Diversity and Geographic Distribution of Dog Tick Species in Sri Lanka and the Life Cycle of Brown Dog Tick, *Rhipicephalus sanguineus* Under Laboratory Conditions

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Abstract

**Purpose** This study determined the diversity and distribution of tick species infesting domestic dogs and the life cycle parameters of the dominant dog tick species.

**Methods** An island-wide, cross-sectional survey of tick species infesting domestic dogs was carried out, and the life cycle of the most commonly occurring dog tick, *Rhipicephalus sanguineus* was studied under laboratory conditions.

**Results** A total of 3026 ticks were collected from 1219 dogs in all 25 districts. Eight species in five genera were identified: *R. sanguineus* (63.4%), *R. haemaphysaloides* (22.0%), *Haemaphysalis bispinosa* (12.5%), *Haemaphysalis intermedia* (0.9%), *Haemaphysalis turturis* (0.6%), *Amblyomma integrum* (0.4%), *Dermacentor auratus* (0.2%) and *Hyalomma* sp (0.1%). *R. sanguineus* was the dominant species in the Dry and Wet zones, while *R. haemaphysaloides* was the dominant species in the Intermediate Zone. Species diversity (Shannon diversity index H) was 1.135, 1.021 and 0.849 in the Intermediate, Dry and Wet zones, respectively. The three-host life cycle of *R. sanguineus* was completed within 70–126 days, and all three stages successfully fed on New Zealand white rabbits under laboratory conditions. The Reproductive Efficiency Index (REI) and Reproductive Fitness Index (RFI) were 50.8 ± 9.69 and 9.1 ± 5.01, respectively. Larger females had higher reproductive success.

**Conclusions** Of the eight species infesting domestic dogs in Sri Lanka, *R. sanguineus* was the most frequently occurring tick species. The three-host life cycle of *R. sanguineus* was successfully completed within an average of 98 days on New Zealand white rabbits. The number of eggs laid, duration of the pre-oviposition period, incubation period and parasitic periods of all three life stages were lower than in previous records.

**Keywords** Dog ticks · Diversity · Geographic distribution · Life cycle · Sri Lanka

Introduction

Ticks are important ectoparasites, with dog ticks of particular interest as dogs are companion animals. Dogs have a worldwide distribution, and their unrestricted movement may carry ticks together with tick-borne pathogens to new habitats. Ticks transmit a wide variety of infectious agents to dogs. These diseases are of great concern causing costs to pet owners, suffering in dogs, and the risk of transmission of pathological agents from dogs to humans. Tick-borne diseases of dogs have recently become a focus of interest globally, especially in areas of the world, where they have traditionally been considered non-endemic. The concern that these diseases might become established in new geographical locations arose from the increased international mobility of dogs and increased contact of these animals with non-urban environments containing wildlife disease reservoirs [1]. Ticks, especially the larval stages, can travel undetected with pets and other animal trade globally. Therefore, the potential impact of increased movement between countries of people and the global pet trade on the distribution of ticks is currently an area of increasing public health concern.
Information on the tick species infesting dogs, and their life cycle patterns, is, therefore, vital for study tick-borne diseases, their control, and prevention.

Historical records and recent studies in the British Isles show that the distribution of *Ixodes ricinus* in Great Britain has expanded by 17%, with the abundance of ticks increasing in most of the locations surveyed [2–4]. Moreover, in Central Europe, *I. ricinus* has expanded its geographic range northwards and upwards to altitudes of up to 1100 m [5]. In another study carried out in 1965, *I. ricinus* was not recorded above 700 m [6]. The distribution of tick-borne infections has also been expanded accordingly. For example, tick-borne encephalitis now occurs in mountainous regions of the Czech Republic [5]. Human cases of Lyme disease have increased 30-fold between 1999 and 2008 in Scotland [7]. The expansion of the tick-borne infections among animal is evident globally. For instance, the vector of canine babesiosis in Europe, caused by *Dermacentor reticulatus* (European meadow tick) is extended northwards into Poland, Belgium, Germany, the Netherlands, and southern England [8–11].

Among the tick species that infest dogs, *Rhipicephalus sanguineus*, the brown dog tick is the most commonly occurring species with a three-host life cycle. All three stages in the life cycle, the larva, nymph and adults, feed primarily on dogs. Each stage drops off after feeding and moulting occurs off-host. The life cycle takes up to 2 years to complete in nature [12]. However, under laboratory conditions, *R. sanguineus* completes its entire life cycle within 17 weeks [13]. It feeds occasionally on other hosts, including humans. It has a wide distribution globally and is a known vector of pathogens such as *Babesia canis*, *Ehrlichia canis*, *Rickettsia conorii*, *Rickettsia rickettsii* and *Leishmania* spp. [14, 15]. Other tick species recorded infesting dogs include *Ixodes ricinus*, *I. hexagonus*, *I. canisuga* from Great Britain [16]. From Japan *Haemaphysalis longicornis*, *H. flava*, *I. avatus*, *H. hystricis*, *I. persulcatus*, *I. nipponensis*, *A. testudinarium* has been reported [17]. From USA, *I. dammini* and *Dermacentor variabilis* were recorded [18].

Several studies have reported tick species infesting dogs together with those on other wild and domesticated animals in Sri Lanka [19–22]. Liyanaarachchi et al. [23] surveyed the ticks infesting dogs and reported eight tick species: *D. auratus*, *Ha. turturis*, *Ha. cuspidata*, *A. testudinarium*, *A. clypeolatum*, *Ha. spinigera*, *Hy. isaaci*, and *Ha. aculeata* on dogs. The same study detected spotted fever group rickettsia in *R. sanguineus* collected from a dog [23]. However, all the above studies are restricted to one or a few locations in the country. Island-wide surveillance data on tick species' diversity and geographic distribution is important, because it will provide valuable baseline information to detect future changes in tick prevalence and distribution patterns. The objectives of the current study are to determine the range of ticks infesting domestic dogs in Sri Lanka, to ascertain which life stages they are in, and to determine whether tick distribution varies depending on climatic zone. In addition, to describe the life cycle parameters of the dominant dog tick species under laboratory conditions.

**Materials and Methods**

**Study Design**

First, a descriptive, island-wide survey was conducted to assess the diversity and distribution of dog ticks. Then, the life cycle of the most common tick species encountered during the survey was studied using New Zealand white rabbits (*Oryctolagus cuniculus*) under controlled laboratory conditions.

**Geographic Distribution and Diversity ofTicks Infesting Dogs**

Ticks infesting the domestic dog (*Canis familiaris*) of different breeds, sex and age were collected from all of the districts covering the dry, wet, and Intermediate zones of Sri Lanka (Adopted from Karunaweera et al.) [24] using a non-probability convenience sampling technique. At least five towns/villages were selected from each district, and each site was visited and sampled only once. However, in certain districts, where the dogs were fewer in number, less than ten dogs were sampled, and where there were more dogs, more than ten were sampled. All the ticks on one side of the host body were collected.

Only the ticks that were attached to the host and feeding were collected. Ticks were located by visual appraisal and by running the hand over the dog’s body. Ticks were removed using a pair of tweezers or/and fingers to grasp the tick as close to the skin surface as possible. Specimens were preserved in absolute alcohol. The preferred attachment site was determined by dividing the host torso into ten different regions, ear (dorsal, inner sides), eyelids, neck, body, face, tail region, snout, forelimb pads, and hind limb pads. Information about the breed, age, sex of the dogs and the site of attachment of the tick, the parasitic burden were noted. Ticks were brought to the laboratory, observed under a dissecting microscope, and identified using available standard keys and literature [19]. The number and percentage of different life cycle stages, and species diversity according to the district, climatic zone, and diversity (Shannon diversity index) were calculated. Following the calculation of percentages, ratios and bivariate analysis, chi-squared testing was utilized to see the independence of categories.
The Life Cycle of *Rhipicephalus Sanguineus* Under Laboratory Conditions

*Rhipicephalus sanguineus* was the most abundant and widely distributed dog tick species; thus, its life cycle parameters were studied in a colony established by collecting engorged females in the Kandy District from four localities. They were kept under laboratory conditions (Temperature 27 ± 1 °C; Relative humidity 70–80%) and were allowed to lay eggs. Life stages were fed on the New Zealand white rabbits. After hatching, 100 larvae were added into a plastic feeding vial glued onto the rabbit’s clean-shaved skin. Then, the larvae were allowed to feed, and once they dropped off, they were transferred to sampling vials and allowed to moult. When larvae moulted, the nymphs (20) were introduced to the feeding chamber and allowed to feed on the rabbit. Once the engorged females in mg) were calculated. Pearson correlations to determine their survival.

Biological parameters such as the weight of the wild-caught females, pre-oviposition period, oviposition period, incubation period of eggs, and the parasitic period of larva, nymph, and adult were recorded. Then the Reproductive Efficiency Index (REI; the weight of eggs laid/weight of the engorged females × 100%), percentage of eclosion (percentage of hatched eggs with respect to the total number of eggs laid by each female) and Reproductive Fitness Index (RFI; number of eggs that hatched into larvae/weight of the eggs laid by each female) were computed using Minitab 17 version.

The study protocol was read and approved by the Ethical Review Committee at the Postgraduate Institute of Science, University of Peradeniya, Sri Lanka.

Results

Geographic Distribution and Diversity of Ticks Infesting Domestic Dogs

A total of 3026 ticks were collected from 1219 dogs of different breeds from the 25 districts in Sri Lanka. The collection consisted of five genera of hard ticks belonging to eight species: *Rhipicephalus sanguineus*, *Rhipicephalus haemaphysaloides*, *Haemaphysalis intermedia*, *Haemaphysalis bispinosa*, *Haemaphysalis turturis*, *Amblyomma integrum*, *Hyalomma sp.* and *Dermacentor auratus* (Family Ixodidae; Fig. 1). Adults and nymphs of four species were recorded: *R. sanguineus*, *R. haemaphysaloides*, *Haemaphysalis intermedia* and *H. bispinosa*. Moreover, nymphs of *D. auratus* and *A. integrum* and only the adults of *Hyalomma sp.* and *H. turturis* were recorded (Table 1). Adults formed 94.7% of the collection with a significantly higher number of females (54.8%) was in the collection than males (40.0%; $\chi^2 = 40.3787, p < 0.0001$).

In Sri Lanka, *Rhipicephalus sanguineus* was the dominant dog tick species ($n = 1918, 63.4%$; Table 2). It was the most common dog tick in all the districts except in Polonnaruwa, Nuwara-Eliya, Monaragala, Badulla and Mannar. In these exceptions, *R. haemaphysaloides* was the dominant species, which was the second most common tick ($n = 667, 22.0%$) infesting dogs in Sri Lanka. The least common species was *Hyalomma sp.* (0.06%) found only in the Vavuniya district (Table 3; Fig. 2). In the three climatic zones, *R. sanguineus* was the dominant species encompassing 73.8% in the Wet Zone and 58.6% in the Dry zone, whereas *Rhipicephalus haemaphysaloides* was the dominant species (42.0%) and *R. sanguineus* (34.3%) was the second most dominant species in the Intermediate zone. *Haemaphysalis bispinosa* was recorded from all three zones, but the distribution was limited to some districts such as Anuradhapura, Polonnaruwa, Matale, Ampara, and Matara. *Haemaphysalis turturis* were only found in Daraniyagala, Trincomalee, and Kilinochchi, while *Hyalomma sp.* was found only in the Vavuniya district (Fig. 2). *Amblyomma integrum* was restricted to the Wet and Intermediate zones.

Site of Attachment

Most ticks were attached to the anterior part of the body, especially the head region than the posterior. The only exception was, *R. haemaphysaloides* which preferred the rear side of the host (Table 4). The most common species *R. sanguineus* preferred the head region, specifically the inner and outer ear, whereas *R. haemaphysaloides* was found attached to limbs, mostly the hind limbs (Table 4).

Life Cycle Parameters of *Rhipicephalus Sanguineus*

The engorged, wild-caught females had a mean weight of 133.2 (54–187) mg and completed oviposition in 14.0 ± 3.47 days with a pre-oviposition period of 4.9 ± 1.02 days (Tables 4 and 5). The mean number of eggs laid by a female was 1444.3 ± 531.08 (101–2708) (Table 5). The egg incubation period was 29.6 ± 3.96 days (range 20–43 days; Table 4). Larvae had a mean parasitic period of 3.1 ± 0.56 days, and of the larvae introduced 62.7% successfully fed and dropped off for moulting (Tables 4 and 5). Of those engorged larvae, 31.1% moulted into nymphs after a moulting period of 13.4 ± 1.32 days (Tables 4 and 5). The nymphs fed for 5.0 ± 0.0 days, dropped off and spent a moulting period of 14.3 ± 0.48 days. The parasitic period of adult females was 12.6 ± 2.94 days (Table 4).
The REI and RFI values were 50.8 ± 9.69 (22.0–70.0) and 9.1 ± 5.01 (0–22.6), respectively (Table 5). Male: female sex ratio was 5:2 in laboratory-raised adults. The number of eggs laid increased rapidly within the first 3 days and gradually decreased. There were positive correlations found between the female weight and three reproductive parameters tested; the total number of eggs laid, the number of eggs hatched, and the weight of the egg mass (Pearson correlation: $r = 0.468, 0.355, 0.896$, respectively; $p < 0.05$; Table 6, Fig. 3). The egg-laying potential of an engorged female is directly related to her capacity to feed; therefore, heavier females showed the highest values in the number of eggs laid as well as the weight of the egg mass, and after that, a higher hatch rate. However, no significant correlations were found between the three calculated reproductive parameters (REI, RFI and percent eclosion) with the female weight ($p > 0.05$; Table 6 and Fig. 4). In general, larger females have shown higher REI and percent eclosion in contrast, RFI showed a negative relationship with the female weight (Table 7). Nonetheless, the regression fit does not fully explain REI, RFI or percent eclosion, since the $R^2$ values were <5.0% (Fig. 4).

![Tick species infesting domestic dog in Sri Lanka.](image)

**Table 1** Species and the life stage (females, males and nymphs) of ticks infesting dogs in Sri Lanka ($n = 3026$)

| Tick species                               | Adults (%) | Nymphs (%) |
|--------------------------------------------|------------|------------|
| Rhipicephalus sanguineus                   | Females    | Males      | Total |
| Rhipicephalus haemaphysaloides             | 1040 (54.2)| 774 (40.4) | 1817 (94.6) |
| Haemaphysalis intermedia                   | 299 (44.8) | 343 (51.4) | 642 (96.3) |
| Haemaphysalis bispinosa                    | 288 (76.2) | 80 (21.2)  | 368 (79.4) |
| Haemaphysalis turturis                     | 10 (58.8)  | 5 (29.4)   | 15 (88.2) |
| Amblyomma integrum                        | –          | –          | –       |
| Hyalomma sp.                               | 1 (50.0)   | 1 (50.0)   | 2 (100.0) |
| Dermacentor auratus                       | –          | –          | –       |

Fig. 1 Tick species infesting domestic dog in Sri Lanka. *a-f* Rhipicephalus species *a* R. sanguineus Adult male, *b* R. sanguineus Adult female, *c* R. sanguineus Nymph, *d* R. haemaphysaloides Adult male, *e* R. haemaphysaloides Adult female, *f* R. haemaphysaloides Nymph *g-m* Haemaphysalis species *g* H. intermedia Adult male, *h* H. intermedia Adult female, *i* H. intermedia Nymph, *j* H. bispinosa Adult male, *k* H. bispinosa Adult female, *l* H. turturis Adult male, *m* H. turturis Adult female, *n-p* Other species *n* Dermacentor auratus Nymph, *o* Hyalomma sp. Adult female, *p* Amblyomma integrum Nymph. R. Rhipicephalus, H. Haemaphysalis
All the life cycle stages, including larvae, nymphs, and adults successfully fed on the New Zealand white rabbits under controlled laboratory conditions and completed their life cycle within 70–126 (mean 98 ± 14.74) days (Table 5).

**Discussion**

The survey results showed the brown dog tick, *R. sanguineus* was the most commonly occurring tick species that infests domestic dogs island-wide. More than 50 years ago, Seneviratne [19] reported *R. sanguineus* was the most frequently found tick on dogs in Ceylon (now Sri Lanka). It is also the most widespread dog tick worldwide [25]. This tick can be found on dogs living in both urban and rural areas, being highly adapted to life within human dwellings and being active throughout the year not only in tropical and subtropical regions but also in some temperate areas [25]. Although the dog is the main host, it has also been recorded on other animals such as wild canids [26] and a wide range of wild and domestic animals of Sri Lanka including ox, horse, buffalo, cat, goat, sheep, and also humans [19, 21, 22, 27]. This indicates that free-ranging wild animals might be involved in its maintenance and dispersion through different regions. This could have implications in tick control and in the epidemiology of tick-borne diseases, particularly in areas, where dogs live in close contact with wildlife [25]. Studies have shown that some dog breeds appear to be more resistant than others to infestations by *R. sanguineus* [28]. The local mongrels, also known as the Sinhala Hound (*C. familiaris*), found in Sri Lanka and parts of India seem more resistant to tick infestations (personal observations), but further studies are needed to assess the dog breed’s susceptibility to ticks. *R. sanguineus* was attached everywhere on the dog but the preferred site was the head region, consistent with the review of Dantas-Torres [25] who reported that *R. sanguineus* ticks can attach everywhere on the dog, but the head (particularly on ears), interdigital spaces, back, inguinal region, and axilla are among their preferred attachment sites. Dantas-Torres [14] showed that adult *R. sanguineus* generally feed on sites (e.g., ears) that make it difficult for dogs to remove them, whereas immature stages feed on lower areas of the dog’s body (e.g., belly, rump, and hind legs), probably because of their more limited mobility. *Rhipicephalus sanguineus* is the most important species from the veterinary standpoint as it a vector of many pathogens affecting dogs and occasionally humans [25, 29–31]. It is known to carry many pathogens, including *Babesia vogeli*, *Ehrlichia canis*, *Hepatozoon canis*, *Rickettsia conorii* and *Rickettsia rickettsii*, the last two have been responsible for disease in humans [15]. Liyanaarachchi et al. [23] detected DNA of spotted fever group rickettsiae in *R. sanguineus* collected from a domestic dog in Sri Lanka.

In addition to *R. sanguineus*, seven other species were recorded in dogs: *Rhipicephalus haemaphysaloides*, *Haemaphysalis intermedia*, *Haemaphysalis bispinosa*, *Amblyomma integrum*, *Hyalomma sp.*, *Dermacentor auratus*. Previously, Seneviratne in 1965 [19] reported six species of ticks, *R. sanguineus*, *R. haemaphysaloides*, *Ha. intermedia*, *Ha. bispinosa*, *Boophilus sp.*, *A. integrum* (immature stages) collected from dogs in Sri Lanka. Later, Liyanaarachchi et al. [21] recorded 14 species of ticks including, *R. sanguineus*, *R. haemaphysaloides*, *Ha. intermedia*, *Ha. bispinosa*, *R. microplus*, *A. integrum*, *Ha. cuspidata*, *Ha. spinigera*, *Ha. aculeata*, *A. testudinarium*, *A. clypeolatum*, *Hy. isaeaci* and *D. auratus* from dogs. Compared to these previous studies, previously recorded six species, *R. microplus*, *Ha. cuspidata*, *Ha. spinigera*, *Ha. aculeata*, *A. testudinarium* and *A. clypeolatum* were not reported in the present study. Some of these rare species could be accidental occurrences due to close contact of dogs with livestock and wildlife.

*Rhipicephalus haemaphysaloides* was the second most common tick on dogs recorded from all over the island with a wide geographical distribution but is less common at elevations above 3000 ft. It was the dominant dog tick

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| Table 2 Distribution of tick species collected from dogs by the Wet, Dry and Intermediate climatic zones of Sri Lanka (n = 3026) |
|---------------------------------------------------------------|
| Tick species | No. of ticks (percentage of species in a zone) | Total no. (overall %) |
|---------------|-----------------------------------------------|----------------------|
|               | Wet zone          | Dry zone          | Intermediate zone |
| *Rhipicephalus sanguineus* | 1036 (73.8) | 785 (58.6) | 97 (34.3) | 1918 (63.4) |
| *Rhipicephalus haemaphysaloides* | 192 (13.7) | 356 (26.6) | 119 (42.0) | 667 (22.0) |
| *Haemaphysalis intermedia* | 12 (0.9) | 14 (1.0) | 0 (0.0) | 26 (0.9) |
| *Haemaphysalis bispinosa* | 143 (10.2) | 173 (12.9) | 62 (21.9) | 378 (12.5) |
| *Haemaphysalis turturis* | 8 (0.6) | 9 (0.7) | 0 (0.0) | 17 (0.6) |
| *Amblyomma integrum* | 8 (0.6) | 0 (0.0) | 5 (38.5) | 13 (0.4) |
| *Hyalomma sp.* | 0 (0.0) | 2 (0.1) | 0 (0.0) | 2 (0.1) |
| *Dermacentor auratus* | 5 (0.4) | 0 (0.0) | 0 (0.0) | 5 (0.2) |
| Total | 1404 (46.4) | 1339 (44.2) | 283 (9.4) | 3026 |
| Shannon diversity index (H) | 0.849 | 1.021 | 1.135 | 0.991 |
### Table 3  Distribution of tick species collected from dogs in different districts in Sri Lanka (n = 3026)

| Tick species | Number of ticks recorded in each district |
|--------------|-----------------------------------------|
|              | Hambanthota | Ampara | Trincomalee | Kilinochchi | Anuradhapura | Vavuniya | Puttalam | Batticaloa | Jaffna | Monaragala | Polonnaruwa | Mannar | Mullaitivu | Nuwaraeliya | Ratnapura | Colombo | Kandy | Kegalle | Matara | Galle | Gampaha | Kalutara | Kurunegala | Badulla | Matale |
| R. sanguineus | 92           | 5       | 143         | 31          | 52          | 35        | 20       | 62        | 305    | 25         | –          | –       | 15        | 20        | 46        | 165      | 211      | 115      | 125     | 154    | 85      | 115      | 60      | 5       | 32      |
| R. haemaphysaloides | 40          | 32      | 12          | 7           | 37          | 20        | 32       | 25        | 25     | 55         | 52         | 14      | 5         | 50        | 31        | 10       | 20       | 40       | 9       | –      | 12      | 20       | 56      | 38      | 25      |
| H. turturis | –            | –       | 6           | 8           | –           | –         | –        | –         | –      | –          | –          | –       | –         | –         | –         | –        | –        | –        | –       | –      | –      | –       | –       | –      |
| H. intermedius | 25          | 10      | 16          | 1           | 51          | –         | 6        | 12        | 2      | 5          | 35         | 4       | 6         | 42        | 22        | 4        | 6        | 10       | 20      | 11     | 20     | 8        | 27      | 23      | 12      |
| H. bispinosus | 1            | 2       | –           | 4           | –           | –         | –        | –         | –      | –          | –          | –       | –         | –         | –         | –        | –        | –        | –       | –      | –      | –       | –       | –      |
| A. intregum | –            | –       | –           | –           | –           | –         | –        | –         | –      | –          | –          | –       | –         | –         | –         | –        | –        | –        | –       | –      | –      | –       | –       | –      |
| Hya-lomma sp. | –            | –       | –           | –           | 2           | –         | –        | –         | –      | –          | –          | –       | –         | –         | –         | –        | –        | –        | –       | –      | –      | –       | –       | –      |
| D. auratus | –            | –       | –           | –           | –           | –         | –        | –         | –      | –          | –          | –       | –         | –         | –         | –        | –        | –        | –       | –      | –      | –       | –       | –      |

*R Rhipicephalus, H Haemaphysalis, A Amblyomma, D Demacentor*
species in the Intermediate Zone, especially in Polonnaruwa, Nuwara-Eliya, Monaragala, Badulla and Mannar districts. Although rare in urban areas, it was common in rural areas and areas closer to the forests. It has a limited global distribution occurring over the Oriental and parts of the Palaearctic and Australasian zoogeographic regions from Afghanistan in the west to the Philippines and Indonesia in the east and in the Indian subcontinent [19, 32, 33]. It is known to infest all domestic animals, including ox, water buffalo, and horses but is more commonly seen on sheep and goats [19, 22]. This tick species has the potential to transmit Kaysanur forest disease virus in India [34] and Rickettsia rhipicephali in Taiwan [35], and as the principal vector of bovine babesiosis (e.g., Babesia orientalis) in China [36].

Three species of Haemaphysalis were recorded in the present study: H. intermedia, H. bispinosa and H. turturis, among which H. intermedia were widely distributed in all the districts in all three agro-climatic zones but the abundance was low. In 1965, Seneviratne [19] also reported that Ha. intermedia was a widespread tick species in Sri Lanka and collected from all domestic animals throughout the island. These two species, H. bispinosa, and H. intermedia are the major goat ticks in Sri Lanka [22] and also infest cattle (unpublished observations). Globally, H. bispinosa has a limited geographical distribution, being restricted to certain parts of Southern India and Sri Lanka. Haemaphysalis turturis was a rare species found only in Kegalle, Kilinochchi and Trincomalee Districts.

Dermacentor auratus and Hyalomma sp. were recorded from only one location in the Kandy and Vavuniya Districts, respectively. The primary host of D. auratus in wild boars and the tick has an island-wide distribution and a rapid increase in the population has been observed due to restricting the killing of wild boars. Nymphs of D. auratus have been identified as the major tick species responsible

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**Table 4** Attachment site of the tick species collected from the host dogs in all districts of Sri Lanka

| Stage | Tick species | Percentage of ticks | Total anterior (%) | Total posterior (%) |
|-------|--------------|---------------------|--------------------|--------------------|
|       |              | Eye lids | Inner ear | Outer ear | Snout | Face | Body | Neck | Tail | Fore Limb | Hind limb |         |         |
| Adult | R. sanguineus | 7.2     | 25.5     | 21.4     | 0.8    | 1.5  | 1.5  | 1.5  | 4.1  | 5.5      | 0.4       | 21.1   | 12.3   |
|       | R. haemaphysaloides | 10.5   | 14.8     | 20.9     | 1.2    | 2.1  | 5.9  | 8.7  | 8.7  | 0.0      | 28.1      | 15.1   | 47.4   |
|       | H. intermedia  | 35.5   | 12.1     | 10.2     | 0      | 1.2  | 0.2  | 0.2  | 28.1 | 13.9     | 13.9      | 57.8   | 42.2   |
|       | H. bispinosa   | 0      | 85.7     | 4.3      | 0      | 0    | 0    | 0    | 0    | 0        | 100       | 100    | 0      |
|       | H. turturis    | 0      | 100      | 0        | 0      | 0    | 0    | 0    | 0    | 0        | 0         | 100    | 0      |
|       | Hyalomma sp.   | 0      | 100      | 0        | 0      | 0    | 0    | 0    | 0    | 0        | 0         | 100    | 0      |
| Nymphs| R. sanguineus  | 0      | 88.0     | 0        | 0      | 0    | 0    | 0    | 0    | 0        | 8         | 4      | 88.0   |
|       | R. haemaphysaloides | 0     | 0       | 0        | 0      | 0    | 0    | 0    | 0    | 0        | 61.0      | 39.1   | 0      |
|       | A. integrum    | 92.1   | 8.0      | 0        | 0      | 0    | 0    | 0    | 0    | 0        | 0         | 0      | 100    |
|       | D. auretus     | 0      | 100      | 0        | 0      | 0    | 0    | 0    | 0    | 0        | 0         | 100    | 0      |

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R Rhipicephalus, H Haemaphysalis, A Amblyomma, D Demacentor

 Springer
for human otoacariasis in Sri Lanka [27, 37, 38]. Dogs also carry this tick species. It is possible that when the wild boars visit the human habitats, the engorged females drop off and lay eggs and larvae can be easily picked by dogs as well as humans. *Hyalomma* sp. was found only in one location in the Dry Zone. According to Seneviratne [19], they were collected from buffalo, neat cattle and goats but not from the dogs. This could be an accidental occurrence and may be due to their close contact with cattle.

Immature stages of *Amblyomma integrum* were recorded from several locations in Rathnapura, Matara, Monaragala and Badulla districts. This species is very widespread in Sri Lanka and is more common in jungle areas [21]. According to Seneviratne [19] the incidence of *A. integrum* was lower in the higher elevations around Nuwara-Eliya which is similar to the present study and the more thickly populated parts of the Western Province which is not similar to the present study. All the life stages except larvae of *R. sanguineus* and *R. haemaphysaloides* were found on dogs. Among adults, more females were present than males. The presence of more females has been reported in the study of Shimada et al. [17] and the presence of more males has been reported in Dantas-Torres and Otranto and Diyes & Rajakaruna [22, 39]. Only nymphs of *D. auratus* and *A. integrum* and only adults of *H. turturis* and *Hyalomma* sp were recorded.

The three-host life cycle of *R. sanguineus* was successfully completed within an average of 98 days (70–126 days) and all three stages fed on the New Zealand white rabbits. The duration of the life cycle was shorter compared to the previous studies, where it has taken 162–177 days to complete the life cycle [13, 40]. This might be due to the diverse conditions of temperature and relative humidity in which ticks were maintained, as well as the climatic conditions of different geographic regions. However, there might be also some strain-related differences [40]. The weight of the wild-caught females in this study was 133.2 (54–187) mg which is lower than previously recorded values (289.5 mg) [40]. Wild-caught females were removed deliberately from the host, while in the study done by Dantas-Torres [40], females were allowed to naturally drop off after feeding. The mean number of eggs laid was lower compared to the previous records [13, 40]. Similarly, the recorded pre-oviposition period, incubation period and parasitic periods of all three life stages were lower than previously recorded durations [13, 40]. The REI and RFI were 50.8 ± 9.69 (22.0–70.0) and 9.1 ± 5.01 (0–22.6), respectively. Dantas-Torres [40],

### Table 5

| Life stage Parameter | Number of days |
|---------------------|---------------|
|                     | Mean  | SD       | Minimum | Maximum |
| Female£ Pre-oviposition | 4.9   | 1.02     | 4       | 7       |
| Oviposition period   | 14.0  | 3.47     | 3       | 19      |
| Post-oviposition survival | 1.1   | 0.99     | 1       | 5       |
| Eggs Incubation period | 29.6  | 3.96     | 20      | 43      |
| Larva Parasitic period | 3.1   | 0.56     | 2       | 3       |
| Moulting period      | 13.4  | 1.32     | 13      | 14      |
| Nymph Parasitic period | 5.0   | 0.00     | 5       | 5       |
| Moulting period      | 14.3  | 0.48     | 13      | 15      |
| Female Parasitic period | 12.6  | 2.94     | 9       | 15      |

£R *Rhipicephalus*, SD Standard deviation

### Table 6

| Parameter | Mean | SD | Minimum | Maximum |
|-----------|------|----|---------|---------|
| £Engorged females weight (mg) | 109.7| 35.09 | 25.0 | 200.0 |
| £Number of eggs laid by engorged females | 1444.3| 531.08 | 101 | 2708 |
| £Reproductive Fitness Index (RFI) | 9.1 | 5.01 | 0.0 | 22.6 |
| £Reproductive Efficiency Index (REI) | 50.8 | 9.69 | 22.0 | 70.0 |
| £Percent eclosion | 63.0 | 22.72 | 0.0 | 95.4 |

£Wild caught females

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**Table 5** Life cycle parameters of *Rhipicephalus sanguineus* fed on New Zealand white rabbits under controlled laboratory conditions (Temperature 27 ± 1 °C; Relative humidity 70–80%)

**Table 6** Biological parameters of *Rhipicephalus sanguineus* fed on New Zealand White rabbits under controlled laboratory conditions (Temperature 27 ± 1 °C; Relative humidity 70–80%)
reported a REI of 13 and RFI of 13.2 for the same tick species in Italy. The egg-laying potential of an engorged female is directly related to her capacity to feed; therefore, heavier females show the highest values in the number of eggs laid as well as the weight of the egg mass and after that a higher hatch rate. This would explain higher REI, Reproductive Affinity Index (RAI) and RFI in Italy’s population [40, 41].

The distribution and abundance of dog tick species may depend on climatic factors such as temperature, humidity, rainfall, presence of other domestic and wild animals and management practices including usage of acaricides and the life cycle can be different from other geographic regions.

![Fig. 3](https://example.com/fig3.png) Total number of eggs, hatched eggs and weight of egg clutch per female in wild-caught *Rhipicephalus sanguineus* ($R^2 = 21.9\%$, 12.6\% and 80.4\%, respectively)

![Fig. 4](https://example.com/fig4.png) Percent eclosion, Reproductive Efficiency Index (REI) and Reproductive Fitness Index (RFI) per female in wild-caught *Rhipicephalus sanguineus* ($R^2 = 5.0\%$, 3.3\% and 2.6\%, respectively)

### Table 7

Correlation (Pearson Correlation) between reproductive parameters and the female weight of wild caught females of *Rhipicephalus sanguineus* measured at the laboratory after and during oviposition (Temperature $27\pm1^\circ C$; Relative humidity 70–80%)

| Reproductive parameter          | $R$  | $p$   |
|--------------------------------|------|-------|
| Total laid eggs per female      | 0.468| 0.001*|
| Total hatched eggs per female   | 0.355| 0.014*|
| Weight of egg mass per female   | 0.896| <0.001*|
| Reproductive Fitness Index (RFI)| 0.181| 0.224 |
| Reproductive Efficiency Index (REI)| 0.162| 0.277 |
| Percent eclosion               | 0.223| 0.132 |

* Indicate the significance $p < 0.05
according to the different climatic factors present. Moreover, Danta-Torres (2010) [25] highlights that in the era of globalization and climate changes; R. sanguineus is becoming increasingly relevant from a public health perspective. This tick has also been implicated in the transmission of pathogens of zoonotic concern (e.g., Rickettsia rickettsii) and recent studies have shown that R. sanguineus ticks exposed to high temperatures are more prone to bite humans [42]. This scenario highlights that climate change could affect R. sanguineus populations around the world and, consequently, the epidemiology of certain tick-borne infections [42]. The dominant dog tick species and the species diversity varied in different climatic regions of Sri Lanka. Information on diversity, distribution and life cycle parameters is fundamental for studies of canine tick-borne infections, zoonoses, and their epidemiology.

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Availability of Data and Materials All data are available in hard copies and soft copies with the principal investigator stored securely releasable upon any reasonable request.

Code Availability Not Applicable.

Declarations

Conflict of interest Authors declare that there is no conflict of interest.

Ethical Approval All the study protocols and objectives were approved by the Institutional Ethical Clearance Committee of Postgraduate Institute of Peradeniya, Sri Lanka.

Consent to Participate Not Applicable.

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