Ticks (Acari: Ixodidae) Associated with Wild Herbivorous Mammals in South Africa

by

Habib Golezardy

Submitted in partial fulfilment of the requirements for the degree of

MAGISTER SCIENTIAE (Veterinary Science)

in the

Department of Veterinary Tropical Diseases

Faculty of Veterinary Science

University of Pretoria

Pretoria

2006

This dissertation is dedicated

with love and respect

to

my father, mother, sister

and

to all who taught me

how to cherish

the natural world and it's creatures

and

filled me with curiosity about its wonderings

Declaration

Apart from the assistance received that has been reported in the acknowledgements and in the appropriate places in the text,
this dissertation represents the original work of the author.

No part of this dissertation has been presented for
any other degree at any other university.

Candidate …Habib Golezardy….. **Date**….4th. September. 2006 …

Summary

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by

Habib Golezardy

Supervisor: Prof. I. G. Horak

The Republic of South Africa is rich in the species of large and small wild herbivores and ixodid ticks that infest them and the domestic livestock within its borders. The primary objective of this study was to determine the species composition and actual size of the tick burdens of a variety of small and large herbivorous animals in several localities in South Africa. To this end a total of 95 wild herbivores ranging in size from hares to giraffes and belonging to 25 species were examined at 20 various localities in South Africa. The survey localities in alphabetical sequence were the Addo Elephant National Park, "Bucklands" farm, the Eastern Shores Nature Reserve, the Hluhluwe Nature Reserve, the Karoo National Park, the Kgalagadi Transfrontier Park, a farm at Kirkwood, eight localities within the Kruger National Park, the Mountain Zebra National Park, the Tembe Elephant Reserve, the Thomas Baines Nature Reserve, the Umfolozi Nature Reserve, and the West Coast National Park. Sampling took place between 1982 and 1996.

The animal species surveyed were giraffe, *Giraffa camelopardalis*; African buffalo, *Syncerus caffer*; eland *Taurotragus oryx*; Burchell's zebra, *Equus burchelli*; black wildbeest, *Connochaetes gnou*; blue wildbeest, *Connochaetes taurinus*; tsessebe, *Damaliscus lunatus*; Lichtenstein's hartebeest, *Sigmoceros lichtensteinii*; bontebok, *Damalisus pygargus dorcas*; red hartebeest, *Alcelaphus buselaphus*; nyala, *Tragelaphus angasii*; bushbuck, *Tragelaphus scriptus*; greater kudu, *Tragelaphus strepsiceros*; gemsbok, *Oryx gazella*; springbok, *Antidorcas marsupialis*; grey rhebok, *Pelea capreolus*;

mountain reedbuck, *Redunca fulvorufula*; boer goats, *Capra hircus*; a domestic calf, *Bos* sp.; suni, *Neotragus moschatus*; steenbok, *Raphicerus campestris*; rock hyrax, *Procavia capensis*; cape ground squirrels, *Xerus inauris*; scrub hares, *Lepus saxatilis*; and Smith's red rock rabbits, *Pronolagus rupestris*.

Ticks were collected from the survey animals after they had been killed by a process of soaking in a tick-detaching agent followed by scrubbing and sieving, or by careful scrutiny after the animals had been chemically immobilized. Thirty ixodid tick species, namely *Amblyomma hebraeum, Amblyomma marmoreum, Rhipicephalus* (*Boophilus*) *decoloratus, Haemaphysalis parmata*, *Haemaphysalis silacea, Hyalomma glabrum, Hyalomma marginatum rufipes, Hyalomma truncatum, Ixodes rubicundus, Ixodes pilosus* group, *Margaropus winthemi, Rhipicephalus appendiculatus, Rhipicephalus arnoldi, Rhipicephalus capensis, Rhipicephalus distinctus, Rhipicephalus evertsi evertsi, Rhipicephalus exophthalmos, Rhipicephalus follis, Rhipicephalus glabroscutatum, Rhipicephalus gertrudae, Rhipicephalus kochi, Rhipicephalus maculatus, Rhipicephalus muehlensi*, *Rhipicephalus neumanni*, *Rhipicephalus* sp. near *pravus, Rhipicephalus theileri, Rhipicephalus simus, Rhipicephalus zambeziensis*, and an unidentified *Ixodes* and *Rhipicephalus* species were recovered from the animals. All the tick species recovered in this study have been tabulated according to their distributions within the climatic zone of the Republic of South Africa.

A total of 64 of the abovementioned herbivores ranging in size from medium to very large, belonging to 15 various species were examined in 11 national parks, or nature reserves or farms during 1982 - 1996. The tick species infesting the medium and small-sized animals were to some extent similar to those of very large animals. The medium-sized survey animals mostly harboured *A. hebraeum*, *R.* (*B.*) *decoloratus*, *R. appendiculatus*, *R. evertsi evertsi* and *R. glabroscutatum* whereas the tick burdens of the very large antelopes consisted mostly of *A. hebraeum*, *R.* (*B.*) *decoloratus*, *R. appendiculatus*, *R. maculatus* and *R. muehlensi*.

The very large hosts harboured proportionately more adult ticks than the smaller animals which harboured proportionately more immature ticks. An interesting finding was the recovery of *Rhipicephalus* sp. near *R. pravus* from giraffes in the north-eastern Mpumalanga province and these very closely resembled the true *R. pravus* which occurs in East Africa.

A further objective of this study was to make an inventory of the ixodid tick species infesting wild animals in three of the western, semi-arid nature reserves in South Africa. To this end the tick burdens of a total of 45 animals in the Karoo National Park, the Kgalagadi Transfrontier Park and the West Coast National Park were determined. Fourteen ixodid tick species were recovered, of which *H. truncatum*, *R. exophthalmos* and *R. glabroscutatum* were commonly present in two reserves and the remaining species each only in one reserve. *H. truncatum*, *R. capensis* and *R. glabroscutatum* were the most numerous of the ticks recovered, and eland were the most heavily infested with the former two species and gemsbok and mountain reedbuck with *R. glabroscutatum*.

Nine very small antelopes, six of which were steenbok and three were sunis and to my knowledge whose total tick burdens had never before been determined were also examined. The steenbok were examined in three nature reserves and harboured nine tick species and the sunis were examined in a fourth reserve and were infested with eight tick species. The steenbok and sunis were generally infested with the immature stages of the same tick species that infest larger animals in the same geographic regions. In addition the sunis harboured *H. parmata*, which in South Africa is present only in the eastern and north-eastern coastal and adjacent areas of KwaZulu-Natal Province. They were also infested with *R. kochi*, which in South Africa occurs only in the far north-east of the KwaZulu-Natal and Limpopo Provinces.

A further objective of the study was to assess the host status of African buffaloes for the one-host tick *R.* (*B.*) *decoloratus*. To this end the *R.* (*B.*) *decoloratus* burdens of ten buffaloes examined in three north-eastern KwaZulu-Natal Province (KZN) nature reserves were compared with those of medium-sized to large antelope species in these reserves and in the southern Kruger National Park (KNP), Mpumalanga Province. The *R.* (*B.*) *decoloratus* burdens of the buffaloes were considerably smaller than those of the antelopes in the KNP, but not those in the KZN reserves. The life-stage structure of the *R.* (*B.*) *decoloratus* populations on the buffaloes, in which larvae predominated, was closer to that of this tick on blue wildebeest, a tick-resistant animal, than to that on other antelopes. A single buffalo examined in the KNP was not infested with *R.* (*B.*) *decoloratus*, whereas a giraffe, examined at the same locality and time, harboured a small number of ticks. In a nature reserve in Mpumalanga Province adjacent to the KNP, two immobilized buffaloes, from which only adult ticks were collected, were not infested with *R.* (*B.*) *decoloratus*, whereas greater kudus, examined during the same time of year in the KNP harboured large numbers of adult ticks of this species. African buffaloes would thus appear to be resistant to infestation with *R.* (*B.*) *decoloratus*, and this resistance is expressed as the prevention of the majority of tick larvae from developing to nymphs.

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Barker, SC. Department of Microbiology and Parasitology, University of Queensland, Brisbane 4072, Queensland, Australia. s.barker@uq.edu.au

Dominguez, G. Servicio Veterinario Official de Salud Publica, Centro de Salud, 09572-Soncillo, Burgos, Spain. phetin@telefonica.net

Irwin, P. School of Veterinary Clinical Science, Division of Veterinary and Biomedical Science, Murdoch University, Murdoch, WA 6150, Australia. irwinp@numbat.murdoch.edu.au

Jongejan, F. Department of Parasitology and Tropical Veterinary Medicine, Faculty of Veterinary Medicine, Utrecht University, PO Box 80.165, 3508 TD Utrecht, Netherlands. F.Jongejan@vet.uu.nl

Oliver, J. H. Jr. Institute of Arthropodology and Parasitology, Department of Biology, P.O.Box 8056, Georgia Southern University, Statesboro, Georgia 30460, USA. joliver@Georgia Southern.edu

Poulin, R. Department of Zoology, University of Otago, P. O. Box 56, Dunedin, New Zealand. ROBERT.POULIN@STONEBOW.OTAGO.AC.NZ

Wikel, S. K. Centre for Microbial Pathogenesis, School of Medicine, University of Connecticut, Health Centre, 263 Farmington Avenue, MC3710, Farmington, CT 06030, USA. swikel@up.uchc.edu

Acknowledgements

I, Habib Golezardy, am most grateful to Ezemvelo KZN Wildlife, South African National Parks, and the Provincial Divisions of Nature Conservation of Mpumalanga Province and of the Eastern Cape Province for placing the animals in their reserves at our disposal, and for providing both assistance and facilities for processing the animals for tick recovery. I am particularly indebted to Dr Pete Rogers who facilitated the arrangements for the studies in the KZN nature reserves. The assistance of Ms M. Cohen, Dr J.P. Louw, Messrs Johan Sithole, Michael Knight and Eddie Williams with processing the immobilized animals or carcasses for tick recovery is greatly appreciated.

The Department of Veterinary Tropical Diseases of the University of Pretoria provided laboratory space for the conduct of this project and the University of Pretoria and the National Research Foundation provided financial support.

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Dr. A.C. Uys and Prof. I.G. Horak, of the Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria, and I, have been responsible for collecting the ticks present in the skin scrubbings obtained from the carcases of the survey animals. They and I have also been responsible for identifying and counting these ticks.

Chapter 1:

General introduction

"The entire wide world is little less,

but

parasites and sub-parasites"

Jonson, 1960

Introduction

If one assumes a broad view of parasitism, such as obligate feeding on a living organism without causing death to the host, then almost 50% of identified animal species can be classified as parasites (Price, 1980; Windsor, 1998). Parasitism as a highly specialised way of life is viewed as one of the most successful and common life styles that has developed and evolved independently in nearly every phylum of animals, and on at least as many occasions as other modes of life, such as predation (Roberts & Janovy, 1996; Poulin & Morand, 2000). It may be responsible for speciation, sexual dimorphism and various social behaviours among several types of animals (Keymer & Read, 1990), or for generating and maintaining genetic diversity within species (Haldane, 1949). Diversity of parasite species is closely related to the particular animal species parasitized and parasites may thus be ideal biological models for the study of ecological specialization, speciation mechanisms and diversification (May, 1986).

Parasitic infections compromise the host in some way, even in the wild. It is unusual to examine a domestic or wild animal without finding at least one species of parasite on or in it. Parasites include representatives from many phyla. Arthropods are involved in virtually every kind of parasitic relationship and may also function as vectors, transmitting infective stages of parasites to vertebrates. Ectoparasites are important causes of disease in animals, either through direct pathological effects, or as vectors of viral, bacterial, rickettsial or protozoal diseases (Windsor, 1998). They may even serve as definitive and intermediate hosts of other parasites and many parasite species are of great importance to medical and veterinary science.

At some stage of their life cycle ticks are versatile, resilient, ectoparasites of terrestrial vertebrates. They are highly adapted to a parasitic way of life through their morphology, physiology and behaviour, but may spend more than ninety percent of their lives off their hosts (Hoogstraal & Kim, 1985). Because of the direct and indirect effects on their hosts, ticks are regarded not only as a serious threat to successful stock farming, but also a very real hazard to human well-being in many parts of the world, particularly in Africa (Hoogstraal, 1956). The ticks present in a region are usually not specific to domestic livestock, but are parasites of the ungulates of the region, and are characteristic for the local biogeographical conditions (Cumming, 1998). Their ungulate hosts may consist largely, predominantly, or almost exclusively of domestic herbivores, depending on the coexistence, reduction, or disappearance of the wild ungulates that originally inhabited the region.

Tick systematics

a. Evolution of ticks

Studies on tick evolution previously placed emphasis on the hosts, arguing that the main driving force of tick evolution is host specificity. There is, however, a hypothesis suggesting that ticks evolved along with their hosts and that primitive ticks had ancient hosts (Oliver, 1989). However, various constituents in the ecology of ticks would appear to play a significant role in their evolution. Hoogstraal & Kim (1985) and earlier researchers also hypothesized that modifications in tick structure in different stages of the life cycle took place in association with the evolution and specialisation of particular hosts which were parasitized by each stage. These alterations and adaptations played a major role in tick evolution. That was the initiation of tick classification.

The origins of ticks go back to the late Silurian [43-417 MYA (Million years ago)] when ticks were considered as the earlier ancestors of terrestrial arachnids (Lindquist, 1984). However, based on comparison of the distribution of ixodid ticks worldwide, some believe that their origins only go back to the late Cretaceous [144- 65 MYA] where some of the presumably basal lineages are exclusively Australian and suggest a major role for Australia in the origin and evolution of ixodid ticks (Filippova, 1977).

b. Classification of ticks

The taxonomic assemblage referred to as ticks, is a relatively small group, comprising approximately 860 species (Horak, Camicas & Keirans, 2002). Within the vast phylum Arthropoda, ticks and their allies can be separated from insects and other mandibulate forms (Centipedes, Millipedes, and Crustaceans) into the subphylum Chelicerata on the basis of the presence of an anterior pair of chelicerae that function as trophic appendages.

Since this group of ectoparasites is more closely related to the spiders and scorpions, it has been placed in the class Arachnida, subclass Acari, which also includes all taxa commonly referred to as mites. The suborder of Ixodides (order Acarina) contains the hard and soft ticks of the families Ixodidae and Argasidae (Beaver, Jung & Cupp, 1984).

The Superfamily of Ixodiodea includes three families of ticks, namely Argasidae, Ixodidae and Nuttalliedae. There are approximately 860 spp. in 22 genera and three families (Keirans, 1992; Keirans & Robbins, 1999). Of the three families the Ixodidae (hard ticks) is the largest, consisting of more than 650 species (Hoogstraal, 1956). The Ixodidae and Argasidae are large and cosmopolitan families, whereas the Nuttalliellidae contains only one species (monotypic), which is restricted to some areas in South Africa and Tanzania (Bedford, 1934; Keirans, Clifford, Hoogstraal & Easton, 1976). In South Africa approximately 82 ixodid tick species have been identified (Walker, 1991).

The majority of ixodid ticks use three-hosts, one host for each stage of the life cycle (larva, nymph and adult), but in some species this has been reduced to two or even one host. The latter ticks spend two or more life cycle stages on the same host individual (Oliver, 1989). Ixodid ticks need several days to feed, and once the female is engorged she drops from the host to deposit several thousand eggs, and then dies. Argasid ticks feed intermittently and several species do not remain attached to their hosts. They may feed several times during their lifetime on a number of different hosts and lay a few hundred eggs in batches. Argasid ticks also exhibit remarkable longevity and live for many years and may endure long periods of starvation (Sonenshine, 1991).

The phylogenetic relationships of the three families of ticks, the Argasidae, Ixodidae and Nuttalliellidae, are unresolved. The monospecific Nuttalliellidae (*Nuttalliella namaqua*) has morphological features of both the Argasidae and Ixodidae (Keirans, Clifford, Hoogstraal & Easton, 1976), so its phylogenetic relationship to them is unclear. Although molecular analyses of the phylogenetic relationships of the Argasidae and Ixodidae have been done (Black & Piesman, 1994; Dobson & Barker, 1999), these studies did not include the Nuttalliellidae because so few individuals of *N. namaqua* have ever been found (Roshdy, Hoogstraal, Ranaja & El Shoura, 1983).

c. Morphology of ticks

Ticks are closely related in general body structure to parasitic mites. The separation of ticks from mites is based on two useful morphologic characteristics: firstly the occurrence of a hypostome (ventral mouthpart) that has been modified into a piercing organ (usually with recurved teeth) and secondly the presence of a distinct sensory apparatus (Haller's organ) on the dorsal aspect of the tarsus of the first leg (Krantz, 1978).

The conscutum covers nearly the entire dorsal surface of male ixodid ticks and so limits the amount of blood that can be ingested. Female ticks and larvae and nymphs also have a scutum, but it covers only the anterior third of the dorsum, thus allowing the tick to expand when engorging.

Biology of ticks

a. Life cycle of ticks

There are four stages in the life cycle of an ixodid tick, namely the egg, the larva, the nymph, and the adult (Sonenshine, 1991). The three instars (larva, nymph and adult) climb on to the vegetation in order to attach to a passing host or quest for a host from the soil surface. Once on the host, the tick crawls to a predilected feeding site where it cuts the skin with its chelicerae and inserts its hypostome that together with cement secreted by the salivary glands, anchors the tick firmly in place. The tick remains in place for several days (larva, 3–6 days; nymph, 4–7 days; adult female, 7–9 days) during which time active growth of gut and cuticle occurs in order to accommodate the blood meal, most of which will be acquired in the final 24 hours of engorgement. During feeding the blood meal is concentrated by the extraction of water, which is then secreted back into the host by specialised salivary gland cells and is an important means by which tick-borne pathogens invade their hosts. Once fully engorged the tick withdraws its hypostome and falls to the ground where it begins digesting the blood meal and developing to the next instar.

Digestion is slow, and development of the new instars takes several months in temperate regions. The newly moulted (or hatched) unfed tick may remain quiescent for a time, but will eventually ascend the vegetation to quest for a host and a blood meal. After the engorged female detaches from a host digestion of the blood meal and oogenesis take place followed by oviposition. The incubation period of the eggs varies with the species and ambient temperature. Embryogenesis usually lasts 20 – 50 days.

Ixodid ticks have substantial capability to swallow and concentrate a large volume of host blood, their rapid metabolism and body development can explain the on-host intervals. During off-host periods, ticks experience some environmental distress such as climate and temperature. High temperatures and body-water homeostasis are of importance in processes that influence off-host survival. Ticks as a group have this capability to survive without food and/or water longer than most other arthropods. Ixodid species usually spend an annual total of 12-21 days on the host compared to the off-host period (Needham & Teel, 1991).

Off-host fasting is characterized by slow metabolism with lengthy intervals of immobility, interrupted by movement within the microhabitat to increase water uptake, or to seek a position for detection of a passing blood-meal source. Spending a long period off the host gives the tick an opportunity to find a suitable species of animal to which to attach (Camin, 1963).

Ticks as gorging and fasting creatures, are considered to be two exceptionally different animals. A creature that is adapted for existing on a host body as a blood feeder, the other as a conservative one that can survive off the host and has the ability to expand its life strategies to adjust to the availability of water and energy resources to increase its chances of obtaining a blood meal (Knülle & Rudolph, 1982). Diversity in daily and seasonal behaviour influences both physiological ageing and the balance of energy and water resources.

Ticks may have one, two or three-host life cycles, depending on the species:

i. **One-host ticks**

Larvae hatch from eggs, climb on to a host, attach, engorge and moult on the host to nymphs. The nymphs re-attach, engorge and moult to males and females on the same host. The adult ticks re-attach to the same host, partially engorge and mate and the females engorge fully. After detaching from the host, the females drop to the ground and deposit eggs and eventually die.

With the elimination of the waiting period for a host and shortening of metamorphosis, the monoxenic cycle on the host is shortened to possibly 3-4 weeks. There are not many one-host species, but some are important from the veterinary point of view. One-host ticks include *Rhipicephalus* (*Boophilus*) *decoloratus*, *R.* (*B.*) *microplus*, and *Margaropus* species.

ii. Two-host ticks

After the new generation of larvae hatch from eggs laid by females, they climb on to the first host, engorge and moult to nymphs. The nymphs re-attach, engorge, detach, drop to the ground and moult to females and males. The adult ticks climb on to the second host, attach, partially engorge and mate. The females engorge fully, detach and drop to the ground and eventually lay eggs that give rise to the next generation. In the dixenic host life cycle, the three stages develop on two different individuals that may or may not belong to the same species. In the first, the engorged larva moults on the host and the nymph reattaches close by. At the end of the blood meal the nymph detaches and metamorphoses on the ground. There are only two searches for a host, which eliminate the risks linked with the need for nymphal host searching and attachment. *Hyalomma* species and some *Rhipicephalus* species belong to this group.

iii. Three-host ticks

Briefly, each stage of the parasitic cycle takes place on a different host. The fully engorged females detach from the third host, lay eggs in a sheltered locality and then die. *Amblyomma* species and the majority of *Rhipicephalus* species belong to this group. In the life cycle of a three-host tick, which is common to most ticks, host finding occurs three times. The tick requires three hosts (irrespective of the host species) for development and completion of its life cycle. There are three parasitic phases separated by two phases on the ground, when metamorphosis occurs (Shah-Fischer & Ralph Say, 1989; Walker, Bouattour, Camicas, Estrada-Peña, Horak, Latif, Pegram & Preston, 2003).

b. Tick ecology

Parasite distribution and dispersal between host populations is regarded as the most significant factor affecting the dynamics and co-evolution of host-parasite interactions. Theoretical studies have already demonstrated that parasite dispersal between distinct host territories can play a vital role in the evolution of local adaptation. The capability of parasites to disperse always depends on various factors such as the complexity of their life cycles, the number of propagules produced, the parasitic environment and the presence and duration of free-living stages.

Parasites have a close relationship with their hosts; therefore opportunities for dispersal should also depend on the mobility and characteristic of the involved hosts (McCoy, Boulinier, Tirard & Michalakis, 2003).

Factors limiting tick variability and population

Environmental variables, which occur over predetermined regions, are shared by a variety of species. The environment changes through either space or time, but in different ways and the position of a given point may be as important as its individual properties in understanding its place in the ecosystem (Legendre, 1993). Variations in the occurrence of organisms can be related to some extent to variations in the properties of the environment, and give valuable insights into the relationships between organism and its environment. There are a number of factors that can affect the localities where ticks are found:

a. Hosts

There are always variable potentialities for presence or absence of hosts (George, 1990; Klompen, Black, Keirans & Oliver, 1996; Cumming, 1998). Factors, including different host preferences of ticks (Hoogstraal & Aeschlimann, 1982), physiological compatibilities of hosts and ticks (Fivaz, Petney & Horak, 1992), survival of tick eggs (Dipeolu & Akinboade, 1984), successful attachment of ticks on various hosts (Bonsma, 1981), differences in host movements and habitat use and specific host behaviours such as their tendency to walk through or around clumps of undergrowth and bushes (MacLeod, 1975), tremble reflex (Bonsma, 1981) and grooming activities can influence the abundance of ticks in the environment (Fivaz & Norval, 1990). An integral and vital aspect of arthropod life cycles is accessibility of food. Since all tick species are obligate parasites, existence of food means availability of appropriate vertebrate hosts. Some ticks accept a wide variety of host species, others might be more selective, and some are extremely demanding and attach to only one host species (Oliver, 1989). Mammals serve as hosts for more tick species than other animals.

b. Dispersal ability

The ability of ticks to disperse throughout a region is related to some extent to preferred hosts. The main movement of ticks is climbing up and down the grass and bushes rather than along the ground (Londt & Whitehead, 1972). There is an argument whether ticks will deliberately climb onto unsuitable hosts for dispersal reasons, and then drop off without feeding. If ticks are consistently carried by hosts into areas where their eggs cannot survive, dispersal will instead lead to mortality.

It should be considered that long-range dispersal is always dependant on the host. Host movements may lead to an increase in tick's population in a particular region (Minshull & Norval, 1982).

c. Environment

The climate will determine the plant population and herbivore biomass in a habitat (Coe, Cumming & Pillipson, 1976), not to mention that it also affects the tick population directly. Factors such as rainfall, minimum and maximum daily temperatures, duration of intense periods (Needham & Teel, 1991), and seasonality can play potential roles in confining the tick population to a certain region (Rechav, 1984; Pegram, Perry, Musisi & Mwanaumo, 1986). Since many tick species deposit their eggs in the soil, its properties such as water retaining capacity and its roughness (as it might cause mechanical damage to the soft parts of ticks' body) will play an important role in the survival of eggs and juvenile ticks (Randolph, 1994). Vegetation cover and type can influence tick survival by improving environmental boundaries (Tukahirwa, 1976), through their influence on microclimate and in the course of interactions with various herbivores in the ecosystem (Coe, Cumming & Pillipson, 1976; Cumming, 1982).

The frequency and intensity of natural disasters and disturbances such as fire, seasonal changes, grazing levels, severe drought, and floods on tick populations in Africa have mostly not been documented and it seems that they reasonably affect tick populations in certain habitats (Wilson 1986; Spickett, Horak, Van Niekerk & Braack, 1992). During a severe drought, the animals are nutritionally stressed which can cause lower resistance to infestation and/or energy deficiency so that the animal stops grooming (O'Kelly & Seifert, 1969). This results in a higher tick burden.

Fire has secondary effects on tick abundance by altering landscape heterogeneity (Turner, Hargrove, Gardner & Romme, 1994) and the densities of grazing hosts in recently burned areas (Minshull & Norval, 1982). Ticks can live in areas where the habitat is considered inappropriate at a broader scale. Conversely, suitable areas can be converted into unsuitable areas or habitats over periods of time, for example such as sandy patches within woodland or pools of water within low-lying grassland. Microhabitat will be influenced by vegetation and also soil types in many instances, and is most likely to affect ticks by affecting their dispersal (Minshull & Norval, 1982). Strong evidence exists to suggest that the distribution of ticks in a habitat is determined by their microclimatic requirements (Lees, 1946; Londt & Whitehead, 1972).

d. Inter- and intraspecific competition

Ticks may compete with one another directly, for sites of attachment on the host, or indirectly through the mediation of host immune responses (Norval & Short, 1984; Matthysse, 1984). The adults and young of many tick species feed on different host species (Walker, 1974), which may be either an adaptive response to minimize competition or a simple consequence of differences in questing heights (Randolph & Storey, 1999).

e. Human activities

The distribution of ticks in a locality can be changed by the frequent use of the various kinds of pesticides (Norval, Perry, Meltzer, Kruska & Booth, 1994). Failure in tick control and the administration of pesticides can lead to rapid proliferation and growth in the tick population because of the huge number of eggs deposited (Norval, Short, & Chisholm, 1985).

Factors in the environment limiting tick population on the host

Tick populations on hosts are limited by varied mechanisms expressed through natural host-parasites relationships. On the other hand, the presence of the ticks is closely related to the presence of their hosts. An optimised and ideal host-parasite relationship is one where host and parasite coexist without any threat to other living species (Tatchell, 1987). Thus the implication of host-parasites relationships need to be studied and various patterns of these relationships need to be discussed in greater detail. Each tick species has its own behaviour and characteristics, which may affect its role in infesting domestic and wild vertebrate animals.

a. Host specificity

Host specificity is defined as an association between tick species and one or a group of vertebrate species for the continuation of ticks` life cycles. A variety of societal and cultural factors will raise host susceptibility and exposure to infectious agents, particularly parasites (Thompson, 2001). Ticks have conventionally been observed as comparatively host-specific and it has generally been believed that their geographic distributions can be determined by that of their host/hosts. The strict or limited degree of host specificity of the majority of tick species (at least 700 out of 800 ixodid species) have been determined (Hoogstraal & Aeschlimann, 1982).

Host-finding of ambushing tick larvae is achieved by a sequence of behavioural processes. Under natural conditions this behaviour pattern constitutes localization, identification and invasion of the tick's host (Sonenshine, 1991).

In a relatively recent review by Klompen *et al.* (1996) suggests that the perception of host specificity in ticks may be an artefact of incomplete sampling. The following are two hypotheses concerning tick-host associations: firstly, ticks choose their own hosts in a particular environment and secondly, ticks pick certain environments and feed only on the available hosts in the region (Cumming, 1998).

Hard ticks seek hosts by an interesting behaviour called "questing." Questing ticks crawl up the stems of grass or perch on the edges of leaves on the ground in a typical posture with the front legs extended, especially in response to a host passing by. Subsequently, these ticks climb on to a potential host, which has brushed against their extended front legs. Certain bio-chemicals such as carbon dioxide as well as heat and movement serve as stimuli for host seeking behaviour (Sonenshine, 1991).

The appearance of haematophagy in ticks started with the divergence of various hosts such as birds and mammals (Mans, Louw & Neitz, 2003). This suggests that evolution of ticks was influenced by ecological factors not host specificity. This may lead to environmental adaptation, but host diversity could have influenced the adaptation of ticks to the host's body systems (Klompen *et al.*, 1996).

Indeed, host specificity is an important biological factor in confining the geographical distribution and also population densities of tick species. Occasionally a tick species is dependant on a single host species. In this case, co-speciation of host and parasite may lead to topological similarities between their phylogenies (Brooks, 1979).

The host preference(s) of a particular parasite may provide valuable information on the history of its evolution. Nevertheless, tick evolution usually has been dependant on its relationship with hosts, and this is regarded as a guideline to finding the origins of the major tick genera. Larvae and nymphs feeding on various animals have expressed a variety of relationships that are characterized by stage specificity. Usually the immature stages of ticks are found on small sized hosts. This will ensure that a sufficient number of immature ticks will actually take benefit of the host's body to complete the life cycle. The larger number of ticks attaching to large animals will lead to a massive multiplication. Animals with inadequate resistance play an important role in this population growth (Hoogstraal & Kim, 1985; Tatchell, 1987; Cumming, 1998).

b. Stage and site specificity

One of the factors limiting the distribution of ticks on the host's body is the restriction of many tick species to certain parts of the body. This characteristic leads to reduction of the area available for attachment of any particular species. At the site of attachment, ticks cause skin irritation, which stimulates the animal to groom itself with the tongue. This act successfully limits the number of ticks feeding and engorging on these areas. Exposure to the sunlight and moisture frequently can prevent successful attachment and feeding at various sites. The common phenomenon of limitation of ticks to certain parts of the host body is thus either due to the host or characteristics of the environment and climate which are considered as evolutionary forces (Cupp, 1991; Hoogstraal & Aeschlimann, 1982; Tatchell, 1987; Norval, 1979). However, tick behaviour itself can restrict the distribution on the host and also sites of attachment. Some species of ticks have predilection sites for attaching, whereas in heavy infestations they will disperse throughout the host's body (Moorhouse, 1969).

Trager (1939) showed that hosts are capable of controlling their tick burdens. Certain aspects of host resistance to ticks became apparent over a period of time. The ability to acquire resistance is heritable and also the resistance outcome is density-dependant. The variation in host resistance is as important in the variability in tick numbers as changes in climate (Hewetson, 1972). Host resistance might vary seasonally, declining during cold seasons and rising during warm seasons. Changes in resistance are generally stress-related and factors such as nutrition and lactation, sex and age also play significant roles and contribute to the larger tick burdens of males compared to females (Tatchell, 1987).

c. Host immunity

Host-acquired immunity might be expressed in various ways. The outcome possibly will range from simple rejection of the parasite, increased feeding time, inadequate engorgement, infertility, or decreased viability of eggs, to fatality of ticks on the host's body (Willadsen, Muller & Baker, 1980). Immunity is the result of particular host-parasite interactions, and not necessarily a characteristic of the parasite or the host separately. Immunological interactions at the host-tick interface involve natural and acquired host defences and immuno-modulatory countermeasures by the tick (Wikel, 1996).

Present studies

The tick burdens of many large and small herbivorous animals have been determined in South Africa (Knight & Rechav, 1978; Horak, Potgieter, Walker, De Vos & Boomker, 1983), but not all species or regions of the country have been covered. Furthermore, it has been suggested that buffaloes are not suitable hosts for the tick species *R.* (*B.*) *decoloratus* (Norval, 1984) and this needs to be confirmed particularly as wildlife ranching with buffaloes is becoming more and more popular.

The geographic distributions of several ticks occurring in South Africa have been determined, plotted and illustrations of some of these distributions have been made (Howell, Walker & Nevill, 1978; Walker, Keirans & Horak, 2000; Walker *et al*., 2003). As new data are continuously being added, these illustrations cannot ever be considered to be complete, and thus all the data gathered in the various present surveys will assist in this respect.

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Chapter 2:

Materials and methods

Survey localities

Animals were examined for ticks at various localities in six of the nine provinces of South Africa listed below and illustrated in Fig. 1.

1. **Limpopo (Northern Province)**
    - Kruger National Park
        - Ngirivane
        - Nwashitsumbi
        - Pafuri
        - Satara
        - Sweni
        - Renoster Koppies

2. **Mpumalanga**
    - Kruger National Park
        - Mzanzene
        - Pretoriuskop
        - Skukuza

3. **KwaZulu-Natal**
    - Eastern Shores Nature Reserve

- Hluhluwe Nature Reserve
- Tembe Elephant Reserve
- Umfolozi Nature Reserve

4. Northern Cape

- Kalahari National Gemsbok Park (now part of the Kgalagadi Transfrontier Park)

5. Eastern Cape

- Bucklands farm
- Farm at Kirkwood
- Mountain Zebra National Park
- Thomas Baines Nature Reserve

6. Western Cape

- Karoo National Park
- Langebaan National Park (now part of the West Coast National Park)

Survey period

Large, medium-sized and small herbivorous mammals were examined in various surveys in the above-mentioned localities during the period 1982 to 1996.

Fig 1: Map of South Africa

Survey animals

A total of 95 animals belonging to 25 species were processed for ectoparasite recovery. These animals were culled especially for survey purposes. After they had been shot their carcasses were transported to the nearest field laboratory for processing for the collection of ectoparasites from their skins. The animals examined in the various surveys are listed in Tables 1, 2 and 3.

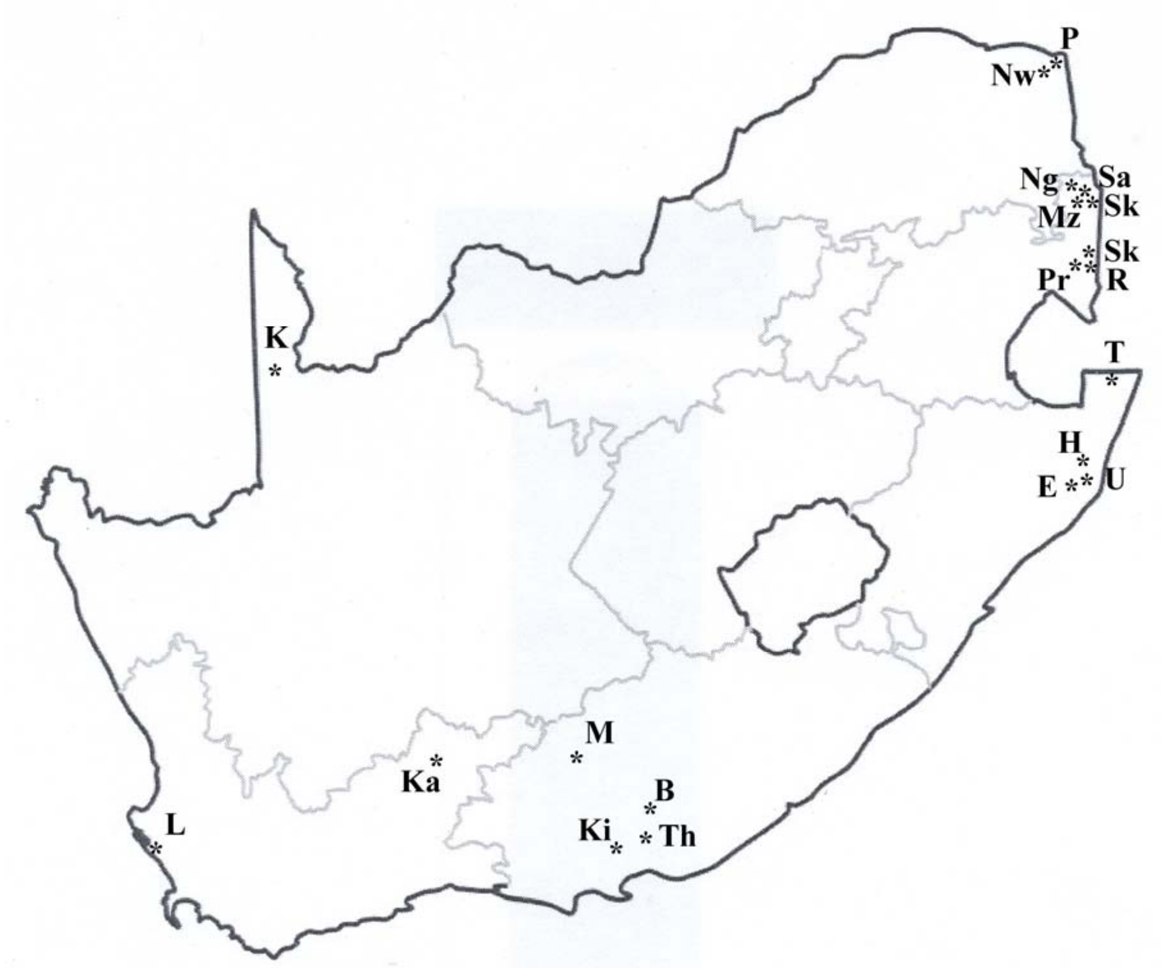

Fig 2: Approximate location of various survey localities in South Africa

P= Pafuri. **Nw**= Nwashitsumbi. **Ng**= Ngirivane. **Sa**= Satara. **Sw**= Sweni. **Mz**= Mzanzene. **Sk**= Skukuza. **Pr**= Pretoriuskop. **R**= Renoster Koppies. **T**= Tembe National Elephant Reserve. **H**= Hluhluwe Nature Reserve. **U**= Umfolozi Nature Reserve. **E**= Eastern Shores Nature Reserve. **B**= Bucklands farm. **Ki**= Farm at Kirkwood. **Th**= Thomas Baines Nature Reserve. **M**= Mountain Zebra National Park. **Ka**= Karoo National Park. **L**= West Coast National Park. **K**= Kgalagadi Transfrontier Park.

TABLE 1: Very large species of animals examined for ixodid ticks

Species of animals	**Scientific names**	**Localities**
Giraffe **(4)**	*Giraffa camelopardalis*	Kruger National Park
African buffalo **(12)**	*Syncerus caffer*	Eastern Shores, Umfolozi, and Hluhluwe Nature Reserves
Eland **(6)**	*Taurotragus oryx*	Kgalagadi Transfrontier Park, Thomas Baines Nature Reserve and West Coast National Park

TABLE 2: Large to medium-sized species of ungulates examined for ixodid ticks

Species of animals	**Scientific names**	**Localities**
Burchell's Zebra **(4)**	*Equus burchelli*	Kruger National Park
Black wildbeest **(4)**	*Connochaetes gnou*	Karoo and Mountain Zebra National Parks
Blue wildbeest **(2)**	*Connochaetes taurinus*	Kgalagadi Transfrontier Park
Tsessebe **(2)**	*Damaliscus lunatus*	Kruger National Park
Lichtenstein's hartebeest **(1)**	*Sigmoceros lichtensteinii*	Kruger National Park
Bontebok **(2)**	*Damalisus pygargus dorcas*	West Coast National Park
Red hartebeest **(2)**	*Alcelaphus buselaphus*	Kgalagadi Transfrontier and Mountain Zebra Parks
Nyala **(2)**	*Tragelaphus angasii*	Kruger National Park
Bushbuck **(3)**	*Trangelaphus scriptus*	Kruger National Park
Greater kudu **(5)**	*Tragelaphus strepsiceros*	Bucklands Farm , Kruger National Park
Gemsbok **(9)**	*Oryx gazella*	West Coast National and Kgalagadi Transfrontier Parks
Springbok **(8)**	*Antidorcas marsupialis*	Karoo, West Coast National and Kgalagadi Transfrontier Parks
Grey rhebok **(2)**	*Pelea capreolus*	Karoo National Park
Mountain reedbuck **(2)**	*Redunca fulvorufula*	Karoo National Park
Boer goats **(5)**	*Capra hircus*	Farm at Kirkwood
Domestic calf **(1)**	*Bos* sp.	Bucklands farm

TABLE 3: Small species of animals examined for ixodid ticks

Species	Scientific names	Localities
Suni **(3)**	*Neotragus moschatus*	Tembe National Elephant Reserve
Steenbok **(6)**	*Raphicerus campestris*	Kgalagadi Transfrontier Park, Kruger and Mountain Zebra National Parks
Rock hyrax (dassie) **(4)**	*Procavia capensis*	Karoo and West Coast National Parks
Cape ground squirrels **(3)**	*Xerus inauris*	Kgalagadi Transfrontier Park
Scrub hares **(3)**	*Lepus saxatilis*	Karoo and Kgalagadi Transfrontier Parks
Smith's red rock rabbits **(2)**	*Pronolagus rupestris*	Karoo National Park

Tick collection

At the field laboratories with the exception of the rock dassies, ground squirrels, scrub hares and red rock rabbits the carcass was skinned and half of the skin of the head, half the skin of the body and upper legs, the whole skin of the tail as well as one lower front leg and one lower back leg with skin attached were placed separately in heavy-duty plastic bags. A tick-detaching agent (Triatix: Afrivet) was added to the skins in the bags and these were tightly secured and stored overnight. The following morning the skins were thoroughly washed and then scrubbed with brushes with steel bristles. The washings and scrubbings were sieved over stainless steel sieves with mesh apertures of 250 µm, and the contents of the sieves were collected and preserved with 10% formalin in labelled bottles (Horak, Boomker, Spickett & De Vos 1992). The labels included animal species name and sex, date of collection, locality, and body part. These bottles were transported to the Ectoparasitology Laboratory of the Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria for further processing.

The smaller animals were not skinned, but their lungs, hearts, livers and gastro-intestinal tracts were removed before their carcasses were immersed in tick detaching agent in heavy-duty plastic bags and left there overnight (Horak, Sheppey, Knight & Beuthin 1986). The following morning the skins were thoroughly washed and then scrubbed with brushes with steel bristles and the washings and scrubbings treated in the same way as those of the large animals

At the laboratory one sample at a time was processed. The total contents of the bottle were measured in a measuring cylinder and the volume recorded. Then the contents were poured into a container, and using a pressurized air pump the contents were thoroughly mixed. During mixing, one third of the total contents was collected, sieved and washed with a strong jet of water over a steel mesh sieve, with 250 µm apertures. The content of the sieve were transferred to a container and from there, bit by bit into a square perspex tray and examined under a stereoscopic microscope for ticks, lice and other ectoparasites. The remaining 2/3rds of the contents was poured onto a sieve with 150 µm apertures and washed under a strong jet of water. The contents of this sieve were examined following the same procedure as before, but only for adult ticks. The ectoparasites so collected were either identified immediately or preserved in 70% ethyl alcohol for later identification and counting.

Tick identification

After sorting and processing all the samples from a particular locality, the ticks present in them were identified and counted under a stereoscopic microscope. The process of tick identification included three steps. The first step led to the name of the genus to which a tick belongs, the sex, and the stage of development, if it was still immature. The second step selected the species of that particular genus that occur in the area where the unidentified tick was collected. The third step identified the tick to species level. Steps 1 and 3 involved visual matching.

Data presentation

The dissertation has been constructed in such a manner that it consists of a general introduction, general Materials and Methods followed by the Results and their discussions presented in the form of four manuscripts, namely “Ticks (Acari: Ixodidae) of large herbivorous mammals in South Africa”; “Ticks (Acari: Ixodidae) collected in three of the western, semi-arid parks of South Africa"; "Ticks (Acari: Ixodidae) of suni, *Neotragus moschatus* and steenbok, *Raphicerus campestris*"; and "African buffalo, *Syncerus caffer*, as hosts of *Rhipicephalus* (*Boophilus*) *decoloratus*". The latter format necessitated inclusion of the tick burdens of some animals in more than one of these manuscripts. This dissertation concludes with a general Discussion.

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Chapter 3:

Ticks (Acari: Ixodidae) of large herbivorous mammals in South Africa

Introduction

Ticks have always been regarded as a constraint to farming with domestic or wild animals in South Africa with its vast number of wildlife reserves and farms and numerous species of large and medium-sized herbivorous wildlife species. When problems arise on these farms or reserves studies of ixodid tick burdens reveal the involvement of either a single or several tick species on a single host or on a number of hosts. Parasite distribution and dispersal between host populations is regarded as the most significant factor affecting the dynamics and co-evolution of host-parasite interactions (Price 1980; McCoy, Boulinier, Tirard & Michalakis, 2003).

Theoretical studies have demonstrated that parasite dispersal between distinct host territories can play a vital role in the evolution of local adaptation. The ability of a parasite to disperse depends on various factors such as the complexity of its life cycle, the number of propagules produced, the parasitic environment and the presence and survival of its free-living stages. Because of the close relationship between parasites and their hosts, opportunities for dispersal would thus also depend on the characteristic of the hosts involved (McCoy *et al.*, 2003).

The study of how tick diversity varies can offer various insights into the ecology of these parasites. In an ideal world, diversity data can be obtained through non-destructive live-sampling in various localities, but when sampling demands a dead host to be sampled the sampling locality is usually dictated by the availability of animals that are going to be killed for various reasons. In this study the diversity of ticks on large herbivorous mammals has been examined to answer three questions:

1. Is the diversity of tick assemblages repeatable among the same host population?

2. Does the similarity in the composition of the tick population among the same host population decay with geographical distance?
3. Does the diversity of the tick assemblage correlate with climatic variables?

The geographic distributions of many ixodid ticks occurring in South Africa have already been determined and some of these distributions have been illustrated (Howell, Walker & Nevill, 1978; Walker & Olwage, 1987; Walker, Keirans & Horak, 2000; Walker, Bouattour, Estrada-Peña, Horak, Latif, Pegram & Preston, 2003). The tick burdens of herbivorous animals of various sizes have also been determined in a variety of surveys in various localities in South Africa (Horak, Potgieter, Walker, De Vos & Boomker, 1983a; Horak, De Vos & Brown, 1983b; Horak, De Vos & De Klerk, 1984; Horak, MacIvor, Petney & De Vos, 1987; Fourie, Vrahiminis, Horak, Terblanche & Kok, 1991a; Horak, Knight & Williams, 1991b; Horak, Fourie, Novellie & Willliams, 1991c; Horak, Boomker, Spickett & De Vos, 1992b; Horak, Boomker & Flamand, 1995; Horak, Gallivan, Braack, Boomker & De Vos, 2003).

However, additional data are required on an ongoing basis in order to fine-tune the geographic distributions of ticks, as well as make comparisons between their historic distributions and their current distributions in the light of climate changes accompanying global warming. Furthermore, because of a lack of data the geographical distributions of some of the uncommon tick species have not been determined and the data gained in the present survey will help in this respect.

Materials and methods

- **Survey localities**

1. Bucklands farm

The Bucklands farm is 5 480 ha in extent, and is situated at 33˚ 07´ S; 26˚ 42´ E in the Great Fish River Valley, 50 km north of Grahamstown in the Eastern Cape Province. It shares a common 11 km boundary with the Andries Vosloo Kudu Reserve (AVKR). The climate is very mild. Acocks (1975) classifies the vegetation of this area as Valley Bushveld. A more detailed description on the farm has been given by Rechav (1982).

2. Eastern Shores Nature Reserve

The Eastern Shores Nature Reserve consists of an area of roughly 250 km^2 at the southern end of the Mosambique coastal plain, between 27˚ 51´ and 28˚ 25´ S latitude and 32˚ 20´ and 32˚ 40´ E longitude. The vegetation is of the Zululand Palm Veld type, subdivision of Coastal Thornveld and Coastal communities (Acocks, 1988).

3. Farm at Kirkwood

The Farm at Kirkwood (25˚ 28´ E, 23˚ 25´ S) is located 25 km north of the Addo Elephant National Park in the Eastern Cape Province. The vegetation of this region is classified as Valley Bushveld (Acocks, 1988).

4. Hluhluwe Nature Reserve

The Hluhluwe Nature Reserve (28˚ 07′ S; 32˚ 03′ E) is about 150 – 450 m above the sea level in the north-eastern inland of KwaZulu-Natal Province. The vegetation is classified as Zululand Thornveld and Lowveld (Acocks, 1988).

5. Karoo National Park

The Karoo National Park (32º 12´-32º 20´ S; 22º 25´-22º 39´ E) is situated in a semi-arid region (hot summers and cold winters with snow on the high lands) near the town of Beaufort West in the north-western part of the Western Cape Province at an altitude of 600-1932m. It comprises an area of 17 706 ha. The vegetation consists of typical Karroid Broken Veld (Acocks, 1988; White, 1983).

6. Kgalagadi Transfrontier Park

The Kgalagadi Transfrontier Park (27º 13′ S, 22º 28′ E) now includes the old Kalahari Gemsbok National Park, and is located in a semi-arid region in the north western part of South Africa and extends into the neighbouring countries of Namibia and Botswana. The vegetation is a mosaic of lightly wooded grassland on the dune crests, pure grassland in shallow depressions between the dunes and *Rhigozum trichotomum* shrubby grassland in deeper hollows where the underlying calcrete is near the surface (Acocks, 1988; White, 1983).

7. Kruger National Park

The Kruger National Park, which is approximately 2 Million ha in size, is situated in the eastern Lowveld of Mpumalanga and Limpopo Provinces and the landscape zones of the park have been described in some detail by Gertenbach (1983). The region has warm to hot days in summer and a mild winter. The average rainfall ranges from 600 – 700 mm per annum. The vegetation is classified mainly as Lowveld, but can fall into four categories namely, Arid Lowveld, Mopani Veld, Lowveld and Lowveld Sour Bushveld (Acocks, 1975, Anonymous, 1984).

Animals were available for examination at Mzanzene (24˚ 29΄ S, 31˚ 38΄ E, 30 km south west of Satara, Lowveld type), Ngirivane (24˚ 21΄ S, 31˚ 42΄ E, 12 km north-west of Satara, Arid Lowveld), Nwashitsumbi (22˚ 47΄ S, 31˚ 16΄ E, 21 km south east of Punda Maria, Lowveld Sour Bushveld), Pafuri (23˚ 27΄ S, 31˚ 19΄ E; Alt. 305m, mixed bushveld), Pretoriuskop (25˚ 10΄ S, 31˚ 16΄ E, Lowveld type), Renoster Koppies (25˚ 07΄ S, 31˚ 36΄ E, 15 km due south of Skukuza, Lowveld type), Satara (24˚ 23′ S, 31˚ 47΄ E; Alt. 275m; Arid Lowveld and Lowveld), Skukuza (24˚ 58΄ S, 31˚ 36΄ E; Alt. 262m, Lowveld type), Sweni (24˚ 29΄ S, 31˚ 49΄ E, 22 km south-east of Satara, Arid Lowveld type) in the Kruger National Park .

8. West Coast National Park (Langebaan National Park)

The Langebaan National park (33º 06΄- 33º 10΄ S; 17º 57΄- 18º 02΄ E; Alt. 0-50m) has been incorporated into the West Coast National Park and is situated in a semi-arid region on the west coast of the Western Cape Province and comprises an area of 24779 ha. The vegetation consists of Strandveld and isolated patches of Coastal Fynbos. The park falls within the winter rainfall region where summers are moderate to hot, and winters cold and wet (Acocks, 1988; White, 1983).

9. Mountain Zebra National Park

The Mountain Zebra National Park (32º 15´ S; 24º 41´ E; Alt.1200–1957m) comprises an area of 6536 ha in extent and is located 20 km south-west of Cradock in the Eastern Cape Province. Fourie (1983) has given a detailed description of the physiography and climate of this park. The vegetation in the park consists of Karroid *Merxmeullera* Mountain Veld replaced by Karoo on the higher slopes and Karroid Broken Veld in the northern section.

10. Thomas Baines Nature Reserve

The Thomas Baines Nature Reserve (33˚ 23´ S; 26˚ 28´ E) is a provincial nature reserve and is located in the Eastern Cape Province to the south of Grahamstown. It is situated at 335-518 m above sea level and the vegetation is classified as False Macchia, Eastern Province Thornveld and Valley Bushveld (Acocks, 1988).

11. Umfolozi Nature Reserve

The Umfolozi Game Reserve (28˚ 12´ - 28˚ 21′ S; 31˚ 42´ - 31˚ 59′ E), is 47 753 ha in extent and is situated in a hilly area of the country, at about 130-600m above sea level in north-eastern KwaZulu-Natal Province. Two vegetation types, namely Zululand Thornveld (along the slopes and crests of the hills) and Lowveld (in the valleys) are recognized (Acocks, 1988).

- **Survey animals**

  The animals examined were either immobilized or culled especially for survey purposes or were killed for other reasons and their skins made available for the collection of ticks. A total of 64 wild herbivores ranging in size from medium to very large, belonging to fifteen species (Tables 1 & 2), were examined in the 12 above mentioned national parks, nature reserves and farms. Five Boer goats and a domestic calf, which were also examined for ticks in the Eastern Cape Province, have been included in this section for comparative purposes with the wildlife.

- **Survey period**

  The animals were either chemically immobilised or killed for the purpose of this study during the period 1982 to 1996.

- **Tick recovery**

  The dead animals were skinned and their skins were processed for ectoparasite recovery as described by Horak, Boomker, Spickett & De Vos (1992b). The immobilized animals were carefully examined for adult ticks and these were collected. The ticks collected from the various animals were identified to species and stage of development under a stereoscopic microscope and counted.

TABLE 1: Medium-sized to large herbivorous species involved in the study

Common name	**Date of examination**	**Locality**	**Scientific name**
Burchell's zebra	28.08.83	Kruger National Park	*Equus burchellii*
Burchell's zebra	28.08.83	Kruger National Park	
Burchell's zebra	28.08.83	Kruger National Park	
Burchell's zebra	18.07.85	Kruger National Park	
Red hartebeest	15.02.84	Mountain Zebra National Park	*Alcephalus buselaphus caama*
Red hartebeest	09.10.84	Kgalagadi Transfrontier Park	
Black wildebeest	10.05.83	Mountain Zebra National Park	*Connochaetes gnou*
Black wildebeest	10.09.85	Mountain Zebra National Park	
Black wildebeest	08.02.91	Karoo National Park	
Black wildebeest	08.02.91	Karoo National Park	
Blue wildebeest	02.10.84	Kgalagadi Transfrontier Park	*Connochaetes taurinus*
Blue wildebeest	04.10.84	Kgalagadi Transfrontier Park	
Blue wildebeest	06.10.84	Kgalagadi Transfrontier Park	
Tsessebe	03.11.80	Pretoriuskop - Kruger National Park	*Damaliscus lunatus lunatus*
Tsessebe	06.10.82	Pretoriuskop - Kruger National Park	
Tsessebe	03.06.83	Pretoriuskop - Kruger National Park	
Lichtenstein's hartebeest	Exact date unknown - 96	Unknown - Kruger National Park	*Sigmoceros lichtensteinii*

TABLE 1: Continued

Common name	Date of examination	Locality	Scientific name
Bushbuck	04.04.90	Unknown - Kruger National Park	*Tragelaphus scriptus*
Bushbuck	11.05.92	Pafuri – Kruger National Park	
Bushbuck	04.09.92	Pafuri – Kruger National Park	
Nyala	03.10.92	Pafuri –Kruger National Park	*Tragelaphus angasii*
Nyala	03.04.93	Pafuri –Kruger National Park	
Greater kudu	18.10.82	Satara - Kruger National Park	*Tragelaphus strepsiceros*
Greater kudu	20.09.83	Renoster Koppies - KNP	
Greater kudu	18.07.84	Bucklands farm	
Greater kudu	18.07.85	Nwashitsumbi - Kruger National Park	
Greater kudu	04.09.92	Pafuri – Kruger National Park	
Gemsbok	03.10.84	Kgalagadi Transfrontier Park	*Oryx gazella*
Gemsbok	06.10.84	Kgalagadi Transfrontier Park	
Gemsbok	06.10.84	Kgalagadi Transfrontier Park	
Gemsbok	07.10.84	Kgalagadi Transfrontier Park	
Gemsbok	08.10.84	KgalagadiTransfrontier Park	
Gemsbok	08.10.84	Kgalagadi Transfrontier Park	
Gemsbok	08.10.84	Kgalagadi Transfrontier Park	
Gemsbok	20.02.90	West Coast National Park	
Gemsbok	20.02.90	West Coast National Park	

KNP = Kruger National Park

TABLE 1: Continued

Common name	Date of examination	Locality	Scientific name
Domestic calf	11.07.84	Bucklands farm	*Bos* sp.
Boer goat	31.10.86	farm at Kirkwood	*Capra hircus*
Boer goat	31.10.86	farm at Kirkwood	
Boer goat	31.10.86	farm at Kirkwood	
Boer goat	31.10.86	farm at Kirkwood	
Boer goat	31.10.86	farm at Kirkwood	

ABLE 2: Very large herbivorous species involved in the study

Common name	Date of examination	Locality	Scientific name
Giraffe	27.09.85	Satara - Kruger National Park	*Giraffa camelopardalis*
Giraffe	20.05.86	Ngirivane - Kruger National Park	
Giraffe	29.07.86	Sweni (east) - Kruger National Park	
Giraffe	30.07.86	Sweni (east) - Kruger National Park	
Eland	06.07.84	Thomas Baines Nature Reserves	*Taurotragus oryx*
Eland	07.07.84	Thomas Baines Nature Reserves	
Eland	08.10.84	Kgalagadi Transfrontier Park	
Eland	08.10.84	Kgalagadi Transfrontier Park	
Eland	22.02.90	West Coast National Park	
Eland	22.02.90	West Coast National Park	

TABLE 2: Continued

Common name	Date of examination	Locality	Scientific name
African buffalo	26.09.85	Satara - Kruger National Park	*Syncerus caffer*
African buffalo	13.11.85	Thomas Baines Nature Reserve	
African buffalo	03.07.94	Eastern Shores Nature Reserve	
African buffalo	03.07.94	Eastern Shores Nature Reserve	
African buffalo	09.06.94	Umfolozi Nature Reserve	
African buffalo	10.06.94	Umfolozi Nature Reserve	
African buffalo	10.06.94	Umfolozi Nature Reserve	
African buffalo	11.06.94	Umfolozi Nature Reserve	
African buffalo	14.06.94	Hluhluwe Nature Reserve	
African buffalo	14.06.94	Hluhluwe Nature Reserve	
African buffalo	15.06.94	Hluhluwe Nature Reserve	
African buffalo	16.06.94	Hluhluwe Nature Reserve	

Results and discussion

General observations

We have used the method described by Horak, Boomker, Spickett & De Vos (1992b) for the recovery of ticks since the ticks recovered by this method are mostly undamaged and hence easier to identify even though the actual numbers recovered may not represent the total tick burden (MacIvor, Horak, Holton & Petney, 1987; Van Dyk & McKenzie, 1992). The fact should also be considered that whatever method is used, a number of ticks are likely to have detached by the time the carcasses are skinned.

In the context of our current knowledge, and given the large species ranges and apparently high dispersal ability of many tick species, the present results confirm that the distributions of African ticks are typically determined by the direct effects of environmental variables. Factors such as climate and the vegetation are now generally considered as the broad-scale factors that determine the species ranges of ticks and also serve as predictors of tick diversity within a region (Walker, 1974; Norval, 1977; Cumming, 2002). However, Cumming's (2002) categorical analysis shows that climate is a considerably better predictor of tick distributions than vegetation type.

The results of many recent surveys support the proposals made by MacLeod (1970) and Horak (1982) who stated that the intensity of tick infestation is proportional to body mass. This hypothesis has also been assessed by Gallivan & Horak (1997) who demonstrated that the larger the host species, the more ticks it will generally harbour. In this respect the current survey will provide a relatively good comparison with previous data.

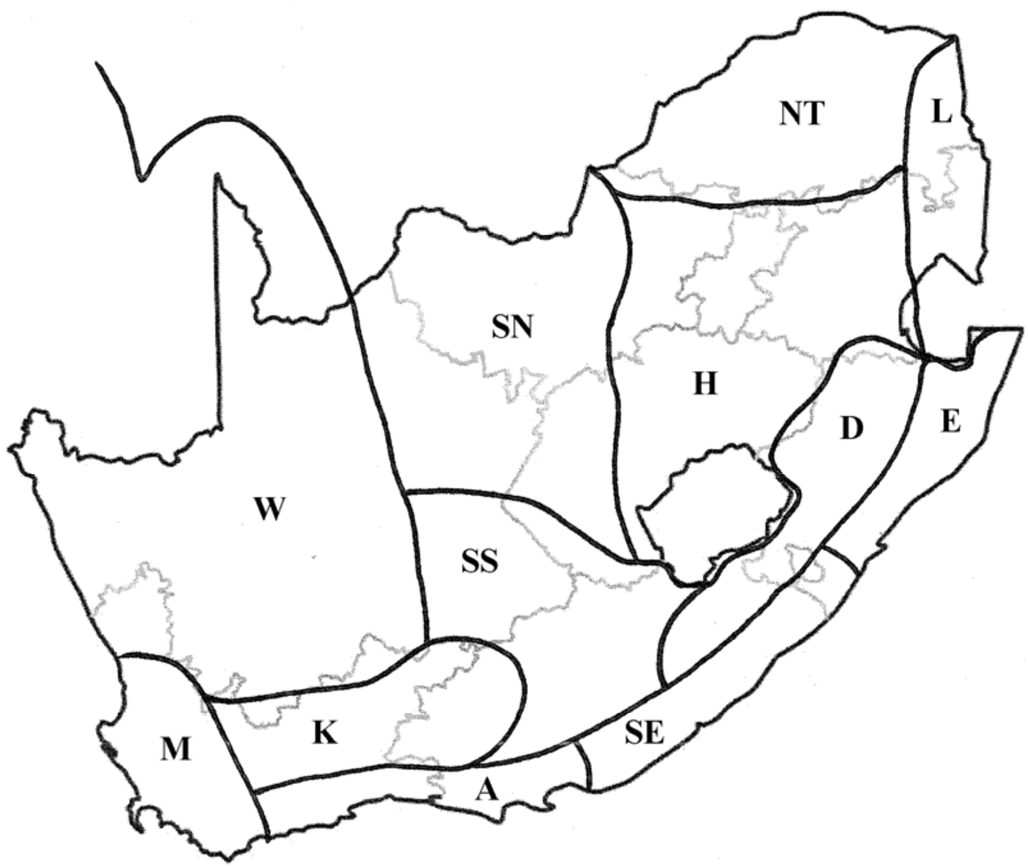

Fig 1: The climatological regions of the Republic of South Africa
(Compiled by the climatology branch, Weather Bureau, Pretoria 1956)

M = Winter rains, hot dry summer. **A** = Temperate, warm and moist, occasional hot and dry "bergwinds". **K** = Desert and transition zone from winter to summer rains. **SE** = Warm, temperate and moist. **E** = Warm and moist. **D** = Warm, temperate monsoonal type of climate. **L** = Subtropical, warm and muggy except in midwinter. **NT** = Subtropical, semi-arid. **H** = Warm, temperate monsoonal type of climate, dry winter. **SS** and **SN** = Semi-arid, summer rains. **W** = Desert

All the ticks recovered in this entire study have been tabulated below according to the distribution in the climatic regions shown in Fig. 1.

TABLE 3: Tick assemblage according to the climatic zones of South Africa

Tick species	**Distribution**
Amblyomma hebraeum	L, E, SE
Amblyomma marmoreum	L, SS, SE, E, (K, cf. Chapter 4)
Rhipicephalus (*Boophilus*) *decoloratus*	L, SE, E
Haemaphysalis parmata	(SE, cf. Chapter 5)
Haemaphysalis silacea	SE, L, E
Hyalomma glabrum	SS, K
Hyalomma marginatum rufipes	L, W
Hyalomma truncatum	L, SS, M, W, E
Ixodes rubicundus	SS
Ixodes pilosus group	M, W, L
Margaropus winthemi	SS
Rhipicephalus appendiculatus	L, SE, E
Rhipicephalus arnoldi	(K, cf. Chapter 4)
Rhipicephalus capensis	SE, M, W
Rhipicephalus distinctus	(K, cf. Chapter 4)
Rhipicephalus evertsi evertsi	L, SS, M, SE , E
Rhipicephalus exophthalmos	SE, (K, W, cf. Chapter 5)
Rhipicephalus follis	SE
Rhipicephalus glabroscutatum	M, SE, SS, (K, cf. Chapter 4)
Rhipicephalus gertrudae	M
Rhipicephalus kochi	L, (E, cf. Chapter 5)
Rhipicephalus maculatus	E
Rhipicephalus muehlensi	E
Rhipicephalus neumanni	K
Rhipicephalus sp. near *R. pravus*	L
Rhipicephalus simus	L, SE, E
Rhipicephalus theileri	(W, cf. Chapter 4)
Rhipicephalus zambeziensis	L

The medium--sized herbivorous species

Burchell's zebra

Burchell's zebras are present in the northern provinces of South Africa and in KwaZulu-Natal. They prefer savanna, open scrub and grasslands (Skinner & Smithers, 1990). The ixodid tick burdens of the Burchell's zebras examined consisted of six species, namely *A. hebraeum*, *R.* (*B.*) *decoloratus*, *H. truncatum*, *R. appendiculatus*, *R. evertsi evertsi* and *R. simus*.

Among the *Rhipicephalus* species, *R. evertsi evertsi* was the most numerous. Compared to the adults, substantial numbers of immature *R. evertsi evertsi* were recovered (Table 4). Norval (1981) and Horak, De Vos & De Klerk (1984) consider Burchell's zebras as preferred hosts of this two-host tick because of the successful translation of a large number of larvae into nymphs and the large numbers of adults recovered from these animals. .

Horak, De Vos & De Klerk (1984) determined the tick burdens of 33 Burchell's zebras in the north-eastern Lowveld of Mpumalanga Province in the Kruger National Park. *R.* (*B.*) *decoloratus* and *R. evertsi evertsi* were the most numerous species found on these animals. The proportional distribution of the tick burden indicated that *R.* (*B.*) *decoloratus* has site preference for the neck, body, tail and upper legs. Horak, De Vos & De Klerk (1984) also showed that peak number of *R.* (*B.*) *decoloratus* were present on zebras in the Kruger National Park during spring. The mean ratio of larvae to nymphs to adults of this one-host tick on the Burchell's zebra was 3.0:1.1:1.0 and this implies a good translation of larvae to nymphs and to adults without a large loss of ticks during and just after the moults, and thereby indicates that these animals are good hosts of *R.* (*B.*) *decoloratus*. However, few *R.* (*B.*) *decoloratus* were recovered from the zebras in the present study.

The seasonal occurrence of the immature developmental stages of *R. appendiculatus* and *R. zambeziensis* on the zebras is the same as that on the blue wildebeest (Horak, De Vos & Brown, 1983b) in the Kruger National Park. However, in our study infestation with *R. appendiculatus* was not significant.

Red hartebeest

Historically red hartebeest were widely distributed in South Africa (Skinner & Smithers, 1990), but hunting reduced their distribution considerably. However, in recent times they have been reintroduced into many nature reserves and farms. The red hartebeest examined in the Mountain Zebra National Park harboured *R. evertsi evertsi* (only immature stages) and *R. glabroscutatum* (both immatures and adults), but no ticks were recovered from the red hartebeest examined in the Kgalagadi Transfrontier Park (Table 5).

Although equids are preferred hosts of all stages of development of *R. evertsi evertsi* (Norval, 1981; Horak, De Vos & De Klerk, 1984), other large wild herbivores such as eland are also good hosts, and smaller antelopes and scrub hare are often good hosts of the immature stages. The peak of infestation with immature stages in the Mountain Zebra National Park occurs from February-May and with adults from December-February (Horak, Fourie, Novellie & Williams, 1991).

The greatest numbers of the immature stages of the two-host tick *R. glabrosccutatum* are present from March-June and the adults from August-February (MacIvor & Horak, 2003). That both immature and adult ticks were present on the animal in the Mountain Zebra National Park can be ascribed to the fact that it was examined during February in the late summer transition phase of immature to adult ticks of this two-host species.

Black wildebeest

Nine ixodid tick species were collected from the black wildebeests, namely *A. marmoreum, H. glabrum, H. truncatum, I. rubicundus, M. winthemi, R. evertsi evertsi, R. follis, R. glabroscutatum*, and *R. neumanni* amongst which *M. winthemi* and *R. glabroscutatum* were the most abundant on an animal examined in the Mountain Zebra National Park and *R. neumanni* was the least numerous species recovered from an animal in the Karoo National Park (Table 6).

Only one black wildebeest, a very old animal, was heavily infested and its burden consisted chiefly of *M. winthemi*, *R. evertsi evertsi* and *R. glabroscutatum*. The ratio of the developmental stages (larvae to nymphs to adults) of *M. winthemi*, which is a one-host tick, on this animal was 1.4: 1.4: 0.2: 1.0. This ratio is skewed in favour of the adults and can be ascribed to the fact that the animal was examined in October towards the very end of the seasonal occurrence of this tick (Horak *et al.*, 1991), which is colloquially known as the winter horse tick.

Previously four ixodid tick species, namely *R.* (*B.*) *decoloratus*, *H. truncatum*, *R. capensis* and *R. evertsi evertsi* were recovered from these animals in the Golden Gate Highlands Park and the Rietvlei Nature Reserve (Horak, De Vos & Brown, 1983), whereas black wildebeest previously examined in the Mountain Zebra National Park were infested with five species which included *Rhipicephalus lounsburyi* (Horak, Fourie, Novellie & Williams, 1991).

Blue wildebeest

The blue wildebeest carried small number of *H. truncatum* in addition to two larvae of a *Rhipicephalus* species (Table 7). An earlier survey on the arthropod infestation of blue wildebeest in the Kruger National Park during the 1970s indicated that their parasite burdens were never very large, and they have been described as a tick resistant species (Horak, De Vos & Brown, 1983).

Tsessebe

The three tsessebes examined in the Kruger National Park harboured four ixodid tick species (Table 8). The one host tick *R.* (*B.*) *decoloratus* followed by *R. evertsi evertsi* were the most numerous species, and comprised 85.5% and 7.2% respectively of the total number of ticks recovered.

The size of tsessebes would normally qualify them for good hosts of only the immature stages of *A. hebraeum* (Horak, MacIvor, Petney & De Vos, 1987). The large numbers of adult ticks of this species collected from one of these animals imply that it was suffering from stress and its immunity compromised. The comparatively large number of adult *R. appendiculatus* present on the same animal after the season of peak abundance of the adults of this species is further confirmation of the preceding observation. The large numbers of *R.* (*B.*) *decoloratus* and particularly the adults present on the tsessebe implies that they are good hosts of this tick species. The presence of immature *R. evertsi evertsi* and fairly large numbers of adults on all the tsessebes indicates that should more animals of this species be examined they may prove to be good hosts of this tick.

Lichtenstein's hartebeest

This animal was infested with four ixodid species namely *A. hebraeum*, *A. marmoreum*, *R.* (*B.*) *decoloratus* and *R. evertsi evertsi* among which *R.* (*B.*) *decoloratus* was the most abundant and *A. marmoreum* was the least (Table 9).

The ratio of immatures to adults of R. (*B.*) *decoloratus* (14.8: 3.2: 1.1: 1) showed that there is a huge loss during the translation from one developmental stage to another. Thus Lichtenstein's hartebeest can not be considered as suitable host for *R.* (*B.*) *decoloratus*.

Furthermore, *R.* (*B.*) *decoloratus* made up 94% of the total ixodid tick burden and the proportional distribution on the body showed that it attached mainly on the body and then on the head, feet and the tail, respectively (Table 10).

Bushbuck

Bushbuck are generally solitary animals, and they are associated closely with riverine habitats and are distributed in the northern provinces, Swaziland, and the coastal regions of KwaZulu-Natal and the Eastern and Western Cape Provinces (Skinner & Smithers, 1990).

Horak, Potgieter, Walker, De Vos & Boomker (1983) have previously determined the tick burdens of bushbuck in the Kruger National Park and recovered six ixodid tick species of which *R.* (*B.*) *decoloratus* was the most numerous. The large numbers of all developmental stages of the latter tick on the bushbuck might indicate that they are good hosts of *R.* (*B.*) *decoloratus*. However, the mean ratio of larvae to nymphs to adults was 17.4: 14.5: 2.4:1.0, which is indicative of a considerable loss during the translation of the developmental stages. Horak, Keep, Spickett & Boomker (1989) examined bushbuck in the Weza State forest in south-western Kwa-Zulu Natal Province where they recovered nine species from these animals of which *Ixodes* spp. was the most numerous. This species was morphologically different from *I. pilosus*. In our survey *R.* (*B.*) *decoloratus* followed by *R. kochi* were the dominant species found on the bushbuck (Table 11).

Nyala

Nyala are gregarious, medium-sized antelopes that are restricted to the Limpopo River Valley between Swartwater and the Kruger National Park and further southwards to KwaZulu-Natal Province. They are mixed grazers-browsers and feed on various parts of plants (Skinner & Smithers, 1990). Since nyala prefer dense bushes, it is expected that host preferences and host habitat will play an important role in the composition of their tick infestations.

In our survey, the nyalas carried six ixodid tick species, namely *A. hebraeum*, *R.* (*B.*) *decoloratus, H. silacea, R. appendiculatus, R. kochi* and *R. zambeziensis* (Table 12). *R.* (*B.*) *decoloratus* followed by *R. kochi* were the most numerous, and constituted 84% and 12% of the total number of ticks collected respectively. The relatively large numbers of all stages of development of *R.* (*B.*) *decoloratus* implies that nyalas are good hosts of this species.

Five ixodid tick species have previously been reported on two nyalas at Pafuri in the Kruger National Park (Horak, Potgieter, Walker, De Vos & Boomker, 1983a). Of these *R.* (*B.*) *decoloratus*, *R. appendiculatus* and *R. kochi* were the most numerous. In a survey on nyalas conducted by Horak, Boomker & Flamand (1995) in the KwaZulu-Natal Province, nine tick species were recovered and *R. muehlensi* followed by *R. maculatus* were the most abundant species. The recovery of large numbers of immature ticks of various species from the nyalas in both the above-mentioned surveys indicates that they serve as efficient hosts of immature ticks.

Greater kudu

Ansell (1971) describes kudus as large antelopes, which are widely distributed in Southern and East Africa. They prefer light forest and dense bush as habitat. They commonly occur in the Northern Province, KwaZulu-Natal Province, Eastern Cape Province and Swaziland (Skinner & Smithers, 1990).

The five kudus that we examined harboured twelve ixodid species namely *A. hebraeum, A. marmoreum*, *R.* (*B.*) *decoloratus, H. silacea,* ticks of the *Ixodes pilosus* group*, H. truncatum, R. appendiculatus, R. evertsi evertsi, R. glabroscutatum, R. zambeziensis, R. oculatus* and *R. kochi* (Table 13 & 14).

A. hebraeum was present on all the kudus, *R.* (*B.*) *decoloratus* on those examined in the Kruger National Park and *H. silacea* and *R. glabroscutatum* on the single animal examined on Bucklands farm in the Eastern Cape Province (Table 13).

In a preliminary survey, Knight & Rechav (1978) reported *A. hebraeum, H. silacea, R. appendiculatus* and *R. glabroscutatum* on kudus in the Eastern Cape Province. Horak, Potgieter, Walker, De Vos & Boomker (1983a) recovered six tick species from four kudus that they examined in the north and the south of the Kruger National Park. These animals were infested with the immature stages of *A. hebraeum* and *R. appendiculatus* and all stages of development of *R.* (*B.*) *decoloratus* while the two kudus examined in the north of the park were infested with all stages of development of *R. kochi*. Horak, Boomker, Spicket & De Vos (1992b) reported the tick burdens of kudus in the eastern Mpumalanga Province Lowveld and the Eastern Cape Province, and MacIvor & Horak (2003) of kudus in the Eastern Cape Province. The immature stages of *A. hebraeum* were present in large numbers on kudus in both provinces, while all stages of development of *R.* (*B.*) *decoloratus* and all stages of development of *R. glabroscutatum* were present in large numbers on the kudus in Mpumalanga Province and the Eastern Cape Province respectively. Also, Horak *et al.* (1992) reported the overall ratio of immature stages to adults of *R.* (*B.*) *decoloratus* on kudu as 3.0: 2.1: 1.0 which implies an excellent translation of immatures to adulthood, and that kudus are thus excellent hosts of this tick.

Gemsbok

This antelope is mainly found in the open arid area since it prefers open grassland, bush savanna and woodland (Skinner & Smithers, 1990).

The gemsboks in the Kgalagadi Transfrontier Park and the West Coast National Park harboured five ixodid tick species, namely *H. truncatum*, which was present on the gemsbok in both parks and *R. capensis*, *R. evertsi evertsi*, *R. gertrudae* and *R. glabroscutatum*, which were present on the animals in the West Coast National Park. *R. glabroscutatum* constituted 92% of the total tick burdens, and these animals and this locality must be considered preferred hosts and a preferred habitat of this tick respectively (Table 15).

The two gemsbok examined in the Mountain Zebra National Park by Horak, Potgieter, Walker, De Vos & Boomker (1983a) harboured seven tick species of which *M. winthemi*, *R. evertsi evertsi* and *R. glabroscutatum* were the most numerous. In a survey conducted in central Free State Province Fourie *et al.* (1991a) recovered nine tick species from gemsbok, with *M. winthemi* and *R. evertsi evertsi* being the most numerous. Forty-eight gemsbok examined for ticks in Namibia harboured four tick species and those 26 of these animals examined in the Hardap Nature Reserve were infested with a total of 350 adults of *R. exophthalmos* (Horak, Anthonissen, Krecek & Boomker, 1992a).

Domestic calf

If this animal had been adult it could have been classed amongst the very large herbivorous animals. The calf carried six ixodid species, namely *A. hebraeum*, *R.* (*B.*) *decoloratus*, *H. silacea*, *R. appendiculatus*, *R. evertsi evertsi* and *R. glabroscutatum* among which *R. glabroscutatum* followed by *H. silacea* were the most abundant species (Table 16).

R. glabroscutatum constituted 84% of the total tick burden of the calf, and is one of the most abundant tick species of domestic and wild animals on the farm Bucklands and in the Valley Bushveld (Horak, Boomker, Spickett & De Vos, 1992b; Horak, 1999).

Boer goats

Boer goats are extensively farmed in the Valley Bushveld regions of the Eastern Cape Province, and Aucamp (1979) has observed the browsing habits of these animals in this vegetation type. A total of 677 ticks belonging to seven species namely *A. hebraeum*, *A. marmoreum*, *R.* (*B.*) *decoloratus*, *H. silacea*, *R. evertsi*

evertsi, *R. glabroscutatum*, and *R. capensis* like larvae and nymphs were recovered during the survey. All stages of development of *H. silacea* and *R. glabroscutatum* were present, and they were also the most numerous of the ticks collected (Table 17).

MacIvor & Horak (2003) determined the tick burdens of 24 Boer goats on the farm "Brakhill", close to Kirkwood in the Eastern Cape Province. The burdens consisted of *A. hebraeum*, *H. silacea*, *H. truncatum*, *R. evertsi evertsi*, *R. glabroscutatum*, *R. oculatus* and *R. simus*. Among those species, *R. glabroscutatum* followed by *A. hebraeum* were the most numerous species comprising 71% and 27% of the total tick burdens, respectively. Recovering a substantial number of immature and mature stages of *A. hebraeum* and *R. glabroscutatum* makes Boer goats preferred hosts of theses species. *R. oculatus* is a tick of scrub hares and must be regarded as an accidental infestation on the Boer goats.

The very large herbivorous species

Giraffe

Giraffe prefer dry savannas with vegetation types ranging from scrub to woodland. They are present in north-eastern Limpopo and Mpumalanga Provinces (Skinner & Smithers, 1990), but in recent times have been reintroduced to a number of regions in which they previously occurred.

In our survey the four giraffes were infested with eight tick species (Tables 17 & 18), and appeared to be good hosts of the adults of *A. hebraeum*, *H. truncatum*, *R. evertsi evertsi* and ticks of the *R. pravus* group, while only one of the giraffes harboured a substantial number of *R.* (*B.*) *decoloratus.* Although only four adult *H. m. rufipes* were collected from the four giraffe, it must be stressed that to our knowledge these are the only four ticks of this species ever collected in the Kruger National Park. Proportional distribution *R.* (*B.*) *decoloratus* on one giraffe showed that 52% of the total tick burden was recovered from the body. (Table 20)

Horak *et al.* (1983a) recovered six ixodid tick species from two giraffes they examined in the Kruger National Park. These two animals harboured large numbers of all stages of development of both *A. hebraeum* and *R.* (*B.*) *decoloratus*, thus proving to be good hosts of both these species. Four ixodid tick species were recovered from six giraffes examined in the Etosha National Park in Namibia (Horak, Anthonissen, Krecek & Boomker, 1992a). The most numerous ticks on the latter animals were *H. m. rufipes* and *H. truncatum* of which certain animals harboured several hundred.

Eland

Eland are versatile in their habitat requirements and are at home in arid semi-desert scrub associations and on montane grassland (Skinner & Smithers, 1990). Historically they were present throughout South Africa and because of reintroductions now occupy the same regions in which they occurred historically. Because of their wide-spread distribution and their size they are probably hosts to more ixodid tick species and greater numbers of ticks than any other bovids in South Africa. The six eland examined in the present survey were infested with ten species of ixodid ticks (Table 21), and with the possible exception of *H. m. rufipes* and *R. glabroscutatum* appeared to be good hosts for all of them.

The tick burdens of an eland in the Thomas Baines Nature Reserves and another in the Andries Vosloo Kudu Reserve in the Eastern Cape Province have already been determined by Horak *et al.* (1983a). These animals also harboured ten tick species, including a large number of all stages of development of *R. glabroscutatum* on one of them. The same authors also recovered seven ixodid tick species from two eland examined in the Kruger National Park. Horak *et al.* (1991c) recovered eleven tick species from 11 eland they examined in the Mountain Zebra National Park, Eastern Cape Province. These animals harboured small numbers of *I. rubicundus* and *R. lounsburyi* and large numbers of *H. glabrum*, *H. truncatum*, *M. winthemi*, *R. evertsi evertsi* and *R. glabroscutatum*. It is thus obvious that eland are good hosts of several of those tick species that are present in the various regions in which these large antelopes occur.

African buffalo

African buffalo are very large ruminants that prefer savanna-type habitats and require a plentiful supply of grass, shade and water for optimal survival. They occur in herds, which increase in size in the dry season, but decrease during the wet season because of the usual abundance of both food and water (Skinner & Smithers, 1990). Large numbers of these animals are present in the Kruger National Park in north-eastern Mpumalanga and Limpopo Provinces, and in the Umfolozi and Hluhluwe Nature Reserves (recently combined to form the Hluhluwe-Umfolozi Park) in the north-eastern regions of KwaZulu-Natal Province, with smaller populations in national, provincial and privately owned reserves in these and nearly all other provinces of South Africa.

The tick burdens of 12 African buffaloes were determined in the present surveys, one in north-eastern Mpumalanga Province, one in the Eastern Cape Province, and the remainder in north-eastern KwaZulu-Natal and their tick burdens are summarized in tables 22 and 23. Eleven ixodid tick species were recovered from the buffaloes, namely *A. hebraeum, A. marmoreum,* *R.* (*B.*) *decoloratus, H. truncatum, H. silacea*, *R. appendiculatus, R. evertsi evertsi, R. follis*, *R. maculatus, R. meuhlensi,* and *R. simus*. The buffaloes in all three provinces harboured substantial numbers of immature and adult *A. hebraeum*, those in the Eastern Cape Province and KwaZulu-Natal harboured substantial numbers of all stages of development of *R. appendiculatus* and those in north-eastern KwaZulu-Natal substantial numbers of all stages of development of *R. maculatus* making them preferred hosts of these three tick species. Although the buffaloes in KwaZulu-Natal harboured large numbers of immature *R. muehlensi*, they carried few adults of which nyalas are the preferred hosts (Horak, Boomker & Flamand, 1995). It was surprising to find that the buffaloes harboured few *R.* (*B.*) *decoloratus* and with the exception of a buffalo calf, which was infested with 306 adult ticks of this species, very few adult ticks were recovered. The overall ratios of larvae to nymphs to males to females of *R.* (*B.*) *decoloratus* on the buffaloes in the Umfolozi Nature Reserve and in the Hluhluwe Nature Reserve were 9.7: 1.7: 1.6: 1.0 and 12.3: 2.5: 1.52: 1.0 respectively. The mean ratio for the *R.* (*B.*) *decoloratus* collected from all the buffaloes combined in the three reserves was 10.6: 1.8: 1.56: 1.0 (refer to Chapter 5).

It would appear as if African buffaloes express resistance to natural infestations with the one-host tick *R.* (*B.*) *decoloratus* in that the majority of larvae are prevented from moulting to the second immature stage (nymphs) of the life cycle.

Horak *et al.* (1983a) determined the tick burdens of four buffaloes in the Hluhluwe Game Reserve. These animals were infested with eight ixodid tick species, of which *A. hebraeum*, *R. appendiculatus*, and *R. maculatus* were the most numerous.

Ixodid tick species

Amblyomma hebraeum

The distribution of the bont tick, *A. hebraeum*, extends from the northern and north-western provinces into KwaZulu-Natal, Swaziland and the Eastern Cape Province of South Africa (Norval, 1977). Its climatic and vegetational requirements are similar to those of *Rhipicephalus appendiculatus* and therefore their distributions largely overlap within the borders of South Africa. *A. hebraeum* prefers "tall grassveld" where rainfall exceeds 380mm annually thus providing adequate shrub and bush cover (Theiler, 1948; Theiler, 1969).

Norval (1977) determined the effects of climate (day-length, temperature, rainfall and humidity) on the eggs of *A. hebraeum* and consequently its larvae. Norval (1977), Knight & Rechav (1978), Londt, Horak & De Villiers (1979) and as well as Horak (1982) remarked that adult *A. hebraeum* reached peak numbers during the summer months. In the Lowveld regions of north-eastern KwaZulu-Natal, Mpumalanga and Limpopo provinces the occurrence of *A. hebraeum* appears to be non-seasonal (Horak *et al.*, 1992b) and Horak *et al.* (1983a) recovered large numbers of adults from eland, giraffe and African buffalo examined during the winter and spring. Seasonal changes can affect the intensity of infestation and also the size of the tick burden.

The larvae, and to a lesser extent the nymphs, of *A. hebraeum* infest a variety of small and large mammals, including carnivores, and also infest ground-frequenting birds (Horak *et al*., 1987). On the other hand adults of *A. hebraeum* generally favour animals with a large body mass (Gallivan & Horak, 1997) and consequently large numbers of adult ticks have been recovered from large hosts such as African buffaloes, giraffes and eland compared to smaller hosts such as kudus, bushbuck and nyalas (Horak *et al*., 1983a).

Theiler (1962) and Howell, Walker & Nevill (1978) have stated that the deep wounds caused by the long mouthparts of *A. hebraeum* can become secondarily infected with bacteria with the subsequent development of abscesses. However, in our study no abscesses were observed.

Amblyomma marmoreum

A. marmoreum is widely distributed in South Africa and all stages of development prefer tortoises, and more particularly leopard tortoises, *Geochelone pardalis*, as hosts (Horak, McKay, Heyne & Spickett, 2006). However, the larvae may infest a large variety of mammals and birds (Norval, 1975; Horak *et al*., 2006). There are large numbers of leopard tortoises in the Mountain Zebra National Park, in the Valley Bushveld regions of the Eastern Cape Province and in the Kruger National Park. It is consequently not surprising that a black wildebeest in the Mountain Zebra National Park, the Lichtenstein's hartebeest in the Kruger National Park and four Boer goats on the Kirkwood (farm) were infested with the larvae of this tick species. The highest number of larvae recovered was 146 from the black wildebeest.

Rhipicephalus* (*Boophilus*) *decoloratus

This tick is commonly known as the blue tick and parasitizes both domestic and wild ungulates in South Africa. Cattle and horse are the chief domestic animal hosts (Theiler, 1911; Hoogstraal, 1956; Baker & Ducasse, 1967; Walker, 1991), while wild animals such as kudus, Burchell's zebras and impalas may harbour large numbers of all stages of development of this one-host tick (Mason & Norval, 1980; Horak, De Vos & De Klerk, 1984; Horak *et al*., 1992b; Horak *et al*., 2003). Horak (1999) stated that "Bucklands" farm is not a suitable habitat for *R.* (*B.*) *decoloratus*.

In our survey the domestic calf and a kudu from this locality harboured only a small number of *R.* (*B.*) *decoloratus* confirming Horak's observation.

Since *R.* (*B.*) *decoloratus* completes its life cycle in 21 days and as it is a one- host tick, its immature stages do not need to seek for a new host, thus an excellent translation of larvae to nymphs to adulthood should be expected (Londt & Spickett, 1976; Horak *et al*., 1992b). Horak, Boomker & Flamand (1995) reported a fairly large number of *R.* (*B.*) *decoloratus* on nyalas in KwaZulu-Natal Province, and the overall ratio of larvae to nymphs to adults on these animals was 3.7:1.5:1.0. This indicated a good translation of the immature stages to adulthood and thus it also makes nyalas excellent hosts of this tick.

Horak, De Vos & De Klerk (1984), Horak *et al.* (1992b) and Horak *et al.* (2003) collected large numbers of all stages of development of *R.* (*B.*) *decoloratus* from Burchell's zebras, greater kudus and impalas in the Kruger National Park, indicating that the park provided an excellent habitat for the tick.

In South Africa *R.* (*B.*) *decoloratus* is present in all the Provinces except the Northern Cape Province (Howell, Walker & Nevill, 1978). The peak periods of infestation differ in different localities. In KwaZulu-Natal, it is from November to June (Baker & Ducasse, 1967) whereas in the Eastern Cape Province it occurs from February to June (Rechav, 1982) and in the Kruger National Park it is from September to January (Horak, De Vos & De Klerk, 1984; Horak *et al*., 1992b; Horak *et al*., 2003).

Haemaphysalis silacea

It is commonly named The Ciskei tick and is a three-host tick, of which the adults are most abundant in summer and the immatures in the winter (Howell, Walker & Nevill, 1978; Horak *et al*., 1992b). Domestic livestock and wild antelopes such as kudus and elands are favoured by all stages of this tick species, whereas the immature stages also favour helmeted guineafowls (Knight & Rechav, 1978; Horak *et al*., 1983a; Horak & Williams, 1986; Horak & Knight, 1986; Horak *et al*., 1992b). This species is distributed in hot dry wooded ravines and river valleys in the Eastern Cape Province and to a lesser extent, in KwaZulu-Natal Province. The vegetation type favoured by this species is Valley Bushveld (Norval, 1975; Howell, Walker & Nevill, 1978; Walker, 1991).

Hyalomma marginatum rufipes

H. m. rufipes is a tick of dry climates and is mostly found in the arid regions of southern Africa (Theiler, 1962; Howell, Walker & Nevill, 1978). Walker (1991) stated that its distribution falls in the northern provinces, Swaziland, KwaZulu-Natal, Orange Free State, the Eastern, Western and Northern Cape Provinces.

Theiler (1962) stated that a variety of wild ungulates such as zebras, *Equus* spp.; Giraffe, *Giraffa camelopardalis*; African buffaloes, *Syncerus caffer*; and eland, *Taurotragus oryx*, were parasitized by this species. Furthermore, Fourie *et al.* (1991) reported the abundance of *H. m. rufipes* on gemsbok in the Orange Free State.

Hares, both Cape hares and scrub hares, are favoured by the immatures stages as hosts (Rechav, Zeederberg & Zeller, 1987; Walker, 1991). In addition Uys & Horak (2005) reported the immature stages on ground-frequenting birds.

Rechav, Zeederberg & Zeller (1987) described that eland are favoured by *H. m. rufipes*. However in our study the eland only harboured a small number, mainly because those in the Kgalagadi Transfrontier Park were examined in October before the period of peak seasonal abundance of this species, while *H. m. rufipes* does not occur in the West Coast National Park.

This tick completes only one life cycle per year and the adults are present on large ungulates in summer and the immature stages on hares from autumn to spring (Londt, Horak & De Villiers, 1979; Horak, 1982; Horak & Fourie, 1991).

Hyalomma glabrum

The tick previously known as *Hyalomma marginatum turanicum* is a two-host tick (Knight, Norval & Rechav, 1978), which was reportedly introduced into South Africa on sheep imported from Asia. However, Apanaskevich & Horak (2006) believe that the so-called *H. m. turanicum* of South Africa, which hitherto has been considered identical to the Asian *H. m. turanicum* is a South African tick, and they have reinstated it as *H. glabrum*, a name originally given to it by Theiler (1956).

Theiler (1956) reported *H. glabrum* (as *H. m. turanicum*) as being a South African tick, but there is one report of its presence in Namibia (Zumpt, 1956). Howell, Walker & Nevill (1978) have illustrated the distribution of this species (as *H. m. turanicum*) which lies in the Karoo regions of the Eastern Cape Province, the southern parts of the Orange Free State, and the western and south-western Western Cape Province. The preferred habitat of this tick is grassland with a desert climate.

The adults of *H. glabrum* occur on Cape mountain zebras, gemsbok and eland (Apanaskevich & Horak, 2006) and the peak of infestation is during the summer months. The immature stages prefer scrub hares and ground-frequenting birds (Horak *et al*., 1991c; Apanaskevich & Horak, 2006).

In our survey a small number of adults were recovered from the black wildebeest in the Karoo National Park.

Hyalomma truncatum

Theiler (1962) and Walker (1991) have reported that this tick species just like *H. m. rufipes* occurs in the drier western regions of southern Africa. Its distribution includes the drier regions of all the provinces and of Swaziland (Theiler, 1956; Theiler, 1962). Howell, Walker & Nevill (1978) stated that *H. truncatum* (one of the bont-legged ticks) occurs commonly in the western and northern parts of the Republic and MacIvor & Horak (2003) reported that only small numbers were recovered in the southern coastal regions.

It has been recovered from a wide range of ungulates of various sizes, but it usually parasitizes the larger species (Norval, 1982). A substantial and strong predilection for Cape hares and scrub hares by the immature stages has been stated by Horak & MacIvor (1987) as well as MacIvor & Horak (2003). A large number of adults were recovered from the eland examined in the West Coast National Park (Table 10) confirming their status as good hosts for this tick species. The gemsbok in this park also harboured a fairly large number of adults (Table 14).

This tick completes only one life cycle per year and the adults are present on large ungulates in summer and the immature stages on hares from autumn to spring (Londt, Horak & De Villiers, 1979; Horak, 1982; Horak, Spickett, Braack & Penzhorn, 1993).

Ixodes rubicundus

I. rubicundus is a three-host tick whose life cycle takes two years to complete (Neitz, Boughton & Walters, 1971: Fourie & Horak 1994), and since it is associated with livestock paralysis, it is commonly known as the Karoo paralysis tick. The adults are present during the winter months of one year and the immature stages during the winter months of the following year (Fourie & Horak, 1994). This species parasitizes domestic and wild animals in the Karoo regions of South Africa (Howell, Walker & Nevill 1978; Walker, 1991).

Caracals are hosts of all the developmental stages of *I. rubicundus* (Horak, Moolman & Fourie, 1987) while Fourie, Horak & Woodall (2005) reported rock elephant shrews, *Elephantulus myurus*, as the prime host of the immature stages. Mountain reedbuck and eland are reported to be favourite hosts of the adults, whereas red rock rabbits are also favoured by the immature stages (Stampa, 1959; Horak *et al.*, 1991c; Horak, Moolman & Fourie, 1987).

***Ixodes pilosus* group**

Ticks of this group are three-host ticks, and all the developmental stages may infest the same host species. Mckay (1994) has described three species within this group, namely:

1. *Ixodes pilosus sensu strictu*, which occurs in the forest regions and is distributed from the northern provinces to KwaZulu-Natal and the Eastern Cape Province. It parasitizes a variety of wild hosts such as bushbuck and common duiker.
2. "Thick haired *pilosus*", which is a common tick in KwaZulu-Natal, but is infrequently observed in the northern provinces and the Eastern Cape Province. It infests bushbuck and common duiker.

3. "Hairless *pilosus*" is a species restricted to the coastal forests and fynbos of the Eastern and Southern Cape Provinces. Grey rhebuck, bontebok and scrub hares are favoured by this tick.

Horak & Boomker (1998) stated that grey rhebuck are favourite host of *Ixodes* sp. (near *I. pilosus*). Additionally Howell, Walker & Nevill (1978) reported *I. pilosus* species from savanna and Mediterranean climates and illustrated its wide distribution along the eastern and southern coastal regions of South Africa. In our survey, *Ixodes* sp. (near *I. pilosus*) was recovered from eland in the Thomas Baines Nature Reserve and the West Coast National Park.

Horak, Sheppey, Knight & Beuthin (1986) as well as Horak & Boomker (1998) remarked that within the south-western regions of the Western Cape Province, all the developmental stages can parasitize a variety of hosts, and furthermore, that grey rhebuck, and scrub hares seem to be the hosts most favoured by *Ixodes* sp. (near *pilosus*) and this could be related to the habitat preference of both the tick and its hosts. In our survey *I. pilosus* group ticks were recovered from eland.

Since the number of females collected is virtually always more than the number of males, it is assumed that mating might take place off the host's body (Fourie & Horak, 1994).

Margaropus winthemi

This one-host tick is known as the winter horse tick because of its presence on equids during winter, or the South African beady-legged tick because of the size of the segments of the fourth pair of legs of the males. Special characteristic such as size, expanded leg segments and being active in the winter can be used to distinguish this species from *Rhipicephalus* (*Boophilus*) species (Walker *et al.*, 2003).

Theiler & Salisbury (1958) and also Howell, Walker & Nevill (1978) described the biology of *M. winthemi* and stated that horses are its preferred hosts although it has adapted itself to other domestic hosts such as cattle. Cape mountain zebras are probably the original hosts of this tick (Horak, Knight & De Vos, 1986). Horak *et* *al.* (1983a) have recovered small numbers of *M. winthemi* from gemsbok in the Mountain Zebra National Park during summer.

Its geographical distribution falls in South Africa and it is found in highland areas where the winter is cold. It has been recorded from North West Province, Lesotho, parts of the Orange Free State and the Eastern and Western Cape Provinces (Howell, Walker & Nevill, 1978; Walker 1991). In our study, *M. winthemi* was recovered from only one black wildebeest in the Mountain Zebra National Park (Table 5).

Rhipicephalus appendiculatus

This tick is commonly known as the “brown ear tick”. *R. appendiculatus* can parasitize an extremely wide range of wild and domestic hosts (cattle and larger bovids such as eland and African buffalo) many of which can carry all of its developmental stages, however; smaller-size antelopes usually harbour only the immature stages (Yeoman & Walker, 1967; Walker 1974; Walker, 1991). African buffaloes, eland, kudus, nyalas and also impalas are considered as good hosts (Norval, Walker, & Colborne, 1982; Horak *et al.*, 1992b; Horak, Boomker & Flamand, 1995; Horak *et al.*, 2003).

The distribution of *R. appendiculatus* in South Africa includes the Bushveld and Lowveld regions of North West, Limpopo, Mpumalanga, Gauteng, KwaZulu-Natal and the Eastern Cape Provinces as far as Grahamstown and it is also present in Swaziland (Theiler, 1949; Howell, Walker & Nevill, 1978) Between Grahamstown and Cape Town, it can be confused with *Rhipicephalus nitens* (Walker Keirans & Horak, 2000). “Bucklands” farm is located near the south-western extremity of the distribution of *R. appendiculatus*, and both the kudu and domestic calf from that region were infested.

The seasonal occurrence of *R. appendiculatus* was first described by Wilson (1946). The various stages of *R. appendiculatus* are present at different seasons. The immature stages prefer the drier seasons, whereas the adults prefer the hot wet season (Baker & Ducasse, 1967; Rechav, 1982). The activity of the adult life stage is influenced by rainfall, temperature and day-length (Short & Norval, 1981). In surveys on kudus and impalas in the Kruger National Park the larvae were more active during autumn and winter, and the nymphs during winter and spring (Horak *et al.*, 1992b; Horak *et al.*, 2003).

Rhipicephalus capensis

As a three-host species (Gertrud Theiler, unpublished data), the adults favour mainly large wild animals such as eland and gemsbok, and the immature stages murid rodents (Theiler, 1962; Walker, Keirans & Horak, 2000). This species is more or less restricted to the south-western regions of the Western Cape Province (Walker, Keirans & Horak, 2000). Moreover the West Coast National Park would appear to be an ideal habitat judging by the large numbers of this tick found on the eland and gemsbok examined in this park (Tables 10 & 14).

Rhipicephalus evertsi evertsi

The widespread distribution of this tick species, including semi-arid areas, of South Africa has been described by Howell, Walker & Nevill (1978). Norval (1981) reported that *R. evetrsi evertsi* has the capability to tolerate a broad diversity of climatic conditions.

Theiler (1962), Norval (1981) and additionally Walker, Keirans & Horak (2000) have described the preferred range of hosts of *R. evertsi evertsi*. Hoogstraal (1956) stated that horses, mules, donkeys and wild zebras possess the highest host preference. Horak *et al.*, (1991c) reported that compared to other hosts in the Mountain Zebra National Park, *R. evertsi evertsi* infests eland and zebras in large numbers in all its developmental stages. In the current survey the two eland in the Thomas Baines Nature Reserve in the Eastern Cape Province were the most heavily infested of the very large wild ruminants (Table 10).

Rhipicephalus exophthalmos

This tick was recently described by Keirans, Walker, Horak & Heyne (1993). The adults usually infest a variety of domestic and wild hosts including scrub hares (Walker, Keirans & Horak, 2000). It prefers vegetation types of bushy Karoo

Namib shrubland or dry wooded grassland as well as bush land (White, 1983) and it is generally present in the drier and semi-arid regions of South Africa such as south-eastern Cape, and its distribution also extends into Namibia (Keirans, Walker, Horak & Heyne, 1993).

Rhipicephalus follis

Theiler (1950; 1962) misidentified this species as *R. capensis*. Favourite hosts of the adults are listed as antelopes such as elands, and rodents are favoured by the immature stages (Horak *et al*., 1991c; Walker, 1991). Its distribution falls within the south-eastern Mpumalanga Province, central Orange Free State, KwaZulu-Natal and the Eastern Cape Province (Walker, Keirans & Horak, 2000).

Rhipicephalus glabroscutatum

As a two-host tick, it is related to *R. evertsi evertsi*. This tick species is widely distributed in the Eastern and Western Cape Provinces and is capable of parasitizing a variety of wild and domestic animals and all the stages of development are frequently present on the same host. Horak *et al.* (1991c) reported that scrub hares are good hosts of the immatures, but infestation of other non-ungulates is considered accidental. Moreover Horak & Knight (1986) reported kudu as an excellent host. The lower legs and areas around the hooves are the preferred sites of attachment of all the developmental stages (Horak *et al*., 1992b). The seasonal pattern of occurrence of this tick has been illustrated by Horak, Sheppey, Knight & Beuthin (1986) and also by MacIvor & Horak (2003). The adults are present from spring to late summer and the immature stages from late summer to spring and only one life cycle is completed annually. The presence of a large number of larvae and nymphs and adults on the gemsbok examined during February in the West Coast National Park (Table 14) indicates the end of peak adult seasonality and the commencement of the activity of the immature stages.

MacIvor & Horak (1987) demonstrated the association of *R. glabroscutatum* with foot abscess in domestic goats, but no cases of foot abscess were observed in our survey on wildlife.

Rhipicephalus gertrudae

Its distribution range falls in the centre and western regions of South Africa. The larvae and nymphs prefer small rodents as their hosts (Fourie, Horak & Van Den Heever, 1992), and the adults prefer cattle, sheep and wild ruminants, and also dogs (Walker, Keirans & Horak, 2000; Horak & Matthee, 2003).

Rhipicephalus kochi

Rhipicephalus kochi was previously reported in 1964 (Gertrud Theiler, unpublished data) from an impala at Pafuri in the Kruger National Park and identified as *Rhipicephalus neavei*. In South Africa this species is found only at the northern extremity of the Kruger National Park (Horak *et al*., 1983a) and in north-eastern KwaZulu-Natal (Walker, Keirans & Horak, 2000).

All the developmental stages have been recovered from kudus, nyalas and bushbuck in the Pafuri region of the Kruger National Park (Horak *et al*., 1983a).

Rhipicephalus maculatus

The immature stages of this species often feed on the same hosts as the adults (Walker, Keirans & Horak, 2000). Baker & Keep (1970), Horak *et al*., (1983a) and Horak, Boomker & Flamand (1991) have described large animals such as African Buffaloes, bushpigs and rhinoceroses with thick skins as the preferred hosts of *R. maculatus* adults. Large numbers of immatures might occur on those animals as well as on smaller species of wildlife such as nyalas (Horak, Boomker & Flamand, 1995).

R. maculatus is distributed in the coastal region of north-eastern KwaZulu-Natal and in many places its distribution overlaps with that of *R. muehlensi* (Walker, Keirans & Horak, 2000).

Rhipicephalus muehlensi

All developmental stages of *R. muehlensi* can occur on the same host, and it has been reported that nyalas and possibly bushbuck are the preferred hosts of this tick (Horak *et al*., 1983a; Horak, Boomker & Flamand, 1995). In addition, a large number of larvae and nymphs have been recovered from red duikers and some from scrub hares (Horak, Boomker & Flamand, 1991; Horak, Spickett, Braack, Penzhorn, Bagnall & Uys, 1995).

The distribution of this tick is similar to that of *R. maculatus* and lies within the coastal region of KwaZulu-Natal Province in South Africa (Walker, Keirans & Horak, 2000). Smithers (1983) mentioned that nyalas and bushbuck prefer habitats containing thickets, various types of woodland or forests and these are present in the coastal regions of KwaZulu-Natal.

Rhipicephalus* sp. near *R. pravus

This tick species, collected from giraffes in the Kruger National Park in north-eastern Mpumalanga Province (Table 18), resembles true *R. pravus*, which is present further north in East Africa (Walker, Keirans & Horak, 2000). However, a similar tick has been collected from animals in neighbouring countries such as Namibia, Botswana and Mozambique (Walker, Keirans & Horak, 2000). Zumpt (1958) as well as Paine (1982) showed in various surveys that wild ruminants such as giraffe and impala can act as preferred hosts of the adults. However, hares can harbour all the developmental stages (Horak, Spickett, Braak & Penzhorn, 1993; Horak *et al*., 1995).

Rhipicephalus simus

The adults mostly prefer to parasitize cattle and dogs among domestic animals (Horak, Jacot Guillarmod, Moolman & De Vos, 1987; Walker, Keirans & Horak, 2000). The adults have also been recovered from many wild animals (Norval & Mason, 1981; Horak *et al*., 1983a; Horak, Biggs & Reinecke, 1984; Horak *et al*., 1987; Horak, Boomker, De Vos & Potgieter, 1988). The immature stages prefer small burrow-dwelling rodents, in particular murid rodents as hosts (Hoogstraal, 1956; Norval & Mason, 1981; Braack, Horak, Jordaan, Segerman & Louw, 1996).

R. simus is a widely distributed southern African tick (Walker, Keirans & Walker, 2000). With the exception of the drier regions of the Northern Cape Province it is present virtually throughout South Africa, but never occurs in really large numbers (Walker, Keirans & Horak, 2000).

Rhipicephalus zambeziensis

All the developmental stages of *R. zambeziensis* have been described by Walker, Norval & Corwin (1981), who also compared its morphology with that of *R. appendiculatus*. *R. zambeziensis* is considered to have a wide range of ruminant hosts and all stages may use the same host species. The preferred hosts of *R. zambeziensis* seem to range from impalas, bushbuck, nyalas, kudus, eland and African buffaloes to cattle (Norval, Walker & Colborne, 1982; Horak *et al*., 1983a; Horak *et al*., 1992b, Walker, Keirans & Horak, 2000; Horak *et al*., 2003). The distribution of *R. zambeziensis*, which is confined to the North West, Limpopo and Mpumalanga Provinces of South Africa, and its seasonal changes in terms of prevalence and intensity of infestation, virtually completely coincide with that of *R. appendiculatus* in this country (Norval, Walker & Colborne, 1982; Horak *et al*., 1992b; Horak *et al*., 2003).

TABLE 4: The ixodid tick burdens of Burchell's zebra in the Kruger National Park

Tick species	**Date examined**															
	28.08.83				**28.08.83**				**28.08.83**				**28.08.83**			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
Amblyomma hebraeum	16	0	0	0	320	32	0	0	34	0	0	0	1	48	0	0
Rhipicephalus* (*Boophilus*) *decoloratus	0	0	0	18	0	0	0	0	0	0	0	2	0	0	0	0
Hyalomma truncatum	0	0	6	3	0	0	3	1	0	0	4	1	0	0	5	3
Rhipicephalus appendiculatus	0	0	4	2	0	0	3	4	0	0	0	5	0	0	4	4
Rhipicephalus evertsi evertsi	16	64	46	24	80	0	27	14	96	32	6	8	32	256	10	6
Rhipicephalus simus	0	0	9	2	0	0	10	1	0	0	5	1	0	0	3	6

L = Larvae; N = Nymphs; ♂ = Males; ♀ = Females

TABLE 5: The ixodid tick burdens of red hartebeest in the Mountain Zebra National Park

Date examined	***Rhipicephalus evertsi evertsi***				***Rhipicephalus glabroscutatum***			
	L	N	♂	♀	L	N	♂	♀
13.02.84	656	132	0	0	268	50	10	28
09.10.84	0	0	0	0	0	0	0	0

TABLE 6: The ixodid tick burdens of black wildebeest

Tick species	Date of examination															
	10.05.83				10.09.85				8.02 91				8.02 91			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
Amblyomma marmoreum	0	0	0	0	146	2	0	0	0	0	0	0	0	0	0	0
Hyalomma glabrum	0	0	0	0	0	0	4	2	0	0	3	14	0	0	0	4
Hyalomma truncatum	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
Ixodes rubicundus	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Margaropus winthemi	58	0	0	0	2726	2768	428	1888	0	0	0	0	0	0	0	0
Rhipicephalus evertsi evertsi	32	4	0	2	464	64	62	25	0	0	0	0	0	0	0	0
Rhipicephalus follis	0	0	0	0	0	0	17	4	0	0	0	0	0	0	0	0
Rhipicephalus glabroscutatum	90	4	0	0	64	138	202	76	0	0	0	0	0	0	0	0
Rhipicephalus neumanni	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0

TABLE 7: The ixodid tick burdens of blue wildebeest in the Kgalagadi Transfrontier Park

Date examined	***Hyalomma truncatum***			
	L	N	♂	♀
02.10.84	0	0	1	0
04.10.84 *	0	0	0	0
06.10.84	0	0	0	2

* *Rhipicephalus* spp.: 2 L

TABLE 8: The ixodid tick burdens of tsessebe the Kruger National Park

Tick species	**Date examined**											
	03.11.80				**06.10.82**				**03.06.83**			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
Amblyomma hebraeum	72	112	6	2	0	0	6	4	24	81	106	40
Rhipicephalus (Boophilus) decoloratus	1376	2360	544	440	778	992	260	320	145	296	478	325
Hyalomma truncatum	0	0	0	0	0	0	6	4	0	0	8	0
Rhipicephalus appendiculatus	0	48	0	0	0	38	0	0	105	8	104	36
Rhipicephalus evertsi evertsi	152	112	10	5	18	34	8	2	112	128	8	8

TABLE 9: The ixodid tick burdens of Lichtenstein's hartebeest in the Kruger National Park

Date examined	*Amblyomma hebraeum*				*Amblyomma marmoreum*				*Rhipicephalus (Boophilus) decoloratus*				*Rhipicephalus evertsi evertsi*			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
9/96	168	54	0	0	24	0	0	0	10707	2343	786	723	585	12	12	3

TABLE 10: Proportional distribution of *Rhipicephalus* (*Boophilus*) *decoloratus* on Lichtenstein's hartebeest

Total № of *Rhipicephalus* (*Boophilus*) *decoloratus* recovered	**Percentage of *Rhipicephalus* (*Boophilus*) *decoloratus* recovered from**			
	Head	Body	Feet	Tail
14559	12.4	81.2	6	0.4

TABLE 11: The ixodid tick burdens of bushbuck in the Kruger National Park

Date of Examination	*Amblyomma hebraeum*				*Rhipicephalus (Boophilus) decoloratus*			
	L	N	♂	♀	L	N	♂	♀
14/90	840	150	0	0	1344	264	78	6
11.05.92	169	180	35	25	269	492	57	63
04.09.92	0	42	0	0	24	84	6	21

***Rhipicephalus* species**

Date of Examination	*R. appendiculatus*				*R. evertsi evertsi*				*R. kochi*				*R. zambeziensis*			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
14/90	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
11.05.92	34	0	24	30	34	0	0	0	809	837	528	235	371	132	3	6
04.09.92	0	0	0	0	24	0	3	0	0	18	50	26	0	12	0	0

TABLE 12: The ixodid tick burdens of nyala in the Kruger National Park

Tick species	**Developmental Stages**	**Animals and dates examined**	
		03.10.1992	**04. 1993**
Amblyomma hebraeum	L	51	0
	N	15	18
	♂	0	0
	♀	0	0
Rhipicephalus (Boophilus) decoloratus	L	489	6
	N	1983	90
	♂	222	3
	♀	195	3
Haemaphysalis silacea	L	0	0
	N	0	0
	♂	0	1
	♀	0	0
Rhipicephalus appendiculatus	L	3	6
	N	6	0
	♂	0	0
	♀	0	0
Rhipicephalus kochi	L	198	3
	N	66	0
	♂	96	3
	♀	48	1
Rhipicephalus zambeziensis	L	21	3
	N	30	0
	♂	0	6
	♀	0	13

TABLE 13: The ixodid tick burdens of greater kudu excluding *Rhipicephalus* species

Date examined and localities	***Amblyomma hebraeum***				***Amblyomma marmoreum***				***Rhipicephalus (Boophilus) decoloratus***				***Haemaphysalis silacea***			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
18.10.1982 (at Satara)	91	273	100	61	0	0	0	0	491	786	329	262	0	0	0	0
20.09.1983 (at Renoster Koppies)	28	32	11	14	0	0	0	0	0	4	6	1	0	0	0	0
18.07.1984 * (at Bucklands farm)	0	4	22	6	0	0	0	0	0	0	0	0	171	360	85	14
18.07.85 ** (at Nwashitsumbi)	8	9	0	0	0	0	0	0	18	58	10	10	0	0	0	0
04.09.1992 (at Pafuri)	0	21	2	0	0	0	0	0	21	165	90	6	0	0	0	0

* *Ixodes pilosus*: 2 ♀

** *Hyalomma truncatum*: 1 ♂

TABLE 14: The *Rhipicephalus* species tick burdens of greater kudu

Date examined and localities	***R. appendiculatus***				***R. evertsi evertsi***				***R. glabroscutatum***				***R. zambeziensis***			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
18.10.1982 (at Satara)	0	0	0	0	17	17	1	0	0	0	0	0	0	19	0	0
20.09.1983 (at Renoster Koppies)	0	0	4	0	0	0	0	0	0	0	0	0	0	6	0	0
18.07.1984 * (at Bucklands farm)	248	65	0	0	0	4	0	0	992	846	32	6	0	0	0	0
18.07.1985 (at Nwashitsumbi)	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
04.09.1992 ** (at Pafuri)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* *Rhipicephalus exophthalmos*: 6 ♂, 6 ♀

** *Rhipicephalus kochi*: 6 ♂, 3 ♀

TABLE 15: The ixodid tick burdens of gemsbok

Tick species	Stages	03.10.84 (KTP)	06.10.84 (KTP)	06.10.84 (KTP)	07.10.84 (KTP)	08.10.84 (KTP)	08.10.84 (KTP)	08.10.84 (KTP)	20.02.90 (WCNP)	20.02.90 (WCNP)
Hyalomma truncatum	L	0	0	0	0	0	0	0	0	0
	N	0	0	0	0	0	0	0	0	0
	♂	3	1	9	1	1	1	2	19	86
	♀	10	0	0	0	0	0	2	8	18

***Rhipicephalus* species on gemsbok in the West Coast National Park**

Date examined	***R. capensis***		***R. evertsi evertsi***				***R. gertrudae***		***R. glabroscutatum***			
	♂	♀	L	N	♂	♀	♂	♀	L	N	♂	♀
20.02.90 *	49	24	116	10	8	6	1	1	1472	1775	217	78
20.02.90 **	110	51	50	26	18	12	0	0	740	3285	270	123

* *Ixodes pilosus*: 4 ♀
** *Ixodes pilosus*: 2 ♂, 4 ♀

KTP: Kgalagadi Transfrontier Park

WCNP: West Coast National Park

TABLE 16: The ixodid tick burdens of a calf on the Bucklands farm

Date examined	*Amblyomma hebraeum*				*Rhipicephalus (Boophilus) decoloratus*				*Haemaphysalis silacea*			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
11.07.84	264	0	2	0	0	0	2	2	216	25	3	2
	***Rhipicephalus* species**											
	R. appendiculatus				*R. evertsi evertsi*				*R. glabroscutatum*			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
	0	24	2	0	0	0	0	1	1332	1536	20	8

TABLE 17: The ixodid tick burdens of Boer goats on the farm at Kirkwood

Animal examined	*Amblyomma hebraeum*				*Amblyomma marmoreum*				*Rhipicephalus (Boophilus) decoloratus*				*Haemaphysalis silacea*			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
BG 1	7	1	0	0	0	2	0	0	2	1	1	0	16	27	7	2
BG 2	26	7	0	0	1	6	0	0	1	1	1	1	6	27	12	10
BG 3	26	6	0	0	0	1	0	0	2	3	0	2	10	24	5	3
BG 4	9	3	0	0	0	4	0	0	0	16	4	4	5	24	17	5
BG 5	61	9	0	0	1	1	0	0	5	6	0	0	26	22	7	2

***Rhipicephalus* species**

Animal examined	*R. evertsi evertsi*				*R. capensis- like*				*R. glabroscutatum*			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
BG 1	0	0	0	0	0	0	0	0	6	0	5	2
BG 2	0	2	0	0	0	2	0	0	9	4	16	2
BG 3	2	10	7	3	2	0	0	0	24	6	10	1
BG 4	3	8	2	0	0	0	0	0	4	2	11	3
BG 5	5	12	9	2	0	0	0	0	20	3	8	1

BG = Boer goat

TABLE 18: The ixodid tick burdens of giraffe excluding *Rhipicephalus* species

Date examined and localities	***Amblyomma hebraeum***				***Rhipicephalus (Boophilus) decoloratus***				***Hyalomma m. rufipes***		***Hyalomma truncatum***	
	L	N	♂	♀	L	N	♂	♀	♂	♀	♂	♀
30.07.86 (at Satara)	7	32	463	58	0	3	4	8	2	0	7	2
20.05.86 (at Ngirivane)	12	76	353	76	0	4	6	3	0	0	38	19
29.07.86 (at Swein)	2	5	431	45	72	608	755	539	0	2	28	9
25.07.85 (at Swein)	0	9	214	54	0	3	18	2	0	0	16	1

TABLE 19: The *Rhipicephalus* species tick burdens of giraffe

Date examined	***R. appendiculatus***				***R. evertsi evertsi***				***R. pravus* group**		***R. simus***	
	L	N	♂	♀	L	N	♂	♀	♂	♀	♂	♀
30.07.86	0	5	0	0	0	10	20	0	2	2	7	0
20.05.86	0	0	35	4	0	2	10	8	12	4	5	3
29.07.86 *	168	51	14	0	4	130	44	3	18	14	0	0
25.07.85	0	2	0	0	0	0	20	5	0	0	8	3

* *Rhipicephalus pravus* group: 4 L

TABLE 20: Proportional distribution of *Rhipicephalus* (*Boophilus*) *decoloratus* on one giraffe

Total № of *Rhipicephalus* (*Boophilus*) *decoloratus* recovered	**Percentage of *Rhipicephalus* (*Boophilus*) *decoloratus* recovered from**						
	Head	Neck	Body	Tail	Front Feet	Hind Feet	Anus and Vulva
2232	24.5	20	52	0.6	0.4	2.6	0

TABLE 21: The ixodid tick burdens of eland

Tick species	Stages	Date examined and localities					
		06.07.84 (TBNR)	**07.07.84** (TBNR)	**08.10.84** (KTP)	**08.10.84** (KTP)	**21.02.90** (WCNP)	**22.02.90** * (WCNP)
Amblyomma hebraeum	L	13696	6731	0	0	0	0
	N	113	200	0	0	0	0
	♂	60	19	0	0	0	0
	♀	42	6	0	0	0	0
Haemaphysalis silacea	L	2554	1201	0	0	0	0
	N	261	208	0	0	0	0
	♂	222	127	0	0	0	0
	♀	87	11	0	0	0	0
Hyalomma marginatum rufipes	L	0	0	0	0	0	0
	N	0	0	0	0	0	0
	♂	0	0	2	3	0	0
	♀	0	0	0	0	0	0
Hyalomma truncatum	L	0	0	0	0	0	0
	N	0	0	0	0	0	0
	♂	0	0	25	13	168	268
	♀	0	0	1	0	74	99
Ixodes sp. **(near *Ixodes pilosus*)**	L	2513	0	0	0	0	0
	N	97	0	0	0	0	0
	♂	10	4	0	0	0	4
	♀	26	14	0	0	10	2
Rhipicephalus appendiculatus	L	6526	4761	0	0	0	0
	N	325	754	0	0	0	0
	♂	76	56	0	0	0	0
	♀	40	6	0	0	0	0
Rhipicephalus capensis	L	0	0	0	0	0	0
	N	0	0	0	0	0	0
	♂	4	10	0	0	496	996
	♀	0	2	0	0	222	184
Rhipicephalus evertsi evertsi	L	2448	982	0	0	2	40
	N	512	177	0	0	8	6
	♂	17	2	0	0	0	10
	♀	5	0	0	0	0	0
Rhipicephalus glabroscutatum	L	0	0	0	0	2	0
	N	0	0	0	0	7	0
	♂	0	0	0	0	2	0
	♀	0	0	0	0	4	0

* *Rhipicephalus gertrudae*: 4 ♂; 2 ♀

TBNR: Thomas Baines Nature Reserve

KTP: Kgalagadi Transfrontier Park

WCNP: West Coast National Park

TABLE 22: The ixodid tick burdens of African buffalo excluding *Rhipicephalus* species

Date examined	***Amblyomma hebraeum***				***Amblyomma marmoreum***				***Rhipicephalus (Boophilus) decoloratus***				***Hyalomma truncatum***			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
26.09.85 (at Satara)	0	96	44	162	0	0	0	0	0	0	0	0	0	0	0	0
13.11.85 * (TBNR)	309	815	1036	284	8	1	0	0	0	0	0	0	0	0	0	0
09.06.94 (UNR)	4008	178	73	27	0	14	0	0	590	28	8	4	0	0	4	0
10.06.94 (UNR)	1716	370	18	12	0	2	0	0	234	178	186	120	0	0	0	0
03.07.94 (ESNR)	9	6	18	0	0	0	0	0	8	0	0	0	0	0	0	0
03.07.94 ** (ESNR)	16	0	34	2	0	0	0	0	44	0	0	0	0	0	0	0
10.06.94 (UNR)	7275	446	604	188	0	9	0	0	180	0	2	0	0	0	2	0
11.06.94 (UNR)	14349	754	695	117	0	0	0	0	200	0	0	0	0	0	0	0
14.06.94 (HNR) ***	3708	664	260	58	0	0	0	0	188	82	48	28	0	0	0	0
14.06.94 (HNR)****	3742	685	574	106	0	0	0	0	6	0	0	6	0	0	0	0
15.06.94 (HNR)*****	5943	734	538	142	0	0	0	0	10	2	2	2	0	0	0	0
16.06.94 (HNR)	5321	445	172	52	0	0	0	0	116	0	2	0	0	0	0	0

* *Haemaphysalis silacea*: 4 L, 357 N, 130 ♂, 76 ♀

** *Haemaphysalis silacea*: 3 L

** * *Haemaphysalis silacea*: 2 ♂

**** *Haemaphysalis silacea*: 74 L

***** *Haemaphysalis silacea*: 2 ♂

TBNR: Thomas Baines Nature Reserve

ESNR: Estern Shores Nature Reserve

UNR: Umfolozi Nature Reserve

HNR: Hluhluwe Nature Reserve

TABLE 23: The *Rhipicephalus* species tick burdens of African buffalo

Date Examined	*Rhipicephalus appendiculatus*				*Rhipicephalus evertsi evertsi*				*Rhipicephalus maculatus*				*Rhipicephalus meuhlensi*				*Rhipicephalus simus*			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
26.09.85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.11.85 *	40	138	65	28	36	12	10	6	0	0	0	0	0	0	0	0	0	0	30	12
09.06.94	2568	160	32	10	56	0	6	6	136	6	0	0	7368	0	0	0	0	0	0	0
10.06.94	2492	374	10	10	18	0	2	0	123	10	0	0	24	10	0	0	0	0	0	0
03.07.94	6502	996	84	48	1	6	8	8	740	111	8	5	93	25	0	0	0	0	0	0
03.07.94	6485	860	106	46	48	4	2	0	515	52	13	4	76	8	0	0	0	0	0	0
10.06.94	15110	949	165	172	60	0	8	6	1694	44	52	18	22	26	34	14	0	0	0	0
11.06.94	36425	1265	197	138	210	0	11	0	3378	146	39	8	472	24	30	24	0	0	11	5
14.06.94	18834	1946	126	29	226	4	1	2	2136	202	6	6	2268	56	8	4	0	0	5	2
14.06.94	29213	1492	166	74	32	4	2	0	1008	281	90	42	572	70	24	20	0	0	1	2
15.06.94	16397	1899	285	183	16	4	8	2	655	122	103	54	104	66	40	38	0	0	4	0
16.0694	5321	75	56	12	18	0	2	2	4994	310	12	10	776	64	36	20	0	0	0	0

* *Rhipicephalus follis* : 40 ♂, 32 ♀

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Chapter 4:

Ticks (Acari: Ixodidae) collected from wildlife in three of the western, semi-arid parks of South Africa

Introduction

South Africa with its various nature reserves ranging from the Kruger National Park with its huge size to various small private game reserves contains an assortment of ticks and local ungulate hosts with a variety of complex interactions. The density of the host and tick populations determines the intensity of infestation. However, some hosts are preferred by certain species of ticks, and consequently may harbour a considerable number of ticks, signifying that factors other than the tick density may determine the mosaic of infestations (Gallivan & Horak, 1997).

Identification of the factors that determine tick abundance and quantification of their importance is necessary if there is to be any understanding of spatial and temporal differences in questing tick population densities. Tick abundance in any particular habitat is determined by factors such as vegetation cover, climate and weather, which affect the survival and development of the free-living stages, and by the success of host acquisition and feeding by the parasitic stages. The free-living stages of most ticks are dependent on availability of a humid microclimate and adequate temperatures for development. An understanding of the factors that determine the density of tick populations has predictive value for the effects of such phenomena as climate change (Sonenshine, 1991; Randolph & Storey, 1999; Lindgren, Tälleklint & Polfeldt, 2000).

In particular, interspecific interactions are considered to play a major role in the diversification of parasites. Because of the effects of climatic change and habitat sub-division, the importance of such interactions is progressively being documented. Climate and vegetation are the major factors affecting the distribution of ticks. Climate is most commonly attributed as the factor limiting the distribution of animals and particularly of poikilo-thermic taxa and the geographic distributions of species are limited by a number of climatic factors (Sutherst & Maywald, 1985).

Climate affects the life cycle of ticks in a variety of ways, which are common for separate points with very different environmental characteristics. Determination of the tick's response to the environmental changes must involve an understanding of the effect on the tick of the microclimate in which it lives (Sutherst, 1987). Both environmental temperature and relative humidity are considered as key factors controlling the main aspects of the tick life cycle, and the ability to predict the presence and intensity of infestation of a specific tick species is an old challenge in veterinary parasitology.

Previous studies have used multivariate analyses to estimate the likely occurrence of particular species in a spatially explicit manner, and make dinferences about the importance of different environmental variables as determinants of their distributions (Randolph, 1993).

Categorical analysis shows that climate is a significantly better predictor of tick distributions than vegetation type. The monthly mean values for minimum temperature, maximum temperature, and rainfall have predictive abilities similar to one another. This may be due to their correlation with one another, but the much greater accuracy of regressions that use all three climatic variables suggests that tick survival and reproduction are dependent on the covariance between temperature and rainfall, rather than on one of these variables alone. Such a hypothesis is consistent with smaller scale studies. Taken in the context of current knowledge, the results may imply that the distributions of African ticks are typically determined by the direct effects of climate. This conclusion is supported by smaller scale findings of several previous studies (Walker, 1974; Dipeolu, 1989; Needham & Teel, 1991).

A number of studies have been carried out in the past few years in various national parks throughout the Republic of South Africa in order to determine the ixodid tick burdens of a variety of mammals and birds. In this respect the tick burdens of one or several animal species may compromise the ecology of the ticks (Sutherst, Wharton, Cook, Sutherland & Bourne, 1979; Randolph, 1975a; Randolph, 1975b). It has, however, been observed that in many cases several species of ticks are involved in infestation of a host or a number of hosts (Baker & Ducasse, 1967; Rechav, 1982). The number of host species and the numbers of hosts of each species that are present facilitate the determination of host preference of various ticks in addition to estimating the role of each host in influencing the total tick population.

Materials and methods

- **Survey localities**

1. **Karoo National Park**

   The Karoo National Park (32º12´-32º20´S; 22º25´-22º39´E) is situated in a semi-arid region (hot summers and cold winters with snow on the high lands) near the town of Beaufort West in north-western Western Cape Province at altitude of 600-1932m. It comprises an area of 17 706 ha. The vegetation consists of typical Karroid Broken Veld (White, 1983; Acocks, 1988).

2. **Kgalagadi Transfrontier Park (incorporating the old Kalahari Gemsbok Park)**

   The Kgalagadi Transfrontier Park (27º13″S, 22º 28″E), which now includes the old Kalahari Gemsbok Park, is located in a semi-arid region in the north-western region of South Africa and extends into the neighbouring countries of Botswana and Namibia. The vegetation consists of a mosaic of lightly wooded grassland on the dune crests, pure grassland in shallow depressions between the dunes, and *Rhigozum trichotomum* shrubby grassland in deeper hollows where the underlying calcrete is close to the surface (White, 1983; Acocks, 1988).

3. **West Coast National Park (incorporating the reserve previously known as Langebaan National Park)**

   The West Coast National Park (33º6´- 33º10´S; 17º57´- 18º2´E; Alt. 0-50m) is situated in a semi-arid region on the western coast of the Western Cape Province and comprises an area of 24 779 ha. The vegetation consists of Strandveld and isolated patches of Coastal Fynbos (White, 1983; Acocks, 1988). The park lies within the winter rainfall region where summers are moderate to hot, and winters cold and wet.

- **Survey animals**

For the purpose of this survey, a total of 45 animals of various sizes belonging to 15 different wildlife species were examined in the three above-mentioned western, semi-arid national parks. The surveyed animals were either culled or chemically immobilized specifically for survey purposes.

The antelopes and small mammal species involved in this study were as follows:

TABLE 1: Animals examined in the Kgalagadi Transfrontier Park

Host species	Number examined	Scientific names
Blue wildebeest *	2	*Connochaetes taurinus*
Gemsbok *	7	*Oryx gazella*
Eland *	2	*Taurotragus oryx*
Springbok	2	*Antidorcas marsupialis*
Red hartebeest	1	*Alcelaphus buselaphus*
Steenbok	1	*Raphicerus campestris*
Scrub hare	2	*Lepus saxatilis*
Cape ground squirrel	3	*Xerus inauris*

* Chemically immobilised

TABLE 2: Animals examined in the West Coast National Park

Host species	Number examined	Scientific names
Rock hyrax (dassie)	2	*Procavia capensis*
Eland	2	*Taurotragus oryx*
Gemsbok	2	*Oryx gazella*
Bontebok	2	*Damaliscus pygargus dorcas*
Springbok	2	*Antidorcas marsupialis*

TABLE 3: Animals examined in the Karoo National Park

Host species	Number examined	Scientific names
Black wildebeest	2	*Connochaetes gnou*
Springbok	4	*Antidorcas marsupialis*
Grey rhebok	2	*Pelea capreolus*
Mountain reed buck	2	*Redunca fulvorufula*
Scrub hare	1	*Lepus saxatilis*
Smith's red rock rabbit	2	*Pronolagus rupestris*
Rock hyrax (dassie)	2	*Procavia capensis*

- **Survey periods**

  The survey on the antelopes in the Kgalagadi Transfrontier Park Park was conducted during October 1984, while those in the West Coast National Park and the Karoo National Park took place during February 1990 and February 1991 respectively.

- **Tick recovery**

  The animals were processed for ectoparasite recovery as described by Horak, Sheppey, Knight & Beuthin (1986) for small mammals and Horak, Boomker, Spickett & De Vos (1992) for the antelopes. The arthropod parasites collected from the processed material were stored in 70% alcohol for later identification and counting under a stereoscopic microscope.

Results

For comparative purpose, the ticks are listed per locality and host rather than locality only. The ectoparasites collected from animals examined in the Kgalagadi Transfrontier Park during October 1984 are listed in tables 4 and 5. The species and number of ticks collected from the animals in the West Coast National Park in February 1990 are summarized in tables 6 and 7, and those from animals in the Karoo National Park in February 1991, are listed in tables 8 and 9.

- **Kgalagadi Transfrontier Park (incorporating former Kalahari Gemsbok National Park)**

  The antelopes in this park were not heavily infested with ticks. The black wildebeest, eland and gemsbok harboured only a small number of *Hyalomma truncatum*, which comprised 67% of the overall tick burdens, whereas the steenbok, springbok and the red hartebeest were completely free of ticks. *Rhipicephalus theileri* and *Rhipicephalus exophthalmus* were collected from the ground squirrels and scrub hares respectively.

- **West Coast National Park (incorporating former Langebaan National Park)**

  The gemsbok and eland harboured the largest tick burdens. The gemsbok were predominantly infested with *Rhipicephalus glabroscutatum* and the eland with *Hyalomma truncatum* and *Rhipicephalus capensis*. Neither of the rock dassies examined in the park was infested with ticks.

  The study showed that species such as *R. glabroscutatum* followed by *R. evertsi evertsi, H. truncatum* and *R. capensis* are dominant tick species infesting antelopes in the park, whereas *Ixodes pilosus* was less abundant. *R. glabroscutatum* accounted for 71.2% to the total number of ticks collected, and *R. capensis* 19%.

- **Karoo National Park**

  The most abundant tick species in this park was *R. glabroscutatum*, which accounted for about 94.5% of the total number of ticks collected, with *Rhipicephalus neumanni* the least abundant contributing only 1% to the total number of ticks collected. The survey revealed that mountain reedbuck are the most heavily tick infested of the animals examined, followed by grey rhebuck.

TABLE 4: Ticks (excluding *Rhipicephalus* species) collected from various wildlife species in the Kgalagadi Transfrontier Park

Animals examined	***Hyalomma truncatum***				***Hyalomma marginatum rufipes***			
	L	N	♂	♀	L	N	♂	♀
Black wildebeest	0	0	1	0	0	0	0	0
Black wildebeest	0	0	0	2	0	0	0	0
Gemsbok *	0	0	36	10	0	0	0	0
Gemsbok *	0	0	1	0	0	0	0	0
Gemsbok *	0	0	9	0	0	0	0	0
Gemsbok *	0	0	1	0	0	0	0	0
Gemsbok *	0	0	1	0	0	0	0	0
Gemsbok *	0	0	1	0	0	0	0	0
Gemsbok *	0	0	2	0	0	0	0	0
Gemsbok *	0	0	1	0	0	0	0	0
Eland *	0	0	13	0	0	0	3	0
Eland *	0	0	25	1	0	0	2	0

* Chemically immobilised

TABLE 5: *Rhipicephalus* species collected from various wildlife species in the Kgalagadi Transfrontier Park

Animal species	*R. exophthalmus*		*R. theileri*			
	♂	♀	L	N	♂	♀
Blue Wildebeest **(2)**	0	0	0	0	0	0
Gemsbok **(7)**	0	0	0	0	0	0
Gemsbok	1	1	0	0	0	0
Eland **(2)**	0	0	0	0	0	0
Scrub hare **(1)***	8	2	0	0	0	0
Scrub hare **(1)**	12	6	0	0	0	0
Cape ground squirrel **(1)**	0	0	0	0	0	3
Cape ground squirrel **(1)** **	0	0	0	0	1	3
Cape ground squirrel **(1)**	0	0	1	1	0	2
Springbok **(2)**	0	0	0	0	0	0
Red hartebeest **(1)**	0	0	0	0	0	0
Steenbok **(1)**	1	1	0	0	0	0
Blue wildebeest **(1)****	0	0	0	0	0	0

* One *Rhipicephalus* sp. tick was recovered

** Two *Rhipicephalus* sp. ticks were recovered from each animal

( ) The number of animals examined

TABLE 6: Ticks (excluding *Rhipicephalus* species) collected from various wildlife species in the West Coast National Park

Animal species	***Hyalomma truncatum***				***Ixodes pilosus* group**			
	L	N	♂	♀	L	N	♂	♀
Rock hyrax (dassie)	1	0	0	0	0	0	0	0
Gemsbok	0	0	19	8	2	0	0	4
Gemsbok	0	0	86	18	0	0	2	4
Eland	0	0	168	74	0	0	0	10
Eland	0	0	268	99	0	0	4	2

TABLE 7: *Rhipicephalus* species collected from various wildlife species in the West Coast National Park

Animal species	***R. capensis***		***R. evertsi evertsi***				***R. glabroscutatum***				***R. gertrudae***	
	♂	♀	L	N	♂	♀	L	N	♂	♀	♂	♀
Rock hyrax (dassie) *	0	0	0	0	0	0	0	0	0	0	0	0
Rock hyrax (dassie)	0	0	0	0	0	0	0	0	0	0	0	0
Springbok	0	0	0	0	0	0	4	0	0	0	0	0
Springbok	0	0	2	0	0	0	0	0	0	0	0	0
Bontebok	0	0	0	0	0	0	0	0	0	0	0	0
Bontebok	0	4	14	2	0	0	0	0	0	0	0	0
Gemsbok	49	24	116	10	8	6	1472	1775	217	78	1	1
Gemsbok	110	51	50	26	18	12	740	3285	270	123	0	0
Eland	496	222	2	8	2	0	2	7	2	4	0	0
Eland	996	184	40	6	10	0	4	0	4	2	4	2

* *Rhipicehalus* sp.: 2 L

TABLE 8: Ticks (excluding *Rhipicephalus* species) collected from various wildlife species in the Karoo National Park

Host species	***Amblyomma marmoreum***	***Hyalomma glabrum***	
	L	♂	♀
Grey rhebok	58	0	0
Springbok	2	0	0
Springbok	2	0	0
Black wildebeest	0	3	14
Black wildebeest	0	0	4

TABLE 9: *Rhipicephalus* species collected from various wildlife species in the Karoo National Park

Animal species	*R. arnoldi*		*R. distinctus*				*R. exophthalmos*		*R. glabroscutatum*				*R. neumanni*	
	L	N	L	N	♂	♀	♂	♀	L	N	♂	♀	♂	♀
Smith`s red rock rabbit	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Smith`s red rock rabbit	8	1	0	0	0	0	0	0	0	0	0	0	0	0
Scrub Hare	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Scrub Hare	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock hyrax (dassie)	27	2	37	6	0	0	0	0	4	1	0	0	0	0
Rock hyrax (dassie)	0	0	69	15	1	1	0	0	2	0	0	0	0	0
Grey rhebok	0	0	0	0	0	0	0	0	130	16	2	0	0	0
Grey rhebok	0	0	0	0	0	0	0	2	120	4	2	0	2	0
Mountain Reedbuck	0	0	0	0	0	0	7	4	2320	276	14	8	0	0
Mountain Reedbuck	0	0	0	0	0	0	0	2	1976	306	12	4	0	2
Springbok	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Springbok	0	0	0	0	0	0	6	13	0	0	2	0	0	2
Springbok	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Springbok	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black wildebeest	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Black wildebeest	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Discussion

- **Animal species**

Red hartebeest

Red hartebeest are gregarious antelope that prefer grassland of various types, ranging from the semi-desert bush savanna to open woodland. Like gemsbok they have a preference for the dryer regions of the country. They are present in the Northern Cape Province and are distributed narrowly along the border with Botswana (Skinner & Smithers, 1990). No ticks were recovered from this animal.

Black wildebeest

Black wildebeest are a fairly gregarious and common antelope species in the colder regions of South Africa. They are widespread in the Subregion and browse on karroid bushes. The main diet consists of 63% grass and 37% karroid shrubs (Skinner & Smithers, 1990). Horak, De Vos & Brown (1983a) recovered four ixodid tick species including *Rhipicephalus* (*Boophilus*) *decoloratus*, *H. truncatum*, *R. capensis* and *R. evertsi evertsi* from these animals in the Golden Gate Highlands Park and the Rietvlei Nature Reserve. Horak, Fourie, Novellie & Williams (1991) reported *Ixodes sp.* and *Rhipicephalus lounsburyi* from black wildebeest examined in the Mountain Zebra National Park. However, in this survey, which was conducted in a locality with a semi-arid climate, only *H. glabrum* and *R. neumanni* were recovered.

Blue wildebeest

Blue wildebeest are also referred to as brindled gnu, and occur marginally in the northern part of the country. They are abundant in north-eastern Swaziland (in the Hlane Game Reserve and neighbouring areas) occurring southwards to the Umfolozi-Corridor-Hluhluwe Game Reserves in Natal. They are adapted to savanna woodland. Shade and adequate water are their essential habitat requirements (Skinner & Smithers, 1990).

An earlier survey was carried out to determine the cause of the marked decline in the numbers of blue wildebeest (*Connochaetes taurinus*) in the Kruger National Park during the 1970s, and also to ascertain whether endo or ectoparasites were involved. Although the wildebeest harboured a large number of species of helminths, botfly larvae, and ticks, with the exception of the botfly larvae, their parasite burdens were never very large (Horak, De Vos & Brown, 1983a). It was thus concluded that ectoparasites were not the cause of death in these animals. Horak, De Vos & Brown (1983a) also recovered eight tick species from these animals, mainly *R.* (*B.*) *decoloratus*. Probably the most outstanding finding of this study was that very few adult ticks were recovered from these antelopes.

Comparing the tick burdens of the wildebeest with those of other large herbivores examined in the Kruger National Park it was apparent that blue wildebeest are tick resistant animals.

Springbok

Springbok are gregarious and they prefer to move around in small groups. They occur in karoo shrubs and in areas where surface water is seasonally obtainable (Skinner & Smithers, 1990). The tick burdens of springbok have been documented in Gauteng Province and North West Province (part of old the Transvaal Province) (Krugersdorp Game Reserve and the Wildlife Reserve of the National Zoological Gardens), the Bontebok National Park (Western Cape Province) and also in the Mountain Zebra National Park (Eastern Cape Province) (Horak, Meltzer & De Vos 1982; Horak, MacIvor, Petney & De Vos, 1987; Horak *et al.*, 1991).

R. evertsi evertsi and *R. nitens* were present in fair numbers on the springbok examined in the old Transvaal and Western Cape Provinces respectively. Whereas the springbok surveyed in the Mountain Zebra National Park carried a small number of ticks.

Steenbok

Steenbok, *Raphicerus campestris* belong to the subfamily Antilopinae of the family Bovidae and are small antelopes that prefer grassland in savannahs in dry climates (Kingdon, 1997).

Not many surveys have been done on this antelope. Because steenbok are small they are hence likely to harbour only the immature stages of several tick species such as *A. hebraeum*, *R. appendiculatus*, *R. evertsi evertsi* and *R. zambeziensis*, that infest them (Horak *et al*., 1987; Gallivan & Horak, 1997). A survey done on six steenbok collected from the Kgalagadi Transfrontier Park, the Kruger National Park and the Mountain Zebra National Park (refer to Chapter 6), revealed that this antelope is a host of tick species such as *A. hebraeum, R. glabroscutatum* and *R. evertsi evertsi*.

Bontebok

The common name is derived from their colourful coats. As the least common antelope in the southern African Subregion, its distribution is restricted to the south-western Cape Province. They are sociable animals, which prefer short grass to graze on (Skinner & Smithers, 1990). In a previous study in the Bontebok National Park in the Western Cape Province, Horak, Sheppey, Knight & Beuthin (1986) reported that bontebok were infested with nine tick species, namely *A. marmoreum*, *H. aciculifer*, *H. truncatum*, *I. pilosus*, *R. evertsi evertsi*, *R. gertrudae*, *R. glabroscutatum*, and *R. nitens* among which *R. nitens* was the most numerous (83.9%).

Horak and Boomker (1998) also reported 34 bonteboks examined in the Bontebok National Park, harboured *A. marmoreum*, *Ixodes sp.* (near *I. pilosus*), *R. glabroscutatum,* and *R. nitens*, with *R. nitens* being the most dominant species.

Eland

Eland are very large antelope, which previously were distributed over vast areas of South Africa. They have adapted to semi-arid areas and are highly selective mixed feeders (Skinner & Smithers, 1990). They are hosts of a large number of tick species of which large numbers of both the immature and adult stages may infest them. Horak, Potgieter, Walker, De Vos & Boomker (1983b) determined the tick burdens of eland in the Thomas Baines Nature Reserve and Andries Vosloo Kudu Reserve in the Eastern Cape Province.

The eland from the Thomas Bianes Nature Reserve harboured nine tick species, namely *A. hebraeum, R.* (*B.*) *decoloratus, H. silacea, Ixodes* sp*, I. pilosus, R. appendiculatus, R. evertsi evertsi* and *R. glabroscutatum*, among which *A. hebraeum*, *R. appendiculatus* and *H. silacea* were the most numerous. The tick burden of the eland examined in the Andries Vosloo Kudu Reserve in the Eastern Cape Province consisted of *A. hebraeum, H. silacea, I. pilosus, R.appendiculatus, R. evertsi evertsi* and *R. glabroscutatum*, with *A. hebraeum* and *R. glabroscutatum* being dominant. Out of the eight tick species recovered from the eland in the Kruger National Park, *A. hebraeum* followed by *R.* (*B.*) *decoloratus* were the most numerous tick species occurring on them.

In the Mountain Zebra National Park, Eastern Cape Province small numbers of *I. rubicundus*, and *R. lounsburyi* and large numbers or *H. glabrum*, *H. truncatum*, *M. winthemi* and *R. evertsi evertsi* were recovered from eland (Horak *et al*., 1991).

It seems as if elands are preferred hosts for some ixodid tick species, mainly *A. hebraeum*, *R.* (*B.*) *decoloratus* and *R. appendiculatus* (Horak *et al*., 1987; Horak *et al*., 1983b)

Gemsbok

This antelope is mainly found in the open arid area of the country and is a popular antelope with game farmers and hunters. They prefer open grassland, bush savanna and woodland. In dry areas, they usually eat roughage (Skinner & Smithers, 1990).

With the exception of two gemsbok examined in the Mountain Zebra National Park by Horak *et al*., (1983b) and those examined in the Willem Pretorius Nature Reserve in Free State Province by Fourie, Vrahiminis, Horak, Terblanche & Kok (1991), few surveys on the ticks infesting gemsbok in South Africa have been conducted. The gemsbok in the Mountain Zebra National Park harboured seven ixodid tick species, among which *R. glabroscutatum* and *M. winthemi* were the most abundant (Horak *et al*., 1983b). The 24 gemsbok examined in the Orange Free State harboured nine ixodid tick species of which *M. winthemi* followed by *R. evertsi evertsi* were the most numerous (Fourie *et al.*, 1991). A study performed on 18 gemsboks in Namibia revealed that these antelopes harboured only four species of ticks of which *R. exophthalmos* (previously referred to as *Rhipicephalus* sp. near *R. oculatus*) was the most numerous, and that their overall tick burdens were low (Horak, Anthonissen, Krecek & Boomker, 1992).

In this study, the gemsbok from the West Coast National Park harboured a large number of ticks compared to the ones in the Kgalagadi Transfrontier Park (Kalahari Gemsbok National Park). In the former park *R. glabroscutatum*, *R. evertsi evertsi* and *R. capensis* were the dominant species, and in the latter park *H. truncatum* was the dominant species.

Mountain reedbuck

The distributional range of these medium-sized antelope is confined to the mountains and rocky hills. They also occur in the Ndzindza Nature Reserve in eastern Swaziland and in the Malolotja Nature reserve in the northwest. They have adapted to the dry, grass-covered stony slopes of hills where scattered trees are found (Skinner & Smithers, 1990).

Mountain reedbuck are hosts of a number of ixodid tick species such as *H. truncatum, I. rubicundus, M. winthem, R. evertsi evertsi and R. glabroscutatum*. They have previously been found to carry a large number of immature *R. glabroscutatum* in the Mountain Zebra National Park (Horak *et al.*, 1991). This tick species is wide spread in the Western and Eastern Cape Provinces (Walker, Keirans & Horak, 2000).

Grey rhebok

Grey rhebok are smallish, slender and elegant antelopes that are distributed throughout the country excluding the northern parts of Limpopo Province. They are found in small family groups. Grey rhebok are browsers and tend to be mixed feeders and live on the mountain slopes at levels ranging between 1400 and 2500 m (Skinner & Smithers, 1990).

This antelope is a good host for only a few ixodid tick species. Horak & Boomker (1998) recovered *A. marmoreum* , *Ixodes* sp. (near *I. pilosus*) and also some *Rhipicephalus* species such as *R. eversti evertsi, R. gertrudae, R. glabroscutatum* and *R. nitens* from 37 grey rhebok in the Bontebok National Park with *R. nitens* being the most numerous, followed by *Ixodes sp*. (near *I. pilosus*). The mean tick burden was 163.9.

Rock hyrax (dassie)

As the name of this diurnal and tail-less animal implies, it only occurs where there are projections of rocks. However, they also occur in erosion gulleys in areas such as the Karoo (Skinner & Smithers, 1990). From the biological point of view, several studies have been conducted on this animal in South Africa (Fourie, 1983). A list of ticks that have been recovered from hyraxes in sub-Saharan Africa has been compiled by Theiler (1962). Amongst the ten tick species that have so far been recovered from rock dassies, there are three species, namely all stages of *Haemaphysalis hyracophila*, the immature stages of *Rhipicephalus arnoldi* and all developmental stages of *Rhipicephalus distinctus* that have a preference for these animals (Theiler, 1947; Hoogstraal, Walker & Neitz 1971; Hoogstraal & Wassef 1981; Horak & Fourie, 1986).

In the survey conducted by Horak & Fourie (1986) during which six rock dassies were sampled each month in the Mountain Zebra National Park, ten species of ixodid ticks were recovered, with *R. distinctus* comprising 89% of the total tick population.

Horak *et al.* (1991) in a later survey on various animals in the Mountain Zebra National Park, also collected *H. hyracophila, R. arnoldi, and R. distinctus* from dassies, with *R. arnoldi* being most dominant.

Cape ground squirrel

Ground squirrels are diurnal and widely distributed in many provinces in South Africa. In the Northern Cape Province they are wide spread in the north and north-eastern part of the province and distributed southwards. They prefer arid parts of this sub-region in which there is a large temperature difference between day and night (Skinner & Smithers, 1990).

Theiler (1962) reported Cape ground squirrels as the preferred hosts for a range of ixodid tick species such as *H. leachi, R. appendiculatus, R. pravus, R. simus* and *R. theileri*. In our study the Cape ground squirrels in the Kgalagadi Transfrontier Park were only infested with *R. theileri*.

Scrub hare

Comparing to Cape hares, they are nocturnal, associated with scrub type of habitat and feed at sundown. They occur in savanna woodland and scrubs throughout the Republic of South Africa (Skinner & Smithers 1990).

There are numerous reports on the ixodid tick species harboured by scrub hares. Horak *et al.* (1986) examined 11 scrub hares in the Bontebok National Park. The ixodid tick burden of those animals consisted of *A. marmoreum, R.* (*Boophilus*) *sp., Haemaphysalis aciculifer, Haemaphysalis leachi, H. truncatum, Ixodes* sp.*, R. evertsi evertsi, R. glabroscutatum* and *R. nitens* among which *R. nitens* followed by *I. pilosus* were dominant. Horak & Boomker (1998) recovered all the developmental stages of *R. nitens* from scrub hares, which makes it a good host for this tick species. Scrub hares frequently harbour the immature stages of *A. hebraeum* (Horak *et al*., 1987).

In a survey conducted on scrub hares by Horak *et al.* (1991) in the Mountain Zebra National Park, *A. marmoreum*, *H. truncatum, H. glabrum*, *Ixodes rubicundus, M. winthemi*, *R. arnoldi, R. oculatus, R. distinctus, R. evertsi evertsi*, and *R. glabroscutatum* were recovered from these small mammals, among which the immature stages of *H. glabrum* were dominant and comprised 37% of the ticks collected. MacIvor & Horak (2003) examined 48 scrub hares on the farm "Brakhill", in Valley Bushveld in the Eastern Cape Province.

A. hebraeum, *H. silacea*, *H. truncatum*, *R. evertsi evertsi*, *R. glabroscutatum* and *R. oculatus* were recovered, with *R. oculatus* comprising 82.7% of the tick population.

Smith's red rock rabbit

They are nocturnal animals, which spend the daylight hours in their shelters. They are distributed throughout the country excluding the northern regions and the coastal forested areas of South Africa (Skinner & Smithers, 1990).

This rabbit is a host for a number of ixodid tick species. Horak & Fourie (1991) recorded *A. marmoreum*, *H. m. rufipes, H. truncatum, I. rubicundus, R. arnoldi, R. evertsi evertsi* and *Rhipicephalus warburtoni* (then known as *Rhipicephalus punctatus*) on Smith's red rock rabbits on the farms "Preezfontein" and "Slangfontein", south-western Orange Free State, with the immature and mature stages of *R. arnoldi,* being the most dominant species.

All stages of development of *R. arnoldi* and *R. oculatus* prefer these rabbits as hosts (Walker, Keirans & Horak, 2000), but the immature stages of *R. arnoldi* are also found on rock dassies (Horak & Fourie, 1986), whose habitats frequently overlap those of the red rock rabbits.

Ixodid tick species

Amblyomma marmoreum

It is a widely distributed tick in South Africa (Horak, McKay, Heyne & Spickett, 2006). Adults have a preference for tortoises and the immature stages infest a variety of reptiles and mammals as hosts (Norval, 1975; Horak *et al*., 2006). The size of the host appears to affect the magnitude of the adult tick burden and leopard tortoises, which are the largest of the tortoise species in South Africa, harbour most adult *A. marmoreum* (Horak *et al*., 2006). In the present study no tortoises were examined, thus no comparison between the tick burdens of the various mammals and tortoises could be made.

Among the animals examined in the current surveys only those in the Karoo National Park were infested with the larvae of this tick species. The highest number of larvae recovered was 58 from a grey rhebuck, and two springbok were also infested. The small numbers of larvae recovered could possibly be ascribed to the fact that February is not a month during which peak larval numbers are present (Norval, 1975; Horak *et al*., 2006).

Hyalomma marginatum rufipes

The adults of this tick are found on large hosts, whereas the immature stages infest hares and ground-frequenting birds (Rechav, Zeederberg & Zeller, 1987; Horak *et al*., 1991). *Hyalomma marginatum rufipes* has a preference for the arid regions in southern Africa (Theiler, 1962; Howell, Walker & Nevill, 1978; Walker, 1991). Rechav *et al*. (1987) found that elands are one of the preferred hosts of *H. marginatum rufipes*, but in our study they only harboured small numbers.

Hyalomma glabrum (formerly considered to be *Hyalomma marginatum turanicum*)

Hyalomma glabrum has been reported in South Africa (Theiler, 1956), and there is one report from Namibia (Zumpt, 1956). Until recently this tick was thought to be identical to Asian *Hyalomma marginatum turanicum*, but Apanaskevich & Horak (2006) re-established it as a valid species. Howell *et al*. (1978) mapped this species as being present in the Karoo regions of the Eastern Cape Province, southern parts of the Orange Free State and the Western Cape Province. The preferred habitat of this tick is grassland with a desert climate. Apanaskevich & Horak (2006) have shown that the immature stages of *H. glabrum* prefer scrub hares and ground-frequenting birds. The adults prefer large animals such as eland and zebras (Apanaskevich & Horak, 2006). In our survey a small number of adults were recovered from the black wildebeest in the Karoo National Park.

Hyalomma truncatum

This tick has been recorded in the drier western regions of southern Africa (Theiler, 1962; Howell *et al*., 1978; Walker, 1991). Adult ticks prefer large animals such cattle, eland and zebras (Norval, 1982; Horak *et al*., 1991). One dassie, two gemsbok and two eland were infested with *H. truncatum* in the West Coast National Park. A substantial number of adults were recovered from the elands, confirming that they are good hosts for this tick species. The gemsboks also harboured a fairly large quantity of adults, whereas the dassie was only infested with a single larva.

Ixodes pilosus

Howell, Walker & Nevill (1978) noted that this tick prefers savanna and Mediterranean climates and is widely distributed along the eastern and southern coastal regions of South Africa. Within these regions, all the developmental stages are found on a variety of hosts (Horak *et al*., 1986).

All the developmental stages of this three-host tick might also be present on the same animal. Amongst the wildlife host species that are infested, grey rhebuck, bontebok and scrub hares seem to be some of its preferred hosts. This may be related to the habitat preference of both the tick and these hosts (Horak *et al*., 1986; Horak & Boomker, 1998). Since the number of females collected from host animals is always greater than that of males, it can be assumed that mating might take place off the host's body (Fourie & Horak, 1994).

Rhipicephalus arnoldi

This is a common tick of the Karoo regions of the Eastern and Western Cape Provinces and of the south-western Free State Province (Walker, Keirans & Horak, 2000). All stages of development infest Smith's red rock rabbits, but the immature stages are frequently also found on rock dassies (Horak & Fourie, 1986). This is not surprising as the habitats of these two small mammals largely overlap. The red rock rabbits are nocturnal while dassies are diurnal (Skinner & Smithers, 1990). No adult ticks were recovered in the current studies, and a few immature ticks were recovered from a Smith's red rock rabbit, a dassie and a scrub hare.

Rhipicephalus capensis

This is a large tick of which the adults favour large hosts such as eland and gemsbok (Walker *et al*., 2000). The distributions of *R. capensis* and *R. gertrudae* overlap and it is possible that both species can be found on the same animal. In the present study one gemsbok and one eland carried small numbers of *R. gertrudae*. Walker (1991) suggested that the Cape mountain zebra could be a preferred wild host. Theiler (1962) proposed a list of rodents that could act as hosts of the immature stages.

With the exception of a single record in the Eastern Cape Province, the distribution of this species is confined to the Western Cape Province.

Rhipicephalus distinctus

Theiler (1947) reported that *R. distinctus* prefers rock dassies as hosts, and the present survey has confirmed this. Horak & Fourie (1986) determined the ectoparasite burdens of rock dassies in the Mountain Zebra National Park, and found that the peak in larval numbers occurred from December to May and the number of nymphs gradually increased from January to March, whereas most adults were present from August to January. Therefore, apparently only one life cycle per annum is completed in this region.

In this survey dassies in the Karoo National Park were infested with all the developmental stages of this tick. According to Horak & Fourie (1986) the numbers of larvae and nymphs collected from dassies were not adequate to yield the number of adults collected and they suggested that some other host species must also have harboured the immature stages. It is possible that red rocks rabbits, whose habitat overlaps that of dassies may fulfil this role.

Rhipicephalus evertsi evertsi

The widespread distribution of this tick species, which includes some of the drier, but not arid regions of South Africa, has been described by Howell, Walker & Nevill (1978). This is a two-host tick with a very extensive host and distribution range in Africa (Hoogstraal, 1956; Theiler, 1962; Walker, Keirans & Horak, 2000). Its preferred wild hosts in South Africa appear to be zebras and eland, on which large numbers of both adult and immature ticks occur (Horak, De Vos & De Klerk, 1984; Horak *et al*., 1991). The absence of this tick on animals in the Kgalagadi Transfrontier Park and the Karoo National Park is probably an indication that the climates of both these parks are too arid.

Rhipicephalus exophthalmos

This species prefers a semi arid climate and a vegetation type of bushy Karoo namib shrubland or dry wooded grassland and bushland (White, 1983). It is thus present in the drier regions of South Africa such as the Karoo regions of the Western Cape Province and the Valley Bushveld regions of the Eastern Cape Province, and also in Namibia, and it has a preference for some of the antelope species that occur in these regions (Walker, Keirans & Horak, 2000). It also infests scrub hares (Keirans, Walker, Horak & Heyne, 1993) whereas its immature stages prefer elephant shrews (Fourie, Horak & Woodall, 2005). In the present study adults were present on hares and antelopes in the Kgalagadi Transfrontier Park, but only on antelopes in the Karoo National Park.

Rhipicephalus gertrudae

The distribution range of this tick species extends from the southern central regions to the western regions of the Western Cape Province to the central regions of Free State Province, South Africa. It is a three-host tick of which the immature stages feed on murid rodents (Fourie, Horak & Van Den Heever, 1992) and the adults on cattle and sheep and a variety of antelopes as well as on dogs and baboons (Horak & Fourie, 1992; Walker, Keirans & Horak, 2000; Horak & Matthee, 2003). A few adult ticks were collected from gemsbok and eland in the West Coast National Park during the present survey, but were completely overshadowed by the large numbers of *R. capensis* on these animals.

Rhipicephalus glabroscutatum

This tick is mainly distributed in the central and south-western regions of the Eastern Cape Province and the southern and western regions of the Western Cape Province and a variety of wild and domestic ungulates that are present in these regions are infested (Walker, Keirans & Horak, 2000). All the developmental stages are usually found on the lower parts of the legs and around the hooves (Walker, Keirans & Horak, 2000). All the stages of development of this two-host tick may be present on the same host. Horak *et al*. (1986) and also MacIvor &

Horak (2003) have illustrated the pattern of seasonality of this tick, which completes only one life cycle annually. The largest numbers of immature stages are present from late summer to spring (February to September) and of adults from spring to late summer (September to February). The presence of larvae and nymphs as well as adults on the gemsbok in the West Coast National Park implies that the seasonal activity of the immature stages has just commenced, while that of the adults is tailing off.

Rhipicephalus neumanni

This species, which is scattered in various localities in the Karoo regions of the Western and Northern Cape Provinces, prefers mountainous or hilly semi-desert areas (Walker, 1990; Walker, 1991). The most commonly recorded hosts of this tick are sheep (Horak & Fourie 1992) and then goats. The ticks attach to the feet between the claws (Walker, 1990).

R. neumanni has previously also been recovered from a horse and some wild antelope (Walker, Keirans & Horak, 2000). The ticks recovered from four species of antelope in the Karoo National Park in the present survey confirm both the habitat preferences and the host preferences of this tick.

Rhipicephalus theileri

Theiler (1962), Hoogstraal & Kammah (1974) and Horak, Chaparro, Beaucournu & Louw (1999) reported this tick species as associated with yellow mongoose (*Cynictis penicillata*), Cape ground squirrel and suricate. *R. theileri* prefers habitats with a hot, arid climate.

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Chapter 5:

Ticks (Acari: Ixodidae) of suni, *Neotragus moschatus* and steenbok, *Raphicerus campestris*

Introduction

During the past few years numerous surveys have been carried out in order to determine the ixodid tick burdens of several wild herbivorous mammals in South African nature reserves (Horak, Potgieter, Walker, De Vos & Boomker, 1983; Horak, Keep, Flamand & Boomker, 1988; Horak, Fourie, Novellie & Williams, 1991). The ticks infesting wild and domestic animals in this country have been listed by Walker (1991) and Walker, Keirans & Horak (2000). During these surveys a number of small herbivorous antelopes such as common duikers, *Sylvicapra grimmia*, red duikers, *Cephalophus natalensis* and grysbok, *Raphicerus melanotis* have been examined for ticks (Horak, Keep, Spickett & Boomker, 1989; Horak, Boomker & Flamand, 1991; MacIvor & Horak, 2003). However, the tick species infesting two other small antelope species namely sunis, *Neotragus moschatus* and steenbok, *Raphicerus campestris* have as yet not been determined.

The common name suni, used for *Neotragus moschatus*, probably comes from Kenya. It is a dwarf antelope species, weighing approximately 5 kg and feeds on the forest floor, mostly at dawn and dusk. It takes freshly fallen leaves, fruits and flowers dislodged from trees. This tiny animal has retiring habits and is not often seen. They inhabit forests with a dense understory, as well as shrub and low ground cover (Skinner & Smithers, 1990). In South Africa their distribution is restricted to the northern parts of the Kruger National Park and reserves and game farms in north eastern KwaZulu-Natal. Illegal hunting and agricultural encroachment have caused a drastic decline in suni populations. They are considered vulnerable but not yet endangered (Kingdon, 1997).

The common name for *Raphicerus campestris*, in both English and Afrikaans is steenbok and is probably derived from the Afrikaans word 'steen' meaning brick and refers to the reddish brick-like colour of their hair coats (Skinner & Smithers, 1990). Steenbok are a member of the group of small antelope which are classified in the family Bovidae, subfamily Antilopinae and the initial taxonomic record can be found in Wilson & Reeder (1993) who have listed over 24 subspecies of this antelope. Two disjunctive populations of steenboks are present, the eastern race is present in southern Kenya to central Tanzania, and the southern race inhabits Angola, western Zambia, Zimbabwe, and southern Mozambique south to South Africa (Skinner & Smithers, 1990). Steenbok weigh approximately 11 kg, are largely diurnal, although in hot weather the activity pattern will shift to the cooler hours in the early morning and evening. Steenbok are primarily browsers, feeding at or near ground level. They inhabit savannas in dry climates and in South Africa they are typically found in more open territories (Kingdon, 1997).

The objective of the present study was to determine the tick species infesting both these small antelopes. The sunis were examined in one habitat only, but the steenbok in a number of habitats making it possible to determine the broader spectrum of tick species that infest these animals. The localities, at which particular tick species were recovered, were recorded and these will eventually be used to add to the maps that already exist for some tick species in South Africa (Howell, Walker & Nevill, 1978; Walker, Keirans & Horak, 2000).

Materials and methods

- **Survey localities**

  This study was conducted on animals resident in the below mentioned localities:

  1. **Kgalagadi Transfrontier Park**

     Kgalagadi Transfrontier Park (27º13″30′S, 22º28″40′E), which now includes the former Kalahari Gemsbok Park, is located in a semi-arid region in the north-western region of South Africa and extends into the neighbouring countries of Namibia and Botswana. The vegetation is a mosaic of lightly wooded grassland on the dune crests, pure grassland in shallow depressions between the dunes and *Rhigozum trichotomum* shrubby grassland in deeper hollows where the underlying calcrete is near the surface (Acocks, 1988; White, 1983).

2. Kruger National Park

The Kruger National Park, which is approximately 2 Million ha in size, is situated in the Lowveld of north-eastern Mpumalanga and Limpopo Provinces and the vegetation and landscape zones of the park have been described by Gertenbach (1983). The park has warm to hot days in summer and a mild winter. The vegetation is classified mainly as Lowveld (Acocks, 1988).

3. Mountain Zebra National Park

The Mountain Zebra National Park (32º15´S; 24º41´E; Alt.1200–1957m) comprises an area 6 536 ha in extent situated 20 km south-west of Cradock in the Cape Province, Republic of South Africa. Fourie (1983) has described the physiography and climate of this park in detail. The vegetation in the park consists of Karroid *Merxmeullera* Mountain Veld replaced by Karoo on the higher slopes and Karroid Broken Veld in the northern section.

4. Tembe National Elephant Reserve

Tembe National Elephant Reserve established in 1983, is situated on the South Africa / Mozambique border. The park was proclaimed to protect some of the last remaining herds of free-ranging African elephants in that region of South Africa. At 300 km^2 Tembe is the third largest game reserve in KwaZulu-Natal, and is home not only to African elephants, but to a profusion of other wildlife species, including rhinoceroses. Tembe is also home to the rare and elusive suni, one of the smallest and shyest antelope species in southern Africa.

- **Survey animals and period**

The survey was conducted on three sunis, which died during and just after translocation from the Tembe National Elephant Reserve to the Kruger National Park during the period 1989 - 1991. Six steenboks were also examined, four in the Kruger National Park, and one each in the Mountain Zebra National Park and the Kgalagadi Transfrontier Park during the period of 1982 – 1989 (Table 1).

TABLE 1: The localities at which the suni and steenbok were examined

Antelope examined	Date of examination	Survey localities
Suni	05.07.89	Tembe National Elephant Reserve
Suni	12.07.89	Tembe National Elephant Reserve
Suni	23.07.91	Tembe National Elephant Reserve
Steenbok	22.10.82	Kruger National Park
Steenbok	08.10.84	Kgalagadi Transfrontier Park
Steenbok	19.03.85	Mountain Zebra National Park
Steenbok	17.07.85	Kruger National Park
Steenbok	19.12.89	Kruger National Park
Steenbok	04.05.93	Kruger National Park

- **Tick recovery**

The skins of the sunis and steenbok were processed for the recovery of arthropod parasites as described by Horak, Boomker, Spickett & De Vos (1992). The ixodid ticks were collected from the processed material under a stereoscopic microscope, and preserved in 70% ethanol. They were identified and counted under the same microscope.

Results

Mature and immature ticks of a total of 12 ixodid tick species were recovered from the sunis (Table 2) and steenbok (Table 3). With the exception of *Amblyomma hebraeum*, *Amblyomma marmoreum* and *Rhipicephalus* (*Boophilus*) *decoloratus*, the tick species collected from the sunis were completely different from those recovered from the steenbok. In addition to the above-mentioned three species, the steenbok were infested with *Hyalomma truncatum*, *Rhipicephalus appendiculatus*, *Rhipicephalus evertsi evertsi*, *Rhipicephalus exophthalmos*, *Rhipicephalus glabroscutatum* and *Rhipicephalus zambeziensis*, and the sunis were infested with *Haemaphysalis parmata*, *Rhipicephalus kochi*, *Rhipicephalus maculatus* and *Rhipicephalus meuhlensi* and an *Ixodes* species. All developmental stages of three species, namely *A. hebraeum*, *R.* (*B.*) *decoloratus* and *R. evertsi evertsi* were present on the steenbok.

All the steenbok in the Kruger National Park were infested with *A. hebraeum* and *R. evertsi evertsi*, and all the sunis were infested with the immature stages of *A. hebraeum*, *R. maculatus* and *R. muehlensi*. The larvae of *R. glabroscutatum* were the most abundant of all species on the steenbok in the Mountain Zebra National Park.

TABLE 2: The ixodid tick burdens of three sunis in the Tembe National Elephant Reserve

Date examined	**Species, stage of development and number of ticks recovered**									
	Amblyomma hebraeum		***Haemaphysalis parmata***			***Rhipicephalus* spp.**				
						R. kochi	***R. maculatus***		***R. muehlensi***	
	L	N	L	♂	♀	♂	L	N	L	N
July 89*	1	0	2	20	2	2	156	32	60	23
July 89**	1	0	0	0	0	0	162	27	18	0
July 91	1	1	0	2	0	2	0	1	4	2

* = *A. marmoreum*, 1 L; *R.* (*B.*) *decoloratus*, 1 ♂; *Ixodes* sp. 1L, 1N

** = *Ixodes* sp. 1 N

TABLE 3: The ixodid tick burdens of six steenbok at various localities

Date Examined	Species, stage of development and number of ticks recovered															
	Amblyomma hebraeum				*R. (B.) decoloratus*				*Rhipicephalus* species							
									R. evertsi evertsi				*R. glabroscutatum*		*R. zambeziensis*	
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	L	N
Kruger National Park																
Oct 82 *	184	196	62	16	40	92	32	24	4	60	14	8	0	0	0	38
July 85	0	3	0	0	0	0	0	0	0	7	0	2	0	0	0	0
42/89	28	18	0	0	0	0	0	0	6	4	0	0	0	0	0	0
21/93 **	1	32	0	0	0	0	0	0	3	2	0	0	0	0	13	0
Mountain Zebra National Park																
March 85 ***	0	0	0	0	0	0	0	0	416	176	0	0	7 728	32	0	0
Kgalagadi Transfrontier Park									*R. exophthalmos*							
Oct 84	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0

* = *H. truncatum*, 2 ♂; *R. appendiculatus* 192 N

** = *A. marmoreum*, 8 L, 1 N

*** = *R. glabroscutatum* 2 ♂, 2 ♀

Discussion

The majority of tick species recovered from the sunis are ticks that are only encountered in the coastal and inland wooded regions of north-eastern KwaZulu-Natal in South Africa. This applies to *Haemaphysalis parmata*, which has also been recovered in all its developmental stages from another small antelope species, namely the red duiker, *Cephalophus natalensis* in this region (Horak *et al*., 1991), and to *Rhipicephalus maculatus* and *Rhipicephalus muehlensi*, of which the adults of *R. maculatus* prefer buffaloes and bush pigs (Horak *et al*., 1983; Horak *et al*., 1991) and those of *R. muehlensi*, prefer nyalas, *Tragelaphus angasii* (Horak, Boomker & Flamand, 1995). The immature stages of the latter two ticks are found on a variety of smaller antelope species (Baker & Keep, 1970; Walker, Keirans & Horak, 2000).

Steenbok are small antelopes and are hence likely to harbour only the immature stages of most tick species that infest them (Horak, MacIvor, Petney & De Vos, 1987; Gallivan & Horak, 1997). This would normally apply to the immature stages of *A. hebraeum*, *R. appendiculatus*, *R. evertsi evertsi and R. zambeziensis*, but one of the steenbok examined during 1982 in the Kruger National Park, was examined during a very severe drought, and was consequently badly stressed. It was probably immuno-compromised and because of starvation it probably conserved energy by not grooming itself, leading not only to an increased tick burden, but also to the attachment of adult ticks that would usually not be found on a small animal.

Adult *A. hebraeum* prefer large herbivores as hosts, but their immature stages can be found on smaller animals including carnivores and birds (Horak *et al*., 1987). Adult *Amblyomma marmoreum* prefer tortoises as hosts, but their immature stages can be found on a large variety of hosts (Horak, McKay, Heyne & Spickett, 2006). The immature stages of *R. appendiculatus*, *R. evertsi evertsi* and *R. zambeziensis* all readily infest small herbivores (Walker, Keirans & Horak, 2000). The composition of the tick population of some of the antelopes is undoubtedly associated with the season during which the animals were examined.

The Mountain Zebra National Park has a mean annual rainfall of only 398 mm, and the tick species recovered from the steenbok in that region are species associated with semi-arid conditions. This applies to both *R. evertsi evertsi* and *R. glabroscutatum* (Walker, Keirans & Horak, 2000). MacIvor (1985) and also Walker, Keirans & Horak (2000) have illustrated the distribution of *R. glabroscutatum* in South Africa. It is present in both the Western and Eastern Cape Provinces and all stages of development have been collected from around the lower legs and hooves of various antelope species and from domestic livestock. MacIvor & Horak (2003) demonstrated that the immature stages of this two-host tick are most numerous from late summer to spring; hence the large numbers on the steenbok examined in the Mountain Zebra National Park.

Rhipicephalus exophthalmos is a parasite of several antelope species and also of scrub hares, and is present in the drier western regions of the country and in Namibia (Walker, Keirans & Horak, 2000). The vegetation type in which *R. exophthalmos* occurs is described as semi-arid, bushy Karoo Namib shrubland or dry wooded grassland and bushland (White, 1983).Very few immature ticks of this species have been collected, but it would seem as if elephant shrews are good hosts of these stages (Fourie, Horak & Woodall, 2005).

Rhipicephalus kochi has a very limited distribution in South Africa although it is widespread in East Africa, where it has been collected from a variety of wild herbivore hosts including scrub hares (Walker, Keirans & Horak, 2000). In South Africa it is present in the far north-eastern corner of the Kruger National Park in Limpopo Province and in the far north-east of KwaZulu_Natal Province close to the border of Mozambique. The recovery of this tick from two of the sunis in the Tembe Elephant Park represents the most southerly collection yet.

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Chapter 6:

African buffalo, *Syncerus caffer,* as hosts of *Rhipicephalus* (*Boophilus*) *decoloratus*

Introduction

The African buffalo, *Syncerus caffer*, is a large bovid with a large body surface. It prefers savanna-type habitats and needs a plentiful supply of grass, shade and water for maintenance. The savanna buffaloes occur in herds, which increase in size in the dry season. Because of the plentiful supply of water and grazing in the wet season, the herds are more scattered and fragmented (Skinner & Smithers, 1990). The current distribution of African buffaloes in South Africa is generally patchy. Large numbers are present in the Kruger National Park, the Umfolozi and Hluhluwe Nature Reserves in the north-eastern regions of the Limpopo, Mpumalanga and KwaZulu-Natal Provinces, with smaller populations in national, provincial and privately owned reserves in these and nearly all other provinces of South Africa (Skinner & Smithers, 1990).

The one-host ticks belonging to the subgenus *Rhipicephalus* (*Boophilus*) are represented by two species in South Africa, namely the indigenous species *R.* (*B.*) *decoloratus*, commonly known as the blue tick, and the introduced species *R.* (*B.*) *microplus*. *R.* (*B.*) *decoloratus* is one of the most geographically widespread ixodid ticks in South Africa and is present in habitats from open grassveld to wooded savanna (Howell, Walker & Nevill, 1978). *R.* (*B.*) *microplus* is less widespread and seems to prefer warmer and more humid habitats than the former tick. From the vector point of view both ticks have been the subject of various studies (Heyne, 1986; Tønnesen, Penzhorn, Bryson, Stoltsz & Masibigiri, 2004; Phalatsi, Fourie & Horak, 2004).

In the national tick survey conducted in Zimbabwe, Mason & Norval (1980) indicated that very few collections of *R.* (*B.*) *decoloratus* had been made from African buffaloes. Similar findings had been made earlier by Yeoman & Walker (1967) in Tanzania and by Walker (1974) in Kenya. In an experimental study performed in Zimbabwe by Norval (1984), repeated artificial infestations of a hand-reared young buffalo with *R.* (*B.*) *decoloratus* resulted in increased irritability, grooming rate and a decreased number of detached engorged female ticks after the third infestation. It would thus appear as if African buffaloes are resistant to infestation with *R.* (*B.*) *decoloratus*.

The main objective of this study was to evaluate the suitability of African buffaloes as hosts of *R.* (*B.*) *decoloratus* by comparing their tick burdens with those of other wildlife species examined in the same localities.

Materials and methods

Ten buffaloes were darted and then shot in the north-eastern KwaZulu-Natal nature reserves in a survey on the prevalence of tuberculosis in these animals. Four of these buffaloes were shot in the Umfolozi Nature Reserve and four in the Hluhluwe Nature Reserve during June 1994, and two buffaloes were shot in the Eastern Shores Nature Reserve in July 1994. The vegetation types and also the coordinates of the survey localities are summarized in Table 1 (Acocks, 1988).

The skins of the animals were processed for ectoparasite recovery as described by Horak, Boomker, Spickett & De Vos (1992). The material recovered from each skin was examined under a stereoscopic microscope and the ectoparasites were collected and stored in 70% ethyl alcohol in labelled glass tubes for later identification and counting. For the purpose of this chapter only the *R.* (*B.*) *decoloratus* collected from the buffaloes will be dealt with.

TABLE 1: Localities in KwaZulu-Natal at which buffaloes were examined

Hosts	Localities	Coordinates	Veld types (Acocks 1988)
Buffalo **(2)**	Eastern Shores Nature Reserve	27˚51´, 28˚25´S; 32˚20´, 32˚40´E	Zululand Palm Veld
Buffalo **(4)**	Umfolozi Nature Reserve	28˚17′S; 31˚50′E	Zululand Thornveld and Lowveld
Buffalo **(4)**	Hluhluwe Nature Reserve	28˚07′S; 32˚03′E	Zululand Thornveld and Lowveld

( ) number of animals examined

Results

A total of 2 372 *R.* (*B.*) *decoloratus* immatures and adults were recovered from the buffaloes. The individual tick burdens of the buffaloes are summarized in Table 2. The results reveal that the buffaloes from the Umfolozi Nature Reserve had larger burdens of *R.* (*B.*) *decoloratus* than the animals in the Hluhluwe Nature Reserve and the Easern Shores Reserve. The maximum number of *R.* (*B.*) *decoloratus* recovered from a single buffalo was 718 and the least eight. All the buffaloes were infested with the larvae of this tick species, but there was a substantial decline in the number of adult ticks, and more particularly female ticks, compared to the number of *R.* (*B.*) *decoloratus* larvae collected. The mean ratios of larvae to nymphs to males to females on the buffaloes in the Umfolozi Nature Reserve and in the Hluhluwe Nature Reserve were 9.7: 1.7: 1.6: 1.0 and 12.3: 2.5: 1.52: 1.0 respectively. The mean ratio for the *R.* (*B.*) *decoloratus* collected from all the buffaloes combined in the three reserves was 10.6: 1.8: 1.56: 1.0.

TABLE 2: Individual *Rhipicephalus* (*Boophilus*) *decoloratus* tick burdens of buffaloes

Host	Date	Locality	***Rhipicephalus* (*Boophilus*) *decoloratus***				
			L	N	♂	♀	Total
Buffalo	3.7.94	Eastern Shores NR	8	0	0	0	8
Buffalo	3.7.94	Eastern Shores NR	44	0	0	0	44
Buffalo	9.6.94	Umfolozi NR	590	28	8	4	630
Buffalo*	10.6.94	Umfolozi NR	234	178	186	120	718
Buffalo	10.6.94	Umfolozi NR	180	0	2	0	182
Buffalo	11.6.94	Umfolozi NR	200	0	0	0	200
Buffalo	14.6.94	Hluhluwe NR	288	82	48	28	446
Buffalo	14.6.94	Hluhluwe NR	6	0	0	4	10
Buffalo	15.6.94	Hluhluwe NR	10	2	2	2	16
Buffalo	16.6.94	Hluhluwe NR	116	0	2	0	118
Total	--	--	**1676**	**290**	**248**	**158**	**2372**
Ratio	--	--	**10.6**	**1.8**	**1.57**	**1**	**--**
Ratio with the burden of the calf excluded							

* Six month-old calf

TABLE 3: *Rhipicephalus* (*Boophilus*) *decoloratus* tick burdens of some large mammals at various localities in South Africa

Animal species (№ examined)	Localities	***Rhipicephalus* (*Boophilus*) *decoloratus***				Total number
		L	N	♂	♀	
Blue wildebeest **(47)**	KNP*	19722	3805	1271	940	25738
Zebra **(33)**	KNP	35321	13222	7924	3834	60301
Impala **(60)**	Biyamiti, KNP	126952	50692	18276	8724	204644
Impala **(63)**	Skukuza, KNP	88620	43029	15148	7353	154150
Impala **(12)**	Crocodile Bridge, KNP	11040	8260	4300	1947	25547
Kudu **(95)**	Malelane, KNP	161815	107711	35959	18140	323625
Bushbuck **(8)**	Skukuza, KNP	13084	4527	1811	752	20174
Nyala **(40)**	Umfolozi NR	4611	3225	1526	1063	10425
Nyala **(19)**	Mkuzi NR	6882	1966	492	214	9554
Nyala **(14)**	Ndumu NR	388	164	66	36	654
Total	**--------**	**468435**	**236601**	**86773**	**43003**	**804812**
Ratio	--------	**10.9**	**5.5**	**2**	**1**	**-------**

* KNP = Kruger National Park; NR = Nature Reserve

TABLE 4: Comparison of the mean *Rhipicephalus* (*Boophilus*) *decoloratus* tick burdens of blue wildebeest, impala, nyala, kudu, bushbuck and Zebra with those of African buffaloes

Animal species (№ examined)	***Locality***	***Rhipicephalus* (*Boophilus*) *decoloratus***				**Total number**
		L	**N**	♂	♀	
Blue wildebeest **(47)**	KNP	419.6	81	27	20	547.6
Impala **(60)**	Biyamiti, KNP	2115.8	844.8	304.6	145.4	3410.6
Kudu **(95)**	Malelane, KNP	1703.3	1134	378.5	191	3406.8
Bushbuck **(8)**	Skukuza KNP	1635.5	565.8	226.3	94	2521.6
Zebra **(33)**	KNP	1009.2	378	262.4	109.5	1723.1
Nyala **(19)**	Mkuzi NR	362.2	103.4	26	11.3	502.9
African Buffalo **(10)**	KZN NR	167.6	29	24.8	15.8	237.2

TABLE 5: Comparison of *Rhipicephalus* (*Boophilus*) *decoloratus* tick burdens of buffaloes with nyala in various nature reserves in KwaZulu-Natal

Animal species (№ examined)	***Locality***	***Rhipicephalus* (*Boophilus*) *decoloratus***				**Total number**
		L	**N**	♂	♀	
Nyala **(2)**	Hluhluwe NR	24	0	16	0	40
Nyala **(6)**	Mkuzi NR	1785	375	160	146	2466
Nyala **(40)**	Umfolozi NR	4611	3225	1526	1063	10425
Nyala **(19)**	Mkuzi NR	6882	1966	492	214	9554
Nyala **(14)**	Ndumu NR	388	164	66	36	654
Buffaloes **(10)**	KZN- NR	1676	290	248	158	2372

NR = nature reserve; KZN NR = KwaZulu-Natal nature reserves

Discussion

As an indigenous African tick *R.* (*B.*) *decoloratus* has evolved as a parasite of wild ungulates and since it has seldom been collected from African buffaloes in the wild, there is the possibility that buffaloes may possess some resistance to infestation with this tick species.

The one-host life cycle strategy of *R.* (*B.*) *decoloratus* decreases the potential for failure among the developmental stages in comparison to multi-host tick species, which moult off their hosts and then have to attach to a new host. Larvae of *R.* (*B.*) *decoloratus* usually attach to various parts of the body and thus have different chances and possibilities of surviving and developing to the nymph stage. The nymphs due to their size and searching for a favourable site for attachment, are usually more prone to be dislocated than larvae (Londt & Spickett, 1976), and the same applies to the adults and more particularly the engorging female ticks.

Baker & Keep (1970) recorded the presence, but not the quantities of *R.* (*B.*) *decoloratus* on various wild hosts in KwaZulu-Natal. However Horak, *et al.* (1983a, 1988, 1989, 1991, 1995) found that the *R.* (*B.*) *decoloratus* tick burdens of various wild hosts in this province were not large. In general buffaloes prefer savanna-type habitats whereas, antelopes such as impala (*Aepyceros melampus*) and kudu (*Tragelaphus* strepsiceros) prefer woodland and denser bush (Skinner & Smithers, 1990). The different intensities of *R.* (*B.*) *decoloratus* on various animals are suggestive of the suitability of the habitats for the ticks as well as their host preferences. However, the tick burdens of these animals, and particularly the impalas and nyalas that are usually good hosts of *R.* (*B.*) *decoloratus* that were examined in the north-eastern KwaZulu-Natal nature reserves indicate that the environment of the study locality in which the buffaloes were examined is not suitable for *R.* (*B.*) *decoloratus* (Table 2). This is confirmed by the small tick burdens of impalas and nyalas, both of which are good hosts of *R.* (*B.*) *decoloratus* (Horak *et al.*, 1983a; Table 3) that were examined during the same time of year in the same localities as the buffaloes (Horak *et al.*, 1988; 1995).

R. (*B.*) *decoloratus* is by far the most abundant tick species occurring on herbivore hosts in the Kruger National Park (Horak *et al.*, 1983b, 1984, 1992, 2003). Comparing the mean tick burdens of different animals reveals that certain species harbour large numbers of larvae, nymphs and adults and are hence considered as good hosts for *R.* (*B.*) *decoloratus*

(Table 4). Consequently cattle, examined in KwaZulu-Natal by Baker & Ducasse (1967), and greater kudus, Burchell's zebras, impalas, bushbuck and nyalas examined in the Kruger National Park by Horak *et al*., (1983b, 1984, 1992, 2003), are considered as excellent hosts of *R.* (*B.*) *decoloratus*. However, since there was a large reduction in tick numbers between the larval and nymph stage on the blue wildebeests examined in the same park (Horak *et al*., 1983b; Table 3) they are not considered to be good hosts of *R.* (*B.*) *decoloratus*, but rather as hosts that are resistant to infestation by this tick.

On good hosts the ratio of larvae to nymphs to males to females is approximately 8: 4: 2: 1, respectively, which suggests a suitable conversion from one developmental stage to the next. The overall ratio on some large antelopes examined in various localities in South Africa is 10.9: 5.5: 2: 1 (Table 3). The mean ratio of larvae to nymphs to adults on the impala examined in the Kruger National Park is 3.49: 1.69: 1.0 (Horak, Gallivan, Braack, Boomker & DeVos, 2003) and on the nyalas examined by Horak, Booker & Flamand (1995) is 3.7:1.5:1.0, in contrast to kudu, and Burchell's zebra on which the ratios are 3.0:2.0:1.0 and 3.0:1.1:1.0, respectively. This implies a good transformation of the larvae to nymphs and to adults without a large degree of loss, and also entails that these animals are good hosts of *R.* (*B.*) *decoloratus*. However, the overall ratio on the blue wildebeest is 8.9:1.7:1.0, which makes it a poor host of this tick species (Horak *et al*., 1983b). Comparing the overall ratios of ticks on nyalas to those on African buffaloes in the same locality shows that there is a substantial reduction in the number of ticks on the African buffaloes during translation from the larvae to adulthood (Table 1 & 5) and this is even more evident if the tick burden of the buffalo calf is excluded. This is similar to the findings on blue wildebeest, an innately tick resistant animal (Horak *et al*., 1983b; Table 3). However, blue wildebeest are resistant to infestation with *R.* (*B.*) *decoloratus* from one month of age (Horak *et al*., 1983b), whereas judging by the burden of the buffalo calf examined in the present survey (Table 2) buffaloes only acquire resistance at an older age and after having been exposed to ticks (Norval, 1984). This reduction in numbers between the larval and nymph stage demonstrates the potential for resistance of African buffalo to *R.* (*B.*) *decoloratus* infestation.

The differences in the intensity of infestation of *R.* (*B.*) *decoloratus* and the proportion of the total tick burdens in various regions and also among the individuals in the same region may be as a result of a variety of factors such as host preference, climate, host behaviour (such as grooming), immunity, stress, host habitat and host availability (Gallivan & Horak, 1997; Olubayo, Jono, Orinda, Grootenhuis & Hart, 1993). Some of these factors may play a significant role in determining the composition and quantity of tick burdens of buffalo compared to large antelopes.

It has also been perceived that the red-billed oxpecker (*Buphagus erythrorhnchus*) favours large ungulates with sparse hair such as African buffaloes, and feeds habitually on the ticks on these hosts (Bezuidenhout & Stutterheim, 1980), with *R.* (*B.*) *decoloratus* being one of its preferred food items. This bird is present in most of the larger nature reserves in the north-east of the country (the Kruger National Park and KwaZulu-Natal Province) where it plays an important role in reducing the number of ticks and more particularly engorging female *R.* (*B.*) *decoloratus* on animals. This could also contribute towards the skewed life-stage structure of this tick on the buffaloes.

The buffaloes surveyed were also examined for other tick species during the current survey and were infested with a total of 10 ixodid tick species and their total burdens differed between 5 911 and 58 498 ticks (Refer to chapter 3). In total 97% of the ticks collected from the buffaloes were immatures and 3% were adults. The total number of 236 845 ticks recovered from the buffaloes is large and despite the presence of red-billed oxpeckers most of these were immature ticks which are a second preferred food item of the bird. This suggests that even when these birds are present they may not be able to control the huge tick burdens of large animals such as buffaloes.

From the above results it would appear that African buffaloes are resistant to natural infestations with the one-host tick *R.* (*B.*) *decoloratus*. This resistance is expressed in this way that the majority of larvae are prevented from moulting to nymphs. However, the suitability of African buffaloes as hosts of *R.* (*B.*) *decoloratus* can only be verified when buffaloes are exhaustively examined for ticks in a locality in which susceptible hosts belonging to other wildlife species are heavily infested with *R.* (*B.*) *decoloratus*.

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Chapter 7:

General discussion

We are far from a complete knowledge of all species sharing the planet with us, and this is even truer for parasite species. During the past decades there has been a growing awareness of the importance of parasitic and other infectious diseases. As biological entities parasites, including ticks exert a cohesive force that holds ecosystems together. A number of studies have been carried out to demonstrate structures of the parasite populations within various regions of South Africa (Horak, MacIvor, Petney & De Vos, 1987; Petney & Horak, 1988, 1997; Gallivan & Horak, 1997; Fellis, Negovetich, Esch, Horak & Boomker, 2003). The dynamics and co-evolution of host-parasite interactions is dependent on the dispersal of parasites throughout a host population. How this dispersal occurs, and what possible factors are involved, have to an extent been addressed in the present study.

Although the tick burdens of a relatively small number of host animals were determined a number of basic features emerged. Animals of the same species were inclined to be infested with ticks of the same species and the species make-up of the tick populations that were found on animals of the same species differed with the region in which the animals were examined. This confirms the observations that the spatial variation in tick diversity amongst populations of the same mammal species is constrained by the fact that it appears to be a species character, but is also driven by local climatic conditions and vegetation types (Cumming, 2002; Estrada-Pena, 2003; Hubálek, Halouzka & Juøcová, 2003). The patterns of biological diversity recorded in the present studies underline this fact, and the number of studies aiming to explain patterns of parasites species among different host populations has indeed increased during the last decade.

The result of the series of studies undertaken in this project demonstrates that:

1. Tick species richness was repeatable within the population of a host species.

2. Similarities in tick assemblages among different populations of the same host species decreased with an increase in the geographical distances between these populations.
3. In general, local environmental conditions influenced the diversity of tick species in various regions of South Africa.

The repeatability of tick species richness among populations of the same host species suggests that the number of tick species that can be supported is a true attribute of a host species (Hoogstraal & Aeschlimann, 1982). This implies the existence of a threshold of defence against parasites in a host species that limits the host's ability to cope with multiple parasite species.

In most of the mammal species examined in the present study, similarity in tick assemblages within a host species decreased with an increase in the distance between the hosts populations examined. In spite of tick species richness being a true host character, this character varied across the geographic range in many hosts, indicating that the diversity of tick assemblages is also influenced by local factors. Variation across regions in the diversity of tick populations in some host populations is clearly related to climatic conditions.

Taken within the context of our current knowledge, the results imply that the distributions of African ticks are typically determined by the direct effect of climate. Biotic variables, such as vegetation type and host behaviour (grooming) and distributions, that respond to the same abiotic conditions may be important in creating heterogeneity of tick diversity at a smaller scale, but play a less important role in limiting the species ranges of ticks at broad spatial scales (Walker, 1974; Tukahirwa, 1976; Hoogstraal & Aeschlimann, 1982; Poulin & Morand, 2000).

From the information about tick species detailed here, patterns in the distribution of tick diversity amongst various host species or geographical areas are clearly demonstrated.

It is difficult to draw conclusions concerning ticks that have been collected from only a few individuals. However, there is undoubtedly a relationship between the number of hosts on which a tick can occur and the number of times it is collected (Cumming, 1998). Most of the well-collected genera of African ticks are found mainly on mammals, and amongst these the Bovidae are apparently the most heavily parasitized artiodactylid family. The latter observation is possibly biased by the sampling intensity of this family; however it gives some idea of the likely importance of various ungulates as reservoirs of tick-borne diseases.

In the present set of studies sampling effort was not uniform across various localities and the data set is strongly biased towards the availability of animals. In describing a tick species population two points demand consideration: firstly, the diversity of tick species throughout the country and secondly, the spectrum of hosts and with it the host-preference of ticks.

One of the most important demographic factors influencing the emergence of diversity has been the increase in susceptible populations. Many factors influence this susceptibility of populations to infestation; including immunosuppressant diseases and drugs, ageing of the population, and malnutrition. This study gives us a specific reference framework from which we can approach complex issues of tick diversity and host preference of various tick species in the different national parks of South Africa.

Consideration of ectoparasites and their natural hosts throughout the country offers valuable insights into their distributions and the parasitic diseases, which they can cause particularly if they transfer to domestic animals. It may also reveal certain aspects of host resistance. For instance much interest has been generated by my confirmation of Norval's (1984) claim that African buffaloes are not good hosts for the tick *R.* (*Boophilus*) *decoloratus*. My results demonstrate that there is a huge loss of ticks during the translations of larvae to nymphs in this one-host tick. The resistance to this tick species in African buffaloes is apparently acquired and not innate as it is in blue wildebeest. With genetic manipulation such observations may be translatable into future viable alternatives to chemical tick control in domestic animals.

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