

RESEARCH ARTICLE

Diversity and distribution of tick species infesting goats with two new host records from Sri Lanka

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Abstract: An island-wide study on ticks that infest the domestic goat, *Capra aegagrus hircus* was carried out from June 2011 to May 2013. A total of 2,628 ticks were collected in 22 districts within the three agro-climatic zones in Sri Lanka from 740 goats belonging to various breeds. Eight species of ticks belonging to the two genera *Haemaphysalis* and *Rhipicephalus* (Family Ixodidae) including *Haemaphysalis bispinosa*, *H. intermedia*, *H. cuspidata*, *Rhipicephalus sanguineus*, *R. haemaphysaloides*, *R. turanicus*, *R. (Boophilus) annulatus* and *R. (Boophilus) microplus* were recorded. The most common species in the overall collection were *H. intermedia* (44.0 %) and *H. bispinosa* (43.8 %). *Haemaphysalis bispinosa* was the dominant species in the Wet and Intermediate Zones, except in a few locations. In these exceptions *H. intermedia* was the dominant species, which was also the most abundant species found in the Dry Zone. *Haemaphysalis bispinosa* and *R. sanguineus* were restricted only to the Wet and Intermediate Zones. Of the eight tick species found, the two species, *R. turanicus* and *R. microplus* were new host records from Sri Lanka. More adult stages (70.8 %) were found in goats, where nymphs and larvae formed 25.9 and 3.3 %, respectively. All three stages of the dominant tick species were found on goats except for immature stages of *R. haemaphysaloides* and *R. sanguineus*. Most ticks preferred the anterior side of the body with one exception, *R. microplus*, which was more attracted to the posterior side of the host. This study reports the tick species infesting goats with zoonotic potential and also known vectors of many tick borne diseases of human and livestock.

Keywords: Agro-climatic zones, attachment sites, goat ticks, *Haemaphysalis*, *Rhipicephalus*, Sri Lanka.

INTRODUCTION

Ticks damage the host in two ways; directly by tick bites and indirectly by disease transmission. Failure to control tick infestations in livestock may result in

reduced live weight, reduced milk production and even death in young animals (Ghosh *et al.*, 2006; Rony *et al.*, 2010). Knowledge on the diversity of ticks, geographic distribution, infections they carry and their zoonotic potential is important for the prevention and effective control of ticks and tick borne diseases. Wild animals can maintain and reintroduce ticks and tick borne diseases to livestock via alternative hosts. Goats are known to act as alternative hosts for many tick species when a suitable host (wild or domestic) is not available (Nyangiwe & Horak, 2007). For example, *Rhipicephalus microplus* usually infests cattle but can successfully complete its life cycle on goats (Daemon *et al.*, 1998; Nyangiwe & Horak, 2007). Wild animals can transmit tick borne viral infections like flaviviruses, bacterial agents as *Anaplasma*, *Borrelia*, *Rickettsia* and protozoans as *Babesia*, *Theileria* to livestock (Uilenberg, 1999; Jongejan & Uilenberg, 2004). These infections have been frequently reported in livestock in neighbouring countries including India, Bangladesh and Pakistan (Estrada-pena & Jongejan, 1999; Ghosh *et al.*, 2007). In these countries *Haemaphysalis bispinosa*, *Rhipicephalus sanguineus* and *R. microplus* have been identified as possible vectors for *Babesia motasi*, *B. ovis* and *Theileria ovis* infections to goats (Ghosh *et al.*, 2007). Among tick borne infections a high prevalence of *Babesia bigemina*, *B. bovis*, *T. annulata* and *T. orientalis* have been recorded in cattle from many parts of the world including Sri Lanka (Brown, 1990; Bock *et al.*, 2004; Aktas *et al.*, 2006; Sivakumar *et al.*, 2012). Moreover, many rickettsial infections have also been reported in humans in Sri Lanka (Kularatne *et al.*, 2003; Premaratna *et al.*, 2008), which are suspected as tick borne infections. The reservoir and the vector of these infections in Sri Lanka are largely unknown.

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Since the ticks, pathogens and their specific hosts are linked (Jongejan & Uilenberg, 2004; Petney *et al.*, 2011), information about the diversity and distribution of tick fauna is very important to understand the zoonotic potential of tick borne diseases (Leger *et al.*, 2013). Three genera of ticks, namely, *Haemaphysalis*, *Rhipicephalus* and *Hyalomma* include most of the tick species that infest goats and sheep in many parts of the world (Al-Khalifa *et al.*, 2007; Sajid *et al.*, 2008; Matos *et al.*, 2009; Iqbal *et al.*, 2014). In addition to the above genera *Dermacentor*, *Amblyomma* and *Ixodes* have also been reported infesting goats (Latha *et al.*, 2004; Ghosh *et al.*, 2007; Yin & Luo, 2007). Studies on the tick fauna of Sri Lanka are scanty. Seneviratne (1965) listed seven tick species belonging to the three genera *Haemaphysalis*, *Rhipicephalus* and *Hyalomma* infesting goats. A subsequent survey carried out much later in a State livestock farm in the Dry Zone of Sri Lanka recorded five tick species belonging to the genera *Haemaphysalis* and *Rhipicephalus* infesting goats (Halim *et al.*, 1983). More recently, Liyanarachchi *et al.* (2013) reported eight species of ticks from farm goats.

Goats (*Capra aegagrus hircus*) are important in the livestock production system in Sri Lanka. Owing to their high fertility, short generation time and adaptability to arid and semiarid conditions, goats are popular livestock animals in many rural communities. The goat and sheep population in the country has been recorded as 393,000 with 62,928 goat farms in the country (Department of Animal Production and Health, 2012). Goat distribution is mostly linked with the socio-cultural pattern in the country, and are mainly reared for meat and rarely for their milk. In Sri Lanka goat farming is mainly concentrated in the Dry and Intermediate Zones where about 75 % of the goat population is distributed (Department of Animal Production and Health, 2012). Rest of the goat population is distributed in pockets in the Wet Zone, with herd sizes ranging from 5 or less than 5 to 150, and are mainly confined to smallholder farmers. In Sri Lanka there are five goat breeds commonly found, namely, Boer, Beetal, Kottukachchiya, Jamunapari, Sannan and their cross breeds. Of these, Sannan is the common goat breed in the Wet Zone of Sri Lanka (*personal observation*). All the goats sampled for the present study were reared as free grazers in almost all the areas except in a few localities in the Wet Zone, where cut grasses were provided during the rainy season. The objective of this study is to determine the diversity and island-wide distribution of goat ticks of Sri Lanka, which will be useful for controlling ticks and tick borne diseases in livestock because only some tick species act as vectors of tick borne infections.

METHODS AND MATERIALS

Study area

The study was conducted in three agro-climatic zones of Sri Lanka (7.00° N, 81.00° E) in the Dry, Wet and Intermediate Zones. The Dry Zone covers the northern and eastern parts of the country, while the Wet Zone is in the south-western parts with central hills and the intermediate zone being the frontier between the above two zones. The Wet Zone receives a high mean annual rainfall (> 2,500 mm) compared to the Dry (< 1,750 mm) and Intermediate Zones (1,750 – 2,500 mm). Although the Wet Zone has no clear dry period, the Dry Zone has a distinct dry season from May - September, and a short dry period is present in the Intermediate Zone. Both Wet and Intermediate Zones are further divided into low-country, mid-country and up-country zones and spread across all elevations above 300 m and the Dry Zone is defined below 300 m elevations (only low-country). In the Wet and Intermediate Zones the maximum temperature ranges from 27 - 35 °C and 22 - 35 °C, respectively. In the Dry Zone it ranges from 29 - 38 °C (Department of Agriculture, 2006).

Study animals and sample collection

A cross sectional, island-wide collection of ticks infesting goats (*C. a. hircus*) was carried out covering the Dry, Intermediate and Wet Zones of Sri Lanka from June 2011 to May 2013. The collection was done in domestic, semi-domestic and farm goats belonging to various breeds including, Sri Lankan Boer, Beetal, Kottukachchiya, Jamunapari, Sannan and their cross breeds. Sampling was done on kids and adult male and female goats. Ticks were collected from selected sites in each district according to the distribution of goats using an adaptive sampling technique. Only the goats with tick infestation were sampled and if the captured individual from the herd did not show any tick infestation, that animal was released and not included as sampled. Farms or animals that had a history of recent (one month prior to the visit) application of acaricides prior to sampling were not visited. For each district at least three sites were selected including both rural and urban areas. For each site, a minimum of seven goats were sampled. If the tick abundance was very low (< 5 ticks per host) more sampling sites and more individuals were selected per district. All the ticks on a goat were removed if the infestation is low and 100 ticks were collected from heavily infested animals from all the attachment sites in the body. Sampling was done twice a month during dry periods when the tick abundance was high, and each sampling site was visited only once.

The attachment site of the tick was noted when the tick was removed as, around eye, face, ear (dorsal, ventral sides), ear canal, legs (hind), body (dorsal, ventral and lateral areas of the trunk), neck, tail region, and groins. Only the ticks that were attached to the host and those who were feeding (engorged) were collected. The ticks were located by visual appraisal and by running the hand across the body. Ticks on both sides of the goats were removed using a thin-tipped pair of tweezers without damaging the mouth parts and were preserved in 70 % ethanol. Intensity of the infestation in each host was recorded as low (< 10 ticks), medium (< 20) and high (20 <). Samples were brought to the laboratory and the species, sex and life stages were identified morphologically using a stereoscopic dissecting microscope, and standard keys and references (Trapido *et al.*, 1964; Seneviratne, 1965). Uncertain specimens (different life stages of *Haemaphysalis intermedia* and *H. bispinosa*) were sent to the Institute of Arthropodology and Parasitology (IAP), University of Georgia, USA, for confirmation of identification. The data obtained from the study were expressed as percentages, and the male to female ratios of different tick species were analysed by using a chi-square test. Preference of attachment sites were analysed only for the five most common tick species.

RESULTS

Of the 25 districts in the country, ticks were collected from 22 districts (seven districts in the Dry Zone; nine districts in the Wet Zone and six districts in the Intermediate Zone) and a total of 2,628 ticks were collected from 740 goats. Eight species of ticks belonging to the two genera *Haemaphysalis* and *Rhipicephalus* (Family Ixodidae) were recorded (Table 1; Figure 1). The two most common species in the overall collection were *Haemaphysalis intermedia* (n = 1157, 44.0 %) followed by *H. bispinosa*

(n = 1151, 43.8 %; Table 1). *Haemaphysalis intermedia* was dominant in the Dry Zone (85.4 %; Table 1) and was found in the other two zones as well. However, *H. bispinosa* was the most common goat tick in the Wet

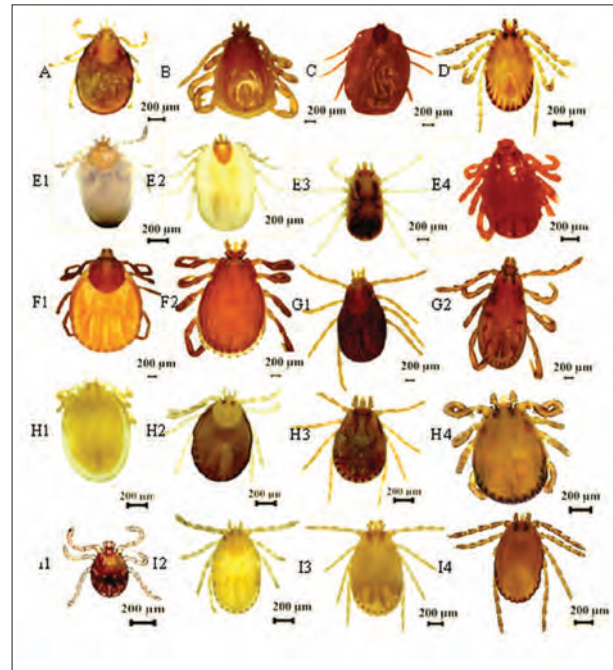


Figure 1: Tick species and their different stages collected from goats in the Wet, Intermediate and Dry Zones of Sri Lanka. A) *Rhipicephalus haemaphysaloides* nymph; B) *R. turanicus* male; C) *R. annulatus* female; D) *Haemaphysalis cuspidata* male; E) *R. microplus* E1) Larvae, E2) Nymph, E3) Female, E4) Male; F) *R. Haemaphysaloides* F1) Female, F2) Male; G) *R. sanguineus* G1) Female, G2) Male; H) *H. intermedia* H1) Larvae, H2) Nymph, H3) Female, H4) Male; I) *H. bispinosa* I1) Larvae, I2) Nymph, I3) Female, I4) Male

Table 1: Distribution of tick species in the Wet, Intermediate and Dry Zones (N = 2,628)

Tick species	Wet Zone	Number of ticks (%)		Total
		Intermediate Zone	Dry Zone	
<i>Haemaphysalis intermedia</i>	260 (25.0)	142 (20.1)	755 (85.4)	1157 (44.0)
<i>H. bispinosa</i>	656 (63.1)	495 (70.2)	0.0	1151 (43.8)
<i>H. cuspidata</i>	1 (0.1)	1 (0.1)	2 (0.2)	4 (0.2)
<i>Rhipicephalus sanguineus</i>	39 (3.8)	16 (2.3)	0.0	55 (2.1)
<i>R. haemaphysaloides</i>	24 (2.3)	35 (5.0)	98 (11.1)	157 (6.0)
<i>R. turanicus</i>	0	0	8 (0.9)	8 (0.3)
<i>R. annulatus</i>	0	0	8 (0.9)	8 (0.3)
<i>R. microplus</i>	59 (5.7)	16 (2.3)	13 (1.5)	88 (3.3)
Total	1,039	705	884	2,628

(N = total number of ticks)

Table 2: Distribution of tick species in different districts in Sri Lanka

Tick species	Number of ticks recorded in each district (number of goats sampled)																					
	Wet Zone						Intermediate Zone						Dry Zone									
	Galle (27)	Matara (64)	Ratnapura (39)	Kandy (61)	Kegalle (30)	Kalutara (23)	Colombo (33)	Gampaha (23)	Nuwara Eliya (28)	Kurunegala (31)	Puttalam (24)	Hambantota (21)	Matale (26)	Badulla (29)	Monaragala (37)	Kilinochchi (39)	Jaffna (33)	Anuradhapura (42)	Ampara (36)	Batticaloa (41)	Polonnaruwa (37)	Vavuniya (16)
<i>H. bispinosa</i>	104	130	10	73	18	181	92	39	9	135	51	89	50	27	143	0	0	0	0	0	0	0
<i>H. intermedia</i>	2	10	66	39	0	8	11	119	5	5	67	3	9	47	11	112	103	94	123	116	98	109
<i>H. cuspidata</i>	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	2	0	0	0	0	0	0
<i>R. haemaphysaloides</i>	0	0	5	3	4	0	7	5	0	12	16	0	0	0	7	12	14	19	0	21	15	17
<i>R. sanguineus</i>	1	0	4	1	2	0	21	12	0	11	1	0	0	1	1	0	0	0	0	0	0	0
<i>R. turanicus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
<i>R. microplus</i>	20	8	3	2	0	24	2	0	0	6	1	0	3	0	6	1	0	2	3	3	4	0
<i>R. annulatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0	0	0

and Intermediate Zones, except in Ratnapura, Gampaha, Puttalam and Badulla Districts (Table 2). In these exceptions *H. intermedia* was the dominating species. *Haemaphysalis bispinosa* was not reported from the Dry Zone. *Rhipicephalus sanguineus* was restricted only to the Wet and Intermediate Zones whereas *R. annulatus* and *R. turanicus* were restricted only to the Dry Zone. *Rhipicephalus turanicus* was found only in Anuradhapura District. Of the eight tick species found on goats, two species, *R. turanicus* and *R. microplus* were new host records for Sri Lanka.

The two major tick species in the collection, *H. intermedia* and *H. bispinosa* showed a wide distribution within the country and within the Wet and Intermediate Zones, respectively (Figure 2). *Haemaphysalis intermedia* was recorded in every district except Kegalle. In the areas of Hambantota District belonging to the Intermediate Zone, a higher number of *H. bispinosa* was recorded (Table 2). Colombo District had a high *R. sanguineus* infestation compared to the other areas. *Rhipicephalus haemaphysaloides* was found in every district in the Dry Zone except Ampara and *R. microplus* was high in Kalutara and Galle Districts. *Rhipicephalus annulatus* was only found in Anuradhapura and Ampara Districts (Table 2). The least common species, *H. cuspidata* was found in very low numbers with a limited distribution within the Puttalam, Gampaha and Killinochchi districts (Table 2; Figure 2).

Adults formed 70.8 % (males 58.4 %; females 41.6 %; Table 3) of the total tick collection where the nymphs and larvae formed 25.9 % and 3.3 %, respectively (Table 3). Overall, more male ticks were found than females (χ^2 , $p < 0.05$) except for *H. bispinosa* where there was no significant difference (χ^2 , $p > 0.05$; Table 3). The larval stages of *R. haemaphysaloides* and *R. sanguineus* were not recorded. Only one nymph of *R. haemaphysaloides* was recorded in the Intermediate Zone (Kurunegala District), which could be an accidental occurrence. All the life stages of *H. bispinosa*, *H. intermedia* and *R. microplus* were recorded with a few larval stages.

Most of the tick species preferred the anterior side of the host than the posterior side with one exception, *R. microplus* (Table 4). In general, the most preferred sites were dorsal and ventral sides of the ear of the goat. Among the most common tick species, *Haemaphysalis* species were found attached to the dorsal side of the ears, while *Rhipicephalus* species (except *R. microplus*) preferred the ventral sides of the ear.

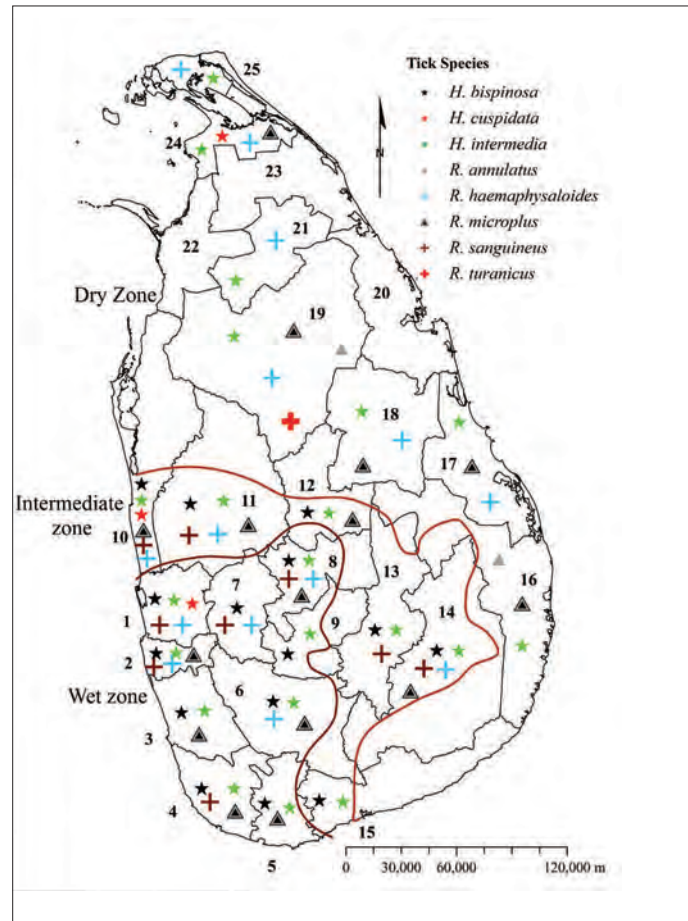


Figure 2: Distribution of goat tick species in the three agro-climatic zones of Sri Lanka. Wet Zone; 1) Gampaha; 2) Colombo; 3) Kalutara; 4) Galle; 5) Matara; 6) Rathnapura; 7) Kegalle; 8) Kandy and 9) Nuwara Eliya. Intermediate Zone; 10) Puttalam; 11) Kurunegala; 12) Matale; 13) Badulla; 14) Monaragala and 15) Hambantota. Dry Zone; 16) Ampara; 17) Batticaloa; 18) Polonnaruwa; 19) Anuradhapura; 21) Vavuniya; 24) Kilinochchi and 25) Jaffna. Districts that were not sampled; 20) Trincomalee; 22) Mannar and 24) Mullativu

Table 3: Distribution of different life stages of goat ticks in the Wet, Intermediate and Dry Zones

Tick Species	Adults n (%)			Nymphs n (%)	Larvae n (%)
	Male	Female	Total		
<i>H. bispinosa</i>	311 (11.8)	344 (13.1)	655 (24.9)	427 (16.3)	69 (2.5)
<i>H. intermedia</i>	606 (23.1 *)	313 (11.8 *)	919 (34.9)	223 (8.4)	15 (0.6)
<i>H. cuspidata</i>	4 (0.2)	0 (0.0)	4 (0.2)	0 (0.0)	0 (0.0)
<i>R. haemaphysaloides</i>	92 (3.5 *)	64 (2.4 *)	156 (5.9)	1 (0.04)	0 (0.0)
<i>R. sanguineus</i>	48 (1.8 *)	7 (0.3 *)	55 (2.1)	0 (0.0)	0 (0.0)
<i>R. turanicus</i>	5 (0.3)	3 (0.2)	8 (0.5)	0 (0.0)	0 (0.0)
<i>R. microplus</i>	17 (0.7 *)	33 (1.3 *)	50 (2.0)	32 (1.2)	6 (0.2)
<i>R. annulatus</i>	0 (0.0)	8 (0.3)	8 (0.3)	0 (0.0)	0 (0.0)
Total	1083 (58.4)	772 (41.6)	1855 (70.8)	683 (25.9)	90 (3.3)

* Statistically significant (χ^2 , $p < 0.05$) (n = total number of ticks)

DISCUSSION

The results of this study show that the goats in Sri Lanka are infested by eight tick species, namely, *Haemaphysalis intermedia*, *H. bispinosa*, *H. cuspidata*, *Rhipicephalus haemaphysaloides*, *R. sanguineus*, *R. microplus*, *R. annulatus* and *R. turanicus*. Previously, Seneviratne (1965) reported six species of ticks; *R. haemaphysaloides*, *R. sanguineus*, *R. annulatus*, *H. bispinosa*, *H. leachi* var. *indica* and *Hyalomma marginatum isaaci* (*Hyalomma isaaci* according to current classification) from goats. Later, Halim *et al.* (1983) recorded *Hy. m. isaaci* (*Hy. isaaci*) and *R. annulatus* along with *H. intermedia*, *R. haemaphysaloides* and *R. sanguineus* in Kotukachchiya Farm in the Dry Zone of Sri Lanka. Recently, Liyanaarachchi *et al.* (2013) recorded eight tick species including *R. boophilus* (which is not a valid tick name however), *R. sanguineus*, *R. haemaphysaloides*, *H. bispinosa*, *H. intermedia*, *H. cuspidata*, *Amblyomma testudinarium* and *Haemaphysalis aculeata* from farm goats. Compared to these previous records, four species, *Hy. isaaci*, *H. leachi* var. *indica*, *A. testudinarium* and *H. aculeata* were not found in the present study; instead two new species, which were not previously recorded on goats, namely, *R. turanicus* and *R. microplus* were found.

Halim *et al.* (1983) reported *H. intermedia* as the dominant tick species in the Dry Zone, which is consistent with the findings of the present study. However, *H. bispinosa* was the major tick species that infested goats in both Wet and Intermediate Zones. *Haemaphysalis intermedia* seems to prefer dry climates, while *H. bispinosa* prefers wet climates. Moreover, among the lesser species, *R. sanguineus* was not recorded in the Dry Zone, while *R. annulatus* and *R. turanicus* were reported only from the Dry Zone. This shows that depending on the agro-climatic region, the dominant species and the distribution of tick species varied. However, Seneviratne (1965) has recorded *H. bispinosa* infesting goats throughout the country from Jaffna to the highest elevation in Nuwara Eliya as well as a wide range of domestic and wild animals. Although Seneviratne (1965) recorded *H. leachi* var. *indica* in goats, none of the studies carried out later (Halim *et al.*, 1983; Liyanaarachchi *et al.*, 2013) or the present study record this tick species on goats.

Haemaphysalis ticks, specially *H. bispinosa* has a vast range of geographic distribution in the Oriental Region (Trapido *et al.*, 1964). A recent survey carried out in Bangladesh with sub-tropical monsoon climate (Islam *et al.*, 2006) and Tamil Nadu State in India with tropical

climate and little seasonal variations (Soundararajan *et al.*, 2014) shows that *H. bispinosa* parasitise more goats than any other domesticated animal and that it is widely distributed. In the present study *H. bispinosa* was the most common species in the Wet and Intermediate Zones of Sri Lanka. In general, adults of this tick species parasitise wild and domestic artiodactyls, but can also infest carnivores and the immature ticks can be found on birds (Kaul *et al.*, 1979; Hoogstraal & Kim, 1985). In Sri Lanka *H. intermedia* was the most widespread and most abundant goat tick species. However, it has a restricted geographic distribution in the world where it has been recorded from the southern parts of India and Sri Lanka (Trapido *et al.*, 1964). Principal hosts of *H. intermedia* are livestock, mainly sheep and goats and the immature ticks mainly feed on birds (Kaul *et al.*, 1979; Jeevanandam, 1991).

Four species of the genus *Rhipicephalus* were recorded during the study, where infections of *R. sanguineus* were found only in the Wet and Intermediate Zones. *Rhipicephalus sanguineus* is a three-host species and mainly parasitises domestic dog, on which all the stages feed. It also parasitises other carnivores and ungulates (Kolonin, 2009). *Rhipicephalus sanguineus* is the common dog tick in Sri Lanka (*Unpublished observations*). The presence of *R. sanguineus* on goats may be because the dogs mingle in the areas where the goats are reared specially in the Wet Zone. In the Dry Zone, sampling was mostly done in Muslim villages where dogs were less common as household pets. Absence of *R. sanguineus* on goats in the Dry Zone may be due to the absence of mingling of goats with dogs.

Rhipicephalus haemaphysaloides and *R. microplus* were recorded on goats from all three agro-climatic zones. These two species are the most abundant cattle tick species in Sri Lanka (*unpublished data*). According to the management practices of livestock in Sri Lanka, cattle and goats are kept in the same farmland or their grazing pasture may overlap. Although goats are known to harbour a large number of immature stages of ticks and a few adults (Baker & Ducasse, 1968; MacIvor & Horak, 2003), and cattle may harbour larger numbers of both adult and immature ticks (Baker & Ducasse, 1967), in the present study the majority of *R. haemaphysaloides* were adults while there were some immature stages of *R. microplus* on goats. *Rhipicephalus microplus* is an invasive tick of European cattle breeds (Leger *et al.*, 2013). Goats are not ideal for the development of *R. microplus* but when the suitable host (cattle) is not present goats can act as the alternative host (Daemon *et al.*, 1998; Nyangiwe & Horak, 2007). Goats may play

Table 4: Details of tick attachment sites on the host*

Tick Species	Anterior region (%)					Posterior region (%)					Total (%)	
	Around eye	Face	Ear dorsal	Ear ventral	Ear canal	Legs	Body	Neck	Tail	Groin	Anterior	Posterior
<i>H. bispinosa</i>	3.3	22.1	10.3	41.7	2.0	5.6	3.7	3.5	8.1	0.2	79.1	20.9
<i>H. intermedia</i>	1.3	10.9	37.0	42.7	6.1	0.3	0.2	1.9	0.0	0.0	97.8	2.2
<i>R. sanguineus</i>	7.3	21.9	31.0	27.3	7.3	0.0	0.0	3.7	0.0	1.9	94.5	5.5
<i>R. haemaphysaloides</i>	18.0	14.8	48.8	13.5	2.6	0.0	0.0	0.7	2.0	0.0	97.4	2.6
<i>R. microplus</i>	0.0	0.0	0.0	9.1	1.2	3.5	4.6	1.2	4.6	76.2	11.3	88.7
Total	3.2	15.9	24.4	39.2	3.9	2.8	1.9	2.5	3.9	2.8	86.5	13.6

* Data on the attachment sites of five most common tick species are given

an important role in maintaining infestations of ticks that normally infest cattle, dogs and other domestic animals.

Due to the transport of goats within the country (to farms and abattoirs located in different areas) ticks are introduced into new areas with goats. Once they are introduced into a new area they exploit new host species. The present study reports low infestation levels of *R. microplus*, *R. turanicus*, *H. cuspidata* and *R. annulatus*, which indicate that goats may not be the suitable host. But with time they can evolve associations with their new hosts for successful invasion. For example, *R. microplus*, which invaded cattle in New Caledonia, Australia has adapted to feed on rusa deer (*Cervus timorensis*) as a new host (Leger *et al.*, 2013). These two populations (deer feeding and cattle feeding) have evolved into two genetically different groups as cattle-adapted and deer-adapted populations within a few tick generations (de Meeus *et al.* 2010; Leger *et al.*, 2013; Pfaffle *et al.*, 2013).

Among the adults, significantly more males (58.4 %) were present than females (41.6 %). The presence of more males has been reported in many studies (Halim *et al.*, 1983; Foldvan & Farkas, 2005; Dantas-Torres & Otranto, 2011). Usually males stay for a longer period on the host mating with several females and taking short blood meals, whereas the females drop off to oviposit after their parasitic phase. However, in *R. microplus* fewer males were recorded. *Rhipicephalus microplus* males are extremely small compared to their females, so the males can easily be missed during sampling. All the life stages of *H. bispinosa* and *H. intermedia* (multi host ticks) occurred on goats. Only the adults of *R. sanguineus*, a three-host monotropic tick of domestic dog on which

all stages usually feed (Dantas-Torres, 2010), is found on goats. When the goats are confined to enclosed sheds with limited space, when considering multi host ticks, completing its life cycle in such environment and finding a different new host could be hard for immature ticks. Therefore the abundance and distribution of ticks with limited movements can greatly be affected by the chances of encounter with a potential host and their population densities (Pfaffle *et al.*, 2013). Migrating hosts with high population densities and their social activities facilitate the dispersion of ticks (tick borne diseases as well) that eventually increases the chance of finding a suitable host. That may be the reason of associating immature ticks more with small mammals, which allow the ticks to reach a suitable large host (Kiffner *et al.*, 2011a; Leger *et al.*, 2013).

Different tick species have different preferred sites of attachment on the host body. Most were found on the anterior parts of the host, specifically dorsal and ventral sides of the ears. However, *R. microplus* preferred posterior parts of the host. This may be an evolutionary adaptation to reduce the competition with other tick species and at the same time to minimize the host defence mechanisms (Belan & Bull, 1991; Shaw *et al.*, 2002). Preferred attachment sites are influenced by various factors such as the morphology of the tick (e.g. length of the hypostome), morphology of the host (length of the fur coat), host immune responses, self-grooming, inter-specific interactions, heat dissipating behaviour and length of the feeding phase (Belan & Bull, 1991; Shaw *et al.*, 2002). Ticks select an area with a good blood supply, minimal host defence, where predators (e.g. birds) cannot easily reach and where they can easily penetrate the skin. They may avoid sites, which

are accessible for grooming and where the host skin is hard to penetrate (Fourie *et al.*, 1991; Kiffner *et al.*, 2011b) and prefer the dorsal side of the ear, which has a short fur coat. Fur can retain humidity, give a suitable micro habitat and also give protection from predators. The present study reports that *R. microplus* preferred the posterior region of the host, which is consistent with previous records of Daemon *et al.* (1998) and Latha *et al.* (2004). This behaviour is important because it will reduce the competition for attachment sites with the dominating species *H. bispinosa*, which preferred the anterior part.

All the tick species reported in this study, except for *R. microplus* and *R. annulatus* were three host ticks where the larvae, nymphs and adults feed on different hosts except *R. sangenius* in which all three stages feed on dog. Most tick infections show transovarian transmission. Ticks with two or three hosts therefore have a higher risk of transmitting tick borne diseases among livestock and humans than one host ticks. Thirty three strains of Ganjam virus has been isolated from *Haemaphysalis* ticks in India, which caused morbidity and mortality in cross breed goats (Sudeep *et al.*, 2009). The risk of spreading this virus in Sri Lanka is high due to the presence of *H. bispinosa*, *H. intermedia* as dominating tick species. Species of *Rhipicephalus* act as vectors for *Leishmania*, *Babesia*, *Ehrlichia* and possibly transmit Kyasanur Forest disease virus (Estrada-pena & Jongejan, 1999; Coutinho *et al.*, 2005; Dantas-Torres & Otranto, 2011). Infectious agents carried by goats are not known in Sri Lanka although many of the species recorded are known to carry many infectious agents elsewhere.

The abundance and distribution of ticks depend upon many factors such as the climate and microclimate (temperature, humidity and wind speed), habitat characteristics (soil temperature, vegetation and direct sunlight), presence of other domestic and wild animals, nature of the host (susceptibility, breed, age and sex) and management practices including the use of acaricides (de Meeus *et al.* 2010). This study was an island-wide cross sectional survey. A longitudinal study for at least a two-year period in a few locales would determine the seasonal dynamics of tick species.

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