

Geographical distribution of hard ticks (Acari: Ixodidae) and tick-host associations in Benin, Burkina-Faso, Ivory-Coast and Togo

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ARTICLE INFO

Keywords:

Host-parasite interaction
biodiversity of ticks
animal
tick-borne pathogens
West Africa

ABSTRACT

Knowledge of ticks and associated pathogens is crucial to assess the risk of exposure of humans and animals to pathogens. For this review, we collected relevant data from published articles and field collections to provide an update on the biodiversity of ticks, and tick-host associations in four countries of West Africa: Benin, Burkina-Faso, Ivory-Coast, and Togo. The literature review was done according to Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. The search was limited to literature published from 1953 to 2021 in English and French sources. Out of 104 articles retrieved, only 41 studies met the eligibility criteria and were included in the review. The final database included a total of 53,619 adults, nymphs and larval ticks belonging to 24 species and five genera (*Amblyomma*, *Haemaphysalis*, *Hyalomma*, *Ixodes* and *Rhipicephalus*) that were collected from 23 different species of wild and domestic animals. This is the first record of *Ixodes aulacodi* and *Rhipicephalus simpsoni* in Benin, together with two new host records for *A. latum*. This checklist allows an update on tick-host associations and provides information on the diversity of ticks in West Africa.

1. Introduction

The hard ticks (Ixodidae) include approximately 700 species with worldwide distribution (Guglielmine et al., 2010; Estrada-Peña and de la Fuente, 2014). Ticks have the ability to transmit a wide variety of pathogens (viruses, bacteria, protozoa, and some nematodes) (Nii-Trebi, 2017; Salehi-Vaziri et al., 2020) and numerous studies highlighted the medical and economic importance of ticks (Asman et al., 2017; Nava et al., 2017; Khalaf et al., 2018; Petney et al., 2019). In addition to their role in the transmission of pathogens, ticks also can have a direct negative impact on their hosts, e.g: severe weakening due to blood feeding behavior and subsequent anemia. Microlesions may represent a gateway for infection with opportunistic bacteria (Jongejan and Uilenberg, 1994; de la Fuente et al., 2008). Some tick species may also cause paralysis, toxicosis, or allergic reactions in both humans and animals (Hall-Mendelin et al., 2011).

The distribution of tick-borne disease is closely linked to associated tick vector species and their reservoir hosts (Parola and Raoult, 2001). Climate and environmental changes are central to the spread and establishment of new tick species in non-endemic areas (Kulkarni et al., 2018). Such events can be responsible for an increase in tick densities and spatial range, which may result in the emergence of tick-borne diseases in new regions. This justifies the importance of having updated distribution maps to mark the starting point for following temporal changes and tick distribution (Semenza and Suk, 2018; Bouchard et al., 2019).

It is also important to develop and implement effective control methods against ticks and pathogens they transmit. Effective control is dependent upon knowledge of the habitat, ecology, and host spectrum of ticks (Hansford et al., 2017; Sonenshine, 2018; Tufts et al., 2019). The long trophic relationships that ticks maintain with their hosts and the wide host spectrum of certain species favours the transmission of

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pathogens either between vertebrates of the same or closely related species or even between evolutionary distant vertebrate groups (Jon-gejan et al., 2007). Updating and reviewing the list of tick hosts is necessary to understand the dynamics of tick populations and the epidemiology of tick-borne diseases (Mccoy et al., 2013). Hard ticks are abundant in the West African ecosystem, but unfortunately, updated information on their identification, as well as their host spectrum and geographic distribution are limited (Walker et al., 2003). Our aim was to compile a complete dataset on the distribution and host spectrum of ticks from West Africa, using data from a large field collection of ticks from domestic and sylvatic and domestic hosts including data extracted following a comprehensive literature review. Such an approach provides a basis for further studies related to ticks, tick-borne pathogens, and their relationships with vertebrate hosts in this geographical area.

2. Materials and Methods

2.1. Study area

West Africa (including Benin, Burkina-Faso, Ivory-Coast, and Togo) extends over five latitudinal zones of 5° each, namely zones (0-25° N). Ghana was excluded from our approach, as the tick fauna was recently reviewed (Ntiamo-Baidu et al., 2004, 2005). Information for vegetation and climate have been previously reported for Benin, Burkina-Faso, Ivory-Coast and Togo (Adomou, 2005; Adewi et al., 2010; Ahokossi, 2018; Zougrana et al., 2018; Kouao et al., 2020).

2.2. Tick collection

Between 2019 and 2021, ticks were collected from wild and domestic animals in Benin (Kandi, Tanguiéta, Tchaourou, Djidja, Dassa, Bassila, Pehunco, Natitingou, Zangnanando, Abomey-Calavi, Adjara, Grand-Popo, and Ketou districts), and in Togo (Kamina, Tabligbo, Adétikopé, and Kékékopé districts) (Fig. 1). Ticks were preserved in 70% ethanol and transported to the Department of Parasitology and Parasitic Diseases of the University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Romania. Tick identification was done by using morphological keys (Walker et al., 2000, 2003; Estrada-Peña et al., 2004).

2.3. Systematic literature review

A literature review was performed in accordance with guidelines for performing and reporting systematic reviews (PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Liberati et al., 2009). To ensure the broadest possible coverage of scientific literature, searches were conducted in the following online databases: Science Direct, PubMed, Scopus, CabDirect, and Web of Science to identify studies on ticks in publications from 1953 to 2021 in English

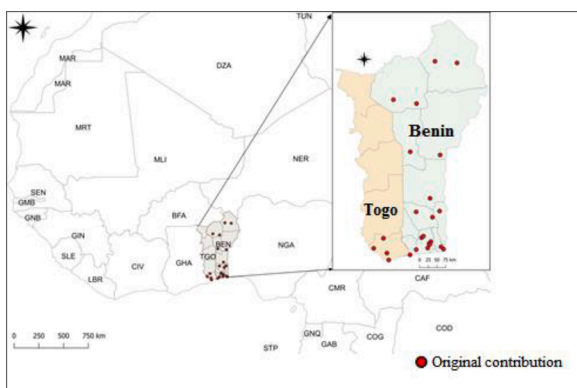


Fig. 1. Geographical distribution of tick collection areas in Benin and Togo

and French. Key terms searched in the title, abstract and/or keywords of studies were: (“ticks” AND “West Africa”), (“tick hosts” AND “West Africa”), (“tick” AND “Benin”), (“tick” AND “Burkina-Faso”), (“tick” AND “Ivory-Coast”), (“tick” AND “Côte d’Ivoire”), and (“tick” AND “Togo”).

Several criteria were used to select eligible publications, e.g (1) study areas of Benin, Burkina-Faso, Ivory-Coast, and Togo; (2) study of hard ticks; (3) analysis of ticks collected from the environment, human, domestic or wild animals. Other inclusion criteria included availability of the article in English or French. The extracted data included: country and region of study, year of study, tick species; sex/stages of ticks; host species of ticks were collected, tick sample size, study area, latitude, and longitude.

2.4. Processing of literature data regarding geographical distribution of ticks

All literature information tick collection areas, as well as the geographic coordinates, were entered in a database. The georeferenced data was mapped to a decimal degree coordinate system using Google Earth. Analysis of the distribution of ticks for each of the areas surveyed; was performed and digital maps were created using QGIS ArcMap.

3. RESULTS

The geographic locations of existing and new data on the presence of hard tick species in Benin, Burkina-Faso, Ivory-Coast, and Togo are shown in (Fig. 2). One hundred and one collection points were identified in four West African target countries. Overall, 24 species of ticks were identified that included 23 species reported from literature and 13 species from field collections.

A total 936 adults, nymphs and larvae were collected from animals in the field in Benin and Togo, and six new tick-host species associations (*Cricetomysgambianus*, *Atelerixalbiventris*, *Python regius*, *Rhamphiphis oxyrhynchus*, *Xerus erythropus* and *Thryonomys swinderianus*) (Table 1 and Figs. 3–7). The literature survey identified 41 relevant studies that included adults, nymph, and larval ticks. In total, 52,483 adults, nymphs and larvae were included representing five tick genera (*Amblyomma*, *Haemaphysalis*, *Hyalomma*, *Ixodes*, and *Rhipicephalus*) collected from 23 wild and domestic animal host species (Table 1 and Figs. 3–7).

4. DISCUSSION

Ticks pose a serious threat to the health and well-being of animals and humans around the world. New tick species may be introduced to non-endemic regions, due to both socio-economic development, environmental and climatic changes (Bouchard et al., 2019). This is illustrated by the recent introduction and establishment of *R. microplus* into

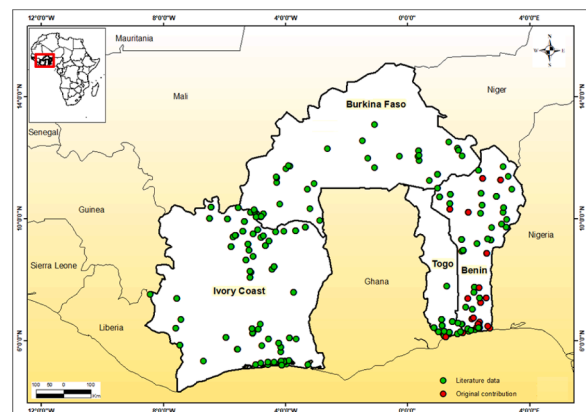


Fig. 2. Geographic locations of literature (green dots) and original (red dots) data on hard ticks present in Benin, Burkina-Faso, Ivory-Coast, and Togo.

Table 1
Hard tick species and associated hosts reported from Benin, Burkina-Faso, Ivory-Coast and Togo from 1953 to 2021

Tick species	Tick sample size	Country	Host Common name	Scientific name	Stage	Study Reference		
<i>Amblyomma compressum</i>	279	Ivory-Coast	Grasscutter	<i>Thryonomys swinderianus</i>	A, N	(Faustin et al., 2015)		
			African black-bellied pangolin	<i>Manis longicaudata</i>	A	(Rahm, 1956; George and Aeschlimann, 1985)		
			Long-tailed pangolin	<i>Manis tetradactyla</i>	A	(Aeschlimann, 1963)		
			Tree pangolin	<i>Manis tricuspis</i>	A, N	(Rahm, 1956; Aeschlimann, 1963; George and Aeschlimann, 1985)		
			Bushbuck	<i>Tragelaphus scriptus</i>	A	(Aeschlimann, 1963)		
<i>Amblyomma latum</i>	173	Benin	Rufous beaked snake	<i>Rhamphiophis oxyrhynchus</i>	A	the present study		
<i>Amblyommaspp.</i>	163	Ivory-Coast and Togo	Ball python	<i>Python regius</i>	A	the present study		
			Wolf	<i>Canis lupus</i>	Nt	(Matei et al., 2016)		
			Nt	Nt	A	(Kulo et al., 2012)		
<i>Amblyomma variegatum</i>	18760	Benin, Burkina-Faso, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Toure et al., 2012)		
			Cattle	<i>Bos taurus</i>	A, N	(Graf et al., 1981; Kabore et al., 1998; Knopf et al., 2002; Stachurski, 2006; Farougou et al., 2006, 2007; Adakal et al., 2009; Socolovschi et al., 2009; Farougou et al., 2012; Biguezoton et al., 2016; Ehounoud et al., 2016; Tomassone et al., 2016; Yao-Acapovi et al., 2018; Mollong et al., 2018; Moumouni et al., 2018a, 2018b; Yessinou et al., 2018a; Huber et al., 2019; Ouedraogo et al., 2020; Yéo et al., 2020), the present study		
			Benin, Ivory-Coast	Wolf	<i>Canis lupus</i>	N, L	(Graf et al., 1981; Dougnon et al., 2015)	
			Burkina-Faso	Goat	<i>Capra hircus</i>	A	(Huber et al., 2019)	
		Benin	Four-toed hedgehog	<i>Atelerix albiventris</i>	A	the present study		
		Ivory-Coast	Red junglefowl	<i>Gallus gallus</i>	Nt	(Graf et al., 1981)		
			Sheep	<i>Ovis aries</i>	A, N	(Graf et al., 1981; Hounzangbe-Adote et al., 2001; Farougou et al., 2007a; 2012; Yao-Acapovi et al., 2018; Huber et al., 2019; Yéo et al., 2020)		
		Benin	Forest Buffalo	<i>Syncerus caffer planiceros</i>	A	(Adinci et al., 2018)		
			Grasscutter	<i>Thryonomys swinderianus</i>	A	(Adinci et al., 2018)		
		<i>Haemaphysalis hoodi</i>	-	Ivory-Coast	Red junglefowl	<i>Gallus gallus</i>	Nt	(Graf et al., 1981)
		<i>Haemaphysalis leachi</i>	263	Benin, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Mollong et al., 2018)
					Wolf	<i>Canis lupus</i>	A, N	(Camicas et al., 1973; Graf et al., 1981; Dougnon et al., 2015; Matei et al., 2016)
Grasscutter	<i>Thryonomys swinderianus</i>				A	(Faustin et al., 2015)		
African civet leopard	<i>Civettictis civetta</i>				A	(Camicas et al., 1973)		
<i>Haemaphysalis spp.</i>	62	Togo	Nt	Nt	A	(Kulo et al., 2012)		
			Nt	Nt	A	(Kulo et al., 2012)		
<i>Hyalomma impeltatum</i>	37	Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Mollong et al., 2018; Yao-Acapovi et al., 2018)		
<i>Hyalomma impressum</i>	167	Benin, Ivory-Coast and Togo	Goat	<i>Capra hircus</i>	A	(Yao-Acapovi et al., 2018)		
			Sheep	<i>Ovis aries</i>	A	(Yao-Acapovi et al., 2018)		
<i>Hyalomma rufipes</i>	387	Benin, Burkina-Faso, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Farougou et al., 2006, 2007b; Ehounoud et al., 2016; Mollong et al., 2018; Yao-Acapovi et al., 2018)		
<i>Hyalomma nitidum</i> <i>Hyalomma spp.</i>	47	Benin, Burkina-Faso, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Kabore et al., 1998; Knopf et al., 2002; Farougou et al., 2006, 2007b; Ehounoud et al., 2016; Tomassone et al., 2016; Mollong et al., 2018; Yao-Acapovi et al., 2018; Ouedraogo et al., 2020) the present study		
			Sheep	<i>Ovis aries</i>	A	(Farougou et al., 2007b; Yao-Acapovi et al., 2018)		
			Cattle	<i>Bos taurus</i>	Nt	(Farougou et al., 2007b)		
			Cattle	<i>Bos taurus</i>	A, N	(Biguezoton et al., 2016; Yessinou et al., 2018a)		
			Wolf	<i>Canis lupus</i>	Nt	(Matei et al., 2016)		
			Gambian pouched rat	<i>Cricetomys gambianus</i>	A	(Adinci et al., 2018)		
			Nt	Nt	A	(Kulo et al., 2012)		
			common warthog	<i>Phacochoerus africanus</i>	A	(Adinci et al., 2018)		
			Forest buffalo	<i>Syncerus caffer planiceros</i>	A	(Adinci et al., 2018)		
			Grasscutters	<i>Thryonomys swinderianus</i>	A	(Adinci et al., 2018)		
<i>Hyalomma truncatum</i>	627	Benin, Burkina-Faso, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Graf et al., 1981; Farougou et al., 2006, 2007b; Ehounoud et al., 2016; Tomassone et al., 2016; Mollong et al., 2018; Ouedraogo et al., 2020; Yéo et al., 2020), the present study		

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Table 1 (continued)

Tick species	Tick sample size	Country	Host Common name	Scientific name	Stage	Study Reference
			Sheep	<i>Ovis aries</i>	A	(Farougou et al., 2007a; Yéo et al., 2020)
<i>Ixodes aulacodi</i>	849	Benin and Ivory-Coast	Grasscutter	<i>Thryonomys swinderianus</i>	A, N	(Faustin et al., 2015; Chiřimia-Dobler et al., 2016), the present study
<i>Rhipicephalus annulatus</i>	1499	Benin, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A, N	(Graf et al., 1981; Knopf et al., 2002; Farougou et al., 2006; 2007b; Biguezoton et al., 2016; Mollong et al., 2018; Yéo et al., 2020), the present study
			Sheep	<i>Ovis aries</i>	A	(Farougou et al., 2007a; Yéo et al., 2020)
<i>Rhipicephalus decoloratus</i>	3252	Benin, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Biguezoton et al., 2016; Mollong et al., 2018), the present study
			Horse	<i>Equus caballus</i>	Nt	(Graf et al., 1981)
			Antelope	<i>Kobus kob</i>	A	(Adinci et al., 2018)
			Sheep	<i>Ovis aries</i>	A	(Farougou et al., 2007a; Yao-Acapovi et al., 2018)
			Forest buffalo	<i>Syncerus caffer planiceros</i>	A	(Adinci et al., 2018)
<i>Rhipicephalus evertsi evertsi</i>	11	Togo	Cattle	<i>Bos taurus</i>	A	(Mollong et al., 2018)
<i>Rhipicephalus geigy</i>	2456	Benin, Burkina-Faso, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Graf et al., 1981; Knopf et al., 2002; Farougou et al., 2006, 2007b; Adakal et al., 2013; Biguezoton et al., 2016; Mollong et al., 2018; Ouedraogo et al., 2020; Yéo et al., 2020), the present study
			Sheep	<i>Ovis aries</i>	A	(Graf et al., 1981; Farougou et al., 2007a; Yao-Acapovi et al., 2018; Yéo et al., 2020)
<i>Rhipicephalus guilhoni</i>	50	Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Mollong et al., 2018; Yao-Acapovi et al., 2018)
<i>Rhipicephalus leporis</i>		Ivory-Coast	Wolf	<i>Canis lupus</i>	A	(Hornok et al., 2017)
<i>Rhipicephalus lunulatus</i>	89	Burkina-Faso, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Mollong et al., 2018; Yao-Acapovi et al., 2018; Ouedraogo et al., 2020), the present study
<i>Rhipicephalus microplus</i>	20575	Benin, Burkina-Faso and Togo	Cattle	<i>Bos taurus</i>	A, N	(Toure et al., 2012; Adakal et al., 2013; Adehan et al., 2016; Biguezoton et al., 2016; Ehounoud et al., 2016; Mollong et al., 2018; Yao-Acapovi et al., 2018; Yessinou et al., 2018a, 2018b, 2018c; Coulibaly et al., 2020; Yéo et al., 2020), the present study
			Hares	<i>Lepus spp.</i>	A	(Adinci et al., 2018)
			Nt		A	(Adakal et al., 2013)
			Sheep	<i>Ovis aries</i>	A	(Yao-Acapovi et al., 2018; Yéo et al., 2020)
			Nt		Nt	
			Forest buffalo	<i>Syncerus caffer planiceros</i>	A	(Adinci et al., 2018)
			Grasscutter	<i>Thryonomys swinderianus</i>	A	(Faustin et al., 2015)
<i>Rhipicephalus muhsamae</i>	148	Benin and Togo	Cattle	<i>Bos taurus</i>	A	(Farougou et al., 2006, 2007b; Mollong et al., 2018), the present study
<i>Rhipicephalus sanguineus</i>	980	Benin, Burkina-Faso, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Knopf et al., 2002; Mollong et al., 2018; Ouedraogo et al., 2020), the present study
			Wolf	<i>Canis lupus</i>	A, N	(Graf et al., 1981; Socolovschi et al., 2012; Dougnon et al., 2015; Hornok et al., 2017;), the present study
			Goat	<i>Capra hircus</i>	A	(Yao-Acapovi et al., 2018)
			Gambian pouched rat	<i>Cricetomys gambianus</i>	A	(Adinci et al., 2018), the present study
			cat	<i>Felis catus</i>	Nt	(Matei et al., 2016)
			Hares	<i>Lepus spp.</i>	A	(Adinci et al., 2018)
			Sheep	<i>Ovis aries</i>	A	(Farougou et al., 2007a; Yao-Acapovi et al., 2018)
			Grasscutter	<i>Thryonomys swinderianus</i>	A	(Adinci et al., 2018), the present study
<i>Rhipicephalus senegalensis</i>	688	Benin, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A	(Farougou et al., 2006, 2007b; Ehounoud et al., 2016; Mollong et al., 2018; Yéo et al., 2020)
			Wolf	<i>Canis lupus</i>	Nt	(Graf et al., 1981)
			Sheep	<i>Ovis aries</i>	A	(Graf et al., 1981; Farougou et al., 2007a; Yéo et al., 2020)
<i>Rhipicephalus simpsoni</i>	330	Benin and Ivory-Coast	Gambian pouched rat	<i>Cricetomys gambianus</i>	A	the present study
			Squirrel	<i>Xerus erythropus</i>	A	the present study
			Grasscutter	<i>Thryonomys swinderianus</i>	A	(Faustin et al., 2015), the present study
<i>Rhipicephalus spp.</i>	1483	Benin, Burkina-Faso, Ivory-Coast and Togo	Cattle	<i>Bos taurus</i>	A, N	(Biguezoton et al., 2016; Yao-Acapovi et al., 2018)
			Goat	<i>Capra hircus</i>	N	(Yao-Acapovi et al., 2018)
			Gambian pouched rat	<i>Cricetomys gambianus</i>	A	(Adinci et al., 2018)
			cat	<i>Felis catus</i>	A	(Adinci et al., 2018)
			Antelope	<i>Kobus kob</i>	A	(Adinci et al., 2018)
			Hares	<i>Lepus spp.</i>	A	(Adinci et al., 2018)
			Nt	Nt	A	(Kulo et al., 2012)
			Sheep	<i>Ovis aries</i>	A, N	(Hounzangbe-Adote et al., 2001; Yao-Acapovi et al., 2018)
					A	(Adinci et al., 2018)

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Table 1 (continued)

Tick species	Tick sample size	Country	Host Common name	Scientific name	Stage	Study Reference
			Common warthog	<i>Phacochoerus africanus</i>		
			Forest buffalo	<i>Syncerus caffer planiceros</i>	A	(Adinci et al., 2018)
			Grasscutter	<i>Thryonomys swinderianus</i>	A	(Adinci et al., 2018)
<i>Rhipicephalus sulcatus</i>	44	Benin and Togo	Cattle	<i>Bos taurus</i>	A	(Farougou et al., 2007b; Mollong et al., 2018), the present study
			Sheep	<i>Ovis aries</i>	A	(Farougou et al., 2007a)

A=Adult; N=Nymph; L= Laval; Nt=Not mentioned

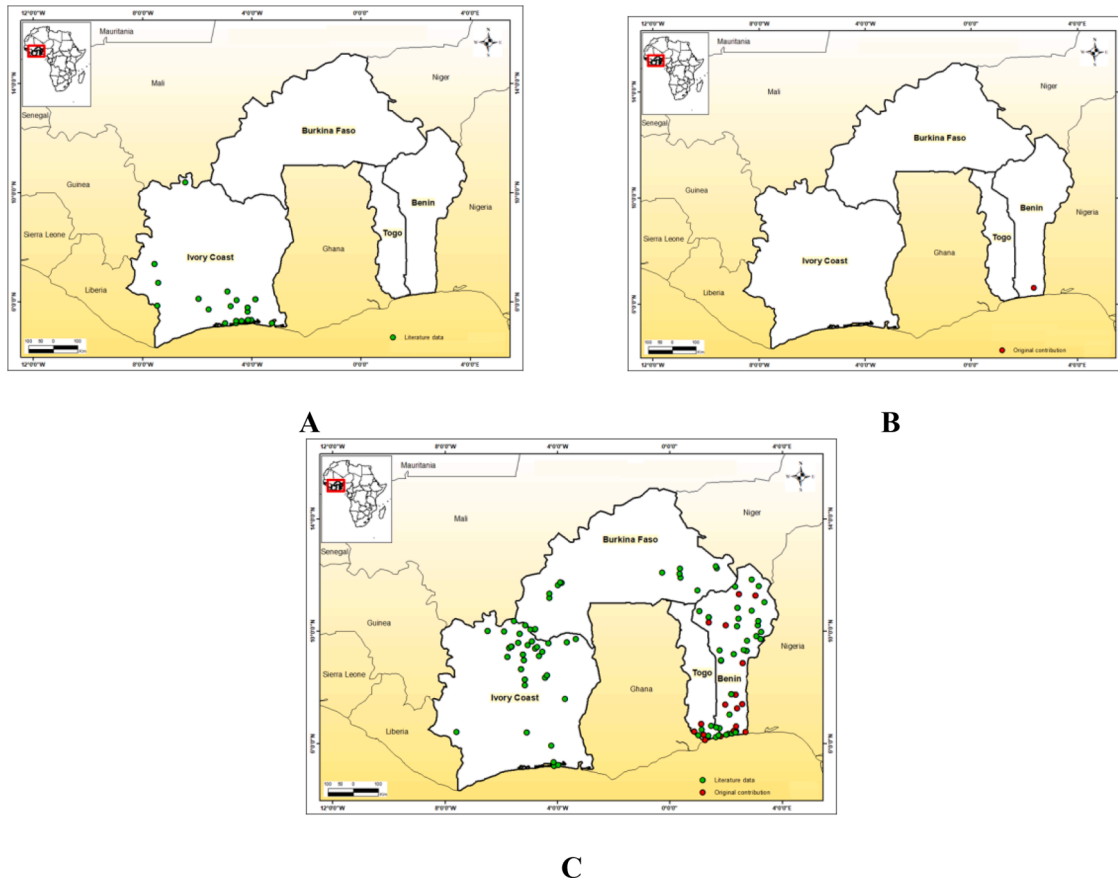


Fig. 3. Distribution of genus *Amblyomma* in Benin, Burkina-Faso, Ivory-Coast, and Togo. Green dots show literature data and red dots show our original contribution. A: *A. compressum*, B: *A. latum*, C: *A. variegatum*.

West African (Madder et al., 2012). Tick population densities and distribution within a biogeographic zone depends on the biotope, which can be more or less favorable to tick development (ecological preferences), the availability of preferred hosts (trophic preferences), and climatic conditions. Most literature examined were one-time studies on pathogens transmitted by ticks, resistance to acaricides, control methods, studies updating the list of tick species over large geographic areas often did not define tick habitats and ecology (Semenza and Suk, 2018). In addition, the majority of studies focused on a few species of medical and veterinary importance. To fill this yield in West Africa, survey data were compiled from both published articles on tick presence in Benin, Burkina-Faso, Ivory-Coast and Togo, and field collections that were conducted in Togo and Benin. The results of this work show that a rich fauna of tick species of medical and veterinary importance has been reported in many ecological and geographical areas from West Africa (Fig. 2).

4.1. *Amblyomma compressum*

Macalister (1872) has been recorded in Africa mainly in forests and Guinean-type savannah vegetation, including termite mounds (Neumann, 1901; Aeschlimann, 1963; Pourrut et al., 2011; Mediannikov et al., 2012b). The range of *A. compressum* coincides with that of pangolins (Aeschlimann, 1963), including the ground, giant ground, long tailed and tree pangolins (Aeschlimann, 1963; Mediannikov et al., 2010). Main hosts of *A. compressum* are pangolins, they also infest forest hogs, black guinea fowl, plumed guinea fowl, warthogs, brush-tailed porcupines, green-crested turaco, and grasscutter (Robinson, 1926; Morel, 1958; Theiler, 1962; Faustin et al., 2015). Adult and nymphs have been recorded only on pangolins (Aeschlimann, 1963). This tick has a three-host life cycle and is a potential vector of rickettsiae (Mediannikov et al., 2012a, 2012b). Investigations in Benin, Burkina-Faso and Togo have not been done to verify its presence, as

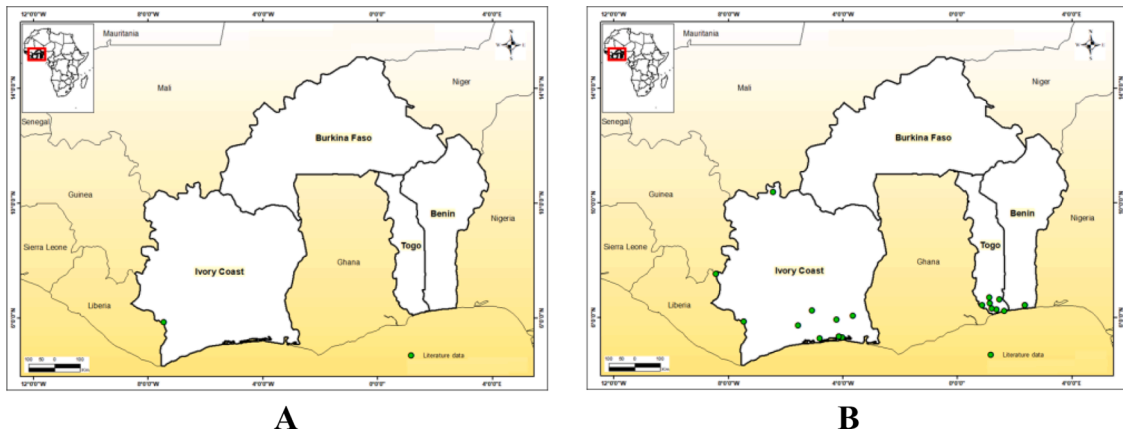


Fig. 4. Distribution of genus *Haemaphysalis* in Benin, Ivory-Coast, and Togo. Green dots show literature data. A: *Hae. hoodi*, B: *Hae. leachi*.

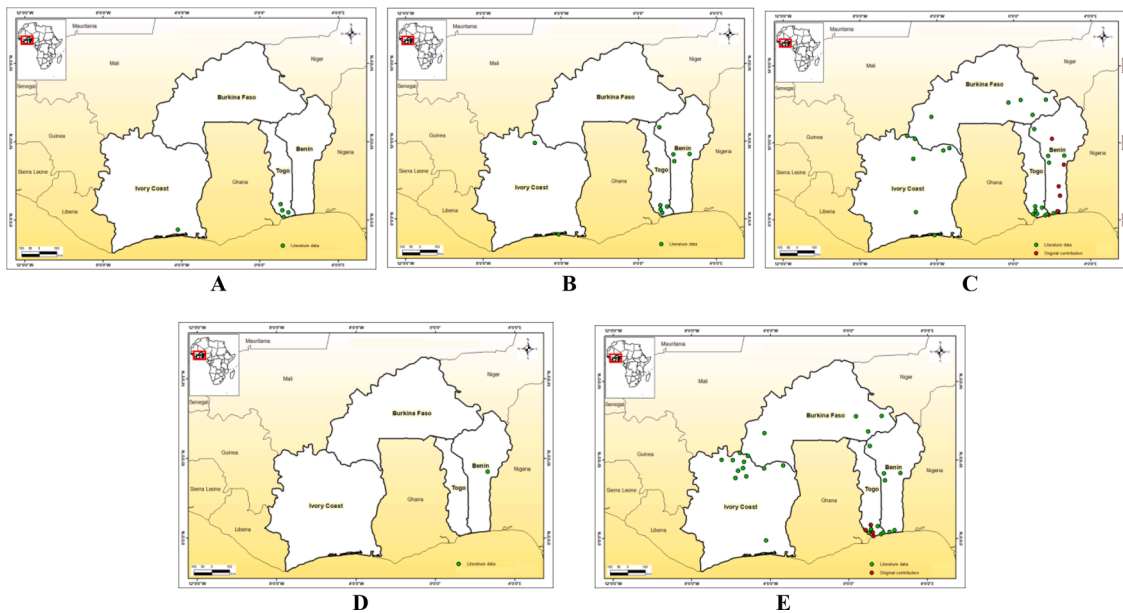


Fig. 5. Distribution of genus *Hyalomma* in Benin, Burkina-Faso, Ivory-Coast, and Togo. Green dots show literature data and red dots show our original contribution. A: *Hy. impeltatum*, B: *Hy. impressum*, C: *Hy. rufipes*, D: *Hy. nitidum*, E: *Hy. truncatum*

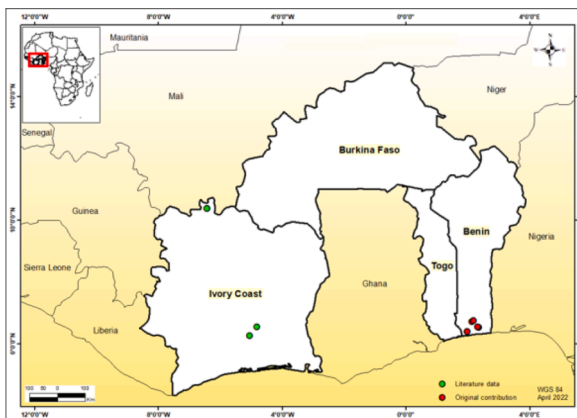


Fig. 6. Distribution of *I. aulacodi* in Benin and Ivory-Coast. Green dots show literature data and red dots show our original contribution.

pangolins are very rare due to poaching and deforestation (Challender et al., 2015).

4.2. *Amblyomma latum*

Koch (1844) has been reported in Afrotropical regions and Asia (Elbl and Anastos, 1966; Aeschlimann, 1967; Dias, 1993) and is often present in grasslands, savannas and shrublands (Horak et al., 2009, 2018). The primary host of adult *A. latum* are snakes, they have been reported on lizards, tortoises, and occasionally on humans (Hoogstraal and Aeschlimann, 1982; Dias, 1993; BurrIDGE et al., 2000; BurrIDGE, 2011; Guglielmo et al., 2014). The vectorial role of *A. latum* is not well known, although Kenny et al. (2004) identified *Hepatozoon* spp./*Babesia* spp., *Ehrlichia* spp. and *Anaplasma* spp. in ticks collected in Ghana. Very few studies are available on *A. latum* in Benin, Burkina-Faso, Ivory-Coast, and Togo. Our study provides new data on this species with its first detection in Benin and the report of two new hosts: rufous beaked snake (*Rhamphiophis oxyrhynchus*) and royal python (*Python regius*). *A. latum* has been reported on the Gaboon viper in Ghana (Kenny et al., 2004), but has also been found on reptiles imported to USA and Europe (BurrIDGE et al., 2003; Mihalca, 2015). *A. latum* which was attached to

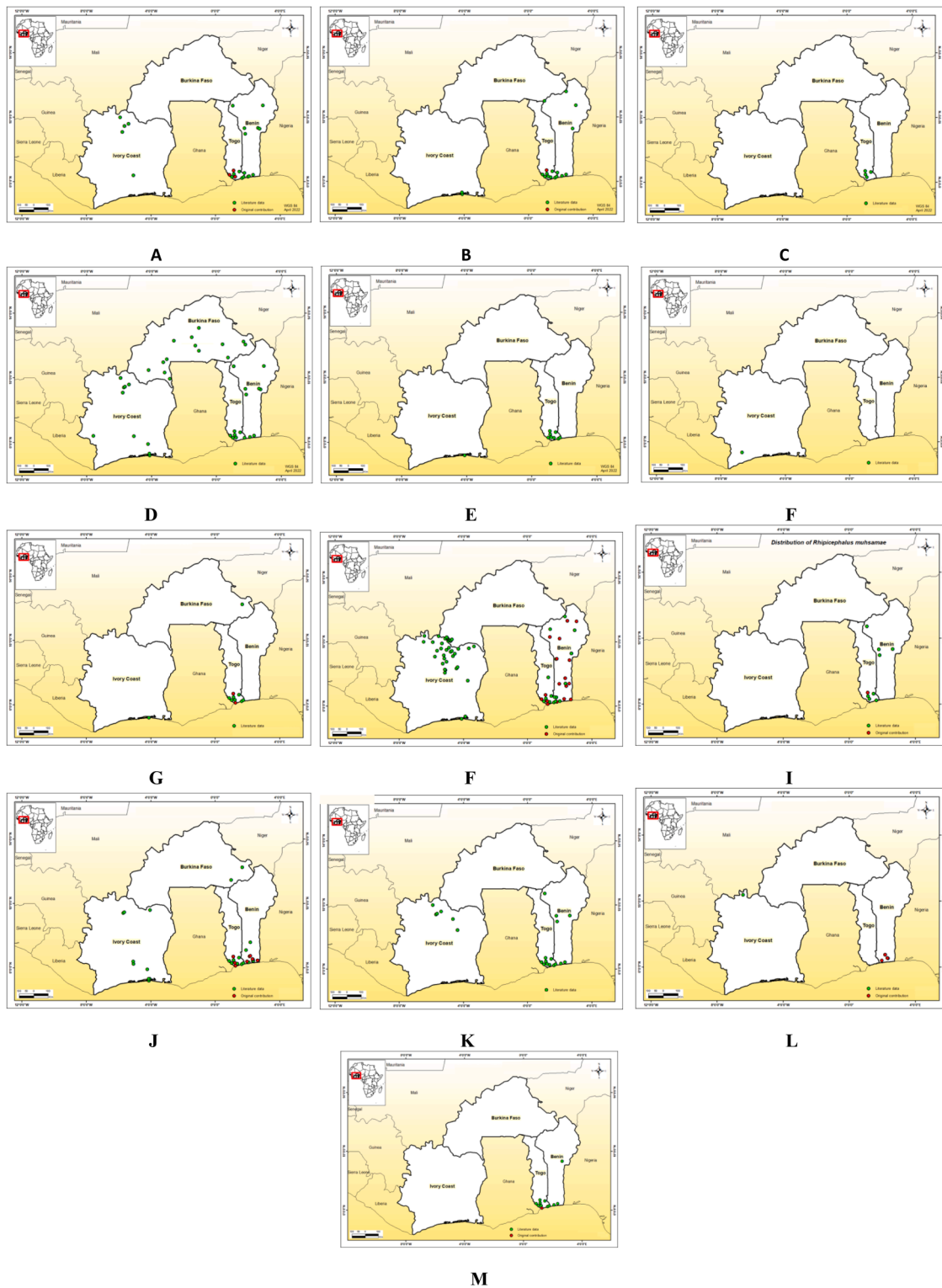


Fig. 7. Distribution of genus *Rhipicephalus* in Benin, Burkina-Faso, Ivory-Coast and Togo. Green dots show literature data and Red dots show our original contribution. A: *R. annulatus*, B: *R. decoloratus*, C: *R. evertsi evertsi*, D: *R. geigy*, E: *R. guilhoni*, F: *R. leporis*, G: *R. lunulatus*, H: *R. microplus*, I: *R. muhsamae*, J: *R. sanguineus*, K: *R. senegalensis*, L: *R. simpsoni*, M: *R. sulcatus*.

African reptiles, have been also found on neotropical reptiles such as *Boa constrictor* and tortoises (González-Acuña et al., 2005).

4.3. *Amblyomma variegatum*

Fabricius (1794) distribution in worldwide, including steppes,

savannas and meadows, of sub-Saharan Africa and Madagascar (Makala et al., 2003; Walker et al., 2003; Lorusso et al., 2013), Guatemala, Caribbean and Mascarene Islands, Yemen, West India, Comoro, and Turkey (Neumann, 1901; Walker and Olwage, 1987; Barré and Uilenberg, 2010). This tick is adapted to a wide variety of climates constituted of moist and hot areas (Walker et al., 2003; Beati et al., 2012) and

present in more than 30 African countries. Hosts are predominantly mammals and more rarely birds (Burridge, 2011; Horak et al., 2018). *A. variegatumis* a three-host species and a vector of *Ehrlichia ruminantium* (heartwater) (Mediannikov et al., 2012a; Horak et al., 2018).

4.4. *Haemaphysalis hoodi*

Warburton and Nuttall (1909) has been reported in sub-Saharan Africa and Morocco (Walker, 1991) and much more in grasslands (Nuttall and Warburton, 1915; Morel, 1956). *Hae. hoodi* has been found on red junglefowl (Morel, 1958; Graf et al., 1981). Nymphs of *Hae. hoodi* have been reported on the African moustached warbler and francolin (Cornet, 1995). This species is involved in the transmission of *Rickettsia* spp., *Babesia* spp. and *Trypanosoma* spp. (Graf et al., 1981). *Hae. hoodi* has not been described in Benin, Burkina-Faso or Togo. Ikeme (1972) reported the infestation of *Hae. hoodi* on local chickens in Nigeria but it has also been collected on wild birds in the Sudanian and Sudano-guinean domains of Senegal (Sylla et al., 2018). Kolonin (2009) ignores mammals as hosts of *Hae. hoodi*, this observation is contrary to the results of Cumming (2000), which collected *Hae. hoodi* from animals.

4.5. *Haemaphysalis leachi*

Audouin (1826), has been reported in sub-Saharan Africa (Graf et al., 1981), especially in forests, meadows and savannas regions. It is primarily collected from dogs, although it has also been reported occasionally on grasscutter, African civet and cattle (Mediannikov et al., 2010; Faustin et al., 2015; Matei et al., 2016). Nymphs were found on murid rodents (Walker et al., 2003). *Hae. leachi* is a three-host tick and a vector for *Anaplasma* spp., *Babesia* spp. and possibly West Nile virus (Blackburn, 1990; Guan et al., 2010; Matei et al., 2016; Kamani, 2021). It was listed in Benin, Ivory-Coast and Togo in the literature but we did not collect this species.

4.6. *Hyalomma impeltatum*

Schulze and Schlottke (1930) was reported in forests and grasslands in various Afrotropical regions but also in the Arabian Peninsula (Apanaskevich and Horak, 2009). Usual hosts of this tick are domestic animals, particularly cattle. Nymphs of *Hy. impeltatum* have been reported on small wild animals, camels, sheep (El-Azazy et al., 2001; Alanazi et al., 2020) as well as ground birds. It has a three-host life cycle and is a vector of *Babesia* spp., *Theileria annulata* and the Crimean-Congo hemorrhagic fever virus (CCHF) (Dipeolu and Amoo, 1984; Mustafa et al., 2011; Dohm et al., 2014). Yao-Acapovi et al. (2018) reported that long and dry seasons are suitable for *Hy. impeltatum* as well as arid and semi-arid biotopes climates. *Hy. impeltatum* was recorded in Ivory-Coast and Togo on sheep, goats, and cattle, but was not collected in Benin and Togo.

4.7. *Hyalomma impressum*

Koch (1844) has been reported in West Africa, Algeria, Sudan, and Ethiopia (Bakheit et al., 2012; Djerbouh et al., 2018) in savanna and steppe habitats (Walker et al., 2003). The main hosts of *Hy. impressum* adults are cattle, sheep, camels, warthogs, and pigs (Morel, 1958; Theiler, 1962; Apanaskevich, 2004; Apanaskevich et al., 2007; Literak et al., 2007; Ogrzewalska et al., 2010; Kiffner et al., 2011). Camicas et al. (1998) recorded the *Hy. impressum* larvae on African grass rat and hedgehog as well as the nymphs on Muridae. It has a three-host life cycle (Centurion, 1983) and vector of *Crimean-Congo hemorrhagic fever* (CCHF) and *Babesia* spp. (Hoogstraal, 1979; Dipeolu and Amoo, 1984). Here we reported literature data on its presence in Benin, Ivory-Coast and Togo but the species was not collected in Benin nor in Togo.

4.8. *Hyalomma rufipes*

Koch (1844) is widespread in Africa and has been recorded from arid regions to rain forest (Walker et al., 2003). The primary hosts of adult *Hy. rufipes* are cattle but the species has been reported also on migratory birds, wild ungulates, sheep, goats, horses, and humans (Walker et al., 2003; Apanaskevich and Horak, 2008; Jameson et al., 2012; Chitiimia-Dobler et al., 2014; Hosseini-Chegeni, 2015; Chitiimia-Dobler et al., 2019). Larvae and nymphs of *Hy. rufipes* were recorded on small mammals and birds. This tick has a two-host life cycle and it is vector for *Anaplasma* spp., *Babesia* spp., *Rickettsia* spp. and the Crimean-Congo hemorrhagic fever virus (Walker et al., 2003; Mediannikov et al., 2010; Jameson et al., 2012; Estrada-Peña and de la Fuente, 2014). In literature, *Hy. rufipes* has been recorded on sheep and cattle in Benin, Burkina-Faso and Ivory-Coast.

4.9. *Hyalomma nitidum*

Schulze (1919) has been recorded in humid regions from sub-Saharan Africa. Adults of *Hy. nitidum* have been collected from domestic and wild animals (Tomassone et al., 2005). Cornet (1995) reported *Hy. nitidum* larvae and nymphs on African savanna hare and striped grass mouse. This tick has a two-host life cycle and is a vector for the Crimean-Congo hemorrhagic fever virus (Schulz et al., 2020). In our study, *Hy. nitidum* was only collected on cattle in Benin.

4.10. *Hyalomma truncatum*

Koch (1844) is present in almost the entire Afrotropical region and mostly recorded from steppe and desert climates (Apanaskevich and Horak, 2008). The adult ticks of *Hy. truncatum* prefer domestic and wild animals as cattle, sheep, goats, horses and ground birds. The nymphs and larvae have been collected in hares and rodents (Guglielmone et al., 2014). This tick has a two-host life cycle and is a vector for the Crimean-Congo hemorrhagic fever virus and *Babesia caballi* (equine babesiosis) (De Waal, 1990; Schulz et al., 2020). *Hy. truncatum* has been collected on cattle in Togo and on sheep in Benin and Ivory-Coast.

4.11. *Ixodes aulacodi*

Arthur (1956) is reported in humid areas of sub-Saharan Africa (Jori et al., 1995) and is probably co-distributed with its main host, the greater cane rat, *Thryonomys swinderianus*. It occasionally feeds also on *Civettictis civetta* (Clifford and Anastos, 1962; Chitiimia-Dobler et al., 2016) but immature stages also feed on rabbits and guinea pigs. *I. aulacodi* has a three-host life cycle and is capable to transmit *Babesia* spp., *Anaplasma* spp., and *Ehrlichia* spp. (Adenyo et al., 2020). *I. aulacodi* has been reported in Ivory-Coast and a new collection has identified this tick on cane rat (*Thryonomys swinderianus*) in Benin. The distribution of *I. aulacodi* in Benin and Ivory-Coast can be attributed to similarities in vegetation types, climate as well as hosts in these countries (Ntiemoa-Baidu et al., 2004).

4.12. *Rhipicephalus annulatus*

Say (1826) is widely distributed in sub-Saharan Africa and Arabian Peninsula and has been recorded from Mediterranean forests, humid broadleaf forests as well as in steppe areas with hot and dry seasons (Walker et al., 2003). *R. annulatus* is one of the main tick species found on cattle, sheep, goats, dogs, and horses (Mediannikov et al., 2010; Reye et al., 2012). Its development cycle takes place on a single host for around two months under optimal temperature and humidity. This tick plays an important vectorial role in the transmission of babesiosis and anaplasmosis in cattle. *R. annulatus* has been recorded on cattle (*Bos taurus*) in Benin, Burkina-Faso, Ivory-Coast and Togo in the literature.

4.13. *Rhipicephalus decoloratus*

Koch (1844) has been reported in Africa in savannas and shrublands (Guglielmone et al., 2014). The main hosts include cattle, goats, sheep, horse, dogs, donkeys and also on wild ruminants (Horak et al., 2006). It is a one-host tick and it is involved in the transmission of *Babesia bigemina*, *Babesia bovis*, *Anaplasma marginale*, *Borrelia theileri* and various arboviruses (Theiler, 1909; Theiler, 1912; Neitz, 1956; Tuppurainen et al., 2013). *R. decoloratus* has been reported in Benin, Ivory-Coast and Togo. In Africa, the replacement of *R. decoloratus* by *R. microplus* has been reported in some countries (Tønnesen et al., 2004; De Clercq et al., 2012; Nyangiwe et al., 2017).

4.14. *Rhipicephalus evertsi evertsi*

Neumann (1897) is present in the Afrotropical region (Walker et al., 2003) and prefers grasslands, steppe and savannas (Norval, 1981; Mushi et al., 1996; Horak et al., 2009). Adults of *R. evertsi evertsi* are commonly found on domestic hosts such as cattle, donkeys, horses, and sheep but also wildlife (Howell, 1978; De Vos et al., 1984). Immatures can infest the same hosts as the adults but may also be found on hares and elephant shrews (Hoogstraal, 1956). It is a two-host tick (Londt and Van der Bijl, 1977) and a vector of *Rickettsia aeschlimannii* and *Babesia caballi* (De Waal and Potgieter, 1987; Sambou et al., 2014).

4.15. *Rhipicephalus geigy*

Aeschlimann and Morel (1965) is present in West Africa and Sudan mainly in savannas and grasslands (Guglielmone et al., 2014). All stages of *R. geigy* are found on cattle, sheep, dog, goats and wild ungulates (Cumming, 1998; Toure et al., 2012). *R. geigy* is a one-host tick and a potential vector of Kindia tick virus and *Borrelia theileri* (McCoy et al., 2014; Ternovoi et al., 2020).

4.16. *Rhipicephalus guilhoni*

Morel and Vassiliades (1965) has been reported in West African steppes, savannas, and shrublands (Guglielmone et al., 2014). The main hosts of adults are cattle, sheep, horses, dogs, and birds. The immatures feed on the wild carnivores and various domestic animals (Morel, 1969; Guglielmone et al., 2014). It is a three-host tick involved in the transmission of *Rickettsia massiliae* (Mediannikov et al., 2010).

4.17. *Rhipicephalus leporis*

Pomerantsev (1946) has been recorded mainly in the Palearctic region in deserts and shrublands (Guglielmone et al., 2014). The main hosts of adults and nymphs are lagomorphs, long-eared hedgehog, golden jackal, red fox, and sheep (Shamsuddin and Mohammad, 1988; Kolonin, 2007; Mohammad, 2015). This tick has a three-host life cycle and its role in the transmission of diseases to animals is unknown. Although reported in Ivory-Coast, its presence in West Africa remains debatable and might represent a misidentification.

4.18. *Rhipicephalus lunulatus*

Neumann (1907) has been reported in Afrotropical, Nearctic and Palearctic regions and found in various habitats such as savannas, grasslands, bushlands, and woodland (Matthysse and Colbo, 1987; Guglielmone et al., 2014). Cattle are the main hosts but goats, sheep, birds, humans, and wild ungulates can also be infested. It is a one-host tick (Saratsiotis, 1977; Norval and Colborne, 1985; Kolonin, 2009) and transmits several pathogens such as *Rickettsia* spp., *Babesia* spp. or *Anaplasma* spp. (Dupont et al., 1994).

4.19. *Rhipicephalus microplus*

Canestrini (1888) has spread globally and is currently present in most tropical and subtropical countries (Estrada-Peña et al., 2006). The main hosts are cattle but it has been occasionally reported on small domestic ruminants, horses, and dogs. *R. microplus* is a one host tick play vector role for *Anaplasma* spp., *Ehrlichia* spp., *Theileria* spp., *Rickettsia* spp. and various arboviruses (Andreotti et al., 2011; Moumouni et al., 2018a; Gómez et al., 2020; Makenov et al., 2021).

4.20. *Rhipicephalus muhsamae*

Morel and Vassiliades (1965) has been signaled in Afrotropical regions (Langguth et al., 2017). Cattle and dogs are the preferred domestic hosts of adult *R. muhsamae*, but immature stages also infest various wild micromammals and primates. It is a three-host tick and its vectorial role is unknown.

4.21. *Rhipicephalus sanguineus*

Latreille (1807) has a worldwide distribution (Jacobs et al., 2001). The main host is the domestic dog, but it may be occasionally found on horse, cattle, and humans. It is a three-host tick and a vector for *Rickettsia* spp., *Babesia* spp., *Anaplasma* spp., *Ehrlichia* spp., *Hepatozoon* spp., and Thogoto virus (Taylor et al., 1966; Estrada-Peña and Jongejan, 1999; Dantas-Torres, 2010; Maggi et al., 2013; Kamani et al., 2013; Latrofa et al., 2014; Galay et al., 2018).

4.22. *Rhipicephalus senegalensis*

Koch (1844) is widely distributed in Afrotropical area and was recorded in regions with savanna and rain forests (Guglielmone et al., 2014). The preferred hosts of this tick are sheep, goats, cattle, and dogs but occasionally they feed on horses, suids and African buffaloes. The nymphs were collected on rodents (Morel, 1958). It has a three-host cycle and represent a potential vector of *Rickettsia* spp. (Ehounoud et al., 2016).

4.23. *Rhipicephalus simpsoni*

Nuttall (1910) has been recorded in Afrotropical regions with grasslands, savannas and shrublands (Adenyo et al., 2020). Cane rat (*Thryonomys swinderianus*) are the main hosts but *R. simpsoni* occasionally infests kob, bushbuck, red river hog, black duiker, Maxwell's duiker, leopard, civet and crested porcupine (Ntiamao-Baidu et al., 2005). *R. simpsoni* is a one-host tick (Wilson, 1950) and its role in the transmission of diseases is unknown. This study signaled *R. simpsoni* on striped ground squirrel (*Xerus erythropus*); cane rat (*Thryonomys swinderianus*) and Gambian rat (*Cricetomys gambianus*) in Benin and from *Thryonomys swinderianus* in Ivory-Coast (Faustin et al., 2015). *Rhipicephalus simpsoni* has been recorded for the first time in Benin.

4.24. *Rhipicephalus sulcatus*

Neumann (1908) is widespread in the Afrotropical region and has been reported in habitats such as grasslands, savannas and shrublands (Morel and Vassiliades, 1962; Pegram et al., 1987). The preferred hosts of this tick are donkey, pig, cat, dog, horse, fox and lion (Morel and Vassiliades, 1962; Sylla et al., 2021) but immatures feed on various micromammals (Sylla et al., 2021). It is three-host tick and plays a vectorial role for *Rickettsia massiliae* and Dugbe virus.

5. Conclusion

The present study updated information on hard ticks (Acari: Ixodidae) of West Africa as well as the tick-host associations. These results

improved our knowledge on the distribution of ticks in the West African sub-region, which has experienced in these years the introduction, installation and propagation of new species under the effect of climate change and animal movement. Despite the controversy over the role of climate change, it should be noted that ticks are highly dependent on climatic factors such as temperature and hygrometry for survival. The study reported solid information on tick and their hosts, which would undoubtedly allow us to understand the evolution and dynamics of the different species in the study area. This review is intended as a guide for the scientific community to better plan tick control programs as well as the circulation and emergence of tick-borne pathogens.

Author Statement

The authors accept all the conditions of your journal and reassure you of their common agreement on all the points concerning the manuscript. All the authors have read and agreed to its content.

Declaration of Competing Interest

The authors declare no competing interest.

Acknowledgments

We are grateful to the Francophony University Agency (AUF) for Postdoctoral Fellowship 'EUGEN IONESCU and Department of Parasitology and Parasitic Diseases, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Romania to have support this research.

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