Preliminary study on the tick population of Benin wildlife at the moment of its invasion by the *Rhipicephalus microplus* tick (Canestrini, 1888)

Kossi Justin Adinci1, Yao Akpo2, Camus Adoligbe3, Safiou Bienvenu A데ahn, Roland Eric Yessinou1, Akoeugnigan Idelphonse Sodé4, Guy Appolinaire Mensah5, Abdou Karim Issaka Youssao6, Brice Sinsin7 and Souaibou Farougou1

1. Laboratory of Research in Applied Biology, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, 01 P.O. Box 2009, Cotonou, Benin; 2. Laboratory of Ecology, Health and Animal Production, Faculty of Agronomy, University of Parakou, P.O. Box 123 Parakou, Benin; 3. National Institute for Scientific Research, Research Center of Agonkanmey (CRA/INRAB), Benin; 4. Laboratory of Biomathematics and Forest Estimations Faculty of Agronomic Sciences (FSA) University of Abomey-Calavi, 04 BP 1525, Cotonou (Bénin); 5. Department of Animal Production, Faculty of Agronomic Sciences (FSA), University of Abomey-Calavi (Benin), 01 BP 526 Cotonou, Benin.

Corresponding author: Kossi Justin Adinci, e-mail: justinmario8@gmail.com
Co-authors: YA: yao.akpo@gmail.com, CA: adolcam83@yahoo.fr, REY: eric.yessinou@uac.bj, SBA: adehankarim@gmail.com, AJS: sidelphonse@gmail.com, AKIY: iyousao@yahoo.fr, SF: farougou@gmail.com, BS: bsinsin@gmail.com, GAM: mensahga@gmail.com

Received: 11-01-2018, Accepted: 17-05-2018, Published online: 25-06-2018

doi: 10.14202/vetworld.2018.845-851 How to cite this article: Adinci KJ, Akpo Y, Adoligbe C, A데ahn SB, Yessinou RE, Sodé AI, Mensah GA, Youssao AKI, Sinsin B, Farougou S (2018) Preliminary study on the tick population of Benin wildlife at the moment of its invasion by the *Rhipicephalus microplus* tick (Canestrini, 1888), *Veterinary World*, 11(6): 845-851.

Abstract

**Background and Aim:** *Rhipicephalus microplus* (*Rm*) is one of the most problematic livestock tick species in the world. Its rapid propagation and resistance to acaricides make it control difficult in the sub-region and Benin particularly. The aim of this work was to check its presence in wildlife and to confirm the possible role of reservoir wildlife may play in the propagation of the parasite. This will help to design more efficient control strategy.

**Materials and Methods:** This study was conducted from February to March 2017 in the National Parks of Benin (Pendjari and W Park) and wildfowl’s assembly and selling point in Benin. Ticks were manually picked with forceps from each animal after slaughtering by hunters then stored in 70° ethanol. Collected ticks were counted and identified in the laboratory using the identification key as described by Walker.

**Results:** Overall, seven species of ticks (*Amblyomma variegatum*, *Boophilus decoloratus*, *Rm*, *Boophilus spp.*, *Hyalomma spp.*, *Rhipicephalus sanguineus*, *Rhipicephalus spp.*) were identified on nine wild animal species sampled (Cane rat, wildcat, Hare, Doe, Cricetoma, Buffalo, Buffon Cobe, and Bushbuck and Warthog). The average number of ticks varies from 3 to 6 between animal species, 3 to 7 between localities visited, and 2 to 5 between tick species. However, these differences are statistically significant only for localities. Considering tick species and animal species, the parasite load of *Rm* and *Rhipicephalus spp.* is higher; the buffalo being more infested. The analysis of deviance reveals that the abundance of ticks observed depends only on the observed localities (p>0.05). However, the interactions between animal species and localities on the one hand and between animal and tick species on the other hand, although not significant, have influenced the abundance of ticks as they reduce the residual deviance after their inclusion in the model.

**Conclusion:** This study reported the presence of *Rm* in wildlife of Benin and confirmed its role in the maintenance and spread of the parasites. It is, therefore, an important risk factor that we must not neglect in the epidemiological surveillance and ticks control strategies in the West African sub-region and particularly in Benin.

**Keywords:** Benin, *Rhipicephalus microplus*, ticks, wild animals.

Introduction

Ticks’ host, like all parasites host, plays an important role in their distribution. Ticks spend almost all their time with the host and move from one point to another with them. Female ticks leave their host and fall into the environment, lay eggs when they are fully engorged. New larvae will look for another host, and the cycle will restart [1]. Tick-borne diseases have a significant impact on animal productivity and cause economic losses for livestock owners. This is a major obstacle for the livestock sector development in Africa and Benin, in particular, due to the presence of a large number of tick species including *Rhipicephalus microplus* (*Rm*), one of the most feared species [2]. The previous study has shown that *Rm* is a vector of Babesia bovis, Babesia bigemina, and *Anaplasma marginale* [3]. In Benin, the introduction of *Rm* was largely attributed to the importation of Girolando cattle from Brazil by the Government of Benin through the Pafilav Project which aim was to improve local breed milk production [4]. The first study conducted on October 2008 in the village of Kpinnou, the main site of Girolando cattle in Benin, indicated the presence of *Rm* and the suitability of local conditions for its development [5]. As stated by different findings, this tick species has rapidly spread all over the country [6]. Ticks collection and identification from domestic animals were done several times for research purposes.
Wildlife is often pointed to act as a reservoir of tick-borne disease for domestic animals and, vice versa [7-9]. Some studies confirm this perception for some diseases (severe acute respiratory syndrome, bird flu) [10-12]. For pastoralist, wildlife can be the cause of economic disasters when the survival or profitability of the domestic herd is threatened by epizootics or endozooties in which the fauna acts as a carrier, reservoir, or intermediate host [13]. However, no investigation has yet been done on wild species following the identification and spread of *R. m.* which stands out for its resistance to common acaricides and is a real problem for ruminant farms in Benin [14].

Studies related to the identification of the tick population of Benin’s wildlife are, therefore, necessary. These will make it possible to check the presence of this new species tick in the wildlife of Benin. Furthermore, they will allow to have a good knowledge of the acarological environment of this tick and to take it to account in the strategies of control.

**Materials and Methods**

**Ethical approval**

The samples taken during the present study knew no ethical requirements. In fact, these samples were taken from animals slaughtered by legal and illegal hunters.

**Study area**

This study was conducted in Southern, Central, and Northern Benin located in the intertropical zone between parallels 6 ° 30 ' and 12 ° 30 ' of north latitude on the one hand and meridians 1° and 3° 40 ' of east longitude, on the other hand, Benin covers an area of 112,622 km². The relief is slightly uneven, consisting of 2 plains and plateaus whose average altitude does not exceed 200 meters. The highest region (Atacora) where many rivers take their source (Alibori, Mekrou…) is located at the northwestern part of the country (Alibori and Mekrou) Benin has three main climatic zones as follow:

- The northern part is characterized by a semi-arid Sudanese climate beyond latitude 10° N with a unimodal climatic regime (900–1100 mm of rain), two seasons (one dry and one rainy) and a beginning of saheli station, with shallow soils, often degraded and not very fertile;
- The central part own a transitional Sudano-Guinean climate, between 7° and 10° N parallels, with both unimodal and bimodal climatic conditions (1000-1200 mm of rain). It has poor colluvial soil at the reliefs foot and the top of the undulations, with a weak ecological situation in certain localities;
- The Southern part is characterized by a sub-equatorial climate (between parallels 6° 30' and 7° N). It has four-seasons (two rainy and two dry seasons) with fertile soils and degradation of ecological conditions. The rainfall reaches 1500 mm.

Benin has five agro-pastoral zones: the dry Sudanese zone with marginal pastures, the Sudanese surplus grassland zone, the Sudano-Guinean zone with abundant forage resources, the semi-humid zone with agricultural vocation which becomes a zone of breeding and the forest zone [15,16]. Benin cattle herd is estimated at 2,166,000 head on 2015 [17]. 90% of the animal is found in the Northern part of the country. The town of Banikoara, where W Park is located has the greatest number of cattle all over the country. The main ruminant breeds raised in these different agro-pastoral areas are Borgou, Somba, Ndama, Lagunaire, Mbororo, and White Fulani and their crossbred’s products for cattle; Djallonke sheep, Peulh sheep, Guinean dwarf goat, Maradi red goat, and Peulh goat for small ruminants. The whole country is suitable for animal husbandry, except a small area in the northern and southern part of the country [18].

**Sampling sites**

In southern and central Benin, samples were taken at the grouping and selling points of wildfowl in the commune of Kpomasse, Dassa-Zoume, Agbanhizoun, and Zogbodome, respectively. In northern Benin, sampling was performed in the two national parks (W Park and Pendjari Park). These sampling sites are illustrated in Figure-1.

**Materials**

To achieve our goal, we used a stereo-microscope (Zeiss Stemi 2000) with a 60× resolution, a microscope with a 100× resolution, a Geographic Position System, 70° of ethanol, plastic bottles, pliers, a pencil, and adhesive papers, A4 papers.

**Animal species and period of study**

Ticks were collected from February to March 2017 on 9 wild animal species that were freshly slaughtered and visibly infested (Table-1). Sampling area selection was made randomly.

**Ticks collection**

Ticks were manually picked with forceps from each animal after they were slaughtered by hunters. These ticks were kept in different vials of 100 ml containing 70° of ethanol. One vial is used per animal species. At the end of each sampling, a tag made of A4 paper with the necessary information (date of collection, sampling area, and animal species sampled) was directly inserted into each vial before it was completely closed.

![Sampling sites](Available at www.veterinaryworld.org/Vol.11/June-2018/18.pdf)
Ticks identification

Ticks identification was made at the laboratory based on the identification key as described by Walker et al. [19] using a binocular loupe. The genus and species of each tick examined were recorded.

Statistical analysis

The average number of ticks was calculated for the different factors including localities, animal species, and tick species. The same parameters were calculated for localities, and animal species for each species of tick observed. Then these averages were tested using a Kruskal–Wallis test. Histograms were also constructed to highlight the proportion of different stages of tick development per animal species and localities. In addition, the proportion of each tick species was calculated by animal species and locality to assess the importance of its prevalence. Finally, to evaluate the effect of the factors studied on tick’s abundance, the data were adjusted to the Poisson model since the latter come from counts. All analyses were done with R Core Team version 3.2.2 software (Vienna, Austria).

Results

Comparison of average number of ticks according to factors levels

The average number of ticks varies from 3 to 6 between animal species, 3 to 7 between visited localities, and 2 to 5 between tick species (Table-1). However, these differences are statistically significant only for localities (Table-1). With regard to animal species, the highest average number of ticks is obtained on doe (Cervus elaphus) and Wildcat (Felis silvestris) in the locality of Adomougon (Table-1). Considering simultaneously localities and tick species, Rm has the highest average number in the locality of Mekrou (Table-2). Taking into account tick species and animal species, the parasite load of Rm and Rhipicephalus spp. is higher and Buffalo is the most infested animal (Table-3).

Variation in tick number by sex and development stage

Tick number collected within different localities and on different animal species was counted by sex and development stage. Overall, the results reveal that in all the localities and for all animal species considered, female ticks are the most prevalent (Figure-2a-b). Larvae or nymphs are less observed or almost absent in certain species such as the cricetoma (Gambia rat) and buffalo cobe. Table-4 shows that only Rhipicephalus sanguineus is found on doe (C. elaphus) whereas only Rhipicephalus spp. is found on wildcat (F. silvestris). The other animal species are infested by several tick species; however, ticks belonging to Boophilus and Rhipicephalus genus are predominant.

Adjustment of the data to Poisson model

The deviance analysis table reveals that the abundance of ticks observed depends only on localities (p<0.05) (Table-5). However, the interactions between animal species and localities on the one hand and between animal and tick species on the other hand, although not significant, can influence the abundance of ticks as they reduce the residual deviance after their integration into the model.

Discussion

Previous studies on domestic animal particularly cattle have shown the existence of for genus of ticks (Amblyomma, Boophilus, Rhipicephalus, and Hyalomma) in Benin. Meanwhile, these works revealed that September, October, November, June, July, and August are favorable to the proliferation of ticks and the months of February and March are periods of low abundance [20-22]. The results of our work on wild animals at Northern, central, and southern localities improve our knowledge of tick abundance in the country.
### Table-3: Average number of ticks and standard error by location and tick species.

| Localities   | Statistics | Tick species | Av | Bd | Rm | Bsp | Hsp | Rsa | Rsp |
|--------------|------------|--------------|----|----|----|-----|-----|-----|-----|
| Adomougon    | Avg.       |              |    |    | 7  | 6   | -   | 14  | 4   |
|              | SE         |              |    |    |    |     |     |     |     |
| Hounkpogon   | Avg.       |              |    |    | 3.5| 3   | 4   | 6   |
|              | SE         |              |    |    | 0.5| 0   | 1   | 0   | 1.55|
| Koncombri    | Avg.       |              |    |    | 2  | 8   | 3   | 3   | -   |
|              | SE         |              |    |    |    |     |     |     |     |
| Mekrou       | Avg.       |              | 2  | 2  | 8.5| 3   | 4   | -   | 4.75|
|              | SE         |              |    |    |    |     |     |     |     |
| Porga        | Avg.       |              |    | 2  | 2.5| 3   | -   | 2   |     |
|              | SE         |              |    |    |    |     |     |     |     |
| Segbohoue    | Avg.       |              |    |    | 4  | -   | 6   | 6   |
|              | SE         |              |    |    |    |     |     |     | 2   |
| Tegon        | Avg.       |              |    | 8  | -  | 3   | 1   | 4   |
|              | SE         |              |    |    |    |     |     |     |     |
| Prob.        | 0.317      | 0.354        | 0.391| 0.900| 0.867| 0.403|

SE=Standard error, Prob.=Probability of the significance of the Kruskal–Wallis test at only 5%. Av=Amblyomma variegatum, Bd=Boophilus decoloratus, Rm=Rhipicephalus microplus, Bsp=Boophilus spp., Hsp=Hyalomma spp., Rsa=Rhipicephalus sanguineus, Rsp=Rhipicephalus spp.

### Table-4: Average number of ticks and standard error per tick and animal species.

| Animal species | Statistics | Tick species | Av | Bd | Rm | Bsp | Hsp | Rsa | Rsp |
|----------------|------------|--------------|----|----|----|-----|-----|-----|-----|
| wildcat        | Avg.       |              |    |    |    |     |     | 6   |     |
|                | SE         |              |    |    |    |     |     |     |     |
| Cane rat       | Avg.       |              | 8  | -  |    | 3   | 4   | 5   |     |
|                | SE         |              |    |    |    |     |     |     | 1   |
| Doe            | Avg.       |              |    |    |    | -   | -   | 6   |     |
|                | SE         |              |    |    |    |     |     |     |     |
| Buffalo        | Avg.       |              |    | 2  | 7  | 3.5 | -   | 9   |     |
|                | SE         |              |    | 0  | 2.08 | 0.5 | -   |     |     |
| Buffon cobe    | Avg.       |              |    | 2  |    | -   | -   | 3   |     |
|                | SE         |              |    |    |    |     |     |     |     |
| Cricetoma      | Avg.       |              |    |    | 6  | 3   | 3   | 4   |     |
|                | SE         |              |    |    |    |     |     |     | 0   |
| Bushbuck       | Avg.       |              |    |    | 4  | 3   | -   | 3.5 |     |
|                | SE         |              |    |    | 1.53 | -   | 0.96 | -   |
| Hare           | Avg.       |              |    |    | 5  | 3   | -   | 6.5 |     |
|                | SE         |              |    |    | 1   | -   | 2.9 |     |     |
| Warthog        | Avg.       |              |    |    | 3  | 3   | -   | 5   |     |
|                | SE         |              |    |    | 1   | -   | 0.96 | -   |
| Prob.          | 0.317      | 0.2101       | 0.391| 0.654| 0.199| 0.495|

SE=Standard error, Prob.=Probability of the significance of the Kruskal–Wallis test at only 5%. Av=Amblyomma variegatum, Bd=Rhipicephalus decoloratus, Rm=Rhipicephalus microplus, Bsp=Boophilus spp., Hsp=Hyalomma spp., Rsa=Rhipicephalus sanguineus, Rsp=Rhipicephalus spp.

### Table-5: Full model deviance analysis table.

| SSV          | DF | Deviance | Resid. DF | Resid. Dev | Pr(>χ²) |
|--------------|----|----------|-----------|------------|---------|
| Null         | 42 | 57.31    | 34        | 49.51      | 0.453   |
| Species      | 8  | 7.80     | 28        | 31.77      | 0.007** |
| Localities   | 6  | 17.74    | 6         | 25.01      | 0.344   |
| Ticks        | 6  | 6.76     | 6         | 4.43       | 0.274   |
| Species: Localities | 7 | 9.56 | 15 | 15.45 | 0.214 |
| Species: Ticks | 9 | 11.02 | 6 | 4.43 | 0.274 |
| Localities: Ticks | 6 | 4.42 | 0 | 0 | 0.619 |
| Species: Localities: Ticks | 0 | 0 | 0 | 0 | - |

**Significant at the 5% threshold**
Benin also showed the presence of the four geniiuses of ticks previously found on domestic animals. Morel [23] reported the presence of four kinds of ticks on wild animals in Benin including Amblyomma, Boophilus Rhipicephalus, and Haemaphysalis. The latter, specific to carnivores, was not identified in this study.

Among the ticks of Boophilus genus, we have identified three species, namely Boophilus microplus, Boophilus decoloratus, and Boophilus spp. [24] identified Boophilus geigi in Benin on hartebeest and in Niger (north of W park) on hartebeest and roan. It has also been identified in Senegal on Luzarches hartebeest and then the bushbuck and warthog in the Niokolo-koba National Park. In the North East of Central Africa, the work of Thal [25] also mentioned the presence of this species on hartebeest and roan. Indeed, according to this author, it is the only Boophilus that could be found on wild ungulates in West Africa. However, although our samples were taken from ungulates such as C. elaphus, Syncerus caffer planiceros, Kobus kob, Tragelaphus scriptus, and Phacochoerus aethiopicus, this species has not been identified. Its absence could be linked to a mutation phenomenon leading to the appearance of Rm. This phenomenon was already described in East Africa where Rm replaced the other Rhipicephalus species [26]. The highest presence Rm in the hunting camp of the Mekrou and Koncombri can be explained by the fact that there are next to Burkina Faso. Moreover, the presence of water table next to W park hunting area in Popoman attract transhumant animals from Burkina-Faso and could explain the strong representation of Rm in the Mekrou area. Indeed, these camps are located at the Benin-Burkina border where there is a large movement of live cattle from Burkina to Benin through livestock trade. This is corroborated by recent findings that revealed the presence of this tick in Benin and Benin-Burkina Faso border [27].

However, the presence of B. decoloratus mentioned in this study does not confirm the results of Lamontellerie [28] who state that B. decoloratus is a tick of arid environments an only found on livestock and never on wild ungulates. Several authors have reported its presence on cattle in Benin [23,29]. Its presence on wild ungulates may be due to the possibility of being transported on long distances by the host from one environment to another as it development cycle is monophasic.

Altogether, two species of Boophilus were identified in our study. The undefined (Boophilus spp.) species may be originated from the different crossings that occur, nowadays, between Boophilus species [7].

One species of Rhipicephalus (R. sanguineus) and some undefined species (Rhipicephalus spp.) were identified. R. sanguineus is collected from doe (C. elaphus), cricetoma (Cricetomys gambianus), hare (Lepus spp.), and cane rat (Thryonomys swinderianus) in areas located in Central and Southern Benin. However, Rhipicephalus spp. is present in all the prospected localities. The absence of R. sanguineus in this study in the parks may be related to the prohibition of hunting that would have limited dog access to the parks. In fact, illegal hunters are often accompanied by their dogs, which constitute the main host of R. sanguineus in the tropics and subtropics as reported by Fahmy et al. [30]. A high probability of dissemination of this tick on the natural route by these dogs and thus an infestation of wild animals is possible. This has been proven by the work of Smith et al. [31].

Amblyomma tick is widespread in Africa, and its hosts are domestic and wild ruminants such as buffaloes, cattle, sheep, and goats [32]. However, they are able to infest others animals species. This is the case in our study where Amblyomma variegatum was found on cane rats (T. swinderianus).

The buffalo hosts two specific ticks, Amblyomma splendidum and Rhipicephalus cliffordi; both species were identified in Ivory Coast, and A. splendidum only in central Benin [23].

None was identified in western, central, and eastern Burkina-Faso although the number of buffalo one by the country [23].

Similarly, Barre [33] found this tick, at the adult stage, on Caribbean and Guadeloupe dog’s, where it was introduced 150 years ago. Our results confirm the great variability of hosts susceptible to be infested by the ticks of the Amblyomma genus.
Hyalomma spp. populations have been identified on C. gambianus, T. swinderianus, S. caffer, and P. aethiopicus. This demonstrates its ability to infest a diversity of hosts. These results are in concordance with those obtained by Morel [23]. Indeed, Hyalomma ticks are generally found on wild ungulates and rodents. The same author reports the presence of Hyalomma nitidum in Central African Republic where it was collected on Buffalo, Antelope, Buffalo Cob, and warthog. It is also known in Senegal and Benin.

Of all these species, it should be noted that the proportion of nymph and larva is very low or almost absent. Indeed, previous work carried in the same areas and during the same month’s revealed low abundance of nymph and larva [34]. This observation can be explained by several factors such as the height of the animals considered, targeted animals are old, and old animals are big in size what makes does not favor nymph and larva to attach to them; the climate: February and March are hot and larva and nymph are more sensitive to heat than adults. Moreover, this period is the most favorable for the availability of wildfowl, and illegal hunters use bushfires to find wildfowl. As a result, these bushfires, kill immature ticks hidden in the environment. According to Verdonck [35], immature survival is very dependent on humidity during the hot season; the abundance of Rm, for example, begins to decrease at the end of the rainy season. Likewise, tick activity varies according to species and climatic conditions [36]. However, the massive presence of ticks does not always correspond to the rainiest months. Farougou et al. [22] showed a low correlation between rainfall and number of ticks collected. This result can be explained by the fact that some ticks appear before the rainy season. The finding may also be related to genus and stage of development that persist in moisture and sometimes other sources of moisture at the vegetation level. Similarly, Fahmy et al. [30] showed that Rm can grow in warm and humid regions, B. decoloratus in dry and cold areas, and Boophilus annulatus can survive in areas suitable both for Rm and B. decoloratus. This fact has also been confirmed by several researchers [37,38]. Madder et al. [27] and Muhimuzi et al. [39] also reported that B. annulatus and B. geigi might share the same habitats associated with woods and forests and favor similar environmental requirements as well.

In summary, during this cross-sectional study on wild animals in Benin, seven species of ticks were identified including Rm on buffalo, the bushbuck, and the hare. Although the number of animals surveyed and the number of ticks taken are low for specific reasons related to the low parasite load of the animals encountered, the reluctance of some illegal hunters and the limited number of legal hunters with a hunting license at the level of national parks. 24 tick species have been recorded on wild animals in Upper Volta [23]; In the Democratic Republic of Congo, three species of ticks were identified on natural grasslands, including Rhipicephalus appendiculatus, B. decoloratus, and Haemaphysalis Leachi Leachi [39]. The lower number of tick collected in our case is due to the reluctance of some hunters to allow ticks collection from their animals. Moreover, the number of hunters that can be survey is also limited as few hunters own a hunting license.

Conclusion

This study shows that Rm is established in the wildlife of Benin. Its presence confirms the reservoir role and maintenance that wildlife plays in the spread of parasites. Wildlife is, therefore, an important risk factor that should not be neglected in the epidemiological surveillance and tick control strategies particularly Rm in Benin and the West African sub-region. Thus, it is important to involve in the programs of protection of the faunistic reserves the control of ticks in particular and a sanitary management of wildlife in general.

Authors’ Contributions

KJA; BS, GAM; YA, and SBA have participated in developing the protocol, the sample of ticks and in drafting the manuscript. REY participated in the identification of ticks and the development of the database. CA contributed to the translation of the manuscript. AKIY; SF and AIS supervised the analysis of the statistical results and the correction of the manuscript. All authors have read and approved the final manuscript.

Acknowledgments

We thank the authorities of the Wildlife Reserves Management National Center (CENAGREF) for permitting us to access to national parks. We are grateful to Prof Farougou Souaibou and our collaborators of URBPSA/laboratory of acarology for their help. This project is self-funded.

Competing Interests

The authors declare that they have no competing interests.

References

1. Barré, N., Uilenberg, G. (2010) Propagation de parasites transportés avec leurs hôtes: Cas exemplaires de deux espèces de tiques du bétail. Rev. Sci. Tech. Off. Int. Epiz., 29(1): 135-147.
2. De Clercq, E.M. (2013) Assessment of the Ecological Niche of Rhipicephalus microplus in West Africa. Thesis of Master in Bio-science Engineering: Forest and Nature Management. p1.
3. Jonsson, N., Bock, R. and Jorgensen, W. (2008) Productivity and health effects of anaplasmosis and babesiosis on Bos indicus cattle and their crosses, and the effects of differing intensity of tick control in Australia. Vet. Parasitol., 155(1-2): 1-9.
4. Lempereur, L., Geysen, D., Madder, M. (2010) Development and validation of a PCR–RFLP test to identify African Rhipicephalus (Boophilus) ticks. Acta Trop., 114: 55-58.
5. Madder, M., Thys, E., Achi, L., Toure, A. and De Deken, R. (2011) Rhipicephalus (Boophilus) microplus: A most successful invasive tick species in West-Africa. Exp. Appl. Acarol., 53(2): 139-145.
6. De Clercq, E.M., Vanwambcke, S.O., Sungirai, M., Adehan, S., Lokossou, R. and Madder, M. (2012) Geographic distribution of the invasive cattle tick
Rhipecephalus microplus, a country-wide survey in Benin. Exp. Appl. Acarol., 58: 441-452.

7. Keck, F. (2013) Santé animale et santé globale: La grippe aviaire en Asie. Rev. Tiers Monde, 215(3): 35-52.

8. Ariane, P. (2014) Rôle de la Faune Sauvage dans le Système Multi-hôtes de Mycobacterium bovis et Risque de Transmission Entre Faune Sauvage et Bovins: Etude Expérimentale en Côte d’Or. Biologie Animale. Université Claude Bernard, Lyon I, «NNT: 2014LYO10040». etel-01081144a.

9. Artois, M., Biteau-Coroller, F., Rossi, S. and Hars, J. (2002) La surveillance et le contrôle des maladies infectieuses de la faune sauvage en France et en Europe. Bull. Soc. Méd. Vét. Pratique, 86: 36-51.

10. Bengis, R.G., Leighton, F.A., Fischer, J.R., Artois, M., Mörner, T. and Tate, C.M. (2004) The role of wildlife in emerging and re-emerging zoonoses. Rev. Sci. Tech. Off. Int. Epiz., 23(2): 497-511.

11. Hestvik, G., Warns-Petit, E., Smith, L.A., Fox, N.J., Uhlihorn, H., Artois, M., Hannant, D., Hutchings, M.R., Mattssson, R., Yon, L. and Gavier-Widen, D. (2015) The status of tularemia in Europe in a one-health context: A review. Epidemiol. Infect., 143: 2137–2160.

12. Vagneron, F. (2015) Surveiller et s’unir: Le rôle de l’OMS dans les premières mobilisations internationales autour d’un réservoir animal de la grippe. Rev. Sci. Tech. Off. Int. Epiz., 24(2): 139-162.

13. Michel, A.L. and Bengis, R.G. (2012) ‘The African buffalo: A villain for inter-species spread of infectious diseases in southern Africa. Onderstepoort. Online J. Vet. Res., 79(2), Article ID: #453, 5 Pages.

14. Eric, Y.R., Akpo, Y., Adoligbe, C., Adinci, J., Assogba, M.G., Koutinhoun, B., Abdou Karim, I.Y. and Farougou, S. (2016b) Resistance of tick Rhipicephalus microplus to aac-ricides and control strategies. J. Entomol. Zool. Stud., 4(6): 408-414.

15. ANOPER Benin, (2014) Current situation of livestock and ruminant farmers in Benin. 10p.

16. Marc, M. (2015) Breeders’ challenges: the case of Benin in West Africa. SOS Hunger/Farming Dynamics no36, 2p. https://www.sossfaim.org/be/publication.

17. Countrystat (2018) Elevage: Total des Effectifs D’animaux Vivants par Année, Niveau Administratif 2, Produits. Available from: http://www.countrystat.org/home.aspx?c=benetta=053SPD135ettr=-2. Last accessed on 14-04-2018.

18. Wint, W. and Robinson, T.P. (2007) Gridded Livestock of the World. FAO, Rome.

19. Walker, A.R., Bouattour, A., Camicas, J.L., Estrada–Peña, A., Horak, I.G., Latif, A.A., Pegram, R.G. and Preston, P.M. (2007) Ticks of Domestic Animals in Africa: A Guide to Identification of Species. © The University of Edinburgh, p221.

20. Vercruysse, J., Lafia, S. and Camicas, J.L. (1982) Les tiques (Amblyomminae) parasites des bovins en republique populaire du Bénin. Rev. Elev. Med. Vét. Pays Trop., 35(4): 361-364.

21. Farougou, S., Tassou, A.W., Tchabode, M., Kpodekon, M., Boko, C. and Youssao, A.K.I. (2007b) Ticks and hemoparasites in cattle in the north of Benin. RMV, 158(8-9): 463-467.

22. Farougou, S., Kpodekon, S.M., Adakal, H. and Sagbo, R. (2007a) Seasonal abundance of ticks (Acarini: Ixodidae) infesting sheep in the southern area of Benin. RMV, 12(158): 627-632.

23. Morel, P.C. (1978) Tiques d’animaux sauvages en Haute-Volta. Rev. Elev. Méd. Vét. Pays Trop., 31(1): 69-78.

24. Hoffmann, G. and Lindau, M. (1971) Zecken an Nutz-und Wildtiere in Niger. J. Appl. Entomol., 69(1-4), 72-82.

25. Thal, J.A. (1972) Similar Diseases to Plague: Study and Control. Ndele, Central African Republic. FAO/UNDP CAF Project 13. Final Report. Maisons- Alfort, E. M. V. T., 37 p4.

26. Estrada-Peña, A., Bouattour, A., Camicas, J.L., Guglielmone, A., Horak, L., Jongejan, F., Latif, A.A., Pegram, R.G. and Walker, A.R. (2006) The known distribution and ecological preferences of the tick subgenus Rhipicephalus (Acarini: Ixodidae) in Africa and Latin America. Exp. Appl. Acarol., 38: 215-235.

27. Madder, M., Adehan, S., De Deken, R., Adehan, R. and Lokossou, R. (2012) New foci of Rhipicephalus microplus in West Africa. Exp. Appl. Acarol., 56: 385-390.

28. Lamontellerie, M., (1966) Tiques (Acarina, Ixodoidea) de Haute-Volta. Bull. L’IFAN A, 28: 597-642.

29. Sungirai, M. (2012) Identification of the Four Rhipicephalus (Boophilus) Ticks Species and their Hybrids from Benin: Morphology Versus Genetics. ITMA-MSTAH Thesis, No. 179, p55.

30. Fahmy, M.A.M., Arafa, M.S., Mandour, A.M. and Sema, A.A.A. (1981) Survey of hard tick (Ixodidae) infesting domestic animals in Assuit Governorate, Upper Egypt. Acta Parasitol. Polonica, 28(9): 91-96.

31. Smith, F.D., Ballantyne, R., Morgan, E.R. and Wall, R. (2011) Prevalence and risk associated with tick infestation of dogs in Great Britain. Med. Vet. Entomol., 25: 377-384.

32. Dougmon, T.J., Adéhan, S., Anago, E., Houessonjon, J. and Farougou, S. (2015) In vitro effect of the ethanolic extract of Tephrosia vogelii on Rhipicephalus sanguineus in Abomey-Calavi. Avicenna J. Phytomed., 5(3): 247-259.

33. Barre, N. (1989) Biology and Ecology of the tick Amblyomma Variegatum (Acarina: Ixodida) in Guadeloupe (French West Indies). Thèse de Doctorat en Sciences, Université de Paris Sud, p268.

34. Farougou, S., Kpodekon M., Tchabode D.M, Youssao, A.K.I., et Boko, C. (2006) Abondance saisonnière des tiques (Acarina, Ixodoidea) parasites des bovins dans la zone soudanienne du Bénin: Cas des départements de l’Atacora et de la Donga. Bull. Soc. Méd. Vét. Pays Trop., 69(1-4), 72-82.

35. Estrada-Peña, A. (2015) Ticks as vectors: Taxonomy, biology and epidemiology. Rev. Sci. Tech. Off. Int. Epiz., 34(1): 53-65.

36. Sutherst, R.W. (1987) The dynamics of hybrid zones between tick (Acarina) species. Int. J. Parasitol., 17(4): 921-926.

37. Lynen, G., Zeman, P., Bakuname, C., Di, G.G., Mtui, P., Sanka, P. and Jongejan, F. (2008) Shifts in the distributional ranges of Rhipicephalus ticks in Tanzania: Evidence that a parapatric boundary between B. microplus and B. decoloratus follows climate gradients. Exp. Appl. Acarol., 44(2): 147-164.

38. Muhimuza, A.B., Ombei, B.E., Chishibani, B.W. and Masunga, M.B. (2014) The infestation of natural grasslands by ticks in groups of Bugorhe and Irhambi-katana area in the province of South Kivu, Democratic Republic of Congo. Int. J. Innovat. Appl. Stud., 9(4): 1966.

Available at www.veterinaryworld.org/Vol.11/June-2018/18.pdf