Stilesia globipunctata	Fragments

Warthogs

Ten helminth species were recovered from the warthogs. The total burdens of each parasite are presented in Table 4.8.

Two nematodes occurred in all the warthogs, namely *O. mwanzae* (Figure 4.9) and *P. vivipara*. *Murshidia hamata* (Figure 4.10) was recovered from four of the six warthogs and *O. mocambiquei* from three of the warthogs. *Murshidia pugnicaudata* (Figure 4.11) was only recovered from two warthogs.

Hydatid cysts of *Echinococcus granulosus* (Figure 4.12) was recovered from the lungs of one of the warthogs.

The helminth with the highest intensity was *P. vivipara*, with burdens ranging between 276 000 and 825 000 per host. The helminth with the second highest intensity was *O. mwanzae* with a total of 3 700 recovered from one warthog.

The highest total helminth burden was 825 940 including *P. vivipara* for warthog BWh1. However, Warthog BWh3 had the highest helminth burden of 5 920 excluding *P. vivipara*.

No *Trichinella* were found in any carcass.

Bushpig

Two nematode species were recovered from the single bushpig, namely ten *Physocephalus sexalatus* (Figure 4.13) and 70 *Globocephalus versteri* (Figure 4.14), a total of 80 worms*.*

Table 4.8 The total helminth burdens of warthogs examined

Helminth species	**Musina**		**Lephalale**				**Mean burden (ñ=6)**	**Prevalence %**
	YWh1	**AWh1**	**BWh1**	**BWh2**	**BWh3**	**BWh4**		
Cooperia hungi	4						0	17
Impalaia tuberculata				12			2	17
Murshidia hamata	50	90	90	250			80	67
Murshidia pugnicaudata	35			80			20	33
Oesophagostomum mocambiquei		380			2 300	1 100	1 064	50
Oesophagostomum mwanzae	1 075	130	850	350	3 600	3 700	1 185	100
Probstmayria vivipara	276 000	380 000	825 000	407 000	648 000	470 000	501 000	100
Physocephalus sexalatus	3		27	13	20	9	12	83
Echinococcus sp. cyst						1	0	17
Paramonezia phacochoeri				1			0	17
Total helminth burden	277 167	38 600	825 940	407 706	653 920	474 810	226 358	
Total burden excluding *P. vivipara*	1 167	600	162	706	5 920	4 810	2 228	

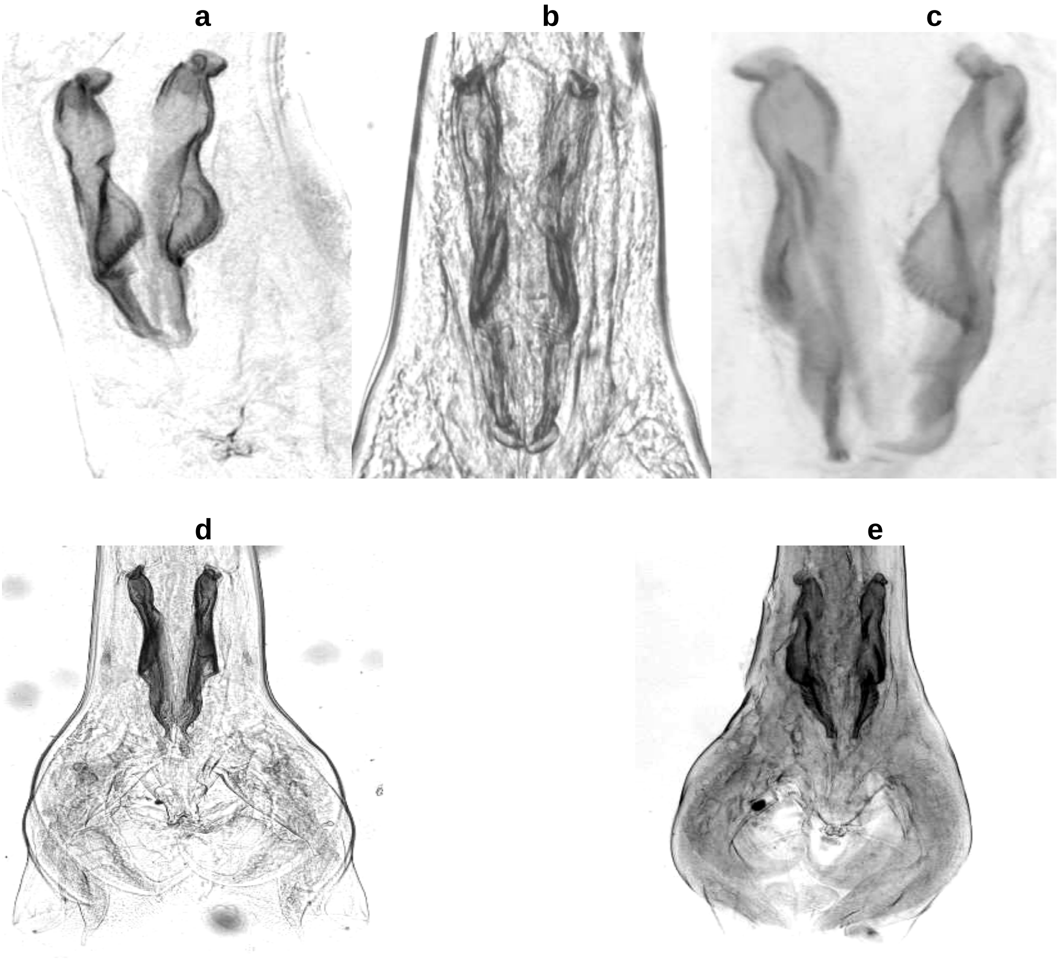

Figure 4.1 The spicules of (a) *Cooperia connochaeti*, (b) *Cooperia curticei*, (c) *Cooperia fuelleborni,* (d) *Cooperia hungi*, and (e) *Cooperia neitzi*

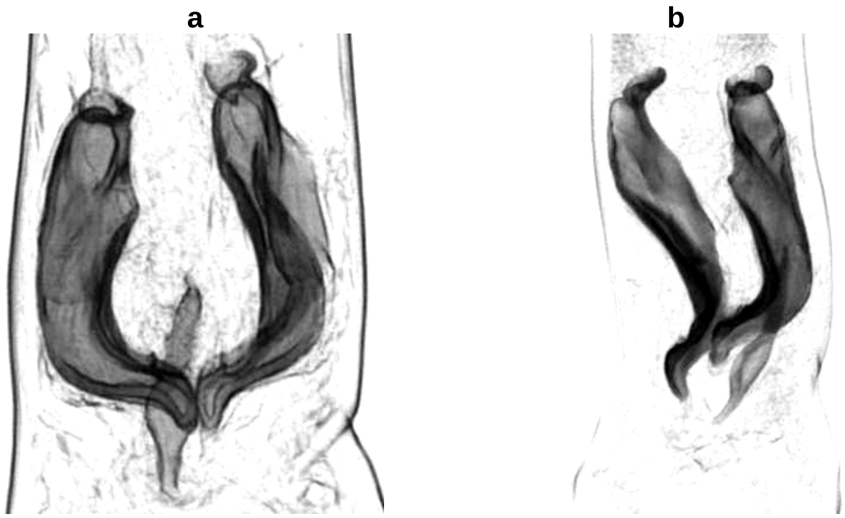

Figure 4.2 The spicules of (a) *Trichostrongylus deflexus*, and (b) *Trichostrongylus colubriformis*

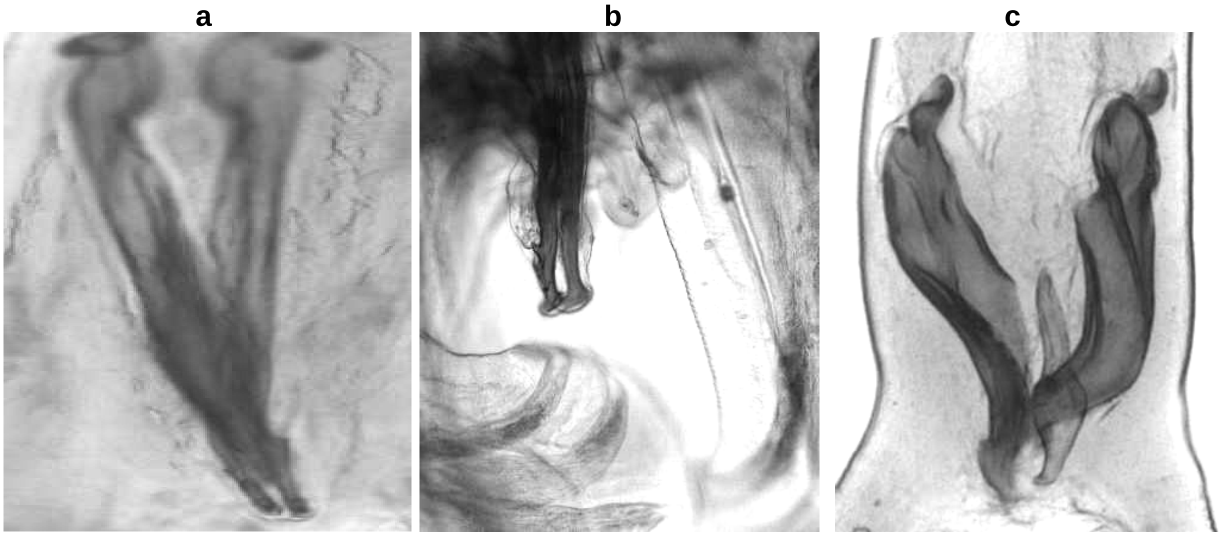

Figure 4.3 The spicules of (a) *Haemonchus contortus*, (b) *Haemonchus vegliai*, and (c) *Haemonchus krugeri*

Figure 4.4 *Agriostomum gorgonis,* anterior end

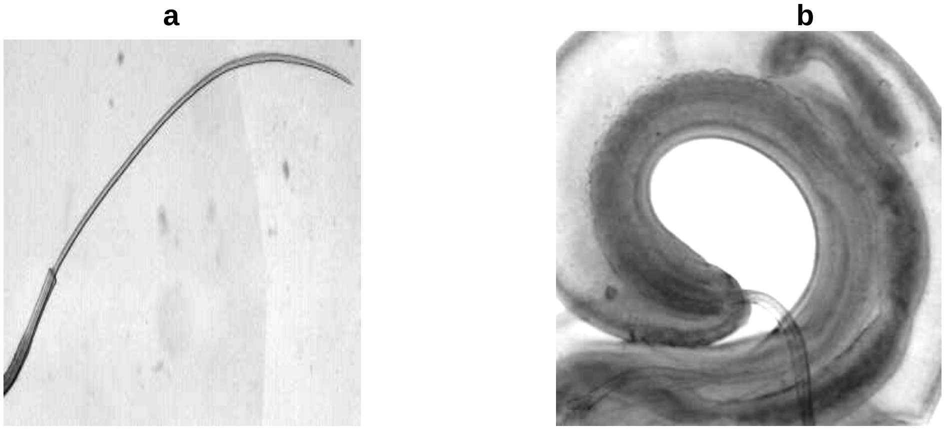

Figure 4.5 The spicule of a *Trichuris* sp.

Figure 4.6 *Setaria hornbyi*, anterior end

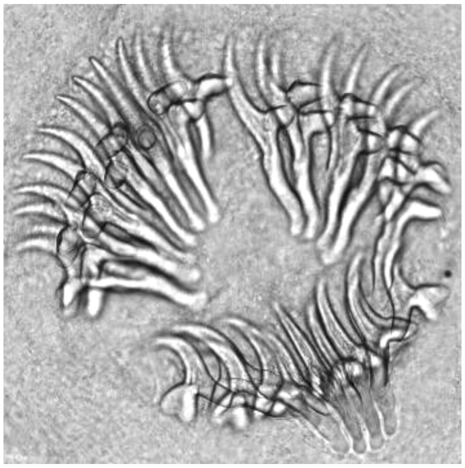

Figure 4.7 Rostellar hooks of a *Taenia hydatigena* larva

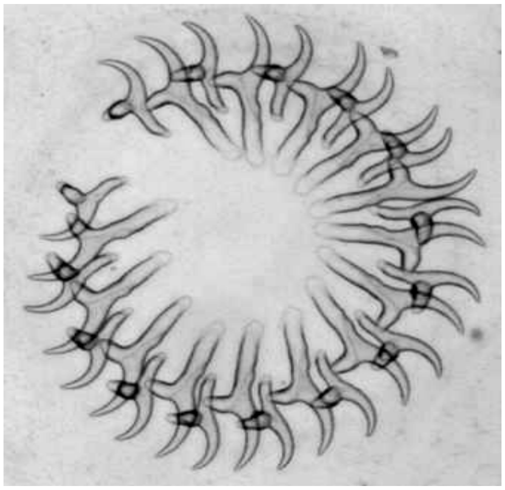

Figure 4.8 Rostellar hooks of a *Taenia hyaenae* larva

Figure 4.9 *Oesophagostomum mwanzae,* anterior end

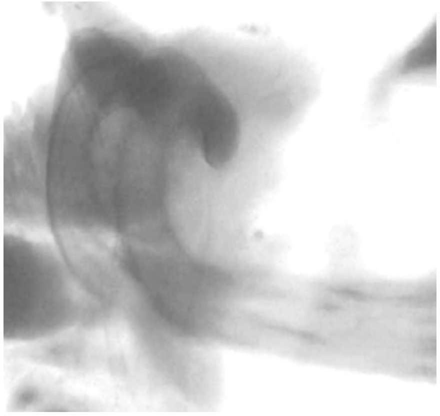

Figure 4.10 *Murshidia hamata,* distal tip of a spicule, showing the hook-like appearance

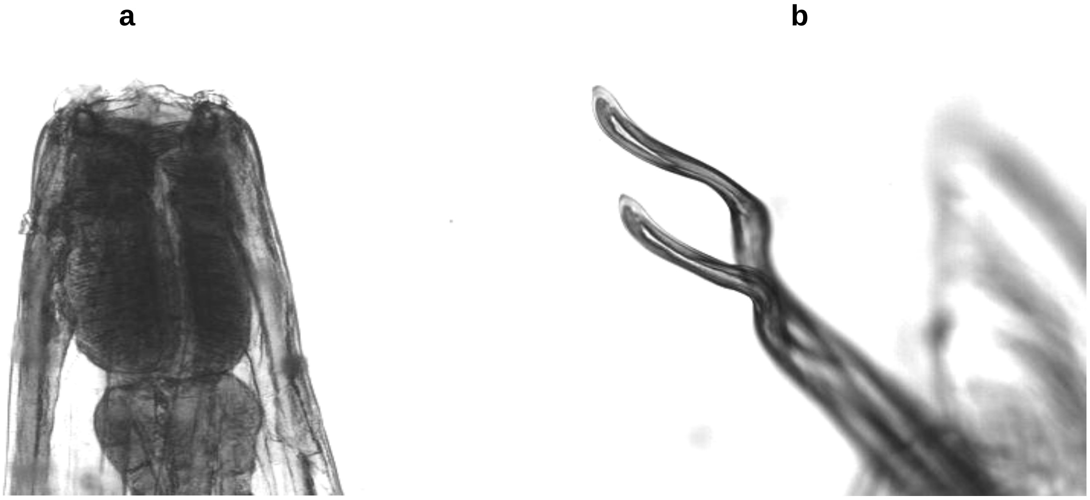

Figure 4.11 *Murshidia pugnicaudata* (a) anterior end, and (b) distal tip of the spicule

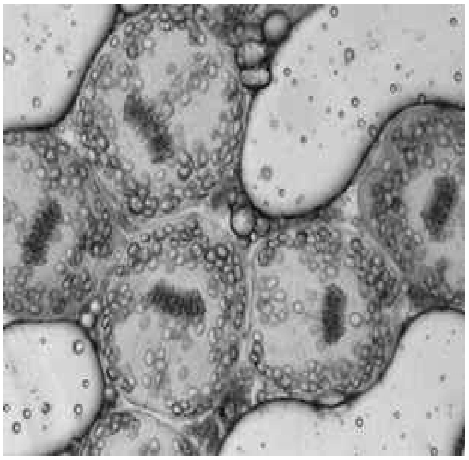

Figure 4.12 *Echinococcus granulosus* protoscoleces

Figure 4.13 *Physocephalus sexalatus,* anterior end

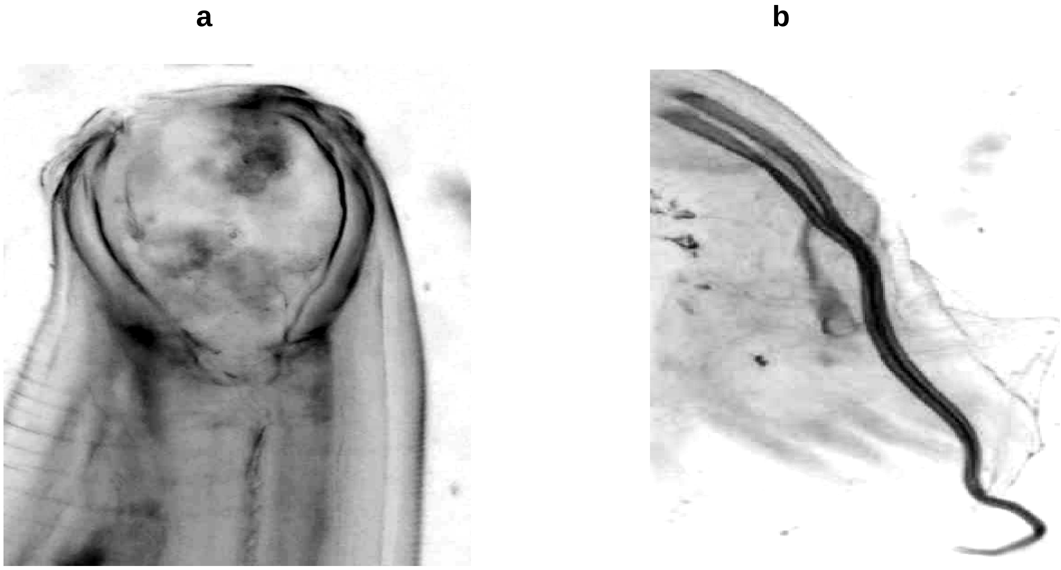

Figure 4.14 *Globocephalus versteri* (a) anterior end and (b) spicules

CHAPTER 5

DISCUSSION

Impala

Cooperia hungi was recovered from 90% of the impala and this confirms that it is a definitive parasite of these animals in the area. The other parasites all occurred in five or fewer animals which classifies them as either occasional or accidental parasites (Horak 1980).

In Horak's (1978) study on impala at Nylsvley more than 90% of the worms were retarded in the 4th stage at different times of the year. The helminths involved included *Longistrongylus sabie*, which was retarded during April and May, and July to October 1975, *Impalaia tuberculata* during May and July to September 1975 and *C. hungi/Cooperioides* spp. during September 1975. Adult *L. sabie, I. tuberculata* and *Cooperia* species were only present in significant numbers from November 1975 which coincides with rise in ambient temperatures and rainfall (Horak 1978).

Since digests were not done in this study the recovery rate of larval stages was low, and may account for the low total helminth counts. The harsh environment in the northern and western parts of the Province would necessitate that helminth parasites would employ strategies to protect the vulnerable free-living larval stages, not only during winter, when temperatures and rainfall are low, but also during summer, when temperatures are high and rainfall often low. It is doubtful that the same levels of larval retardation exist for worms in the current study area than at Nylsvley because of the higher rainfall and milder climate at the latter locality. Comparisons of worm burdens to other studies will therefore be of limited value because the larvae recovered in this study are probably underrepresented.

The relative few helminth species recovered could also be due to a smaller number of antelope species in the private game farms where sampling took place. Where a large number of antelope species are present, cross-transmission can take place more readily (Boomker *et al.* 1988)

Two impalas from Nwanedi in the Soutpansberg had eosinophilic granulomata in the lungs but no parasites were recovered from these lesions. The most common gross lesions that were associated with *Pneumostrongylus calcaratus* found in the lungs of the impala in Swaziland were firm tan-grey nodules along the lateral borders of the caudal lung lobes (Gallivan, Barker, Alves, Culverwell & Girdwood 1989). *Pneumostrongylus calcaratus* is a lungworm of impala and very prevalent in the Eastern Transvaal Lowveld (Limpopo and Mpumalanga) as found by Ortlepp (1962) and Young & Wagener (1968). Gallivan *et al*. (1989) also found a prevalence of 85% in impala from Mlawula Nature Reserve in Swaziland. Horak (1978, 1980) did not recover any lungworms from impala at Nylsvley Nature Reserve nor from Pafuri in the northern Kruger National Park. Young & Wagener (1968) however did find a high prevalence in impala in the south of the park. Horak (1981) ascribed this difference in prevalence to climate. He suggested that *Pneumostrongylus* is restricted to warm, moist regions, where the mollusk intermediate host occurs. The low prevalence of lungworms may be attributed to the dry climate or the absence of the intermediate hosts in the study area.

Kudu

Except for one kudu from the Soutpansberg area the helminth burdens were relatively low but are of similar range as from kudu sampled in the Etosha Game Reserve (Boomker *et al.* 1988) and the Eastern Cape (Boomker *et al*. 1991d). Twenty-three kudus were surveyed in Etosha Game Reserve (June 1983 to April 1984), which is an arid area with shrub savanna and Mopani savanna (Boomker *et al*. 1988). The mean burden of the animals was 399, with the smallest burden 4 worms and the largest 1 326. Two animals had no helminth parasites at all (Boomker *et al.* 1988).

In the Eastern Cape, one of two kudu sampled at Addo Elephant National Park (April 1985) harboured no worms and at Andries Vosloo Kudu Reserve six out of 15 kudu sampled monthly (March 1985 to January 1986) harboured no worms at all (Boomker *et al.* 1991d).

This is in contrast to the 96 kudus that were sampled in the Kruger National Park (April 1981 to March 1983) that had a mean helminth burden of 2 281 (Boomker *et al.* 1989a). The kudu were mainly from the south of the Park which has an annual rainfall of 600-700 mm. The dry climate of the localities in the present study area is more similar to that in Etosha and the Eastern Cape, and is too harsh for the survival of the free-living infective stages of helminths (Boomker *et al.* 1989a).

Of the helminths considered as definitive parasites of kudu in the Kruger National Park (Boomker *et al.* 1989a) only *C. neitzi* and *E. sagittus* were recovered from the kudu in this study. However, *C. neitzi* was only recovered in one kudu and in small numbers. *Elaeophora sagittus* was recovered from three kudus representing only two of the localities sampled in the study area, also not in significant numbers. Their presence is an indication of the abundance of their intermediate host (Boomker 2007).

Because kudus roam considerably they are only to a limited extent subject to reinfection with their own parasites (Boomker et al. 1986). However, animals that are known to roam, especially because their movement is not limited by fences, are more likely to become infected with accidental parasites (Horak 1980). *Agriostomum gorgonis* (Figure 4.4) and *Oesophagostomum* spp. are considered accidental parasites since they only occurred in one kudu each and in low numbers.

Nyala

The nyala bull examined was in poor condition and died during the rutting season. It would be expected that this animal would harbour some parasites under these conditions, yet none were recovered. The farm where the nyala originated from keeps cattle in the same camp as the game. Deworming of the cattle could reduce the parasite contamination of the pasture. The sample was also taken at the end of the dry season before the first spring rain. Many larvae were probably also still in seasonal hypobiosis.

Bushbuck

Boomker *et al.* (1987) investigated the helminth burdens in bushbuck from Charter's Creek and Weza State Forest, Natal. Bushbuck from Charter's Creek had lower helminth burdens and species variation compared to bushbuck from Weza and the Kruger National Park (Boomker *et al.* 1986). Boomker *et al.* (1987) considered this to be possibly due to less cross-infection because of fewer antelope species occur at Charter's Creek.

Bushbuck from the Kruger National Park (Boomker *et al*. 1986) had helminth burdens between 4 and 4 127. Although a part of the Park is in the eastern Limpopo Province, rainfall is higher there compared to the drier western and northern parts. This likely contributes to the higher prevalence of helminths in the Park.

No helminths were recovered from the bushbuck from Last Post. Underdispersion is a possible reason for this since only one animal was sampled. The farm has low stocking densities of antelope which will also limit the exposure of animals to cross-infection of helminths.

Blue and black wildebeest

The blue wildebeest in this study had comparatively similar mean burdens than the two black wildebeest but showed a higher species variation. Six helminth species were recovered from the blue wildebeest compared to three from the black wildebeest.

The total helminth burdens of the two black wildebeest differ markedly, one with a total burden of 100 compared to 1 075 in the second animal. The sample size is too small to make any deductions with respect to possible population burdens. However, overdispersion or underdispersion could play a role.

Haemonchus bedfordi appears to be equally well-adapted to both wildebeest species as well as to subtropical and temperate climates (Horak *et al.* 1983b). It was recovered from one blue wildebeest and both black wildebeest, all from the same locality. This is a common parasite of blue wildebeest and has been recovered from blue wildebeest from the Kruger National Park (Horak *et al.* 1983b). *Haemonchus bedfordi* was the only nematode recovered from one blue wildebeest from the Kalahari Gemsbok National Park (Boomker *et al.* 1986).

Cooperia connochaeti is a helminth of blue wildebeest and has been recovered from three of the four blue wildebeest. It is considered a definitive parasite for this species.

Gemsbok

The translocations of antelope to climatic or vegetation regions where they naturally did not occur can be hazardous to the health of animals (Boomker *et al.* 2000). This is illustrated in gemsbok from the West Coast National Park where gemsbok do not naturally occur. The total helminth burden of gemsbok from the West Coast National Park was 28 681 (Boomker *et al*. 2000) compared to gemsbok from the Kalahari Gemsbok National Park that had a total burden of 5 877 (Boomker *et al.* 1986). The high burdens for gemsbok in the West Coast National Park is attributed to the climatic conditions in the area. The climatic conditions appear to be favourable for the parasites but cause stress in the gemsbok (Boomker *et al.* 2000).

Considering that gemsbok do not naturally occur in the northern parts of the Limpopo Province, one would expect high parasite burdens as a result of stress of the host. However, relatively low burdens were found in the two gembok from Musina. The harsh climate is likely to be very unfavourable for the survival of the free-living stages of parasites and thus limit infection rates.

Warthogs

Four of the warthogs originated from Bushman's Safaris, two of which were examined in August 2006 and two in August 2007. The two warthogs from 2006 harboured *Murshidia* spp. but no *O. mocambiquei*, compared to two warthogs from 2007 that harboured no *Murshidia* spp., but both harboured *O. mocambiquei*. The two warthogs from 2006 also had lower total helminth burdens (excluding *P. vivipara*) of 162 and 702 each. The warthogs from 2007 had total burdens (excluding *P. vivipara*) of 5 920 and 4 810 each. It is possible that, although Lephalale had below average rainfall for the season (July 2006 to June 2007), rain during the dry season in 2007 could have affected the abundance of parasites in the region.

Bushpigs

The total worm burden of 80 of the bushpig was low when compared to warthogs. Ortlepp (1964b) made no note on the burdens of the worms he recovered form bushpigs. Because only one animal was examined, a low burden due to underdispersion can not be ruled out.

Helminths

Agriostomum

Agriostomum gorgonis was only recovered from one kudu and one black wildebeest and in small numbers in both animals. It is considered an occasional parasite of kudu in the Kruger National Park (Boomker *et al.* 1989a). No record could be found of the worm in black wildebeest, but is listed as a parasite of blue wildebeest (Horak *et al.* 1983b; Round 1968). The worms showed no seasonal pattern in kudu in the Park (Boomker *et al.* 1989a), yet showed a seasonal increase towards the end of the year in blue wildebeest from the same area (Horak *et al.* 1983b). Boomker *et al.* (1989a) considered the low *A. gorgonis* burdens of kudu compared to blue wildebeest to be due to the smaller herds and lower water dependency of kudu compared to blue wildebeest. The free living stages of hookworms occur in moist areas and the lower rainfall in the present study area will be limiting to the survival of the larvae of these parasites.

Cooperia

Cooperia hungi was recovered from only one warthog in this study. It was previously recovered from warthogs from Hoedspruit in the eastern Transvaal (Boomker e*t al.* 1991a). It is primarily a parasite of impala (Horak 1978), but is considered an accidental parasite in warthogs (Boomker *et al.* 1991a).

Cooperioides

Cooperioides hepatica is the only extra-intestinal trichostrongyloid of impala and is considered a common parasite of impala in the Kruger National Park (Pletcher, Horak, De Vos & Boomker 1988; Young & Wagener 1968). Their studies were done in the southern parts of the park that is wetter than the northern parts. Although many adult impala were found to be infected, the burdens were relatively small with fewer active parasitic nodules. Yearling impala had larger burdens as well as substantially more pathology than infected adults. Pletcher *et al.* (1988) suggest that smaller burdens may be due to acquired partial immunity in adults due to previous exposure.

Total burdens of *C. hepaticae* peaked in September in adult impala from Nylsvley (Horak 1978). In the present study *C. hepaticae* was recovered from only two impala and both had very small burdens. One reason for the low prevalence and intensity could be that the animals sampled were all adults and thus would have an acquired immunity. The animals were also all sampled before August and the peak burdens of this parasite might have been missed. The dry climate of the study area will affect the survival of free-living stages of the parasites.

Cooperioides hepaticae is generally considered to be of minor pathological significance unless they are present in large numbers in combination with other trichostrongyles, or when burdens are associated with poor nutritional conditions (Pletcher *et al*. 1988). Yearlings in particular develop lesions under such conditions (Pletcher *et al*. 1988). Fourteen percent of impala livers from the Kruger National Park that were infected with *C. hepaticae* showed secondary bacterial infection (Young & Wagener 1968), but the infected livers of impala in this study showed no such infection.

Elaeophora

Elaeophora sagittus is a definitive parasite of the tragelaphine antelope (Boomker 1988). This worm was recovered from only three kudu and none from the bushbuck or nyala from the current study area. This can be because either the parasite or its vector, thought to be a tabanid fly (Boomker *et al*. 1986) is not common in the study area.

Haemonchus

Haemonchus contortus was the most prevalent worm in kudu in this study. It was recovered from six kudu from three different localities in the study area. Expect for one kudu, the individual burden of the worm was small.

Haemonchus contortus was collected from three blue wildebeest and three kudu from one locality, Langgedachte. At this game farm domestic livestock are kept together with game. *Haemonchus contortus* is considered a parasite of domestic animals and the high prevalence is possibly due to cross-transmission from domestic animals and the high stocking densities on the farm.

Impalaia

Impalaia tuberculata is a parasite of antelope, in particular impala and blesbok (Horak 1978). It has been recovered from only one warthog in this study, but from many warthogs in the Kruger National Park (Horak *et al.* 1988). *Impalaia nudicollis* was recovered from warthogs from Namibia (Horak *et al.* 1983a). Warthogs are not considered to be definitive hosts to these parasites (Horak *et al.* 1988) and infection was probably accidental.

Murshidia

Ortlepp (1964b) recovered *M. hamata* from Pilgrim’s Rest and Zululand, but *M. pugnicaudata* only from Pilgrim’s Rest. No *Murshidia* spp. was recovered from warthogs in Namibia (Horak *et al.* 1983a). Both species were recovered from warthogs from Hoedspruit (Boomker *et al.* 1991a) and the Kruger National Park (Horak *et al.* 1988). Only *M. hamata* was recovered from warthogs in the north-western Transvaal (Boomker *et al.* 1991b). *Murshidia hamata* was recovered from four of the warthogs in this study with a range in burdens of 50 – 250 in the infected animals. *Murshidia pugnicaudata* was, however, only recovered from two animals, including one from the Musina area in the north and the second from the Lephalale area in the west and in low numbers. Both species do thus occur in the north, east and west of the Province, but *M. pugnicaudata* possibly not in the north-western Transvaal. However, it is not stated where the warthogs from the north-western Transvaal originated from (Boomker *et al.* 1991b). It should be noted that *M. pugnicaudata* was only recovered from warthogs examined during 2006. It is possible that climatic factors played a role in the prevalence of the parasites.

Oesophagostomum

Oesophagostomum columbianum is a common parasite of many antelope species (Boomker 2007). It is the most prevalent helminth in this study and was recovered from four hosts, namely the waterbuck, blue and black wildebeest and impala. In neither of these animals did this worm occur in large numbers. The typical lesions in the large intestines of sheep due to *O. columbianum* infestation were not found in any of the animals examined. Horak (1981) considers *O. columbianum* as a definitive parasite of impala.

Both *O. mwanzae* and *O. mocambiquei* were recovered from warthogs from Hoedspruit (Boomker *et al.* 1991b), the Kruger National Park (Horak *et al.* 1988) and Pilgrim's Rest (Ortlepp 1964b). Both species were also recovered in this study from the Musina and Lephalale. It would appear that these are the only two *Oesophagostomum* species that occur in warthogs in the Limpopo Province. *Oesophagostomum mwanzae* is the dominant of the two species and both can be considered as a definitive parasite of warthogs in the area.

Setaria

Setaria spp. are filarid worms and the adults are usually found in the abdominal cavity of their hosts. Mosquitoes are the intermediate hosts (Reinecke 1983). The *Setaria* spp. are considered non-pathogenic and are usually only found at necropsy.

Trichostrongylus

Trichostrongylus deflexus has only relatively recently been described as a separate species (Boomker & Reinecke 1989b). It has been recovered from blue wildebeest and impala in this study. Mönnig (1933) described specimens of *T. instabilis* (synonymous with *T. colubriformis*) from impala with extreme variation in the spicule shape. Similarly, Horak (1980) found the same extreme variation in spicule shape from *Trichostrongylus* males that he recovered from sheep, calves and goats which he artificially infested from faecal cultures of impala. He referred to these worms as *T. colubriformis*. Boomker & Reinecke (1989b) re-evaluated some specimens and proposed that these worms represent a definitive species and should be named *T. deflexus*.

Horak *et al.* (1983b) described *T. colubriformis* from blue wildebeest from the Kruger National Park. He made no mention of the spicule morphology. After having examined the material collected by Horak *et al*. (1983b) Boomker & Reinecke (1989b) considered *T. colubriformis* from this material as synonymous with *T. deflexus*.

Trichuris

Ortlepp (1937) described *T. barbertonensis* from an ox with spicules and sheath that measured between 6.83 to 7.3 mm that did not end in a bulb or swelling as is described for *T. globulosa* or *T. ovis*. Two individual adult *Trichuris* worms were recovered from the large intestine of the waterbuck. The spicules of the male measured 5.8 mm in length and did not end in a bulb or swelling either (Figure 4.5). It is possible that the specimen collected from the waterbuck was *T. barbertonensis.*

Many *Trichuris* spp. have been described to occur in antelope, of which *T. globulosa* is the most common. *Trichuris globulosa* occurs widespread in southern Africa (Ortlepp 1937). *Trichuris* spp. are more of a problem in enclosures and zoos due to its monoxenous life cycle and thick-shelled eggs (Boomker 2007). Environmental build up of the parasite is not likely to happen in a free-range system.

Avitellina

Avitellina sp. is common in semi-arid areas (Reinecke 1983) but was only recovered from the waterbuck.

Stilesia

Stilesia globipunctata fragments were recovered from the waterbuck. No record of this parasite in waterbuck could be found. Both *Stilesia* and *Avitellina* require an invertebrate intermediate host, probably one of the oribatid soil mites, and because of this the adult worms are more likely found in animals that feed close to the ground (Boomker *et al*. 1986).

In this study *S. hepatica* was recovered from only one impala. Gallivan, Barker, Culverwell & Gridwood (1996) reported no difference between seasons or sexes, but adult animals had larger burdens, possibly indicating that it is an accumulative infection. Horak (1978) recovered no *S. hepatica* from impala at Nylsvley. An prevalence of 10.13% was described for animals from the Kruger National Park (Young & Wagener 1968).

Echinococcus

A hydatid cyst was recovered from the lungs of one warthog. Hydatid cysts are usually found in the lungs and livers of the intermediate host (Young 1975). *Echinococcus granulosus* has remarkably low intermediate host specificity (MacPherson 1985). Hydatid cysts have been recovered from many species including impala, warthog, and zebra (Young 1975). Possible definitive hosts of *Echinococcus* spp. on the farm in Lephalale are spotted hyena, black-backed jackal, *Canis mesomelas*, African wild cat, *Felis lybica,* (Verster & Collins 1966) and domestic dogs.

Taenia spp.

Metacestodes sometimes occur in aberrant sites or less obvious sites, e.g*. T. olngojinei* that occurs subdurally in the sacrum of certain alcelaphine antelopes, and can therefore can easily be missed. Also, light infections can easily be missed at meat inspection.

The larval stage of *T. hydatigena* was recovered from all three gemsbok. The larval stage is much larger than that of other species, and is thus more easily identified (Verster 1969). The intermediate hosts are ruminants and pigs, while the final hosts are canines and other wild carnivores (Loos-Frank 2000). In sheep the migratory tracts through the liver commonly known as *hepatitis cysticercosa* can cause the death of the animal (Reinecke 1983). No macroscopic liver pathology was noted in any of the gemsbok affected.

Taenia hyaenae utilizes many ruminant species as intermediate hosts. The definitive hosts for these species are hyaena and the African wild dog, *Lycaon pictus* (Loos-Frank 2000). Cysticerci found in muscles of antelopes in the Serengeti were mainly *T. hyaenae* and *T. gonyamai* (Sachs & Sachs 1968). The spotted hyaena, brown hyaena, *Hyaena brunnea*, African wild dog, black-backed jackal and leopard, *Panthera pardus,* are all known to frequent the farm where these gemsbok originated. Cysticerci that resemble this species in the number and shape of the rostellar hooks have been recovered from impala and sable antelope, *Hippotragus niger* (Verster 1969). Macroscopically it can not be distinguished from the cysticerci of other *Taenia* spp., including Cysticercus bovis. Cysticercus bovis is the larval stage of *T. saginata* in which humans are the definitive host and have been recovered from various game species (Sachs & Sachs 1968). Only microscopically can *T. saginata* be identified by the absence of rostellar hooks. This is of importance in meat hygiene and public health.

Fasciola

Two specimens of *Fasciola hepatica* have been recovered from a kudu from Nwanedi Game reserve. *Fasciola hepatica* has not previously been described in kudu. As browsers, kudus are not normally exposed to aquatic vegetation and thus few get infected with trematodes (Condy 1972). *Fasciola gigantica* has been described from Greater kudu form a game ranch in Zambia (Zieger, Boomker, Cauldwell & Horak 1998) as well as Rhodesia (Zimbabwe) where deaths in kudu were attributed to this parasite (Condy 1972; Hammond 1972). Kudu appeared to be very susceptible to infection (Condy 1972). *Fasciola gigantica* is the most common liver fluke in domestic ruminants in Africa and accounts for most liver fluke infections in wild animals (Hammond 1972). Nwanedi Nature Reserve, where the infected kudu originated from, has a large dam that is fed by the Nwanedzi River. This creates a favourable environment for the freshwater snail that serves as intermediate host to the flukes. Domestic stock has previously had access to the Reserve and is currently kept upstream from the dam is one possible source of contamination. Game animals that have been introduced into the Reserve is another possible source of contamination. Hammond (1972) considers game as potential maintenance hosts for *F. gigantica*. Although fasciolosis is not very common in wildlife, under intensive conditions game might become more important in the epidemiology of the disease (Hammond 1972).

CHAPTER 6

CONCLUSIONS

The aim of the study was to describe the helminth parasites of the common game species in the Limpopo Province, focusing on the northern and western parts. The climate of these parts is harsh and dry, with a large area that is considered to be semi-arid. This has an impact on the prevalence of the parasites that occur in these areas. In total 36 animals were examined and their helminths recorded. New host records for species include *Trichostrongylus deflexus* in the blue wildebeest, *Agriostomum gorgonis* in the black wildebeest, *Stilesia globipunctata* in the waterbuck, and *Fasciola hepatica* in the kudu.

The materials for this study were all opportunistically collected from hunting and culling operations over a wide area. Single random sampling from groups of animals may not be representative of the spatial or temporal variation in parasite infection in the whole population due to overdispersion and seasonal variation in the prevalence of the helminths. Because the sampling was done over a limited period each year and the sample size for each locality very low, comparisons between seasons or between localities within the study area are of little value.

However, for the study area as a whole, comparisons to other studies did reveal some valuable information. The total burdens and species variation of especially the adult helminths in this study were all consistently low compared to other studies done in areas with higher rainfall.

It is evident that parasites also have limited ranges where they occur. *Oesophagostomum mwanzae* and *O. mocambiquei* appear to be the only *Oesophagostomum* species that occur in warthogs in the Limpopo Province. *Oesophagostomum mwanzae* is the dominant of the two species and both species can be considered as definitive parasites of warthogs in the area.

The only trematode recovered was *Fasciola hepatica* from one kudu at Nwanedi. The dry climate is not conducive for the survival of the intermediate hosts, namely freshwater snails. These parasites typically occur in areas with more humid or wetter conditions.

There are practical implications of the low prevalence and species variation of helminths. When animals are translocated from the drier parts of the Limpopo Province to areas with higher rainfall, they will be relatively naive to the higher parasite loads in those areas and/or completely naive to other parasites, such as lungworms.

Animals that are translocated here from areas with higher rainfall are likely to harbour higher parasite loads. They should be dewormed prior to translocation, because the stress of the dry climate and change in vegetation can cause them to succumb to the parasite loads they already harbour. At the same time, new parasites could be introduced, with variable results to the game animals already present.

Game is kept together with domestic stock on many farms in the Province. Helminths that typically occur in domestic stock were recovered from some antelope species. *Haemonchus contortus* was recovered from all the kudu and blue wildebeest from Langgedachte. High stocking densities of animals on this farm have in all likelyhood contributed to the frequency of cross-transmission of parasites between species. With parasites that have a high fecundity, such as *Haemonchus* or *Oesophagostomum,* environmental build up may become considerable under certain conditions or specific times of the year. This will impact on the worm control programme for the domestic animals, but may also cause morbidity in game at times. It is possible that only individual animals will suffer significantly, for example females around partus or males during rut. On a commercial farm where optimal population growth is required, the farmer will suffer indirect financial losses due to under-performance of these animals.

Some parasites are more problematic in intensive situations such as animals that are kept in a boma or very small camps. This is especially true for parasites with a monoxenous life cycle such as *Trichuris* spp. Animals that are kept intensively should be dewormed to prevent environmental build up of the parasite. Under extensive conditions, these parasites are unlikely to cause any problems.

The only known zoonotic helminth recovered was *Echinococcus granulosus* from the lungs of a warthog. The infective stage for humans is the eggs that are deposited by the final host, namely carnivores. Offal is often fed to domestic dogs. One should be aware that the parasite can potentially become established in the local human population through this route, especially in communal areas where people live in close association with their dogs. Infected material should be destroyed and only cooked meat should be used for either human consumption or to feed dogs.

Cysticerci of *Taenia hyaenae* and *T. hydatigena* were recovered from the gemsbok. Although the tapeworms are not known to be zoonotic, the cysticerci are not macroscopically distinguishable from cysticeri of *T. solium* or *T. saginata* which are zoonotic. This has public health implications because the cysticerci render the meat aesthetically unacceptable. In addition, a lack of proof of non-infectivity does not prove that these cestodes are not in fact infective to humans.

The host species included in the study are some of the more common ones that occur on game farms in the Limpopo Province. The parasites of many game species are not well studied, including species that are also relatively common, such as giraffe, *Giraffa camelopardalis*, common reedbuck, *Redunca arundinum*, and grey rhebuck, *Pelea capreolus*, and also the scarcer game such as red duiker, *Cephalophus natalensis*. Because these animals all share the same, mostly confined environment, there is a need to gain more knowledge on the parasites, including the helminths, of these species, in order to scientifically farm with game.

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