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The haematophagous arthropods (Animalia: Arthropoda) of the Cape Verde Islands: a review

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ABSTRACT

Arthropoda is the most diverse phylum of the animal kingdom. The majority of bloodsucking arthropods of public health concern are found in two classes, Arachnida and Insecta. Mosquitoes, ticks, cattle flies, horseflies and biting midges are the main hematophagous groups occurring in the Cape Verde Islands and whose role in infectious disease transmission has been established. In this literature review, the main morphological and biological characters and their role in the cycle of disease transmission are summarized.

RESUMO

Os artrópodes constituem o mais diverso entre todos os filos do reino animal. É na classe Arachnida e na classe Insecta que encontramos a maioria dos artrópodes com importância na saúde pública. Os mosquitos, os carrapatos, as moscas do gado, os tabanídeos e os mosquitos pólvora são os principais grupos hematófagos que ocorrem em Cabo Verde e possuem clara associação com a transmissão de agentes infecciosos. Nesta revisão da literatura apresentamos os principais caracteres morfológicos e biologicos e o seu papel no ciclo de transmissão de doenças.

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INTRODUCTION

With over a million described species, Arthropoda is the most diverse and species rich clade of the animal kingdom. Five main taxonomic groups are usually recognized: the extinct Trilobitomorpha and the extant Chelicerata, Miriapoda, Hexapoda and Crustacea (Ruppert & Barnes 1994). Because they represent an important source of food, transmit numerous infectious agents and include an array of agricultural pest species, arthropods are widely studied (Chown & Nicolson 2004). Haematophagous arthropods occur in two major groups, i.e. Arachnida (Chelicerata) and Insecta (Hexapoda) (Fig. 1), and are vectors of pathogens worldwide. So far, more than 16,000 haematophagous species have been identified, of which *ca*. 500 are strongly associated with the transmission of infectious agents (Grimaldi & Engel 2005, Lehane 2005). It has been estimated that of infectious diseases worldwide, about 17% are vector-borne. Unfortunately, vaccines for most of these diseases are not available. Therefore, increased emphasis on vector control strategies is required, based upon the selection of proven intervention methods tailored to biological characters and ecological circumstances of local vectors (WHO 2004).

The terrestrial arthropod fauna of the Cape Verde Islands was reviewed by van Harten (1993), while a summary update was recently provided by Arechavaleta *et al*. (2005). In Cape Verde, several vector-borne diseases occur.

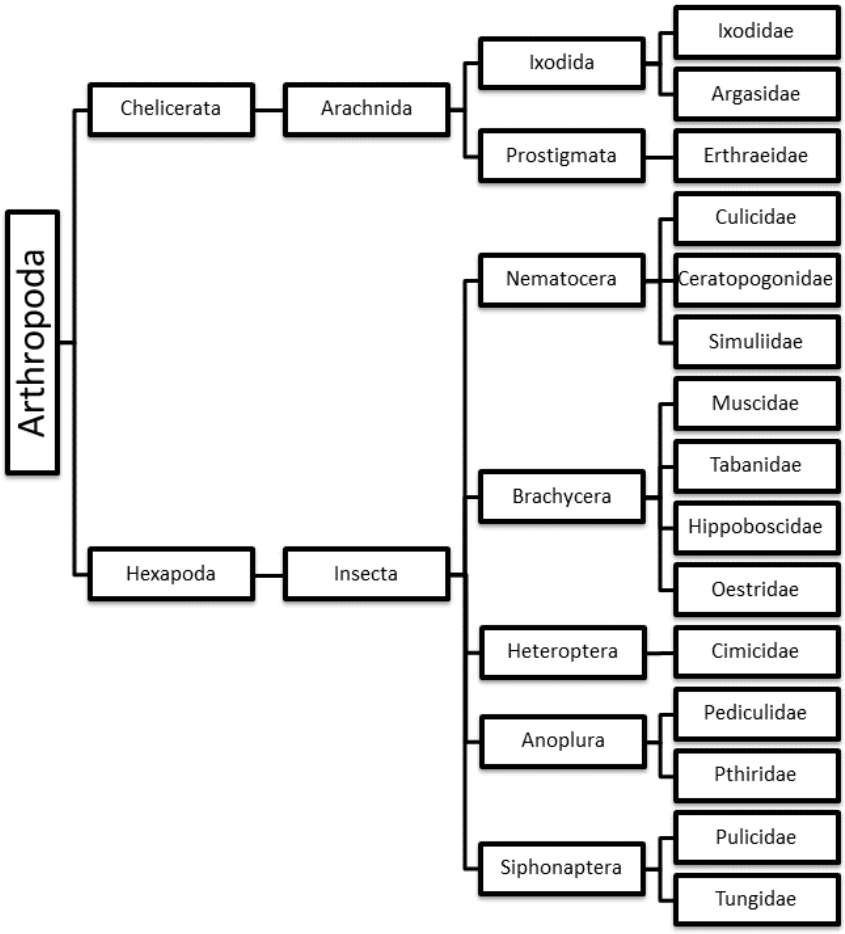

Fig. 1. Main groups of haematophagous arthropods occurring in the Cape Verde Islands. Modified after Lehane (2005) and Estrada-Peña *et al.* (2010).

Many of these are emerging and/or re-emerging as a result of ecological and environmental changes that favour increased vector densities (Gratz 1999). In order to reduce the chance of (re)emergence of arthropod-transmitted diseases, knowledge of local vector populations is crucial in tracking any changes in their biology. This review was conducted in order to draw attention to the importance of bloodsucking arthropods in the Cape Verde archipelago and to better understand their role in the most common infectious agent transmissions. The result will hopefully be useful in making policy decisions and in formulating new strategies in the fight against vector-borne diseases in the Cape Verde Islands.

METHODS

The literature was scanned using the PubMed, Google Scholar and SCIELO databases from January 2013 to December 2013. Combinations of the following key words were used: arthropods, arthropod-borne disease, blood-sucking, haematophagy and Cape Verde Islands. Three different languages (English, French, Portuguese) were used to obtain results. Unpublished reports in national institutions (e.g. Ministry of Health, Ministry of Rural Development, National Library, National Historical Archive) were also scrutinized. Relevant references were organized in a spreadsheet, but only those references actually mentioning bloodsucking arthropods were maintained. Using the same databases, the medical and/or veterinary importance of the references was assessed. Medical and/or veterinary importance was allotted when at least one infectious agent was isolated in the wild or when experimental infection was successfully realized in the laboratory.

RESULTS

The database search resulted in 22 publications (articles, books, reports) mentioning the presence of haematophagous arthropods in the Cape Verde Islands. Of extant bloodsucking arthropods, only Lepidoptera (represented by a single haematophagous species in Southeast Asia) do not occur in the archipelago. Only one study (on mosquitoes) was conducted exclusively by national researchers (Duarte *et al.* 2012). Also focusing on mosquitoes, six publications were published by a combined team of national and foreign workers (Appendix 1). The remaining studies were conducted solely by foreign workers and dealt with ticks, cattle flies, horseflies, biting midges, blackflies, mites, fleas and lice. Publications appeared in 19 journals and other sources (Appendix 1). Up until now, a role in the disease transmission cycle has been confirmed for three taxonomic groups in the Cape Verde archipelago (see group descriptions below).

TICKS (ARACHNIDA: ACARI: IXODIDA)

Ticks are mandatory ectoparasites that parasitize a variety of vertebrates and cause direct and indirect financial loss (Parola & Raoult 2001, Estrada-Peña *et al*. 2010). This large group is subdivided into three families: i) Ixodidae (hard ticks), with over 700 species, including the most important vectors; ii) Argasidae (soft ticks), comprising *ca*. 200 species; iii) Nuttalliellidae, with a single species (*Nuttalliella namaqua*), exclusively found in southern Africa (Parola & Raoult 2001, Basu *et al*. 2012).

Being arachnids, ticks can be easily distinguished from insects by having three pairs of appendices during the immature stage and four pairs as adults, by having the mouthpart transformed into chelicerae and by the absence of wings (Randolph 1998). Only few studies on ticks have been conducted in the Cape Verde Islands (Tendeiro 1954, Meira *et al*. 1957, Kirchner *et al*. 2008, Götsch *et al*. 2009, Gómez-Díaz *et al*. 2012). All except the study by Gómez-Díaz *et al*. (2012) were conducted fully or partially in Santiago Island. Recent studies showed domestic animals to be highly parasitized and it was recommended to prevent transportation of animals (especially dogs) from Cape Verde to Europe (Kirchner *et al*. 2008, Götsch *et al*. 2009). *Ripicephalus sanguineus* was the only species found in recent studies, although other species such as *Amblyomma variegatum*, *Margaropus decoloratus* and *Hyalomma* sp. had previously been reported (Tendeiro 1954, Meira *et al*. 1957), all of them

Ixodidae. The most recent study of ticks conducted in the archipelago (Gómez-Díaz *et al*. 2012) dealt with diversity and genetic structure of *Ornithodoros capensis*, a parasite of seabirds.

LIFE CYCLE

Ticks have a complex life cycle, which – depending on family, species and environmental parameters – may take 2-3 years (Parola & Raoult 2001). Their feeding behaviour is also complex. Hard ticks need a long time to feed (2-15 days) and feeding only takes place once during each stage (larva, nymph and adult). Soft ticks consume several meals per stage but, unlike hard ticks, these may take from a few minutes to a few hours (Vial 2009). Approximately 75% of a hard tick's life cycle is spent while being attached to an animal (Parola & Raoult 2001), whereas soft ticks only attach to animals to feed (Vial 2009).

MEDICAL AND VETERINARY IMPORTANCE

African swine fever (ASF) is a highly contagious and extremely deadly disease in domestic pigs (FAO 2000) and is one of the most important tick-borne ailments in Cape Verde. Ticks of the genus *Ornithodoros* play an important role as vector of the disease (Basto *et al*. 2006). Although there is no consensual view on their precise role in ASF transmission, the persistence of the disease after several veterinary interventions and absence of transmission during various months (Penrith 1998) suggests that vectors or pigs (or both) act as reservoirs.

No human diseases transmitted by ticks are known to occur in the archipelago. Lyme disease is an illness caused by the spirochete *Borrelia burgdorferi s.l.* and is transmitted by hard ticks of the genus *Ixodes* (Karami 2012), but has not been found in Cape Verde so far. Beyond their implication in disease transmission, ticks themselves pose problems to both man and animals because they cause various harmful side-effects to the host, ranging from anaemia caused by massive infestation to allergy due to the inoculation of saliva during blood meals (Lehane 2005).

MOSQUITOES (INSECTA: NEMATOCERA: CULICIDAE)

Mosquitoes are dipteran insects belonging to the family Culicidae, in which three subfamilies are recognized: Anophelinae, Culicinae and Toxirhichitinae (Consoli & Lourenço de Oliveira 1994). Diptera have only one pair of wings, the forewings, while the hindwings are reduced to dumbbell-shaped knobs called halteres. They have long legs and antennae, chipper-shaped mouthparts adapted to suction and generally show marked sexual dimorphism (Consoli & Lourenço de Oliveira 1994, Harbach 2007). In the Cape Verde archipelago, 11 species of mosquitoes occur, representing two subfamilies, i.e. Anophelinae (two species in one genus) and Culicinae (nine species in three genera) (Ribeiro *et al.* 1980, Alves *et al.* 2010, in press). Of these, about half is involved in the transmission of infectious agents, particularly *Anopheles arabiensis*, *Aedes aegypti* and two members of the *Culex pipiens* complex (*C. p. pipiens* and *C. p. quinquefasciatus*) (Alves *et al*. 2010).

LIFE CYCLE

During their life cycle, mosquitoes pass through four stages: eggs, larvae, pupae and adults, of which the first three are aquatic (Consoli & Lourenço de Oliveira 1994, Lehane 2005). The larvae feed mostly on organic particles in water, while pupae only use the energy stored during the larval stage. Adult mosquitoes are terrestrial, this being the stage of reproduction and dispersion. Males feed exclusively on plant fluids, while females need animal (including human) blood for the maturation of their eggs (Consoli & Lourenço de Oliveira 1994).

MEDICAL AND VETERINARY IMPORTANCE

In Cape Verde, mosquitoes have been identified as vector of several infectious agents that cause malaria, yellow fever, lymphatic filariasis and, more recently, dengue (Franco & Menezes 1955, Ribeiro *et al*. 1980; Alves 2004, WHO 2009).

A. arabiensis is the only member of the *A. gambiae* complex occurring in Cape Verde (Cambournac *et al*. 1982, Diallo 2003, Alves *et al*. 2010, Dia *et al*. 2011). In addition to being the only vector of malaria, it was also the vector of *Wulchereria brancrofti*, the infectious agent causing lymphatic filariasis (Franco & Menezes 1955). Since the 1950s, no new cases of lymphatic filariasis have become known in Cape Verde and the decease has seemingly been eradicated in the islands. In a recent study conducted in all inhabited islands, no cases were diagnosed (Benzerroug 2005). Before the 1950s, the annual incidence of malaria was more than 100 cases/1000 inhabitants (Rodriguez *et al*. 2012), but currently only limited and localized transmission occurs in two (Santiago and Boa Vista) of the 10 islands (WHO 2012).

Epidemic dengue fever occurred in Cape Verde in 2009 when *ca*. 21,000 cases were reported (WHO 2009, Monteiro 2010), mainly in Santiago and Fogo Islands. *A. aegypti*, the only vector of dengue described in the archipelago (Alves *et al*. 2010), was also the only vector of yellow fever, being resistant to DDT 4% and also suspected to be resistant to propoxur (Dia *et al*. 2012). During the dry season, it takes advantage of household water containers for its reproduction, thus maintaining high densities over the reproductive period (Duarte *et al*. 2012, 2013). Using experimental infection techniques, it has been shown that *A. aegypti* (ssp. *formosus*) from Santiago Island has a moderate ability to transmit dengue virus serotype 3, but a high susceptibility of becoming infected with and to transmit chikungynya (CHIKV) and yellow fever virus (Vazeille *et al*. 2013).

Despite their role in the transmission of several infectious agents in other countries, the two members of the *C. pipiens* complex that occur in Cape Verde have as yet not been associated with infectious agent transmission. Elsewhere, these taxa are instrumental in the transmission of West Nile virus, *Wulchereria brancrofti*, Rift Valley fever viruses, encephalitis viruses and others (Turell 2012). In Cape Verde, *C. p. quinquefasciatus* was first documented in 1950 (although the presence of *C. pipiens* s.*l.* had already been reported in 1947), while the occurrence of *C. p. pipiens* was established in 1977 (Ribeiro *et al*. 1980). Based on morphological studies of the male genitals, Ribeiro *et al*. (1980) identified hybrids *C. p. pipiens* x *C. p. quinquefasciatus*. This was subsequently confirmed by molecular analysis (Alves *et al*. 2010, Gomes *et al*. 2012). These hybirds have been shown to have the ability to enhance arbovirus transmission in areas where they occur (Gomes *et al*. 2012).

CATTLE FLIES (INSECTA: BRACHYCERA: MUSCIDAE)

Cattle flies are bloodsucking ectoparasites of mammals (especially cattle) in the genus *Stomoxys*. They are similar to houseflies *Musca domestica*, but the distinguishing character is the cattle flies' mouthparts, which are adapted to bloodsucking (Zumpt 1973). Both males and females feed on blood. Three species occur in Cape Verde, i.e. *Stomoxys calcitrans*, *S. niger* and *S. sitiens* (Arechavaleta *et al*. 2005), of which only *S. calcitrans* has anthropophagic preferences.

LIFE CYCLE

During their life cycle, cattle flies go through four stages: egg, larvae, pupae and adult (Lehane 2005). The eggs are laid in groups of 40 to 80. Hatching occurs approximately 24 hours after laying, while larval development time depends on temperature and other environmental conditions. After the last instar, larvae move to dry areas for pupation. Adults live for about 30 days, with males on average living slightly longer than females (Zumpt 1973, Lehane 2005).

MEDICAL AND VETERINARY IMPORTANCE

Cattle flies are characterized by having interrupted blood meals and they can bite several hosts during the course of the same feeding round. This has important epidemiological consequences (Zumpt 1973). Therefore, their economic damage is categorized as either direct or indirect. Direct damage is inflicted by blood spoliation, decrease in immune defense (inducing latent diseases), production loss, diminished weight, etc. Indirect damage is caused by the transmission of viruses, bacteria and other infectious agents (Zumpt 1973, Lehane 2005).

S. calcitrans is a pest species with a worldwide distribution, known for disturbing cattle and causing considerable losses (Lehane 2005). The species can also transmit trypanosomes, mainly *Trypanosoma equinum* in Neotropical countries and *T. evansi* (which causes severe disease in horses and dogs and less severe illness in cattle) and it has a secondary role in the transmission of the infectious agent causing African trypanosomiasis or sleeping sickness (Lehane 2005). The only reported link between *S. calcitrans* and disease in Cape Verde occurred in the past, when its larvae caused myiasis among humans (Azevedo & Moreira 1946).

HORSEFLIES (INSECTA: BRACHYCERA: TABANIDAE)

Horseflies are robust insects (adults: 5-25 mm) with a cosmopolitan distribution. The males feed on plants, while the hematophagous females also feed on nectar (Middlekauff & Lane 1980, Lehane 2005). Their head is larger than the thorax, the mouthparts are of the chipper/sucking type and they have long antennae. The Tabanidae comprise more than 4,300 described species in more than 130 genera and three subfamilies (Tabaninae, Chrysopsinae, Pangoninae) of which the first two are the epidemiologically more important (Lehane 2005). *Atylotus agrestis* is

probably the only species that occurs in the Cape Verde Islands (Arechavaleta *et al*. 2005).

LIFE CYCLE

The life cycle of horseflies includes eggs, larvae (with 6-13 stages), pupae and adults. Egg laying occurs in aquatic environments and eggs hatch 2-3 days after laying. Larvae also need humid environments to survive; they are carnivorous and feed on small invertebrates. Horseflies can remain at the larval stage for up to two years before transforming into pupae. After 1-3 weeks, adults emerge and live for about two months. Mating occurs soon after emergence and females lay their eggs only after having consumed blood meals (Middlekauff & Lane 1980, Lehane 2005).

MEDICAL AND VETERINARY IMPORTANCE

Horseflies possess some characteristics that favour the transmission of infectious agents: only few species are autogenous (most require a blood meal for egg maturation), they are telmophagous (skin deceleration during blood meal), they require a fair amount of blood (and thus have a long engorgement time) and they interrupt their meal due to being chased off because of their painful bite, thus seeking another host (Middlekauff & Lane 1980, Lehane 2005). They may transmit a large variety of infectious agents, including bacteria, viruses, protozoa, filariae and others. Anthrax, anaplasmoses, Q fever, trypanosomiasis, filariasis, encephalitis and African swine fever are some of the diseases transmitted (Lehane 2005). Because some of these diseases occur in Cape Verde and due to the fact that *Atylotus agrestis* is associated with the transmission of some infectious agents (Desquesnes & Dia 2003a, 2003b), further studies are needed to clarify the role of this species as a vector in the archipelago.

BITING MIDGES (INSECTA: NEMATOCERA: CERATOPOGONIDAE)

Biting midges are small (1-4 mm) flies of the family Ceratopogonidae, having composed eyes, chipper-shaped mouthparts, short legs and the abdomen divided into 10 segments (Mellor *et al.* 2000). With the exception of New Zealand, Patagonia, the Hawaiian Islands and the polar regions, they have a worldwide distribution. The genus *Culicoides* includes *ca*. 1,400 species of which 96% engage in bloodsucking (females only). They parasitize mammals (including humans) and birds (Mellor *et al.* 2000, Zimmer *et al*. 2008). *C. imicola* – the main vector of African horse sickness virus (AHSV) and Bluetongue virus (BTV) in Africa – *C. schultzei* and *C. nivosus* occur in the Cape Verde archipelago (Boorman & van Harten 1992).

LIFE CYCLE

The *Culicoides* life cycle includes eggs, four larval stages, pupae and adults. The immature stages require humid places to survive (Kettle 1977, Mellor *et al.* 2000). Breeding sites are similar to those of mosquitoes. Eggs are laid at the substrate surface and, depending on species and environmental conditions, hatching occurs 2-7 days after laying (Mellor *et al.* 2000). Larvae feed on vegetal debris, but some species are predators. Pupae can be found moving free in the water or fixed on the substrate. Depending on the species, adults are active during daylight or twilight, possess only limited capacity for flight and dispersal and are generally passive (Kettle 1962, 1977, Mellor *et al.* 2000).

MEDICAL AND VETERINARY IMPORTANCE

Worldwide, more than 50 arboviruses have been isolated from *Culicoides*, sometimes playing a secondary role in the transmission cycle (Mellor *et al.* 2000). Many species transmit infectious agents causing diseases in animals, but only few of them in humans. Among infectious agents transmitted, Rift Valley fever (RVF) virus, African horse sickness (AHS) virus, bluetongue virus (BTV), equine encephalitis viruses and epizootic hemorrhagic disease (EHD) virus are some examples (Mellor *et al.* 2000, MacLachlan & Guthrie 2010). Two of these agents, AHSV and BTV (Orvivirus, Reoviridae), cause diseases of significant international impact and have been reported in the Cape Verde Islands (Sellers *et al*. 1977, Boorman & van Harten 1992). AHSV is a non-contagious disease that causes 90% mortality in infected horses and has been introduced in Cape Verde from Senegal (Sellers *et al*. 1977, MacLachlan & Guthrie 2010). Nine serotypes of AHSV that occur in Africa are transmitted by *C. imicola* and *C. bolitinos* (MacLachlan & Guthrie 2010).

OTHER TAXA

A single species of black fly (Nematocera: Simuliidae), *Simulium ruficorne*, occurs in the Cape Verde archipelago (Arechavaleta *et al*. 2005). Worldwide, there are about 1,800 species of black flies in 25 genera, of which four are of public health concern: *Austrosimulium*, *Cnephia*, *Prosimulium* and *Simulium* (Lehane 2005).

These black flies transmit *Onchocerca volvulus*, which causes onchocerciasis in Africa, but in Cape Verde *S. ruficorne* has as yet not been shown to be a vector of infectious agents.

Not surprisingly, *Cimex hemipterus* (Heteroptera: Cimicidae), the common bedbug, also occurs in Cape Verde (van Harten 1993, Arechavaleta *et al*. 2005). Both sexes are hematophagous and preferably bite at night (Lehane 2005). Although they are suspected of transmitting infectious agents, the role of bedbugs in spreading them is not clear and there is no clear evidence for their involvement in the transmission of disease agents (Delaunay *et al*. 2011).

Both Hippoboscidae (louse flies) and Oestridae (botflies) occur in the Cape Verde archipelago (van Harten 1993, Arechavaleta *et al*. 2005). Van Harten (1993) cited three species for the archipelago: *Hippobosca rufipes, H. equine* and *Olfersia aenescens*. Worldwide, more than 200 species have been described and several of them have been implied in the transmission of infectious agents (e.g. Rahola *et al.* 2011). *Oestrus ovis* is the only species of botfly occurring in Cape Verde and it has been implicated in causing myiasis in several species elsewhere in the world (Denion *et al.* 2004).

Although many species of mites (Siphonaptera) have been confirmed to occur in the Cape Verde Islands (Mahunka 1991, Arechavaleta *et al*. 2005, Haitlinger 2009), only Eryrthraeidae (*Leptus salicus*, *L. korneli*, *Erythraeus capeverdensis*) may have some degree of hematophagous habits. Although few data are available for these species, it has been shown elsewhere that *Balaustium* mites (Eryrthraeidae) have very generalized feeding habits, including references to attacks on humans causing dermatitis (Newell 1963, Ido *et al*. 2003).

It appears that all taxa of lice (Anoplura) that affect humans occur in the Cape Verde archipelago, i.e. *Pediculus humanus* (Pediculidae) and *Pthirus pubis* (Pthiridae) (van Harten 1993, Arechavaleta *et al*. 2005). Louse-borne diseases affect all levels of society, but they are most common under poor hygienic circumstances and extreme poverty. Of the two, only *P. pubis* is associated with sexual activity (Brouqui 2011).

Among the 2,000 species of fleas (Siphonaptera) that have been described (Krasnov 2008), at least four occur in the Cape Verde archipelago, i.e. *Ctenocephalides felis*, *Pulex irritans* and *Echidnophaga gallinacea* (Pulicidae) and *Tunga penetrans* (Tungidae) (Gomes 1969, Arechavaleta *et al*. 2005). *P. irritans* and *T. penetrans* have a preference for human blood (Lehane 2005, Krasnov 2008). They are potential vectors of numerous infectious agents, among them viruses and bacteria, and especially *Yersinia pestis*, the causal agent of Black Death (Lehane 2005, Krasnov 2008).

CONCLUSIONS

Although many bloodsucking arthropods, including known vectors, occur in the Cape Verde Islands, only few studies have been carried out on their biology and role in disease transmission in the archipelago. Most studies have largely or exclusively been carried out by foreign researchers, illustrating the need to encourage local research teams to study the biology of these species, which include several taxa imposing serious threats to public health, and obtain a better understanding of their environmental requirements in Cape Verde.

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APPENDIX 1. Haematophagous arthropods of the Cape Verde Islands and sources used in this review.

Taxonomic group	**Authors**	**Source**	**Taxa**	**Researchers (Cape Verde and/or Foreign)**
Mosquitoes (Insecta: Nematocera: Culicidae)	Ribeiro *et al*. (1979)	Journal	*Anopheles gambiae s.l.*	Foreign
	Ribeiro *et al*. (1980)	Book	*Aedes aegypti*, *Ae. caspius meirais*, *Anopheles gambiae s.l.*, *An. pretoriensis*, *Culex bitaeniorynchus* (Syn. *Cx. ethiopicus*), *Cx. p. pipiens*, *Cx. p. quinquefasciatus*, *Culiseta longiareolata*	Foreign
	Cambournac *et al*. (1982)	Journal	*Anopheles arabiensis*	Foreign
	Cambournac *et al*. (1984)	Journal	*Culex tigripes*	Foreign/CV
	Diallo (2003)	Report	*Anopheles arabiensis*, *An. pretoriensis*, *Aedes aegypti*, *Culex pipiens s.l.*	Foreign
	Alves *et al*. (2010)	Journal	*Aedes aegypti*, *Ae. caspius*, *Anopheles arabiensis*, *An. pretoriensis*, *Culex bitaeniorynchus* (Syn. *Cx. ethiopicus*), *Cx. perexiguus*, *Cx. p. pipiens*, *Cx. p. quinquefasciatus*, *Cx. pipiens s.l.* hybrids, *Cx. tigripes*, *Culiseta longiareolata*	CV/Foreign
	Dia *et al*. (2011)	Report	*Anopheles arabiensis*, *An. pretoriensis*, *Aedes aegypti*, *Ae. caspius*, *Culex bitaeniorynchus* (Syn. *Cx. ethiopicus*), *Cx. pipiens s.l.*, *Culex sp.*	Foreign/CV
	Dia *et a*l. (2012)	Journal	*Aedes aegypti*	Foreign
	Duarte *et al*. (2012)	Journal	*Aedes aegypti*, *Anopheles gambiae s.l.*, *Culex* sp.	CV
	Vazeille *et al*. (2012)	Journal	*Aedes aegypti* ssp. *formosus*	Foreign/CV
	Duarte *et al*. (2013)	Journal	*Aedes aegypti*	CV/Foreign
	Alves *et al*. in press	Journal	*Culex tritaeniorhynchus*	CV/Foreign

APPENDIX 1 continued.

Ticks (Arachnida: Ixodida)	Tendeiro *et al*. (1954)	Journal	*Amblyomma variegatum*	Foreign
	Meira *et al*. (1957)	Journal	*Amblyomma variegatum, Hylomma sp., Margaropus decoloratus, Rhipicephalus sanguineos*	Foreign
	Kirchner *et al*. (2008)	Journal	*Rhipicephalus sanguineos*	Foreign
	Götsch *et al*. (2009)	Journal	*Rhipicephalus sanguineos*	Foreign
	Gómez-Díaz *et al*. (2012)	Journal	*Ornthodoros capensis*	Foreign
Cattle flies (Insecta: Brachycera: Muscidae)	Arechavaleta *et al*. (2005)*	Book	*Stomoxys calcitrans, S. sitiens, S. niger*	Foreign
Horse flies (Insecta: Brachycera: Tabanidae)	Arechavaleta *et al*. (2005)	Book	*Atylotus agrestis*	Foreign
Biting midges (Insecta: Nematocera: Ceratopogonida)	Boorman & van Harten (1992)	Journal	*Culicoides imicola, C. schultzei, C. nivosus*	Foreign
Other taxa	van Harten (1993)	Journal	*Simulium rificorne, Ctenocephalides felis, Echidnophaga galinácea, Pulex irritans, Tunga penetrans, Pediculus humanus, Pthirus pubis, Cimex hemipterus, Hippobosca rufipes, H. equina, Olfersia aenescens, Oestrus ovis*	Foreign
	Haitlinger (2009)	Journal	*Leptus salicus, L. korneli, Erythraeus capeverdensis*	Foreign

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