THE EPIDEMIOLOGY OF GASTROINTERSTINAL PARASITES IN PAINTED DOGS (*Lycaon pictus*) IN HWANGE NATIONAL PARK(HNP).

BY

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ABSTRACT

An epidemiological survey was conducted on the prevalence and risk factors associated with intestinal parasites of African Painted dog in Hwange National Park between June 2016 and July 2017. Centrifugal flotation and McMaster techniques were employed to obtain comprehensive data on the prevalence and diversity of gastrointestinal parasites observed in faecal samples collected from painted dogs. A total of 58 painted dogs were surveyed. Out of these, all were infected with at least one intestinal parasite and 10 parasite genera of gastrointestinal i.e. *Alaria*, *Physolaptera*, *Isospora*, *Spirocerca*, *Dipylidium*, *Uncinaria*, *Toxoscaris, Toxocara*, *Taenia*, *Ancylostoma* and *Sarcocystis* spp were recorded. Two parasites (*Physolaptera and Spirocerca*) have been reported for the first time in this study. *Sarcocystis* had the highest prevalence (28.2%) and intensity (629.18±113.01), while the lowest prevalence was for *Physolaptera* and *Alaria* spp (0.6% prevalence and 50± 0 intensity). Level of parasitism was statistically significant across all parasites species ($F=0.036$; $p<0.05$). The findings also revealed significant difference in intensity between packs ($F= 0.037$; $p <0.05$), no significant difference in level of parasitism between season ($F=0.275$; $p > 0.05$). Results were comparable basing on location but with no statistical significance ($P=0.132$). Coinfection was dominant with 82.8% dogs having multiple infection (>2 parasites) while 17.2% had single infection (<2 parasites). This coinfection affected intensity of parasitism with 27.1% of multi infected dogs having a heavy infection (>1000e.p. g) whilst 20% of single infected having a heavy infection. Overall, most parasite species were consistent with those found from studies in other regions of Africa and are likely a result of ingesting infected prey. The identification of two new parasite genera shows the scarcity of information on the subject. To our knowledge this study provides the most comprehensive survey of gastrointestinal parasite infection in painted dogs from this region to date and provides baseline data for future studies.

Key word: *epidemiology, Lycaon pictus, Gastrointestinal parasite, co infection, Hwange National park*

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DECLARATION OF THESIS

I hereby declare that the thesis is composed of work carried out by myself unless otherwise acknowledged and that this thesis is of my own composition. The research was carried out during the period of June2016 to July 2017. This thesis has not in whole or in part been previously submitted for any other degree or professional qualification.

Takunda T. Tauro

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DATE: _____/____/_________

CERTIFICATION OF THESIS

I the undersigned, certify that Takunda T. Tauro a candidate for the degree of Bachelor of Science (Honours) Animal and Wildlife Sciences has presented this thesis with title:

THE EPIDEMIOLOGY OF GASTROINTERSTINAL PARASITES IN PAINTED DOGS (Lycaon pictus) IN HWANGE NATIONAL PARK(HNP).

That this thesis is accepted in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate through an oral examination held on the 27th of April 2018.

Major Supervisor ……………………………………

Date ………………………………...

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CHAPTER 1

1.1 Introduction

The painted dog (Lycaon pictus) also known as the African Wild dog or the Cape hunting dog is one of the most endangered species in Africa. They once occupied 39 range states throughout sub-Saharan Africa but are now found in Namibia, Botswana, Mozambique, parts of Zimbabwe, Swaziland, and the Transvaal (Kingdon, 1997). Hundred years ago, the estimated population size was 300-500 000 dogs (Painted Dog Conservation Project, Zimbabwe ,2006). The African wild dog populations have since dramatically declined over time (McNutt *et al*., 2008). According to IUCN (2017) "their population is currently estimated at approximately 6,600 adults in 39 subpopulations, of which only 1,400 are mature individuals."

The loss of this canid will be a great tragedy as they differ significantly from other canids morphologically, physiologically and behaviourally (Woodroffe *et al.*, 2011). In many parts of Africa, large predator populations have undergone severe declines or extinction and this is a cause for concern on species conservation. This was due to anthropogenic factors, however health issues such as parasitic infections and infectious diseases (canine distemper, rabies, canine parvo virus), have also caused local declines (Ray *et al*., 2005).

Parasites significantly affect the lives of animals as they have negative effects such altering host behaviours and population dynamics (Lindenfors *et al.*, 2007). Generally parasitic infection in wild animals are believed to affect the hosts competitive fitness (Labaude *et al*., 2015) and higher parasite infection may cause mortality (Flacke *et al.*, 2010).

Previous investigations have shown that parasitism is affected by weight, diet factors, population density geographical range size, gender and age (Poulin & Morand, 2004; Nunn *et al*., 2003; Olifiers *et al*.,2015). In addition, weather changes with more cases occurring during the wet season and host immune response also influence the level of parasitism (Altizer *et al.*, 2006).Carnivores generally tend to have higher parasite loads and species richness compared to herbivores because of their diet (Lindenfors *et al.*, 2007). Hyper carnivorous diets of painted dogs are also intermediate hosts of a variety of parasites and also attracts flies and beetles, which are passive carriers of parasite propagules (Watve and Sukumar, 1995) .

Painted dogs tend to be more susceptible to parasitic infection because of their large home ranges (>750km^2) and nomadic lifestyle (Creel, Mills and McNutt, 2004). This increases the contact of painted dogs with domestic dogs directly or indirectly increasing the chances of transmission of parasites common to both species (Woodroffe and Donelly,2011).

There have been a few studies on gastro intestinal parasitism in painted dogs. The gastro intestinal parasites that have been observed by other researchers in painted dog wild populations (i.e. Zambia and South Africa) consisted of *Taeniid*, *Ancylostoma, Spirometra, Giardia, Isospora, Dipylidium, Sarcocystis* and *Filaroides* species (Ash, 2011;Berentsen *et al.*, 2012 ; Flacke *et al.*, 2010). Researches have clearly shown that there's parasitic diversity between geographical locations in Southern Africa (Berentsen *et al.*, 2012;Flacke *et al.*, 2010). Previous studies (KZN) have not seen any clinical signs associated with heavy G.I parasitic infection in painted dogs such as ascites, diarrhoea, weight loss and pale mucous membranes (Flacke *et al.*, 2010). *Sarcocystis* had the highest prevalence in all studies but however does not result in disease (Flacke *et al.*, 2010).

Information of gastro intestinal parasites in painted dogs is rare and the aim of this research study was to investigate the distribution and prevalence of the parasites in painted dogs in Hwange National Park, Zimbabwe. The study will be significant in creating a baseline database of parasitism which can be used in conservation efforts of the highly endangered species.

1.2 Problem Statement

The population of the painted dogs have been declining for the past several years with only 6,600 adults left in 39 subpopulations, of which only 1,400 are mature individuals (IUCN 2017).In 2013 HNP had an estimate of 144 dogs(Blinston, 2013).The species is now facing extinction and is listed as Endangered in the IUCN red list.

Parasitism affect the competitive fitness of animals thereby controlling the population hence lack of information of gastrointestinal parasites in painted dogs can detrimental to their survival. Furthermore, extinction of painted dogs in the wild can cause adverse effects on the ecosystem structure and function.

Data on epidemiology of parasites in painted dogs is limited especially in the wild hence the need to investigate the epidemiology of parasites.

1.3 Justification

Painted dogs have vanished from much of their former range with a dwindling population currently estimated to be 6,600 adults in 39 subpopulations, of which only 1,400 are mature individuals (IUCN, 2017).

There is insufficient data on the epidemiology of gastrointestinal parasites affecting the painted dog and major studies have been focused mainly on anthropogenic issues and infectious diseases (Ash, 2011). Understanding all threating processes within the wild environment including parasites will be vital in the conservation efforts of the species (Peterson., 1991). Moreover, painted dogs have a significant impact on the structure and function of an ecosystem by regulating the population of herbivores hence the need to prevent their decline.

The study will be vital in recognizing possible parasitic disease which may be a threat to the painted dogs. As mortality in the dogs can be as a result of heavy infection of hookworm in young or immunocompromised animals due to anaemia (Bowman *et al*.,2003). Since rational management strategies are vital in an effort to prevent transmission of parasites to rare and endangered species, such as the painted dog (*Lycaon pictus*) the study will help create a baseline database of natural parasitism within wild populations of the dogs (Ash, 2011). Some of the parasites are of public health importance such as *Dipylidium* spp. It is therefore essential for the future conservation of this animal to understand the life threatening processes, such as parasitism, to which this species is routinely exposed.

The loss of parasites can cause a sequence of long-term, indirect effects whose dynamics and extents are unknown (Strona, 2015). Hence the understanding of parasitism within wild populations is vital in any part of wildlife monitoring and conservation efforts. More importantly the painted dog has an economical role in our country as more tourists come with the exception to see the dogs and this study will help contribute to the conservation efforts of this species.

The study will help solve the problem of the decline in numbers of the species by coming up with mitigation factors to parasitism in the wild.

1.4 Study Objectives

1.4.1 Main Objectives

- To investigate the epidemiology of gastrointestinal parasites in the painted dogs in Hwange National park.

1.4.2 Specific Objectives

- To determine the parasitic load of the gastrointestinal parasites in the painted dogs.
- To investigate risk factors associated with parasitism in painted dogs.

1.5 Research Questions

What are the gastrointestinal parasites in painted dogs from HNP?

What is the load of gastrointestinal parasites in painted dogs?

What are the determinants of this parasitic load?

CHAPTER 2: LITERATURE REVIEW

2.1 General Introduction

The Painted Dog also known as cape hunting dog, African hunting dog, African wild dog, is one of the most critically endangered large carnivores in Africa(IUCN,2017), with approximately less than 6600 individuals left. The painted dogs have a short, thin fur which is coloured in spots of grey ,yellow, black and white (Rosevear., 1974), hence their scientific name of *Lycaon pictus* which means 'painted wolf' in Greek (Hartstone-rose *et al.*, 2010). The fur is longer on the neck and each dog has a unique colouration pattern, which is also used for identification of individuals (Woodroffe *et al.,* 2007). The species is built for running endurance with a thin and muscular body, a bushy tail with a white tip and long legs (Creel & Creel, 2002). The body length of the species is between 75 and 110 cm, the tail is between 30 and 40 cm long, and their weight ranges between 18 to 36 kg (Stuart &Stuart, 1995). Males are slightly large than females however the dimorphism in this species is very small (IUCN, 2017). They are also unique and unlike other canid species they lack the vestigial digit (dewclaw) (Creel and Creel, 2002). The dogs' huge round ears, probably help with heat loss as well as picking up long distance vocal signals therefore tracking pack members (Creel & Creel, 2002). The species prefer woodlands or broken woodlands although they are also found on open plains and savannas (Lindsey *et al.*, 2004). Their habitat also includes semi-arid deserts to mountainous areas (Nowak,1999).

These animals are estimated to live up to 11years in the wild (Kingdon, 1997) and 17 years in captivity (Nowak, 1999), although 15.1 years has been recorded in captivity (Weigl, 2005).

2.2 Painted Dogs *(Lycaon Pictus)*

2.2.1 Taxonomy of painted dogs

Painted dogs vary according their geographic location, morphologically and genetically (IUCN, 2017). The species (*Lycaon pictus*), like the domestic dog (*Canis familiaris*) and the wolf (*Canis lupus*) all belong to the Canidae (order *Carnivora*) (Van den Berghe *et al*., 2012). It is the largest canid in Africa, and the only extant member of the genus *Lycaon*, which is distinguished from *Canis* by its lack of the vestigial digit and its unique dentition which is specially adopted for a hyper carnivorous diet (Hartstone-rose *et al.*, 2010). The evolutionary pathway of *Lycaon pictus* is poorly known and also its relationship to other canids is highly controversial (Hartstone-rose *et al.*, 2010).

Taxonomic Hierarchy

Kingdom	Animalia – Animals
Subkingdom	Bilateria
Infrakingdom	Deuterostomia
Phylum	Chordata – chordates
Subphylum	Vertebrata – vertebrates
Infraphylum	Gnathostomata
Superclass	Tetrapoda
Class	Mammalia Linnaeus, 1758 – mammals
Subclass	Theria Parker and Haswell, 1897
Infraclass	Eutheria Gill, 1872
Order	Carnivora Bowdich, 1821 – carnivores
Suborder	Caniformia Kretzoi, 1938 – dog-like carnivores
Family	Canidae Fischer, 1817 – coyotes, dogs, foxes, jackals and wolves
Genus	Lycaon Brookes, 1827
Species	Lycaon pictus (Temminck, 1820) – Africa hunting dog, African Wild Dog, painted hunting Dog

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2.2.2 Subspecies

The five acknowledged subspecies are categorised according to their geographical locations namely: *L.p. pictus* (Southern Africa), *L.p. lupinus* (East Africa), *L.p. manguensis* (West and Central Africa), *L.p. saharicus* (Sahara) and *L.p. somalicus* (Horn of Africa) (Kingdon, 2013). According to IUCN (2017), the last three subspecies are near extinction due to their extreme low numbers in their sub regions and ongoing threats to their survival.

Figure 1 *Lycaon pictus pictus* *Source:* *http://www.waza.org/files/images*

Lycaon pictus pictus also known as the Cape hunting is found in Southern Africa, Angola and Mozambique (Kingdon, 2013). It is characterised by orange-yellow fur overlapping the black, and whitish hairs on the throat mane. Those in Mozambique are notable by their almost equal growth of yellow and black, as well as having less white fur on the neck (Bryden, 1936).

Figure 2 *Lycaon pictus lupinus* *SOURCE:https://animaldiversity.org/accounts/Lycaon_pictus/pictures/*

The East African wild dog (*Lycaon pictus lupinus*) is a subspecies of painted dogs and is found in East Africa. Unlike the cape hunting dog, east African wild dogs are characterised by a smaller body compared to the cape hunting dog (*Lycaon pictus pictus*) (Estes, 1992) and much blacker coat.

Figure 3 *Lycaon pictus manguensis* *Source: https://www.pinterest.com/pin/497366352585347485/*

Lycaon pictus manguensis is found in Western African savannas (Kingdon,2013). Thus, they are found in northern Cameroon, Togo from Manga, Benin, Nigeria (Sillero-Zubiri et al. 1997) and probably extend to central Africa (Matschie,1915). It is classified as Critically Endangered by IUCN, as it was estimated that 70 adult individuals are left in the wild. The subspecies is characterised by more white patches compared to the other subspecies.

Figure 4*: Lycaon pictus saharicus* *Source: https//www.easyvoyage.com*

The Chadian wild dog (*Lycaon pictus saharicus*) also known as Shari River hunting dog, Saharan wild dog or Central African wild dog is native to Central Africa(Wozencraft,2005). The Manovo-Gounda St. Floris National Park in Central Africa Republic is the only place where the chadian wild dogs are found.

The sub species *Lycaon pictus somalicus* has some similarities with the East painted dog (*Lycaon pictus lupinus*). The somalicus subspecies however differ as it is smaller, has shorter and coarser fur, and has a weaker dentition (Fanshawe *et al*., 1997). Moreover, the colour closely resembles that of the *Lycaon pictus pictus* (Bryden, 1936). The sub species is found in Somalia and Eritrea however, the numbers are critically low and not known and the species is feared to be probably extinct in Eritrea (Fanshawe *et al*., 1997).

2.2.3 Painted dogs of Hwange National park

In 2013 Hwange National Park was estimated to have 144 dogs in 22 packs (Blinston, 2013).The subspecies found in HNP is *Lycaon pictus pictus*. However, there is evidence of cross breeding between the Southern and Eastern populations. Research has shown that there was genetic exchange between these two populations (Girman *et al.,* 2001). Unique nuclear and mitochondrial alleles have been observed in populations in Southern Africa and Northeast Africa which proves that there have been cross breeding between the species resulting in genetic change (Girman *et al.,* 2001; Edwards, 2009). Edwards (2009) stipulates that transitional populations are found in Botswana, Zimbabwe and
south-eastern Tanzania.

Figure 5 Dog from the Nyamandlovu pack in HNP

The painted dog fit the description of cape hunting dog (Lycaon pictus pictus) found in the Southern parts of Africa. However, some populations in HNP closely resembles the East African wild dog supporting the notion of genetic change in the past.

2.3: Ecology

2.3.1 Social and Reproductive behaviour

The painted dog is one of the most social canid. The species demonstrates a highly social hierarchy (Davies *et al.*, 2016). It is an obligate cooperative breeder commonly living in packs of up to 6-20 adults, in which only the alpha pair breeds (Newell-Fugate, 2008). The subdominants are reproductively suppressed and rarely breed but help to raise the pups (Van den Berghe *et al.*, 2012). This alpha pair is identified by increased urine marking and leading hunts. Sexual maturity in the species is reached at approximately 12 to 18 months, though they mate much later usually at 22 months old (Nowak, 1999). Lycaon pictus has the largest litter size which fluctuate considerably, from 2 to 20 pups and a gestation period of approximately ten weeks (Estes, 1991).Painted dogs also have the highest pup survival rate (Newell-Fugate, 2008). Painted dogs are obligate breeders which ensures pup survival however their need for helpers may become a constraint (Courchamp, 2002). The alpha female is mostly left at the den to guard the pups. The main disadvantage of this social set up is that the individual with the task of babysitting does not contribute in hunts and is fed by other members. In other words, small packs find it difficult to maintain themselves, to such a scenario that the pack can be extinct (Franck *et al.*, 2002). Litter size in the species is positively correlated with pack size and the age of the breeding female (Creel and Creel, 2002).

In all African subspecies, the pups are born between the winter months of May and July (Mcnutt, 1996), however in the northern hemisphere the pups are born between November and January (Verberkmoes,2008). Throughout this phase also known as the denning period, the pack displays refuging rather than nomadic behaviour and this phase lasts about 12 weeks (Franck *et al.*, 2002). The painted dogs are obliged to spend most of their time around the den and return to it after each successful hunt to regurgitate feed for the alpha female (lactating) and subsequently for the pups (Creel and Creel, 2002). Pups are weaned at 5 weeks and the species litters every 12 to 14 months (Kingdon, 1994). The social and reproductive behaviour is important to understand as it can have negative effects on the population of the painted dogs as it facilitates the spread of parasite.

2.3.2 Hunting and Feeding habits

Understanding the feeding behaviour of painted dogs is of great importance in understanding the epidemiology of parasites affecting the species. The painted dogs are efficient hunters with success rates ranging from 44% up to as high as 91% compared to other carnivores (Van Der Meer *et al.*, 2011). Painted dogs are cooperative hunters and hunt most commonly at sunset and early in the morning or under moonlight (Fanshawe and Fitzgibbon, 1993 and Rasmussen, 2009). By cooperatively hunting together, larger preys are caught than one would have if it hunted alone (Woodroffe *et al*., 1997). This has negative impacts as it exposes all the pack members to the same parasites.

They also use a widely foraging strategy, thus increasing the likelihood of an encounter and thus increasing the chances of prey capture using sight, sound and smell to hunt for their prey (Rasmussen, 2009). The dogs are spread out around the prey so that a member of the pack can intercept the prey as it turns. Also, during chases, painted dogs reach speeds of up to 60 km/h, for long distances and are specifically adapted to deal with the heat stress thus they usually tire their prey before they kill (Taylor *et al*., 1971). They usually prey on ungulates averaging 50 kg but sometimes as large as 200 kg (Creel and Creel 1995). Painted dogs do not scavenge and prey mostly on kudu (*Tragelaphus strepciseros*), Thomson's gazelle *(Gazella thomsonii*), impala (*Aepyceros melampus*), bushbuck(*Tragelaphus scriptus)*and duiker *(Sylvicapra grimmia*) being the most preyed on prey in Hwange National Park (Rasmussen, 2009).

2.4 Factors That Affect Painted Dog Populations (Conservation)

2.4.1 Wild animals

Painted dog populations are affected by wild animals mainly through competition, especially of the Canid family, Lion (*Panthera leo*) and Hyena (*Crocuta crocuta*) (Creel *et al*., 2001). This could be through direct killing, interfering at kills, kleptoparasitism, and elimination from high prey density areas (Creel *et al*., 2001). Research have shown that painted dog density is correlated with the intensity of interspecific competition with larger carnivores (Creel, 1998), thus densities are lowest where lions and hyenas are prevalent (Creel *et al.,* 2001). This forces the dogs to move to areas with low prey densities, making them vulnerable to extinction (Creel *et al.,* 2007). Moreover, all canids depend on the same resources which leads to interspecific competition which might result in fatalities (Creel 1998).

Intense competition from larger carnivore was recorded in Serengeti dogs and increased pup mortality by lions (Frame, 1986). Adult mortality by lions have been also recorded ,9% of 45 deaths in Selous ,33% of 57 deaths in Kruger National park and 50% of deaths in Morewi were from lion predation (Heerden *et al.,* 1995; McNutt 1995). Hyenas have caused little mortality through predation; however, their impact is seen through kleptoparasitism(Van Der Meer *et al.,* 2011). This has an adverse effect on the dogs as it reduces the feed thus starvation, compromised fitness and death of pups. Moreover, mortality of painted dogs is through intraspecific competition. The painted dogs fight with other dogs from neighbouring packs which in some cases result in fatalities (Creel, 1998). Cases of infanticide in the species have been recorded. However, it is hard to assess the impact of other animals as deaths from predation and other causes go unobserved (Creel,1998).

2.4.2 Human Influence

Painted dog numbers have declined all over Africa, mainly as a result of human wildlife conflict (Woodroffe *et al.,* 1997) and introduced disease (Creel and Creel, 2002; Sillero-Zubiri *et al*., 2004).

Human persecution of this species under the pretext of stock protection was the biggest problem in painted conservation. Between 1965 and 1975, 3404 painted dogs in Zimbabwe were shot by farmers (Childes, 1988). However the new threat of painted dogs nowadays is indirect anthropogenic impacts such as transmission of pathogens (Davies and Du Toit, 2004).Moreover, due to Habitat fragmentation there is increased interaction with human activities and more importantly domestic dogs (Ash, 2011). Dogs pose a risk of transmitting infectious canid diseases i.e. rabies, canine distemper virus (CDV) and parvovirus to wild carnivores (Butler, Du Toit and Bingham, 2004). Research shows that 80% of domestic pathogens can infect wildlife animals hence the risk of disease transmission through direct or indirect contact into wild populations is great (Kat *et al.,* 1995; Cleaveland *et al.,* 2001) This was the case in Serengeti, Tanzania were the population of painted dogs declined dramatically due to epidemic outbreaks of the rabies virus (Kat *et al*., 1996; Woodroffe, 1999). These animals live in low populations hence such epidemics can have shattering results on their existence (Creel and Creel, 2002).

Domestic dogs also exert pressure on the populations of the wild canids by competing for feed. It has been recorded that in Africa, domestic dogs compete with the highly endangered Ethiopian wolf (*Canis seminsis*) for rodents (Sillero-Zubiri and Gotelli,1994). This subsequently lead to reduced feeding leading to reduced growth rates in pups that compromise survival of the pack.

Due to habitat fragmentation mortality of the dogs is significantly increased due to road kills, where they are frequently hit by vehicles (Fanshawe *et al*., 1991; Creel and Creel, 1998; Rasmussen, 1999). As Alexander (1995) preludes that the most cause of deaths in Hwange were road kills along the Bulawayo-Victoria Falls road. In Mikumi National park, traffic along the Tanzania –Zambia high way accounted for 3-12% of mortalities annually (Ginsberg and Alexander *et al.,* 1995). Moreover, loss of habitat due to human activities such as agriculture increase the chances of encounters of painted dogs with their enemies which can result in fatalities.

Commercial and subsistence hunting (Loibooki *et al.,* 2002) increases the risk of being caught in snares, which are set by poachers for bush meat, which is another significant driver of mortality in painted dog populations (Rasmussen, 1996). For example, Selous snaring and poisoning by poachers accounted for 11% of 45 known cause deaths and in Hwange 29% of 31 deaths (Creel,1998). All of these actions can lead to decreased survival and adversely impact on population stability.

2.4.3 Disease and impact of Infectious diseases

Infectious diseases have a huge impact on painted dog population dynamics in several ecosystems, numerically and distributional decline (Kat *et al*., 1995). Previous studies clearly show that painted dogs are very sensitive to diseases (Fanshawe *et al*., 1991).Pathogens that have been recorded as a major threat to painted dogs, are canine distemper virus (CDV), canine parvovirus (CPV), and rabies virus (Flacke *et al*., 2013). CDV, which belong to the genus Morbillivirus, causes a contagious disease, associated with respiratory and central nervous system disorders (Deem *et al.,* 2000; Flacke *et al*., 2013). The infection is usually more severe in young and immunologically compromised individuals (Greene *et al,* 2006). The impacts of CDV were seen in South Africa's Tswalu Kalahari Reserve where an outbreak of CDV in a pack of painted dogs in 2005 resulted in the loss of the entire pack (van Dyk *et al*., 2007). Moreover, ten dogs in a pack of twelve perished in an epidemic of canine distemper in Botswana (Alexander *et al*., 1996).

Another infectious disease of importance in painted dogs is CPV. CPV is the most fatal infection not only in painted dogs but in all canids, particularly in young pups (Mcraw *et al*., 2006). Because of low mortality in adults infected showing mild or no clinal signs at all, CPV has not been considered as a major threat to the survival of the species (Flacke *et al.*, 2013).However the disease poses a major risk as the adults are live sources of infection which might be detrimental to small populations due to significant early pup mortality (Mech, 1995). The closely related canid the domestic dog (*Canis familiaris*), show clinical signs such as haemorrhagic diarrhoea, emesis, dehydration and hypoproteinaemia (Flacke *et al.*, 2013).

Rabies from the genus Lyssa virus spp, can be considered the most important disease in all mammals. The rabies infection is not host specific but all mammals can be affected (Flacke *et al.*, 2013).Rabies mainly affect the central nervous system showing clinical signs such as hyperesthesia, ataxia, paresis, and paralysis to tremors, seizures, and convulsions (Flacke *et al.*, 2013). There are reported cases of local extinction of painted dog populations due to recurrent outbreaks of rabies (Gascoyne *et al*., 1993; Alexander & Appel, 1994). Major confirmed rabies outbreaks in painted dogs were reported in the Masai Mara Reserve in Kenya (Kat *et al*., 1995), Madikwe Game Reserve in South Africa (Hofmeyr *et al*., 2000), and Etosha National Park in Namibia (Scheepers *et al*., 1995). Research from Serengeti stipulates that viral diseases can result in significant mortalities and local extinctions (Kat *et al*., 1996 & Woodroffe, 1999).

2.4.4 External parasites

African painted dogs suffer from external parasites and these can have negative impacts on the hosts. External parasites are vital to understand as they are vectors of diseases such as babesiosis and can cause secondary infections on the host. "Serological screening in Kruger showed that most wild dogs (27 of 29) were exposed to spotted fever, transmitted by the tick-borne *Rickettsia concri/africae*" (Creel and Creel, 2002). They also irritate the animal causing restlessness.

Some of the external parasites recorded in painted dogs are bugs of the *Attegenus* spp and *Carpophillus* and ticks including *Rhipicephalus evertsi evertsi*, *R. appendiculatus*, *R. simus, Rhipicephalus(Boophilus) decoloratus*, *Haemaphysalis leachi* and nymphs of *ornithodones* species were recorded (van Heerden 1988). However, *Attegenus* and *Carpophillus* spp are usually found on dead organic material (van Heerden, 1988). Moreover, *Ctenocephalides felis demarensis* and *Echidnophas larina* were also reported in painted populations as well as wild infestation of *Hippobosca longipennis* (van Heerden, 1988). *Amblyoma hebraeum* tick were also reported in Kruger national park.

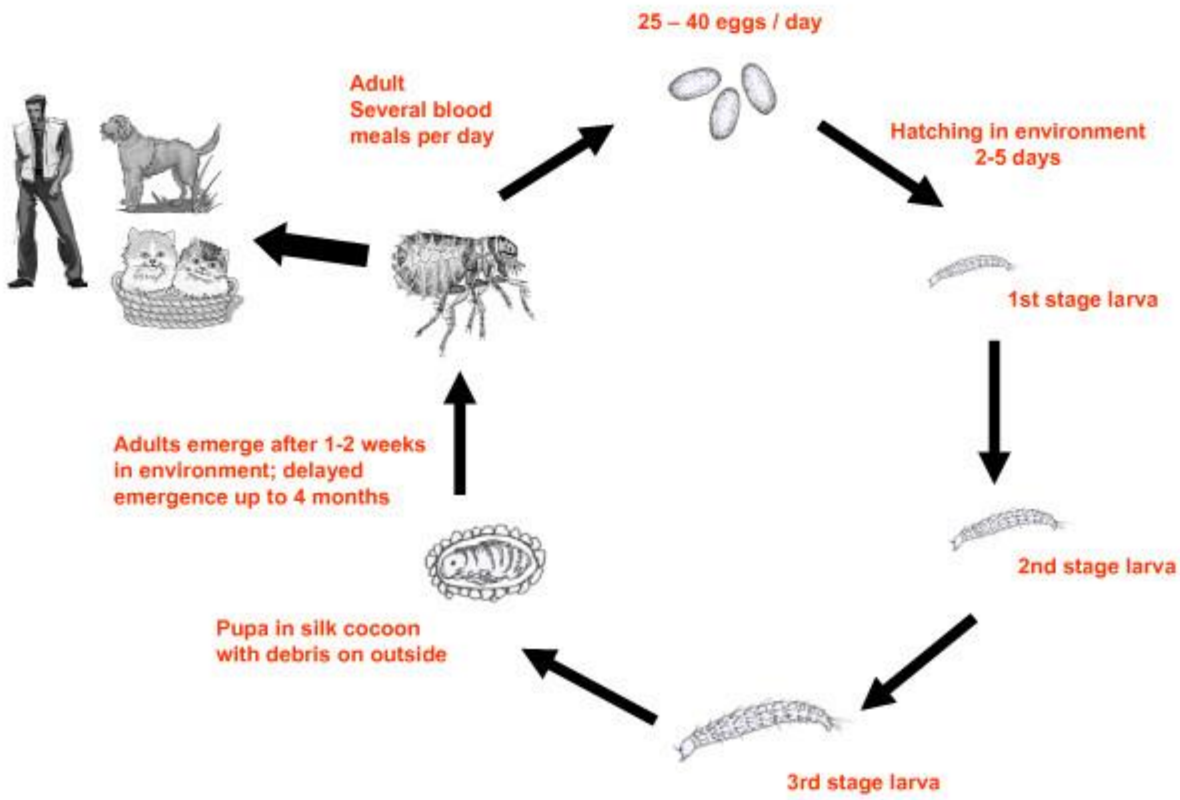

Figure 6 Schematic Life cycle of Ctenocephalides felis *Source:* [*https://www.researchgate.net*](https://www.researchgate.net)

2.4.5 Internal parasites

Even though there have been few studies on the epidemiology of internal parasites understanding them is vital in any conservation effort. *Lycaon pictus* like any other mammal is affected by gastrointestinal parasite and it is only logical to assume that the same effects of gastrointestinal parasites on domestic dogs can be suffered also by painted dogs (Flacke *et al.*, 2010). Previous literature have identified gastrointestinal parasites such as *Ancylostoma* , *Dipylidium* , *Isospora* ,*Sarcocystis, Taenia, Toxocara, Trichuris* and *Toxoscaris* species as the common parasites in wild dog populations (Woodroffe *et al.*,2007; Flacke *et al*., 2010).According to Jain (1993) wild canids are also the reservoir of a wide range of parasites as well as parasites that are zoonotic for example the parasite *Dipylidium* and *Toxocara* (Flacke *et al.*, 2010).

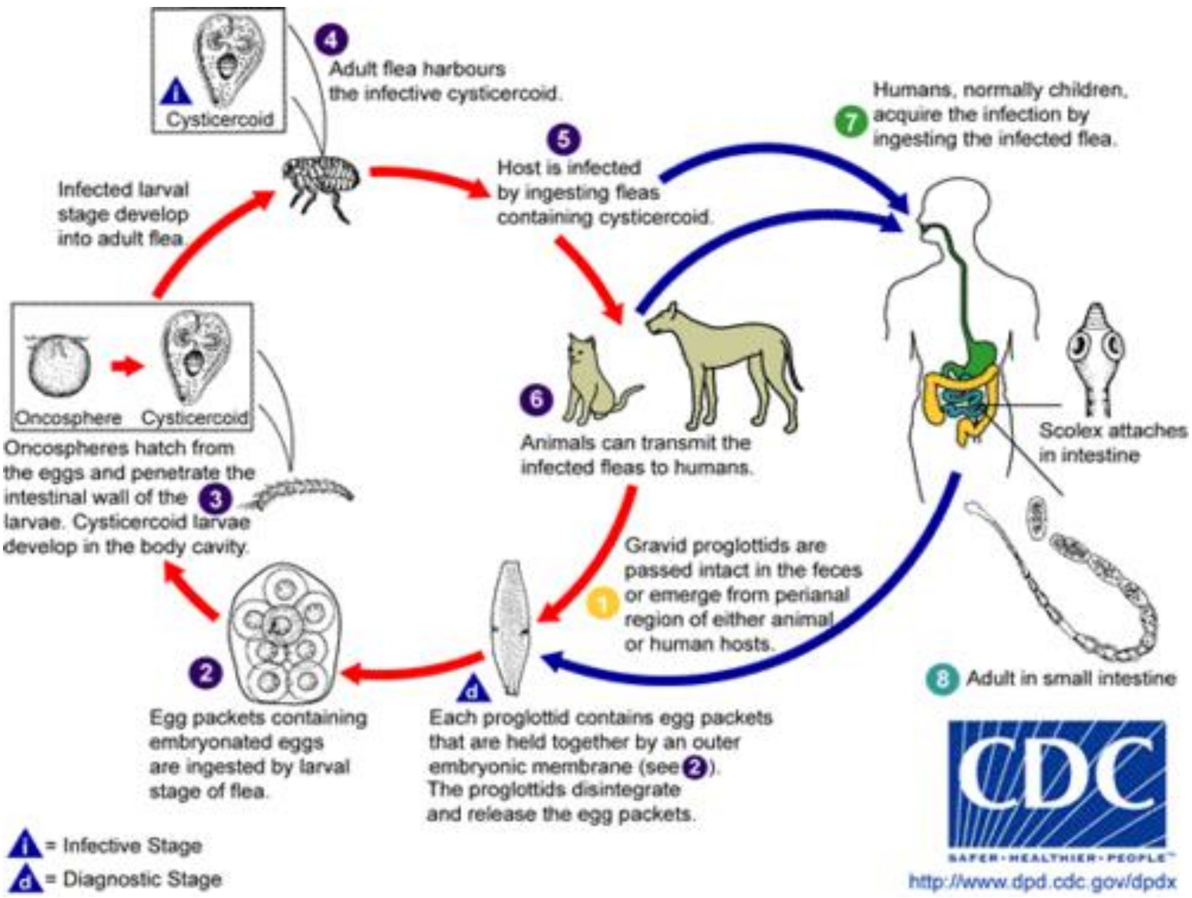

Figure 7: Life cycle of Dipylidium

Source: https://www.cdc.gov/parasites/dipylidium/biology.htm

Exposure of painted dogs to a variety of parasites is mainly through their diet as they are intermediate hosts of parasites. Different animals especially rodents act as intermediate hosts for parasites such as members of the cestode family *Taenia*, and the protozoans *Toxoplasma gondii* and *Sarcocystis spp* (Krucken *et al.*, 2017). Hunting in packs will see all individuals exposed to the same infected prey species. Additionally, as they are extremely social animals, other parasites requiring direct transmission between hosts such as *Ancylostoma* spp., *Giardia spp*. and ectoparasites will be easily transmitted between pack members (Altizer *et al.*, 2003a). Hence one can assume that the parasitic loads of these parasite will be high during the denning period when environmental contamination with parasite stages increase and subsequently transmission rates of these parasites between individuals would also increase (Altizer *et al.*, 2003b). Finally, as these animals have large home ranges, packs will often move outside the park borders and through human communities, thereby raising the risk of them contracting exotic pathogens from domestic dogs (Creel and Creel, 2002).

Gastrointestinal parasites represent key health problems in animals with symptoms ranging from apathy, colic, diarrhoea, pneumonia, malaise and weight loss (Sprenger *et al*.,2018) however painted dogs and other wild animals rarely show clinical signs. This is so because wild canids have evolved in the direction of coping with levels of chronic parasitic infection that has little or no health effects (Kennedy-Stoskopf, 2003). There have been cases were dogs have died from parasitic infection, van Heerden (1985) in his research one pup died from severe infestation with hookworms and another pup died after showing partial anorexia, weight loss and vomiting. Moreover, parasitic infections may reduce competitive fitness (Tompkins *et al*., 2002) therefore making the infected dogs vulnerable to other predators. For this reason, parasites are often associated with lower survival, reproduction, and movement in their hosts (Scott, 1988). Moreover, parasitism might be accountable for extinction (or near extinction) of some host species (de Castro & Bolker, 2005). Secondary effects of parasitism can include the decline of host abundance and can alter the community or ecosystem function and structure (Tompkins *et al*., 2011). Assessing host health therefore is consequently vital in understanding how parasites impact hosts at the individual and population levels (Olifiers *et al.*,2015).

Table 1: Brief history of parasites affecting painted dogs

Parasite species	*Transmission*	*Description/lifecycle*	*Importance*
Ancylostoma sp.	Direct ingestion or skin penetration of infective larvae	Small nematode in the small intestine of the host, which hooks onto the host and sucks blood	Severe anaemia may result in death of host. Possible zoonosis
Taenia sp.	Indirect. Intermediate host, usually a herbivore	Large tapeworms in the gut of the definitive host. Gravid proglottids expelled onto pasture and ingested by the intermediate host	Possible intestinal obstruction of definitive host. Intermediate host may be compromised due to cysts forming in organs. Possible zoonoses
Echinococcus sp.	Indirect. Intermediate host, usually a herbivore	Small tapeworms in the gut of the definitive host. Gravid proglottids expelled onto pasture and ingested by the intermediate host	Non pathogenic to the definitive host. Causes hydatid disease in the intermediate host. Zoonosis
Toxocara sp.	Direct. Ingestion of infective stage	Large roundworms in the intestine of the host	Larval migrans may cause liver and lung damage. Possible zoonoses
Babesia sp.	Indirect. Transfer from tick species during a bloodmeal	Protozoan found in blood cells of the host	Anaemia and/or neurological disease causing death

Source: (Ash, 2011)

Parasites are believed to account for a diversity of behavioural and morphological traits (Moore, 2002).Some of the behavioural traits observed include consumption of specific dietary items e.g. medicinal plants (Huffman, 2001). Regularly, parasitic infections have a tendency to be over dispersed, to where many individual hosts have low parasitic load and few individuals have high parasitic loads (Junker *et al.*, 2008). Thus, several animals may maintain low levels of infection however few actually yield to disease.

2.5 Conservation Status

Conservation strategies have been established for painted dogs in all the regions of Africa (Sillero-Zubiri *et al.*, 2004) and many range states have adopted these strategies as templates in their national action plans (Woodroffe *et al.*, 2012). The strategies are similar in structure, comprising objectives such as reducing human wildlife conflict with the species, promoting sustainable land use planning to sustain and multiply painted dog populations. They also include building capacity for wild dog conservation within range states, outreach to improve public perceptions of wild dogs at all levels of society and ensuring a policy framework compatible with wild dog conservation (Woodroffe *et al.,* 2012). In Hwange National park ,Painted Dog Conservation is involved in the monitoring of the species, vaccinating domestic dogs against the major diseases and community awareness programs in areas surrounding the park (Blinston, 2013).KAZA is another program which is dedicated in the conservation of painted dogs using similar afore mentioned strategies (KAZA TFCA Secretariat, 2014). Also, conservation of painted dogs is mainly through the management of painted dogs in captive environments where the emphasis is on maintaining breeding populations and genetic diversity with the view to eventually reintroducing the back to the wild (Ash, 2011). Management of wild populations has also increased as suitable habitat continues to decline and the use of translocation programs is required to move animals away from human conflict areas.

2.6 Significance of Painted dogs in the Ecosystem

The principal reason to be concerned about the species extinction from n ecosystems is that the services they supply would be lost (Daily *et al*.,1997). Painted dogs play a significant role on the structure and function of ecosystems. They provide non tangible services in the form of regulating prey species abundance in the lower trophic levels, which function in terrestrial ecosystem by altering the foraging location of prey species (Dobson,2008). Painted dogs have indirect effect on plants and abiotic process such as nutrient cycling, erosion and fire (Estes *et al*.,1998; Schmitz *et al*., 2004). The species as an apex predator suppress prey species abundance that in turn shape vegetation structure. The painted dog consumes more meat per day than any other carnivore of approximately 3.00Kg (Hayward *et al.*, 2006). Tree cover which is a factor of herbivory is a key determinant of ecosystem as it affects nutrient cycles (Treydte *et al.,* 2007). Painted dogs and other carnivores hence contribute to the regulation of tree cover via trophic cascades (Estes *et al.*, 2011; Ripple *et al.,* 2014). For example, the suppression of the dik-dik population in Laikipia plateau, Kenya by painted dogs resulted in increased tree abundance (Ford *et al*., 2005). Having an ecological balance is very economical as economic value from ecosystems are approximately valued at $33 trillion dollars (Constanza *et al.,* 1997). Moreover, painted dogs help the ecosystem by removing immunocompromised prey.

The painted dogs have a significant impact in ecotourism as many tourists come with the expectation of seeing the species (Blinston, 2013) . According to the 2015 Visitor survey in

Zimbabwe by ZIMSTAT revealed that the sector received 2.1 million visitors in 2015 and these tourists conduct 80% of their business in cash thus bringing foreign currency. The Zimbabwe Tourism Authority (ZTA) receipted $819 million in 2016.

Moreover, the species offer cultural history as their featured in folk tales of many African tribes.

CHAPTER 3: METHODS AND METHODOLOGY

3.1 Study Area

The study area is Hwange National park which is 14 600 km squared which is located in the north western part of Zimbabwe.

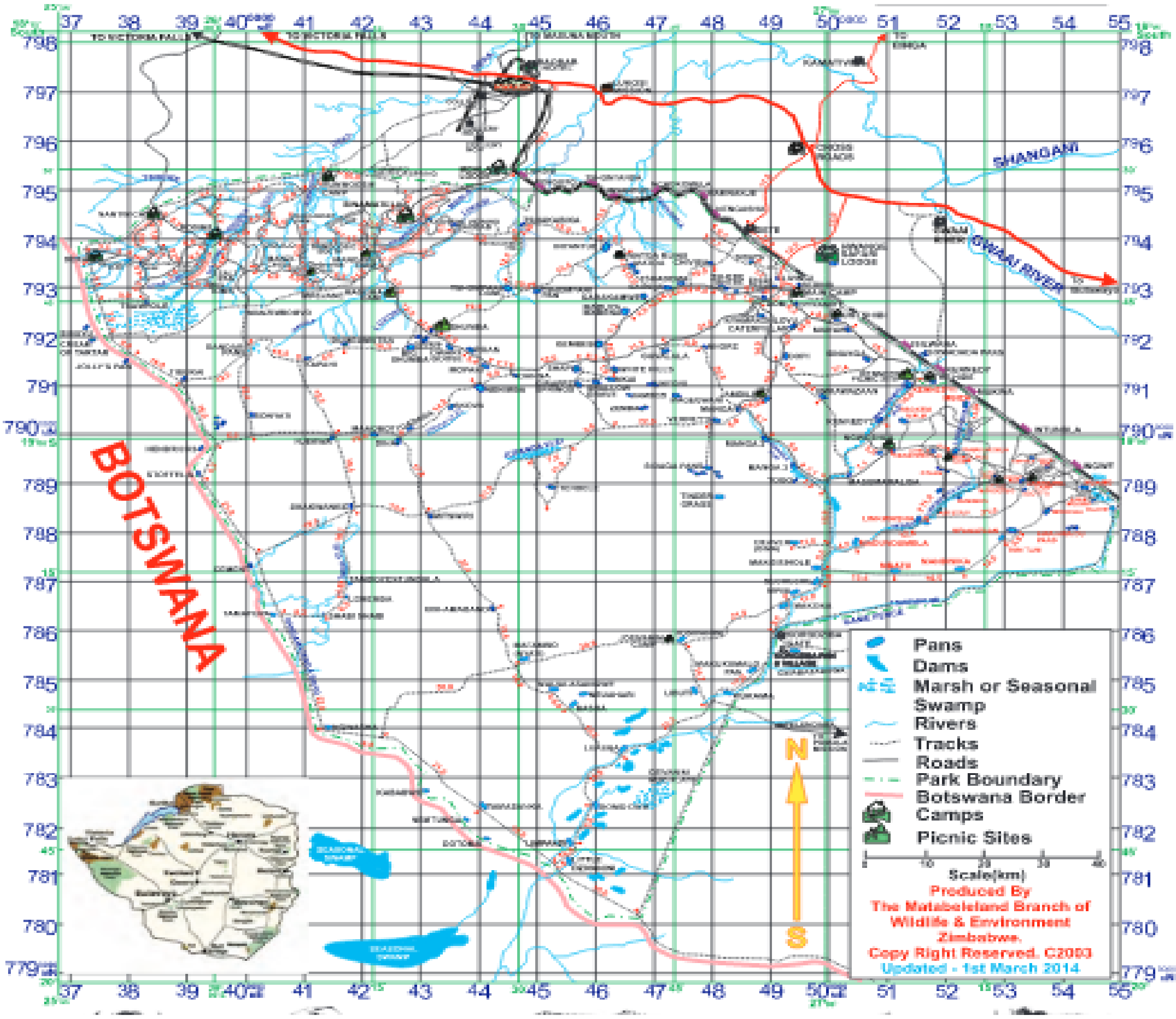

Figure 8: A Map of HNP   Source: https://www.wezmat.org

The park's vegetation consists of scattered woodland scrub of Teak, Miombo and Mopane woodlands mixed with open grass plains lined with acacia. The Hwange region is classified as semiarid with a mean annual rainfall of 606 mm and a wet season from December to April. During the wet season, the bush becomes lush and wildlife disperses. The dry season is characterised by rapid drying and thinning out of the vegetation with only artificial water holes remaining and a very few natural water holes surviving the dry season.

3.2 Study Design

A randomised parasitological study was conducted in Hwange National Park from June 2016-July 2017 and involved the collection of faecal samples from the African painted dog (*Lycaon pictus*) wild populations in HNP. The collection of faecal samples was done randomly and opportunistically during field trips however, collaborators in the field collected other samples during their own monitoring season.

3.3 Sample Collection

Collection of fresh faecal samples was done opportunistically from droppings of the animal as soon as it defecates. The samples were placed into collecting jars with Sodium acetate-acetic acid-formalin (SAF) preservative. Each sample was clearly label with animal identification, pack name, location, date, time and GPSloc-stat. The samples were then packed in cooler boxes and transported to the laboratory for analysis. Tracking of the dogs was done early in the morning and in the evening every day in the park and faecal samples were collected.

3.4 Parasitological techniques

For identification of the parasite eggs we used the Centrifugal/ Flotation and also the McMaster technique for egg counts (Pratt,1997). The Centrifugal/ Flotation test detects the eggs of mature parasites that live inside the body and pass their eggs to the outside by shedding them into the host's stool. The eggs are collected from the surface using a glass slide, then the slide is examined under a microscope, and the appearance of the eggs identifies what type of adult parasite is present.

The McMaster counting technique is a quantitative technique to determine the number of eggs present per gram of faeces (e.p.g.). A flotation fluid (Saturated Salt, NaCl; SG 1.18–1.20) 350 g NaCl 1,000 ml tap water) is used to separate eggs from faecal material in a counting chamber (McMaster) with two compartments. The technique detected 50 or more e.p.g. of faeces.

Four grams of faeces from each sample were added to 50ml of floatation fluid and then centrifuge. After centrifuging the solution was placed in the chambers of the McMaster slides and stand for five minutes before they are observed under the microscope.

3.5 Data Analysis Methods

The data was analysed using Statistical Package for the Social Sciences(SPSS). Univariate analyses at 95% Confidence intervals was used to test associations of level of parasitism, seasonal variation, geographical variation and gender. The Chi square test was used to compare prevalence of infection and intensity of parasitism was evaluated using One-way analysis of variance

CHAPTER 4: RESULTS

A total of 58 dogs were sampled from different locations of the park. During the study 11 parasite genera of gastrointestinal were recorded i.e. 6 nematodes with a prevalence of 76,8% ,2 cestodes with prevalence of 20,9% ,1 trematode with a prevalence of 0,6% and 1 protozoa with a prevalence 1,1% were recorded. On the parasites recorded (Table 2), *Sarcocystis* had the highest prevalence of (28.2%) and intensity (629±113) followed by *Ancylostoma* with prevalence (18.6%) and intensity (324±82). *Alaria* and *Physolaptera* parasite had the lowest prevalence of (0.6%) and intensity (50±0), being recorded once during the research.

Table 2: Showing the prevalence of parasites

Parasite	Prevalence	Intensity (SE)	Confidence Interval (95%)	
			Lower	Upper
Alaria	1(0.6%)	50.00±0	.	.
Physolaptera	1(0.6%)	50.00±0	.	.
Isospora	2(1.1%)	75.00±25.000	-242.66	392.66
Spirocerca	6(3.4%)	141.67±47.288	20.11	263.22
Dipylidium	10(5.6%)	80.00±11.055	54.99	105.01
Uncinaria	11(6.2%)	122.73±31.162	53.29	192.16
Toxoscaris	12(6.8%)	83.33±16.667	46.65	120.02
Toxocara	24(13.6%)	81.25±10.344	59.85	102.65
Taenia	27(15.3%)	111.11±16.087	78.04	144.18
Ancylostoma	33(18.6%)	324.24±82.029	157.15	491.33
Sarcocystis	50(28.2%)	629.18±113.01	402.07	856.29

Level of parasitism was statistically significant across all parasites species with p value <0.05 of 0.00.

A total of 9 packs ,4packs from Main camp area, 4 packs from Sinamatella/Robins area and 1 unknown pack were recorded. A p value <0.05 of 0.037 was observed showing that there was statistical difference between the packs. Unknown pack and Banyayi pack from Main camp area had the highest mean e.p.g 1050 and 770 respectively. Mabuyamabena had the least mean e.p.g of 208 as shown below.

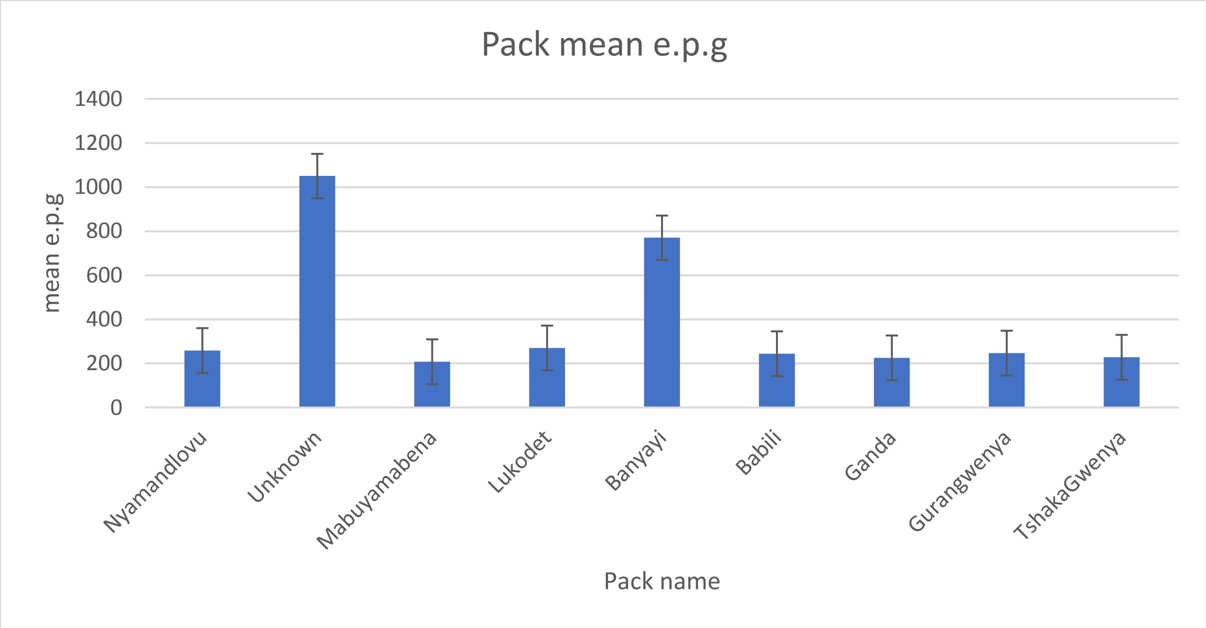

Figure 9: Mean e.p.g of packs in HNP

According to location the results were comparable but with no statistical significance (P=0.132), Sinamatella packs had a total mean e.p.g of (646.46±184.18) and Main camp had (1000±138.76) Fig 10.

Packs in Main camp had an odds ratio of 3.3 over packs in Sinamatella/Robins to have multiple infections, with 89.2% having a multiple infection compared to 70.4% of Sinamatella and Robins having multiple infection shown in Fig 14. Overally, 82.8% dogs had multiple infection (>2 parasites) while 17.2% had infection of <2 parasites (FIG 11).

Moreover 29.7% of Main camp packs had a heavy infection compared to 19% in Sinamatella. The odds Main camp having a heavy infection are 1.798 odds of dogs in Sinamatella/Robins. The likelihood of a heavy infection was 1.941.

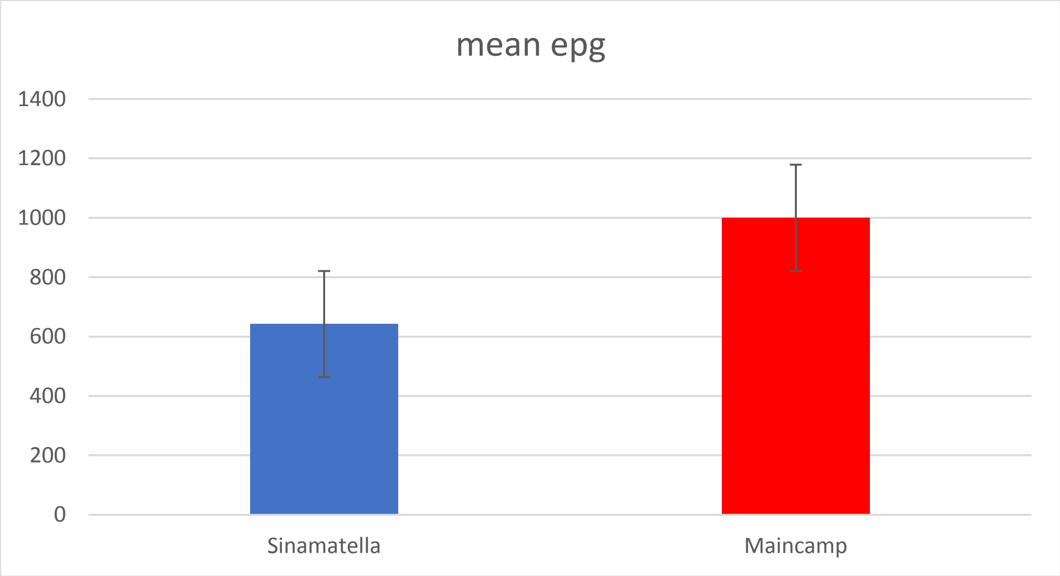

Figure 10**:** Mean e.p.g of locations

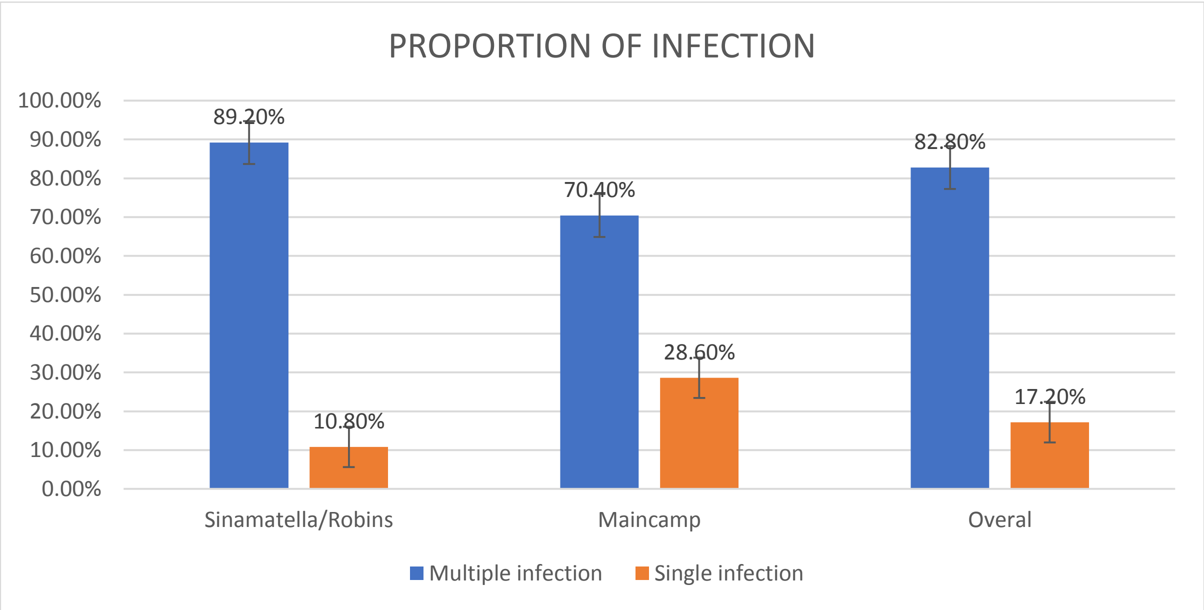

Figure 11: proportion of multiple infections in locations

Further statistics showed that 27.1% of multiple infected dogs had a heavy infection (light infection<1000e.p.g; heavy>1000 e.p.g(Maeda, 2011)) and 20% of single infected dogs were heavily infected. The odds ratio of getting a heavy infection in multiple infected dogs are 1.48.

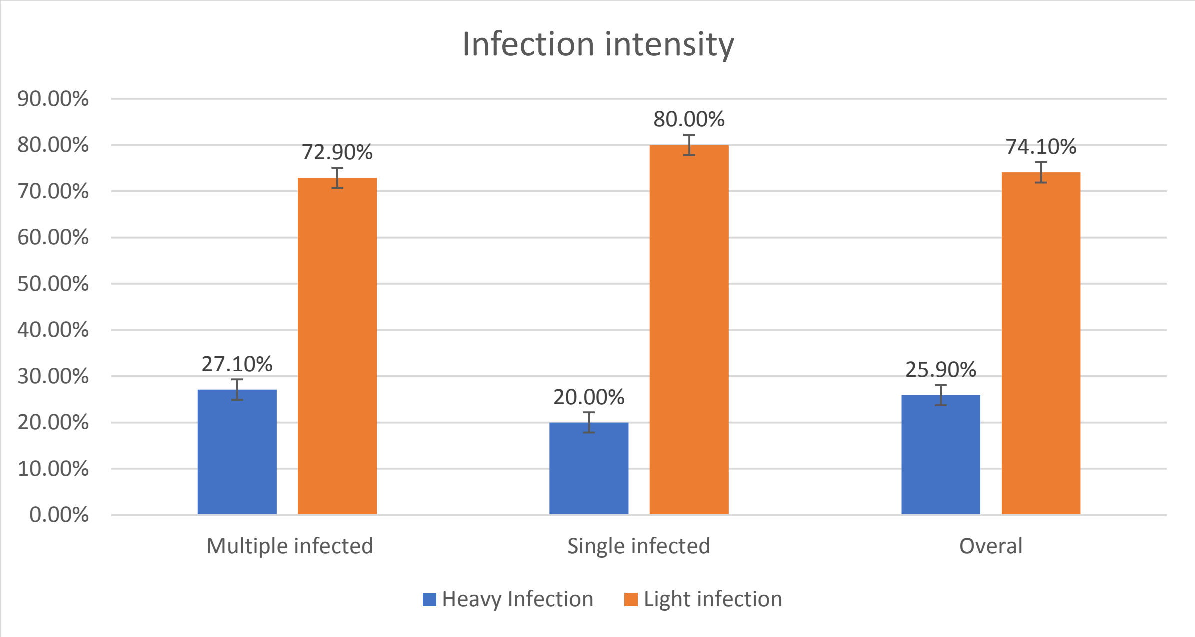

Figure 12: Showing infection according to type of infection

Data on seasonality was comparable however it was not statistically significant (P value=0.275). The months of October 2016 to April 2017 had the highest total counts of e.p.g with January having a total count of 2780 e.p.g. Season had no association with the level of parasitism p value > 0.05 (0.275). The intensity of parasitism in wet season was 207.89 with a standard deviation of 239.93 and in Dry season intensity (312.65) standard deviation (576.267). In dry season 13.3% dogs had a heavy infection and 30.2% in wet season. The odds dry season had a heavy infection are 0.355 odds of a heavy infection in Wet season.

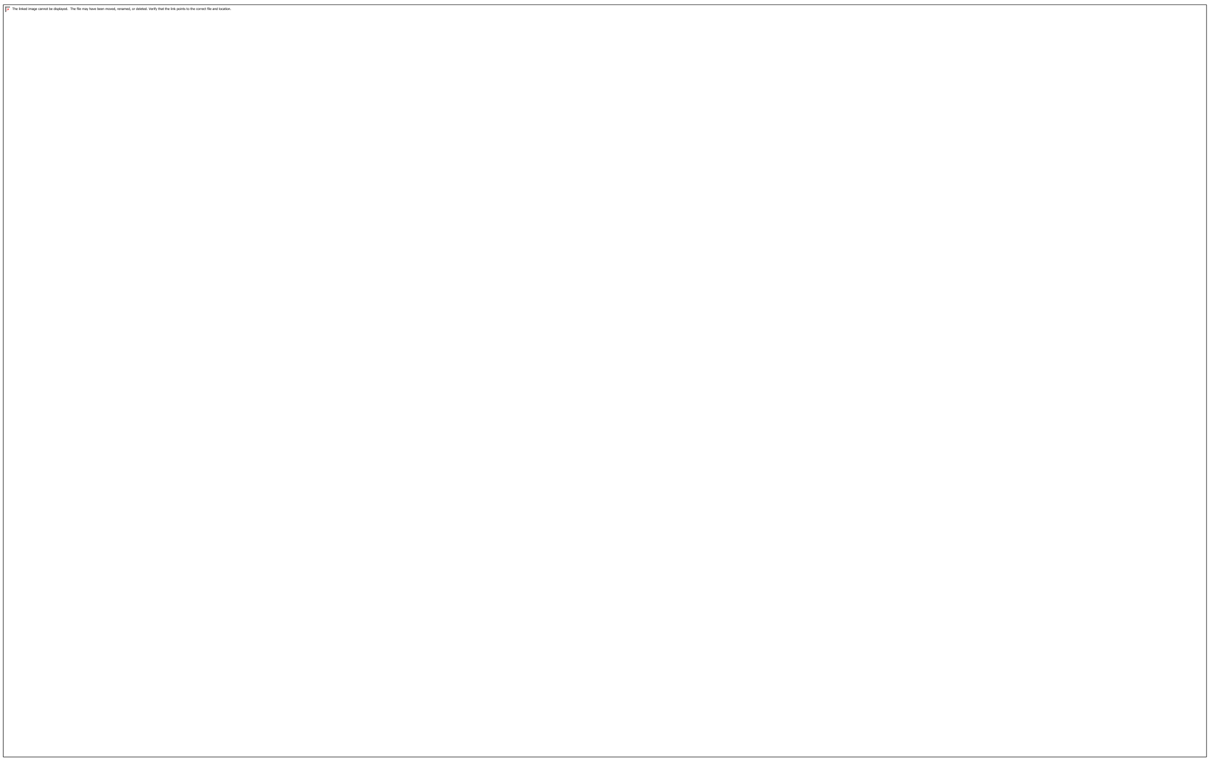

Figure 13: Total e.p.g counts of months

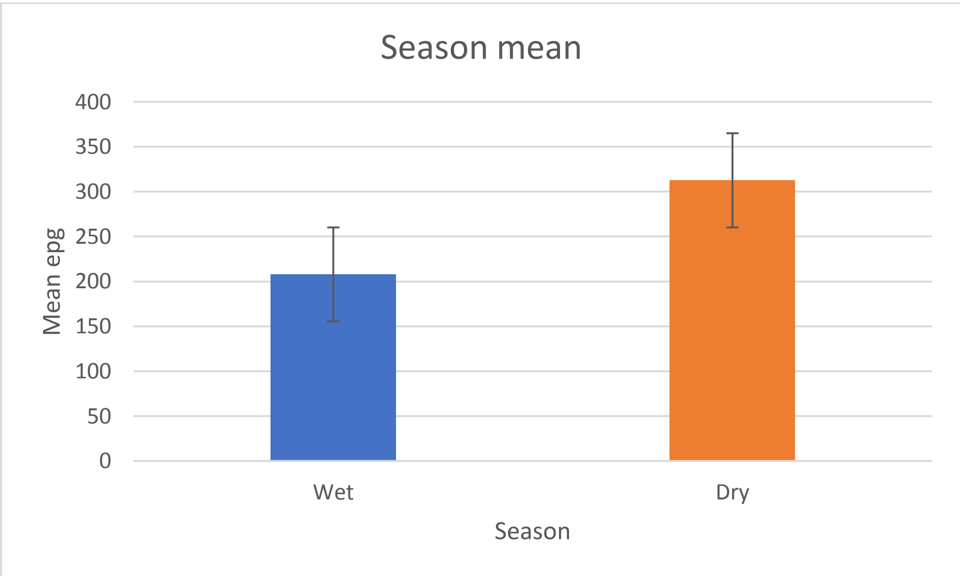

***Figure 14*:** Mean e.p.g of seasons (Wet/Dry season)

Gender did not have a statistically significant difference on the level of parasitism P value =0.694 showing that gender did not influence the level of parasitism. Out of the 58 dogs 13 were of known sex (6 females ,7 males) and 45 were not sexed.

CHAPTER 5: DISCUSSION AND CONCLUSION

5.1 Discussion

The aim of this study was to investigate the epidemiology of gastrointestinal parasites in the painted dogs in Hwange National park. The eleven gastro-intestinal parasites identified were *Alaria*, *Physolaptera*, *Isospora*, *Spirocerca*, *Dipylidium*, *Uncinaria*, *Toxoscaris*, *Toxocara*, *Taenia*, *Ancylostoma* and *Sarcocystis*. The most common parasites in all the studies in Southern Africa i.e. in KwaZulu-Natal ,South Africa and Luangwa, Zambia is *Sarcocystis* (Flacke *et al.*, 2010).*Giardia, Isospora, Spirometra* and *Trichuris spp* were not found in my study but were found in other researches e.g. KZN and Zambia (Berentsen *et al.*, 2012 and Flacke *et al.*, 2010). Two new species of parasites were also recorded for the first time in painted dogs in HNP i.e. *Spirocerca* and *Physolaptera spp*. This suggest that there is difference in parasite diversity in different geographical differences as stipulated by Ash (2011).

The *Sarcocystis* genus had the highest prevalence of 28.2% in the dogs in HNP. The results were lower than prevalence in South Africa, KZN(100% prevalence) and Zambia ,Luangwa(92% prevalence) (Berentsen *et al.*, 2012 and Flacke *et al.*, 2010) suggesting that there is difference in intensity. This further proves that the painted dog and other carnivores (Lions, Hyenas, Leopards, Cheetahs and Jackals) are the definitive host of *Sarcocystis*. The fact that painted dog's diet consists of intermediate hosts of *Sarcocystis* also supports the notion. The diet include mainly angulates which are specific to different *Sarcocystis* spp for example Impala is an intermediate host for *Sarcocystis melampi,* Dik-dik (*S. woodhausi*), Waterbuck (*S. nelsoni*) and Warthog (*S. phacochoeri*) (Ash, 2011). Gastrointestinal infection by *Sarcocystis* spp does not cause any clinical illness in the host (Berentsen *et al.*, 2012 and Flacke *et al.*, 2010).

Zoonotic parasites i.e. *Ancylostoma, Toxocara and Dipylidium spp* were recorded which is consistent with other studies in Southern Africa (Flacke *et al.*, 2010 & Ash, 2011). *Ancylostoma* spp was the second highest prevalent genera in the study. This genus species has been recorded in other studies too and can be problematic to painted dogs. The species can be pathogenic to young and immunocompromised individuals (van Heerden *et al*.,1996).

As in other studies *Taenia* spp were also recorded in the species. In moderate infections the species does not show clinical signs but only cause disease in heavy infections such as intestinal obstruction, diarrhoea, weight loss, restlessness and anal itching can be observed. Painted dogs are infected by *taenia* in their diets. Carnivores are believed to be the definitive hosts, whilst herbivores are intermediate hosts (IOWA State University,2005). We cannot rule out the possibility that prevalence of the species could be higher than observed as *taenia* spp shed eggs periodically hence some might have been missed (Maeda, 2011).

The parasite intensity could be high as gastrointestinal parasites shed eggs periodically and parasites are spread unevenly in the faeces (Cooper *et al*., 2012). This study also revealed that most of the dogs in HNP are co infected (>2parasites) and also co infection influence parasitic intensity. The source of the parasitic infection is likely from infected prey, although the exact prey responsible for individual parasites is unknown, except in the case of *Sarcocystis* (Ash, 2011). Generally, the difference in prevalence, intensity and diversity from other studies proves that there is difference in species richness in different geographical locations.

Diversity of the parasites observed can be as a result of interaction with other carnivores. *Taenia, Dipylidium, Sarcocystis* and *Toxocara* have been observed in other carnivores such as Hyenas and lions (Berentsen, *et al*., 2012). Physolaptera have been recorded in other carnivores such as the Lion (*Panthera leo*) in Zimbabwe (Mukarati *et al.*, 2013). *Physolaptera* spp like many helminths affecting wild canids is spread through intermediate and paratenic hosts such as mice, frogs and grasshoppers. Parasite transmission could be direct during confrontations or indirect.

A significance difference in e.p.g among the packs was recorded. The difference was seen between packs with home ranges that overlaps into communities increasing their interactions with dogs as previous studies have shown that dogs in communal areas venture at least 6km into parks (Butler et al., 2004). Dogs are believed to transmit diseases to wild canid (Butler et al., 2004) hence consequently the *Canis familiaris* also have the potential to transmit parasites to painted dogs. Location was divided into two areas i.e. Main Camp and Sinamatella/Robins. There was no statistically significant difference. The results were comparable with main camp having the highest ratios of dogs with Heavy infection and Multiple infection. This can be explained by the fact that main camp packs home ranges overlap with local communities therefore increasing their contact with parasites from domestic dogs. The high temperatures in Sinamatella/Robins can be used to explain this phenomenon as Lindenfors (2007) shows that temperatures affect survivability of parasites.

In this study seasonality, gender and geographical location did not have a significant difference which is inconsistent with other researches on parasitology in Africa but however comparative. In this study total e.p.g was highest during the wet season and this can be explained by the limitations on faeces collection faced during the study especially during the denning season (May-July). The dogs were particularly hard to locate during this time hence the data could not give us a concise result. However other researches have shown beyond reasonable doubt that seasonal variations influence pattern and intensity of parasitism (Lindenfors *et al.*, 2007).Wet season had the highest proportion of co infection which can be explained by the fact that parasitic infection is high during periods with warm temperatures and moisture (Altizer *et al.*, 2006).Warm and moist environments encourages propagation of parasites (Lindenfors *et al.*, 2007). Moreover dry season had low parasitic loads because high temperature in summer reduce survivability therefore reducing the transmission rate of parasites (Lindenfors *et al.*, 2007).

5.2 Conclusion

The study showed that parasite genera and pack affected parasitic load. Most of the dogs in HNP had a light infection <1000 e.p.g. The mean parasitic load recorded in HNP was 872.41 e.p.g. and *Sarcocystis, Ancylostoma* and *Taenia* spp had the highest prevalence. The study also revealed that there is parasitic diversity in different regions. The parasites can have negative effects such as apathy, ascites, anaemia and diarrhoea and indirect effects such as reducing competitive fitness. Two parasites (*Physolaptera and Spirocerca*) have been reported for the first time in this study which demonstrates the scarcity of parasitic information available for this endangered carnivore. Moreover, parasitic may prove problematic to painted dogs as they reduce competitive fitness in dogs against other carnivores (Flacke *et al.*, 2010).

5.3: Recommendations

- Bio boundaries can be effective in restricting movement of the dogs (The Norwegian University of Science and Technology, 2014), and therefore reducing infection through direct or indirect contact with domestic dogs.
- The study should be done for an extensive period with better tracking systems to accurately collect data. Other parasites might cause clinical signs but the cases go

unnoticed in the wild therefore there's need to come up with better monitoring strategies to locate the dogs and collect samples especially in winter periods.

- There should also be a further investigation on how the parasites are transmitted and from which intermediate hosts to come up with mitigation strategies.

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APENDICES

Appendix A: Parasite Genera observed

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Alaria	1	50.00	.	.	.	.	50	50
Ancylostoma	33	324.24	471.222	82.029	157.15	491.33	50	2550
Dipylidium	10	80.00	34.960	11.055	54.99	105.01	50	150
Isospora	2	75.00	35.355	25.000	-242.66	392.66	50	100
Sarcocystis	50	629.18	799.131	113.014	402.07	856.29	50	5400
Spirocerca	6	141.67	115.830	47.288	20.11	263.22	50	350
Taenia	27	111.11	83.589	16.087	78.04	144.18	50	350
Toxocara	24	81.25	50.675	10.344	59.85	102.65	50	250
Toxoscaris	12	83.33	57.735	16.667	46.65	120.02	50	250
Uncinaria	11	122.73	103.353	31.162	53.29	192.16	50	350
Physolaptera	1	50.00	.	.	.	.	50	50
Total	177	290.16	523.118	39.320	212.56	367.76	50	5400

Appendix B: Univariate analysis of parasite Genera

Tests of Between-Subjects Effects

Dependent Variable: EPG

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9301695.459[a]	10	930169.546	3.973	.000
Intercept	995887.256	1	995887.256	4.254	.041
Parasite	9301695.459	10	930169.546	3.973	.000
Error	38861060.789	166	234102.776		
Total	63065281.000	177			
Corrected Total	48162756.249	176			

a. R Squared = .193 (Adjusted R Squared = .145)

Appendix C: Univariate analysis of category packs

Tests of Between-Subjects Effects

Dependent Variable: EPG

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4408693.133[a]	8	551086.642	2.116	.037
Intercept	13014192.765	1	13014192.765	49.970	.000
PACKNAME	4408693.133	8	551086.642	2.116	.037
Error	43754063.115	168	260440.852		
Total	63065281.000	177			
Corrected Total	48162756.249	176			

a. R Squared = .092 (Adjusted R Squared = .048)

Appendix D: Univariate analysis of location (Sinamatella vs Main camp)

Tests of Between-Subjects Effects

Dependent Variable: Total EPG

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1663481.117[a]	1	1663481.117	2.335	.132
Intercept	36366929.392	1	36366929.392	51.051	.000
LOCATION	1663481.117	1	1663481.117	2.335	.132
Error	39892380.952	56	712363.946		
Total	85700000.000	58			
Corrected Total	41555862.069	57			

a. R Squared = .040 (Adjusted R Squared = .023)

Appendix F: Univariate analysis of Season (wet/dry)

Tests of Between-Subjects Effects

Dependent Variable: E.P.G

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	327503.245[a]	1	327503.245	1.198	.275
Intercept	8086285.166	1	8086285.166	29.583	.000
SEASON	327503.245	1	327503.245	1.198	.275
Error	47835253.003	175	273344.303		
Total	63065281.000	177			
Corrected Total	48162756.249	176			

a. R Squared = .007 (Adjusted R Squared = .001)

Appendix G: Risk estimates of type of infection according to location (main camp/Sinamatellarobins)

LOCATION * tof Crosstabulation

			tof		Total
			Multi	single	
LOCATION	MC	Count	33	4	37
		Expected Count	30.6	6.4	37.0
		% within LOCATION	89.2%	10.8%	100.0%
	SR	Count	15	6	21
		Expected Count	17.4	3.6	21.0
		% within LOCATION	71.4%	28.6%	100.0%
Total		Count	48	10	58
		Expected Count	48.0	10.0	58.0
		% within LOCATION	82.8%	17.2%	100.0%

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for LOCATION (MC / SR)	3.300	.810	13.445
For cohort tof = multi	1.249	.932	1.673
For cohort tof = single	.378	.120	1.191
N of Valid Cases	58		

Appendix H: Risk estimates of intensity according to location

LOCATION * Epgintensity Crosstabulation

			Epgintensity		Total
			Heavy	Light	
LOCATION	MC	Count	11	26	37
		Expected Count	9.6	27.4	37.0
		% within LOCATION	29.7%	70.3%	100.0%
	SR	Count	4	17	21
		Expected Count	5.4	15.6	21.0
		% within LOCATION	19.0%	81.0%	100.0%
Total		Count	15	43	58
		Expected Count	15.0	43.0	58.0
		% within LOCATION	25.9%	74.1%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.797[a]	1	.372		
Continuity Correction[b]	.337	1	.561		
Likelihood Ratio	.823	1	.364		
Fisher's Exact Test				.535	.285
N of Valid Cases	58				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.43.

b. Computed only for a 2x2 table

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for LOCATION (MC / SR)	1.798	.491	6.581
For cohort Epgintensity = Heavy	1.561	.568	4.291
For cohort Epgintensity = Light	.868	.646	1.166
N of Valid Cases	58		

Appendix I: Risk estimates of infection intensity according to type of infection.

tof * Epgintensity Crosstabulation

			Epgintensity		Total
			Heavy	Light	
tof	multi	Count	13	35	48
		Expected Count	12.4	35.6	48.0
		% within tof	27.1%	72.9%	100.0%
	single	Count	2	8	10
		Expected Count	2.6	7.4	10.0
		% within tof	20.0%	80.0%	100.0%
Total		Count	15	43	58
		Expected Count	15.0	43.0	58.0
		% within tof	25.9%	74.1%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.217[a]	1	.642		
Continuity Correction[b]	.005	1	.945		
Likelihood Ratio	.226	1	.634		
Fisher's Exact Test				1.000	.491
N of Valid Cases	58				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 2.59.

b. Computed only for a 2x2 table

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for tof (multi / single)	1.486	.278	7.933
For cohort Epgintensity = Heavy	1.354	.360	5.088
For cohort Epgintensity = Light	.911	.639	1.299
N of Valid Cases	58		

Appendix J: Risk estimates of infection intensity according to season (wet/dry)

Season * Epgintensity Crosstabulation

			Epgintensity		Total
			Heavy	Light	
Season	Dry	Count	2	13	15
		Expected Count	3.9	11.1	15.0
		% within Season	13.3%	86.7%	100.0%
	Wet	Count	13	30	43
		Expected Count	11.1	31.9	43.0
		% within Season	30.2%	69.8%	100.0%
Total		Count	15	43	58
		Expected Count	15.0	43.0	58.0
		% within Season	25.9%	74.1%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.656[a]	1	.198		
Continuity Correction[b]	.892	1	.345		
Likelihood Ratio	1.824	1	.177		
Fisher's Exact Test				.308	.174
N of Valid Cases	58				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 3.88.

b. Computed only for a 2x2 table

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for Season (Dry / Wet)	.355	.070	1.803
For cohort Epgintensity = Heavy	.441	.112	1.732
For cohort Epgintensity = Light	1.242	.939	1.643
N of Valid Cases	58		