Veterinary Parasitology 212 (2015) 318–323

Contents lists available at ScienceDirect

Veterinary Parasitology

journal homepage: www.elsevier.com/locate/vetpar

Altitudinal and seasonal differences of tick communities in dogs from pastoralist tribes of Northern Kenya

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ARTICLE INFO

Article history:
Received 18 June 2015
Received in revised form 4 August 2015
Accepted 22 August 2015

Keywords:
Altitudinal distribution
Rhipicephalus sanguineus
Rhipicephalus pulchellus
Rhipicephalus armatus

ABSTRACT

Studies regarding the distribution and ecology of ticks in dogs from Eastern Africa are scarce. Our research was based on a long-term screening of ticks parasitising the domestic dogs living with indigenous people around Lake Turkana, Mt. Kulal and Mt. Nyiru areas, Northern Kenya. A total of 9977 ticks were collected from 1464 dogs of all ages and both sexes. Identification was performed using morphological keys and data were analyzed using the Repeated Measures ANOVA, post-hoc Scheffe test and F test, relating independent variables as seasons and regions. Final results were translated to maps using GIS software. Five species of ticks were identified: *Rhipicephalus pulchellus*, *Rhipicephalus sanguineus* sensu lato (s.l.), *Rhipicephalus armatus*, *Amblyomma gemma* and *Hyalomma truncatum*. Our results suggest a statistical difference of the tick community structure related to seasonal and altitudinal distribution. Parasitism with *R. armatus* and *R. pulchellus* was higher in September–October than in January, whereas, *R. sanguineus* s.l. was not influenced by the season. *Rhipicephalus armatus* was present exclusively on dogs living in semi-desert areas, while *R. sanguineus* s.l. was the dominant species present on the shores of Lake Turkana. Although *R. pulchellus* was present in the all studied areas, this species had a significantly higher abundance in the afromontane region of Mt. Kulal and montane xeromorphic forest of Mt. Nyiru; these regions are characterized by elevated humidity and cooler climate. Similar geo-climatic distribution is typical also for *A. gemma*, which was found in dogs exclusively in Mt. Kulal afromontane area. The current work represents the most extensive study performed on the tick community structure of dogs in Eastern Africa. The results showed a relatively limited tick species diversity, with clear seasonal differences and altitudinal distribution.

1. Introduction

Almost half of the world's pastoral people live in Africa (Roth and Fratkin, 2005). It is estimated that more than twenty five million pastoralists and agro-pastoralists live in East Africa alone (Roth and Fratkin, 2005). Northern Kenya is particularly known for its harsh environment with prolonged drought and famine, constant demographic increase, ethnic conflicts and political insecurity, which have gradually induced the decrease of pastoralists' mobility (Roth and Fratkin, 2005). The Northwest territory of Kenya between Lake Turkana and Mt. Kulal is inhabited by several pastoral tribes where humans and domestic animals share both resources and diseases. The pastoralists of Turkana, Samburu and Rendille tribes depend on domestic animals such as cattle, camels, goats, sheep, and donkeys for milk, meat, transport, trade and ceremonials (Fratkin and Roth, 2005). The domestic dogs, which are believed to come to the

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http://dx.doi.org/10.1016/j.vetpar.2015.08.025
0304-4017/

area with Nilotic people 2000 years ago, represent a valuable part of the communities. They are traditionally used for protection of the villages and livestock against wild animals and human intruders.

Together with fleas, ticks represent the most common blood feeding arthropods of dogs worldwide. Their complex life cycles and ecology make ticks important vectors for pathogens. Due to their free roaming lifestyle, dogs represent a valuable epidemiological sentinel species for tick-borne pathogens (Halliday, 2010; Millán et al., 2013). Among several tick species from *Amblyomma*, *Hyalomma*, *Haemaphysalis* and *Rhipicephalus* genera that have been reported on domestic dogs in equatorial Africa, members of the latter are the most diversified and frequent (Walker et al., 2003).

Despite the ubiquitous presence of domestic dogs in areas inhabited by semi-nomadic pastoralists and the potential source of infection they represent for humans, livestock and wildlife, only few studies have addressed pathogens other than the zoonotic cestode *Echinococcus* and rabies virus. Most of the ticks occurring on dogs are reported also on humans. Hence, the tick-host associations and their ecology and distribution are important for understanding the natural cycle of tick-borne pathogens. Our aim was to evaluate the community structure of ticks collected from dogs during multi-annual rabies vaccination campaigns organized in remote areas of Lake Turkana region. Based on the extensive spatial and temporal set of samples, we provide an insight into the ecology and seasonal differences of ticks collected in localities covering an extreme range of ecological conditions: from the hot desert of the Lake Turkana shores to mist afromontane forest located in the high altitudes of Mt. Kulal and Mt. Ngyiru.

2. Materials and methods

2.1. Tick sampling

The study was conducted between 2006 and 2012 in 16 pastoral communities in Northern Kenya, under the frame of an international collaborative project focused on preventive veterinary medicine (Mt. Kulal Dogs' Preventive Vaccination). Tick samples were collected in the following months: October (2006), September (2007–2009) and January (2012), covering both the dry and the rainy seasons. The study areas were located in the Marsabit (Eastern Province) and Samburu (Rift Valley Province) counties. Altogether, 1464 dogs were examined for the presence of ticks (Table 1).

2.2. Ecological and climatic characteristics of the area

The settlements included in this study were grouped into four ecological categories based on the majority of the vegetation types and altitude, as follows: margin of high afromontane forest (I), dry savanna/semi-desert (II), montane xeromorphic forest (III) and desert (IV) (Fig. 1). The climate is hot, arid tropical (Nicholson 1991) with median monthly temperatures ranging from 17 to 19 °C in the mountains to 20–26 °C at lower altitudes. August is usually the coldest month, while March is the hottest (Nicholson 1996; de Leeuw et al., 2001). There are two rainy seasons, one short between mid September and November and one long between March and May, intercalated with dry seasons (December–February and June–September (Nicholson 1996).

2.3. Collection and identification of ticks

Ticks were collected from household dogs presented for veterinary screening and anti-rabies vaccination (D'Amico et al., 2013). As the number of ticks on each dog was often of several hundreds, the collection of all the ticks was technically not achievable. If the number of visible ticks on a dog was lower than 20, all the ticks were collected. If the number of ticks was higher than 20, the number of collected ticks was dependent on the estimated level of infestation, and ranged between 30 and 100. In the latter case, for the reliability of morphologic identification, ticks which were not fully engorged were preferred for collection. A total number of 9977 adult ticks were collected. A number of nymphs (n = 251) were also collected, but because of their difficult and uncertain specific identification due to full-engorgement, these were not included in the statistical analyses. All ticks were preserved in absolute ethanol and identified in the laboratory. Morphological identification was done individually for each tick to species level by using morphological keys and descriptions (Walker et al., 2000, 2003).

2.4. Statistical analysis

Each dog received a unique ID number, and information regarding age, sex and locality was collected. All the raw data were included in a database and statistically analysed using the Repeated Measures ANOVA (Analysis of Variance); the species was used as an independent variable, and the season and ecological region as dependent variables. The subsequent comparisons were performed using post-hoc Scheffe and t-protected tests. The results were considered statistically significant at an alpha level of 5%. Classical tests (F test and post-hoc tests) were complemented by estimation indexes (effect size—eta squared) and statistical power. Maps were generated using the ArcMap version 10.3 software.

3. Results

3.1. Characteristics of the tick community structure

Out of 1464 examined dogs, 1121 (76.5%) were infested by ticks. A total number of 9977 adult ticks and 251 nymphs were collected (Table 1). The latter were not included in the statistical analyses because of their difficult and uncertain specific identification due to the full-engorgement. In the adult tick population, 5 different species were identified: *Rhipicephalus pulchellus* (Gerstäcker, 1873), *Rhipicephalus sanguineus* (Latreille, 1806) sensu lato (s.l.), *Rhipicephalus armatus* Pocock, 1900, *Amblyomma gemma* Dönitz, 1909 and *Hyalomma truncatum* Koch, 1844. The prevalence (percent of infested dogs) of each tick species based on the season and region is shown in Table 2. The community structure (percent of individuals of particular species from the total number of collected ticks) of ticks based on season and region is shown in Table 3 and Fig. 2. The statistical analysis showed that there was no significant difference between different host age and sex categories. However, significant differences were detected between the prevalence and community structure among the seasons and the ecological regions.

3.2. Season-based statistical analysis

The overall prevalence of ticks was higher during September–October than in January [F (14,044) = 114.69 (p = 0.0001, η^2 = 0.1, $1 - \beta$ = 0.98)]. The prevalence and frequency of individual tick species were also influenced by the season. *R. armatus* [t (1011) = 2.622 (p = 0.009, CI 95%: 0.35193, 2.4462)] and *R. pulchellus* [t (1011) = 12.45 (p = 0.001, CI 95%: 26.48685, 36.39834)] were more common on dogs in September-October compared to January. *A. gemma* was found on dogs only in September–October. No seasonal statistical difference was found for *R. sanguineus* s.l. and *H. truncatum*. No significant difference was detected for the same season between the years of the study.

3.3. Region-based statistical analysis

The statistical analysis showed significant differences between the prevalence and the community structure between the regions

Table 1
Collection sites with their grouping based on ecological regions, number of dogs analysed and number of ticks collected.

Region	Locality	Latitude	Longitude	Altitude (m)	Number of dogs	Number of ticks
I	Losikiriachi	2.640767	36.951888	1800	34	66
	Gatab	2.643432	36.928944	1690	259	2233
II	Makutano	2.525083	36.920667	882	45	431
	Arapal	2.787055	37.010326	840	122	535
	Ngororoi	2.692222	37.008250	805	21	61
	Larachi	2.713139	36.854611	738	25	698
	Olturot	2.595305	37.083769	550	84	699
III	Tuum	2.146899	36.774569	1440	86	989
	Uaso Rongai	2.038853	36.859358	1300	14	71
	South-Horr	2.098045	36.919722	1030	213	358
	Kurungu	2.168458	36.907196	920	40	54
IV	Sarima	2.513754	36.808990	685	16	69
	Loyiangalani	2.756252	36.720661	385	425	2372
	Soit	3.000000	36.423333	380	12	52
	Palo	2.950833	36.466111	375	8	127
	El-Molo	2.826556	36.696393	370	60	1162

I, high afromontane forest (Mt. Kulal); II, dry savanna/semi-desert; III, montane xeromorphic forest (Mt. Nyiru); IV, desert (Lake Turkana shore).

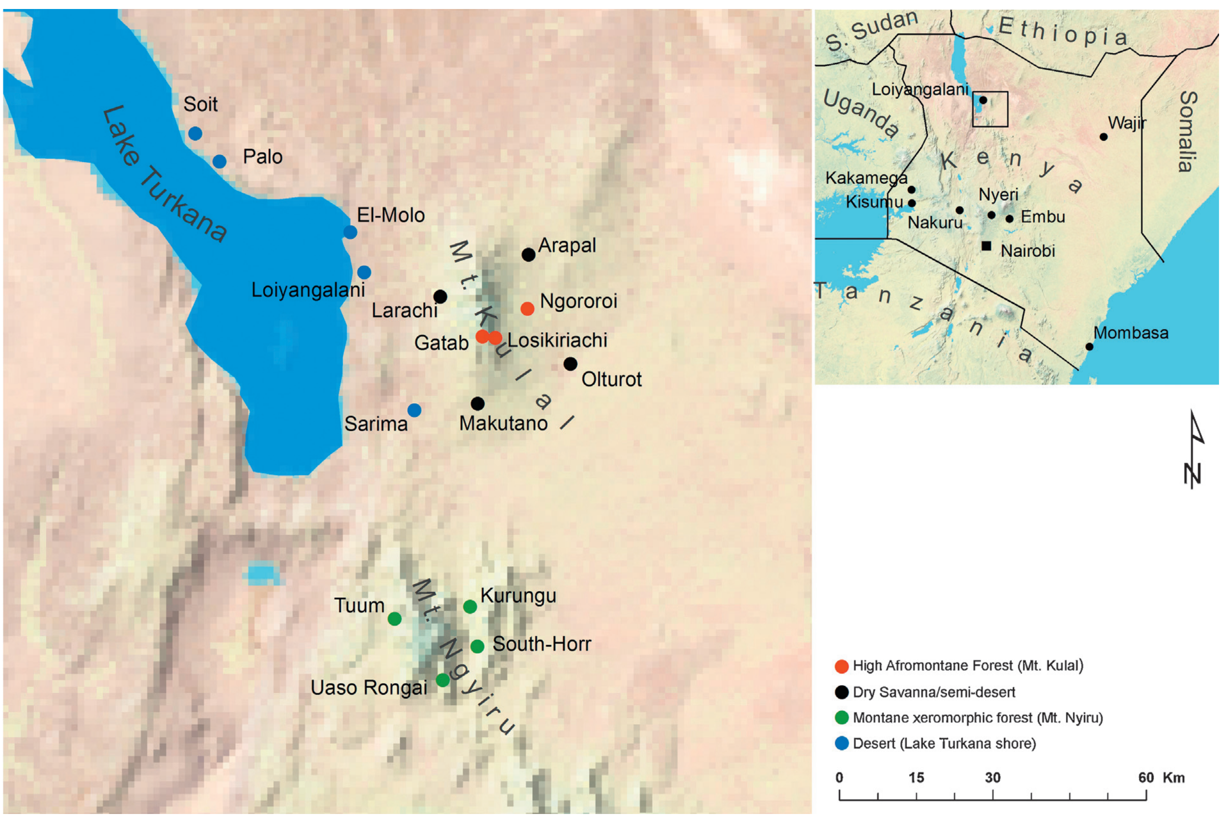

Fig. 1. Collection sites (each black dot in the large map represents a village) and their grouping into ecological categories.

(Table 4). *R. pulchellus* was the most prevalent and abundant tick species in the high afromontane forest (Mt. Kulal) ($p = 0.0001$) while *R. sanguineus* s.l. was the most prevalent and abundant tick species in the desert ($p = 0.0001$). However, no statistical differences were observed between these two species in the dry savanna/semi-desert and montane xeromorphic forest (Mt. Nyiru). *R. armatus* was more common in dry savanna/semi-desert regions ($p = 0.009$). *H. truncatum* was detected only in the high afromontane forest (Mt. Kulal) and in dry savanna/semi-desert regions, whereas *A. gemma* was present on dogs only in the high afromontane forest (Mt. Kulal).

4. Discussion

Despite the high tick biodiversity in tropical regions, the number of species parasitic on dogs in our study was found to be relatively low, with only 5 species present in a large and heterogeneous dataset collected over several years and in different seasons and ecological conditions.

There are few previous studies on the ticks of domestic dogs in Eastern Africa. In a synoptic list of tick-hosts association in Uganda (Matthysse and Colbo, 1987), the following species are mentioned on dogs: *Amblyomma lepidum*, *Amblyomma variegatum*,

Table 2
Prevalence of the tick infestation on dogs based on region, season and tick species.

Region	Season (month)	*R. armatus*	*R. pulchellus*	*R. sanguineus* s.l.	*A. gemma*	*H. truncatum*
I	Sept–Oct	2.3	88.8	10.5	4.7	0.6
	Jan	0	58.0	10.3	0	0
	Total	2.0	84.0	11.9	4.0	0.5
II	Sept– Oct	12.3	58.4	66.2	0	3.9
	Jan	1.0	9.1	41.4	0	0
	Total	7.9	39.1	56.5	0	2.4
III	Sept–Oct	1.0	73.0	53.0	0	0
	Jan	0	9.8	44.4	0	0
	Total	0.4	34.8	47.8	0	0
IV	Sept–Oct	2.0	1.0	83.8	0	0
	Jan	0	0.9	63.0	0	0
	Total	1.3	1.0	76.0	0	0

I, high afromontane forest (Mt. Kulal); II, dry savanna/semi-desert; III, montane xeromorphic forest (Mt. Nyiru); IV, desert (Lake Turkana shore).

Table 3
Tick community structure (% of species from the total number of ticks collected) based on regional and season.

Region	Season	*R. armatus*	*R. pulchellus*	*R. sanguineus* s.l.	*A. gemma*	*H. truncatum*
I	Sept–Oct	0.6	89.8	7.6	1.9	0.2
	Jan	0.0	85.4	14.6	0.0	0.0
	Total	0.6	89.5	8.0	1.7	0.2
II	Sept–Oct	7.9	23.3	66.4	0.0	2.5
	Jan	0.5	5.6	93.9	0.0	0.0
	Total	7.0	21.2	69.5	0.0	2.2
III	Sept– Oct	0.1	50.3	49.6	0.0	0.0
	Jan	0.0	9.8	90.2	0.0	0.0
	Total	0.1	41.8	58.2	0.0	0.0
IV	Sept– Oct	0.2	0.1	99.7	0.0	0.0
	Jan	0.0	0.2	99.8	0.0	0.0
	Total	0.2	0.1	99.7	0.0	0.0

I, high afromontane forest (Mt. Kulal); II, dry savanna/semi-desert; III, montane xeromorphic forest (Mt. Nyiru); IV, desert (Lake Turkana shore).

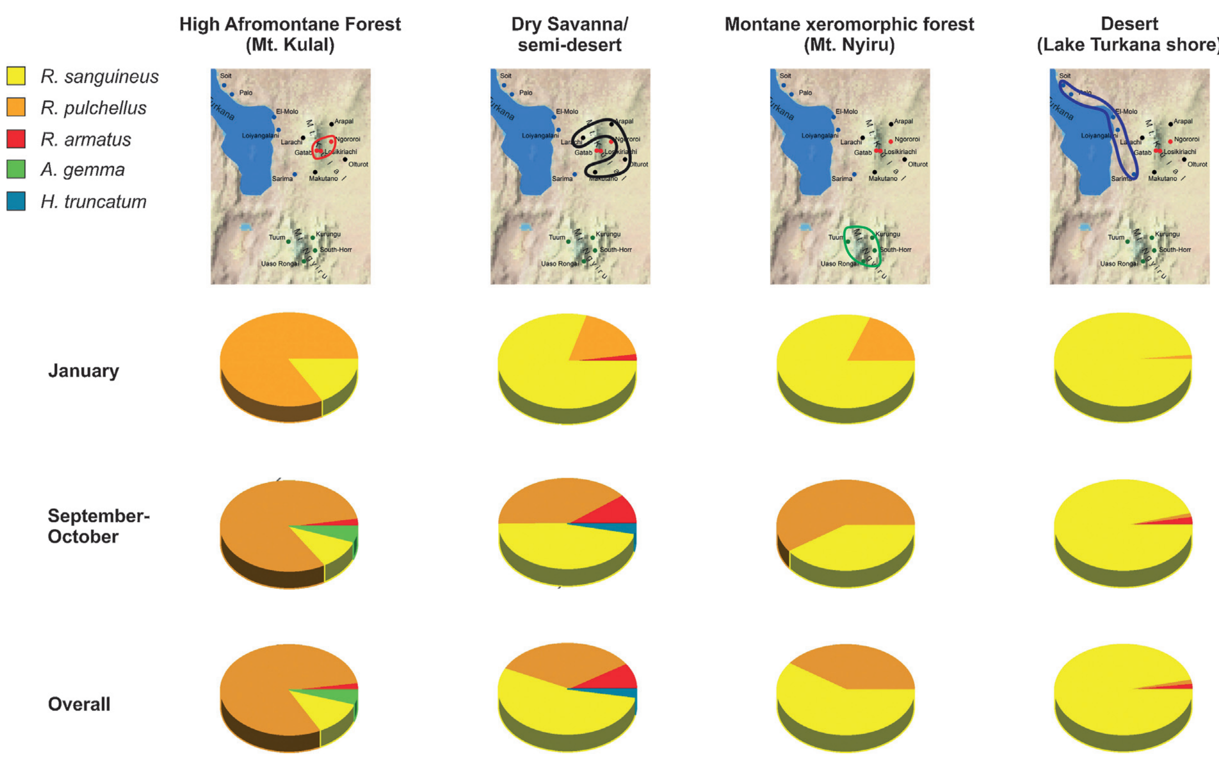

Fig. 2. Tick community structure grouped on ecological categories of sampling and seasons.

Table 4
The value of statistical tests (post-hoc Scheffe) calculated for the main effects of the region on the tick species prevalence.

(I) Region	(J) Region	%Diference (I–J)	p	95% CI	
				Minimum	Maximum
I	II	2.253*	0.006	0.654	3.851
	III	4.624*	0.001	3.026	6.223
	IV	1.820*	0.02	0.284	3.356
II	III	2.372*	0.002	0.867	3.876
	IV	−0.432	0.555	-1.87	1.005
III	IV	−2.804*	0.001	-4.242	-1.366

I, high afromontane forest (Mt. Kulal); II, dry savanna/semi-desert; III, montane xeromorphic forest (Mt. Nyiru); IV, desert (Lake Turkana shore).
*Statistical significance.

Rhipicephalus decoloratus, *Rhipicephalus appendiculatus*, *Rhipicephalus carnivoralis*, *Rhipicephalus hurti*, *Rhipicephalus longus*, *Rhipicephalus lunulatus*, *Rhipicephalus praetextatus*, *Rhipicephalus sanguineus* s.l., *Haemaphysalis leachi*, *Haemaphysalis moreli*, *Haemaphysalis paraleachi* and *Haemaphysalis spinulosa*. The list of ticks reported from dogs in Kenya (Walker, 1974) includes: *A. gemma*, *A. lepidum*, *Amblyomma sparsum*, *A. variegatum*, *R. decoloratus*, *Rhipicephalus longicoxatus*, *R. hurti*, *Rhipicephalus jeanneli*, *R. sanguineus* s.l., *Rhipicephalus simus*, *H. leachi*, *Haemaphysalis aciculifer*, *Haemaphysalis impeltatum*, *Ixodes cavipalpus*, *Ixodes lewisi* and *Ixodes nairobiensis*. In a study conducted in Southern Ethiopia on 199 dogs, the overall prevalence of ticks was very low (less than 4%), with two genera identified only: nymphs of *Amblyomma* spp. (prevalence 3.5%) and unspecified stages of *H. leachi* (prevalence 0.5%) (Kumsa and Mekonnen, 2011). Surprisingly, no representatives of genus *Rhipicephalus* spp. were found in their study. Most of the data regarding ticks parasitic on dogs in Africa originate from the south of the continent. In an extensive study performed in the low altitude coastal forests of South Africa by Horak et al. (2001), out of seven tick species identified in dogs, the most prevalent were: *H. leachi*, *Amblyomma hebraeum* and *R. simus*.

In our study, we have identified five tick species, of which two were dominant in dogs: *R. sanguineus* s.l. and *R. pulchellus*. *Rhipicephalus sanguineus* s.l. is considered to be a typical dog tick worldwide. However, due to extensive taxonomical debates (Gray et al., 2013), the systematics of this group remains unclear. Possibly, the specimens collected from Eastern Africa are a different taxonomic unit compared to those from Europe, Asia or the New World; this is an issue that should be solved in the future. Our results showed that even if *R. sanguineus* s.l. was present in all four regions, the highest prevalence and dominance were reported in dogs living in desert regions, regardless of the season. Similar results were reported by Jacobs et al. (2001) in a study conducted in South Africa, where it has been shown that *R. sanguineus* s.l. was the most common species in all studied regions, with a higher prevalence in dogs during the warmer season, although this tick species was present throughout the year.

The second dominant species in our study, *R. pulchellus,* has no particular affinity for dogs and it can be found on various wild and domestic mammals, particularly ungulates across Eastern Africa (Walker et al., 2000). Although the vast majority of host associations of *R. pulchellus* include domestic ungulates (cattle, sheep, goats and camels), based on our findings, we consider that this tick species should also be considered as an important species parasitic in dogs in Eastern Africa. Its medical and vectorial role in dogs requires further investigations, especially because the same dog is frequently co-parasitized by *R. sanguineus* s.l., known as a vector for a wide range of canine pathogens (Dantas-Torres and Otranto, 2015). Moreover, previous records (Walker et al., 2000) and our own observations (Mihalca and D'Amico personal observation) show that *R. pulchellus* commonly infects also humans (pastoralists, tourists and researchers) in the area. A relatively large number of pathogens have been found associated with *R. pulchellus* (Walker et al., 2000), but none of these are typical canine pathogens. It has been shown that the adults of *R. pulchellus* are more active during the wet season (Walker et al., 2000), and our results confirm this observation. However, our study is the first to show the dominant presence of *R. pulchellus* related to the altitude. In both seasons, we have found this species only accidentally on dogs in the desert environment, but it was the most common tick found in dogs in the villages located in high altitudes (over 1500 m).

R. armatus was less common, with low prevalences in the high afromontane forest region, desert and montane xeromorphic forest, but locally common in dry savanna regions. Moreover *R. armatus* was almost absent in the dry season with most of the records on dogs during the wet season. This species infects a wide range of wild mammals; among the domestic animals it has been reported on sheep, donkeys and dogs (Walker et al., 2000, 2003). According to our knowledge, this is the first study to show the seasonal and regional preferences of adult ticks of this species. Clifford et al. (1976) have studied the seasonal occurrence of immature stages of *R. armatus* in hares in Kenya, suggesting a more intense activity of larvae and nymphs during the wet seasons. Among the three localities included in their study, this tick species was found in the sites located at 1200 m altitude, but not in those located at 600 m and 1800 m altitude. No data on the vectorial role of *R. armatus* are available.

A. gemma is a tick typically associated with domestic and wild ungulates, and rarely with birds and tortoises (Voltzit and Keirans, 2003; Guglielmone et al., 2014). It has been previously reported on dogs in Kenya (Walker, 1974). We found this ticks on 4.7% of the dogs from the high afromontane forest exclusively during the wet months, which is correlated with the known seasonality of *A. gemma* in livestock (Pegram et al., 1981). In our study, its exclusive presence on domestic dogs in Mount Kulal area is related to the abundant presence of cattle in this region. Its vectorial role for possible canine pathogens has not been investigated yet.

H. truncatum is one of the most frequent tick species in the Afrotropical region (Apanaskevich and Horak, 2008). Its presence is associated most commonly with ungulates, but it has also been reported in numerous other groups of mammals, birds and reptiles (Guglielmone et al., 2014). Its presence in dogs is not commonly reported, but this is probably related to the lack of studies targeting this host category. In our study, this tick species had a low prevalence in dogs, being recored only in the areas where cows are common livestock.

An important aspect of our study is the relatively well defined altitudinal distribution of the tick community structure in dogs. Although the dogs belong to pastoralist tribes and they are expected to travel a lot with the herds, there is no comprehensive data available on the extent of dog movements in the area and how could this influence the epidemiology of diseases in general. The majority of tick species found in dogs in our study are shared with livestock and some of them with humans, mainly in the afromontane regions. However, the role of dogs as reservoirs for tick-borne diseases of livestock and humans remains to be investigated.

5. Conclusion

The current work represents the most extensive study performed on the tick community structure of dogs in Eastern Africa. The results showed a relatively limited tick species diversity, with a clear seasonal and altitudinal distribution. The dominant species in the afromontane region was *R. pulchellus* while in other areas, *R. sanguineus* s.l., the brown dog tick, was the predominant one.

Conflict of interest

The authors declare that they are not in any situation of conflict of interest.

Acknowledgments

We would like to present our gratitude to all the pastoral communities from the study area, especially to our local helpers and chiefs of the villages for kindly supporting our work there. We would like to thank for the unconditional logistical support VSF Germany and VSF Czech Republic. Special thanks go also to the students of USAMV Cluj-Napoca and VFU Brno for their valuable help during the field work. Part of the work has been performed using funds by UEFISCDI project PCE 236/2011. CD was supported by POSDRU grant no. 159/1.5/S/136893 grant with title: "Parteneriat strategic pentru creşterea calităţii cercetării ştiinţifice din universităţile medicale prin acordarea de burse doctorale şi postdoctorale—DocMed.Net_2.0". The work of GA, MOD, PS, CD, ADS, DM and ADM was done under the frame of EurNegVec COST Action TD1303. Work of PŠ and DM was further supported by the project "CEITEC—Central European Institute of Technology" (CZ.1.05/1.1.00/02.0068) from the European Regional DevelopmentFund.

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