Distribution and ecology of economically important ticks on cattle, with special reference to the Eastern Cape Province, South Africa and Namibia

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Dissertation presented for the degree of Philosophy Doctorate in Entomology in the Faculty of AgriScience at Stellenbosch University

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The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

December 2017

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Some of the contents contained in this thesis (Chapters 2-5) are taken directly from manuscripts submitted or drafted for publication in the primary scientific literature. This resulted in some overlap in content between the chapters.

December 2017

Abstract

Ticks (Acari: Ixodidae) are parasites of major economic and medical importance that transmit a multitude of pathogenic organisms affecting domestic animals globally and in South Africa. High tick infestations are associated with skin damage, tick worry, reduced growth and milk production, transmission of tick-borne pathogens and mortalities. The aims of the study were to: (1) investigate the effect of vegetation type (Albany Coastal Belt, Amathole Montane Grassland, Bhisho Thornveld and Great Fish Thicket) on the tick species composition and diversity on cattle and on the vegetation on communal farms in the south-west region of the Eastern Cape Province (ECP), (2) obtain baseline data on the perceptions of cattle farmers with regard to ticks, tick-borne diseases (TBDs) and the management practices being used on communal farms in the ECP and (3) record the geographic distribution of an alien invasive tick, *Rhipicephalus microplus* and the closely related endemic species *Rhipicephalus decolaratus* in the environmentally less optimal south-western and north-western regions of South Africa and in Namibia. The study was conducted at two scales: local (ECP) and regional (South Africa and Namibia). At a local scale, ticks were collected from cattle (adult and calves) and from the vegetation from five localities in each of four vegetation types. Ticks were removed from one-side of each animal (n = 1000) and replicated drag-sampling was performed at each locality, to record the ticks on vegetation. In addition, at each locality five cattle owners were randomly selected to participate in a questionnaire study. Face-to face interviews were carried. A total of 100 individual questionnaires were completed (25 in each of the four vegetation types). At a regional scale, ticks were collected through active tick removal from cattle and by passive citizen-science approach where tick samples were provided by private cattle farmers solicited via social media.

Cattle (n = 415) were examined in the Western-, Eastern- and Northern Cape and Free State Province in South Africa and in Namibia (n = 18). About 20 212 ticks belonging to 12 species were collected from adult cattle, calves and on vegetation at the 20 communal localities. Vegetation type did not consistently affect tick abundance, species richness or species composition, though there were differences in the abundance of individual tick species. The abundance of *R. e. evertsi* was significantly higher on cattle in Thornveld and Thicket compared to Coastal belt and Grassland, while *A. hebreaum* was significantly more abundant on the vegetation in Coastal belt compared to Thornveld and absent in Grassland. The effect of individual villages on tick infestations was more important than vegetation types. Tick abundance and species richness was higher on adult cattle compared to calves. In terms of farmer perceptions, significantly more respondents confirmed that adult animals were more affected by ticks compared to calves. All of the respondents identified redwater as the commonest TBDs, followed by gallsickness (90%) and heartwater (43%). For the geographic distribution of *R. microplus*, a total of 8 408 *Rhipicephalus* (*Boophilus*) spp. ticks were recovered from cattle in SA. *R. microplus* extended its range to new areas for the first time in the Northern Cape Province and the western regions of the Eastern- and Western Cape Provinces. In Namibia, *R. microplus* was recorded for the first time with 142 adult *R. microplus* collected from 20 cattle on four farms, whereas *R. decoloratus* was present on all 18 of the survey farms in Namibia. Evident from the study is that the concern of communal cattle farmers in the ECP about ticks and TBDs is supported with field-based studies. The patterns of tick infestation observed in the present study seems to be the result of a combination of factors that include amongst others the uncontrolled movement of cattle within SA and between SA and Namibia, the development of acariside resistance and the highly adaptable nature of the invasive Asiatic tick.

Opsomming

Bosluise (Acari: Ixodidae) is parasiete van groot ekonomiese en mediese belang wat verskei patogene aan huis- en plaasdiere oor dra. Hoë bosluis besmetting hou verband met vel beskadiging, verminderde groei van diere en melkproduksie, oordrag van bosluis-oordraagbare patogene en sterftes. Die doelwitte van die studie was om: (1) die effek van plantegroei tipe (Albany kusstrook, Amathole berggrasveld, Bhisho Doringveld en Groot Vis- bos) op die bosluisspesies samestelling en diversiteit op beeste en op die plantegroei op kommunale plase in die suidweste streek van die Oos-Kaap (OK) te bepaal, (2) basislyndata op die persepsies en kennis van beesboere met betrekking tot bosluise, bosluisoorgedraagde siektes (BOSs) en die bestuurspraktyke wat gebruik word op kommunale plase in die OK te verkry en (3) die geografiese verspreiding van 'n uitheemse bosluisspesie, *Rhipicephalus microplus* en die naverwante endemiese spesies *Rhipicephalus decolaratus* in minder optimale suidwestelike en noordwestelike streke van Suid-Afrika en in Namibië aan te teken. Die studie is uitgevoer op twee skale: plaaslik (OK) en streeks (Suid-Afrika en Namibië). Op 'n plaaslike skaal, is bosluise van beeste (volwasse en kalwers) en van die plantegroei van vyf lokaliteite in elk van vier plantegroeitipes versamel. Bosluise is van die een kant van elke dier (n = 1000) versamel en herhaalde sleep-opnames is uitgevoer by elke lokaliteit, om die bosluise op die plantegroei aan te teken. Daarbenewens, by elke lokaliteit is vyf bees-eienaars ewekansig gekies om deel te neem in 'n vraelys-studie. Aangesig tot aangesig onderhoude is gevoer. 'n Totaal van 100 vraelyste is voltooi (25 in elk van die vier tipes plantegroei). Op 'n streeks skaal is bosluise ingesamel deur middel van aktiewe bosluis verwydering van beeste en deur passiewe burger-wetenskap benadering waar bosluise verskaf is deur private beesboere. Beeste (n = 415) was geondersoekte

in die Wes-, Oos- en Noord-Kaap en Vrystaat in Suid-Afrika en in Namibië (n = 18). Die resultate is soos volg, sowat 20 212 bosluise wat deel uitmaak van 12 spesies is versamel van volwasse beeste, kalwers en op plantegroei by die 20 kommunale lokaliteite. Plantegroei tipe het nie deurgans 'n invloed op spesierykheid of spesiesamestelling gehad nie. Daar was egter verskille tussen individuele bosluisspesies. *Rhipicephalus evertsi evertsi* was aansienlik hoër op beeste in Bhisho Doringveld en Groot Vis-bos in vergelyking met Albany kusstrook en Amathole berggrasveld, terwyl *Ablyomma hebraeum* aansienlik meer volop was op Albany kusstrook in vergelyking met Bhisho Doringveld en afwesig in Amathole berggrasveld. Die effek van individuele dorpe op bosluis besmetting was belangriker as plantegroeitipes. Bosluis getalle en spesierykheid was hoër op volwasse beeste in vergelyking met kalwers. In terme van die persepsies en kennis van kommunale beesboerer het aansienlik meer respondente bevestig dat volwasse diere meer geraak word deur bosluise in vergelyking met kalwers. Al die respondente het gemerk dat rooiwater die algemeenste BOSs is, gevolg deur galsiekte (90%) en hartwater (43%). Die studie wat gefokus het op die geografiese verspreiding van *R. microplus* het 'n totaal van 8 408 *Rhipicephalus* spp. bosluise van beeste in SA verhaal. Daar is gevind dat *R. microplus* se verspreiding uitgebrei het en die spesie kom vir die eerste keer in die Noord-Kaap Provinsie en die westelike streke van die Oos- en Wes-Kaap voor. In Namibië is *R. microplus* vir die eerste keer aangeteken. Meer as 100 volwasse *R. microplus* is versamel van 20 beeste op vier plase, terwyl *R. decoloratus* teenwoordig was op al 18 van die plase in Namibië. Uit die studie blyk dit dat die kommer van kommunale veeboere in die OK oor bosluise en BOSs ondersteun word deur veld-studies. Die patrone van bosluis besmetting wat waargeneem is in die huidige studie blyk die gevolg te wees van 'n kombinasie van faktore. Dit sluit onder andere die onbeheerde beweging van vee in SA en tussen SA en Namibië, die ontwikkeling van weerstand, teen bosluis-beheer middels, en die hoogs aanpasbaar aard van die indringer Asiatiese bosluis in.

Acknowledgements

First, I would like to thank my supervisor for guiding, supporting and mentoring me throughout my PhD studies. This project would not have been a success without her support, patience and encouragement even when at times all seemed a futile exercise.

The farmers are thanked for their willingness to exchange information and agreeing to the collection of ticks from their animals. I also express my gratitude to Dr Andreas Gaugler, Gail Morland, Monique Rentel and their respective families for logistical support during tick collection in Namibia. Dr Roy Williams of the ARC-Onderstepoort Veterinary Institute and Dr Luther Van der Mescht, of the Department of Conservation Ecology, Stellenbosch University, are thanked for compiling the locality and distribution maps. My sincere thanks to the Eastern Cape Department of Rural Development and Agrarian Reform (ECDRDAR) for permitting me to conduct the Eastern Cape segment of the study as part of my official duties. Thanks again to the ECDRDAR district Animal Health Officials for their technical assistance during the sites visit and tick collection. Stellenbosch University and the National Research Foundation (APDS14011861241 and IFR2011032500004) are thanked for infrastructural and financial support. The Grantholder acknowledges that opinions, findings and conclusions or recommendations expressed in any publication generated by the NRF supported research are that of the authors and that the NRF accepts no liability whatsoever in this regard.

Finally, the unwaving support of the most wonderful woman, my wife (Khunjulwa Kwandokuhle Nyangiwe), my children (Odwa, Thembelihle and Thubelihle) and my entire family is grealty appreciated.

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Chapter 1

General Introduction

1.1 Tick biology, pathogens and control

Ticks (Acari: Ixodidae) comprise three important families namely the Argasidae, Nuttalliellidae and the Ixodidae (Klompen et al. 1996). There are nearly 900 tick species of which 191 belong to the family Argasidae, 701 to the family Ixodidae and only one to the family Nuttalliellidae (Jongejan and Uilenberg 2004; Guglielmone et al. 2010). Most ticks that are of importance from the veterinary point of view belong to the family Ixodidae, known as the hard or shield ticks (Howell et al. 1978; Horak and Fourie 1991; Walker et al. 2000). Globally, ticks are considered as the most important external parasites of livestock and can cause great loss to successful stock farming (Jongejan & Uilenberg 2004). Ticks and tick-borne diseases (TBDs) affect almost 80% of the world's cattle population, with an estimated global annual cost ranging between US$ 14-19 billion (De Castro 1997; Kopp et al. 2010). While little data exist on national impact of TBDs, in South Africa, annual losses attributed to tick-borne diseases are estimated to range between R70 - R550 million (Van Rensburg 1981; Spickett et al. 2011).

Directly, ticks cause reduced live weight gains in the host resulting from anemia and tick worry. In addition, poorer quality hides and tick toxicosis have also been recorded. Abscesses due to secondary infections may form which sometimes become maggot-infested and cause crumpled ear pinnae, sloughed teats, missing tail tips, lameness and footrot which eventually increase the mortalities. Indirectly, impacts include the transmission of tick-borne diseases since ticks act as vectors of pathogenic organisms (Howel et al. 1978). These pathogens can cause protozoan diseases (eg. Babesiosis and Theileriosis), rickettsial diseases (eg. Anaplasmosis and Cowdriosis) and viral diseases of livestock which are of great economic importance world-wide (Frans 2000). Several ticks that commonly infest cattle are vectors of disease and can also *per se* cause a decrease in animal productivity. In South Africa *A. hebraeum*, the South African bont tick is the vector of *Ehrlichia* (*Cowdria*) *ruminantium* the causative organism of heartwater in cattle, sheep and goats; *R. decolaratus*, the African blue tick, is the vector of *Babesia bigemina* and *Anaplasma marginale* while *R. microplus*, the Asiatic blue tick, is the vector of *Babesia bovis, B. bigemina* and of *Anaplasma marginale,* the causative organisms of redwater in cattle; while *R. appendiculatus*, the brown ear tick transmits several species of *Theileria*, causing theilerioses in cattle (Howell et al. 1978; Norval and Horak 2004).

Over the last one hundred years, control of ticks and tick borne diseases have been based on the regular use of acaricides. Chemical control with acaricides was regarded as one of the best methods, but it was shown that ticks have developed resistance against a range of acaricides (Martins et al. 1995). These chemicals are poisonous to the ecosystem and expensive. The use of acaricides has drawbacks, such as the presence of residues in the milk and meat and the development of chemical resistant tick strains (Willadsen et al. 1988; Nolan 1990). Beside this, resource poor livestock owners are unable to buy these acaricides. Strategies for tick control such as through vaccination should be explored and there is a need for alternative approaches to control tick infestations (Graf et al. 2004). Moran and Nigarura (1990) defined strategic tick control as “an attempt to control ticks and reduce losses in animal production due to tick infestations while decreasing the cost for this control." To do this successfully, knowledge on the species composition, seasonal occurrence and the geographic distribution of the major tick species in a region is required. Ecological studies can contribute to the design of more efficient and economically sound control strategies for ticks and tick-borne diseases (Kebede 2004). This, in combination with epidemiological data forms the basis for a sustainable tick control programme.

Within the Ixodidae, three types of life cycles can be distinguished based on similarities or differences in tropisms shown by ticks at different instars. These are the monotropic cycle or one-host, the ditropic cycle or two-host and the teletropic cycle or three-host ticks (Kebede 2004). In South Africa one-host ticks, such as *Rhipicephalus decoloratus* (formerly *Boophilus*), remain on the same animal from the time that they attach as larvae, until they finally drop off as fully–fed adults. In two-host ticks, such as *Rhipicephalus evertsi evertsi,* the larvae quest for hosts from the vegetation and then attach to the host where, after feeding, they moult to the nymphs. The nymphs reattache to the host close by, engorge in about two weeks and drop off the host on to the ground to moult to adults. Nymphs can survive on the ground for several weeks (Seifert 1996). The adults attach to the second host on which they feed and copulate (Kebede 2004). Three-host ticks generally require three hosts to enable them to complete their life cycle because each of the two immature stages drops from the host after feeding and then moults to the next stage, with the adults feeding on a third host. Most ixodid ticks belong to the latter group and examples include *Amblyomma hebraeum* and *Rhipicephalus appendiculatus*. The abovementioned ticks are parasites of cattle, but their immature stages and sometimes also adults will feed on other domestic animals (goats and sheep) and some wildlife (Howell et al. 1978;

Horak et al. 1987a; Horak and Fourie 1991; Walker et al. 2000). Three-host ticks spend more time in the environment and it is expected that they have stronger response to environmental conditions.

At a global scale the geographic distribution of tick species is correlated with climate (Norval et al 1992; Olwoch et al. 2009). Studies have highlighted that climate influences the distribution of ticks and that temperature, relative humidity and saturation deficit are the key determining climatic factors. Tick survival and rate of development are dependent on temperature, humidity and photoperiod (Norval 1977; Belozerov and Naumov 2002; Randolph 2004). Warmer temperatures allow shorter interstadial development times and thus this can give rise to higher tick population abundance (Jouda et al. 2004; Schwarz et al. 2009). At the same time conditions may be less favourable when temperatures are too high (>30˚C) resulting in higher tick mortality, particularly as ticks are highly sensitive to desiccation (Cadens et al. 2007). Microclimate is dependent on a variety of biotic and abiotic factors, such as the amount of vegetation present and the type of soil (soil structure for water retention) (Merler et al. 1996; Schwarz et al. 2009). Adequate vegetation cover can provide a suitable environment for tick survival. As a result tick abundance may vary strongly between different vegetation types (Gray et al. 1998). A study conducted in northern Belgium, on how local habitat and landscape affect *Ixodes ricinus* tick abundance, provided information about the importance of forest type and forest edge on the distribution and abundance of this tick species (Tack et al. 2012). The dynamics of temperate tick populations such as *I. ricinus* and *I. scapularis* are particularly influenced by changing environmental conditions, especially variation in temperature as well as vegetation type (Cadenas et al. 2007; Schwarz et al. 2009).

1.2 Tick diversity and species interactions

Walker (1991) listed 77 species of ixodid ticks that occur in southern Africa, and three new species, *R. oreotragi*, *R. warbutoni* and *I. fynbosensis* have subsequently been added (Walker et al. 2000; Apanaskevich et al. 2011). Thirty-seven of these ticks have been recorded on domestic animals. The names of two of these 37 species, namely *Haemaphysalis leachi* and *Hyalomma marginatum turanicum,* neither of which occur in South Africa, have been reinstated as *Haemaphysalis elliptica* and *Hyalomma glabrum,* both of which are valid indigenous species (Apanaskevich and Horak 2006; Apanaskevich et al. 2007). A third species, *H. marginatum rufipes* has recently been raised to species level, namely *Hyalomma rufipes* (Apanaskevich and Horak 2008). Almost a decade ago, the confirmed records of *R. microplus* in Africa were restricted to southern and south eastern Africa (Estrada-Peña et al. 2006). Nevertheless, *R. microplus* has lately established viable populations in West African countries, namely Ivory Coast and Benin (De Clercq et al. 2012; Madder et al. 2012), Burkina Faso, Mali and Togo (Adakal et al. 2013), and Namibia (Nyangiwe et al. 2013b). Although West African cattle are threatened by the invasive tick, *R. microplus*, no records of this species has been reported in Nigeria (Lorusso et al. 2013). *R. decoloratus*, indigenous to Africa, is the most widespread in subgenus *Boophilus* although is displaced by *R. microplus* in certain regions of the continent (Tønnesen et al. 2004; Lynen et al. 2008; Horak et al. 2009; Madder et al. 2011; De Clercq et al. 2012; Nyangiwe et al. 2013a). Howell *et al*. (1978) mapped the geographic distributions of both species in South Africa. At that time *R. decoloratus* was widespread in the eastern region of the Eastern Cape Province (ECP) and *R. microplus* was restricted to coastal pockets. Subsequently a study recorded a considerably more extensive distribution for the latter tick in this region (Baker et al. 1981; Baker 1982. More recently a survey conducted by Horak et al. (2009) show that *R.*

microplus has further extended its range in south-east Africa. In addition, the 1978 distribution pattern of the two ticks has now been reversed (*R. microplus* the major species and *R. decoloratus* the minor). In other regions in SA, Tønnesen et al. (2004) reported the displacement of *R. decoloratus* by *R. microplus* in the Soutpansberg region, Limpopo Province. The same phenomenon was recorded in several other southern African countries, which include Zimbabwe (Mason and Norval 1980), the Eastern Province of Zambia (Berkvens et al. 1998) and Tanzania (Lynen et al. 2008).

The reasons for the displacement may be linked to a shorted life cycle and higher egg production for *R. microplus* compared to *R. decoloratus* (Horak et al. 2009). Moreover, cross mating between the two species results in sterile eggs (Spickett and Malan 1978), and although male ticks prefer to mate with conspecific females (Norval and Sutherst 1986), they will also mate with females of the other species (Spickett and Malan 1978). The males of *R. microplus* are sexually mature a few days sooner than those of *R. decoloratus* (Londt and Arthur 1975), and thus in mixed infestations they have a greater chance of mating with females of their own species. Furthermore, if the sex ratio of male to female *R. microplus* is similar to that of *R. decoloratus* on naturally infested hosts, namely approximately 2:1 (Horak et al. 1992, 2003), the excess numbers of *R. microplus* males could mate with *R. decoloratus* females, rather than the converse happening. As females apparently mate only once, the cross-mated females would produce sterile eggs and *R. microplus* would consequently constitute an ever-increasing proportion of future mixed populations of the two ticks. There are, however, also differences in the host preferences of *R. decoloratus* and *R. microplus*. *R. microplus* is strictly a parasite of domestic cattle and is more exposed to every application of acaricide than *R. decoloratus*, thus enhancing the rapidity with which selection for resistance can take place.

Current distribution maps of tick species on cattle in South Africa are in need of revision. Walker et al. (2000) published updated maps for members within the genus *Rhipicephalus*. However, the geographic distribution of the remaining tick genera was last documented approximately 60 years ago. More recent habitat suitability models predict that the north-eastern, eastern and south-eastern parts of the country are suitable for most of the tick species associated with cattle (Spickett et al. 2010). This is especially so for the endemic African blue tick and the invasive Asiatic blue tick. However, the western part of the ECP and WCP were severely undersampled. It is uncertain if the Asiatic blue tick has extended its range to the western part of the ECP and possibly into the WCP and Northern Cape Province (NCP). The movement of cattle from one region to the next can facilitate the transmission and spread of the invasive species. Recent anecdotal information suggests that some dairy farmers in Namibia obtain their cattle from the ECP, but as yet no information is available of the incidence of *R. microplus* in Namibia.

1.3 Cattle production in South Africa

Cattle production is the most important livestock subsector in South Africa as it plays a very important role in the economy of the provinces and the country at large. Its contribution ranges between 25-30% to the agricultural output per annum (Musemwa et al. 2008). Cattle production in South Africa can broadly be divided into two categories: large-scale commercial farming and small-holder farming in communal areas (Gilimani 2005). Communal farming is the production system where there is no formal farming sector, the land is communal owned, and the farmers do not follow the recommended animal husbandry practices. Communal farmers keep livestock for multiple purposes. Socio-cultural functions of cattle include their use as bride price, ceremonial gatherings such as marriage feasts, weddings, funerals and circumcisions (Chimonyo et al. 1999; Bayer et al. 2004).

The ECP of South Africa has about 3.1 million beef cattle, comprising nearly a quarter of the total cattle population in South Africa [National Department of Agriculture (NDA) 2008]. Of that, over 65% occur in communal areas (Eastern Cape Development Corporation (ECDC) 2003). The highest number of cattle are found in ECP (23%) followed by KZN (20%), FSP (16%). The remaining provinces contribute only 41% of the total cattle population in South Africa (NDA 2008). Animal farming in the communal areas of the ECP is concerned mainly with the production of cattle, goats and sheep. Cattle are, however, considerably more important in rural communities as the status of the farmer is often related to the number of cattle is owned. In the ECP, as in the rest of the country, ticks and tick-borne diseases are considered a major problem in cattle, but less so in goats and sheep farming (Masika et al. 1997).

1.4 Aims

The main aims and predictions of the study were:

1. To establish the effect of vegetation type (Albany Coastal Belt, Amathole Montane Grassland, Bhisho Thornveld and Great Fish Thicket) on the abundance, species richness and composition of ticks on cattle and on the vegetation in the ECP. It is predicted that tick species vary between the vegetation types and more ticks are found in Thornveld and

Thicket vegetation compared to other vegetation type.To determine if tick life history affects the abundance of individual tick species on cattle and on the vegetation in different vegetation types in the ECP.

2. To obtain baseline data on the perceptions of cattle farmers with regard to ticks, tick-borne diseases (TBDs) and the management practices being used on communal farms in the ECP.
3. To record the geographic distribution of an alien invasive tick, *R. microplus* and the closely related endemic species *R. decolaratus* in the environmentally less optimal south-western and north-western regions of South Africa and in Namibia. It is predicted will be prevalent in areas previously not found due to climate change and cattle movement within South Africa and between the two countries.

Chapter 2

Range expansion of the economically important Asiatic blue tick, *Rhipicephalus microplus* in South Africa

*In review *Journal of South African Veterinary Association*

2.1. Introduction

It is well established that ticks and tick-borne diseases (TBDs) significantly impact domestic animal health and the life-stock farming industry globally (De Castro 1997; Jonsson and Piper 2007; Busch et al. 2014). Within Africa it is estimated that animal losses, due to high tick infestations, and the control of TBDs, such as babesiosis and anaplasmosis, cost countries such as Kenya, Tanzania and Zimbabwe around US$ 5.1 million, US$ 6.8 million and US$ 5.4 million annually (McLeod and Kristjanson 1999). The estimated cost for South Africa is much higher and amounts to US$ 21.6 million per annum (McLeod and Kristjanson 1999). The latter is possibly related to the fact that South Africa has a larger commercial cattle farming industry, with >13 million animals compared to >5 million in Zimbabwe (National Department of Agriculture [NDA] 2013; The Food and Agricultural Organisation's Statistical Database [FAOSTAT] 2013). Moreover anaplasmosis is considered the most widespread TBD in South Africa with almost 99% of cattle at risk (De Waal 2000).

More than 80 species of ixodid ticks occur in South Africa (Walker 1991). Ixodid species that are of economic importance to cattle and live-stock farming on the continent belong to 3 genera:

Amblyomma, *Hyalomma* and *Rhipicephalus* (Walker et al. 2003; Jongejan and Uilenberg 2004; Mapholi et al. 2014). Species within these genera are vectors for anaplasmosis, babesiosis, cowdriosis and theileriosis (De Vos 1979; Walker 1991). Within the genus *Rhipicephalus* there are 3 species in particular, *R. appendiculatus*, *R. decoloratus* and *R. microplus*, that pose a threat to cattle health. *R. decoloratus* (the African blue tick) is endemic to Africa and transmits *Babesia bigemina*, the causative agent of babesiosis (African redwater) in cattle (De Vos et al. 2004). Whilst, *R. microplus* (the Asiatic blue tick), is an exotic invasive species, originally imported via Madagascar from Southern Asia to East and South Africa (Hoogstraal 1956; Tønnesen et al. 2004; Madder et al. 2011) but the route of introduction in West Africa was during the importation of cattle from Brazil (Madder et al. 2007; De Clercq et al. 2012). *Rhipicephalus microplus* acts as a vector for *B. bigemina* and *B. bovis*, the causative agents of African and Asiatic redwater respectively. Both ticks also transmit *Anaplasma marginale*, the causative agent of anaplasmosis (gallsickness) in cattle (Lynen et al. 2008). *Rhipicephalus microplus* is regarded as one of the most important cattle ticks worldwide and is responsible for extensive production losses (Piper et al. 2008). The third important species, *R. appendiculatus* and the diseases it transmits, fall outside the limits of this investigation.

Rhipicephalus microplus is considered to be a tick that by preference infests cattle and originally was a parasite of bovid species in India and Indonesia (Osterkamp et al. 1999; Labruna et al. 2009; Barré and Uilenberg 2010). It is hypothesized that the initial introduction of *R. microplus* onto the African continent took place in East and South Africa from Madagascar during the latter half of the nineteenth century on cattle imported after the rinderpest epidemic (Hoogstraal 1956; Madder et al. 2011). Its subsequent spread across southern and eastern Africa was more likely facilitated by its high degree of adaptability but in West Africa, the tick was mainly introduced by importation from cattle from Brazil with the exception of northern areas like Mali, Togo, Ivory Coast and Benin that might be as result of adaptations. However, coupled with the fact that it, together with *R. decoloratus* are one-host ticks (completing their entire parasitic life cycles on the same host individual over an un-interrupted period of 3 weeks) and the large scale movement of cattle within and between regions and countries. To date the affected countries include South Africa (Tønnesen et al. 2004), Namibia (Nyangiwe et al. 2013b), Swaziland (Weddernburn et al. 1999), Mozambique (Horak et al. 2009), Zimbabwe (Mason and Norval 1980), Zambia (Berkvens et al. 1998), Tanzania (Lynen et al. 2008), Ivory Coast and Benin (Madder et al. 2007; De Clercq et al. 2012), Burkina Faso, Mali and Togo (Adakal et al. 2013).

In the case of South Africa, Howard (1908) was responsible for the first record of *R. microplus* amongst ticks collected at King William's Town. Howell et al. (1978) plotted the distribution of ticks infesting domestic animals in South Africa and recorded *R. microplus* in isolated pockets along the southern coast of the Western Cape in the districts of Humansdorp, Knysna, George, Mossel Bay, Heidelberg, Swellendam and at a few inland localities. The environment associated with the coastal belt is favourable for the survival of large numbers of ticks as there is an abundance of grass, more stable temperature ranges and higher annual rainfall compared to inland regions (Horak et al. 2009; Marufu et al. 2011; Nyangiwe et al. 2011). As a consequence it was possible for *R. microplus* to extend its range along the southern and eastern coasts of the Western and Eastern Cape and of KwaZulu-Natal Provinces (Baker et al. 1989; Walker et al. 2003; Nyangiwe et al. 2013a). It has also successfully become established in the mesic savanna interior regions and is now widely distributed in the northern summer rainfall regions of South

Africa (Walker et al. 2003; Tønnesen et al. 2004**;** Spickett et al. 2011). Based on the current distribution data it is evident that the geographic range of *R. microplus* largely overlaps that of *R. decoloratus,* in the north and north-eastern regions of South Africa (Tønnesen et al. 2004; Horak et al. 2015). This pattern is supported by habitat suitability maps recently developed for both tick species by Spickett (2013) (Figure 2.1 and 2.2). However, recent studies suggest that *R. microplus* might be expanding its range further with isolated records (nine *R. microplus* were found on four cattle and a single larva from a drag-sample) in the more centrally located Free State Province (Horak et al. 2015). In addition, *R. microplus* was recorded, although limited to the north-eastern part, in the Northwest Province (Spicket et al. 2011). Furthermore, it seems that the tick is adapting to wildlife with several recent records on wild antelope (Tonetti et al. 2009; Horak et al. 2015).

In general current distribution maps for the different tick species in South Africa are in need of revision. This is mainly due to the fact that most of the locality data for ticks are either based on historic data (Walker et al. 2000; Spickett 2013) or biased towards a few tick and host species that are of economic importance (Horak et al. 2009; Marufu et al. 2011; Nyangiwe et al. 2013a; Horak et al. 2015). Further, there are several factors such as climate change (Tabachnick 2010; Léger et al. 2013), uncontrolled movement of domestic animals and wildlife (Mackenzie and Norval 1980; Bigalke 1994; Peter et al. 1998; Fayer 2000; Biello 2011), development of acaracide resistance (Mekonnen et al. 2002, 2003) and a recent expansion in host range (i.e. number and type of host species that are used by the tick) (Horak et al. 2015; Junker et al. 2015) that make it possible for ticks to survive and then become established in novel localities. More pertinent to the distribution of *R. microplus* is a possible sampling bias towards mesic grass regions because of the perception that the tick does not occur in more xeric regions and/or in predominantly shrub vegetation.

The present study was conducted in an attempt to address the paucity of information on the geographical distribution of blue ticks in the southern and north-western region of South Africa. Its aim was to gain insight into the current distribution of the exotic *R. microplus*, and of its endemic conspecific species *R. decolaratus* in the less well studied regions of South Africa.

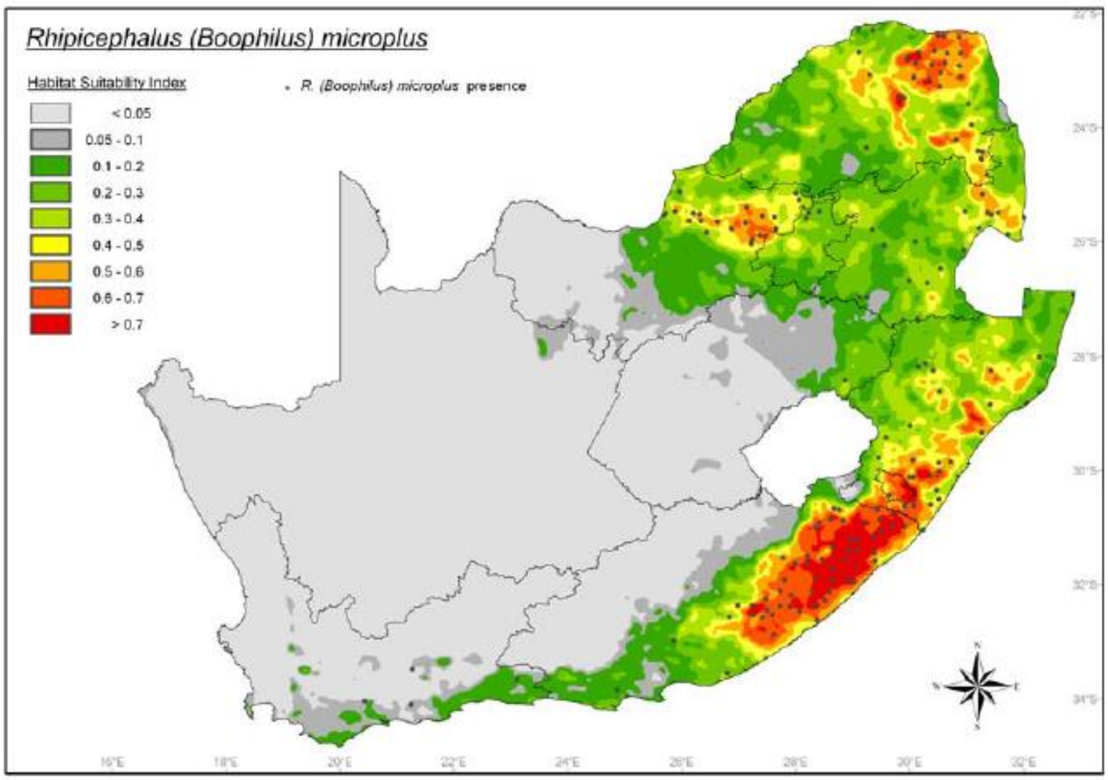

Figure 2.1 Habitability suitability model for *Rhipicephalus microplus* in South Africa. Black dots indicate localities where the tick was recorded (Adapted from Spickett 2013).

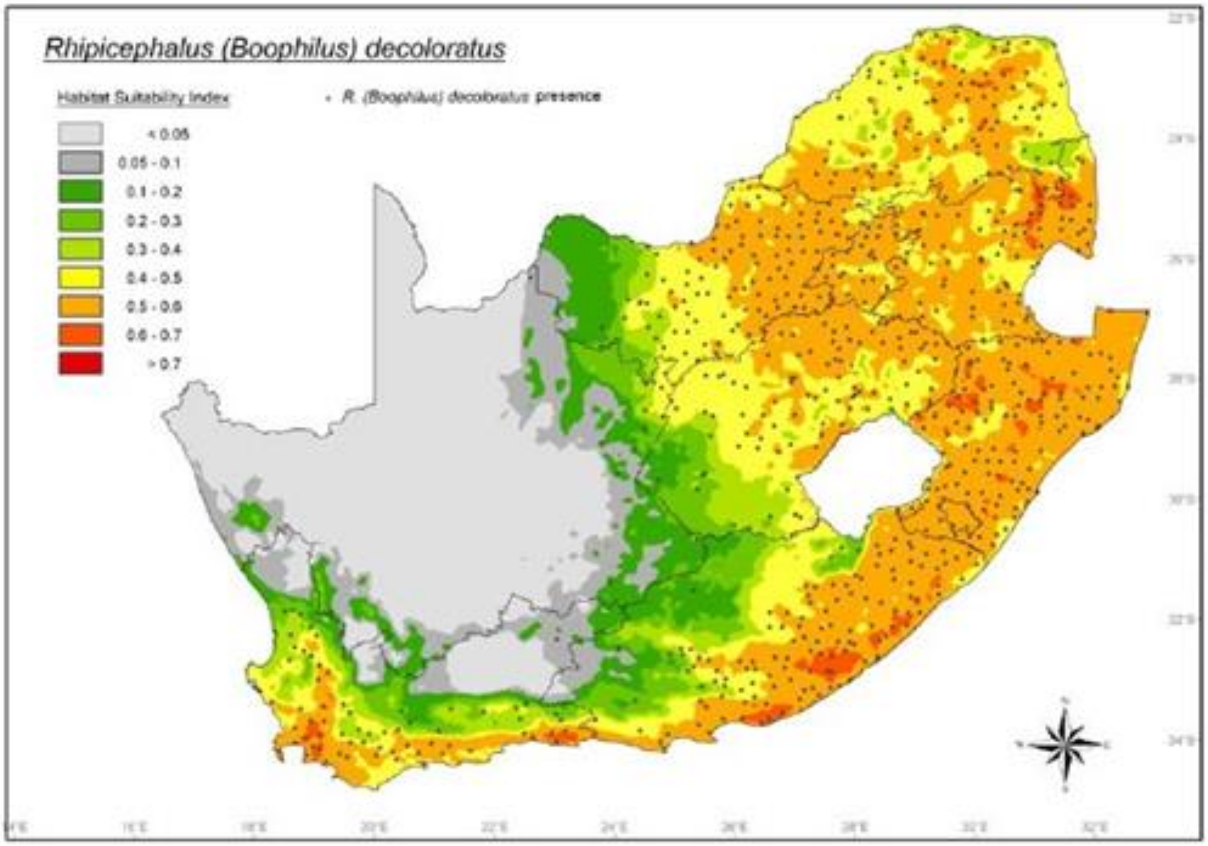

Figure 2.2 Habitability suitability model for *Rhipicephalus decoloratus* in South Africa. Black dots indicate localities where the tick was recorded (Adapted from Spickett 2013).

2.2 Materials and Methods

2.2.1 Data collection and study areas

Three methods were used to obtain ticks: 1) active tick removal from cattle (by NN and SM), 2) passive citizen-science approach where tick samples were provided by private cattle farmers solicited via social media (radio interviews, articles in newspaper and popular magazines), and 3) active sampling of ticks on vegetation using drag sampling (by NN). For the active sampling, a data sample sheet was used. The sheet included information on the project and contact details. Participation was voluntary, all personal information was held confidential and feedback was provided. Active cattle sampling was carried out between October 2013 till February 2014 in the Eastern Cape (ECP), while tick samples were provided by individual farmers from the Northern Cape (NCP) and Western Cape Provinces (WCP) between October 2013 – March 2015 (Figure 2.3). Ticks questing on the vegetation were collected by drag-sampling as described in detail by Nyangiwe et al. (2011). The geographic coordinates of each locality was recorded and used to plot the distribution of the two tick species in A QGIS v 2.6.1 (Quantum GIS Development Team 2015). The rainfall pattern for the three provinces ranges from winter rainfall to summer rainfall. The annual rainfall and summer and winter temperature ranges vary across the provinces, with the highest annual rainfall recorded for the WCP and the lowest for the NCP (Table 2.1).

Table 2.1 Mid-summer and mid-winter temperatures and annual rainfall of the 3 provinces surveyed in South Africa.

Province	Mid-summer temperatures (˚C)	Mid-winter temperatures (˚C)	Annual rainfall (mm)
Eastern Cape	15 – 25	7.5 - 17.5	125 - 1000
Northern Cape	16 – 40	7 – 26	50 - 400
Western Cape	16 – 26	7 – 18	500 - 1000

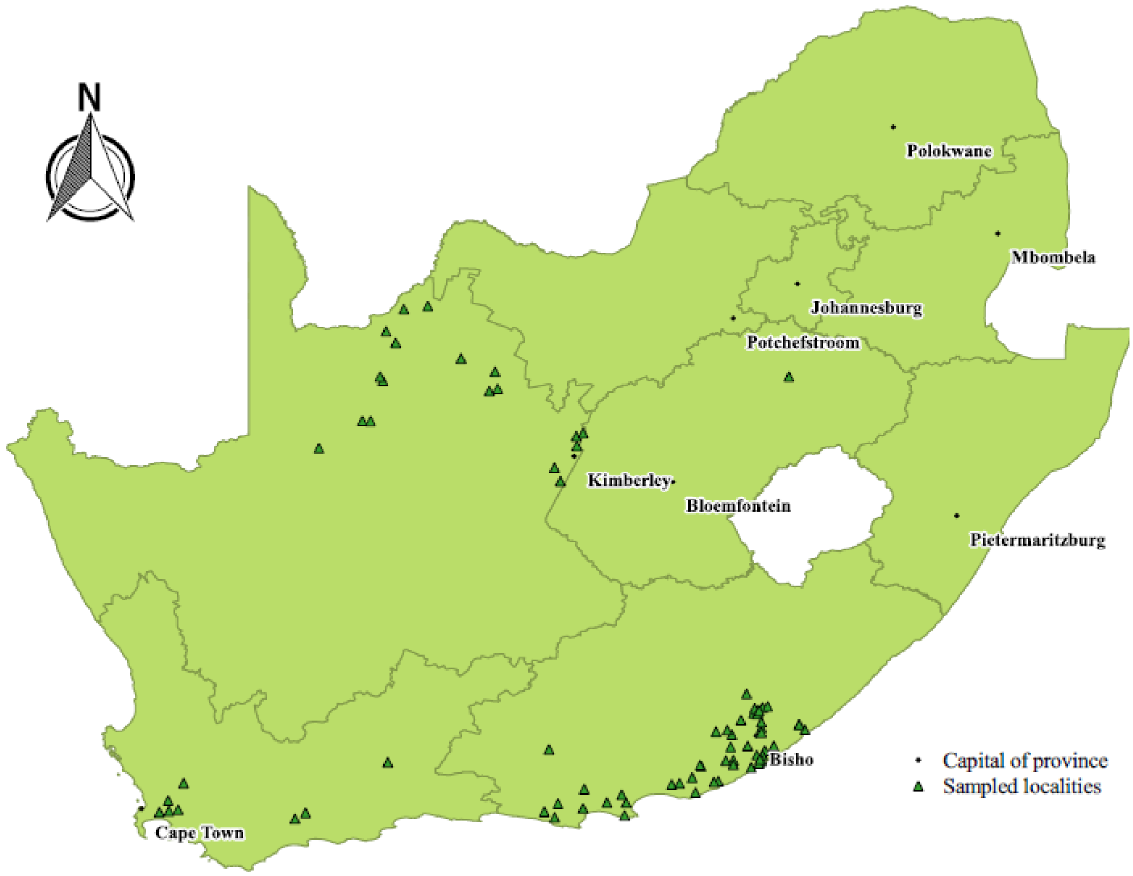

Figure 2.3 Sampling localities from where ticks were collected in the Eastern-, Northern- and Western Cape and Free State Provinces in South Africa, 2013-2015.

2.2.2 Tick collection and identification

At each locality, 3 to 6 cattle were examined for ticks. Attention was paid to the predilection sites of blue ticks and the ears, neck and dewlap, abdomen, feet, tail and peri-anal region of each animal was carefully examined (Baker and Ducasse 1967). During tick collection cattle were either restrained in a crush or in a dipping race (for the communal herds). As the survey was aimed at determining the geographic distribution of *R. microplus* and *R. decoloratus* and not their prevalence or intensity of infestation, none of the collections were intended to be complete.

The aim was to collect at least 20 adult ticks per animal, taking care to also collect the small-bodied male ticks as they are vital for an accurate identification (Figure 2.4).

Figure 2.4 Ventral (female) and dorsal (male) view of the larger female and small male *Rhipicephalus decoloratus* collected in the Eastern Cape Province, South Africa, 2013-2014.

The ticks from each animal were carefully detached from the skin using forceps and were preserved in a separate labeled sample bottle containing 70% ethanol. A single sample bottle was used for each animal and a pencil-written label containing information on date, farm, breed, sex and age of the host was inserted in each bottle. Apart from this, ticks from the vegetation were collected and the samples were identified as hybrids because they resemble neither *R. decoloratus*, nor *R. microplus* regarding the structure of their palps, their overall coloration and the structure of their scutum. All the ticks that were collected were identified to species level and counted using a Leica stereoscopic microscope (Leica Microsystems, Wetzlar, Germany) and the morphological diagnoses as described by Walker et al. (2003). Species identification was confirmed by an expert tick taxonomist, Professor Ivan Horak, at the Faculty of Veterinary Science, Pretoria University.

2.3. Results

A total of 8 408 adult ticks were collected from cattle from 80 localities in the WCP, ECP, NCP and FSP. Of these, 6 034 (71.8%) were identified as *R. microplus* and 2 374 (28.2%) as *R. decoloratus*. Overall, the two species were sympatric at 40 (50%) localities, with *R. microplus* present at more localities (80%) than *R. decoloratus* (58.8%) (Table 2.2). In addition, the abundance of *R. microplus* was higher than that of *R. decoloratus* at most localities where the two tick species were sympatric.

Between provinces, *R. microplus* occurred at more localities within the ECP and WCP than *R. decoloratus*, while its distribution was slightly more restricted than that of *R. decoloratus* in the NCP (Table 2.2, Figures 2.5 and 2.6). Moreover, in addition to *R. microplus* and *R. decoloratus* adults, larvae exhibiting characteristics of both species were collected from drag-samples of the vegetation in the ECP. In the ECP the abundance of *R. microplus* was higher than that of *R. decoloratus*, with hybrid larvae recorded at each of the 20 sampling localities (Table 2.3). No adult hybrids collected from cattle which might be due to fewer hybrid larvae being collected on vegetation, and the fact that adult collection was done half body to the animals might contribute.

Table 2.2 Occurrence data for *Rhipicephalus decoloratus* and *Rhipicephalus microplus* sampled from cattle in the Eastern-, Northern- and Western Cape and Free State Provinces in South Africa during 2013-2015.

Province	No. of localities sampled	No. of cattle examined	Total ticks collected	Localities positive for *R. decoloratus*	Localities positive for *R. microplus*	Localities where species co-occurred
Eastern Cape	53	318	8 101	33 (62.3%)	51 (96.2%)	32 (60.4%)
Northern Cape	18	64	72	10 (55.6%)	8 (44.4%)	5 (27.8%)
Western Cape	8	28	226	3 (37.5%)	4 (50%)	2 (25%)
Free State	1	5	9	1 (100%)	1 (100%)	1(100%)
Total	80	415	8 408	47 (58.8%)	64 (80%)	40 (50%)

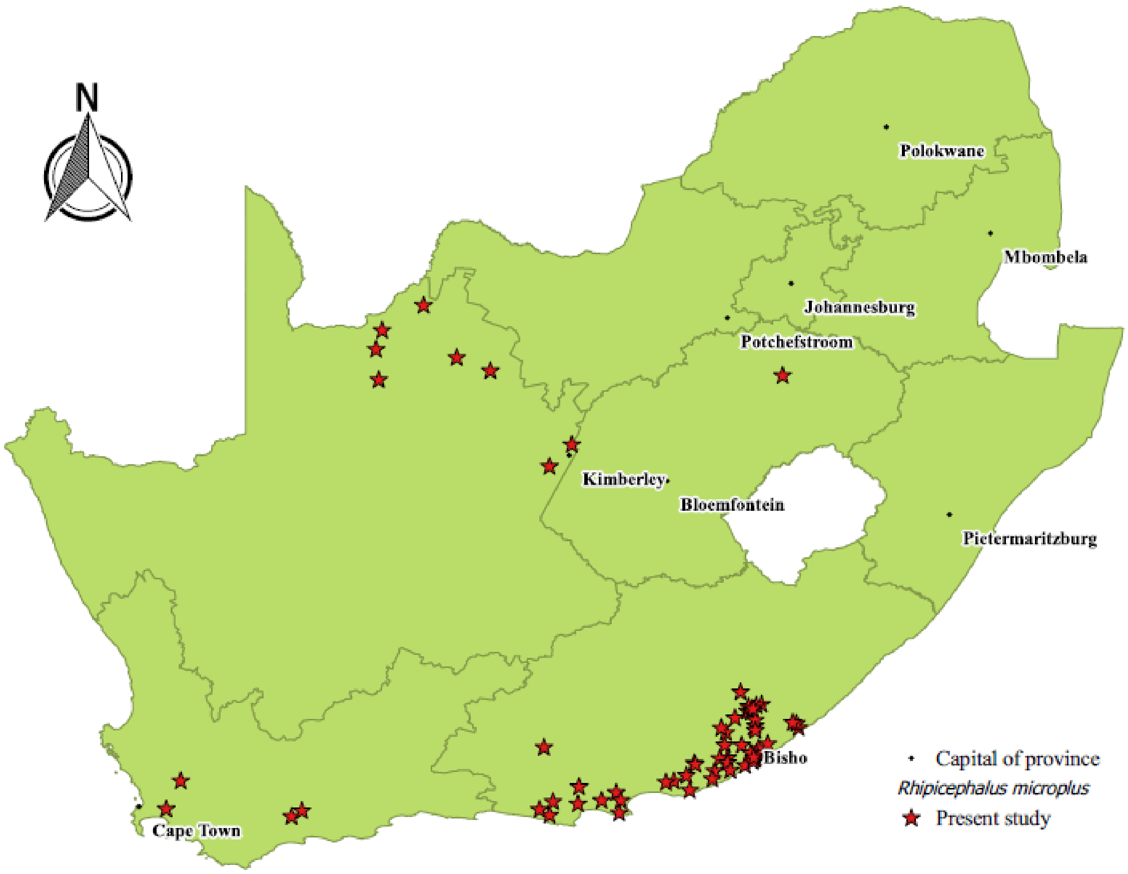

Figure 2.5 Localities positive for *Rhipicephalus microplus* in the Eastern-, Northern- and Western Cape and Free State Provinces in South Africa, 2013-2015.

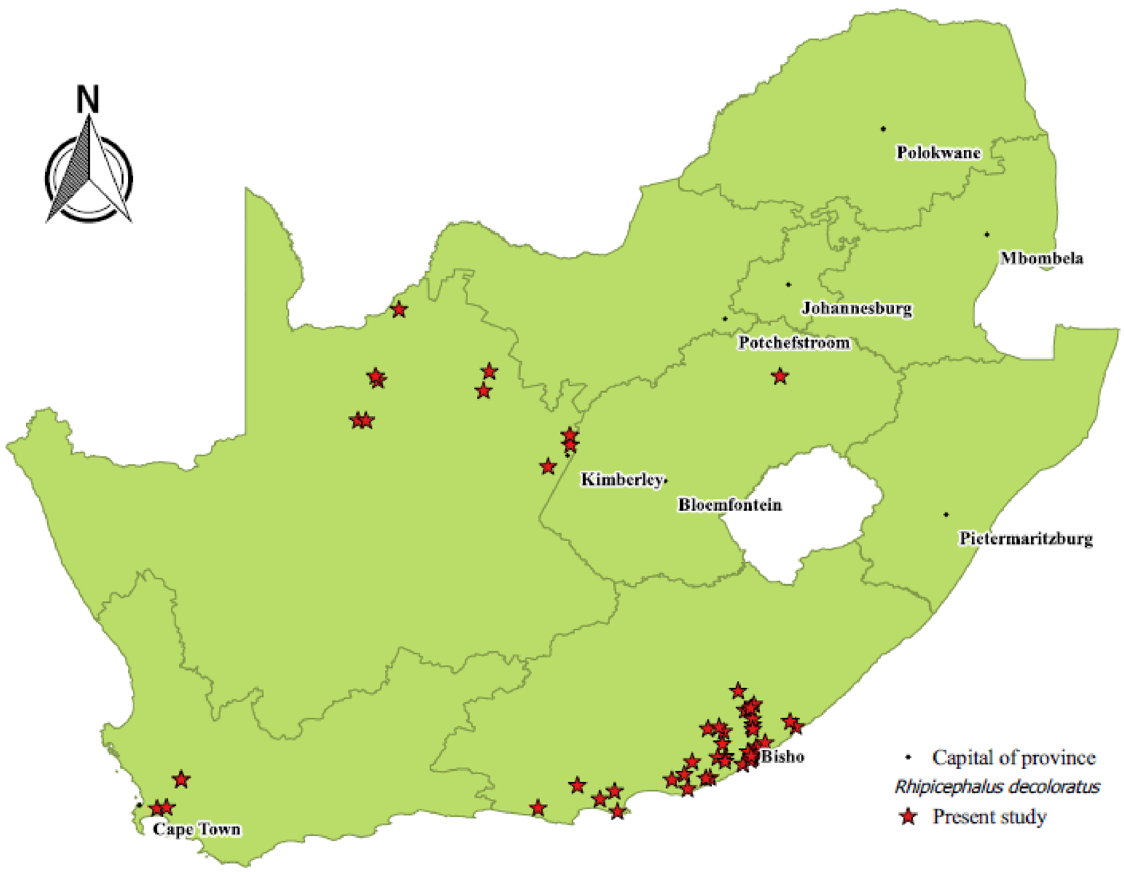

Figure 2.6 Localities positive for *Rhipicephalus decoloratus* in the Eastern-, Northern- and Western Cape and Free State Provinces in South Africa, 2013-2015.

Table 2.3 Total number of *Rhipicephalus decoloratus*, *Rhipicephalus microplus* and *R. decoloratus-R. microplus* hybrid larvae collected from vegetation at 20 communal areas in the Eastern Cape Province of South Africa.

Vegetation Type	Locality (Community)	*R. decoloratus*	*R. microplus*	Hybrids	Total
Albany Coastal Belt	Bhola	16	301	9	326
	Dowu	68	395	1	464
	Mazikhanye	17	346	18	381
	Pozi	23	192	3	218
	Tyhusha	62	268	6	336
Amathole Montane Grassland	Hekele	1	306	12	319
	KwaZidenge	6	609	28	643
	Mgwali	5	371	21	397
	Ndakana	15	479	7	501
	Toyise	14	712	12	738
Bhisho Thornveld	Dontsa	3	376	7	386
	Madubela	138	314	18	470
	Majali	79	277	6	362
	Lusasa	13	43	6	62
	Sotho	276	173	2	451

2.4. Discussion

Evident from the study is the fact that the alien invasive tick *R. microplus* has further expanded its geographic range in South Africa. It would seem that *R. microplus* has developed the ability to survive at localities with a lower percentage of grass cover and a winter rainfall regime.

Both *R. microplus* and *R. decoloratus* are one-host ticks that parasitize domestic herbivores and are a threat to cattle farming in tropical and subtropical countries. *R. microplus* is renowned for its invasive character and is responsible for much heavier losses in the cattle industry than the native *R. decoloratus* (Lynen et al. 2008). A number of recent studies have documented the encroachment of *R. microplus* in various regions of the country (Tønnesen et al. 2004; Horak et al. 2009; Nyangiwe et al. 2013a). Until lately it was presumed to be largely absent from the western part of the ECP and WCP, most of the FSP and the NCP as a whole. However, Nyangiwe et al. (2013a) recorded *R. microplus* for the first time on cattle and vegetation at four localities in the communal grazing areas in the western part of the ECP. The authors surmised that this may be a recent introduction as several previous studies in the same region (west of East London) did not detect the presence of the tick (Rechav 1982; Mekonen et al. 2002, 2003). The present study reports the wide spread occurrence of *R. microplus* on cattle and on vegetation (51 and 20 localities, respectively) along the coastal belt and at multiple inland localities west of East London. East London and Bisho are positioned on the boundary between two vegetation biomes: Savanna to the east and Albany Thicket to the west (Mucina and Rutherford 2006). The vegetation within the broader Albany Thicket biome is dominated by shrubs and succulents, though several C3 and C4 grass species are also present (Mucina and Rutherford 2006). Grass cover increases at higher elevations (>450m) (Mucina and Rutherford 2006), and this may explain the presence of both blue tick species at these localities. Although the vegetation in the

Albany thicket biome differs from the Savanna biome in terms of plant diversity, it appears to provide equally good forage for cattle as the region includes several communal cattle farming areas and large numbers of cattle. Additional support for the finding that *R. microplus* has become established in the Albany thicket biome is the fact that in the present study it was more prevalent than *R. decoloratus* (51 and 33 localities positive, respectively).

Although the sample sizes are not representative of total tick counts per animal, they do give some indication of relative abundances as a standardised sample collection design was followed and the ticks were collected by the same researcher (NN) in the ECP. This pattern of prevalence is also supported by previous studies on cattle in the ECP (Horak et al. 2009) and other provinces (Spickett et al. 2011; Horak et al. 2015). It seems that *R. microplus* is outcompeting and even displacing the endemic *R. decoloratus* when present in sympatry (Horak et al. 2009; Nyangiwe et al. 2013a). Possible factors that may facilitate displacement are that *R. microplus* seems to have developed resistance to the currently widely used acaricide in the ECP, Amitraz, while *R. decoloratus* is still susceptible (Ntondini et al. 2008). In addition, several studies have noted that male *R. microplus* attach to and possibly mate with female *R. decoloratus* (Londt and Arthur 1975; Tønnesen et al. 2004). Indeed, Nyangiwe et al. (2013a) recorded 17 such couplings on cattle and also reported hybrid larvae (*R. microplus*-*R. decoloratus*) on the vegetation at two communal areas in the ECP. The present study confirms the existence of hybrid larvae and provides additional locality records for the presence of these larvae in the western part of the ECP. Other factors that may also play a role is a shorter life cycle of male *R. microplus* compared to *R. decoloratus* males, thus increasing the chances of cross-matings (Horak et al.

2009) and the persistence *R. microplus* larvae, compared to the absence of *R. decoloratus* larvae, on the vegetation during winter (Nyangiwe et al. 2011, 2013a).

In the present study, *R. microplus* was recorded at eight and *R. decoloratus* at ten of the 18 localities in the north-eastern part of the NCP (Figures 5 and 6). This is the first record of *R. microplus* in the NCP. It would seem that *R. microplus* is a recent introduction into the semi-arid region of the NCP and at present there is no indication of *R. decoloratus* displacement there. Similar observations were made for *R. microplus* when it was recently recorded for the first time in Namibia (Nyangiwe et al. 2013b). It is possible that *R. microplus* spread to the NCP via the movement of infested cattle from the neighbouring North-West Province (Spickett et al. 2011). The latter study used a systematic monthly sampling approach across the North-West Province with tick collections focussing on cattle, goats and sheep. Sampling commenced in 2001 in the north-eastern part of the province and was concluded in the western region of the province. The authors recorded the widespread distribution of *R. decoloratus* across the province compared to a limited eastern distribution for *R. microplus* (Spickett et al. 2011). The vegetation types (Central Bushveld) within the savanna biome (Winterbach et al. 2000) of the western region of the North-West Province and the eastern part of the NCP are very similar. The climatic conditions are also comparable; with predominantly summer rainfall in both regions. The mean annual rainfall in North-West Province is 360 mm and the mean annual temperature ranges between 5˚C and 22˚C, while the mean annual rainfall in the NCP is 202 mm and the mean annual temperature ranges between 7˚C and 26˚C. Based on these parameters, it is predicted that with the continuous movement of cattle, *R. microplus* will overtime become established in the savanna region of the NCP.

In South Africa, *R. microplus* is established along the coastline of KwaZulu-Natal, the ECP and eastern part of the WCP (Walker et al. 2003). The indigenous vegetation in the interior regions of the WCP is mainly shrub-like fynbos and contains little grass (Mucina and Rutherford 2006). Consequently, cattle farmers have to supplement this requirement via irrigated pastures. In the present study the eight sampling localities, in the WCP, were situated to the west of Swellendam (one of the first positive localities for *R. microplus* in South Africa). *Rhipicephalus microplus* recorded at four of the localities. In all cases where *R. microplus* and *R. decoloratus* were recorded in the WCP, the cattle were kept on irrigated pastures and not on natural fynbos vegetation. This confirms earlier reports that the two blue tick species are dependent on grass and it also suggests that *R. microplus* might have a more patchy distribution across the shrub dominated WCP when compared to provinces that have predominantly savanna and grassland biomes (Walker et al. 2003; Howell et al. 1978). The presence of *R. microplus* in the WCP may again be due to the movement of cattle across the country and within the province. The locality at which *R. microplus* was recovered in the Wellington area is a cattle breeding stud and animals are regularly transported between Wellington and the northern summer rainfall regions of South Africa. It is thus possible that the cattle became infested with *R. microplus* ticks during one of the visits to the summer-rainfall regions and the ticks subsequently returned with the cattle to the respective farm. Another farmer, in the Cape Flats/Kuilsriver area, reported that he purchased animals from the ECP and subsequently recorded calf deaths, which were confirmed as due to *B. bovis* infection. A third farmer, in the Stellenbosch area, recently recorded cattle deaths, which were also confirmed to be due to *B. bovis* infection. The latter farmer regularly sources cattle from local farms and as such must have acquired the tick through cattle movement within the province.

The present study presents the fourth record of *R. microplus* with three female and three male *R. microplus* ticks recovered from cattle in the FSP. Previous studies recorded low numbers of *R. microplus* in the north-eastern and north-western regions of the Province. In the north-eastern region ticks were present on cattle and on vegetation (Spickett 2013; Horak et al. 2015). However, in the north-west the tick was also recorded on three gemsbok at the Sandveld Nature Reserve (Tonetti et al. 2009).

Among other factors, changes in the distribution of ticks, including that of *R. microplus*, are often related to climate change because of their dependence on both the host and the off-host environment for their survival (Léger et al. 2013). These expansions in distribution have not only been reported in African ticks of the genus *Rhipicephalus* (Lynen et al. 2008; Madder et al. 2007; Olwoch et al. 2007) but also in members of the genus *Amblyomma* (Estrada-Peña et al. 2008). Climate change effects may not always result in ticks expanding their distributional range, and extinction is also possible where temperature and humidity become unfavourable (Cumming and Van Vuuren 2006; Estrada-Peña and Venzal 2006). However, global increases in the movement of humans and domestic animals have, and will, facilitate introductions of non-native host and tick species into foreign territories. The introduction of *R. microplus* to South Africa is such example (Barré and Uilenberg 2010; Pisanu et al. 2010).

Chapter 3

First record of the pantropical blue tick *Rhipicephalus microplus* in Namibia

** Published in Experimental and Applied Acarology 2013, 61:503–507*

3.1. Introduction

Livestock farming is one of the primary contributors to the agricultural sector and the main source of rural livelihood in Namibia (Lange et al. 1997). Currently approximately 75 % of the country's total land area is allocated to livestock farming, with more than 40 % used for commercial cattle farming (Lange et al. 1997). Data from the Namibian Livestock Sector Strategy, Final report (published in December 2011) indicates that for the year 2010/2011 the estimated contribution of the producer value in terms of slaughtering for export or for local consumption and live exports was approximately 2 billion Namibian dollar (N$). Export to neighbouring countries (South Africa and Angola) and Europe contributes significantly to the income generated from cattle production (Namibia Meat Board Chronicle 2013).

Tick records for Namibia date back to the 1890s with subsequent studies expanding on the species lists. Howard (1908) records five ixodid species from Namibia, amongst them *Rhipicephalus decoloratus*, which at the time he referred to as *Margaropus annulatus var. decoloratus*. In his synoptic check-list and host-list of the ectoparasites found on South African Mammalia, Aves, and Reptilia, Bedford (1932) recognizes eight ixodid tick species present in Namibia, while 30 years later this number had increased to 28 species (Theiler 1962). In 2000 five more *Rhipicepalus* species were added to Theiler's list (Walker et al. 2000). With the data at hand it is clear that a diverse assemblage of tick species, including several species of *Rhipicephalus*, exist in the region. From the foregoing it is also evident that comprehensive sampling may indeed reveal higher species richness for the region.

Theiler (1949) plotted the distribution of the regionally common *R. decoloratus*, which she then referred to as *Boophilus* (*Palpoboophilus*) *decoloratus*, in South Africa. In addition, she also listed the localities at which it had been collected in Namibia. Similarly in her treatise on the ticks of vertebrates in Africa South of the Sahara Theiler (1962) lists the localities at which the 28 species she records for Namibia were collected. However, besides Theiler's records and the maps published by Walker et al. (2000) on the distributions of the various *Rhipicephalus* species of the world, in which Namibia was included, little is known about the distribution of tick species in the country.

The invasive success of *Rhipicephalus microplus* has contributed to its widespread distribution with records that include countries in Latin America and also Mexico, Australia and Madagascar (Estrada-Peña et al. 2006). On the African continent *R. microplus* is common along the eastern coastal belt and also in the summer rainfall northern regions of South Africa (Howell et al. 1978; T¢nnesen et al. 2004; Horak et al. 2009; Spickett et al. 2011). It is also present in Swaziland, Mozambique, Zimbabwe and Zambia (Mason and Norval 1980; Berkvens et al. 1998; Wedderburn et al. 1999; Horak et al. 2009). Furthermore, it has recently been reported in the Ivory Coast, Benin and also as mentioned earlier in Burkina Faso, Togo and Mali in West Africa (Madder et al. 2007, 2012).

The distribution of *R. microplus* in Africa seems to be related, amongst other factors, to warm summers and high annual rainfall, it can, however, survive during long dry periods in winter (Estrada- Peña et al. 2006; Nyangiwe et al. 2011). These broad climatic requirements together with the trade in live cattle and goats may facilitate its introduction and establishment in previously uninfested countries. The current investigation was initiated with the aim of detecting the presence of *R. microplus* in Namibia.

3.2 Materials and Methods

3.2.1 Study area

Permits were obtained from the Namibian Ministry of Environment and Tourism (ref no. 1791/2013) and from the Department of Agriculture, Forestry and Fisheries in South Africa (Veterinary import permit ref no. 13/1/1/30/2/10/6-474). Sampling took place towards the end of summer (25 March–6 April 2013). Participating farms were identified through various veterinary practices and by word of mouth. Eighteen commercial livestock farms representing the south-central, central and north-central region of the country took part in the study. The survey cattle comprised several breeds, including Bonsmara, Brahman, Hereford, Nguni and various cross breeds. Mainly adult animals were included in the study.

3.2.2 Tick collection and identification

Ticks were collected from three to five animals per farm. The entire body was examined with special attention paid to the lower perineum and dewlap. The aim was to collect at least ten adult male ticks from each animal. The ticks were placed in pre-labeled tubes filled with 100%

ethanol. The label included the reference code for the animal and for the farm. Geographic co-ordinates, breed, animal age, sex and herd history were recorded separately. Using a stereoscopic microscope, all adult ticks were initially identified to species level at Stellenbosch University, South Africa. Thereafter, all specimens of *R. microplus* were sent to the Faculty of Veterinary Science, University of Pretoria, South Africa for confirmation.

3.3 Results

3.3.1 Tick collection

In total 142 adult *R. microplus* were collected from 20 cattle on four farms, whereas *R. decoloratus* was present on all 18 of the survey farms (Table 3.1). Although not sampled quantitatively, it would seem that few *R. microplus* were present on two of the farms, with larger numbers of ticks collected from cattle on the other two (Table 3.1).

Table 3.1 Collection dates, cattle breeds and tick data for four farms in Namibia in 2013.

	Geo-reference					*R. microplus*		*R. decoloratus*	
no	Latitude	Longitude	Date of collection	Breed	Sex	male	female	male	female
1	S20°58’32.4”	E17°30’52.6”	28/03/2013	Hereford	F	18	14	11	32
2	S21°01’13.5”	E16°04’10.1”	02/04/2013	Bonsmara	F	5	4	7	10
3	S20°56’23.5”	E16°19’43.4”	02/04/2013	Bonsmara	M	6	7	24	65
4	S22°22’12.3”	E19°25’51.2”	04/04/2013	Mixed	F	42	31	14	54

3.4 Discussion

The recorded distribution of *R. microplus* in southern Africa includes South Africa, Swaziland, Zimbabwe and southern Mozambique (Mason and Norval 1980; Howell et al. 1978; Wedderburn et al. 1999; Horak et al. 2009). It is also present in Zambia and Madagascar (Berkvens et al. 1998; Estrada-Peña et al. 2006). However, its presence has as yet not been reported in Lesotho, Botswana, Namibia and Angola.

Rhipicephalus microplus was most probably introduced into Namibia from South Africa. The four farmers from whose cattle it was collected all mentioned that they had previously brought in cattle from South Africa or had bought cattle in Namibia that had a South African history. There has been a ban on the import of cloven-hoofed animals from South Africa since November 2010, due to an outbreak of foot-and-mouth disease in that country. The introductions must therefore have taken place prior to this date. The owners of the first three farms listed in Table 1 mentioned that they had bought bulls in South Africa during 2005 and 2007. The fourth farm is a dairy farm on which mortalities, confirmed as due to redwater, had occurred during June 2012. Approximately a month prior to the mortalities the farmer had purchased cattle from a neighbouring dairy farm. According to the farmer, these animals had been bought in North-West Province, South Africa, in 2005. In a survey on the distribution of ticks in this province, conducted over a number of years, commencing in 2001, Spickett et al. (2011) recorded *R. microplus* at 14 localities, thus supporting the possibility of its introduction into Namibia from here.

The co-occurrence of *R. decoloratus* at all four positive localities suggests that *R. microplus* might not completely displace the endemic African blue tick in Namibia. It is currently unclear as to how

R. microplus displaces *R. decoloratus* as some localities, as reported in Zambia (Berkvens et al. 1998), Swaziland (Wedderburn et al. 1999), southern Mozambique (Horak et al. 2009) as well as at certain localities in South Africa (T¢nnesen et al. 2004; Nyangiwe and Horak 2007), while this is not the case at other localities, even within the same country. For instance, although *R. microplus* was the dominant species, both ticks remained present on cattle and the vegetation during a 5 year study on an experimental farm in the Stutterheim district in the Eastern Cape Province of South Africa (Nyangiwe et al. 2011).

Chapter 4

The effect of vegetation type on tick abundance, species richness and species composition on cattle and the vegetation in communal areas of the Eastern Cape, South Africa

4.1. Introduction

Ticks transmit multiple pathogenic organisms and affect domestic animals and humans around the world (Jongejan and Uilenberg 2004; Estrada-Peña and de la Fuente 2014). Globally, ticks affect the production of approximately 1 billion cattle and can cause skin damage, tick worry, reduced growth, milk production and mortalities (Pegram et al. 1993; Estrada-Peña 2001; Estrada-Peña et al. 2006). To date, approximately 900 tick species have been described of which more than 700 belong to the family Ixodidae (hard ticks) (Jongejan and Uilenberg 2004; Guglielmone et al. 2010). Hard ticks vary in host association (i.e. time spent on the host) and are classified as one-, two- or three-host ticks. The classification is based on the number of hosts required to complete the life cycle and this influences the proportion of time spent in the external environment. For example, a one-host tick will attach once to a host and remain on the hosts for the duration of the larval, nymph and adult stage and thus spend relatively less time in the external environment compared to a three-host tick that has to attach to three hosts (can be the same or different hosts) and spend time in the environment between each attachment. Most ixodid ticks are two- or three-host ticks (Walker et al. 2003) and therefore spend a larger part of their life cycle in the external environment.

Ticks have a dual environment and are dependent on the host and environment for their survival. Host related factors that affect ticks include density, vagility, breed and age, while environmental factors mainly include climate and vegetation structure (Mtshali et al. 2004). Animals that graze together in larger herds may result in more ticks in the environment and on the animals due to density dependent transmission (Pfàffle et al. 2013). According to Walk et al. (2009), pathogens were more prevalent in areas of high tick density, suggesting a correlation between tick establishment and pathogen endemicity. Hosts with higher vagility will more often come into contact with free-living tick stages and thus one would expect higher tick abundances and species richness on hosts that roam more widely compared to hosts that are more restricted in movement (Oliver 1974;Weiss 2008; Barre and Uilenberg 2010). With regard to cattle, the type of breed has a major effect on the level of tick infestation, for example studies done in South Africa recorded that exotic breeds (e.g. Herefords) are more susceptible to tick infestations than local breeds (Nguni) (Spickett et al. 1989). Tick infestations also vary with host age and calves normally have lower tick burdens than adult animals (Barnett and Bailey 1955; Sutherst et al. 1979; Wikel and Bergman 1997; Okello-Onen et al. 1999), mainly due to age-related non-specific immunity (innate). During the first two months of life, calves are usually protected by passive transfer of immunity from their resistant dams but after two months of age calves have a natural resistance to tick-related diseases which lasts for 6 to 9 months, irrespective of the immune status of their dams (Bock et al. 2004; De Vos et al. 2004). Apart from this, a higher tick abundace in adult cattle as compared to calves may be due to difference in management with adult animals often grazing and search for water over longer distance than the calves, and hence the chance of exposure to ticks is much higher (Pawlos and Derese 2013). In the off-host environment tick survival and rate of development are dependent on the microclimate (Norval 1977; Randolph 2004; Merler et al. 1996; Schwarz et al. 2009). Saturation deficit and temperature are the foremost factors controlling the main aspects of the life-cycle of ticks (Randolph and Storey 1999; Estrada-Peña 2001). Unfed ticks (generally found in the environment) require a relative humidity above 80% to survive, while anything less can have a detrimental effect on their survival (Greenfield 2011). Temperature regulates the development rate of free-living environmental stages and these stages are prone to desiccation at temperatures above 30˚C (Obsomer et al. 2013). Interstadial development, such as pre-oviposition, pre-eclosion and premoult periods, depends on the ambient temperatures, with very low and very high temperatures and high saturation deficit preventing successful hatching and development by increasing mortality (Ogden et al. 2004; Petney et al. 2011). In particular, temperature affects the questing potential of larval stages and affects the growth period (moulting of larvae and nymphs) on the vegetation (Gray 1982; Alonso-Carné et al. 2015).

Microclimatic conditions vary between vegetation types mainly due to difference in the vegetation structure (percentage cover and plant growth forms). As such tick abundances and species composition can vary between vegetation types. Studies in Europe have shown that the abundance of *Ixodes ricinus* was higher in forests compared to open habitats due to cooler and more humid microclimate provided to ticks. Host species also benefited from resources (food and shelter) offered in forests (Lindström and Jaenson 2003; Ruiz-Fons and Gilbert 2010; Walker et al. 2001). In Belgium, it was found that vegetation type (pine vs oak trees) influenced the abundance and distribution of free-living *I. ricinus* (nymphs and adults) (Tack et al. 2012). Their results were consistent with other studies where higher tick abundance was observed in oak compared to pine stands (Estrada-Peña 2001; Lindström and Jaenson 2003). Higher tick abunadnces in oak is most likely related to more optimal environmental conditions and a higher density and activity of the tick's main hosts.

Research on the effect of vegetation type on tick infestations are limited in Africa. In the Republic of Guinea, 14 villages were chosen in order to include different ecological zones such as gallery forest, wooded savanna and bushy savanna (Tomassone et al. 2004). Tick abundance was higher in wooded savanna compared to other vegetation type and it was surmised that open grassland that is associated with wooded savanna facilitates the survival of free-living ticks. In Burundi, species composition and abundance of ticks recorded on Ankole cattle varied in five zones that differed in altitude and rainfall (Kaiser et al. 1988). Similarly Bazarusanga et al. (2007) recorded variable abundances of ticks on cattle from four major vegetation types that varied in altitude and climate in Rwanda. In southern Africa Short et al. (1989) recorded that grass length affected tick fecundity with reduced fecundity recorded in long grass during the cool season and also in short grass during the warm season in Zimbabwe. More specifically in South Africa studies have recorded higher tick numbers on cattle grazing on Eastern Province Thornveld (predominantly grasses, small trees and tall shrubs) than those grazing on Döhne Sourveld (predominantly short grasses) in the Eastern Cape Province (ECP). In addition, higher tick loads were observed on cattle grazing on sour rangeland compared to sweet rangeland in communal areas in the ECP (Marufu et al. 2010). This pattern was supported by the fact that cattle reared on sweet rangeland recorded lower seroprevalence of *Babesia bovis* and *Babesia* *bigemina* compared to cattle on sour rangeland in the ECP (Marufu et al. 2011). Though the studies in South Africa allude to vegetation-related differences they are mostly limited to abundance data of adult ticks on cattle. It is as yet uncertain how vegetation type will affect the level of infestation and species composition of ticks on cattle and on the vegetation. Also, given the variation in time spend in the environment it is predicted that species-specific responses will be recorded with the strongest response, to vegetation type differences, associated with tick species that spend more time in the external environment (e.g. on vegetation).

In this study, we investigate the effect of vegetation type on tick infestations on cattle and on vegetation in 20 communal areas in the ECP. The ECP is one of nine provinces in South Africa and is situated south-east in the country with the Indian Ocean as an eastern border. Vegetation in the province comprises several biomes with Albany thicket characteristic for the province (Mucina and Rutherford 2006). The distribution of the biomes within the province differs in altitude with Albany thicket located along the coast line, while higher inland areas are dominated by Grassland and Savanna biomes. The complexity of the ECP vegetation is emphasized by the presence of various vegetation types within each of the biomes with plant growth forms ranging from open tree layers dominated by grass, shrubs and small trees to a more closed system of shrubs and succulents (Mucina and Rutherford 2006). Cattle farming and especially communal cattle farming is one of the major agricultural activities in the province (Mapiye et al. 2009). There are several tick species that are commonly recorded on cattle in the ECP of which *Amblyomma hebraeum* (three-host tick), *R. appendiculatus* (three-host tick), *R. decoloratus* (one-host tick), *R. evertsi evertsi* (two-host tick) and *R. microplus* (one-host tick) are the most abundant and wide spread (Horak et al. 2009; Nyangiwe et al. 2013a). The aims of the study were to: 1) establish the effect of vegetation type on the abundance, species richness and composition of ticks on cattle and on the vegetation, 2) determine if life history affects the abundance of individual tick species on cattle and on the vegetation in different vegetation types.

4.2 Materials and Methods

4.2.1 Study area

The study was conducted in the Amathole District Municipality (a 168 966 km^2 land area) in the ECP between October 2012 and February 2013. The province is predominantly rural with approximately 3.2 million cattle found in the Amathole District Municipality alone. Topographical and climate differences enable the distinction of three biomes. The vegetation of the Albany Thicket biome comprises of dense, woody, semi-succulent and thorny vegetation with an average height of 2-3 m (Acocks 1953; Everard 1987; Mucina and Rutherford 2006). The Grassland biome consists of herbaceous vegetation with a relatively short and simple structure that is dominated by graminoids, from the Poaceae family. Woody plants are rare (usually low or medium-sized shrubs) or absent. In the Savanna biome, there is a herbaceous layer usually dominated by grass species and has open tree layer. Savanna grasslands may grade into tree savanna, shrub, savanna, savanna woodland or savanna parkland (Scholes and Archer 1997). It has moderately dense woodland dominated by *Acacia* spp. In the Amathole District Municipality there are four major vegetation types based on the descriptions of Mucina and Rutherford (2006) (Fig 4.1 and Table 4.1). These are Albany Coastal Belt (in the Albany Thicket biome), Amathole Montane Grassland (Grassland biome), Bhisho Thornveld (Savanna biome) and Great Fish Thicket (Albany Thicket biome). With the exception of Amathole

Montane Grassland, which generally only has a herbaceous layer, all other vegetation types have herbaceous and woody layers.

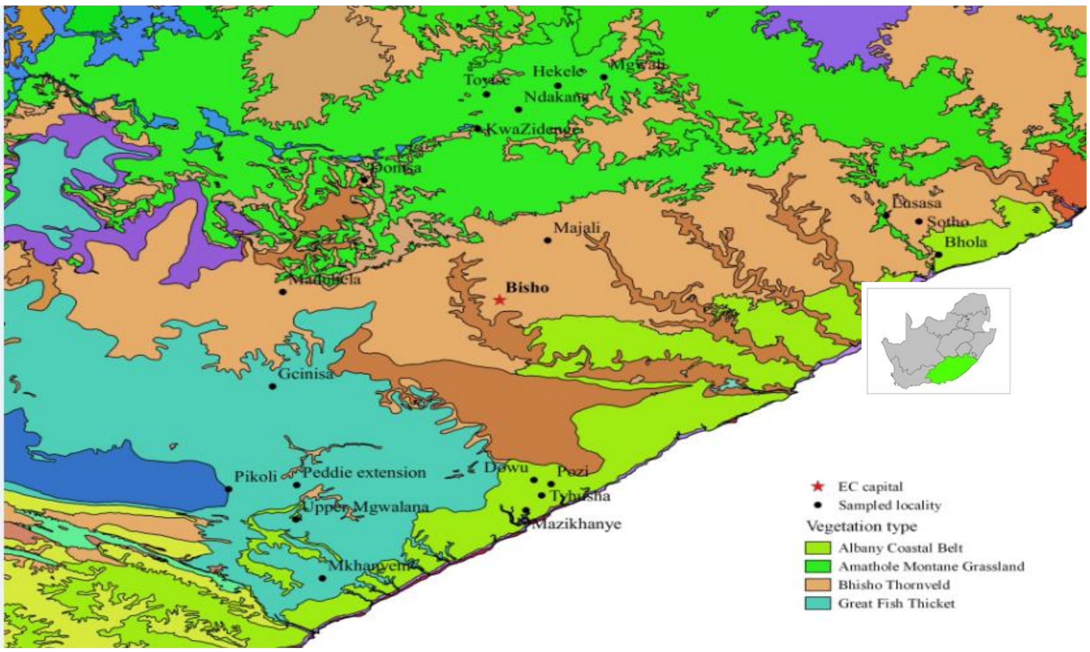

Figure 4.1 Map showing vegetation types and localities (n=20) where ticks were collected from cattle and the vegetation in the Amathole District Municipality, Eastern Cape Province.

In each of the four vegetation types, five communal farming communities were randomly selected and surveyed (Table 4.2). In each case, cattle constitute the main livestock and animals graze on natural vegetation. Each locality was only visited once during the study. The average number of cattle per vegetation type (based on counts from the five communal farming communities in each) varied: Thicket (1090±550.99), Grassland (977.2±567.63), Coastal Belt (920.2±279.86) and Thornveld (813.8±495.94).

Table 4.1 Altitude, temperature and annual rainfall of the four vegetation types in the Eastern Cape Province

Vegetation types	Altitude (m)	Temperature (˚C)	Annual rainfall (mm)
Coastal Belt	10 – 400	5 – 32	450 – 900
Grassland	650 – 1500	3 – 26	500 – 740
Thornveld	200 – 700	9 – 28	500 – 900
Thicket	0 – 1000	9 – 30	300 – 600

Coastal Belt= Albany Coastal Belt; Grassland= Amathole Montane Grassland; Thornveld= Bhisho Thornveld; Thicket= Great Fish Thicket

4.2.2 Study animals

At each locality, 25 adult animals (>24 months) and 25 calves (6 – 24 months) were randomly selected and examined for ticks. In total, 1000 cattle were surveyed during the study period. All animals were kept under extensive management system. Prior arrangements were made with the district veterinary authorities and community members through the headmen or chiefs in a particular area so that tick collections may coincide with livestock inspections or dipping days.

Table 4.2 Locality data showing vegetation type, village name, GPS coordinates, cattle numbers, human population size and grazing area of the four vegetation types in the Eastern Cape Province

Vegetation type	Village	GPS coordinates		Total number of cattle	Human population	Total size of area used for grazing (ha)
		Latitude	Longitude			
Coastal Belt	Bhola	32˚45´,40.7"S	28˚ 09´,22.3"E	504	237	370
	Dowu	33˚11´,53.0"S	27˚ 29´,38.5"E	1240	564	366
	Mazikhanye	33˚15´,25.3"S	27˚ 28´,51.5"E	808	371	393
	Pozi	33˚12´,21.7"S	27˚ 31´,20.3"E	983	471	489
	Tyhusha	33˚13´,41.0"S	27˚ 30´,23.6"E	1066	470	266
Grassland	Hekele	32˚26´,53.0"S	27˚ 32´,14.3"E	890	609	308
	KwaZidenge	32˚28´,02.9"S	27˚ 24´,09.1"E	548	599	397
	Mgwali	32˚25´,53.8"S	27˚ 36´,31.3"E	1966	3429	604
	Ndakana	32˚28´,46.1"S	27˚ 28´,08.7"E	803	478	201
	Toyise	32˚27´,39.6"S	27˚ 25´,26.5"E	679	902	414
Thornveld	Dontsa	32˚37´,13.2"S	27˚ 13´,34.3"E	544	434	296

	Madubela	32°50´,12.3"S	27° 05´,50.7"E	629	608	256
	Majali	32°44´,23.7"S	27° 31´,32.1"E	1656	1304	686
	Lusasa	32°41´,06.5"S	28° 04´,12.1"E	405	228	374
	Sotho	32°41´,47.5"S	28° 07´,25.8"E	835	2410	492
Thicket	Gcinisa	33°01´,24.6"S	27° 04´,45.3"E	690	143	461
	Mkhanyeni	33°23´,19.8"S	27° 08´,53.1"E	756	371	455
	Peddie Extension	33°12´,28.5"S	27° 06´,22.1"E	1450	861	304
	Pikoli	33°12´,57.6"S	26° 59´,40.6"E	670	315	277
	Upper Mgwalana	33°16´,28.5"S	27° 06´,17.21"E	1888	779	504

4.2.3 Tick collections

4.2.3.1 Ticks on cattle

The collection of ticks from animals was in each case performed by the same person using a standardized systematic approach. Tick collections were made from one side of the animal whilst they were restrained in a crush or in a dipping race. Body regions that were examined included the ear, head, neck, chest, abdomen, flank, front and hind leg and feet, tail, and peri-anal region. All ticks collected per animal were stored in labelled sample tubes containing 70% ethanol and identified at the laboratory. Identification was done using a stereoscopic microscope (Leica Microsystems, Wetzlar, Germany) and the morphological diagnoses as described by (Walker et al. 2003). Species identification was confirmed by an expert tick taxonomist, Professor Ivan Horak, at the Faculty of Veterinary Science, Pretoria University.

4.2.3.2 Ticks on the vegetation

Ticks were collected from the vegetation using drag-sampling as described in detail by Nyangiwe et al. (2011). In short, ten flannel strips, each 1m long x 10cm wide, were attached adjacent to each other with Velcro tape to a 1.2m long wooden spar. A rope was attached to the end of this spar, allowing the operator to pull it over the vegetation. At each sampling locality, ten replicate drags of 100m approximately 50m apart were performed. The area around the dip-tank was avoided due to the possible negative effect of dipping compounds that drained from cattle following dipping. Drag-sampling was performed after 10h00 due to the presence of dew on the grass which would make the flannel strips too wet and this would decrease their efficacy in collecting free-living ticks (Zieger et al. 1998; Nyangiwe 2007). Therefore, dragging was done between 10h00 and 16h00. After each drag all instars of all ticks on the flannel strips were collected by means of fine-point forceps and were stored in 70% ethanol for later counting and identification. Again, tick identities were confirmed by Prof I.G. Horak.

4.2.3.3 Vegetation structure

Apart from ticks on the vegetation, five line transect of 50 points, 5m apart and 100m long were performed at each locality. At each point records included what the point touches: plant type (herbaceous/woody) or bare ground (rocks/soil). Percentage cover was calculated using number of points (hit) over the total points by 100 for a locality. Vegetation height was recorded and grouped into categories that included height <0.5m, ≤2 and >2m.

4.2.4 Data analysis

The data were entered in a Microsoft Excel® spreadsheet and all analyses were performed using R software for computation and graphics (v3.1.3, R Core Team (2014). ANOVA's were performed to establish the effect of vegetation type on the overall abundance and species richness of ticks on cattle and on the vegetation. For the ticks on cattle and between vegetation type analyses, effects included age, village and an interaction between village and age. Variables were log+1 transformed prior to analyses. A linear-mixed effects model was used to establish if vegetation type affected the individuals tick species on cattle and on the vegetation. This was also used to test significant difference among villages within vegetation type. To establish the effect of vegetation type on tick species composition on cattle (combined and per age group) and on the vegetation, Cluster analysis based on Bray-Curtis similarities was performed. Non-metric multidimensional scaling (NMDS) plots were drafted and Analysis of Similarity (ANOSIM) performed. The latter is a permutation procedure with the resulted statistic reflecting the observed differences in tick species composition between vegetation types contrasted with differences among replicates (i.e. villages) within vegetation types. This was done for ticks on cattle and on the vegetation. Thereafter we applied Similarity Percentage Analyses (SIMPER) to identify species that mainly determined differences in tick species composition between vegetation types. To analyses the effect of geographic distance on dissimilarity of species composition between sampling localities we calculated a Horn-Morisita Index, which takes into account abundances of species, to evaluate the effect of geographic distance on dissimilarity in tick species composition on cattle and on the vegetation. Thereafter multiple regressions were performed on distance matrices (MRM). In addition, a Sorensen Index, which is based on presence or absence of data, was also used to calculate dissimilarity in ticks.

4.3. Results

4.3.1 Tick abundance

A total of 20 212 ticks belonging to twelve species were collected from adult cattle, calves and on the vegetation at the 20 localities (Table 4.3). The Asiatic blue tick, *R. microplus* followed by *R. appendiculatus* were the most abundant on adult cattle (7.8±46.27 and 7.2±46.14, respectively), while the opposite was found for the two species on calves (3.2±44.77 and 2.58±45.06, respectively). The larval stages of *R. microplus* (100.8±17.7) and *R. decoloratus* (30.93±14.15) were the most abundant on the vegetation. Overall, tick numbers were higher on adult animals (26.0±13.22) compared to calves (9.5±6.26).

Table 4.3. Tick species, total number recorded and number collected on adult cattle, calves and the vegetation in four vegetation types in the Eastern Cape Province

Tick species	Total ticks	Adults	Calves	Vegetation
Amblyomma hebraeum	3 517	2 329	1 099	89
Haemaphysalis elliptica	6	0	0	6
Haemaphysalis silacea	9	7	2	0
Hyalomma rufipes	72	63	3	6
Ixodes pilosus group	224	175	48	1
Rhipicephalus decoloratus	1 114	375	147	592
Rhipicephalus microplus	7 219	3 915	1 288`	2 016
Rhipicephalus appendiculatus	5 014	3 481	1 477	56
Rhipicephalus evertsi evertsi	2 432	1 672	727	33
Rhipicephalus follis	39	24	13	2
Rhipicephalus sanguineus	46	30	16	0
Rhipicephalus simus	520	374	145	1
Total	20 212	12 445	4 965	2 802

4.3.2 Effect of vegetation type on tick abundance and species richness

4.3.2.1 Ticks on cattle – overall tick abundance and species richness

Within-vegetation type comparisons recorded significant differences in tick abundance and species richness both among villages and between ages ($p < 0.05$ in all cases) (Table 4.4). Interactions between village and host age for tick abundance and species richness were significant ($p< 0.01$ in both cases). Between vegetation type comparisons (for both individual animal and herd per age cohort as sampling unit) showed that tick abundances differed marginally ($F=3.17$, $p=0.05$ and $F=3.05$, $p=0.06$, respectively), but species richness did not differ between vegetation types ($p>0.05$). Interactions between vegetation type and host age for tick abundance and species richness were significant when individual animal was used as sampling unit ($p<0.01$ in all cases), but the significance was lost with herd per age cohort as sampling unit ($p>0.05$ in all cases). In general, tick abundance and species richness were lower on calves than on adult animals.

Table 4.4 ANOVA results for among villages and between age groups within vegetation type for tick abundance and species richness recorded from cattle (adult and calves) in four vegetation types in the Eastern Cape Province

Variable	Vegetation types	Effect	F	P
Tick abundance	Grassland	Village	18.3	<0.01
		Age	274.6	<0.01
		Village x Age	5.03	<0.01
	Thornveld	Village	0.05	0.99
		Age	264.9	<0.01
		Village x Age	7.8	<0.01
	Coastal Belt	Village	8.95	<0.01
		Age	124.8	<0.01
		Village x Age	13.59	<0.01
	Thicket	Village	7.0	<0.01
		Age	293.0	<0.01
		Village x Age	2.7	0.03
Species richness	Grassland	Village	4.34	<0.01
		Age	118.11	<0.01
		Village x Age	3.05	0.02
	Thornveld	Village	5.97	<0.01
		Age	173.8	<0.01
		Village x Age	6.66	<0.01
	Coastal Belt	Village	5.2	<0.01
		Age	28.4	<0.01
		Village x Age	4.2	<0.01
	Thicket	Village	12.0	<0.01
		Age	112.7	<0.01
		Village x Age	12.9	<0.01

4.3.2.2 Ticks on vegetation – overall tick abundance and species richness

Within-vegetation type comparisons showed that tick abundance differed significantly among villages (F=5.55-10.63, p< 0.01 for all four vegetation types), but species richness did not (F=0.3, p=0.82) (Table 4.5). Between vegetation type comparisons, using mixed-effect linear models, recorded significantly lower tick abundance in Thicket compared to the remaining three vegetation types (p<0.05). However, ANOVA for the model showed that vegetation type had no significant effect on the abundance of ticks on the vegetation (F=2.04, p=0.15).

Table 4.5 ANOVA results for among villages within vegetation types for tick abundance and species richness recorded for ticks from vegetation in four vegetation types in the Eastern Cape Province

Source of variation	Vegetation type	F	P value
Tick abundance	Coastal Belt	7.43	**0.0001****
	Grassland	5.55	**0.001***
	Thornveld	10.36	**<0.01***
	Thicket	4.78	**0.003***
Species richness	Coastal Belt	1.94	0.12
	Grassland	1.08	0.37
	Thornveld	1.88	0.13
	Thicket	2.48	0.06

Significant effects are indicated in bold. Bold * p<0.01, * * p<0.001

4.3.3 Species compostion

4.3.3.1 Ticks on cattle

From the Cluster analysis it is evident that in most cases the tick species composition was not significantly different between vegetation types (Fig 4.2). However, it does seem that the species composition on cattle in the Grassland were different from the other vegetation types. This pattern was supported by the NMDS plot (Fig 4.3). The ANOSIM also supported this pattern with a Global R value of 0.369 ($p < 0.002$). Pairwise comparisons between vegetation types recorded significant difference between Grassland and the three other vegetation types (Table 4.6). In each case *R. microplus* and *A. hebraeum* contributed the most, of all the tick species, to the dissimilarity in species composition. The contribution of *R. microplus* ranged between 30.01 – 35.72% and for *A. hebraeum* between 25.49 – 26%. In each case, *R. microplus* was present in higher abundance on cattle in the Grassland compared to Thornveld, Coastal belt and Thicket, while *A. hebraeum* was absent from Grassland.

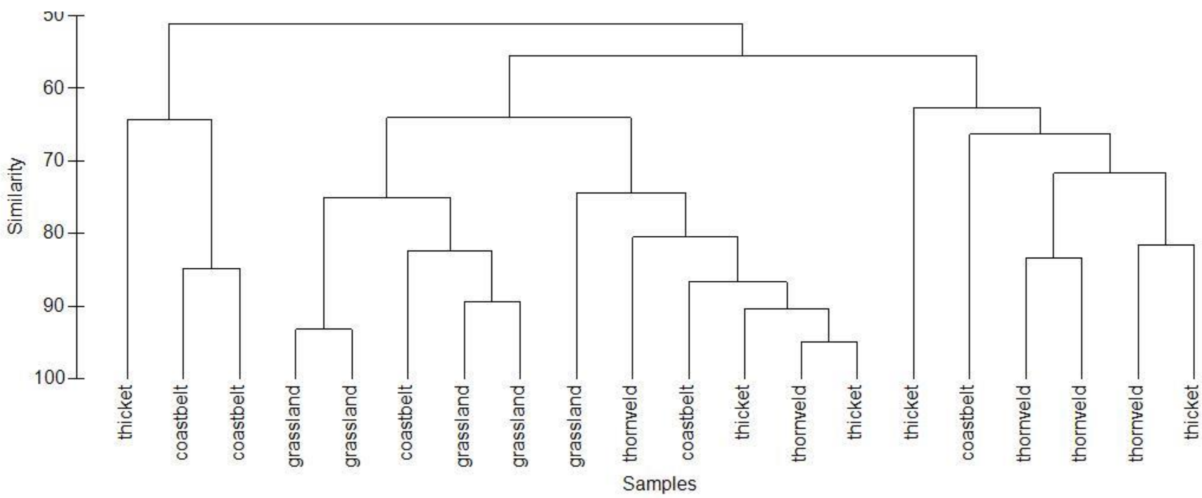

Figure 4.2 Cluster analysis (based on Bray-Curtis similarities) of tick species composition for ticks on cattle recorded in four vegetation types in the Eastern Cape Province.

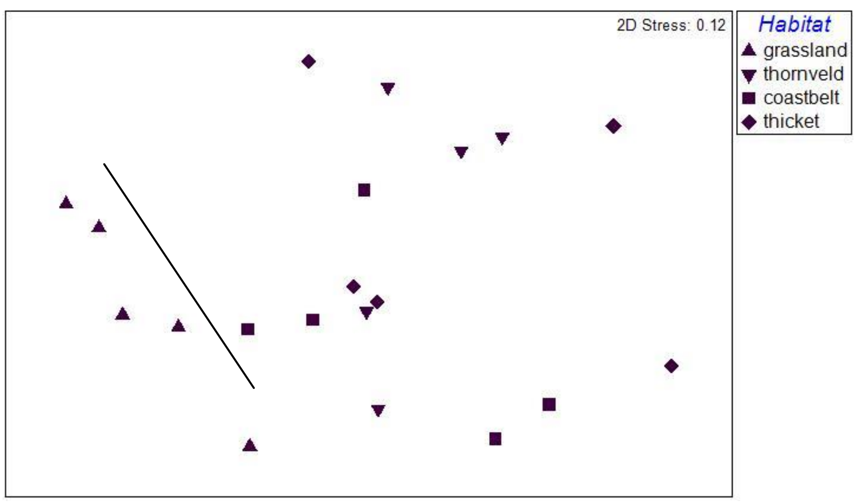

Figure 4.3 Nonmetric multidimensional scaling ordination for the tick species on cattle recorded in four vegetation types in the Eastern Cape Province.

Table 4.6 Analysis of similarity (R values) between the tick species communities recorded on cattle in four vegetation types in the Eastern Cape Province. Global R=0.369, p=0.002

Vegetation types	Thornveld	Coastal Belt	Thicket
Grassland	0.768**	0.576**	0.536**
Thornveld	-	0.288	-0.116
Coastal Belt	-	-	0.08

**p<0.01

Differenciation between age group (adult vs calves) indicated that the pattern observed for cattle combined was largely driven by adult cattle. The global R value was higher and more significant for adult cattle (R=0.334, p<0.005) than for calves (R=0.194, p=0.03). For adult cattle *R. microplus* and *A. hebraeum* again contributed the most to observed dissimilarity between Grassland and the three other vegetation types. However, on calves the most important tick species were *R. appendiculatus*, *R. microplus* and *A. hebraeum*.

4.3.3.2 Ticks on vegetation

From the Cluster analysis it is evident that tick species composition on the vegetation did not differ consistently between vegetation types, except for three villages in Thornveld (Fig 4.4). This pattern was supported by the NMDS plot (data not shown). The general lack of dissimilarity was supported by the low Global R value (R=0.236), though it was significant (p<0.005) (Table 4.7). Pairwise comparisons between vegetation types recorded significant difference between Coastal Belt and Thornveld and Coastal Belt and Thicket (Table 4.7). The tick species that contribute the most to the dissimilarity were *R. decoloratus* (42.64%) and *R. microplus* (38.07%)

between Coastal Belt and Thornveld, with *R. decoloratus* more abundant in Thornveld compared to Coastal belt and *R. microplus* showing the opposite pattern. *R. microplus* (36.01%) and *R. decoloratus*/*R. microplus* hybrid (25.43%) contributed mostly to the dissimilarity between Coastal Belt and Thicket, with *R. microplus* being more abundant on vegetation in the Coastal Belt and *R. decoloratus*/*R. microplus* hybrid showing the opposite pattern.

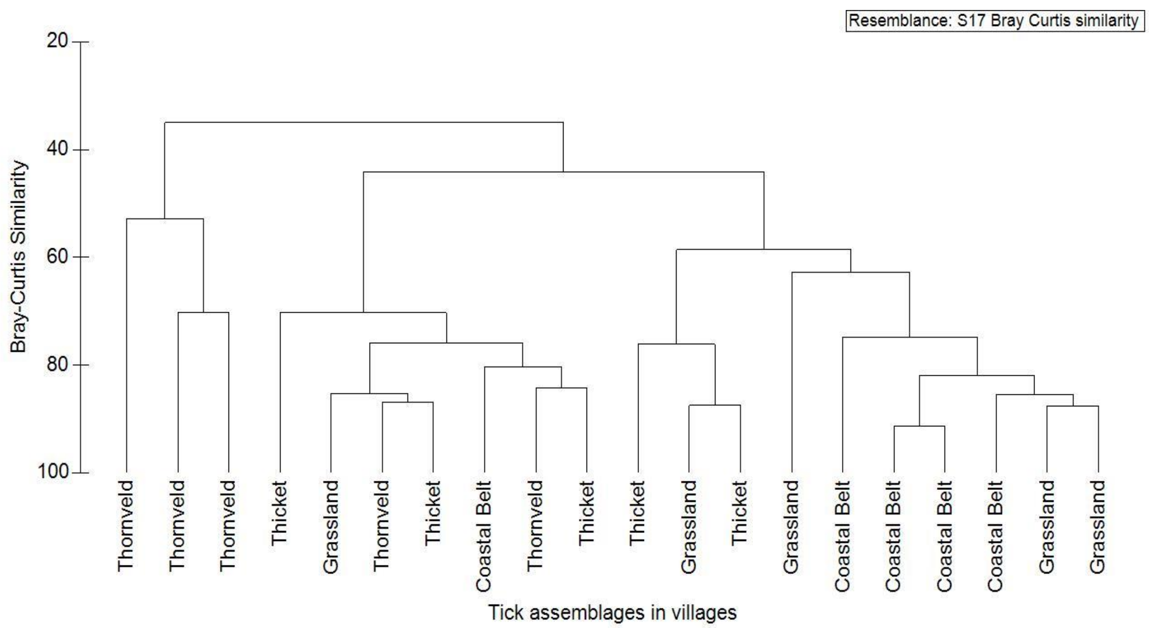

Figure 4.4 Cluster analysis (based on Bray-Curtis similarities) of tick species composition for ticks on the vegetation recorded in four vegetation types in the Eastern Cape Province.

Table 4.7 Analysis of similarity (R values) between the tick species communities recorded on vegetation in four vegetation types in the Eastern Cape Province. Global R=0.236, p=0.005

Vegetation types	Thornveld	Coastal Belt	Thicket
Grassland	0.208	0.142	0.132
Thornveld	-	0.394*	0.232
Coastal Belt	-	-	0.532*

* $p<0.05$

4.3.3.3 Effect of geographic distance on species composition

Results of MRM linking the tick species composition to geographic distance indicated that in general dissimilarity in tick species composition was not affected by increase in geographic distance between sampling localities. This was recorded for ticks collected from either cattle or vegetation (p=0.21 and p=0.26, respectively). However, Sorensen Index showed a weak but significant relationship between geographic distance and dissimilarity of the tick species composition on cattle (p=0.04) but not from vegetation (p=0.20).

4.3.3.4 Ticks on cattle – abundance of individual tick species

Within-vegetation type comparisons show that the mean abundance of individual tick species (*A. hebraeum*, *R. appendiculatus*, *R. decoloratus*, *R. e. evertsi*, *R. microplus* and *R. simus*) was affected by village and or animal age ($p<0.01$ when significant) in most of the vegetation types. The interaction between village and age was also significant ($p<0.01$) for several tick species in some of the vegetation types. Between vegetation type comparisons, using a mixed-effect linear models, recorded no significant differences in the mean abundance of most of the common tick species ($p>0.05$) on cattle. This was the case for *A. hebraeum* ($F=1.63$, $p=0.24$), *R. appendiculatus* ($F=0.86$, $p=0.48$), *R. decoloratus* ($F=1.27$, $p=0.32$) and *R. microplus* ($F=2.68$, $p=0.08$). However, the mean abundance of *R. e. evertsi* was significantly different ($F=9.32$, $p<0.001$) on cattle (combined age groups) between vegetation types. In particular, abundances in Thornveld and Thicket were significantly higher than in Coastal belt and Grassland ($p<0.01$ in each case). The interaction between vegetation type and animal age was significant for each of the tick species ($p<0.05$ for all species). In general tick abundances on calves varied between vegetation types with for example *A. hebraeum* ticks more abundant on calves in the Coastal belt compared to Thicket vegetation. *R. e. evertsi* abundances on calves were significantly higher in Grassland and Thornveld compared to Coastal belt and Thicket vegetation ($p<0.01$ in each case). For *R. microplus* significantly higher abundances were recorded on calves in the Coastal belt compared to the three other vegetation types ($p<0.05$ in each case). No clear pattern was recorded for the other tick species.

4.3.3.5 Ticks on vegetation – abundance of individual tick species

Within-vegetation type comparisons show that the mean abundance of *R. e. evertsi*, *R. microplus* and *R. decoloratus*/*R. microplus* hybrid was affected by village ($p<0.05$ when significant) in some of the vegetation types. This pattern was recorded for *R. e. evertsi* and *R. decoloratus*/*R. microplus* hybrid in Grassland, Thicket and Coastal Belt and for *R. microplus* in Grassland and Coastal Belt. Between vegetation type comparisons, using a mixed-effect linear models, recorded a significant effect of vegetation type on the mean abundance of *A. hebraeum* ($F=7.70$, $p=0.007$), *R. decoloratus* ($F=3.57$, $p=0.04$) and *R. microplus* ($F=5.43$, $p=0.01$) on the vegetation. The mean abundace of *A. hebraeum* was significantly higher in Coastal Belt compared to Thornveld (p<0.001) and marginally so compared to Thicket (p=0.06). *R. decoloratus* was significantly higher in Thornveld compared to the three other vegetation types (p<0.05 in all cases). *R. microplus* was significantly more abundant in the Coastal Belt compared to Thicket (p=0.016) and Thornveld (p=0.003) and marginally more abundant in the Grassland compared to Thornveld (p=0.05). No significant differences were recorded for *R. e. evertsi* (F=0.17, p=0.91), *R. appendiculatus* (F=1.78, p=0.19) and *R. decoloratus*/*R. microplus* hybrid (F=3.19, p=0.05) on the vegetation.

4.3.4 Vegetation structure

The vegetation types were mostly similar in vegetation structure, except for Grassland that seems to have lower vegetation cover and fewer but higher trees compared to the other vegetation types (Table 4.8).

Table 4.8. Vegetation cover, maximum height and proportion of trees, and grass in each of the vegetation types in the Eastern Cape Province

Vegetation type	Mean % cover (± SE)	Mean height of vegetation (± SE)	Mean proportion of trees (± SE)	Mean proportion of grass (± SE)
Coastal Belt	91.68±0.77	10.2±0.99	24.76±1.07	21.08±1.16
Grassland	71.6±2.59	25.48±1.25	6.04±0.77	29.76±1.17
Thornveld	91.04±1.19	17.04±0.85	17.44±1.09	28.08±1.03
Thicket	90.64±1.09	15.6±0.68	23.24±1.04	22.12±1.41

4.4. Discussion

The tick species recorded in the study was previously recorded on cattle in the ECP (Horak et al. 2009; Nyangiwe et al. 2011) and other parts of South Africa (Bryson et al. 2002; Spickett et al. 2011). *Rhipicephalus microplus* and *R. appendiculatus* were the most abundant tick species and similar results have been reported by Nyangiwe and Horak (2007) and Horak et al. (2009) in the eastern region of the ECP. The invasive nature and dominance of the Asiatic *R. microplus* in the present study is supported by previous studies in South Africa (Tønnesen et al. 2004; Horak et al. 2009; Nyangiwe et al. 2013) and in other African countries (De Clercq et al. 2012; Madder et al 2007; Lynen et al. 2008). For example in West Africa, the tick is found in high numbers on cattle and it is reported to be the most invasive tick species (Madder et al. 2011).

In terms of ticks on animals, the overall tick abundance and species richness on cattle and on the vegetation was not significantly affected by vegetation type. Rather, activities related to the village (such as fire burning, tick control measures and other animal practices) are more important determinants for tick abundance and species richness than vegetation type. Further, the uncontrolled movement of cattle (in addition to wild ungulates) in the communal grazing system can also facilitate the movement of ticks between vegetation types (Marufu et al. 2011; Wogayehu et al. 2016). If this is the case then it is to be expected that villages and or vegetation types that are located closer to one another may have more similar species composition. However, this was not supported by an abundance-based distance dissimilarity analyses or the presence/absence-based Sorenson Index.

Although the effect of village-related activities were again important determinants of tick species composition on cattle there was a weak, but significant difference in species composition between the vegetation types with Grassland having a more distinct composition compared to the other vegetation types. The species that contributed most to the dissimilarity was *R. microplus* and *A. hebraeum* with *A. hebraeum* being absent from cattle in Grassland and *R. microplus* being more abundant on cattle in Grassland compared to the other three vegetation types. The tick species composition on the vegetation was more similar, though still significantly different, between the vegetation types. The difference were mainly found between Coastal Belt and Thornveld and Coastal Belt and Thicket with the mean abundances of the African and Asiatic blue ticks and also a hybrid between the two ticks contributing mostly to the observed differences. The patterns observed for differences in species composition is somewhat reflected in the mean abundances of individual tick species. The absence of *A. hebraeum* on cattle in Grassland vegetation type agrees with the finding of Marufu et al. (2011) and Nyangiwe et al. (2011) who reported the absence of *A. hebraeum* on inland localities and on the open grass pastures at Döhne Sourveld in the ECP. Howell et al. (1978) also states that *A. hebraeum* cannot survive in open grasslands. In the present study the Grassland vegetation type generally occurs at a higher altitude (650 – 1500) and as such experience lower temperatures (3-26˚C) compared to the other three vegetation types. *Amblyomma hebraeum* is a three-host tick and it is thus possible that cooler temperatures might affect the survival of free-living stages on the open grassland vegetation. Further, it is possible that the more homogenous grass vegetation and lower percentage cover might have a negative effect the host diversity (such as helmeted guineafowl, scrub hares and small antelope) that is required to complete the initial part of the life cycle (Ostfeld and Keesing 2012). However, Horak et al. (2011) recorded *A. hebraeum* larvae from grassland vegetation, compared to dense bushes, in the Savanna biome in the Kruger National Park, Mpumalanga Province. It is possible that the climatic and host diversity differences can contribute to this pattern as Mpumalanga receives summer rainfall and Kruger National Park (a nature reserve) comprises various medium to large wild ungulate species in addition to preferred hosts for immature stages. This is in contrast to the ECP that receives all-year rain and communal rangelands mainly comprise domestic species (goats and cattle). The Asiatic blue tick, *R. microplus* is a one-host tick and therefore spends most of its life cycle on the host. The tick is regarded as a cattle tick (Madder et al. 2007), which may explain its occurrence on cattle and the vegetation in all four vegetation types. Although the tick was present in all vegetation types higher abundances were recorded in the Coastal Belt and Grassland vegetation. Several studies have recorded displacement of the endemic African blue tick, *R. decoloratus* by *R. microplus* in certain areas in the ECP (Tønnesen et al. 2004; Horak et al. 2009; Nyangiwe et al. 2013). This may explain the observed inverse pattern recorded between the two blue tick species, with higher abundances recorded for *R. decoloratus* in the more closed Thornveld vegetation type. Similarly, Nyangiwe et al. (2013a) reported a higher abundance of *R.decoloratus* larvae from the vegetation at Majali community (under Thornveld) compared to Ncerha community which is in Coastal Belt.

The two-host tick, *R. e. evertsi* varied in abundance being more abundant on cattle in Thornveld and Thicket compared to Coastal Belt and Grassland. Thornveld and Thicket are characterised with having a more open treed savanna than Coastal belt or Grassland (Mucina and Rutherford 2006), which is also the preferred vegetation for goats. It seems that *R. e. evertsi* also has a preference for goats as it was the most abundant tick species recorded on goats in Geluk communal area in Mpumalanga (Bryson et al. 2002). Nyangiwe and Horak (2007) also reported *R. e. evertsi* as the most abundant tick species on goats and cattle at 72 communal dip-tanks surveyed in the eastern region of the ECP. *Acacia* species are the most common tree species found in Thornveld and Thicket (Mucina and Rutherford 2006). Therefore, farmers tend to have more goats in vegetation characterised by *Acacia* species and we can expect some more *R. e. evertsi* in such habitats.

Tick abundance and species richness were lower on calves than adult cattle. The tick species composition, between vegetation types, was also more similar on calves compared to adult animals. This may be due to fewer ticks collected on the calves, which may affect the statistical power. The lower tick burden recorded on calves could be attributed to smaller body surface of calves compared to adults (Mooring et al. 2000), so the chance of exposure is higher in adults than young stock (Pawlos and Derese 2013). Adult animals and calves differ in vagility: adult animals generally graze widely in communal lands but calves are mostly kept in enclosed areas close to the village for protection or for milking purposes. A further contributing factor maybe the innate immunity present in calves, which provides protection for some months after birth (Barnett and Bailey 1955; Sutherst et al. 1979; Wikel and Bergman 1997; Okello-Onen et al. 1999). The lower tick loads observed in calves compared to adults supports similar work carried out in semi-arid rangeland zone of Uganda (Okello-Onen et al. 1999), in the eastern region of the ECP (Marufu et al. 2011), in central Nigeria (Lorusso et al. 2013) and around Sebeta town in Ethiopia (Huruma et al. 2015). These authors suggested different reasons for the lower tick burdens, such as, some form of innate immunity of indigenous cattle (Zebu and Sanga) that decreases with age; the persistent grooming of calves by their respective dams, variable management of adults as opposed to claves with the latter kept in paddocks close to houses and a smaller body surface of younger animals compared to adults.

Chapter 5

Livestock owner's perceptions of ticks and tick borne diseases for cattle reared under communal production systems in the Eastern Cape Province, South Africa

** Prepared for submission to South African Journal of Animal Science*

5.1. Introduction

World-wide ticks and tick-borne diseases (TBDs) negatively affect productivity, condition, fertility and health of animals in the cattle farming industry (Wambura et al. 1998). Most TBDs are associated with protozoan (eg. Babesiosis and Theileriosis), rickettsial (eg. Anaplasmosis and Cowdriosis) and viral diseases (Frans 2000). However, ticks not only serve as transmitters of disease agents but they are also associated with toxicoses such as sweating sickness, paralysis, brown ear-tick toxicosis and bovine dermatophilosis (Howell et al. 1978). Ticks and TBDs have a global impact with huge financial implications for farmers, the industry and the general economy of countries. In 1997, the annual global losses due to ticks and TBDs in cattle were more than US$ 15 billion (De Castro 1997). Whilst in the United States alone, it was estimated that the economic loss of tick transmitted bovine babesiosis was more than US$ 3 billion in 2007 (Busch et al. 2014). With regard to African countries estimates loss are equally high with countries like Tanzania recording over 7 million US$ and South Africa more than 2 million US$ per annum in 1999 (Minjauw and MacLeod 2003).

In South Africa, cattle play a vital role as source of household income together with food crops under different farming systems. Cattle production in South Africa can broadly be divided into two categories: large-scale commercial farming and small-holder communal farming (Gilimani 2005). In commercial farming systems, farmers have the advantage of control over the type of acaricide that is used. In addition, they can afford professional advice on tick control strategies, are more often able to employ veld management practices (e.g. veld resting, burning, rotational grazing) and manage their stocking rate in their camps. In contrast, communal farmers share dip tanks and grazing areas with several other cattle owners in the community. These farmers are often resource limited and have no control over the type of acaricide that is used or the stocking rate. More importantly, frequent depletion of governmental budgets significantly impact the maintenance of dipping stations which increases tick-associated disease risks to communal farmers. As a result, communal farmers often turn to ethno-veterinary practises to treat and prevent TBDs that are prevalent in their region (Mwale and Masika 2009; Ndhlovu and Masika 2013). To date, some studies have been conducted on ticks and TBDs associated with communal farming systems in South Africa (Ntondini et al. 2008; Moyo and Masika 2009; Horak et al. 2009; Marufu et al. 2010). The studies focused on acaricide resistance, tick control strategies, tick distribution and sero-prevalence of TBDs. From these studies it appears that the communal grazed rangelands are characterised by overstocking, overgrazing and absence of a grazing management system (Moyo et al. 2008). Government subsidizes communal farmers for practices such as vaccination and tick control but less is done for deworming and animal identification (Nowers et al. 2013). There also appears to be supplemental dipping with alternative chemical compounds such as household products, mainly due to the perception that the current dipping compound is less effective (Masika et al. 1997; Hlatshwayo and Mbati 2005; Moyo and Masika 2009; Katiyatiya et al. 2014; Slayi et al. 2014).

The Eastern Cape Province (ECP) is characterised by an almost all year rainfall (500 mm - 900 mm in cool dry and hot wet season) and mild temperatures (5˚C - 35˚C). Ninety percent of land in the ECP is rangeland which is more suitable for livestock farming than crop production (CSIR 2004; Nowers et al. 2013). In addition, the ECP consists of seven biomes which are Forest (2%); Fynbos (6%); Grassland (39%); Nama Karoo (26%); Savanna (10%); Succulent Karoo (0.01%) and Thicket (17%) Department of Economic Affairs, Environment and Tourism (DEAET 2003). Of these, Grassland, Nama Karoo, Savanna and Thicket biomes make a considerable contribution to livestock farming and this makes the province a very good farming and cattle farming province. The ECP has the highest number of cattle (approximately 3.2 million) in South Africa followed by KwaZulu Natal Province (2.7 million) and Free State Province (2.3 million) (Anon 2012). Given the high cattle numbers and temperate all-year rain fall recorded in the ECP it is not unexpected that ticks and TBDs are considered a major problem in cattle (Masika et al. 1997). The most common tick-related diseases include heartwater (caused by *Ehrlichia ruminantium* and transmitted by the tick *Amblyomma hebraeum*) and African and Asiatic redwater (caused by *Babesia bigemina* and *B. bovis* and transmitted by the ticks *Rhipicephalus decolaratus* and *R. microplus*) (Nyangiwe 2007; Norval and Horak 2004; Madder et al. 2011). The significance of TBDs in the province is evident in the fact that there are more than a thousand communal dip tanks in the province and the cost associated with plunge dipping in the communal sector of the ECP, South Africa is estimated at 2.2 million US$ per annum (Ndwayi 2014 personal communication).

To date few studies have been conducted on farmers' perception of ticks and TBDs in the ECP and those that have focussed mainly on tick control practices (Masika et al 1997; Moyo and Masika 2009). The current study aims to establish a clearer understanding of the knowledge, attitudes and practices of communal farmers with regard to ticks and TBDs of cattle in the ECP. The information gained during this survey will be compared with current literature on the subject and used for the formulation of sustainable animal health programs for the ECP.

5.2 Materials and Methods

5.2.1 Study area

The ECP is situated on the east coast of South Africa (Figure 5.1A). The province covers an area of 168 966 km^2 which is 13.5% of South Africa's total land area. It has a population of more than 6.5 million people and is the second largest of the nine provinces in South Africa (Anon. 2012). The study was conducted in the Amathole District Municipality (ADM) of the ECP. Twenty cattle-farming communities were randomly selected within 4 vegetation types namely, Albany Coastal Belt, Amathole Montane Grassland, Bhisho Thornveld and Great Fish Thicket (Mucina and Rutherford 2006) (Figure 5.1B). The vegetation types varied in terms of altitude averages with Bhisho Thornveld (468 m above mean sea level (AMSL)) and Amathole Montane Grassland (848 m AMSL) found at higher elevation compared to Great Fish Thicket (193 m AMSL) and Albany Coastal Belt (98 m AMSL).

5.2.2 Study design

Face-to-face interviews were conducted between October 2012 and February 2013. A structured questionnaire was developed (details provided below) and presented to cattle farmers during the community's dip-day. At each dip tank, 5 cattle owners were randomly selected to participate in the study. Face-to face interviews were carried out individually using vernacular Xhosa language. Four trained enumerators together with an animal health technician, associated to each dip tank, were used to conduct the interviews. Before any data collection commenced, the farmers were informed of the purpose of the study and were guaranteed that their involvement was voluntary and would be kept confidential.

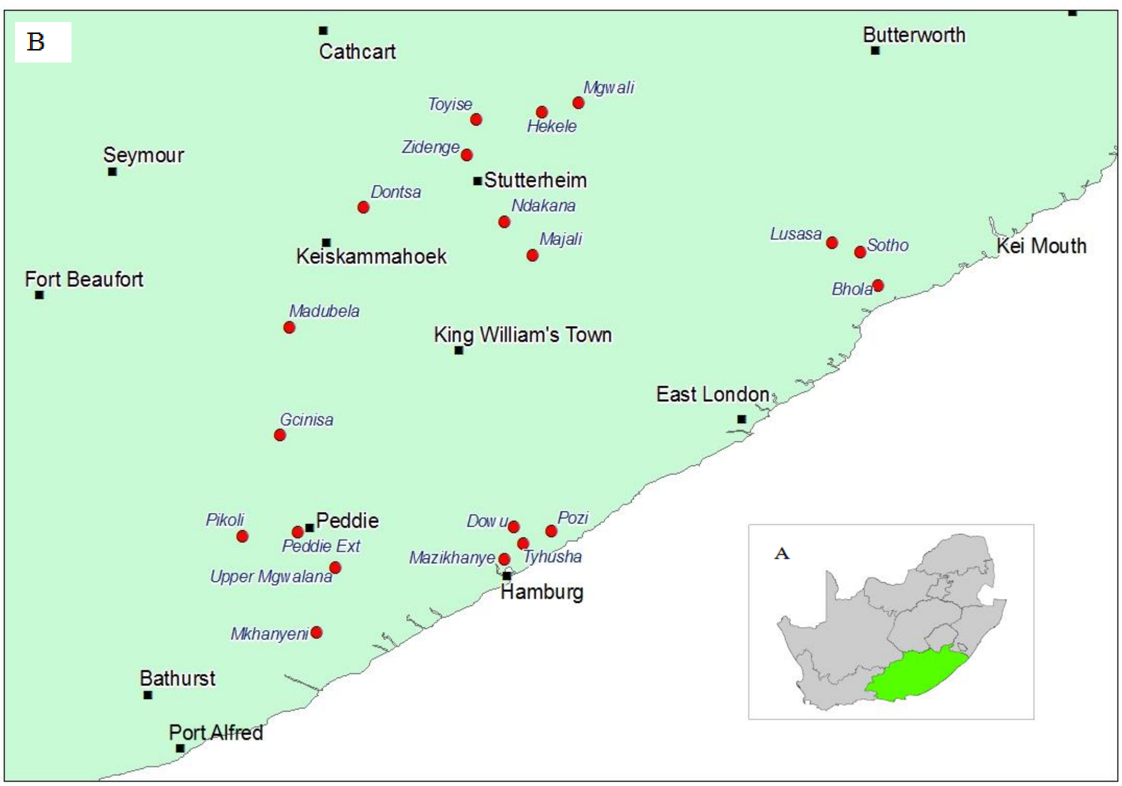

Figure 5.1 Geographic position of the Eastern Cape Province in South Africa (A) and (B) communities that participated (dots) in the Amathole District Municipality of the Eastern Cape Province during 2012 and 2013 in South Africa.

The questionnaire comprised closed, semi-closed and open questions. The questions were organised in different sections to collect socio-economic data and information regarding animal husbandry practices. The first section covered socio-demography such as farmer name, age, gender, level of education and estimated monthly income of the participant. This was followed by characteristics of livestock production such as number of livestock species kept, effect of ticks, TBDs prevalence and management of grazing areas. In addition, questions were asked regarding tick control methods, frequency of dipping in summer and winter, management of dipping services and whether the existing dipping compound was working efficiently or not. Farmers were asked to indicate the reasons for tick problems which they had observed and rank them according to severity from 1 (less severe) to 5 (very severe). Motives for tick problems were categorised into weak acaricides, poor mixing of acaricide, uncovered dip tank roofs, dirty dip tanks and some animals that could not be dipped during the dip day. During the time of the survey, the dip compound in all the dip tanks along the coast (Bhola, Dowu, Mazikhanye, Tyhusha and Pozi) was changed to liquid dip, Delete X5 (MSD Animal Health) containing 5% Deltamethrin active ingredient. This was done after two decade's use of the formamidine compound, Triatix 500 TR® (Afrivet) with 50% Amitraz. The latter product was still being used at dip tanks that were located higher than 300 m above sea level (communities in Amathole Montane Grassland and Bisho Thornveld). The second part of the questionnaire referred to alternative measures for tick challenges and knowledge on ticks and tick species that is commonly observed. The last section of the questionnaire focussed on climate change impact on livestock production. At all times, livestock owners had the opportunity to clarify questions with the enumerator's assistance and they were allowed to add any personal information and comments.

5.2.3 Data analysis

The data were entered in a Microsoft Excel® spreadsheet and all analyses were performed using STATISTICA (StatSoft, Inc. 2013, Edition 12.0). A non-parametric test was performed (Kruskal-Wallis) to determine significant differences between the habitat type and cattle diseases. Descriptive statistics, frequency tables, cross-tabulations, non-parametric ANOVA (Kruskal-Wallis, with corresponding post-hoc tests for multiple comparisons) and t-tests (Mann-Whitney) were computed to describe categorical and ordinal data as well as identify possible significant differences between specified subgroups. A significance level of $\alpha=0.05$ was used for each comparison. A Pearson Chi-square was also used to compare the prevalence of TBDs in different vegetation zones.

5.2.4 Ethical considerations

The permission to carry out this study was granted by the Ethics Committee focussing on Humans at Stellenbosch University (reference no: DESC_Nyangiwe2012). No animals were used in this study. All the participants were informed about the purpose of the study and their participation was voluntary.

5.3. Results

5.3.1 Socio-demographic profile

A total of 100 individual questionnaires were completed (25 in each of the four vegetation types). All respondents were directly involved in livestock practices with 43% being members of the local farmer's associations. The respondents were mostly males (85%) compared to females and there were no significant differences between age groups of farmers in the four vegetation types (p=0.195). Most of the stock owners were older than 50 years (83%) while only 12% were younger than 40 years (Figure 5.2).

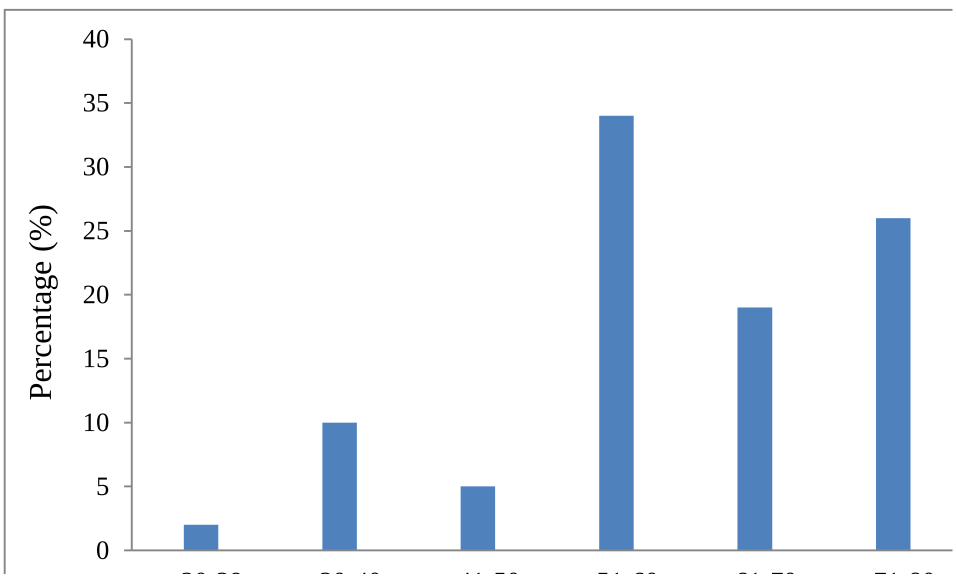

Figure 5.2 Age profile of stock owners responding to a questionnaire survey at communal dip tanks in the Eastern Cape Province of South Africa during 2012/2013.

Less than 10% of respondents completed secondary school, while 65% had some form of education up to primary level and 26% had no school education (Table 5.1). The major source of income, for the cattle farmers, was from government pension grants (70%) with 30% of respondents solely dependent on the income generated through farming of cattle (Table 5.1). The monthly income of most of the participating farmers was less than R2000 (approximately 148.15 USD) (Table 5.1).

Table 5.1. Educational and socioeconomic status of participating communal cattle farmers from four vegetation types in the Eastern Cape Province of South Africa.

Vegetation types	Level of education				Income range per month		
	None	Primary	Secondary	Tertiary	‹R500	R500-R2000	›R2000
Coastal Belt	7	18	0	0	10	15	0
Grassland	5	16	4	0	4	20	1
Thornveld	5	18	2	0	10	14	1
Thicket	9	13	3	0	6	18	1
Total	26	65	9	0	30	67	3

Coastal Belt= Albany Coastal Belt; Grassland= Amathole Montane Grassland; Thornveld= Bhisho Thornveld; Thicket= Great Fish Thicket

5.3.2 Livestock records

All respondents owned cattle which grazed on communal lands during summer and winter months. Most (98%) cattle farmers also owned more than 10 goats, while 49% also owned sheep and 27% owned other livestock species (e.g. horses, donkeys and pigs). There was no significant differences in the mean number of cattle (p=0.596) and goats (p=0.524), while there was a significant difference in the mean number of sheep ($p<0.001$) between the different vegetation types (Table 5.2). The mean number of cattle per farmer ranged between 12.8±1.17 and 15.6 ±1.35 for the different vegetation types (Table 5.2).

Table 5.2 Mean number of cattle, goats and sheep (±SE) per vegetation type in the Eastern Cape Province of South Africa

Variable	Coastal Belt	Grassland	Thornveld	Thicket
Cattle	$15.6^{a} \pm 1.35$	$12.8^{a} \pm 1.17$	$14.4^{a} \pm 1.27$	$14.3^{a} \pm 1.47$
Goats	$16.1^{a} \pm 1.95$	$12.4^{a} \pm 1.88$	$14.2^{a} \pm 1.16$	$15.4^{a} \pm 2.00$
Sheep	0.0^{a}	$28.9^{b} \pm 4.78$	$3.9^{a} \pm 2.70$	$40.2^{b} \pm 4.20$

^{a,b}Means within the same row with different superscripts are significantly different ($P<0.001$). Coastal Belt= Albany Coastal Belt; Grassland= Amathole Montane Grassland; Thornveld= Bhisho Thornveld; Thicket= Great Fish Thicket

5.3.3 Knowledge on ticks and TBDs

Seventy five percent of the respondents stated that they inspected their cattle for ticks on a monthly basis. Significantly more respondents ($\chi2=15.98$, $p<0.001$) confirmed that adult animals were more affected by ticks compared to calves. In addition, the udder (86%) and scrotum (73%) regions on cattle are reported to be mostly affected by ticks. Almost all the respondents (>90%) claimed to be able to distinguish between different tick species with the bont tick *Amblyomma hebraeum* (44%) and blue ticks *Rhipicephalus* (*Boophilus*) spp. (36%) reported as the most common species. Other tick species that were less frequently reported include the brown ear tick *R. appendiculatus* (9%), bont-legged ticks *Hyalomma* spp. (8%) and red-legged tick *R. e. evertsi*

(3%). All of the respondents identified redwater as the commonest TBD, followed by Gallsickness (90%) and heartwater (43%) (Table 5.3). Redwater and Gallsickness were the most common TBDs within and between vegetation types, while Heartwater was less commonly reported and absent in Amathole Montane Grassland (Table 5.3). Using their vernacular language, farmers were allowed to give differences between TBDs in their region. For redwater, they mentioned that symptoms included red urine, lack of appetite and difficulty in walking. While aggressiveness, constipation, and also lack of appetite was mentioned for gallsickness. Furthermore, they explained that high stepping and some foam in mouth and nostrils would appear for heartwater diseases.

Table 5.3 The proportion of cattle deaths as a result of TBDs in four different vegetation types during 2012/2013 in the Eastern Cape Province, South Africa

Vegetation types	Gallsickness (%)	Heartwater (%)	Redwater (%)
Coastal Belt	88	68	100
Grassland	92	0	100
Thornveld	84	32	100
Thicket	96	72	100
Mean	**90**	**43**	**100**

Coastal Belt= Albany Coastal Belt; Grassland= Amathole Montane Grassland; Thornveld= Bhisho Thornveld; Thicket= Great Fish Thicket

Farmers in Bhisho Thornveld and Great Fish Thicket reported higher cattle mortalities compared to farmers in Amathole Montane Grassland and Albany Coastal Belt (Figure 5.3). TBDs are commonly recorded (87%) as a cause for cattle deaths in the communities with an average of 399 tick-related deaths recorded for 2012/2013. However, no significant difference in tick-related deaths were recorded among the four veld types (p=0.081).

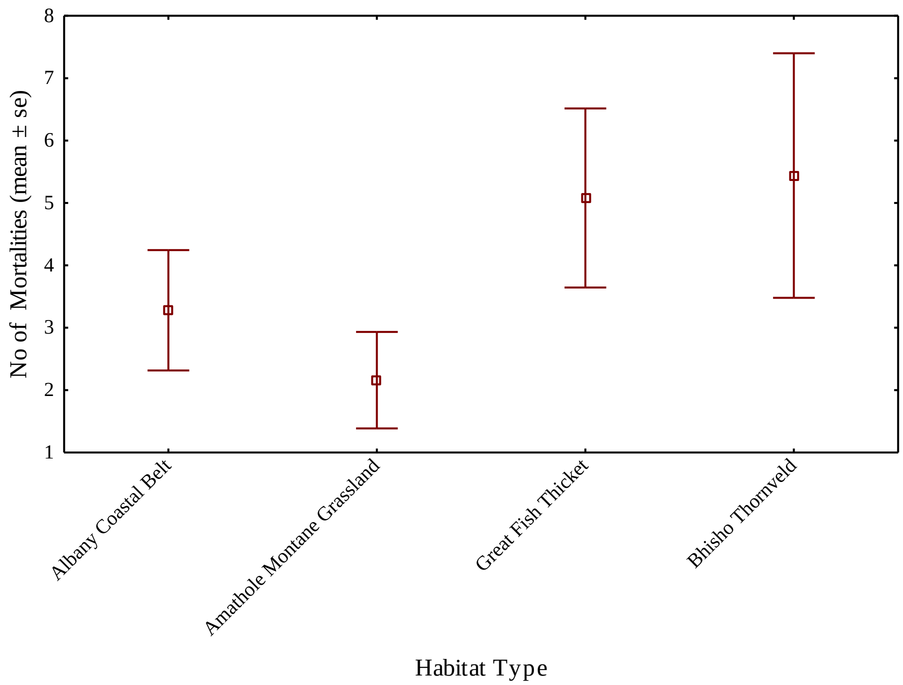

Figure 5.3 Number of reported cattle deaths per vegetation type over a 12 month period (2012/2013) in the Eastern Cape Province of South Africa.

5.3.4 Perceptions on tick control practices

Forty percent of the respondents reported that farming with adaptive breeds such as Nguni and Brahman cattle reduces ticks and TBDs. There was no significant difference in this respect between the respondents in the different vegetation types ($\chi2$=7.00, p=0.07). The farmers that do treat their animals with acaricides prefer plunge dipping (90%) above hand spraying (10%). Animals are dipped once a week and more often so in summer (68%) compared to winter (50%).

Almost 60% of the respondents were not aware of restrictions on animal movement between the districts and that this action may complicate tick control due to the introduction of resistant tick species. More than 70% of the respondents claimed that the current acaricides that were used in the dip tanks were not effective in killing ticks and list ineffective acaricide, undipped animals and poor mixing of the acaricide as the most important constraints of effective tick control practices (Figure 5.4).

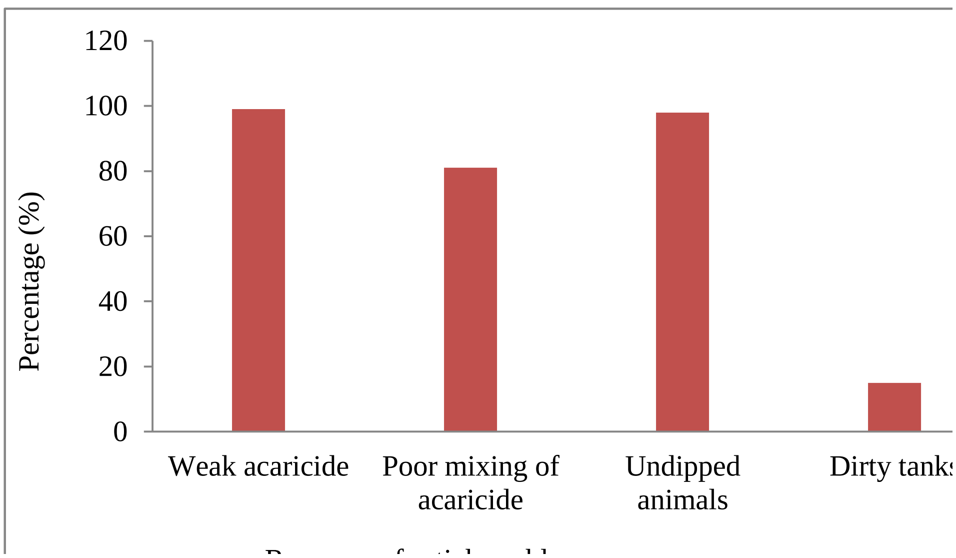

Figure 5.4 Farmer-reported constraints associated with effective tick control in the Eastern Cape Province, South Africa.

Most farmers supplement the government dip by using alternative tick control practices. Products that were listed as being effective against ticks included old car engine oil (54%) and a house-hold disinfectant, Jeyes fluid (35%). The use of engine oil varied between vegetation type ($\chi2=9.82$, $p<0.05$) with 76%, 56%, 52%, and 32% of the respondents from Grassland, Coastal Belt, Thornveld and Thicket respectively. Likewise, veld management differed significantly

($\chi2=11.75$, $p<0.05$) in terms of veld burning with 28%, 56%, 64%, and 28% of the respondents from Coastal Belt, Grassland, Thornveld and Thicket respectively, while no significance difference ($\chi2=1.14$, $p=0.77$) were recorded for rotational grazing between the vegetation types.

5.3.5 Farmers' perception on climate change

More than half (66%) of respondents, were concerned about climate change and have been aware of the changes in weather patterns over the past 20 years. In support of this nearly all respondents (99%) are convinced that increases in tick numbers are associated with changes in climate. Cattle farmers from both Thornveld and Thicket reported that changes in climate resulted in either long wet seasons or long dry seasons (40% and 60%, respectively). All the cattle farmers in the different vegetation types observed a delay in onset of the rainy seasons, a shorter rain seasons and warmer winters.

5.4. Discussion

The present study highlights the importance of and challenges associated with ticks and TBDs in communal cattle farming systems in the ECP. Cattle farmers are aware of the fact that there are different tick species and are concerned about the incidence of TBDs, the efficacy of compounds that are current being used at dip tanks and the role of climate change. The various aspects relating to the knowledge and perceptions of communal cattle farmers with regard to ticks and TBDs are discussed below.

From the study it is evident that cattle farmers were mostly males as opposed to females. This could be attributed to the fact that, traditionally, males always regard themselves as stock owners and the physical challenges associated with managing cattle in general and at dip tanks. This pattern is consistent with previous studies in the eastern and central regions of the ECP (Mapiye et al. 2009; Ndhlovu and Masika 2013; Katiyatiya et al. 2014) and with studies conducted in Nigeria and Tanzania (Kristjanson et al. 2010; Covarrubias et al. 2012).

Most of the respondents in the study were older than 50 years and 25% of respondents were aged between 71-80 years. This is a concern for the sustainability of livestock farming in communal areas and supports previous studies that observed poor participation by youth in agricultural activities in other rural areas (Mapiye et al. 2009; Nqeno et al. 2011). It is possible that this pattern is associated with the high cost of living as young adults and adults need to provide an income for themselves and their families and are thus forced to leave rural villages (where there is little or no work) for cities and towns in search of employment (Cross et al. 2005). In contrast, the elderly receive a monthly pension that is supplemented by cattle farming and or subsistence crop farming (Cross 2005). Undipped animals are ranked as one of the major constraints in tick control and it is possible that this may be due to the fact that elderly cattle owners may be physically unable to herd cattle over long distances (approximately 5 km) during dipping days. Another concerning factor is the limited scholarly training that most of the respondents have: more than half of respondents (65%) had primary level education, while a quarter (26%) had no school training. These results are in contrast with those of Ndlovu and Masika (2013), who reported that in Zimbabwe most (>90%) of the household members, had some formal training up to secondary level. Lack of basic education may influence a farmer's decisions regarding accurate dosages and other component of animal health programs, as in most cases the farmers are responsible for mixing the dipping compounds at the diptanks. The Eastern Cape Department of Rural Development and Agrarian Reform (ECDRDAR) government promote farmer's associations where it is easier to help a specific group of farmers than an individual farmer, but more than half (57%) of the interviewed farmers were not affiliated to any farmer's association. This is also a big concern as farmer's associations provide valuable information on prevailing diseases, recent disease outbreaks and animal health issues. Further, almost 60% of the respondents were not aware of restrictions on animal movement between the districts and that this action may complicate tick control due to the introduction of resistant tick species.

Evident from the study is that communal cattle farmers are aware of the fact that there are several tick species that occur on cattle. The predominant tick species reported by farmers were *A. hebraeum*, *R.* (*Boophilus*) spp. and *R. appendiculatus*, while *Hyalomma* spp and *R. evertsi evertsi* were less commonly observed. The tick species reported in the present study seem to be widely distributed in the ECP (Horak et al. 2009; Spickett et al. 2010) and were also recorded in previous studies in the ECP (Moyo and Masika 2009; Marufu et al. 2011) and the eastern part of the Free State Province (Mbati et al. 2002). Several of these species prefer to attach and feed on the posterior body parts of cattle (Howell et al. 1978), which is confirmed by the presence of high tick loads on the udder and scrotum regions in the present study. All of the reported tick species are associated with TBDs and or tick-induced toxicosis (Howell et al. 1978). Given the high prevalence of blue ticks (*R.* (*Boophilus*) spp.) it is not surprising that redwater (caused by *Babesia bovis* and *B. bigemina*) and gallsickness (caused by *Anaplasma marginale* and transmitted by both *R.* (*Boophilus*) spp.), were commonly recorded. Interesting to note is that the incidence of heartwater (caused by *Ehrlichia ruminantium* and transmitted by *A. hebraeum*) was predominantly recorded in communities within the lower lying vegetation types (Coastal Belt and Thicket, both <200 m). This is in contrast to a lower incidence (in Thornveld) and absence (in Grassland) in communities at higher elevations (>450 m). It is possible that the vector (*A. hebraeum*) was less abundant at higher elevations, which will concur with previous records that suggest that *A. hebrauem* is dependent on a combination of trees, shrubs and grass for cover and as such the tick is absent from grass dominated vegetation found at higher elevations (Howell et al. 1978; Nyangiwe et al. 2011). The two vegetation types at lower elevation (Coastal Belt and Thicket) are close to coast where environmental conditions, such a temperature, may be more stable. So the preference of *A. hebraeum* for lower elevation localities may be linked to vegetation and climatic factors. In support of this, *A. hebraeum* ticks were also absent on cattle examined at two high altitude communities (>1400m) in the ECP (Marufu et al. 2011). Ticks as vectors of TBDs are always reported as the major cause of cattle mortalities in the ECP (Mapiye et al. 2009; Marufu et al. 2010). In the present study, mortalities associated with TBDs were reported higher in Thicket and Thornveld compared to other vegetation types. These vegetation types have more structured vegetation cover, their climatic conditions are more less the same, and probably host abundance are similar compared than other types. With the exception of bont ticks, less tick abundance along the coast and this is also the conditions in more inland grassland areas (Nyangiwe et al. 2011; Marufu et al. 2011).

In communal farming areas, farmers are subsidized by government for dipping, and this may explain the reason that the majority of respondents prefer plunge dipping as a form of tick control though they do not only rely on registered acaricides, which are used in the dip tanks, to control ticks on their cattle. This is mainly due to the perception that the dip-wash is weak and not effective in killing ticks. These findings concurred with a study by Moyo and Masika (2009) who reported that respondents complained about the weak dip wash in the north-eastern region of the ECP. Similar findings were also recorded in the eastern Free State Province where 80% of the farmers experienced high tick challenge and tick related problems on their livestock although they were using commercial acaricides (Hlatshwayo and Mbati 2005). There may be several reasons for poor acaricide efficacy, for instance; the community member that is responsible for mixing the acaricide may unintentionally mix the wrong concentration due to a lack of basic education. Another reason can be that community members may intentionally mix a weaker concentration in an attempt to extend the availability of the compound. During the time of the survey, the ECP government was subsidising some communities with Triatix 500 TR® (Amitraz) dip which was supplied as 3 kg powder but farmers tend to use half (1.5 kg) of the compound claiming that the other half would be useful when government lacked the subsidy (Ndwayi 2014 personal communication). From the field data collected on the same locaties, where the dip-wash was reported to be weak and ineffectively, *R. microplus* was the most numerous species collected. *Rhipicephalus microplus* is strictly a parasite of domestic cattle and will only be found on other host species if they graze with cattle. Consequently virtually the whole population of *R. microplus* is exposed to every application of acaricide, thus enhancing the rapidity with which selection for resistance can take place. Therefore one would expect huge problems of resistance in areas where *R. microplus* is endemic. Irrespective the reason, frequent exposure of ticks to inadequate acaricide concentrations will facilitate the development of acaricide resistance, which is a major problem globally (Ntondini et al. 2008; Abbas et al. 2014). In particular, *R.* (*Boophilus*) spp. ticks are the most frequently associated with the selection for resistance to acaricides because they spend their whole life cycle on cattle (one-host ticks) and are thus more frequently exposed to chemical compounds than tick species with free-living stages (two- and three-host ticks), which have much less exposure. From the survey it is clear that farmers' supplement the current dip wash with alternative tick control methods such as used engine oil, jeyes fluid, chicken pecking and manual removal of ticks (deticking). These findings are in agreement with those of Masika et al. (1997), Mbati et al. (2002) and Moyo and Masika (2009). Use of engine oil and jeyes fluid should not be promoted as practice for farmers as the products both contain toxic substance and have been reported to be ecologically unfriendly (Moyo and Masika 2009). However, chickens (7%) and deticking (6%) were demonstrated as the lowest attribute for tick control strategies, and this is similar to earlier reports by Moyo and Masika (2009). Several farmers (40%) have also indicated that they prefer to farm with adaptive breeds such as Nguni and Brahman cattle as they are less susceptible to tick infestation. These findings are similar with those of Nqeno et al. (2011) who reported that farmers were keeping nondescript cattle that were the crosses between Nguni and Brahman. Furthermore, Marufu et al. (2011) reported that indigenous Nguni cattle are recommended for use in the integrated control of ticks in the communal areas of South Africa as they are more resistant to tick infestations than non-descript cattle.

In the present survey, veld burning and rotational grazing was not a preferred practise by communal farmers. Community members, whether cattle farmer or not, often burn their veld yearly during autumn or winter periods with no consultation from the agricultural extension officers for guidance. This frequency of burning in grassland and savanna vegetation causes the decline in density cover and increase the risk of soil erosion (Mentis and Tainton 1984). In practice, veld burning is used to stimulate out of season growth but there are farmers who burn their veld every year which usually impact on the grazing land during late autumn or winter

(Tainton 1999). Rotational grazing is mainly possible when there is infrastructure (camps), which was lacking in the study period and instead cattle were allowed to graze continuously. The occurrence of ticks is high when the grass sward is in a moribund and unacceptable condition for grazing by live-stock, which requires veld management. In much of southern Africa, it is common practice to burn natural pastures once every two or three years during spring to control shrub invasion and remove dead plant material. These deliberate fires coincide with the post-winter synchronous hatching of *R.* (*Boophilus*) larvae and with their questing on the vegetation and consequently many are destroyed. However, the use of fire in the management of vegetation for domestic livestock is well recognized as tick control strategy in South Africa provided appropriate procedures are followed (Horak et al. 2006; Spickett et al. 1992; Trollope 2011).

Almost all of the respondents are aware of changes in the climate and have reported an increase in cold summers and warm winters. The respondents also stated that tick abundances increased over the years and attribute that to climate change. Although milder more favourable climatic conditions can facilitate increased fecundity and survival of ticks (Estrada-Peña and Salman 2013), it is possible that the combined effect of acaricide resistance and climate change may result in elevated tick numbers. Similar studies in the Limpopo Province of South Africa reported long-term changes in climatic conditions in terms of rainfall and temperature (Bryan et al. 2009; Gbetibouo 2009). These climatic changes are expected to mostly affect communal rangeland farmers due to lack of resources and management technologies (Gbetibouo et al. 2010). Although studies (Lindgren et al. 2000; Githeko et al. 2000; Jaenson et al. 2012) have recorded a relationship between tick abundances and a change in climate, it should be noted that human activities and other factors can play a role in tick distribution and the disease they transmit.

Chapter 6

Conclusion & Recommendations

The study made use of a field-based approach to highlight the continued spread and potential adaptability of the invasive Asiatic blue tick, *R. microplus*, on cattle in South Africa and Namibia. In South Africa the tick has established successfully to preferred conditions and the study shows that it is now in the process of adapting to less optimal climatic conditions and vegetation types. In particular, in the fynbos dominated shrub vegetation in the Western Cape Province the tick, for now, seems to be localised to farming systems that have irrigated pastures. While in Namibia, the current restricted central distribution may merely be a reflection of a recent introduction. It is therefore predicted that over time the movement of cattle within the country will facilitate a range expansion to the north and south. In support of this a local scale study, in the Eastern Cape Province, again highlight the importance of cattle movement in the spread of tick species between different vegetation types. However, the study also suggests that some tick species may be absent from certain vegetation types due to a combination of factors such as microclimatic conditions and vegetation structure. However, the pattern is obscured by between-habitat movement of cattle and or village-related factors. Farmers' perceptions and knowledge of ticks and tick-borne diseases support several of the field-based outcomes in that the uncontrolled movement of cattle is a common practice and heartwater is not regarded as an important tick-borne disease in the Grassland vegetation where *A. hebraeun*, the vector, is absent.

Recommendations that can be made, based on the findings of the study are:

1) Cattle farmers should be encouraged to farm with breeds that are more resistant to infectious agents. Herein lays the value of indigenous breeds like Nguni, because they survive under conditions where other breeds, such as improved European cattle breeds, do not. More importantly, Nguni cattle are more resistance to ticks and tick-borne diseases. Farming with local breeds will save money and reduce the use of acaricides.
2) Management of acaricide resistance is vital. Animals must not be treated with an acaricide from the chemical group to which resistance is evident before moving them to clean area or rested pasture. Use of different chemical group is encouraged in such conditions.
3) Government must be stricter in regulations about controlling cattle movement within South Africa and between South Africa and neighbouring countries. Government must also support the services of animal extention officers that actively work within communities as they play a vital role in transferring information to farmers and local farmer associations. In addition, government must support regular information days in municipal areas. State-veterinarians have a much closer relationship with local communities and government must effectively budget to ensure that there are adequate resources (funds, capacity and training) to maintain this service.
4) Communal cattle farmers need to be part of local farmer associations and attend information days. These associations and events provide a valuable platform for the exchange of information between farmers and also between local and provincial government and farmers. For example, when and where restrictions are in place for movement of animals. Effective communication is important for the control of ticks and

tick-borne diseases and is a proactive approach to prevent disease outbreaks that can have defastating effect on the livelyhoods of local communities.

5) Farmer associations must be encouranged to identify one or two community members that will be responsible for managing and mixing of the dip wash on dip days. These members must be trained to work out the correct concentrations so that under dipping is limited. Associations must also keep a register of all farmers in the municipal region and relevant information of each farmer. This information can facilitate communication and effective management during disease outbreaks.

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Appendix A

Additional publication that was published by candidate durimg period that overlapped with PhD project.

Nyangiwe N, Harrison A, Horak IG. 2013. Displacement of *Rhipicephalus decoloratus* by *Rhipicephalus microplus* (Acari: Ixodidae) in the Eastern Cape Province, South Africa. Experimental and Applied Acaraology 61: 371-382.

Appendix B

Questionnaire

Tick Survey - Eastern Cape Province

Date:……………………………………..; Interviewer's Name………………………………………………..

District:………………………..; Local Municipality……………………….;Village…………………………..

GPS Coordinates: ……………………….S;………………………….E; Altitude………………………………

Farmer`s name:………………………………………. Age:………………… Gender: ………………………….

Level of education: Primary school☐Matric☐National certificate☐Diploma☐Degree☐None☐

Profession: Dip attendant ☐ Farmer ☐ Other……………………………………………..

Monthly income: <500☐500 - 2000☐2000-5000☐5000-10000☐>10 000

Are you a member of a farmer`s association? Yes☐ No☐

Livestock production

Number and livestock species kept (tick if kept & write down the number)

Cattle☐………Sheep☐…………..Goats☐…………Other……………..

Tick effect

Which effect of ticks have you observed in your animals

Udder/Teat damage☐ Skin damage☐ Scrotum☐ tick worry☐ tick borne disease☐ Other……………………….

In which part of cattle do you observe most ticks:………………………………...Age group or part of the body?

If age group: Which age group of the herd has the most ticks…………………………………………………

If body part: Which part of the animal's body is covered the most by ticks……………………………………

Tick borne disease	Prevalence (mark with X)
Heartwater	
Gallsickness	
Redwater	

Have you experienced any mortalities related to ticks? Yes☐No☐

If yes, how many animals have died in the past year…………………………

Veld/Grazing management

Do you have any form of rotational grazing or grazing certain areas at specific times while other areas are rested? Yes☐ No ☐

Do you burn your veld Yes☐ No☐

Why do you burn? Remove moribund ☐ Control ticks ☐

Where have you observed many ticks? Grassland☐ Medium shrub/bush☐ Encroached area☐

Have you recognised a difference in number of ticks in different vegetation types? Yes☐ No☐

Tick control

Do you control ticks in the following livestock and domestic animsl? Cattle☐Sheep☐Goats☐Dogs☐

Reasons for controlling……………………………………………………………………………………….

Reasons for not controlling……………………………………………………………………………………….

Frequency in summer: Weekly☐, After every two weeks☐ Once a month. Other………………………..

Frequency in winter: Weekly☐, After every two weeks☐ Once a month. Other………………………..

Control methods

Plunge dip ☐, Pour on dip ☐ Spraying ☐ other…………………………………………………………………

Complete the following table indicating the probable reason for tick problems? (Tick where appropriate) [On a scale from 1 to 5, where 5 is very severe, and 1 is less severe, please indicate how severe you think the level of the problem is]

Tick problem caused by	Tick appropriate	Severity (1 – 5)
Weak acaricide		
Poor mixing of acaricide		
Uncovered dip tanks roofs		
Uncleaned dip tanks		
Some of the animals are not dipped		

In case of animals with tick wounds do you treat them? Yes☐ No☐

Do you regularly check infestation levels of ticks in your animals? Yes☐No☐

Are you aware of any restrictions in movement of animals between districts? Yes☐ No☐

Management of dipping services

Who is involved in dipping management? Dipping committee☐Stockowners☐Dip attendant☐ Vet department☐ Other…………………………

Do stockowners contribute to the cost of dipping? Yes☐No☐

Is there a legislation which ensures punishment for failure to dip your animals? Yes☐No☐

What is the level of dipping in your village? All farmers dip their animals☐ 50% Dip☐, 25% Dip☐

Is your current dipping compound working efficiently? Yes☐No☐

If No, what do you suggest?
………
……

Complete the following table indicating challenges with dipping management? (Tick where appropriate) [On a scale from 1 to 5, where 5 is very severe challenge, and 1 is less severe, please indicate how severe you think the challenge is]

Dipping management challenge	Tick appropriate	Severity (1 – 5)
Collection of dipping chemical		
Cleaning of dip tank		
Filling of water in the dip tank		
Making sure all animals are dipped		

Response to the Tick challenge

What measures (integrated approach) have you taken besides use of acaricides to solve the problem of ticks (e.g use of tick resistant breeds etc)…………………………………………………………………

Knowlegde on ticks

Do you agree or disagree that you know a lot about ticks and diseases they cause

Strongly agree☐ Agree☐ Uncertain☐ Disagree☐ Strongly disagree☐ Don`t know☐

Do you know the life cycle of ticks? Yes/ No

Common ticks seen

Over the past 20 years, have you noticed new kinds of ticks in your grazing area/animals? Yes☐No☐

Blue ticks ☐ Brown ear tick ☐ Bont ticks ☐ Red-legged ticks ☐ Bont-legged ticks ☐ Yellow dog ticks ☐

In which animal species you observe the most of the ticks? Cattle☐Sheep☐Goats☐Dogs☐Horses☐ Other……………………………………………………..

In which part of the body have you observed many ticks? ………………………………………………

How frequent have you observed oxpeckers in your cattle? Once a week☐Once a month☐Once in two months☐ Seasonal ☐ Don`t know☐

Climate change (c/o causing degradation, hence environment for ticks changes also; temperature and rainfall changes affect ticks)

In general, how concerned are you about climate change? Very concerned☐ Fairly concerned☐ Not concerned☐ Don`t know☐

Do you agree or disagree that climate change is already affecting your area and tick prevalence? Strongly agree☐ Agree☐ Uncertain☐ Disagree☐ Strongly disagree☐ Don`t know☐

What might be the effect of climate change on tick prevalence and tick borne diseases?

Increase in tick numbers☐ Decrease in tick numbers☐ Other…………………………………………………..

Has the tick population been increasing or decreasing in the last 20 years? Increasing☐ Decreasing☐

Have you observed any changes in weather of the past 10 years? Yes☐No☐

Changes observed: Long dry season☐ Long wet season☐

How has been the change in vegetation? Overgrazed☐ Increase in bushes☐ No change☐ Other…………………………………

What kind of impact have you observed…………………………………………………………………………………….

………
………………………….

Thank You