Chapter

Overview of the Main Species of Ticks and Animal and Human Tick-Related Diseases in the Caribbean, Particularly in Haiti

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Abstract

The Caribbean region faces a wide diversity of ticks and tick-borne diseases (TBDs) in animals and humans. But to date, these have been the subject of few studies, resulting in a relative lack of knowledge of their epidemiology, pathogenicity, and the best prevention and control methods. Ticks are hematophagous mites, which feed on the blood of mammals, birds, and reptiles. They are subdivided into two large families: the Ixodidae or hard ticks and the Argasidae or soft ticks. Each collection of blood by ticks from infected hosts can lead to their infection, which will contaminate other previously unharmed animals and contribute to the spread of tick-borne diseases caused mainly by bacteria, viruses, and parasites. It seems important to us to draw up a state of knowledge on ticks. Some long-known tick species like Rhipicephalus, Dermacentor, and Amblyomma and diseases like Anaplasmosis and Babesiosis deserve to be better studied, and others are yet to be identified for further research. The study consists of a review of the various documents published on this theme by Haitian and foreign researchers. The data are analyzed to assess the spatiotemporal distribution of ticks and identify the pathogenic germs they harbor and the various pathologies they induce in the Caribbean and Haiti.

Keywords: ticks, tick-borne diseases, epidemiology, research, Caribbean, Haiti

1. Introduction

Over the past five decades, infestations of human and animal populations by ticks have had a clear upward trend resulting in an increase in the prevalence of tick-borne diseases worldwide and particularly in the Caribbean. Several reasons have been put forward to explain these two facts. These are mainly climate change, new modes of land use linked to deforestation, the strong growth in demography in certain continents such as Asia, Africa, and America, the unprecedented development of the various livestock domestic animals, and their closer proximity to wild fauna in the case of extensive farming [1]. Indeed, ticks and wildlife are major reservoirs of pathogens that cause a whole range of infectious diseases transmitted by ticks, which can be of bacterial, viral, and parasitic origin such as anaplasmosis, babesiosis, borreliosis, ehrlichiosis, and rickettsioses in humans and animals [2].

These tick-borne diseases are distributed throughout the world, but fairly affected areas are found in subtropical and tropical regions such as the Caribbean [3]. Despite the existence of certain studies on this theme in the Caribbean, multidisciplinary teams must develop much more research activities on the epidemiology, ecology, and diagnosis of tick-borne diseases (TBDs) in animals and humans according to the "One Health" approach.

One of the advantages of this approach is that it helps to better understand the epidemiology of ticks and the diseases they transmit to animals and humans, given the fact that wild and domestic animals infested with ticks play an extremely important role in the epidemiology of zoonotic tick-borne diseases [2, 3]. In this study, we propose to present the epidemiological situation of these diseases in the Caribbean to take stock of the progress made and to identify new research projects to be initiated on this theme.

2. Classification and biology of ticks

Ticks are ectoparasites with an exoskeleton and articulated appendages that make them belong to the arthropod branch within the animal kingdom [4]. They belong to the order of mites and arachnids and are of major economic and health importance because of the direct and indirect losses they cause in animal production and their consequences on animal and human health. They are hematophagous mites that are found in almost all vertebrates throughout the world (mammals, birds, reptiles, etc.) but that only occasionally bite humans. During blood meals, they are capable of becoming infected if the hosts are already infected or of transmitting to their host pathogenic germs which induce animal (domestic livestock and wildlife) and human pathologies, some more severe than the others, and even become infected at the same time as they transmit pathogenic infectious agents [2]. They are known to be responsible for various disorders such as paralysis, allergy, abscess, anemia, immunosuppression, and deterioration of the skin at the bite site [5].

2.1 Classification

Ticks or Ixodida are divided into three families: the Nuttalliellidae having a single genus and a single species; the Ixodidae or hard ticks include 14 genera and 700 species; and the Argasidae or soft ticks include 5 genera and around 200 species. In the order of Ixodida, there are two superfamilies:

- Argasoidae (suborder Argasina) are ticks without a dorsal crest and are called "soft ticks."

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- This superfamily includes only one family which is, Argasidae, itself divided into two subfamilies: Argasinae, with a single genus: Argas, and Ornothidorinae which also has only one genus: Ornothodoros;

- the Ixodoidae (of the suborder Ixodina) known as "hard ticks" which include 14 genera and about 700 species), and the Argasidae or soft ticks (which include 5 genera and about 200 species). It has been estimated that nearly 10% of the 900 known tick species can transmit pathogens [6].

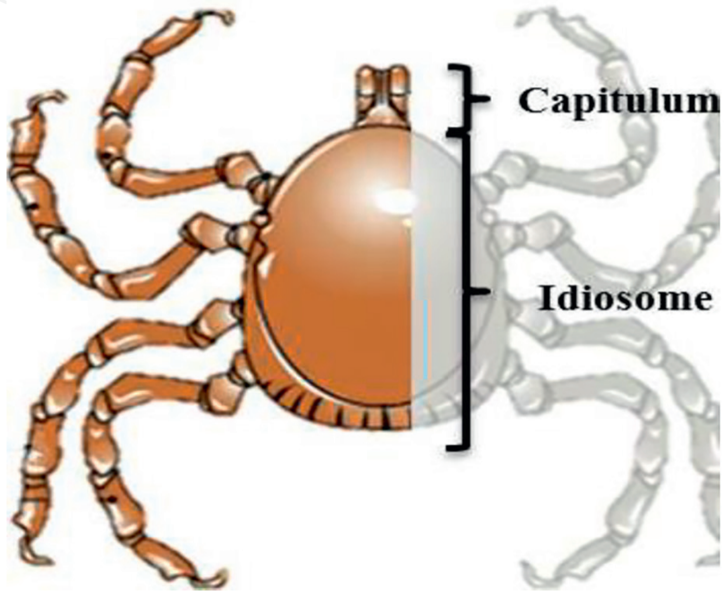

Figure 1.
Body division of an Ixodidae. Source: [3].

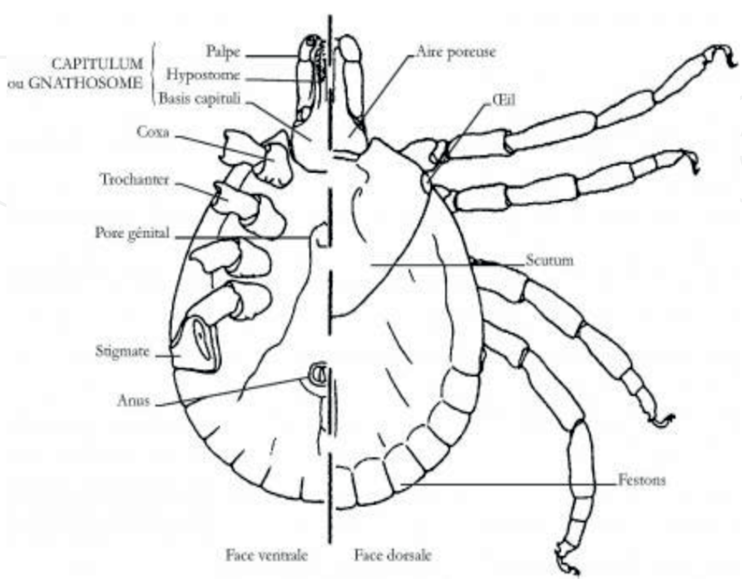

Figure 2.
General morphology of a tick. Source: [9].

Ticks are known to be among the arthropods, the vectors that transmit the greatest variety of pathogenic microorganisms, including bacteria, viruses, protozoa, and helminths [7].

The Ixodoidae superfamily is the best known and the most studied, because it includes most of the ticks that are adapted to domestic animals and/or that can bite humans. They infest different species of domestic animals and wild fauna in which they cause significant economic losses to breeders around the world and especially in the Caribbean. On the other hand, some species of these ticks are capable of accidentally infesting humans and causing severe infectious diseases such as Lyme disease due to the bacterium *Borrelia burgdorferi*, thus disrupting the functioning of health systems, public, and social security in countries other than those of the Caribbean.

The superfamily (Ixodoidae) contains two families: Ixodidae and Amblyommidae. The Ixodidae family has only one subfamily (Ixodinae) and one genus: Ixodes. As for the second family, that of the Amblyommidae, it includes several genera: Haemaphysalis, Amblyomma, Dermacentor, Hyalomma, and Rhipicephalus Boophilus.

The Ixodidae or hard ticks are so called because of their structure and conformation because they have a hard plate or crest on the dorsal side of their body, while the Argasidae or soft ticks have a soft integument devoid of a dorsal crest.

Ixodidae can survive much more easily than Argasidae in unfavorable conditions to be able to go long without feeding and to adapt to several hosts. Hard ticks are also more prolific, because they lay more eggs and are less vulnerable to having fewer natural enemies than soft ticks [8].

2.2 Morphology of ticks

Ticks are mites whose body is divided into two parts, the capitulum or gnatostome, which mainly bears the mouthparts and the idiosome on which the legs are attached. Unlike insects which have three pairs of legs, they have four. A global description of an Ixodidae tick looks like as shown in **Figures 1** and 2.

The morphology of ticks is directly related to their hematophagous lifestyle. The rostrum, carried by the capitulum, is similar to a blood collection instrument composed of two chelicerae and a hypostome which will penetrate the tissues of the vertebrate host for their blood meal. The idiosome is covered almost entirely by an extensible cuticle which allows it to expand and store blood. The males of adult hard ticks absorb little or no blood and, on the contrary, do not have an extensible cuticle but a scutum that covers the entire dorsal surface of its idiosome, preventing the distention of the idiosome and thus not allowing only slight dorsoventral dilation. Also, they absorb little or no blood. On the contrary, in female Ixodidae, the scutum only covers a small part of the body on the dorsal side and is located at the base of the capitulum [4].

2.3 Life cycle and main hosts

Ticks are large mites that present three stasis separated by real metamorphoses: larva, nymph, and male or female adult, corresponding to the mature stasis. The larva is easily distinguished by its small size and the number of its pairs of legs because, at this stasis, it has only three pairs. The nymph is distinguished from the female by the absence of a genital pore and porous areas in species that have them **Figure 3**.

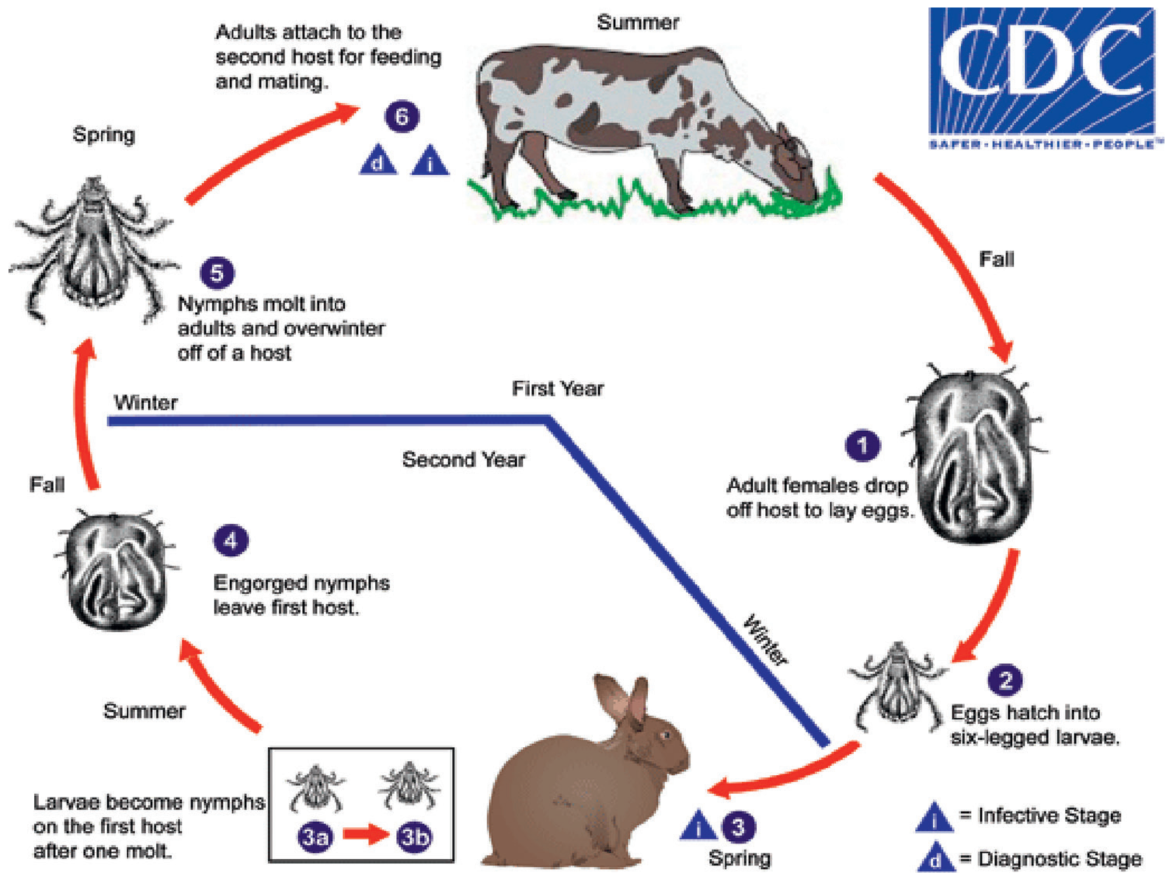

Figure 3.
Life cycle of the two-host ixodid (hard) ticks [10].

2.3.1 Reproduction of ticks

Ixodidae mating usually occurs on the host. At the end of their meal, the fertilized female detaches herself and falls to the ground where she lays her eggs. Hard ticks are reputed to be most often exophilic, that is to say, they live in open biotypes such as forests, pastures, savannahs, or grasslands. But some species are endophilic because they are found in protected habitats such as burrows or nests.

After hatching from the eggs, the larvae quickly seek out a host to feed on blood. Then, they detach and fall to the ground to undergo a metamorphosis into nymphs that can last from 2 to 8 weeks depending on the species and the climatic conditions. As for the phase of transformation into adults, it is generally longer because it extends up to 20 to 25 weeks. Environmental and climatic conditions influence the length of the life cycle of Ixodidae. The males feed little; only females take a large enough blood meal to ensure spawning [4].

The Ixodidae are by far the most important family of ticks in human and veterinary medicine because they include 80% of species in the world and have a triphasic life cycle: larva, nymph, and adult. Each stage of the vector tick cycle corresponds to a different vertebrate host, bites it, attaches to it, and takes a unique blood meal.

As for soft ticks (Argasidae), they have several nymphal stages before metamorphosis into adults. They generally live in dry areas and have great resistance to desiccation and fasting. Most species of Argasidae are endophilic; the distribution of species as well as the diseases transmitted is often limited. Generally, the parasitic stages feed on the host several times over a short period (from a few minutes to a few hours), ingest a relatively small amount of blood per meal, and then return to their nest [7].

In some species, the sting is painful unlike that of the Ixodidae which is often painless. The main soft ticks are of the genus Ornithodoros, vectors of the agents of relapsing fever and African swine fever [2].

2.3.2 Finding the host

In the process of finding the host and a sexual partner, the sensory organs of ticks play a vital role. These are also used in the assessment of climatic conditions. In addition to the bristles distributed over the entire body of ticks endowed with mechano-proprioceptive or chemoreceptor functions and the eyes in certain species of ticks, ticks have a very particular organ, the Haller organ, which is sensitive, among other things, to the degree hygrometry and pheromones, allowing ticks to locate their host by detecting the CO_2 that this emits as well as the heat and metabolites that it releases [11].

Exophilic ticks search for their host in two ways. They can practice passive waiting by climbing on the vegetation at a variable height according to the species or the stages and wait for the passage of a host with their forelegs raised to be able to cling to it. On the contrary, they can resort to an attack strategy by leaving their habitat and going toward hosts that are within their reach to attract them by different stimuli that they emit. Some tick species can use both strategies. The choice of one or the other can then vary according to the stage within the same species.

Ticks have preferential attachment sites on vertebrate animals, which vary according to species and sometimes according to stages within the same species. They can bite humans all over the body but are often found on the head, neck, or groin. But it is important to know that there is no tick specific to humans who always become infected only accidentally when they share the biotope of tick-infested animals [2].

2.3.3 Methods of transmission of infection by ticks

A vector can be defined as a hematophagous arthropod responsible for the active biological transmission of an infectious agent which can be viral, bacterial, or parasitic. The vectorial transmission of this infectious agent implies that it is taken by the vector during its blood meal and that it retransmits it in favor of another blood meal taken from a new host. For there to be the transmission, the infectious agent must remain alive in the vector between the two blood meals, either by transstadial transmission or by transovarial transmission. The biological transmission of an infectious agent implies the existence within the vector of a phase of its life cycle (multiplication or antigenic modifications).

Biological transmission of an infectious agent differs from simple passive transport, which refers to mechanical transmission. The tick, as a vector, has an active role in the contact between the infectious agent and the vertebrate host. A distinction is made between the main vectors of infectious agents which can be responsible on their own for an endemic disease, from those known as secondary or even accidental. These different vectors may very well vary from one region to another for the same infectious agent [2].

Hard ticks typically have a type of transstadial transmission that occurs when a vector retains a pathogenic infectious agent in its body as it transitions from one developmental stage to another, i.e. when the vector tick is infected at the larval stage and that this infection can persist when the larva transforms into a pupa and then into an adult form. This type of transmission is the necessary condition for a tick to be a vector of an infectious agent. Although the nymphs and adult larvae represent the main vectors of pathogenic germs, the larvae also play a role in the transmission of infectious agents by transmission [9].

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. In the light of the phenomena of transstadial transmission and or transovarial transmission, we can explain the problem of co-infections by various microorganisms which are often observed in ticks, making the diagnosis and treatment of certain induced pathologies more difficult [12]. However, reports of co-infections in humans in the Caribbean are rare.

2.3.4 Impact of climate change on ticks

Many facts establish a correlation between the occurrence of tick-borne diseases and climate change. It is indeed known that climatic factors influence the multiplication of ticks, their life cycle, the seasonal variation of their activity and behavior as well as population dynamics. According to data published by the National Climate Assessment of the United States, there would be a 2°C increase in the average annual temperature during the middle of the twenty-first century (2036–2065), which could lead to a 20% increase in the number of cases of Lyme disease in the United States in the decades to come.

The parameter of geography has to be taken into consideration in the study of the distribution of ticks. Indeed, each species tends to present a particular geographical distribution, and the diseases transmitted by ticks which are both vectors and reservoirs of germs are considered geographical diseases. But still, with climate change, some species of ticks are starting to become more and more cosmopolitan.

3. Physical framework for the study of ticks

3.1 Main physical, geographical, and climatological characteristics of the Caribbean

The Caribbean is a geographical unit formed by the Antilles and part of the circumference of the Antilles Sea. It is also called the Caribbean or Caribbean space and represents a region of the American continent that includes the Caribbean Sea, islands, some of which are surrounded by the Caribbean Sea, and other islands which border both this sea and the North Atlantic Ocean and surrounding coasts. It is located, for the most part, on the Caribbean Plate, which is a region with more than 700 islands, islets, and reefs. Generally, when we talk about the Caribbean Community, the first agglomerations that come to mind are the Greater Antilles and some Lesser Antilles.

The Greater Antilles include Cuba, Dominican Republic, Haiti, Jamaica, and Puerto Rico. The Lesser Antilles form part of the Antilles Archipelago which extends from Puerto Rico to the coast of Venezuela. The most representative islands of this group are the Virgin Islands, Saint-Martin Island, Anguilla, ABC Islands: Aruba, Bonaire and Curaçao, Antigua and Barbuda, Saint Kitts and Nevis, Guadeloupe, Dominica, Saint Vincent, and the Grenadines, Grenada, Martinique, Saint Lucia, and Barbados.

This region is often confronted with cyclones and is often the scene of earthquakes, particularly in Haiti. Some areas of this region are also prone to volcanism.

Its temperature levels are typical of a tropical climate and are softened by sea breezes and by altitude. There are two distinct seasons: the dry season which is cool and which extends from December to June, and the wet season which is hot from June to December, known as the hurricane period. It is generally characterized by stormy rains and the passage during the summer of cyclones with destructive effects on agriculture, livestock, various infrastructures (irrigation canals, bridges, etc.), and human life.

3.2 Some aspects of health situation in the Caribbean region

In the Caribbean region, because of the glaring differences between the animal health and public health systems of certain countries of this region, there are great differences between them in terms of overall health and in their capacity for epidemiological surveillance of ticks and tick-borne diseases.

All the islands of the Greater Antilles as well as a good number of the Lesser Antilles are members of the Caribbean Animal Health Network (CaribVET) or are developing cooperative relations with this network in terms of animal health. The Caribbean countries led by CIRAD established this network some 20 years ago with the technical support of certain regional organizations such as IICA and APHIS/USDA. The aim was to network the animal health and veterinary public health services of the countries of the Caribbean region including, among others, Haiti, the French, American, British and Dutch West Indies, as well as Cuba and the Dominican Republic.

CaribVET is today the only animal health and veterinary public health network in the Caribbean, recognized by regional (CARICOM, CAHFSA, and IICA) and international (OIE, FAO, PAHO, and USDA) bodies which are themselves involved in its governance. It also brings together the veterinary services of 34 countries/territories, 7 universities and research and development centers, totaling 48 members.

The purpose of this network is to provide an operational response to health issues and the emergence of animal and zoonotic diseases in this complex region made up of more than 30 territories of quite varied size, level of development, and political status.

4. Ticks and transmission of diseases to animals and man

4.1 Pathogenic power of ticks

Ticks have a pathogenic role that is both direct and indirect. The direct role results in blood loss, paralysis, toxicosis, tropical dyshidrosis, allergic reactions, and wounds which can then become superinfected [4]. The indirect role is exerted through the transmission of infectious agents to their vertebrate hosts. They are vectors that transmit the greatest diversity of infectious agents in the world and are the second vector after mosquitoes, as far as human public health is concerned [13]. They are involved in the transmission of pathogens to both humans and animals [3].

4.1.1 Vectorial capacity of ticks

The vector competence of an arthropod, i.e. its ability to transmit an infectious agent, is an essential condition for it to be considered as a vector of this agent, without however being sufficient. Indeed, other parameters such as the abundance of the vector, the dispersal capacity of the vector via its hosts, the ecological preferences of the vector in terms of habitat, host, and activity, the trophic and ecological preferences of ticks, the age or the stasis of the vector are also important to make an arthropod the vector of an infectious agent or to determine its vectorial capacity [14].

Ticks are considered to be good vectors of infectious agents whose contact with their hosts can be either prolonged in hard ticks which have long and copious blood meals or repetitive in soft ticks with meals of very low volume [4]. In both cases, the exchange of infectious agents is facilitated. Ticks can therefore have broad to very broad host spectra, thus promoting the circulation of infectious agents [15]. In addition, during their metamorphoses, they undergo few rearrangements thus favoring, most often, the preservation of infectious agents between each stasis (transstadial transmission) [15].

It is recognized that the most important ticks in terms of their ability to transmit diseases to ruminants in the Caribbean islands are as follows: Amblyomma variegatum, a vector of heartwater and associated with acute dermatophilosis; Amblyomma cajennense, a potential vector of heartwater; Boophilus microplus, vector of babesiosis and anaplasmosis [16].

4.1.2 Tick infection and co-infection process

As the biological cycles of ticks can be very long, they also serve as reservoirs of infectious agents in nature [4]. As they can be transported by their hosts, especially birds, over very long distances, they cause a very significant dispersion of the infectious agents they carry [17, 18]. The fact of having several meals during their life allows them to undergo co-infections, which are to say to harbor at the same time several infectious agents that can be transmitted to susceptible hosts.

The probability of having an infecting tick vector is all the greater when the concentration of infectious agents is high and their presence in the blood of the host is prolonged. However, it has been observed that infectious agents present in an infected tick can pass to a healthy tick during the co-meal phenomenon in the absence of viremia or bacteremia in the host, even in the presence of targeted antibodies of the host [4]. This is because the bite site undergoes, under such conditions, significant local pharmacological modifications linked to the injection of active substances contained in the saliva of ticks promoting the action of certain infectious agents to contaminate naive ticks [19]. However, co-meal transmission is only possible if the infected tick and the naive tick are attached a short distance from each other.

Such behavior by facilitating both blood feeding and mating contributes to the transmission of pathogens from an infected tick to an uninfected one sharing the same blood meal. Ticks can then become infected with pathogenic germs during co-feeding without the host being bacteremia or viremic, i.e. carrying these germs [2, 20]. Tick co-infections are well known in the Caribbean region, especially in dogs. This fact has been observed in several countries in the region such as Grenada, St Kitts, and Haiti. By way of illustration, let us present some results of co-infections in Haiti and Cuba.

In Haiti, co-infection in dogs with two or more PTBs was detected using serology (20.0%) and molecular methods (10.6%). The most common co-infection involved Dirofilaria immitis and B. Vogeli (3.4%), followed by *D. immitis* and *E. canis (1.9%), D. immitis* and *H. canis (1.4%), E. canis* and *H. canis (1.4%), H. canis* and *Acanthocheilonema recondite (1.0%), D. immitis* and *Anaplasma platys (0.5%), E. canis* and *B. vogeli (0.5%),* and *H. canis* and *A. platys* (0.5%). [21].

In Cuba, different co-infections have been identified with:

- three haemoparasites (B. bigemina, A. marginale, and B. bovis) in 12.0% of water buffaloes, co-infections with B. bovis and A. marginale being the most common (26.0%). %) followed by B. bovis/B. bigemina (20.0%) and A. marginale/B. bigemina (24.0%), suggesting the potential positive interaction between these pathogens.

- B. caballi and T. equi in 20.0% of horses tested.
- A. ovis and B. ovis and between A. ovis and E. ovis
- A. ovis and B. motasi in sheep by microscopic examination of blood smears [22].

4.1.3 Other ways of transmission of a tick-borne disease

Not all tick-borne diseases are transmitted exclusively by tick bites. This is particularly the case for certain pathogenic germs such as Bartonella, Francisella, and Coxiella which use other routes for the transmission of infectious agents. Indeed, the transmission of Q fever or coxiellosis does not generally occur by infected tick bite but by inhalation of contaminated dust (feces of infected ticks) and by contact with infected secretions, including milk, and also the placenta, aborted small ruminants. It has been shown that in the case of certain human epidemics cataloged as tick-borne

Pathogens	Caribbean distribution	Infection (TBDs)	Vector*	Reported host	Detection method
Anaplasma marginale	Antigua, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Puerto Rico, St Kitts and Nevis, St Lucia, St Martin, St Vincent, Trinidad	Anaplasmosis	*Rh. microplus*	Cattle	Serology
Anaplasma phagocytophilum	Puerto Rico	Anaplasmosis (Granulocytic Anaplasmosis)	*Ixodes* spp	Dogs	Serology
Anaplasma platys	Cuba, Grenada, Haiti, St Kitts, Trinidad,	Anaplasmosis (Canine Cyclic Thrombocytopenia)	*Rh. sanguineus, A.cajennense*	Dogs	Serology/ Molecular biology
Bartonella vinsonii subspp. *Berkhoffii*	Grenada, Martinique	Canine and human endocarditis	*Rh.sanguineus*	Dogs	Serology/ Molecular biology
Borrelia burgdorferi sensu lato	Cuba	Borreliosis (Lyme disease)	*A.cajennense*	Humans	Serology
Borrelia Relapsing Fever group (Borrelia hermsii)	US Virgin Islands	Borreliosis (Relapsing fever)	*Ornithodoros* spp	Humans	Serology

Pathogens	Caribbean distribution	Infection (TBDs)	Vector*	Reported host	Detection method
Coxiella burnetii	Puerto Rico	Q fever	*D. nitens*	Cattle	ND
Ehrlichia canis	Aruba, British West Indies, Grenada, Haiti, Puerto Rico, St Kitts and Nevis, Trinidad, Turks and Caicos Islands	Ehrlichiosis (Canine Monocytic Ehrlichiosis)	*Rh. Sanguineus*	Canids, Cats	Serology/ Molecular biology
E. canis or closely related species	Dominica, Grenada, Montserrat, St Kitts and Nevis	Ehrlichiosis	ND	Cattle, Sheep, Goats	Molecular biology
Ehrlichia ruminantium	Antigua, Guadeloupe, Marie Gualante	Ehrlichiosis (Heartwater, Cowdriosis)	*A. variegatum*	Cattle	Serology
Panola Mountain Ehrlichia sp.	Dominica, St Kitts	Ehrlichiosis	*A. variegatum*	Domestic animals	Molecular biology
Candidatus Mycoplasma haematoparvum	Trinidad	Hemotropic mycoplasmosis	*Rh.sanguineus*	Dogs	Molecular biology
Mycoplasma haemocanis	Trinidad	Hemotropic mycoplasmosis	*Rh. sanguineus*	Dogs	Molecular biology
Mycoplasma haemofelis	Trinidad	Hemotropic mycoplasmosis	*Rh. sanguineus*	Cats	Molecular biology
Candidatus Mycoplasma haemominutum	Trinidad	Hemotropic mycoplasmosis	*Rh. sanguineus*	Cats	Molecular biology
Mycoplasma wenyonii	Cuba	Hemotropic mycoplasmosis	ND	Cattle	ND
Mycoplasma ovis	Cuba	Hemotropic mycoplasmosis	ND	Sheep	Serology
Rickettsia africae	Antigua, Dominica, Guadeloupe, Martinique, Montserrat, St Kitts and Nevis, St Lucia, U.S. Virgin Islands	Rickettsiosis (African tick bite fever)	*A.variegatum*	Humans, Cattle, Goats, Sheep	Serology/ Molecular biology
Rickettsia conorii	Guadeloupe	Rickettsiosis (Mediterranean spotted fever)	*A. variegatum*	Humans	Serology
Rickettsia felis	Dominica, St Kitts	Rickettsiosis	*Ctenocephalides felis*	Cats	Molecular biology

Pathogens	Caribbean distribution	Infection (TBDs)	Vector*	Reported host	Detection method
Rickettsia typhi	Puerto Rico	Rickettsiosis (Murine typhus)	*Xenopsylla cheopis*	Rodents	ND
Babesia bigemina	Antigua, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Puerto Rico, St Kitts and Nevis, St Lucia, St Martin, St Vincent, Trinidad	Babesiosis	*Rh. microplus*	Cattle	Serology/ Molecular biology
Babesia bovis	Antigua, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Puerto Rico, St Kitts and Nevis, St Lucia, St Martin, St Vincent, Trinidad	Babesiosis	*Rh. microplus*	Cattle	Serology/ Molecular biology
Babesia caballi	Grenada, Guadeloupe, Martinique, Montserrat, St Kitts and Nevis, Trinidad	Piroplasmosis	*D. nitens*	Equids, Goats, Sheep	Serology/ Molecular biology
Babesia (canis) rossi	Montserrat	Babesiosis	*Rh.sanguineus, Rh. turanicus*	Goats	Molecular biology
Babesia (canis) vogeli	Dominica, Grenada, Haiti, Montserrat, St Kitts and Nevis, Trinidad	Babesiosis	*Rh. sanguineus, Rh. turanicus*	Dogs, Cats, Cattle, Sheep, Goats	Serology/ Molecular biology

Pathogens	Caribbean distribution	Infection (TBDs)	Vector*	Reported host	Detection method
Babesia gibsoni	Dominica, St kitts	Babesiosis	*Rh.sanguineus, Rh.turanicus*	Dogs, Cattle, Sheep, Goat, Equids	Molecular biology
Babesia vulpes	Montserrat	Babesiosis	ND	Goats, Sheep	Molecular biology
Hepatozoon canis	Aruba, Grenada, Haiti, St Kitts, Trinidad	Hepatozoonosis	*Rh. sanguineus*	Dogs	Serology/ Molecular biology
Theileria equi	Dominica, St kitts and Nevis, Trinidad	Piroplasmosis	*D. nitens*	Equids, Cattle, Sheep, Goats	Serology/ Molecular biology
Theileria mutans	Cuba, Guadeloupe, Martinique	Theileriosis	*A. variegatum*	Cattle	Serology (IFA)
Theileria parva	Guadeloupe	Theileriosis	*A. variegatum*	Cattle	ND
Theileria sp. B15a	Grenada	Theileriosis	ND	Cattle	Molecular biology
Theileria sp. NG-2013a	Nevis	Theileriosis	ND	Goats	Molecular biology
Theileria sp. OT3	Montserrat	Theileriosis	ND	Sheep, Goats	Molecular biology
Theileria sp. YW-2014	St Kitts	Theileriosis	ND	Equids	Molecular biology
Theileri velifera	Guadeloupe	Theileriosis	*A. variegatum*	Cattle	Serology
African swine fever	Cuba, Dominican Republic, Haiti	African swine fever	*Ornithodoros* spp	Swine	ND
Estero Real	Cuba	ND	*C. tadaridae*	ND	Isolation
Hugues Virus	Cuba, Trinidad	ND	*C. denmarki*	Seabirds	Isolation
Soldado Virus	Trinidad	ND	*Carios* spp	Seabirds	Isolation
Wad Medani Virus	Jamaica	ND	*A.cajennense*	ND	Isolation

Source: [31].

Table 1.
Tick-borne pathogens and suspected tick vectors reported within the Caribbean.

diseases, such mites may not be directly involved as vectors. Examples include human piroplasmosis which can occur through blood transfusion [23].

- tick-borne encephalitis, the virus of which can be transmitted to humans by drinking infected milk;
- Crimean-Congo hemorrhagic fever, the virus of which can be contracted by handling the carcasses of infected animals.

4.2 Tick species identified

4.2.1 Origin of ticks

In the Caribbean, the tick fauna is made up, on the one hand, of endemic species and, on the other hand, of exotic species which have been introduced there by different routes: movement of animals in the region, movement of birds migratory or non-migratory from North, Central, or South America, occupation of this region by settlers who came with infested cattle and dogs from Europe, Africa, and Asia [24, 25]**.** A total of 56 species of ticks have been recorded in the Caribbean, belonging to 10 genera and 2 families (Argasidae and Ixodidae) including 15 species of Ornithodoros, 10 species of Antricola, 17 species of Amblyomma, 3 species of Argas, Ixodes, and Rhipicephalus, 2 species of Haemaphysalis, and 1 species each of Parantricola, Dermacentor (Anocentor), and Aponomma [26].

Because of their impact on health, the most studied tick species in the West Indies are those associated with the transmission of tick-borne diseases to livestock or pets. However, even if the tropism of ticks for certain hosts is well documented, it is observed that many of them can parasitize different species of hosts, including humans, opening the way to the occurrence of zoonotic diseases [27, 28]. Other species of ticks, present in wildlife, also exist in the Caribbean without arousing much concern and interest to date. As the majority of emerging diseases come from wildlife reservoirs, characterization of the diversity and ecology of ticks present in these wild environments should be addressed [29, 30]. The tick species described in this review are significantly implicated in the epidemiology of animal tick-borne diseases (**Table 1**).

4.2.2 Diseases transmitted by Ixodidae ticks to cattle

- *Rhipicephalus (Boophilus) microplus*

It is the tropical cattle tick considered to be the most important in the world. Although primarily associated with cattle, *Rh. microplus* can feed on a variety of hosts among domestic animals in the Caribbean such as horses, donkeys, goats, sheep, buffaloes, pigs, dogs, and also in some wild animals [32]. According to some cases of human infestation by *Rh. microplus* have sometimes been detected in humans [33]. But these *Rh. microplus* ticks are single host, i.e. they can stay on the same host throughout their life cycle. They are well distributed in the Caribbean, both in the Greater and the Lesser Antilles [16].

This cattle tick is mainly involved in the transmission of bacteria and protozoa such as *Anaplasma marginale, Anaplasma centrale, Babesia bigemina, Babesia bovis, and Theileria spp* [34].

In almost all Caribbean countries with a fairly large livestock population, significant economic losses of several million US dollars have been recorded, as was the case in Puerto Rico.

- *Amblyomma variegatum*

Unlike *Rhipicephalus microplus*, the tropical tick *A. variegatum* is a tick with several hosts which are mainly ruminants (cattle and goats). It causes deep skin lesions through their mouthparts which can facilitate the development of secondary infections leading to acute dermatophilosis. It transmits pathogenic bacteria such as *Ehrlichia spp. and Rickettsia spp*., and protozoa such as *Theileria spp*. [27, 35–37]. It also caused significant losses during the 1990s which amounted to several million US dollars in the English Lesser Antilles.

The tick was first introduced to Guadeloupe and for a time remained confined to Guadeloupe, Antigua, and Martinique until the 1960s. But by the 1980s, it had spread to 18 islands in the Caribbean in the late 1980s. So far, the distribution of *Amblyomma variegatum* in the Caribbean is restricted to the Lesser Antilles [16, 38].

- *Amblyomma cajennense*

A. cajennense, a tick with multiple hosts, has also been reported in several Caribbean countries such as Cuba, Jamaica, and Trinidad. However, due to deficiencies in the epidemiological vigilance system for ticks and tick-borne diseases in some Caribbean countries, it cannot be said with certainty that it is limited only to these three countries. It is suspected to be the vector of the agents *Ehrlichia spp., Rickettsia spp*., and equine piroplasms [39].

- *Dermacentor (Anocentor) nitens*

The tropical horse tick is a single-host tick that primarily parasitizes equines. *D. nitens* is suspected of being the vector of *Babesia caballi and Theileria equi,* the two causative agents of equine piroplasmosis [40].

- *Rhipicephalus annulatus*

The existence of *R. annulatus* has not been established with certainty in the Caribbean because according to some authors, there is a risk of confusion about this tick with Rh. microplus because of their morphological similarities.

- *Rhipicephalus sanguineus*

It is a brown tick commonly found in dogs, but it has three hosts and is considered widespread in the Caribbean and often parasitizes dogs [24–26]. It is prevalent in several Caribbean countries including Haiti and plays an important role in both animal health and public health due to its ability to transmit various Ehrlichia, Anaplasma, Rickettsia, and Babesia pathogens [28].

4.2.3 Tcks and tick-borne diseases in pets

The most common ticks and bacterial and protozoan diseases transmitted by ticks in dogs in the Caribbean are as follows:

- tropical canine pancytopenia (caused by *Ehrlichia canis*),

- canine cyclic thrombocytopenia (*Anaplasma platys*), and

- canine babesiosis (*Babesia canis*) [21, 37, 41,].

- **Canine babesiosis** is one of the most commonly reported infections and is often caused by *Babesia canis vogeli and Babesia gibsoni*. It has been detected in Haiti, Grenada, and St Kitts.

Another hemiparasite, *Hepatozoon canis*, is acquired by ingesting infected ticks; it has been reported in certain Caribbean islands such as Cuba, Grenada, Saint-Kitts, and Trinidad [31, 42–44].

The above pathogens are usually transmitted or associated with the bite or ingestion of *R. sanguineus* ticks. It should be noted that natural infections with *Rickettsia amblyommatis* and *Rickettsia rickettsii* have been detected in *R. sanguineus* [45].

- *Babesia gibsoni* **infections** are usually acute and characterized by anorexia, fever, hepatomegaly, splenomegaly, and pallor. Some animals, after recovery, however, remain carriers. Other Babesia infections reported in mammalian hosts include *B. Gibson and Babesia vogeli* in cats. [3, 46].

4.2.4 Ticks as vectors of human pathogens of bacterial and protozoan origin in the Caribbean

R. rickettsii is a highly pathogenic agent causing Rocky Mountain spotted fever (RMSF) in humans. This has been detected in Belize and some Caribbean countries. Its symptoms are high fever, violent headaches, and exanthema. A less severe rickettsia, African tick-bite fever, caused by *R. africae*, has been reported from the eastern Caribbean [47]. This TBP was probably introduced into the Caribbean with cattle infected with *A. variegatum* imported from Senegal more than 200 years ago. Although a small number of clinical human cases are reported, R. africae and its human-infecting vector, *A. variegatum*, are widely distributed in the Caribbean [48].

4.2.5 Human and animal viruses transmitted by ticks in the Caribbean

Several tick-borne viruses, particularly the Argasidae, have been identified in ticks in the Caribbean region, including Hughes virus in the Ornithodoros capensis (Ornithodoros denmarki and Soldado virus in *Ornithodoros capensis* of Trinidad [49, 50], and *O. denmarki* in Cuba [51], Estero real virus in *Ornithodoros tadaridae* ticks in Cuba [52], and Wad Medani in A. cajennense from Jamaican ticks [53] .

The African swine fever virus, which raged in Haiti, the Dominican Republic, and Cuba in the 1980s, was detected in Ornithodoros ticks [54]. However, there was no evidence that these had participated in the spread of ASF under natural conditions because this virus was not identified in any of the 350 Ornithodoros puertoricensis ticks collected in the Dominican Republic and Haiti. Ticks were unable to acquire and transmit this virus transstadially and transovarially under laboratory conditions [55, 56].

4.3 Veterinary and health importance of ticks

4.3.1 Direct and indirect impact of ticks on human and animal health

The impact of ticks is quite significant in both animal and human health. Their natural hosts are normally wild and domestic animals. But, when man finds himself in the biotopes of ticks, he can become an accidental host, [57]. The medical importance of ticks must be understood on the one hand, through their direct role on the health of their host, which is dependent on their behavior as hematophagous ectoparasites, and, on the other hand, through their indirect action as carriers of a large number of direct pathogens.

4.3.2 Direct health impacts of ticks

The direct effects of ticks on the health of the host are particularly observed in animals where they cause significant economic losses for the livestock industries. Some species of ticks such as those of the genus Amblyomma have the ability to take about 4 ml of blood during their blood meal, thus creating cases of blood loss, anemia, and significant weakening of the animal infested. When the tick is attached to a given host, the rostrum will penetrate the skin of the host, which can often transform this bite into a cutaneous wound capable of causing superinfections, the introduction of opportunistic pathogens or the formation of abscesses. A bacterium like *Dermatophilus congolensis* responsible for bovine dermatophilosis is widely associated with cases of infestation of the animal by *A. variegatum* ticks, whose bite sites are entry routes for the pathogen. The leather industries are particularly affected by the poor quality of animal skin linked to tick infestation. Similarly, domestic animal infestations can result in a significant drop in productivity for livestock industries for meat and milk [7]. Another consideration is that tick saliva is made up of several different molecules in the feeding site during the blood meal with possible consequences of reduced host immune system, transmission of pathogens, and even allergies due to the presence of certain molecules which can prove to be toxic for the host (animal or human) leading to cases of toxicosis or serious paralysis [5, 58].

4.3.3 Indirect health impacts of ticks

Ticks are the most important vectors in animal health, and they are placed before the mosquito. In human health, they come second to mosquitoes. They ensure active transmission (mechanical or biological) of an infectious agent from one vertebrate to another vertebrate. Globally, ticks are responsible for transmitting the widest range of pathogens. They transmit microorganisms responsible for bacterial (Lyme borreliosis and rickettsioses) or parasitic (babesiosis and theileriosis), or even viral (tick-borne encephalitis) diseases. The microorganisms responsible for these diseases constitute a major risk for both human and animal health. Ticks are capable of parasitizing many host species, affecting wildlife, livestock, pets, and even humans.

Without having precise figures, it is estimated that the financial costs related to ticks and tick-borne diseases are considerable in public and animal health in the Caribbean [7].

5. New perspectives for the development of a better system for the epidemiological surveillance of ticks and tick-borne diseases

As has been demonstrated, the Caribbean is a region at risk for the proliferation of vector-borne diseases. Such a situation is explained by favorable conditions for vectors, increasingly important intercontinental exchanges, animal movements, and a strong presence of migratory birds in this region. Also, it is important to develop increasingly efficient epidemiological surveillance systems for ticks and tick-borne diseases. But conventional diagnostic techniques have proven ineffective for a true assessment of the extent of these pests and diseases. New diagnostic tools are needed to draw up a more in-depth inventory of pathogens of medical and veterinary interest present in ticks in the Caribbean region. The use in Guadeloupe and Martinique of high-throughput RNA sequencing techniques extracted from ticks collected in the Caribbean gives great hope for an exhaustive inventory of pathogens (bacteria, parasites, and viruses) present in the region.

The analyses thus carried out revealed a great diversity of pathogenic germs within the samples collected which would not be detected by conventional detection techniques. For example, they revealed:

- The presence of four viruses belonging to new viral genera recently described and associated with arthropods.

- The constitution of a list or directory of pathogens transmitted by ticks requiring health surveillance in the Caribbean and which can make it possible to develop a high-throughput screening system for infectious agents applicable to the entire Caribbean area.

- Important data on the epidemiological situation of the Lesser Antilles with regard to pathogens transmitted by ticks, i.e. 45 bacteria, 17 parasites, and 31 viruses potentially from the sampling of the study carried out in Guadeloupe and Martinique.

Despite the wide variety of ticks and pathogens transmitted, few studies have been devoted to assessing the diversity of tick species and the incidence of tick-borne diseases in humans [59, 60]; it is now necessary to actively monitor the spread of important pathogens transmitted by ticks other than those which have traditionally been transmitted such as *A. marginale, Ehrlichia ruminantium, Babesia. bovis, Babesia bigemina, Babesia caballi, and Theileria equi*, due to their socio-economic impact [61, 62].

The surveillance and control strategy against ticks and tick-borne diseases in the Caribbean benefit from adopting the "One Health" approach, which implies greater collaboration between veterinary health and environmental professionals for a comprehensive approach of health because over the past few decades, changes in ecosystems have contributed to making wildlife the main reservoir of pathogenic germs. The "One Health" approach should enable the improvement of the diagnostic process, the acceleration of treatment decisions, and the adoption of appropriate prevention and control protocols.

6. Conclusion

Several ticks and tick-borne diseases exist in the Caribbean, constituting sources of danger for human and animal health. Many of these pathogens are restricted to cycles of transmission primarily involving domestic Ehrlichia animals. canis) and wild animals and/or livestock (e.g. Ehrlichia ruminantium), while others are comparatively widespread in humans *Anaplasma mixtum, Anaplasma variegatum, and R. sanguineus* are the important vectors in the region due to their potential for transmission of zoonotic pathogens.

However, the Caribbean remains largely understudied with respect to tick-borne diseases because existing studies focus on the identification and epidemiology of pathogens affecting animals such as *E. ruminantium, Babesia (bovis and bigemina), and A. marginale*. But they were carried out using conventional detection tools which proved to be far from being able to answer questions concerning the risk of emergence or re-emergence of tick-borne diseases.

The use of the surveillance method based on the sequencing of new generations of microorganisms and pathogens present in ticks in Guadeloupe and Martinique undoubtedly represents a major improvement in epidemiological monitoring techniques which will allow the rapid and parallel detection of a wide range of pathogens. The ideal would be to be able to apply this method to the high-throughput screening of infectious agents present in ticks collected throughout the Caribbean, at least at the level of all the member countries of the Caribbean Animal Health and Veterinary Public Health Network (CaribVet).

The situation of the Republic of Haiti requires, in this regard, a little more attention because the majority of studies that have been carried out on ticks and tick-borne diseases have been carried out by foreign researchers. There is a great lack of professionals specialized in veterinary and medical entomology in this country, and the "One Health" approach is still slow to establish itself there because of a certain compartmentalization between the sectors of health, agriculture, and the environment. At government level, there does not yet seem to be much importance given to vector-borne diseases, with the exception of those transmitted by certain species of mosquitoes. The research undertaken with the veterinary parasitology and microbiology and public health laboratories did not allow us to discover any interesting data likely to advance the state of knowledge on this topic.

Research on ticks and tick-borne diseases must therefore be approached through networks of researchers throughout the Caribbean to facilitate exchanges of experience. The Caribbean Network for Animal Health and Veterinary Public Health (CaribVet) can therefore play a major role in the coordination of research and training actions on this theme.

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References

[1] Jones KE, Patel NG, Levy MA, Storegard A, Balk D, Gittleman JL, et al. Global trends in emerging infectious diseases. Nature. 2008;**451**:990-993

[2] Moutailler S, George JC, Hansmann Y, Degeilh B, Joncour G, Jourdain E, et al. Principales maladies transmises par les tiques : épidémiologie, clinique et diagnostic. Tiques et maladies à tiques. 2015;**2015**:193-209

[3] Gondard M, Cabezas-Cruz A, Charles RA, Vayssier-Taussat M, Albina E, Moutailler S. Ticks and tick-borne pathogens of the Caribbean: Current understanding and future directions for more comprehensive surveillance. Frontiers in Cellular and Infection Microbiology. 2017;**7**:490

[4] Bonnet S, Huber K, Joncour G, René Martellet M, Stachurski F, Zenner L. Biologie des tiques. Tiques et maladies à tiques. 2015;**2015**:53-84

[5] Mans BJ, Gothe R, Neitz AVH. Biochemical perspectives on paralysis and other forms of toxicoses caused by ticks. Parasitology, Cambridge University Press. 2004;**129**(S1):SS95-S111. DOI: 10.1017/S0031182003004670[Opens in a new window]

[6] Guglielmone AA, Robbins RG, Apanaskevich D, Petney TN. The Argasidae, Ixodidae and Nuttalliellidae (Acari: Ixodida) of the world: a list of valid species names. 2010.

[7] Jongejan F, Uilenberg G. The global importance of ticks. Parasitology. 2004;**129**:S3-S14. DOI: 10.1017/s0031182004005967

[8] Mandell D. Principles and Practice of Infectious Diseases. 9th Edition. 2019;**2**. ISBN-13: 978-0323482554, ISBN-10: 0323482554

[9] Rhodain F, Perez C. Précis d'Entomologie Médicale et Vétérinaire. Paris: Maloine; 1985. p. 458

[10] Centers for Disease Cpntrol and Prevention (CDC). Ticks [Amblyomma spp.] [Dermacentor spp.] [Ixodes spp.] [Ornithodoros spp.] [Rhipicephalus spp]. 2017

[11] Waladde SM, Rice MJ. Chapter 3- The sensory basis of tick feeding behaviour. Physiology of Ticks. Current Themes in Tropical Science. 1982. pp. 71-118

[12] Franke J, Fritzsch J, Tomaso H, Straube E, Dorn W, Hildebrandt A. Coexistence d'agents pathogènes chez les tiques à la recherche d'un hôte et se nourrissant dans un seul habitat naturel en Allemagne centrale. Applied and Environmental Microbiology. 2010;**76**(20):6829-6836

[13] WHO. Vector-borne Diseases, Newsletter WHO; 2020

[14] McCoy KD, Chevillon C. Tiques et maladies à tiques - IRD Éditions – Open Edition Books Chapitre 4. Structuration des populations et adaptation des tiques : implications en épidémiologie. 2015

[15] Chauvin A, Moreau E, Bonnet S, Plantard O, Malandrin L. Babesia and its hosts: adaptation to long-lasting interactions as a way to achieve efficient transmission. 2008. Accepted: 16 April 2009

[16] Camus et Barré. Vector situation of tick-borne diseases in the Caribbean Islands. 1995. https://doi.org/10.1016/0303-4017(94)03118-G

[17] Agoulon A, Butet A, Hoch T, Perez G, Plantard O, Verheyden H, Vourc'h G. IRD Éditions Chapitre Dynamique des populations de tiques et liaison avec les facteurs environnementaux, 2015. pp. 85-112

[18] Chevillon C, Huber K. Tiques et maladies à tiques - IRD Éditions, 2015, pp. 141-164

[19] Nuttal et Labuda. Tick-host interactions: Saliva-activated transmission. Parasitology. 2004;**129**(7):S177-S189

[20] Belli A, Sarr A, Rais O, Rego RO, Voordouw MJ. Ticks infected via co-feeding transmission can transmit Lyme borreliosis to vertebrate hosts. Scientific Reports. 2017;**7**(1):1-13

[21] Starkey LA, Newton K, Brunker J, Crowdis K, Edourad EJP, Meneus P, et al. Prevalence of vector-borne pathogens in dogs from Haiti. Vet. Parasitology. 2016;**224**:7-12

[22] Rodriguez ON, Espaine L, Rivas A, Rodriguez P. Epidemiology of cattle diseases caused by haemoparasites in Cuba. 1989. Available at: http://www.cabi.org/isc/abstract/19902200923 [Accessed March 25, 2017]

[23] Goodell M, Thomas A, Rando TA. Stem cells and healthy aging. Science. 2015;**350**(6265):1199-1204

[24] Morel PC. Étude sur les tiques du bétail en Guadeloupe et Martinique. I. Les tiques et leur distribution (Acariens, Ixodoidea), 1966

[25] De la Cruz JO. Biogeography of the West Indies: Patterns and Perspectives. 2nd ed. Woods CA, Sergile FE, editors. Edition: 2. Illustrated, revised Publisher: CRC Press; 2001

[26] Basu A, Charles R. Ticks of Trinidad and Tobago: An Overview. 1st ed. Elsevier; 2017. Paperback ISBN: 9780128097441. eBook ISBN: 9780128097519

[27] Parola P, Vestris G, Martinez D, Brochier B, Roux VE, Raoult D. Tick-borne rickettiosis in Guadeloupe, the French West Indies: isolation of Rickettsia africae from Amblyomma variegatum ticks and serosurvey in humans, cattle, and goats. The American Journal of Tropical Medicine and Hygiene. 1999;**60**(6):888-893

[28] Dantas-Torres F. Biology and ecology of the brown dog tick, hipicephalus sanguineus. Parasites & Vectors. 2010;**3**(1):1-11

[29] Dantas-Torres F, Chomel BB, Otranto D. Ticks and tick-borne diseases: A One Health perspective. Trends in Parasitology. 2012;**28**:437-446

[30] Baneth G. Tick-borne infections of animals and humans: a common ground. International Journal for Parasitology. 2014;**44**(9):591-596

[31] Charles RA, Bermúdez S, Banović P, Alvarez DO, Díaz-Sánchez AA, Corona-González B, et al. Ticks and tick-borne diseases in Central America and the Caribbean: A one health Perspective. Pathogens. 2021;**10**(10):1273

[32] Walker AR, Bouattour A, Camicas J-L, Estrada-Peña A, Horak I, Latif A, et al. Ticks of Domestic Animals in Africa: A Guide to Identification of Species. University of Edinburgh; 2003. Available online: https://agris.fao.org/agris-search/search.do?recordID=XF2015039701

[33] Guglielmone AA, Beati L, Barros-Battesti DM, Labruna MB, Nava S, Venzal JM, et al. Ticks (Ixodidae) on humans in South America. Experimental & Applied Acarology. 2006;**40**(2):83-100

[34] De Castro JJ. Sustainable tick and tickborne disease control in livestock improvement in developing countries. Vet. Parasitology. 1997;**71**:77-97

[35] Uilenberg G, Zivković D, Dwinger RH, Ter Huurne AA, Perie NM. Cross immunity between strains of Cowdria ruminantium. Research in Veterinary Science. 1983;**35**(2): 200-205

[36] Camus et Barré. The role of Amblyomma variegatum in the transmission of heart water. 1992

[37] Loftis AD, Kelly PJ, Freeman MD, Fitzharris S, Beeler-Marfisi J, Wang C. Tick-borne pathogens and disease in dogs on St. Kitts, West Indies. Veterinary Parasitology. 2013;**196**:44-49

[38] Pegram R, Indar L, Eddi C, George J. The Caribbean Amblyomma program some ecologic factors affecting its success. Annals New York Academy Sciences. 2004, 2004;**1026**:302

[39] Scoles GA, Ueti MW. Amblyomma cajennense is an intrastadial biological vector of Theileria equi. Parasites & Vectors. 2013;**6**(1):1-9

[40] Asgarali Z, Coombs DK, Mohammed F, Campbell MD, Caesar E. (2007). A serological study of Babesia caballi and Theileria equi in Thoroughbreds in Trinidad. Vet. Parasitology. 2007;**144**:167-171

[41] Georges K, Ezeokoli CD, Newaj-Fyzul A, Campbell M, Mootoo N, Mutani A, et al. The application of PCR and reverse line blot hybridization to detect arthropod-borne hemopathogens of dogs and cats in Trinidad. Annals New York Academy Sciences. 2008, 2008;**1149**:196

[42] Rojas A, Rojas D, Montenegro V, Gutiérrez R, Yasur-Landau D, Baneth G. Vector-borne pathogens in dogs from Costa Rica: First molecular description of Babesia vogeli and Hepatozoon canis infections with a high prevalence of monocytic ehrlichiosis and the manifestations of co-infection. Veterinary Parasitology. 2014;**199**:121-128

[43] Díaz-Sánchez AA, Hofmann-Lehmann R, Meli ML, Roblejo-Arias L, Fonseca-Rodríguez O, Castillo AP, et al. Molecular detection and characterization of Hepatozoon canis in stray dogs from Cuba. Parasitology International. 2021, 2021;**80**:102200

[44] Sant C, Georges KC, Pow-Brown P. Novel incidental finding of Hepatozoon canis infection in two dogs of the same household in Trinidad, West Indies. Veterinary Parasitology: Regional Studies and Reports. 2017;**9**:98-103

[45] Guglielmone AA, Nava S, Robbins RG. Neotropical Hard Ticks (Acari: Ixodida: Ixodidae). In: Englischer Sprache Springer. 1st Edition. Springer International Publishing; 2021. ISBN 978-3-030-72352-1

[46] Kelly PJ, Köster L, Li J, Zhang J, Huang K, Branford GC, et al. Survey of vector-borne agents in feral cats and first report of Babesia gibsoni in cats on St Kitts, West Indies. BMC Veterinary Research. 2017;**13**:331

[47] Kelly P, Lucas H, Beati L, Yowell C, Mahan S, Dame J. Rickettsia africae in Amblyomma variegatum and domestic ruminants on eight Caribbean islands. J. Parasitology. 2010;**96**:1086-1088

[48] Kelly PJ. Rickettsia africae in the West Indies. Emerging Infectious Diseases. 2006, 2006;**12**:224

[49] Aitken TH, Jonkers AH, Tikasingh ES, Worth CB. Hughes virus from Trinidadian ticks and terns. Journal of Medical Entomology. 1968;**5**(4):501-503

[50] Jonkers AH, Casals J, Aitken THG, Spence L. Soldado virus, a new agent from Trinidadian Ornithodoros ticks. Journal of Medical Entomology. 1973;**10**(5):517-519

[51] Danielová V, Marhoul Z, Dusbábek F, Ryba J, Fernández A, De La Cruz J, et al. Isolation of Hughes virus from ticks in Cuba. Acta Virologica. 1982;**26**(3):186-189

[52] Málková D, Holubová J, Cerný JV, Daniel M, Fernández A, de la Cruz J, et al. Estero real virus: a new virus isolated from argasid ticks Ornithodoros tadaridae in Cuba. Acta Virology. 1985;**29**(3):247-250

[53] Belle EA, King SD, Griffiths BB, Grant LS. Epidemiological investigation for arboviruses in Jamaica, West Indies. American Journal of Tropical Medicine. 1980;**29**:667-675

[54] Butler JF, Gibbs EPJ. Distribution of potential soft tick vectors of African swine fever in the Caribbean region (Acari: Argasidae). Preventive Veterinary Medicine. 1984;**2**(1-4):63-70

[55] Hess WR, Endris RG, Haslett TM, Monahan MJ, McCoy JP. Potential arthropod vectors of African swine fever virus in North America and the Caribbean basin. Vet. Parasitology. 1987;**26**:145-155

[56] Endris RG, Haslett TM, Hess WR. Experimental transmission of African swine fever virus by the tick Ornithodoros (Alectorobius) puertoricensis (Acari: Argasidae). Journal of Medicine Entomologiste. 1991;**28**:854-858

[57] Pérez-Eid C. Les tiques: identification, biologie, importance. Lavoisier: Google Books Publisher; 2007

[58] Kazimírová M, Štibrániová I. Tick salivary compounds: their role in modulation of host defenses and pathogen transmission. 2013

[59] Rodríguez-Mallon A, Fernández E, Encinosa PE, Bello Y, Méndez-Pérez L, Ruiz LC, et al. A novel tick antigen shows high vaccine efficacy against the dog tick, Rhipicephalus sanguineus. Vaccine. 2012;**30**(10):1782-1789

[60] Wood CL, Lafferty KD. Biodiversity and disease: a synthesis of ecological perspectives on Lyme disease transmission. Trends in Ecology & Evolution. 2013;**28**(4):239-247

[61] Zhang J, Kelly P, Guo W, Xu C, Wei L, Jongejan F, et al. Molecular detection of Theileria spp. in Livestock on Five Caribbean Islands. BioMedical Research International. 2015;**2015**:e624728

[62] Obregón D, Cabezas-Cruz A, Armas Y, Silva JB, Fonseca AH, André MR, et al. High co-infection rates of Babesia bovis, Babesia bigemina, and Anaplasma marginale in water buffalo in Western Cuba. Parasitology Research. 2019;**118**(3):955-967