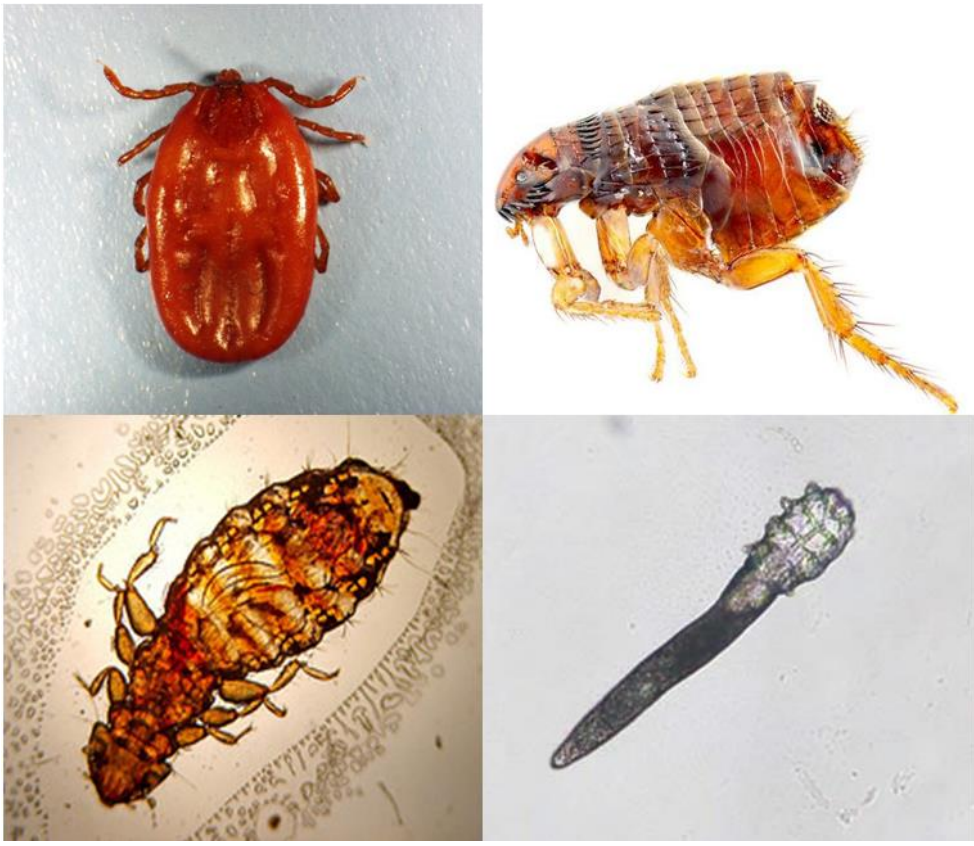
Ixodid ticks, fleas, lice and mites infesting dogs in the Mnisi community, South Africa



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INDEX

ABSTRACT

The prevalence of ectoparasite species infesting dogs in the Mnisi community, South Africa was investigated. Dogs were examined for the presence of ixodid ticks, fleas, lice and mites, in the months of April and May 2012. Of 115 dogs, 97,4% harboured one or more species of ectoparasites, of which 10 different species were identified. Dogs were mostly infested with ticks (87,8%) and fleas (42,6%); infestations of lice and mites were less prevalent (6,1% and 12,5%, respectively). Most abundant ectoparasite species included *Rhipicephalus sanguineus* (39,1%), *Amblyomma hebreum* (35,7%), *Ctenocephalides spp.* (28,7%) and *Haemaphysalis elliptica* (27.8%). Dogs that were reported to come in close contact with cattle were occasionally infested with adult *Amblyomma hebreum* and one dog harboured the cattle tick *Ripicephalus (Boophilus) microplus*, suggesting ectoparasite exchange between cattle and dogs.

To investigate the relationship between the amount of ectoparasite species infesting and severity of skin lesions, 68 dogs received a skin lesion score. It was expected that an increased number of ectoparasites species present on a dog, would relate to more severe skin lesions. However, no obvious relationship could be found.

Keywords: *Amblyomma hebreum, Ctenocephalides spp.,* dogs, ectoparasites*, Haemaphysalis elliptica,* Mnisi Community Programme, *Rhipicephalus sanguineus,* skin lesions, South Africa

INTRODUCTION

Several arthropods that parasitize domestic dogs, can cause skin disease or serve as vectors for pathogenic agents. In the rural areas of South Africa, owners do not always have the resources to bring their animals to the vet, and most dogs do not receive treatment against parasitic disease. Dogs in South Africa that live in these resource-poor communities are often infested with various species of ticks, fleas, lice and mites. These parasites do not only affect dogs, but form a potential risk to humans and other animals as well. In the rural areas, dogs are considered to play an important role in the exchange of ectoparasites between humans, livestock and wildlife (Wells *et al*. 2012).

Ticks, fleas, lice and mites can cause severe lesions of the skin. The extent and type of lesions may vary, depending on the species infesting, immunological condition of the host and parasite intensity (Gonzalez *et al*. 2004, Chanie *et al*. 2010). In general, ectoparasite infestation can cause papules, nodules, erythema, alopecia, scales, crusts, excoriation and ulceration. In chronic cases lichenification occurs, often accompanied with hyperpigmentation. Secondary pyodermia can be presented with lesions as pustules and collaretes. The host can also develop an allergic skin reaction, which can exacerbate clinical signs (Wilkerson *et al*. 2004). In some cases, ectoparasites have been described to cause immunosuppression, however, more knowledge on these mechanisms has yet to be gained (Wikel and Bergman 1997, Paveglio *et al*. 2007, Jackson *et al*. 2009).

In addition, ectoparasites are able to transmit diseases to the host, causing severe clinical illness. Most important tick-transmitted diseases in South African dogs include canine babesiosis and ehrlichiosis (Matjila *et al*. 2008). Tick-borne diseases also occur in cattle, which can have a great impact on the livelihood of farmers in the rural areas. To prevent losses, efforts have to be made to control ticks in livestock (Minjauw and McLeod 2003). Moreover, when dogs are used for herding and are often surrounded by these cattle, tick control should not only be considered for livestock, but for dogs as well.

Ixodid ticks

Common ticks in South Africa include *Haemaphysalis elliptica*, *Rhipicephalus sanguineus* and *Rhipicephalus simus* (Bryson *et al*. 2000, Horak *et al*. 2001, De Matos *et al*. 2008, Horak *et al*. 2009). In some of the studies mentioned, *Haemaphysalis leachi* has been described to be one of the most prevalent tick species in southern Africa. However, the majority of ticks formerly identified as *H. leachi* has been re-examined and re-identified as *H. elliptica* in the above mentioned studies (Apanaskevich *et al*. 2007, De Matos *et al*. 2008).

Immature stages of *H. elliptica* prefer rodents as a host, whereas the adult stages of the tick feed on carnivores including jackals, wild cats and domestic dogs (Horak *et al*. 2001). *R. simus* infests rodents in the immature stages whereas the adults prefer equids, cattle, suids, wild carnivores and domestic dogs (Horak *et al*. 2001). In contrast to *R. simus, R. sanguineus* infests domestic dogs in all stages of development (De Matos *et al*. 2008).

Occasionally, ticks that have a preference to other animals as a host, may also parasitize domestic dogs. For instance, both the adult and immature stages of *Rhipicephalus appendiculatus* preferably parasitize cattle, wild bovids and goats. However, all stages of development may also infest dogs (De Matos *et al*. 2008). In addition, adult *Amblyomma hebraeum* is found on large herbivores, but occasionally on domestic dogs. The immature stages of *A. hebreum* have a broader host spectrum, and are commonly present on dogs (Bryson *et al*. 2000, De Matos *et al*. 2008).

Other ticks seldom found on domestic dogs are *Hyalomma* spp., *Rhipicephalus evertsi evertsi*, *Rhipicephalus (Boophilus) decoloratus* and *Rhipicephalus (Boophilus) microplus* (Horak *et al*. 2005, Horak *et al*. 2009).

Tick bites can lead to local inflammation, reflected by swelling and erythema. In some cases focal ulceration and necrosis occurs. Ticks can also cause a mild pruritis to the host, especially when infested with large numbers. Moreover, ticks serve as vectors for various pathogens. *H. elliptica* is an important vector of *Babesia canis rossi,* the cause of the virulent form of canine babesiosis, which is estimated to account for 10% of the canine case load across South Africa (Jacobson *et al*. 2006). *Babesia vogeli* can be transmitted from the tick *R. sanguineus*, leading to a milder form of babesios in dogs. *R. sanguineus* is also the only efficient transmitter of *Erlichia canis*, the causative agent of canine erlichiosis, and *Rickettsia conori*, the cause of tick-bite fever in humans. Zoonotic *Ehrlichia* and *Anaplasma* species have also been reported in South Africa (Matjila *et al*. 2008).

Fleas

Ctenocephalides felis and *Ctenocephalides canis* are important flea species, affecting dogs and cats worldwide. Studies report *C. felis* to be the predominant species in dogs in South Africa (Horak 1982, Bryson *et al*. 2001) as well as in other parts of the world (Alcaino *et al*. 2002, Durden *et al*. 2005, Kumsa *et al*. 2011, Troyo *et al*. 2012). However, a study in Nigeria noted *C. canis* to be the most prevalent and *C. felis* not to be present at all (Ugbomoiko *et al*. 2008). *Ctenocephalides spp*. can lead to pruriginous skin reactions in humans, and is therefore considered to be a zoonosis. *Ctenocephalides spp.* can serve as an intermediate host of helminths including *Dypilidium caninium*, which can also infect humans, and *Dipetalonema reconditum* (Norhidayou *et al*. 2012).
In addition, *Echidnophaga gallinacea,* also known as the sticktight flea, is a flea of poultry and is also frequently found on South African dogs (Rautenbach *et al*. 1991, Bryson *et al*. 2008). The fleas stick together in clumps, attaching themselves to the skin of the host. Predilection sites are the ear margin and the skin between the toes.
Flea-infested dogs can show mild to severe skin irritation, with lesions as alopecia, excoriations, erythema, crusting and scaling. In some cases, anemia occurs. *C. felis* is also able to induce flea allergic dermatitis, characterized by a heavy pruritis and papular, crusting eruptions, mostly present on the ventral abdomen, tail base, caudomedial thighs and lumbosacral area. Chronic self-mutilation can result in hyperpigmentation and lichenification of the skin. Incidentally, dogs suffer from secondary bacterial infection (Rust 2005, Wuersch et al. 2006, Keith 2011).

Lice

Studies performed in sub-Saharan Africa indicate that *Heterodoxus spiniger* is an important louse species parasitizing domestic dogs (Rautenbach *et al.* 1991, Bryson *et al*. 2008, Kumsa *et al*. 2011). *Trichodectes canis* has also been reported to be a louse species infesting dogs in sub-Saharan African countries (Rautenbach *et al*. 1991, Ugbomoiko *et al*. 2008). *H. spiniger* and *T.canis* both serve as an intermediate host of *D. caninum*, and *H. spiniger* is also an effective intermediate host of *D. reconditum*.
Lice cause mainly pruritis, which is more intense with *Mallophaga* or chewing lice, such as *H. spiniger* and *T. canis*, than with bloodsucking lice or *Anoplura*. *Mallophaga* feed on skin debris and roam through the hair, whereas *Anoplura* are attached to the skin as they suck blood. Lesions such as crusts, alopecia and excoriations may be present. Severe infestation with *Anoplura* can result in anemia, especially in young animals (Mehlhorn *et al*. 2012). In addition, *Anoplura* are more likely to induce an immune response of the host, due to their bloodfeeding activity.

Mites

Prevalent mites parasitizing the skin of domestic dogs in African countries are *Sarcoptes scabiei* var. *canis*, *Demodex canis* and *Otodectes cynotis* (Ugbomoiko *et al*. 2008).
S. scabiei var. *canis* is a burrowing mite present in dogs worldwide. It is the cause of a highly contagious, pruritic skin condition known as sarcoptic mange or scabies (Curtis 2004). Sarcoptic mange is presented with alopecia, erythema, scaling, crusts and papules, occurring initially in the axillary and inguinal areas which later may generalize. In chronic cases, hyperpigmentation and lichenification develops. *Sarcoptes scabiei* var. *canis* can be zoonotic, though the mites are not able to complete a full life cycle on the human skin (Smith and Claypoole 1967).

O. cynotis, the ear mite, is a non-burrowing mite parasitizing the ear canals of dogs and cats worldwide. Ear mange is characterized by erythema of the ear canal and pinnae, with more or less production of ceruminous exudate. Pruritis is very common, and may lead to alopecia and excoriation (Curtis 2004).

D. canis, unlike the mite species previously mentioned, is a natural inhabitant of the intact canine skin and present in small numbers in most dogs (Gothe 1989). The mite infests the hair follicles of the skin, however most dogs do not develop any clinical symptoms. Studies suggest that demodectic mange may develop in dogs exposed to factors such as immunosuppressive disease, and is associated with a depression of T-cell function (Baron and Weintraub 1987).

Clinical symptoms of local demodectic mange include partial alopecia, erythema and scaling, mainly present on the face and feet. The lesions are mostly not pruritic. The clinical symptoms of generalized demodectic mange are more severe and may appear as generalized alopecia, nodules, lichenification, hyperpigmentation and pyoderma. Pruritis commonly occurs, mainly due to secondary bacterial infection.

AIM OF THE STUDY

This study was conducted in the Mnisi community, South Africa, as part of the Mnisi Community Programme (MCP), organized by the Faculty of Veterinary Science of the University of Pretoria. Research of the MCP is engaged within the “One Health” philosophy, and focusses on transmission of diseases between domestic animals, livestock, wildlife and humans.

In this study, the prevalence of ectoparasite species infesting dogs in the Mnisi community was investigated. A particular interest was taken in herding dogs, as they might carry ectoparasites normally present on cattle. Hypothesis is that dogs that come in contact with cattle, are infested with ectoparasite species that primarily have cattle as their host.

Another aim was to find a relationship between ectoparasite infestation and lesions of the skin. Hypothesis is that an increased number of ectoparasites species present on a dog, is related to more severe skin lesions.

MATERIALS AND METHODS

Study area

The study was performed in the Mnisi community in Mpumalanga Province, South Africa. This is a rural area located in the north-eastern corner of the Bushbuckridge Municipal Area, at the border of the Kruger National Park and part of the savannah ecosystem. It is mainly a Shangaan-speaking community, in which cattle farming forms an important agricultural activity, and dogs are predominantly kept for herding and guarding.
The MCP is closely linked to the Hans Hoheisen Wildlife Research Station and the Hluvukani Animal Clinic. As part of the MCP, diptanks have been built for the treatment of ticks in cattle, and farmers bring in their livestock weekly for dipping and veterinary inspection. These cattle are often accompanied by herding dogs. However, for dogs no tick control programme is available, and most of them have not received treatment for parasitic disease prior to this study (*figure 1*).

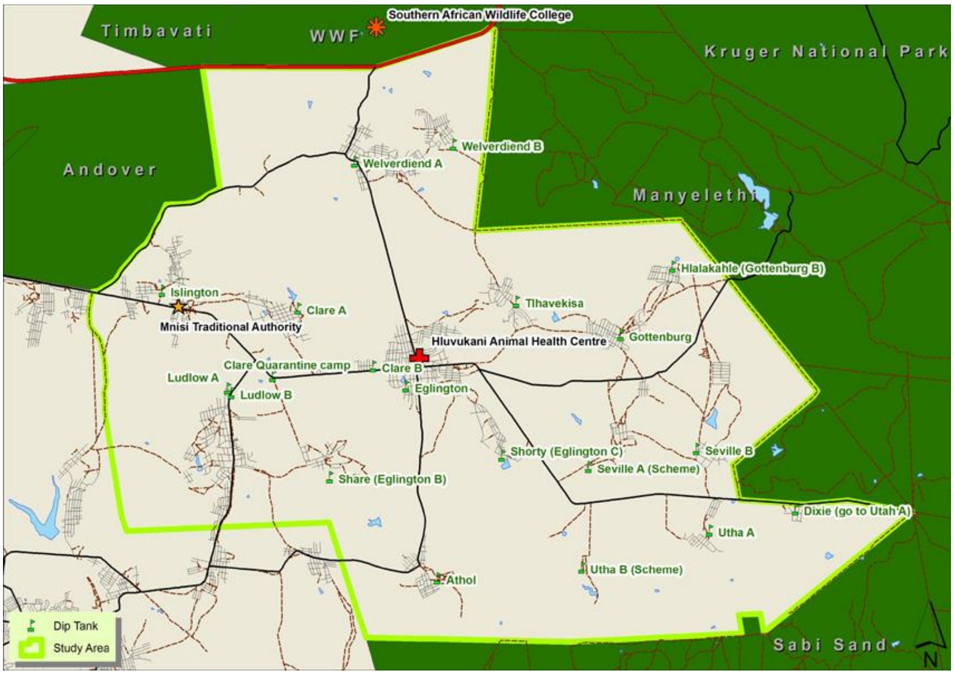

Figure 1: Map of the Mnisi study area (http://web.up.ac.za)

Study population

Screenings were conducted in villages within the Mnisi community, in the months of April and May 2012. A total of 115 dogs were screened for ectoparasites in this study, including 65 dogs (57%) in a house to house screening and 50 dogs (43%) at the diptanks. All dogs have owners and most of them are registered in a database.
Dogs at the diptanks are used for herding cattle, and therefore have close contact with these animals. Dogs screened at the houses, generally do not have contact with cattle.

Ectoparasite sample collection, identification and preservation

For safety reasons most dogs were muzzled and restrained by their owners, and with the help of two veterinary technicians. The skin of the dogs was palpated and visually examined for the presence ticks, fleas, lice and mites. With the exception of mites, all mentioned ectoparasites were collected with the use of forceps and placed in 70% alcohol for preservation.
For the diagnosis of mites, both deep and superficial skin scrapings were made of skin lesions with the use of a scalpel, mixed with mineral oil and placed on a microscope slide with a coverslip. Superficial skin scrapings were performed to detect non-burrowing mites, whereas deep skin

scrapings were used to diagnose burrowing mites and *D. canis*. Preferably more than one scraping per dog was obtained.
Skin scrapings were examined with the use of a microscope under 10x magnification, and identification of the tick, flea and louse samples was performed with a stereomicroscope.
With the methods and the short time available, it was not possible to collect all ectoparasites present on the dogs. Only a certain amount of ectoparasites per dog were collected at random, preferably on different parts of the animal body. Skin scrapings were only obtained from a few dogs, as it was too time consuming to obtain skin scrapings from all dogs. Examined dogs with no ectoparasite infestation were also included in the study.

Collected ticks, fleas and lice have been preserved in 70% alcohol, and can be analyzed for the presence of antigens of vector-borne pathogens, for future research.

Skin lesion score

The skin lesion score was used to indicate the severity of skin lesions present on a dog. Macroscopic lesions were identified, with a main focus on skin lesions associated with ectoparasite infestation; including alopecia, collaretes, crusts, erythema, excoriation, hyperpigmentation, lichenification, nodules, papules, pustules, scales and ulceration.
The number of the different types of skin lesions present on a dog and their extension, were used to determine the score. The skin lesion score scales from 1 to 9 (1 = no skin lesions, 9 = severe skin lesions) (*figure 2*).

	Skin Lesion Score
1	No skin lesions
2	Types of skin lesions = 1, < 12,5 % of body surface
3	Types of skin lesions = 2, < 12,5 % of body surface
	Types of skin lesions = 1, 12,5% to 25% of body surface
4	Types of skin lesions = 3, < 12,5% of body surface
	Types of skin lesions = 2, 12,5% to 25% of body surface
	Types of skin lesions = 1, 25% to 50% of body surface
5	Types of skin lesions = 4, < 12,5% of body surface
	Types of skin lesions = 3, 12,5% to 25% of body surface
	Types of skin lesions = 2, 25% to 50% of body surface
	Types of skin lesions = 1, ≥ 50% of body surface
6	Types of skin lesions ≥ 5, < 12,5% of body surface
	Types of skin lesions = 4, 12,5% to 25% of body surface
	Types of skin lesions = 3, 25% to 50% of body surface
	Types of skin lesions = 2, ≥ 50% of body surface
7	Types of skin lesions ≥ 5, 12,5% to 25% of body surface
	Types of skin lesions = 4, 25% to 50% of body surface
	Types of skin lesions = 3, ≥ 50% of body surface
8	Types of skin lesions ≥ 5, 25% to 50% of body surface
	Types of skin lesions = 4, ≥ 50% of body surface
9	Types of skin lesions ≥ 5, ≥ 50% of body surface

Figure 2: Table presenting the skin lesion score

Serum samples

Serum samples were collected from the dogs, and are stored in the University of Pretoria. For future research, IgE specific antigen against ectoparasites and endoparasites can be determined. In addition, serum samples can be used for the detection of antibodies against vector-borne pathogens.

RESULTS

Of the 115 examined animals, 112 were infested with ectoparasites (97,4%). A total of 10 ectoparasite species belonging to four taxa were identified; six species of ticks (*A. hebreum, H. elliptica, Ixodes spp. R. (Boophilus) microplus, R. sanguineus, R. simus*), two species of fleas (*Ctenocephalides spp., E. gallinacea*), one louse species (*H. spiniger*) and one mite species (*D. canis*) (*figure 3 to 6).*

In total, 101 dogs were infested with ticks (87,8%). Out of the 115 dogs examined, 45 dogs carried the tick identified as *R. sanguineus* (39,1%); including 37 *R. sanguineus* adults (32,2%), seven *R. sanguineus* nymphs (6.1%) and one *R. sanguineus* larva (0.9%). A total of 32 dogs were infested with *H. elliptica* (27,8%). *A. hebreum* was recovered in 41 cases (35,7%); including five *A. hebreum* larvae (4,3%), 30 *A. hebreum* nymphs (26,1%) and six *A. hebreum* adults (5,2%). *R. simus* was found in 17 of the examined animals (14.8%). The cattle tick *Boophilus microplus* was identified once (0,9%). *Ixodes spp.* was also found in one case (0,9%).

Of the six dogs that carried adult *A. hebreum*, four were sampled at the diptanks, and two were sampled at the houses in de village. For the dogs sampled at the houses, in one case the dog was reported to come in contact with cattle and in the other case this was unkown. In addition, the cattle tick *R.* (*Boophilus) microplus* was also recovered from a dog at the diptank.

Forty-nine dogs harboured fleas (42,6%). Thirty-three dogs had fleas of *Ctenocephalides spp.* (28,7%), and 21 dogs carried the flea *E. gallinacea* (18.3%). Out of these dogs, five were infested with both *Ctenocephalides spp.* and *E. gallinacea* (4,3%).

Seven dogs were infested with lice (6,1%), and all samples were identified as *H. spiniger* (6,1%). No other louse species were found.

Skin scrapings were obtained from eight dogs (7,0%), and one of the sampled dogs proved to be positive for *D. canis* (12,5%). This dog was in such poor condition, it eventually had to be euthanized. Multiple skin scrapings were taken from the dog and *D. canis* was found in all of them. On the seven remaining dogs that were examined, no mites were found.

Including the different species of ticks, fleas, lice and mites; 53 dogs harboured one species of ectoparasites (46,1%), 39 dogs carried two species of ectoparasites (33,9%), and 19 dogs had three species of ectoparasites (16,5%). One dog was affected by four species of ectoparasites (0,9%) and three dogs had no ectoparasite infestation (2,6%) (*figure 7)*.

For 68 animals, a skin lesion score was determined, serving as an indication for the severity of skin lesions present. Frequently identified lesions included alopecia, scales, crusts, hyperpigmentation, lichenification, excoriation and nodules. Lesions were mostly present on ears, feet, legs and ventral abdomen (*figure 8 and 9*).

In a scatterplot, the skin lesion scores of the 68 dogs have been set against the number of ectoparasites species present on them. Every ectoparasites species, meaning all species of ticks, fleas, lice and mites recovered from the dogs, were included in this. The scatterplot was used to find a relationship between the amount of ectoparasites species infesting and the severity of skin lesions. Expected was that an increased number of ectoparasites species infesting, relates to more severe skin lesions in dogs. However, no direct relationship could be found *(figure 10)*.

Tables presenting the results of the study

No. of dogs infested								
Ixodid ticks	**Houses (n = 65)**			**Diptanks (n = 50)**				
	Larvae	**Nymphs**	**Adults**	**Larvae**	**Nymphs**	**Adults**	**Total**	**%**
A. hebreum	4	13	2	1	17	4	**41**	**35,7**
H. elliptica	0	0	15	0	0	17	**32**	**27,8**
Ixodes spp.	0	0	0	0	0	1	**1**	**0,9**
R. (Boophilus) microplus	0	0	0	0	0	1	**1**	**0,9**
R. sanguineus	1	5	23	0	2	14	**45**	**39,1**
R. simus	0	0	6	0	0	11	**17**	**14,8**

Figure 3: Table presenting the prevalence of ixodid tick species collected from dogs (n = 115)

No. of dogs infested				
Fleas	**Houses (n = 65)**	**Diptanks (n = 50)**	**Total**	**%**
Ctenocephalides spp.	17	16	**33**	**28,7**
E. gallinacea	15	6	**21**	**18,3**

Figure 4: Table presenting the prevalence of flea species collected from dogs (n = 115)

No. of dogs infested				
Lice	**Houses (n = 65)**	**Diptanks (n = 50)**	**Total**	**%**
H. spiniger	2	5	**7**	**6,1**

Figure 5: Table presenting the prevalence of louse species collected from dogs (n = 115)

No. of dogs infested				
Mites	**Houses (n = 2)**	**Diptanks (n = 6)**	**Total**	**%**
D. canis	1	0	**1**	**12,5**

Figure 6: Table presenting the prevalence of mite species collected from dogs (n = 8)

No. of dogs infested				
No. of ectoparasite species present per dog	**Houses (n = 65)**	**Diptanks (n = 50)**	**Total**	**(%)**
0	2	1	**3**	**2,6**
1	35	18	**53**	**46,1**
2	21	18	**39**	**33,9**
3	6	13	**19**	**16,5**
4	1	0	**1**	**0,9**

Figure 7: Table presenting the number of ectoparasite species present per dog (n = 115)

Examples of determination of skin lesion scores for dogs

Figure 8: Dog with alopecia, excoriation, crusts, hyperpigmentation and lichenification, present at legs and ears; < 12,5% of body surface. The skin lesion score of this dog = 6.

Figure 9: Dog with generalized alopecia, nodules, lichenification and hyperpigmentation present at ≥ 50% of body surface. The skin lesion score of this dog = 8.

Scatterplot used to find relationship between ectoparasite infestation and skin lesions

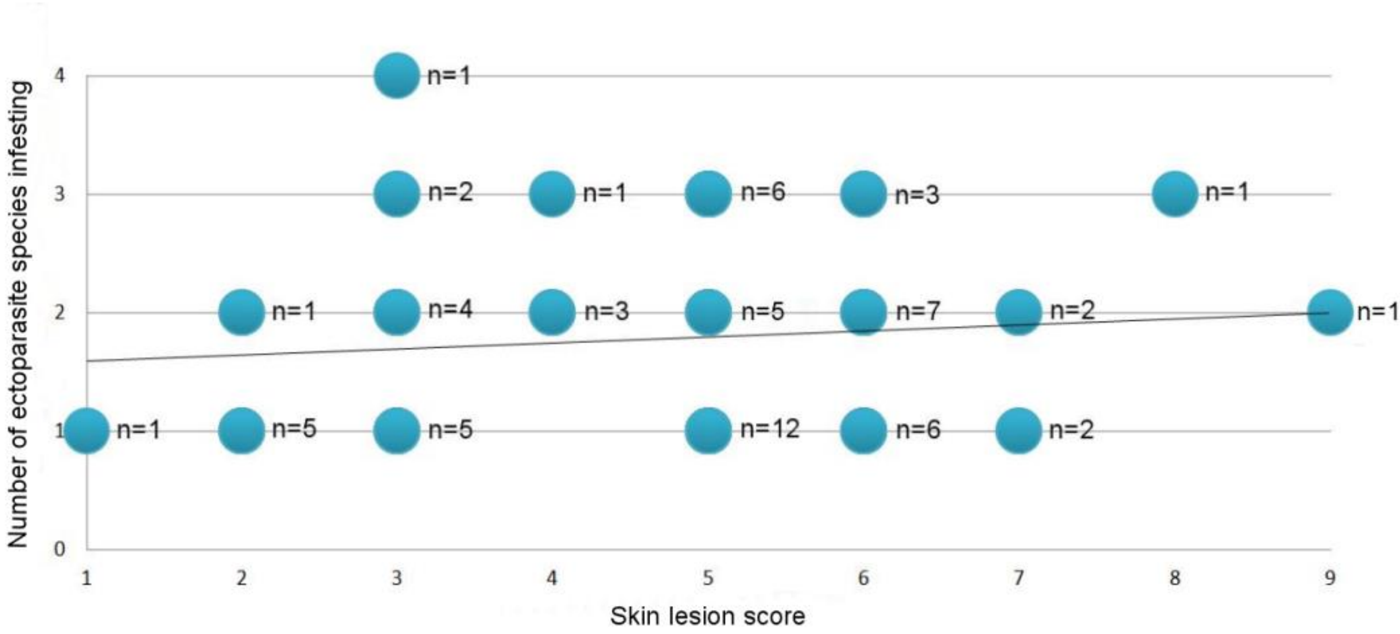

Figure 10: Scatterplot. Sixty-eight dogs received a skin lesion score (n = 68). In this figure the scores of the dogs are set against the number of ectoparasite species present per dog. The trend line is used to find a relationship between the number of ectoparasite species infesting and skin lesion scores.

DISCUSSION

Of all the dogs examined in this study, 97,4% harboured ectoparasites and a total of 10 different species were identified. Most abundant ectoparasite species included *R. sanguineus* (39,1%), *A. hebreum* (35,7%), *Ctenocephalides spp*. (28,7%) and *H. elliptica* (27.8%). Dogs were mostly infested with ticks (87,8%) and fleas (42,6%); lice and mite manifestations were less prevalent (6,1% and 12,5%, respectively).

The most prevalent ticks were adult *R. sanguineus* (32,2%) and *H. elliptica* (27,8%), followed by *A. hebreum* nymphs (26,1%) and *R. simus* (14,8%). This outcome is compatible with other studies performed in rural areas in Southern Africa (Bryson *et al*. 2001, Horak *et al*. 2001, De Matos *et al*. 2008, Horak *et al*. 2009); however, the intensity of infestation differs among studies. For instance, Bryson *et al*. reported *R. sanguineus* to be predominant rather than *R. simus* and *H. elliptica* in resource-poor communities. Suggested is that these poor living circumstances are ideal for the development of all stages of *R. sanguineus* (Bryson *et al*. 2001, Horak *et al*. 2001). This could explain the high number of *R. sanguineus* found in the present survey.

Ixodes spp. was only collected once. Infestation of dogs with *Ixodes spp*. in Southern Africa has occasionally been documented; De Matos *et al*. reported *Ixodes cavipalpus* to be present on two of 132 dogs (De Matos *et al*. 2008).

Adult *A. hebreum* was only present on those dogs that came in contact with cattle, with the exception of one case where this was unknown. Although adult *A. hebreum* is considered to be a tick of cattle and other large herbivores, it is known to occasionally infest dogs (Horak *et al.* 2001, Bryson *et al*. 2008, De Matos *et al*. 2008, Horak *et al*. 2009). However, in the above mentioned studies no differentiation was made between dogs coming in contact with livestock and those that do not.
In addition, *R. (Boophilus) microplus* was found once, also collected from a dog visiting the diptank. *R. (Boophilus) microplus* is known as the cattle tick and is rarely found on carnivores. One study in Zimbabwe reported a small number of dogs had this tick (Goldsmid 1963).
Thus, dogs that come in contact with cattle were occasionally infested ticks that primarily have cattle as their host, which supports the hypothesis. Although only a small number of these ticks were found on dogs, this indicates that cattle play a role in the transmission of ticks to dogs. Moreover, these dogs could be a source of transmission for cattle as well, and even though diptanks are used for tick control, cattle are still exposed and can get reinfested. So in addition to the dipping of cattle, adequate tick control in dogs is essential to achieve a more effective control programme in the Mnisi community**.**

Of the flea samples, *E. gallinacea* and *Ctenocephalides spp*. were both abundant, with the latter being predominant (18,3% and 28,7%, respectively). Bryson *et al*. reported similar numbers, however, Rautenbach *et al*. revealed *E. gallinacea* to be the more prevalent flea species (Rautenbach *et al*. 1991, Bryson *et al*. 2008). But in contrary to these mentioned studies, no differentiation between the species *C. canis* and *C. felis* could be made in the present study. Nevertheless, samples are preserved and determination for further research is possible.

Of the 6.1% of the dogs harbouring lice, only one louse species was identified. Bryson *et al*. conducted research on dogs in the North West Provence of South Africa and reported a 3.1% prevalence of *H. spiniger*, also the only louse species recovered in the survey (Bryson *et al*. 2008). In another study conducted in South Africa, four dogs were infested with *H. spiniger* and one with *Trichodectes canis* (Rautenbach *et al*. 1991). In addition, a study in Ethiopia documented *H. spiniger* to be present in 4.0% of the dogs (Kumsa *et al*. 2011). Despite these low numbers, the louse

H. spiniger is of veterinary importance, as it can cause discomfort to the dog and serves as an intermediate host for *D. caninum* and *D*. *conditum* (Norhidayu *et al*. 2012).

One of the eight dogs sampled for mites, was positive for *D. canis* (12,5%)*.* In the present survey, skin scrapings were only performed on a few dogs. If skin scrapings had been taken systematically, perhaps more dogs would have been diagnosed with mites. Moreover, mites are difficult to detect and negative results of skin scrapings do not exclude the presence of mites (Keith 2011). Hence, it is suspected that more dogs in the study population were suffering from mites than the results show.

Due to the limited time available for this study, not all ectoparasite could be removed from the examined dogs. Skin scrapings were only obtained from eight out of 115 dogs, and mites were probably underdiagnosed. However, results do give an indication of the prevalence of ectoparasites species infesting dogs in the Mnisi community, South Africa. Ticks were present on 87,5% of the studied dogs, and infection with tick-borne diseases form a potential risk to these animals. *H. elliptica* is an important vector of *B. canis rossi,* and *R. sanguineus* is able to transmit *E. canis, B. vogeli* and *R. conori.* In addition, *A. hebreum* can carrry *Erlichia ruminantum*, the cause of heartwater disease in cattle, and *R. (Boophilus) microplus* is a vector of *Babesia bovis*, the causative agent of bovine babesiosis (Marufu *et al*. 2010). However, presence of a vector does not necessarily imply presence of disease. Collected ectoparasites have been preserved, and ticks could be analyzed for the presence of species of *Babesia*, *Ehrlichia*, *Rickettsia* and *Anaplasma* for future research.
For the host to get infected with a tick-borne disease, multiple factors are involved, including the virulence of the agent, host susceptibility, duration of infestation and the time the respective agent requires to be transmitted from the vector and infect the host. To investigate the prevalence of tick-transmitted infections in the Mnisi community, blood specimens of dogs and possibly other animals, could be screened for infection with *Babesia*, *Ehrlichia*, *Rickettsia* and *Anaplasma* species.

Out of the 68 dogs that received a skin lesion score, most of them suffered from one or more types of skin lesions. Dogs often showed lesions of hyperpigmentation and lichenification, indicating chronic infestation. Only one dog received a score of 1, and had no defects of the skin. The scatterplot in figure 8 has been set up to find relationship between the number of ectoparasites species infesting and severity of skin lesions. It was expected, that with an increased number of ectoparasites species present on a dog, more severe skin lesions should be found. However, no direct relationship could be shown (*figure 8*).
A hypothesis is, that parasites are able to bypass host defense and down-regulate immune responses, to establish chronic infections. Therefore animals chronically exposed to parasitic infections, might have a decrease in pro-inflammatory reactions*.* By this mechanism, dogs infested with a high number of ectoparasites species could have less severe lesions of the skin than expected. The ability to modulate immune responses has been described for endoparasites, and helminths in particular*.* Reactions to helminths are predominantly of the T-helper 2 type (Th2), involving interleukines (IL) such as IL-3, IL-5 and IL-13. Production of these pro-inflammatory cytokines result in an increase of IgE antibodies, eosinophils, basophils and mastcells. However, helminths are able to regulate immune responses, shifting them from pro-inflammatory to anti-inflammatory. Helminths can modulate dendritic cell (DC) function and induce regulatory T cells (Treg), regulatory B cells (Breg) and alternatively activated macrophages (AAMs), to generate immune suppression and reduction of allergic responses (Aranzamendi *et al*. 2013).
Immunoregulation serves as a survival mechanism for these helminths, but in addition can lead to protection of the host from allergic reactions. In the Western world, there has been a diminished exposure to parasites and pathogens. The hygiene hypothesis proposes that the decrease of exposure to parasites and pathogens, promotes development of allergic diseases. However, the hygiene hypothesis does not apply for all helminths. For instance, while *Trichinella spiralis* can

induce immune suppression, *Toxocara canis* can exacerbate inflammatory diseases (Aranzamendi *et al*. 2012, Pinelli and Aranzamendi 2012, Aranzamendi *et al*. 2013).
Ectoparasites may also cause a variety of immune responses. Flea allergic dermatitis can develop in animals sensitized to the antigen present in flea saliva. It is usually caused by the species of *C. felis* and is mainly an intermediate hypersensitivity reaction (Wilkerson *et al*. 2004). In addition, mites secrete allergenic substances which can elicit hypersensitivity reactions in the host; studies suggest that the mite *Sarcoptes scabiei* can induce immediate as well as delayed hypersensitivity reactions (Wikel 1984, Wells *et al*. 2012).
Few studies have shown down-regulation of the host's immune system caused by ectoparasites (Paveglio *et al*. 2007, Jackson *et al*. 2009). It is suggested that some ectoparasites may exert a stronger influence on the immunoregulatory environment of the host than do helminth infections. Infestation of the louse *Polyplax serrata* in wild rodents, resulted in approximately 50% reduction in TNF-α responses mediated by toll like receptor (TLR) 2 and TLR 9 (Jackson *et al*. 2009). Immunosuppressive activity has also been documented for ixodid ticks. The saliva of *Ixodes scapularis* contains a protein, salp15, to inhibit early events in the activation of Th2 cells. Salp15 can effectively prevent the generation of a Th2 immune response and the development of experimental asthma (Paveglio *et al*. 2007). Mechanisms of ticks modulating immune response have been described before; including the interference with antigen processing and MHC antigen expression, reducing pro-inflammatory cytokines such as IL-1 and TNFα, altering the ratio of Th1 and Th2 cells and their respective cytokines, selectively targeting local immune responses, and blocking complement activation (Wikel and Bergman 1997).
Measuring of IgE serum levels could provide more information on the involvement of ectoparasites in the development of allergic diseases. Serum samples have been collected and are stored in the University of Pretoria, for IgE levels to be measured in future research. As endoparasitic infection may also have an influence on host immunity, the same dog population was screened for the presence of *Toxocara canis* and *Giardia spp.*. To find support for the hygiene hypothesis, the relation between parasitic infection and allergy should be investigated in this dog population, by measuring IgE antibody levels against both ectoparasites and endoparasites. This could give an explanation for the lack of relationship between the number of ectoparasites species infesting and severity of skin lesions found in this study.

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