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Review

Tick Diversity and Distribution of Hard (Ixodidae) Cattle Ticks in South Africa

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Abstract: Ticks are amongst the important ectoparasites where livestock are concerned, as they adversely affect the animals through bloodsucking. In tropical and subtropical countries, they transmit pathogens such as babesiosis, theileriosis, ehrlichiosis, and anaplasmosis in cattle, causing a reduction in production rate and significant concomitant economic losses. Ticks affect 80% of the cattle population across the world, with an estimated economic loss of USD 20–30 billion per year. In South Africa, economic losses in the livestock industry caused by ticks and tick-borne diseases are estimated to exceed USD 33 million per year (ZAR 500 million). There are seven major genera of ixodid ticks in Southern Africa (i.e., *Amblyomma*, *Dermacentor*, *Haemaphysalis*, *Hyalomma*, *Ixodes* and *Rhipicephalus*). The environment in which a tick lives is made up of all the various biological and abiotic factors that are either necessary or unnecessary for its life. The areas where various ticks have been found have been documented in many publications. Using these data, maps of possible species' habitats can be made. Historical records on tick distribution may be incorrect due to identification mistakes or a change in the tick's name. All the sources used to generate the maps for this review were unpublished and came from a wide range of sources. To identify tick species and the accompanying microbial ecosystems, researchers are increasingly adopting tick identification methods including 16S and 18S rDNA gene sequencing. Indeed, little is known about the genetic alterations that give important traits, including the predilection for tick hosts, transmission, and acaricide resistance. Opportunities for exploring these changes in tick populations and subpopulations are provided by advancements in omics technologies. The literature on the variety of ixodid ticks, their direct and indirect effects, and control methods in South Africa is compiled in this review.

Keywords: cattle; epidemiology; genome; tick-borne diseases

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1. Introduction

Ticks, which are arachnids, are of primary importance in veterinary and human health due to the role they play in transmitting pathogens such as rickettsia, protozoan (*Babesia* spp.), spirochaetes, and viruses [1]. They are ectoparasites of different terrestrial vertebrates, amongst which are birds, amphibians, reptiles, and mammals [2]. Approximately 900 tick species have been described globally, of which more than 700 are hard ticks (Ixodidae) and approximately 200 are soft ticks (Argasidae), with only one species belonging to the *Nuttalliellidae* family [3]. *Nuttalliella namaqua* Bedford, 1931 (from the *Nuttalliellidae* family) have features found in both hard and soft ticks [4,5]. Hard ticks (*Acari: Ixodida*) are divided into two morphological and phylogenetic groups, namely the *Prostriata* and the *Metastriata* [6]. The subfamily *Prostriata* has one genus known as *Ixodes* (240 species), while the subfamily *Metastriata* is further subdivided into five subfamilies: the *Amblyomminae* (129 species), *Bothriocrotoninae* (indigenous Australian, 7 species), *Haemaphysalinae* (164 species), *Hyalomminae* (25 species), and *Rhipicephalinae* (81 species) [7,8].

Ticks evolved over a million years ago. It is further suggested that they may have originated 350–400 million years ago (Norton, Bonamo [9]) and biological, physiological, and ecological evolution have resulted in different abilities to be vectors of tick-borne diseases [10]. Hard ticks can transmit a variety of pathogens and are considered primary vectors of diseases that affect livestock globally [11]. In humans, they are the second most effective arthropods, after the mosquito, in terms of transmitting pathogens in tropical countries [12]. Annual livestock losses due to tick-borne diseases, and the costs associated with the treatment, are estimated at USD 22 billion to 30 billion globally [13]. The livestock industry in South Africa incurs annual losses of ZAR 1.059 billion due to heartwater disease. Heartwater disease is one of the tick-borne diseases that is transmitted by ticks of the genus *Amblyomma* which severely affect livestock in Southern Africa. In Southern Africa, seven significant genera of ixodid ticks exist (i.e., *Amblyomma*, *Dermacentor*, *Haemaphysalis*, *Hyalomma*, *lxodes and Rhipicephalus*) [14]. The identification of these ticks in developing countries is mostly through traditional techniques.

Traditionally, ticks are identified using a binocular magnifying glass with taxonomical key references based on morphological traits [15]. The morphological parameters are the distinguishing features of body size, form, and texture; each feature has two or even more opposing features [16]. This method does not give information regarding genetic diversity, the biological (biotic) factors that cause ticks to be resistant to acaricides, and other key features that lead to tick speciation within individuals of the same species in different regions [17,18]. Due to technological developments, techniques such as the 16S and 18S rDNA gene sequencing allow researchers to identify tick species and the associated microbial communities [19–21]. Admittedly, the genetic changes that confer key characteristics such as tick–host preference, vector competence for specific pathogens, and acaricide resistance, are not well understood. Developments in omics technologies offer avenues for studying these variations in tick populations and sub-populations [22]. In addition, genomic studies linked to gene discovery can further support the identification of new targets for better control of ticks and tick-borne diseases (i.e., vaccines and acaricides) [23]. This review summarizes publications on the diversity of ixodid ticks, their direct and indirect impact, and control measures in South Africa. Furthermore, it identifies and provides survey gaps in the present knowledge of the biology of ticks and currently used techniques for the control of tick and tick-borne disease to help inform policy makers, researchers, and farmers on developing and making use of various available means of controlling ticks in South Africa.

2. Geographical Distribution of Ixodidae in South Africa

Ticks have a parasitic relationship with vertebrate animals, so they spend time in their environmental habitats questing for susceptible hosts [24]. Biotic and abiotic factors play a vital role in determining the distribution and abundance of ticks in specific areas. Factors such as humidity, temperature, landscape, and rainfall influence the life stages and longevity of ticks [25]. According to Tälleklint and Jaenson [26], the distribution of cattle ticks also depends on the availability of preferred host species and the sufficiency of the vegetation.

The most economically important genera of hard ticks are *Amblyomma*, *Dermacentor*, *Haemaphysalis*, *Hyalomma*, *Ixodes*, and *Rhipicephalus* (including the subgenus *Bo.)* [10]. There are major tick species of economic importance found in the Southern Africa region, as reported in Table 1 [27]. In South Africa, three genera, namely *Amblyomma*, *Hyalomma*, and *Rhipicephalus* are the most dominant [28]. There are four endemic tick species, namely *Rhipicephalus appendiculatus*, *Rhipicephalus (Bo.) decoloratus*, *Ixodes rubicundus*, and *Amblyomma hebraeum*, while the non-endemic species include *Haemaphysalis silacea*, *Rhipicephalus evertsi mimeticus*, *Rhipicephalus (Bo.) microplus*, and *Ornithodoros savignyi* which commonly infest cattle in South Africa [28]. It is hypothesized that understanding the geographical distribution of these ticks is crucial for the development and implementation of effective measures to control tick-borne diseases [29]. The sections which follow review the available and recently published results on the economically important genera of hard ticks and their geographic distribution [8].

Table 1. Major ticks found in Southern Africa that are of economic concern [27].

Genus	Species
Amblyomma	*Amblyomma hebraeum* Koch, 1844
	Amblyomma lepidum Dönitz, 1909
	Amblyomma variegatum Fabricius, 1794
Hyalomma	*Hyalomma rufipes* Koch, 1844
	Hyalomma truncatum Koch, 1844
Ixodes rubicundus	*Ixodes rubicundus* Neumann, 1904
Rhipicephalus	*Rhipicephalus (Bo.) annulatus* Say, 1821
	Rhipicephalus appendiculatus Neumann, 1901
	Rhipicephalus (Bo.) decoloratus Koch, 1844
	Rhipicephalus evertsi Neumann, 1897
	Rhipicephalus (Bo.) geigyi Aeschliman & Morel, 1965
	Rhipicephalus (Bo.) microplus Canestrini, 1888
	Rhipicephalus zambeziensis Walker, Norval, and Corwin, 1981

3. Predominant Tick Species on Cattle in South Africa

3.1. *Amblyomma*

Amblyomma is a genus of hard ticks which is considered to have the most species in the group. According to Nava and Guglielmone [8], the genus *Amblyomma* has 129 tick species which are characterized by long hypostomes and palps, flat eyes, festoons, and anal grooves. *Amblomma hebraeum* is the most prevalent species of the *Amblyomma* genus in South Africa, and its geographical distribution varies across the province, as indicated below in Figure 1.

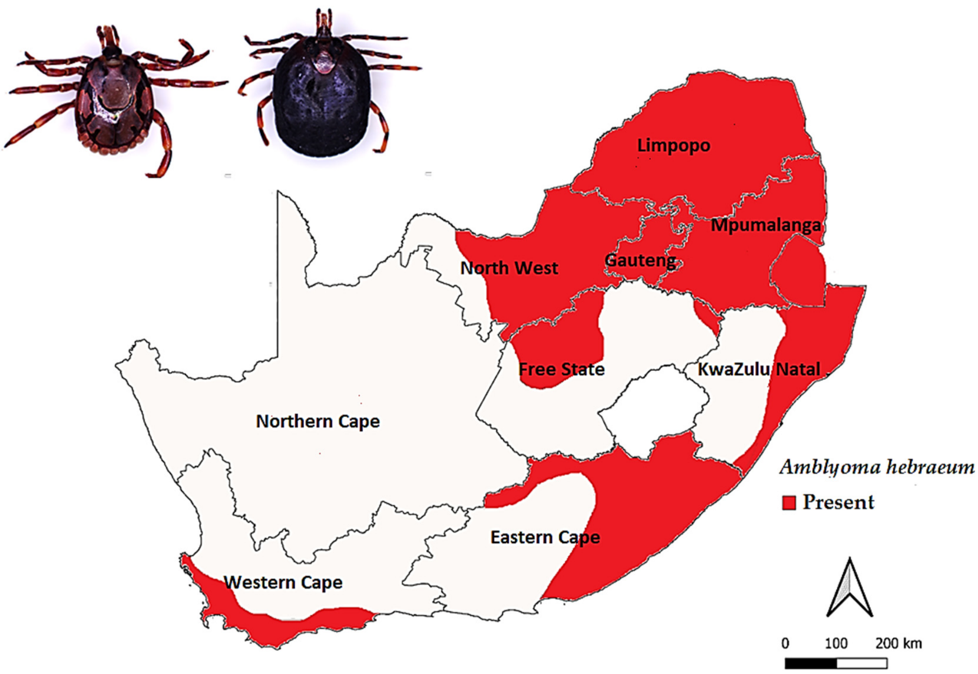

Figure 1. Geographical distribution of *Amblyoma hebraeum* across the provinces of South Africa. The red color represents the localities where the species has been found. This tick species has been previously recovered in Limpopo, North-West, Gauteng, Free State, Mpumalanga, and the coastal regions of KwaZulu-Natal and the west of the Eastern Cape. The localities in this map were adapted [30].

Amblyomma hebraeum Koch, 1844

Amblomma hebraeum Koch, 1844 is a huge and conspicuous tick, with long mouthparts, brightly colored shapes on both the male and female scutum, smooth eyes, and brown and white banded legs. Males are adorned with yellow festoons. This three-host tick is found in wooded and bushed grassland but cannot survive in open grassland. The tick species is predominantly found in the savanna biome in the eastern provinces of South Africa (Figure 1), namely KwaZulu-Natal, the west of the Eastern Cape province, Gauteng, Mpumalanga, and the east of the North-West province of South Africa [30,31]. The occurrence of this species varies from region to region in South Africa; in the Eastern Cape province, larvae were recorded to be abundant on vegetation in late summer (Febuary–March) to early winter (May–June), and least abundant in spring to mid-summer [32]. Conversely, larvae were recorded to be abundant during summer and lowest in winter and early spring at Kruger National Park in Limpopo province [33]. Overall, this species is more prevalent in cattle during spring and summer in South Africa. *Amblyomma hebraeum* adult ticks prefer to attach to less hairy regions including the axillae, belly, groin, sternum, and upper-lower perineum on cattle. Larvae are found on vegetation as they quest for a host [33], while nymphs and adults are found on soil surfaces and leaf litter [34]. This species is a vector of a disease caused by *Ehrlichia ruminantium*, which is responsible for heartwater disease which causes considerable mortality in ruminants. In South Africa, this tick species has been reported to be the main vector of *Rickettsia africae*, which belongs to the spotted fever group Rickettsiae [35]. However, there is little information regarding the diversity of *R. africae* on isolates from *A. hebraeum*, compared to isolates on *A. variegatum* in localities of South Africa [36].

3.2. *Hyalomma*

Twenty-seven species of the genus *Hyalomma* are known worldwide [8]. Reported to have originated in Iran, they are distributed beyond that region and are prevalent in Southern Africa, Europe, and Asia [37]. They include *H. dromedarrii*, *H. glabrum*, *Hy. truncatum*, and *Hy. rufipes*. Hy. *truncatum* and *Hy. rufipes* are predominant in South Africa.

3.2.1. *Hyalomma truncatum* Koch, 1844

Hyalomma truncatum are intermediate ticks with long mouthparts, dark brown bodies, beady eyes, and lengthy, red and white ringed legs. In males, the posterior outer layer of the scutum is described by a depression with multiple big punctations; alternatively, it is comparatively smooth. Adult ticks of this genus prefer both cattle and wild animals [38], attaching to areas such as the legs, lower perineum, tail switch, and anus. They are a two-host tick species but may occasionally have the character of three-host ticks; completion of the life cycle takes approximately 12 months [30]. Adults have peak activities later in wet summer (October–April), and immature stages have their peak activity in autumn (April–May) and spring (September). These ticks are found throughout South Africa, as reported in Figure 2, except for the following areas: the northeast of the Eastern Cape, southern KwaZulu-Natal, the eastern half of the Free State, and the south-eastern Gauteng provinces of South Africa, respectively [39]. *Hyalomma truncatum* transmits *Babesia caballi*, the causative agent of equine piroplasmosis, and the female ticks produce toxins that induce sweating in cattle.

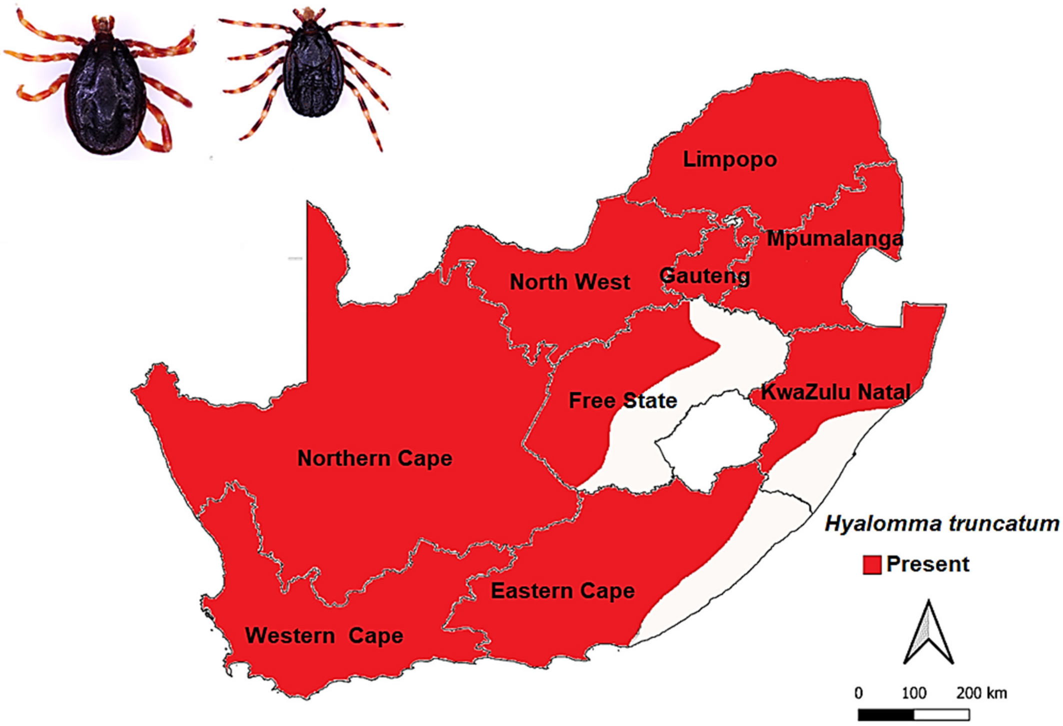

Figure 2. Geographical distribution of *Hyalomma truncatum* across the provinces of South Africa. The red color represents the localities where the species has been found. Hyalomma truncatum is distributed across the western and northern parts of South Africa but is absent from moist areas such as the northern part of the Eastern Cape, the eastern Free State, and southern KwaZulu-Natal. The localities in this map were adapted [30].

3.2.2. *Hyalomma rufipes* Koch, 1844

Hyalomma rufipes ticks have dark brown bodies, long mouthparts, an extensively punctate scutum, beady eyes, and long, red and white banded legs. They vary from *Hyalomma truncatum* in that the entire scutum is punctate and in males it is much more spherical than the latter tick's elongated shape. The adult *Hyalomma rufipes* prefers larger animals, both domestic and wild [40]. They have been collected from cattle in four countries, namely Namibia, Botswana, South Africa, and Mozambique [41]. This tick species takes a year to complete its life cycle and is a two-host tick [30]. It prefers the upper and lower perineum [42]. Adult ticks are found in the ground, questing for passing hosts [30]. *Hyalomma rufipes* is present throughout South Africa, as reported in Figure 3, especially in moist and winter rainfall regions such as the Western Cape, the northeast of KwaZulu-Natal, the North-West, Limpopo, Mpumalanga, and the Free State provinces of South Africa, respectively, including Swaziland and the mountainous areas of Lesotho [30]. The peak season of adult ticks on cattle was recorded in summer (December–February) [43]. *Hy. rufipes* is the vector of *Babesia occultans*, which is responsible for causing bovine babesiosis, and *Anaplasma marginale*, which causes bovine anaplasmosis in South Africa. This tick species causes tissue lesions in cattle, resulting in secondary bacterial infections that lead to abscess formation [30].

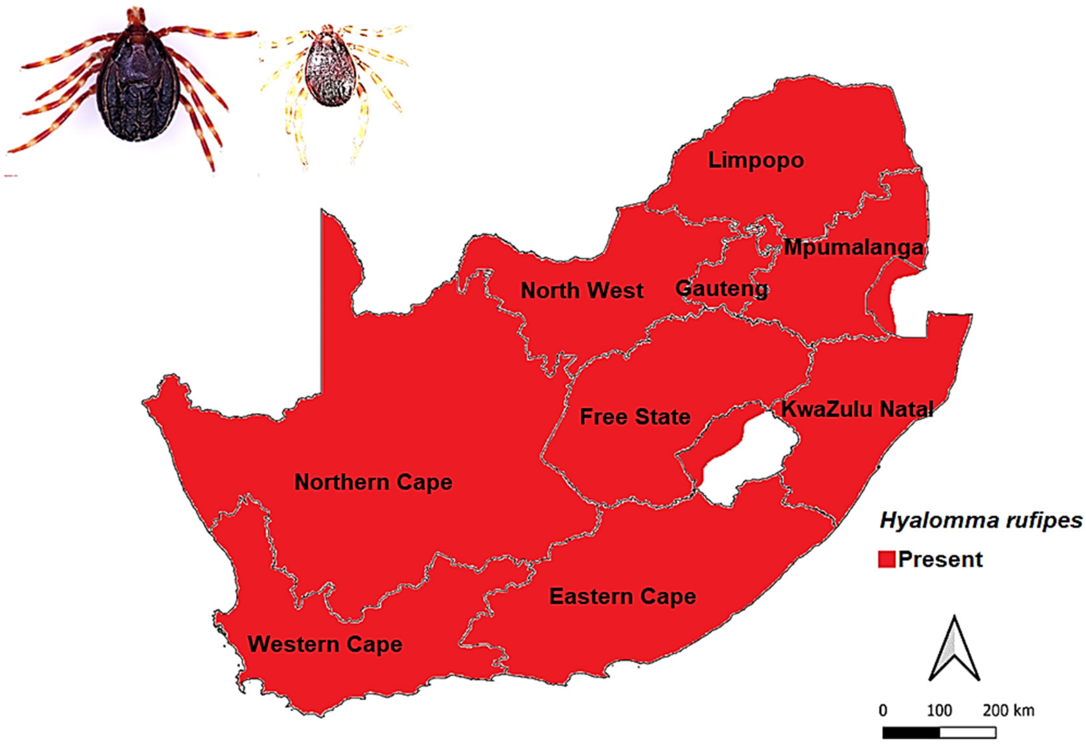

Figure 3. Geographical distribution of *Hyalomma rufipes* across the provinces of South Africa. The red color represents the localities where the species has been found. This tick species is distributed throughout the country. The localities in this map were adapted [44,45].

3.3. *Rhipicephalus*

Of the seventy species belonging to this genus [8], thirty-two are found in Southern African countries. *Rhipicephalus (Bo.) decoloratus* and *Rh. evertsi* are common in all Southern African countries, whereas the other five species of the *Rhipicephalus group*, namely *Rh. capensis* Neumann, 1904, *Rh. follis* Dönitz, 1910, *Rh. glabroscutatum*, *Rh. nitens*, and *Rh. Warburtoni*, are only restricted to South Africa [46]. Below we discuss those which are prevalent in cattle in South Africa.

3.3.1. *Rhipicephalus appendiculatus* Neumann, 1901

Rh. appendiculatus are medium-sized brown ticks with short mouthparts. Male legs grow significantly larger between the first and fourth pair, and engorged males even have a slim caudal process [47]. The common name of this tick species is derived from its uniformly brown color. It is distinguished from the other species by its short mouthparts, flat eyes, and the hexagonal shape of the adult female. This three-host tick species has a wide host range preference, which includes domestic animals and, most importantly, cattle [48]. Exogenous and endogenous factors such as animal activity and environmental change (temperature and humidity) determine questing activities [49]. *Rhipicephalus appendiculatus* prefers the savanna biome and areas that are temperate, and are not present in open savanna [50]. In South Africa, they are widely distributed along the south-eastern coasts, as well as Limpopo, Gauteng, the North-West, the northern part of the Free State, Mpumalanga, and the coastal areas of KwaZulu-Natal and the Eastern Cape provinces in South Africa, respectively, as reported in Figure 4. Moreover, this species has been collected in eastern Botswana across the Limpopo River, the Soutpansberg, the southern end of Kruger National Park, and the northern end of the National Park at Pafuri, near to the borders with Zimbabwe and Mozambique. *Rhipicephalus appendiculatus* carry the pathogen *Theileria parva*, which causes East Coast Fever, Corridor Disease, and January Disease (*Theileriosis*) in cattle [38].

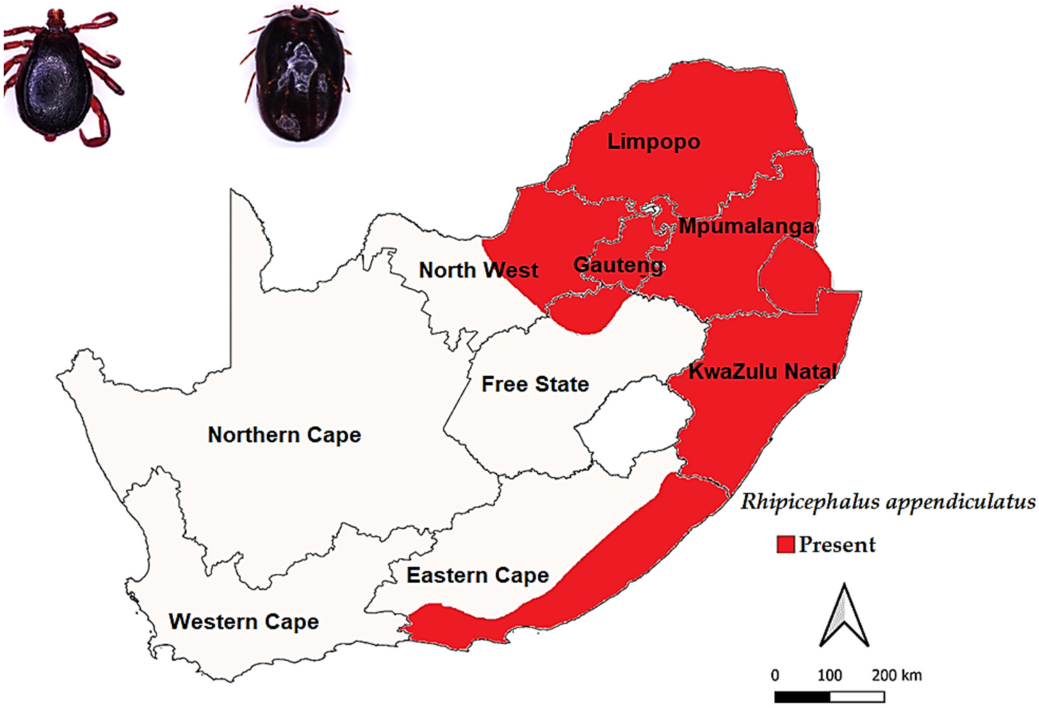

Figure 4. Geographical distribution of *Rhipicephalus appendiculatus* across the provinces of South Africa. The red color represents the localities where the species has been found. In South Africa, it is widely distributed in Limpopo, Gauteng, the northern part of the Free State, the North-West and Mpumalanga, and the coastal areas of KwaZulu-Natal and the Eastern Cape. The localities in this map were adapted [30,51].

3.3.2. *Rhipicephalus (Bo.) decoloratus* (Koch, 1844)

Rhipicephalus (Bo.) decoloratus are small, inconspicuous ticks with thin legs and short mouthparts. The males are brownish-yellow, and the darker gut may be seen through the moderately sclerotized scutum of the females. Males are always encountered in pairs with females. Engorged females are bluish-brown and can be observed adhering to the face, neck, shoulders, and escutcheon of cattle. This tick is indigenous to Africa and is of veterinary importance, as it imposes a burden on cattle by virtue of the tick-borne pathogens it transmits to domestic animals [45]. It is characterized by short mouthparts and teeth arrangement, which is divided into two columns, with three denticles in each row. The scutum of males and the conscutum of females have setae on the surfaces of scutum, and they do not have festoons [52]. This species has been successfully collected in the savanna, fynbos biomes, and grasslands of South Africa [30]. *Rhipicephalus (Bo.) decoloratus* is dominant in South Africa and has adapted to arid regions [53]. *Rhipicephalus (Bo.) decoloratus* is more dominant in the east and north of the Free State, KwaZulu-Natal, east of the Eastern Cape, Mpumalanga, North-West, Gauteng, and west of the Western Cape, Northern Cape, and Limpopo provinces of South Africa, respectively, as shown in Figure 5 [54]. *Rhipicephalus (Bo.) decoloratus* are one-host ticks whose larvae detach from vegetation, attach to the host, and complete all other life cycle stages on the host [32]. Cattle are the preferred host of *Rh. (Bo.) decoloratus* adult ticks [55]. In cattle, *Rh. (Bo.) decoloratus* attaches to the whole body of the host [56]. The activities of *Rh. (Bo.) decoloratus* on cattle were recorded in the spring [57]. Unlike *Rh. (Bo.) microplus*, this tick species transmits African babesiosis [58] and anaplasmosis.

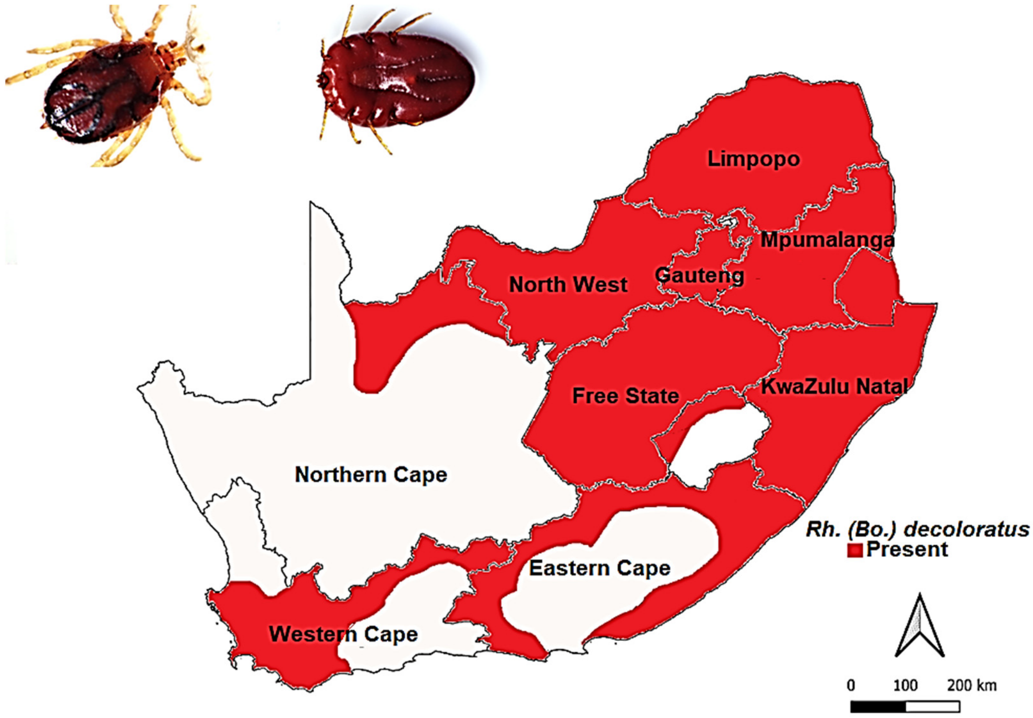

Figure 5. Geographical distribution of *Rh. (Bo.) decoloratus* across the provinces of South Africa. The red color represents the localities where the species has been found. *Rh. (Bo.) decoloratus* is more dominant in the east and north of the Free State, KwaZulu-Natal, east of the Eastern Cape, Mpumalanga, North-West, Gauteng, west of Western Cape, and Limpopo. The localities in this map were adapted [28,54,59].

3.3.3. *Rhipicephalus (Bo.) microplus* (Canestrini, 1888)

Rhipicephalus (Bo.) microplus adults are bigger and slightly redder in color than *Rh. (Bo.) decoloratus* adults, however they are almost practically identical with external structures [52]. In addition, this species' dentition is divided into two columns, with four denticles in each row. The species, which has imposed risk on cattle worldwide (including in African countries), originated in Asia [60]. Cattle transported from Asia in the 19th century carried *Rh. (Bo.) microplus* to other countries in eastern and Southern Africa, the Comoro Islands, and the Mascarene Islands [61]. About 13 decades ago, this species was recorded in South Africa [62] and has recently been established in West African countries such as Burkina Faso, Mali, Togo, the Ivory Coast, and Benin (Madder, Thys et al., 2011). In South Africa, *Rh. (Bo.) microplus* tick species have been recorded across the country, with high abundance in North-West, Limpopo, KwaZulu-Natal, Mpumalanga, Gauteng, and the coastal regions of the Western and Eastern Cape provinces, as reported in Figure 6. The preferred attachment site is not well documented; however, it is said to be similar to that of *Rh. (Bo.) decoloratus* [63]. Cattle are the most susceptible hosts of *Rh. (Bo.) microplus* [64] and, while goats play a significant role, it is to a lesser extent [65]. *Rhipicephalus (Bo.) microplus* is a one-host tick species, and the immature are more abundant in spring, with a slight decline towards summer, and a peak season in late summer (January–April) [57]. This tick transmits babesiosis which is caused by *Babesia bigemina* and *Babesia bovis* [66]. In addition, it also transmits *A. marginale* [67].

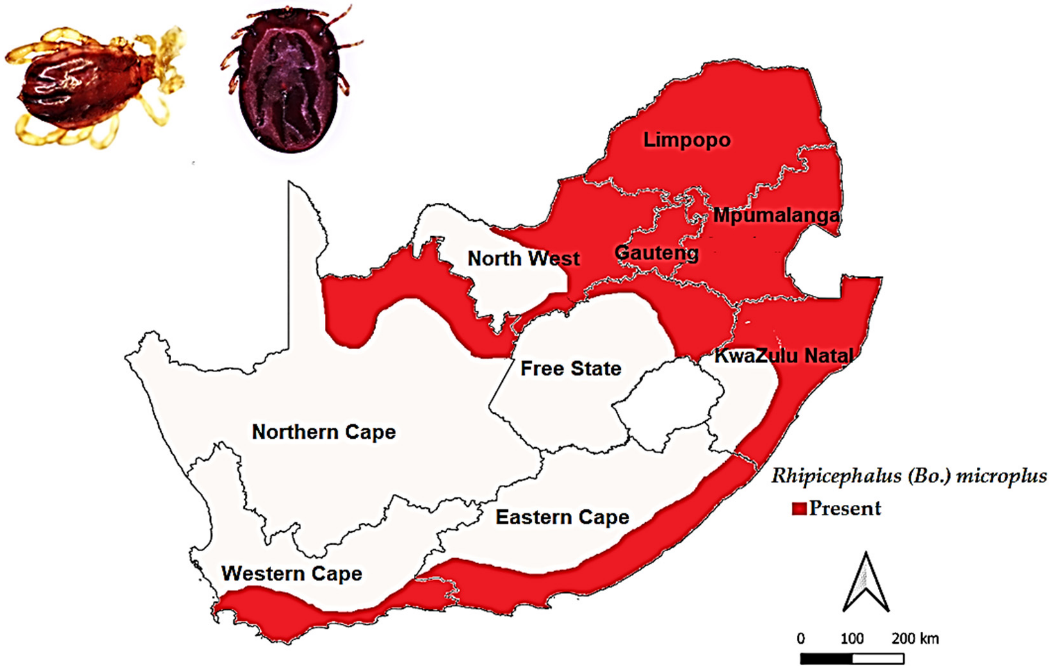

Figure 6. Geographical distribution of *Rhipicephalus (Bo.) microplus* across South Africa. The red dots represent locations where the species was detected. *Rh. microplus* has been sampled in Limpopo, the North-West, Gauteng, the coastal regions of KwaZulu-Natal, and the Eastern and Western Cape. The localities in this map were adapted [30,45,68].

3.3.4. *Rhipicephalus evertsi evertsi* Neumann, 1897

Rhipicephalus evertsi evertsi ticks are medium-sized ticks, with dark brown highly punctate scuta (conscutum and scutum), beady eyes, and legs with an orange to red color [52]. This tick species, which is broadly distributed in the Central and Southern regions of Africa, is known to be a vector of tick-borne pathogens in livestock. It transmits the bacterium *A. marginale*, the agent responsible for bovine anaplasmosis in cattle [45]. With records of being an important and common tick species in Africa, *Rh. Evertsi evertsi* occur year-round, however, they are commonly active in summer (December–January), with minor fluctuations in winter [69]. *Rhipicephalus evertsi evertsi* are two-host tick species, the larvae and nymphs feed and grow on one host, then the nymphs leave the host to the vegetation and turn into adults that quest for a second host [70]. Their seasonal activities and distribution dynamics on the host are determined by the infestation of females attached to the host [71]. They occur throughout South Africa, as reported in Figure 7, and are notably in high abundance in Limpopo, Gauteng, the North-West, Mpumalanga, the Free State, and the Eastern and Western Cape provinces of South Africa, respectively [72]. Bovine anaplasmosis is caused by this tick infecting cattle with the bacteria *A. marginale*, and their saliva contains toxins that paralyze sheep and calves in cattle [45].

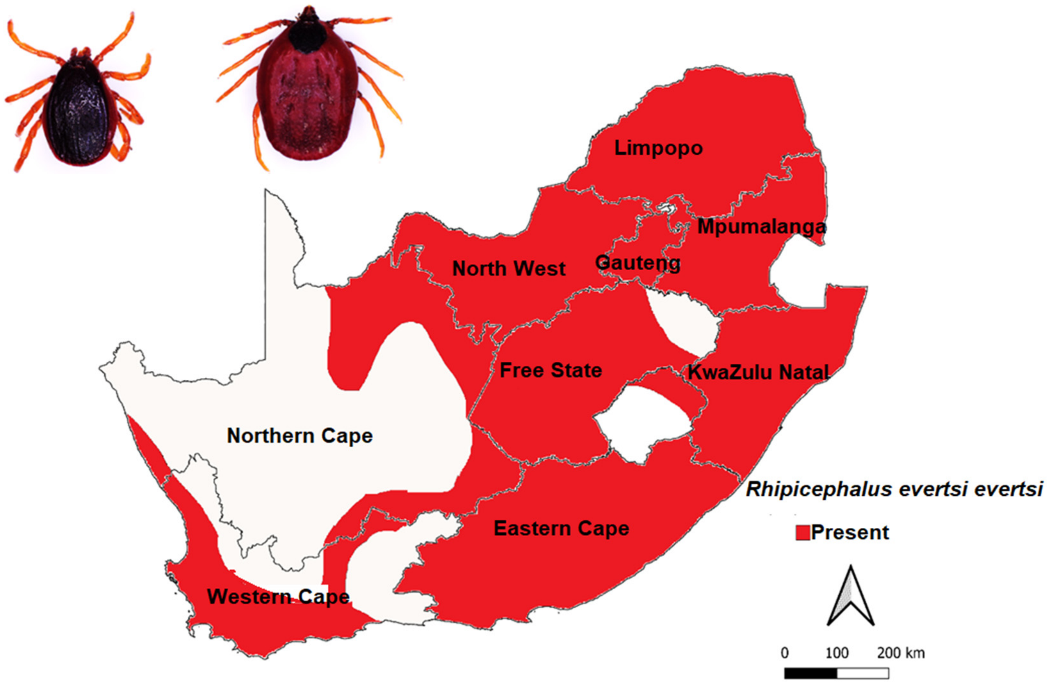

Figure 7. Geographical distribution of *Rhipicephalus evertsi evertsi* across the provinces of South Africa. The red color represents the localities where the species has been found. It occurs throughout the country but is less dominant in the Northern Cape. The localities in this map were adapted [27,28,30,73].

3.4. *Ixodes rubicundus* Neumann, 1904

Ixodes rubicundus ticks are small, reddish-brown, with extended mouth parts and no eyes. Their legs are assembled in front of them. This tick species plays a significant role in economic losses, as it causes paralysis in infected cattle [74]. *Ixodes rubicundus* were initially dominant in the Eastern, Western, and Northern Cape [75]. Their broad distribution in South Africa, as reported in Figure 8, includes the Free State, Western Cape, Eastern Cape, Northern Cape, Gauteng, Mpumalanga, and KwaZulu-Natal provinces of South Africa, in different abundances [38]. This three-host-preference tick species takes 24 months to complete all developmental stages [76]. The peak activities of adult ticks differ across regions where the nymphs and larvae feed on small animals, and the adults feed on large mammals. They are found in mountainous areas [77]. Adult females contain toxins in their saliva that cause paralysis in young mammals such as calves, sheep, and goats [45]. Importantly, most tick species can be found in all the provinces, except for *I. rubicundus*, which was found in six provinces, as shown in Figure 8. This knowledge is important when designing and planning methods to control ticks in the South African livestock production system. From the review materials, different tick species are widely distributed in different abundances across South Africa and thus can be attributed to different ecological regions and seasons. This has a different impact on the economic aspects within the livestock industry. The following sections will summarize the economic impact of ticks and tick-borne diseases in South Africa.

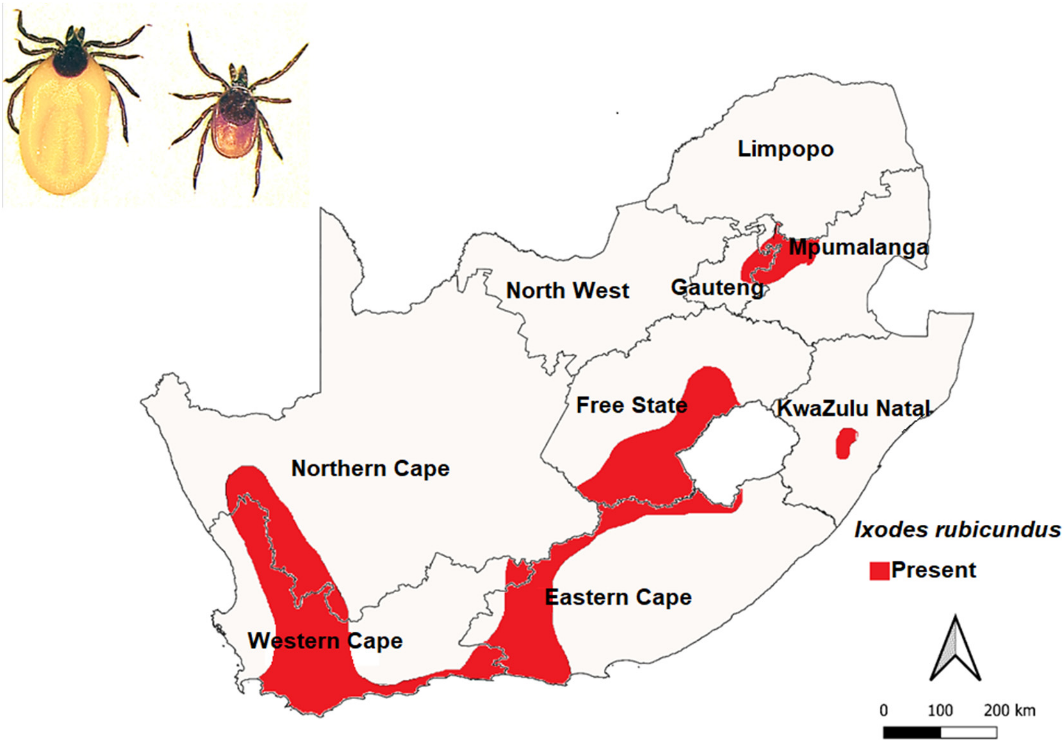

Figure 8. Geographical distribution of *Ixodes rubicundus* across the provinces of South Africa. The red color represents the localities where the species has been found. The distribution of *I. rubicundus* is broad in the Free State, Eastern Cape, Western Cape, Mpumalanga, Gauteng, and KwaZulu-Natal. The localities in this map were adapted [38,61,75].

4. The Economic Impact of Ticks and Tick-Borne Diseases on Cattle Production

Cattle production systems are crucial to the establishment of a country's economy, and sustained production ensures that there is enough food and food security [78]. However, certain factors threaten the sustainability of cattle production, including tick infestation. It is known that livestock farmers in tropical and subtropical areas have a significant problem as a result of the economic effects of ticks and tick-borne diseases on livestock productivity [79,80]. Methods used for tick control, such as chemical acaricide, have not been widely efficient due to factors such as resistance, chemical residues, and associated costs [81].

The effects of tick-borne disease result in cattle suffering from minor to severe illnesses, and eventually dying [24]. These diseases in animals include anaplasmosis, ehrlichiosis, and babesiosis [82]. When some ticks feed on the host's blood, they bite their host and cause injury to the tissue at the feeding site, leaving irritation, inflammation, or hypersensitivity [83], which results in paralysis and allergic reaction [84]. Infestations of ticks in high numbers can result in anaemia due to blood loss and lesions in the infested areas [85]. Also, the damaged skin of cattle due to tick infestation results in wounds that expose the cattle to secondary bacterial infection, which leads to diseases [86]. Moreover, tick infestation on cattle may result in reduced milk production, weight loss, lower pregnancy and birth rates, and increased mortality rates [87]. Tick-borne diseases affect the economy of developing countries in a more adverse way. There have not been sufficient studies conducted to evaluate an economic value associated with tick-borne diseases in South Africa. This has made it difficult to ascertain the true economic impact of ticks and tick-borne diseases in South Africa.

5. Control of Ticks and Tick-Borne Diseases

There are different methods used to control ticks. The most common method used to control ticks is through a chemical approach such as acaricides. However, this method loses its efficiency when the ticks selected are resistant to acaricides [88]. The sections which follow detail traditional and innovative approaches associated with the control of ticks and tick-borne diseases in South Africa.

5.1. Control of Ticks in South Africa

Common methods that have been utilized for tick control include chemicals known as acaricides; however, these have limitations because of their residue which remains present in the environment and meat, the high costs involved, and the selection of cattle breeds which are resistant to ticks [89]. Multiple types of resistance to acaricides occur [90]. For instance, the *Rh. (Bo.) microplus* species have shown significant multi-resistance: the species was reported to be resistant to OP (organophosphates), SP (synthetic pyrethroids), and Am (amidines) [91]. Additional chemicals used in the acaricides include organochloridespyrethroids, amitraz, macrocyclic lactones, insect grown regulators (IGRs), and phenilpirazolons (fipronil) [92]. Currently, chemicals are applied to livestock using systems such as spraying, dipping, or pouring [93]. Uncontrolled usage of chemical acaracides in many countries has resulted in tick species such as *Rh. (Bo.) microplus* developing resistance [94]. The mechanism that the acaricides use to control ticks on the host is either by direct contact with the specific parasites after external application or absorption of the substance from host tissues [95]. These acaricides are neurotoxins that affect the tick's nervous system [96]. Conversely, tick resistance to acaricides has become a major driver of the need for new products and strategies to successfully reduce ticks and tick-borne diseases in South Africa, and worldwide. Ranchers of dairy and beef cattle in South Africa most frequently employ the class of synthetic pyrethroid acaricides. Common acaricides used in South Africa are summarized in Table 2. Every week in the summer and every two weeks in the winter, the government offers a dipping service in which the acaricide Triatix 500 TR® (Amitraz 50 percent) is supplied enough to be used in communal dip tanks [82]. Alternative tick-control techniques used by farmers in South Africa include using old motor oil, having hens peck at the calves, manually removing ticks by cutting and pulling them, applying Jeyes Fluid, and using medicinal plants such as *Aloe ferox* and *Ptaeroxylon obliquum* [97]. These methods have been used commonly in South Africa with sufficient impact. However, the development of resistance and chemical residues have recently rendered these methods not efficient enough. This has motivated the need for other alternative methods such as developing breeding programs which will be used to breed animals that are resistant to ticks. The other method that can be applied is using vaccines.

Table 2. Acaricide use and resistance in South Africa.

Compound	First Used	Resistance 1st Reported
Arsenic	1893	Du Toit and Bekker [98]
DDT	1948	Whitehead [99]
BHC and Toxaphene	1950	Whitnall, Thorburn [100]
Carbamates	1960	Shaw [101]
Organophosphates	1960	Shaw [101]
Synthetic Pyrethroids	1981	Coetzee, Stanford [102]
Growth regulators	2000	Whitehead [99]

5.1.1. Control of Ticks with Vaccines

Vector vaccines have made it possible to lessen the effects of ticks and tick-borne diseases, by (a) reducing tick abundance and, consequently, the likelihood that hosts will contract vector-borne diseases, (b) reducing the ticks' capacity to transmit pathogens, and, preferably (c), a combination of the two factors [98]. Since its invention at Onderstepoort in 1945, vaccination has been widely employed in Southern Africa [99]. The first vaccine to be used on cattle against heartwater was an attenuated vaccine using *E. ruminantium* [100]. The vaccine was administered through the intravenous (IV) route. The vaccine showed 83% protection against heartwater on Friesian cattle [101]. Acaricides and vaccines methods do not completely eradicate ticks; they are also not sustainable and are shaping the use of acaracides due to the costs involved in South Africa and globally, respectively, and environmental health concerns [102]. Other methods that have been employed to control ticks and tick-borne diseases are summarized below.

5.1.2. Other Methods of Tick Control

Manual Removal

This technique involves removing ticks from cattle and is mainly done on small-scale farms where the infestation of ticks on cattle is low [87]. Engorged ticks, ranging from 5 to 10 mm in length, are removed from cattle in the morning, and this method can reduce the tick population by approximately 21% [103]. Approximately 10% of farmers have been documented to make use of blades or scissors to pull and cut ticks off animals [104]; some lowveld smallholders and highveld farmers in Zimbabwe have been reported to use their hands to remove ticks from cattle [105]. This technique has limits, in that the inappropriate removal of ticks manually may cause more damage to the cattle's tissue, particularly with tick species that have long mouthparts [82].

Husbandry Practices That Support Tick Control

Ticks and tick-borne diseases can also be controlled using their habitat through controls that include growing plants that are not tick friendly, grazing management, pasture burning, animal nutrition, plant extracts, essential oils, vaccination, and biological control [87]. Certain plant species such as *Stylosanthes scabra* (a tropical legume) attract and trap ticks at the larval stage in their sticky exudate [106]. Rotating cattle to clean fields is used to starve ticks, as it interrupts their life cycle [107]; however, this technique has limitations due to managerial complexity and the costs involved in fencing paddocks [108]. Another tick control strategy is the burning of pasture.

Burning pasture exposes ticks (at different stages) to high temperatures and also destroys vegetation that serves as tick habitat [94]. The burning of pasture is applied globally, particularly in countries such as South Africa, Zambia and Australia, and in North and South America [107]. This method, however, has effects on the environment such as the decrease in soil nutrients leading to leaching and/or erosion [109]. Animal nutrition also plays a part in controlling ticks, as nutrition mediates host resistance to ticks [110]. Plant species from the *Poaceae*, *Fabaceae*, *Lamiaceae*, *Verbenaceae*, *Piperaceae*, and *Asteraceae* families have been reported to contain acaricidal properties [111]. Their secondary metabolites have been used against ticks of the *Amblyomma*, *Rhipicephalus*, *Hyalomma*, *Dermacentor*, *Argas*, and *Ixodes* genera [112].

5.2. Host Resistance

Animals that are resistant to tick infestation terminate the life stage of ticks as a result of the latter's inability to feed on the host, thus reducing engorgement weights, egg production, and larval development, all of which reduce the tick population [113]. Host resistance of cattle to ticks varies across breeds, including cattle breeds such as *Bos indicus*, which display the strongest innate tick resistance [114]. In South Africa, Nguni cattle are known to be more tick-resistant than other, exotic cattle breeds. Variation in tick resistance within the Nguni cattle population has been reported by Mapholi and Maiwashe [51]. As a result, exotic breeds have been cross bred with South African indigenous breeds with the aim to improve cattle's tick resistance and other local adaptive traits (heat and humidity stress). For example, Bonsmara cattle are a composite breed developed for tick resistance, especially for cowdriosis, and to endure heat stress [115]. Host resistance to ticks is assessed by counting and scoring the number of ticks on the cattle [116]. It is increasingly possible to use genomics tools in combination with phenotyping information to achieve a genomic selection of tick-resistant cattle and it was revealed that utilizing genomic predictions, a joint genetic assessment of the Angus, Hereford, Brangus, Braford, and Brahman breeds may be easily adopted to increase tick resistance within those populations [83]. Their selection is based on the ability to transmit resistant genes from one generation to the next [117]. Currently, the breeding of tick-resistant cattle currently ensures that the animals can still produce in hostile environments and during tick challenges.

6. Conclusions

In this manuscript, we presented a comprehensive overview of ticks, their distribution, and control strategies commonly employed for tick identification and characterization in South Africa. In contrast to conventional approaches that have been used to identify ticks, the molecular characterization approaches using mtDNA markers for the proper classification of ticks within the Ixodidae are very consistent and can provide a foundation for future research of the taxonomy and evolution of Ixodidae ticks. Most of the provinces in South Africa such as Limpopo, Gauteng, Mpumalanga, Northwest, KwaZulu Natal, and the Eastern Cape Province appear to be highly endemic. Apart from this, the impact of ticks and the disease they transmit is not well documented in South Africa, and this needs to be addressed by the authorities in order to plan ahead for control strategies. Future climate change will have an impact on South Africa's habitats and climatic patterns, and it can be predicted that new tick species and diseases carried by ticks will invade the country and spread to other parts of the country where cattle ticks are non-endemic.

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References

1. De la Fuente, J.; Estrada-Pena, A.; Venzal, J.M.; Kocan, K.M.; Sonenshine, D.E. Overview: Ticks as vectors of pathogens that cause disease in humans and animals. *Front. Biosci.-Landmark* **2008**, *13*, 6938–6946. [CrossRef]
2. Klompen, J.; Keirans, J.; Oliver, J., Jr. Evolution of ticks. *Annu. Rev. Ent.* **1996**, *41*, 141–161. [CrossRef] [PubMed]
3. Guglielmone, A.A.; Robbins, R.G.; Apanaskevich, D.A.; Petney, T.N.; Estrada-Peña, A.; Horak, I.G.; Shao, R.; Barker, S.C. The Argasidae, Ixodidae and Nuttalliellidae (Acari: Ixodida) of the world: A list of valid species names. *Zootaxa* **2010**, *2528*, 1–28. [CrossRef]
4. Bedford, G. Nuttalliella namaqua, a new genus and species of tick. *Parasitology* **1931**, *23*, 230–232. [CrossRef]
5. Latif, A.A.; Putterill, J.F.; De Klerk, D.G.; Pienaar, R.; Mans, B.J. *Nuttalliella namaqua* (Ixodoidea: Nuttalliellidae): First description of the male, immature stages and re-description of the female. *PLoS ONE* **2012**, *7*, e41651. [CrossRef] [PubMed]
6. Hoogstraal, H.; Aeschlimann, A. Tick-host specificity. *Bull. Société Entomol. Suisse* **1982**, *55*, 5–32.
7. Horak, I.G.; Camicas, J.-L.; Keirans, J.E. The Argasidae, Ixodidae and Nuttalliellidae (Acari: Ixodida): A world list of valid tick names. *Ticks Tick-Borne Pathog.* **2003**, *28*, 27–54.
8. Nava, S.; Guglielmone, A.A.; Mangold, A.J. An overview of systematics and evolution of ticks. *Front. Biosci.-Landmark* **2009**, *14*, 2857–2877. [CrossRef]
9. Norton, R.A.; Bonamo, P.M.; Grierson, J.D.; Shear, W.A. Oribatid mite fossils from a terrestrial Devonian deposit near Gilboa, New York. *J. Paleontol.* **1988**, *62*, 259–269. [CrossRef]
10. Sonenshine, D.E.; Roe, R.M. *Biology of Ticks Volume 2*; Oxford University Press: Oxford, UK, 2014.
11. Dantas-Torres, F.; Chomel, B.B.; Otranto, D. Ticks and tick-borne diseases: A One Health perspective. *Trends Parasitol.* **2012**, *28*, 437–446. [CrossRef]
12. Goddard, J. *Physician's Guide to Arthropods of Medical Importance*, 4 ed.; CRC Press: Boca Raton, FL, USA, 2003.
13. Tabor, A.E.; Ali, A.; Rehman, G.; Rocha Garcia, G.; Zangirolamo, A.F.; Malardo, T.; Jonsson, N.N. Cattle tick *Rhipicephalus microplus*-host interface: A review of resistant and susceptible host responses. *Front. Cell Infect. Microbiol.* **2017**, *7*, 506. [CrossRef] [PubMed]
14. Jongejan, F.; Uilenberg, G. The global importance of ticks. *Parasitology* **2004**, *129*, S3–S14. [CrossRef]
15. Mediannikov, O.; Fenollar, F. Looking in ticks for human bacterial pathogens. *Microb. Pathog.* **2014**, *77*, 142–148. [CrossRef] [PubMed]

16. Barker, S.C.; Walker, A.R. Ticks of Australia. The species that infest domestic animals and humans. *Zootaxa* **2014**, *3816*, 1–144. [CrossRef] [PubMed]
17. Abd Rani, P.A.M.; Irwin, P.J.; Coleman, G.T.; Gatne, M.; Traub, R.J. A survey of canine tick-borne diseases in India. *Parasites Vectors* **2011**, *4*, 141. [CrossRef]
18. Hawkins, E.; Kock, R.; McKeever, D.; Gakuya, F.; Musyoki, C.; Chege, S.M.; Mutinda, M.; Kariuki, E.; Davidson, Z.; Low, B. Prevalence of *Theileria equi* and *Babesia caballi* as well as the identification of associated ticks in sympatric Grevy's zebras (*Equus grevyi*) and donkeys (*Equus africanus asinus*) in northern Kenya. *J. Wildl. Dis.* **2015**, *51*, 137–147. [CrossRef]
19. Pagel Van Zee, J.; Geraci, N.S.; Guerrero, F.D.; Wikel, S.K.; Stuart, J.J.; Nene, V.M.; Hill, C.A. Tick genomics: The *Ixodes* genome project and beyond. *Int. J. Parasitol.* **2007**, *37*, 1297–1305. [CrossRef]
20. Ali, A.; Shehla, S.; Zahid, H.; Ullah, F.; Zeb, I.; Ahmed, H.; da Silva Vaz, I., Jr.; Tanaka, T. Molecular survey and spatial distribution of *Rickettsia* spp. in ticks infesting free-ranging wild animals in Pakistan (2017–2021). *Pathogens* **2022**, *11*, 162. [CrossRef]
21. Senbill, H.; Tanaka, T.; Karawia, D.; Rahman, S.; Zeb, J.; Sparagano, O.; Baruah, A. Morphological identification and molecular characterization of economically important ticks (Acari: Ixodidae) from North and North–Western Egypt. *Acta Trop.* **2022**, *231*, 106438. [CrossRef]
22. Mohamed, W.M.A.; Moustafa, M.A.M.; Kelava, S.; Barker, D.; Matsuno, K.; Nonaka, N.; Shao, R.; Mans, B.J.; Barker, S.C.; Nakao, R. Reconstruction of mitochondrial genomes from raw sequencing data provides insights on the phylogeny of *Ixodes* ticks and cautions for species misidentification. *Ticks Tick-Borne Dis.* **2022**, *13*, 101832. [CrossRef]
23. De la Fuente, J.; Kocan, K. Strategies for development of vaccines for control of ixodid tick species. *Parasite Immunol.* **2006**, *28*, 275–283. [CrossRef] [PubMed]
24. Magnarelli, L.A. Global importance of ticks and associated infectious disease agents. *Clin. Microbiol. Newsl.* **2009**, *31*, 33–37. [CrossRef]
25. Grigoryeva, L.A.; Shatrov, A. Life cycle of the tick *Ixodes ricinus* (L.)(Acari: Ixodidae) in the North-West of Russia. *Syst. Appl. Acarol.* **2022**, *27*, 538–550. [CrossRef]
26. Tälleklint, L.; Jaenson, T.G. Relationship between *Ixodes ricinus* density and prevalence of infection with *Borrelia*-like spirochetes and density of infected ticks. *J. Med. Entomol.* **2014**, *33*, 805–811. [CrossRef]
27. Jongejan, F.; Uilenberg, G. *Infectious Diseases of Livestock*; Coetzer, J.A.W., Thomson, G.R., Maclachlan, N.J., Penrith, M.-L., Eds.; Anipedia; Oxford University Press: Cape Town, South Africa, 2018; Available online: http://www.anipedia.org/ (accessed on 14 November 2022).
28. Horak, I.G.; Jordaan, A.J.; Nel, P.J.; van Heerden, J.; Heyne, H.; van Dalen, E.M. Distribution of endemic and introduced tick species in Free State Province, South Africa. *J. S. Afr. Vet. Assoc.* **2015**, *86*, 1255. [CrossRef] [PubMed]
29. Dabaja, M.F.; Tempesta, M.; Bayan, A.; Vesco, G.; Greco, G.; Torina, A.; Blanda, V.; La Russa, F.; Scimeca, S.; Lelli, R. Diversity and distribution of ticks from domestic ruminants in Lebanon. *Vet. Ital.* **2017**, *53*, 147–155.
30. Horak, I.G.; Heyne, H.; Williams, R.; Gallivan, G.J.; Spickett, A.M.; Bezuidenhout, J.D.; Estrada-Peña, A. *The Ixodid Ticks (Acari: Ixodidae) of Southern Africa*; Springer: Berlin/Heidelberg, Germany, 2018.
31. Mapholi, N.O.; Marufu, M.C.; Maiwashe, A.; Banga, C.B.; Muchenje, V.; MacNeil, M.D.; Chimonyo, M.; Dzama, K. Towards a genomics approach to tick (Acari: Ixodidae) control in cattle: A review. *Ticks Tick-Borne Dis.* **2014**, *5*, 475–483. [CrossRef]
32. Nyangiwe, N.; Goni, S.; Hervé-Claude, L.P.; Ruddat, I.; Horak, I.G. Ticks on pastures and on two breeds of cattle in the Eastern Cape province, South Africa. *Onderstepoort J. Vet. Res.* **2011**, *78*, 1–9. [CrossRef]
33. Horak, I.G.; Gallivan, G.J.; Spickett, A.M. The dynamics of questing ticks collected for 164 consecutive months off the vegetation of two landscape zones in the Kruger National Park (1988–2002). Part I. Total ticks, *Amblyomma hebraeum* and *Rhipicephalus decoloratus*. *Onderstepoort J. Vet. Res.* **2011**, *78*, 8–17.
34. Bryson, N.; Horak, I.; Venter, E.; Yunker, C. Collection of free-living nymphs and adults of *Amblyomma hebraeum* (Acari: Ixodidae) with pheromone/carbon dioxide traps at 5 different ecological sites in heartwater endemic regions of South Africa. *Exp. Appl. Acarol.* **2000**, *24*, 971–982. [CrossRef]
35. Raoult, D.; Roux, V. Rickettsioses as paradigms of new or emerging infectious diseases. *Clin. Microbiol. Rev.* **1997**, *10*, 694–719. [CrossRef] [PubMed]
36. Maina, A.N.; Jiang, J.; Omulo, S.A.; Cutler, S.J.; Ade, F.; Ogola, E.; Feikin, D.R.; Njenga, M.K.; Cleaveland, S.; Mpoke, S. High prevalence of Rickettsia africae variants in *Amblyomma variegatum* ticks from domestic mammals in rural western Kenya: Implications for human health. *Vector-Borne Zoonotic Dis.* **2014**, *14*, 693–702. [CrossRef] [PubMed]
37. Roberts, L.S.; Janovy, J.; Schmidt, G.; Larry, S. *Roberts' Foundations of Parasitology*; Mcgraw Hill: New York, NY, USA, 2009.
38. Norval, R.; Horak, I. Vectors: Ticks. *Infect. Dis. Livest.* **2004**, *1*, 3–42.
39. Walker, J.B. A review of the ixodid ticks (Acari, Ixodidae) occurring in southern Africa. *Onderstepoort J. Vet. Res.* **1991**, *58*, 81–105. [PubMed]
40. Horak, I.; Anthonissen, M.; Krecek, R.; Boomker, J. Arthropod parasites of springbok, gemsbok, kudus, giraffes and Burchell's and Hartmann's zebras in the Etosha and Hardap Nature Reserves, Namibia. *Onderstepoort J. Vet. Res.* **1992**, *59*, 253–257. [PubMed]
41. Biggs, H.; Langenhoven, J. Seasonal Prevelance of Ixodid Ticks on Cattle in the Windhoek District of South West Africa/Namibia. *Onderstepoort J. Vet. Res.* **1984**, *51*, 175–182. [PubMed]
42. Horak, I.G.; Londt, J.; De Villiers, I. Parasites of domestic and wild animals in South Africa. XIII. The seasonal incidence of adult ticks (Acarina: Ixodidae) on cattle in the northern Transvaal. *Onderstepoort J. Vet. Res.* **1979**, *46*, 31–39.

43. Mapholi, N.; Maiwashe, A.; Matika, O.; Riggio, V.; Banga, C.; MacNeil, M.D.; Muchenje, V.; Nephawe, K.; Dzama, K. Genetic parameters for tick counts across months for different tick species and anatomical locations in South African Nguni cattle. *Trop. Anim. Health Prod.* **2017**, *49*, 1201–1210. [CrossRef]
44. Horak, I.G.; Boshoff, C.R.; Cooper, D.V.; Foggin, C.M.; Govender, D.; Harrison, A.; Hausler, G.; Hofmeyr, M.; Kilian, J.W.; MacFadyen, D.N.; et al. Parasites of domestic and wild animals in South Africa. XLIX. Ticks (Acari: Ixodidae) infesting white and black rhinoceroses in southern Africa. *Onderstepoort J. Vet. Res.* **2017**, *84*, e1–e11. [CrossRef]
45. Walker, A.R. *Ticks of Domestic Animals in Africa: A Guide to Identification of Species*; Bioscience Reports Edinburgh: Edinburgh, UK, 2003.
46. Keirans, J. Systematics of the Ixodida (*Argasidae, Ixodidae, Nuttalliellidae*): An overview and some problems. In *Tick Vector Biology*; Springer: Berlin/Heidelberg, Germany, 1992; pp. 1–21.
47. Walker, J.B.; Keirans, J.E.; Horak, I.G. The genus Rhipicephalus (*Acari, Ixodidae*)—A guide to the brown ticks of the world. *Rostrum Newsl. Entomol. Soc. South. Afr.* **2000**, *2000*, 14.
48. Nijhof, A.M.; Balk, J.A.; Postigo, M.; Jongejan, F. Selection of reference genes for quantitative RT-PCR studies in *Rhipicephalus* (*Boophilus*) *microplus* and *Rhipicephalus appendiculatus* ticks and determination of the expression profile of Bm86. *BMC Mol. Biol.* **2009**, *10*, 112. [CrossRef] [PubMed]
49. Paul, R.E.; Cote, M.; Le Naour, E.; Bonnet, S.I. Environmental factors influencing tick densities over seven years in a French suburban forest. *Parasites Vectors* **2016**, *9*, 309. [CrossRef] [PubMed]
50. Lessard, P.; l'Eplattenier, R.; Norval, R.; Kundert, K.; Dolan, T.; Croze, H.; Walker, J.; Irvin, A.; Perry, B.D. Geographical information systems for studying the epidemiology of cattle diseases caused by Theileria parva. *Vet. Rec.* **1990**, *126*, 255–262. [PubMed]
51. Mapholi, N.O.; Maiwashe, A.; Matika, O.; Riggio, V.; Bishop, S.; MacNeil, M.; Banga, C.; Taylor, J.; Dzama, K. Genome-wide association study of tick resistance in South African Nguni cattle. *Ticks Tick-Borne Dis.* **2016**, *7*, 487–497. [CrossRef] [PubMed]
52. Madder, M.; Horak, I.; Stoltsz, H. Tick identification. *Pretoria Fac. Vet. Sci. Univ. Pretoria* **2014**, *58*, 1–34.
53. Estrada-Peña, A. The relationships between habitat topology, critical scales of connectivity and tick abundance *Ixodes ricinus* in a heterogeneous landscape in northern Spain. *Ecography* **2003**, *26*, 661–671. [CrossRef]
54. Nyangiwe, N.; Harrison, A.; Horak, I.G. Displacement of Rhipicephalus decoloratus by *Rhipicephalus microplus* (Acari: Ixodidae) in the Eastern Cape Province, South Africa. *Exp. Appl. Acarol.* **2013**, *61*, 371–382. [CrossRef]
55. Dreyer, K.; Fourie, L.; Kok, D. Tick diversity, abundance and seasonal dynamics in a resource-poor urban environment in the Free State Province. *Onderstepoort J. Vet. Res.* **1998**, *65*.
56. Baker, M.; Ducasse, F. Tick infestation of livestock in Natal. I. The predilection sites and seasonal variations of cattle ticks. *J. S. Afr. Vet. Assoc.* **1967**, *38*, 447–453.
57. Baker, M.; Ducase, F.; Sutherst, R.W.; Maywald, G. The seasonal tick populations on traditional and commercial cattle grazed at four altitudes in Natal. *J. S. Afr. Vet. Assoc.* **1989**, *60*, 95–101.
58. Terkawi, M.A.; Huyen, N.X.; Shinuo, C.; Inpankaew, T.; Maklon, K.; Aboulaila, M.; Ueno, A.; Goo, Y.-K.; Yokoyama, N.; Jittapalapong, S. Molecular and serological prevalence of *Babesia bovis* and *Babesia bigemina* in water buffaloes in the northeast region of Thailand. *Vet. Parasitol.* **2011**, *178*, 201–207. [CrossRef] [PubMed]
59. Spickett Arthur, M. *Ticks and Tick-Borne Diseases Monograph 1—Ixodid Ticks of Major Economic Importance and Their Distribution in South Africa*, 1st ed.; Agri Connect: Pretoria, South Africa, 2013.
60. Temeyer, K.B.; Davey, R.B.; Chen, A.C. Identification of a third *Boophilus microplus* (Acari: Ixodidae) cDNA presumptively encoding an acetylcholinesterase. *J. Med. Entomol.* **2004**, *41*, 259–268. [CrossRef] [PubMed]
61. De Clercq, E.M.; Leta, S.; Estrada-Peña, A.; Madder, M.; Adehan, S.; Vanwambeke, S.O. Species distribution modelling for *Rhipicephalus microplus* (Acari: Ixodidae) in Benin, West Africa: Comparing datasets and modelling algorithms. *Prev. Vet. Med.* **2015**, *118*, 8–21. [CrossRef] [PubMed]
62. Pottinger, M. *The distribution of Rhipicephalus (Boophilus) microplus and Rhipicephalus (Boophilus) decoloratus on a Farm in the Eastern Cape Province, South Africa*; University of the Free State: Free State, South Africa, 2019.
63. Yessinou, R.E.; Adoligbe, C.; Akpo, Y.; Adinci, J.; Youssao Abdou Karim, I.; Farougou, S. Sensitivity of Different Cattle Breeds to the Infestation of Cattle Ticks *Amblyomma variegatum, Rhipicephalus microplus*, and *Hyalomma* spp. on the Natural Pastures of Opkara Farm, Benin. *J. Parasitol. Res.* **2018**, *2018*, 1–8. [CrossRef]
64. Mason, C.A.; Norval, R. The ticks of Zimbabwe. I. The genus *Boophilus*. *Zimb. Vet. J.* **1980**, *11*, 36–43.
65. De Matos, C.; Sitoe, C.; Neves, L.; Nöthling, J.; Horak, I.G. The comparative prevalence of five ixodid tick species infesting cattle and goats in Maputo Province, Mozambique. *Onderstepoort J. Vet. Res.* **2009**, *76*, 201–208. [CrossRef]
66. Swanepoel, R.; Coetzer, J.; Tustin, R. *Infectious Diseases of Livestock with Special Reference to Southern Africa*; Oxford University Press: Cape Town, South Africa, 1994.
67. de Castro, J.J. Sustainable tick and tickborne disease control in livestock improvement in developing countries. *Vet. Parasitol.* **1997**, *71*, 77–97. [CrossRef]
68. Nyangiwe, N.; Horak, I.G.; Van der Mescht, L.; Matthee, S. Range expansion of the economically important Asiatic blue tick, *Rhipicephalus microplus*, in South Africa. *J. S. Afr. Vet. Assoc.* **2017**, *88*, 1482. [CrossRef]
69. Fivaz, B.; De Waal, D. Towards strategic control of ticks in the eastern Cape Province of South Africa. *Trop. Anim. Health Prod.* **1993**, *25*, 131–143. [CrossRef]

70. Kasaija, P.D.; Estrada-Peña, A.; Contreras, M.; Kirunda, H.; de la Fuente, J. Cattle ticks and tick-borne diseases: A review of Uganda's situation. *Ticks Tick-Borne Dis.* **2021**, *12*, 101756. [CrossRef]
71. Minjauw, B.; McLeod, A. *Tick-Borne Diseases And Poverty: The Impact of Ticks and Tick-Borne Diseases on the Livelihoods of Small-Scale and Marginal Livestock Owners in India and Eastern and Southern Africa*; Centre for Tropical Veterinary Medicine, University of Edinburgh: Edinburgh, UK, 2003.
72. Yawa, M.; Nyangiwe, N.; Kadzere, C.; Muchenje, V.; Mpendulo, T.; Marufu, M.C. In search of the *Rhipicephalus* (*Boophilus*) *microplus* in the western-central regions of the Eastern Cape Province, South Africa. *Ticks Tick-Borne Dis.* **2019**, *10*, 564–567. [CrossRef] [PubMed]
73. Nyangiwe, N.; Matthee, C.; Horak, I.; Matthee, S. First record of the pantropical blue tick *Rhipicephalus microplus* in Namibia. *Exp. Appl. Acarol.* **2013**, *61*, 503–507. [CrossRef] [PubMed]
74. Fourie, L.; Petney, T.; Horak, I.; De Jager, C. Seasonal incidence of Karoo paralysis in relation to the infestation density of female *Ixodes rubicundus*. *Vet. Parasitol.* **1989**, *33*, 319–328. [CrossRef] [PubMed]
75. Theiler, G. Zoological Survey of the Union of South Africa. Tick Survey. Part IV. Distribution of *Rhipicephalus Capensis*, the Cape Brown Tick. *Onderstepoort J. Vet. Sci. Anim. Ind.* **1950**, *54*.
76. Fourie, L.; Horak, I. The life cycle of *Ixodes rubicundus* (Acari: Ixodidae) and its adaptation to a hot, dry environment. *Exp. Appl. Acarol.* **1994**, *18*, 23–35. [CrossRef]
77. Fourie, L.; Kok, O. The role of host behaviour in tick-host interactions: A domestic host-paralysis tick model. *Exp. Appl. Acarol.* **1992**, *13*, 213–225. [CrossRef]
78. Phillips, C.J. *Principles of Cattle Production*, 3rd ed.; CAB International: Cambridge, MA, USA, 2018; p. 271.
79. Zafar, S.N.U.A.; Khan, A.; Niaz, S.; Aktas, M.; Ozubek, S.; Farooq, M.; Adil, M.M.; Zając, Z.; Iqbal, F.; Alhimaidi, A.R. Prevalence of *Anaplasma marginale* in cattle blood samples collected from two important livestock regions in Punjab (*Pakistan*) with a note on epidemiology and phylogeny of parasite. *Saudi J. Biol. Sci.* **2022**, *29*, 1515–1520. [CrossRef]
80. van den Heever, M.; Lombard, W.; Bahta, Y.; Maré, F. The economic impact of heartwater on the South African livestock industry and the need for a new vaccine. *Prev. Vet. Med.* **2022**, *203*, 105634. [CrossRef]
81. Cardoso, F.F.; Matika, O.; Djikeng, A.; Mapholi, N.; Burrow, H.M.; Yokoo, M.J.I.; Campos, G.S.; Gulias-Gomes, C.C.; Riggio, V.; Pong-Wong, R. Multiple country and breed genomic prediction of tick resistance in beef cattle. *Front. Immunol.* **2021**, *12*, 2189. [CrossRef]
82. Moyo, B.; Masika, P. Tick control methods used by resource-limited farmers and the effect of ticks on cattle in rural areas of the Eastern Cape Province, South Africa. *Trop. Anim. Health Prod.* **2009**, *41*, 517–523. [CrossRef]
83. Troyo, A.; Moreira-Soto, R.D.; Calderon-Arguedas, Ó.; Mata-Somarribas, C.; Ortiz-Tello, J.; Barbieri, A.R.; Avendaño, A.; Vargas-Castro, L.E.; Labruna, M.B.; Hun, L. Detection of rickettsiae in fleas and ticks from areas of Costa Rica with history of spotted fever group rickettsioses. *Ticks Tick-Borne Dis.* **2016**, *7*, 1128–1134. [CrossRef] [PubMed]
84. Estrada-PeñA, A. Distribution, abundance, and habitat preferences of *Ixodes ricinus* (Acari: Ixodidae) in northern Spain. *J. Med. Entomol.* **2001**, *38*, 361–370. [CrossRef] [PubMed]
85. Manzano-Román, R.; Díaz-Martín, V.; de la Fuente, J.; Pérez-Sánchez, R. Soft ticks as pathogen vectors: Distribution, surveillance and control. *Parasitology* **2012**, *7*, 125–162.
86. Muchenje, V.; Dzama, K.; Chimonyo, M.; Raats, J.; Strydom, P. Tick susceptibility and its effects on growth performance and carcass characteristics of Nguni, Bonsmara and Angus steers raised on natural pasture. *Animal* **2008**, *2*, 298–304. [CrossRef] [PubMed]
87. Rodriguez-Vivas, R.I.; Jonsson, N.N.; Bhushan, C. Strategies for the control of *Rhipicephalus microplus* ticks in a world of conventional acaricide and macrocyclic lactone resistance. *Parasitol. Res.* **2018**, *117*, 3–29. [CrossRef]
88. de la Fuente, J.; Contreras, M. Tick vaccines: Current status and future directions. *Expert Rev. Vaccines* **2015**, *14*, 1367–1376. [CrossRef]
89. Willadsen, P.; Riding, G.; McKenna, R.; Kemp, D.; Tellam, R.; Nielsen, J.; Lahnstein, J.; Cobon, G.; Gough, J. Immunologic control of a parasitic arthropod. Identification of a protective antigen from *Boophilus microplus*. *J. Immunol.* **1989**, *143*, 1346–1351. [CrossRef]
90. Kunz, S.; Kemp, D. Insecticides and acaricides: Resistance and environmental impact. *Rev. Sci. Et Tech. (Int. Off. Epizoot.)* **1994**, *13*, 1249–1286. [CrossRef]
91. Rodriguez-Vivas, R.; Rivas, A.; Chowell, G.; Fragoso, S.; Rosario, C.; García, Z.; Smith, S.; Williams, J.; Schwager, S. Spatial distribution of acaricide profiles (*Boophilus microplus* strains susceptible or resistant to acaricides) in southeastern Mexico. *Vet. Parasitol.* **2007**, *146*, 158–169. [CrossRef]
92. Aguilar-Tipacamu, G.; Rodriguez-Vivas, R. Effect of moxidectin against natural infestation of the cattle tick *Boophilus microplus* (Acarina: Ixodidae) in the Mexican tropics. *Vet. Parasitol.* **2003**, *111*, 211–216. [CrossRef]
93. Schröder, J. Chemical control of ticks on cattle. In *Tick Vector Biology*; Springer: Berlin/Heidelberg, Germany, 1992; pp. 175–184.
94. Rodríguez-Vivas, R.I.; Rosado-Aguilar, J.A.; Ojeda-Chi, M.M.; Pérez-Cogollo, L.C.; Trinidad-Martínez, I.; Bolio-González, M.E. Control integrado de garrapatas en la ganadería bovina. *Ecosistemas Y Recur. Agropecu.* **2014**, *1*, 295–308.
95. Rodríguez-Vivas, R.I.; Pérez-Cogollo, L.C.; Rosado-Aguilar, J.A.; Ojeda-Chi, M.M.; Trinidad-Martinez, I.; Miller, R.J.; Li, A.Y.; de León, A.P.; Guerrero, F.; Klafke, G. *Rhipicephalus* (*Boophilus*) *microplus* resistant to acaricides and ivermectin in cattle farms of Mexico. *Rev. Bras. De Parasitol. Veterinária* **2014**, *23*, 113–122. [CrossRef] [PubMed]

96. Swanson, S.J.; Neitzel, D.; Reed, K.D.; Belongia, E.A. Coinfections acquired from *Ixodes* ticks. *Clin. Microbiol. Rev.* **2006**, *19*, 708–727. [CrossRef] [PubMed]
97. Mbati, P.A.; Hlatshwayo, M.; Mtshali, M.S.; Mogaswane, K.R.; Waal, T.D.D.; Dipeolu, O.O. Ticks and tick-borne diseases of livestock belonging to resource-poor farmers in the eastern Free State of South Africa. In *Ticks and Tick-Borne Pathogens*; Springer: Berlin/Heidelberg, Germany, 2003; pp. 217–224.
98. Merino, O.; Alberdi, P.; Pérez de la Lastra, J.M.; de la Fuente, J. Tick vaccines and the control of tick-borne pathogens. *Front. Cell Infect. Microbiol.* **2013**, *3*, 30. [CrossRef]
99. Neitz, W.; Alexander, R. Immunization of Cattle Against Heartwater and the Control of the Tick-Borne Diseases, Redwater, Gallsickness and Heartwater. *Onderstepoort J. Vet. Res.* **1945**, *20*.
100. Allsopp, B. Trends in the control of heartwater: Tick-borne diseases. *Onderstepoort J. Vet. Res.* **2009**, *76*, 81–88. [CrossRef]
101. Zweygarth, E.; Josemans, A.I.; Steyn, H.C. Experimental use of the attenuated Ehrlichia ruminantium (Welgevonden) vaccine in Merino sheep and Angora goats. *Vaccine* **2008**, *26*, G34–G39. [CrossRef]
102. Haro, I.; Gomara, M.J. Design of synthetic peptidic constructs for the vaccine development against viral infections. *Curr. Protein Pept. Sci.* **2004**, *5*, 425–433. [CrossRef]
103. da Silva, J.B.; Rangel, C.P.; de Azevedo Baêta, B.; da Fonseca, A.H. Analysis of the risk factors relating to cows' resistance to *Rhipicephalus microplus* ticks during the peripartum. *Exp. Appl. Acarol.* **2014**, *63*, 551–557. [CrossRef]
104. Masika, P.; Sonandi, A.; Van Averbeke, W. Tick control by small-scale cattle farmers in the central Eastern Cape Province, South Africa. *J. S. Afr. Vet. Assoc.* **1997**, *68*, 45–48. [CrossRef]
105. Chamboko, T.; Mukhebi, A.; Callaghan, C.; Peter, T.; Kruska, R.; Medley, G.; Mahan, S.; Perry, B.D. The control of heartwater on large-scale commercial and smallholder farms in Zimbabwe. *Prev. Vet. Med.* **1999**, *39*, 191–210. [CrossRef] [PubMed]
106. Wilson, L.; Sutherst, R.; Kerr, J. Trapping of larvae of the cattle tick Boophilus microplus by *Stylosanthes scabra* under grazing conditions. *Aust. J. Agric. Res.* **1989**, *40*, 1301–1308. [CrossRef]
107. Abbas, R.Z.; Zaman, M.A.; Colwell, D.D.; Gilleard, J.; Iqbal, Z. Acaricide resistance in cattle ticks and approaches to its management: The state of play. *Vet. Parasitol.* **2014**, *203*, 6–20. [CrossRef] [PubMed]
108. Elder, J.; Knott, S.; Kearnan, J. A coordinated approach to control of the cattle tick (*Boophilus microplus*) in south east Queensland, Australia. *CABI* **1983**, 124.
109. Girona-García, A.; Zufiaurre Galarza, R.; Mora, J.L.; Armas-Herrera, C.M.; Martí, C.; Ortiz-Perpiñá, O.; Badía-Villas, D. Effects of prescribed burning for pasture reclamation on soil chemical properties in subalpine shrublands of the Central Pyrenees (NE-Spain). *Sci. Total Environ.* **2018**, *644*, 583–593. [CrossRef]
110. Wikel, S. Ticks and tick-borne pathogens at the cutaneous interface: Host defenses, tick countermeasures, and a suitable environment for pathogen establishment. *Front. Microbiol.* **2013**, *4*, 337. [CrossRef]
111. Muyobela, J.; Nkunika, P.O.Y.; Mwase, E.T. In vitro acaricidal activity of *Bobgunnia madagascariensis* Desv. against *Amblyomma variegatum* (Fabricius) (Acari: Ixodidae). *Trop. Anim. Health Prod.* **2016**, *48*, 625–631. [CrossRef]
112. Cetin, H.; Cilek, J.; Oz, E.; Aydin, L.; Deveci, O.; Yanikoglu, A. Acaricidal activity of *Satureja thymbra* L. essential oil and its major components, carvacrol and γ-terpinene against adult *Hyalomma marginatum* (Acari: Ixodidae). *Vet. Parasitol.* **2010**, *170*, 287–290. [CrossRef]
113. Wikel, S.K. Host immunity to ticks. *Annu. Rev. Entomol.* **1996**, *41*, 1–22. [CrossRef]
114. De Castro, J.; Newson, R. Host resistance in cattle tick control. *Parasitol. Today* **1993**, *9*, 13–17. [CrossRef]
115. Rechav, Y.; Kostrzewski, M. The relative resistance of six cattle breeds to the tick *Boophilus decoloratus* in South Africa. *Onderstepoort J. Vet. Res.* **1991**, *58*, 181–186. [PubMed]
116. Sutherst, R.; Wharton, R.; Utech, K. *Guide to Studies on Tick Ecology*; CSIRO: Melbourne, Australia, 1978.
117. Shyma, K.; Gupta, J.P.; Singh, V. Breeding strategies for tick resistance in tropical cattle: A sustainable approach for tick control. *J. Parasit. Dis.* **2015**, *39*, 1–6. [CrossRef] [PubMed]