SCIENTIFIC REPORT submitted to EFSA

Scientific review on ticks and tick-borne diseases[1]

Prepared by Ilaria Pascucci[a], Nitu Pages[b], Dominique Martinez[c], Frédéric Stachurski[c]

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Affiliations:

[a]Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise "G. Caporale" (IZSA&M);

[b]Centre de Recerca en Sanitat Animal (CReSA);

[c]Centre de Cooperation Internationale en Recherche Agronomique pour le Développement (CIRAD)

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Scientific reviews on Classical Swine Fever (CSF), African Swine Fever (ASF) and African Horse Sickness (AHS), and evaluation of the distribution of arthropod vectors and their potential for transmitting exotic or emerging vector-borne animal diseases and zoonoses

Scientific review on ticks

CFP/EFSA/AHAW/2007/02

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Crimean-Congo Haemorrhagic fever (CCHF) introduction, list of the main vectors and role of ticks in the transmission

Ticks were suspected of transmitting Crimean-Congo hemorrhagic fever (CCHF) virus (CCHFV) shortly after the disease was formally described in the mid-1940s and inoculation of tick suspensions into human volunteers confirmed that ticks contained a filterable agent that caused CCHF. CCHFV was detected in *Hyalomma marginatum* ticks shortly after the disease was described. Since the initial studies in the1940s, CCHFV has been isolated from ticks in several occasions *(*Hoogstraal, 1978*)*, and to date CCHF virus has been isolated from at least 30 species of ticks, both argasids and ixodids, but only members of three ixodid genera, namely *Dermacentor*, *Hyalomma* and *Rhipicephalus* have been shown to be capable of transmitting infection trans-stadially and trans-ovarially and to another animals. In turn these animals can themselves acquire infection from infected tick (Hoogstraal,1956 , Swanepoel,1998, Swanepoel *et al.,1998*)
However the mere isolation of virus from an arthropod does not incriminate it as an actual vector. Although relatively few studies have examined the ability of ticks to actually transmit CCHFV, those that have examined vector competence have consistently shown that ixodid (hard) ticks, particularly members of the genus *Hyalomma* (Table 1, Turrel, *2*007), are highly susceptible to infection with CCHFV and that infected ticks can transmit this virus by bite . The most part of the evidence suggests that *Hyalomma spp.* are the principal vectors, and the known distribution of the virus broadly coincides with the global distribution of these ticks. Infection with the virus is acquired by *Hyalomma spp*. feeding on an infected host. In contrast, several studies indicate that argasid (soft) ticks are not competent CCHFV vectors. *Hyalomma* ticks are mainly abundant in warm, arid, and semiarid, generally harsh lowland and middle altitude biotopes, and those with long dry seasons (Horak *et al., 2001*).

HYALOMMA MARGINATUM

Hyalomma marginatum is a hard tick species complex occurring in southern Europe, southern Asia and most of Africa. It is characteristic of steppe, savanna and lightly wooded hill and valley biotopes with fairly low humidity. *H. marginatum* is a two-host species moulting from larva to nymph on its first host (especially hares, hedgehogs and ground-dwelling birds) and infesting the second host (mainly sheep, goats, swine, cattle and horses) as an adult. As an ixodid tick, it is a slow feeder spending several days on its host while firmly attached by its hypostome. The extraordinarily long duration of host attachment during the preimaginal development (12–26 days) enables the passive transport of the immature *Hyalomma* stages by migrating birds over hundreds or even thousands of kilometers (Rechav, 1987, Manilla, 1998)
There are four *H. marginatum* subspecies which differ in their geographical distribution: *H. m. turanicum*, *H. m. isaaci*, *H. m. rufipes*, and *H. m. marginatum*. The only European subspecies is *Hyalomma marginatum marginatum.*
Hyalomma marginatum subspecies are the most important vectors of CCHV (Merck, 2008)

HYALOMMA MARGINATUM MARGINATUM

Ecobiology

Hyalomma marginatum marginatum is a two-host tick well adapted to different climatic zones: arid, sub-arid, sub-humid and humid.
From area to area, its biotope is represented by different types of vegetation. This species has a great capacity to support a wide range of temperature and humidity conditions.

Geographic range

Hyalomma marginatum marginatum inhabits the Mediterranean climatic zone as well as steppe and foothill landscapes (southwestern Palaearctic Region) from the Caspian Sea to southern Ukrainia and Bulgaria, and spreads westward to Spain, Portugal, and Marocco and Algeria (Manilla,1998) .
Hyalomma marginatum marginatum in Turkey is the most important vectors of CCHF. It seems to be geographically restricted to parts of the middle Black Sea region of Turkey (Tonbak *et al.*, 2006).

Ethology.

Immature stages of *Hyalomma marginatum marginatum* are common parasites of wild and domestic birds, mainly passeriformes but also falconiformes, galliformes, gruiformes, charadriformes, strigifromes, coraciformes, as well as European brown hares *(Lepus europeus*), hedgehogs, wild ungulates. Adults are mainly found on domestic and wild ungulates *(Manilla,1998,* Ruiz-Fons *et al.,2006).*

Seasonal dynamic.

Adults are characterized by a peak of activity during hot season. However, they remain on animals during the whole season.

Control.

An effective control could be reached only for adults by localized acaricide treatment. *Hyalomma marginatum marginatum* is difficult to control on livestock even by regular acaricide application as engorged nymphs are continuously being brought in from other areas by birds.

HYALOMMA MARGINATUM RUFIPES

Identification.

Adults *Hyalomma marginatum rufipes* are large ticks with dark-brown bodies, long mouthparts, a heavily punctated scutum, beady eyes, and long, red and white banded legs . They differ from

H*yalomma truncatum*, that is present in the same geographic area, in that the whole scutum is punctated and in the males it is more circular than the rather elongate shape of the latter tick. While *H. marginatum rufipes* differ *H. marginatum marginatum* for the more hairy spiracular plate. However, it is virtually impossible to distinguish between the species by means of the naked eye *(*Norval and Horak, 2004, Manilla,1998*).*

Ecobiology.
H. marginatum rufipes has a two-host life cycle, which under field conditions in South Africa takes a year to complete *(*Horak, 1982*).*

Geographic range. This tick is widely distributed in sub-saharian Africa (ethiopian biogeografic region), and appears to be absent only from the winter rainfall areas of the Western Cape Province, the mountainous areas of Lesotho and KwaZulu-Natal where snow falls in winter, and some humid, subtropical habitats along the east coast and in the north-east. It is also present in the drier regions of the southern and north-western provinces of Mozambique, south-eastern and north-western Botswana, central and northern Namibia, southern Angola, most of Zimbabwe, southern and western Zambia, central and north-eastern Tanzania, central and southern Kenya, western Burundi, eastern Uganda, and in Somalia, Sudan, Ethiopia and in West Africa (Norval and Horak, 2004, Horak,1998, Mattioli *et al.*,1997)
Isolate populations have been insediate also along Nile river valley and in southern part of the Volga river valley, it is sporadically reported also in Mediterranean area probably introduced by migratory birds. Parasitism of birds by the immature stages undoubtedly contributes to the extensive distribution of this species *(*Pegram *et al., 1981*, Manilla,*1998* , Norval and Horak, *2004).*

Ethology.
Adults parasitize domestic and wild ungulates, showing a preference for the larger species. They attach mainly in the hairless peri-anal region and on the lower perineum and genitalia. The immature stages are parasitic on hares, particularly scrub hares *(Lepus saxatilis)*, as well as on ground-frequenting birds (Norval and Horak, 2004, Walker,1974)

Seasonal dynamic. The adults are most numerous in the early part of the wet season and the immature stages in the dry season.

Control. Control can be accomplished by localized acaricide treatment. *Hyalomma marginatum rufipes* is difficult to control on cattle herds even by regular acaricide application as engorged nymphs are continuously being brought in from other areas by birds (Norval and Horak, 2004).

HYALOMMA TRUNCATUM

Identification.
Adults of *Hyalomma truncatum* are medium-size d ticks with long mouthparts and dark-brown bodies, beady eyes, and long, red and white banded legs. The posterior surface of the scutum in

males is characterized by a depression containing numerous large punctations, otherwise it is comparatively smooth (Norval and Horak, 2004).

Ecobiology.

Hyalomma truncatum has a two-host life cycle, which normally takes a year to complete under field conditions in South Africa.

Geographic range.

This tick is adapted to dry climates of sub-Saharian Africa.

It is absent in Lesotho and, with the exception of the Eastern Cape, the eastern half of the Free State, south-eastern Gauteng and Mpumalanga, and southern KwaZulu-Natal, it is present throughout South Africa, Zimbabwe and much of Mozambique. It is also present in south-eastern and north-western Botswana; central and northern Namibia; southern Angola; western, southern, central and eastern Zambia; central and southern Malawi; south-western and north-eastern Tanzania; southern, central and western Kenya; and eastern Uganda (Howell *et al.*, 1978, Norval and Horak, 2004, Santos Dias, 1993). It also occurs in many countries in north-eastern, central and west Africa (Mattioli *et al.*,1997, Pegram *et al.*, 1981). At a local level the abundance of *H. truncatum* is influenced by the abundance of hares, which are the preferred hosts of the immature stages (Horak *et al.*, 2001).

Ethology.

The preferred hosts of the adults are large ungulates, both domestic and wild. They attach in the tail switch, around the anus, on the lower perineum, and on the legs, including around the feet.The immature stages feed on hares, mainly scrub hare *(Lepus saxatilis)* and on certain rodents, particularly gerbils (Norval, 1982).

Seasonal dynamic.

Adults occur in the greatest numbers in the late wet summer months and the immature stages in the dry autumn to spring months (Horak,1982).

Control.

Hand-dressing of the preferred attachment sites with an acaricide will assist in controlling the adults. It is impractical to control the immature stages because of their preference for hares and rodents.

Genetic resistance has been described in West African indigenous cattle; studies conducted in N'Dama and Gobra zebu cattle in The Gambia showed the former to possess a higher degree of resistance than Gobras against adult ticks of two genera characterized by long hypostome, such as *A. variegatum*, *H. truncatum* and *H. marginatum rufipes*. N'Dama appears to be a unique breed in that it exhibits resistance to several parasitic diseases, including helminths, tse tse transmitted trypanosomosis and tick borne pathogens infections when compared to other cattle breeds in West Africa, suggesting that the use of this cattle will be of benefit to limit the use of chemicals in traditional farming (Mattioli *et al.*, 2000).

Summary as provided by the authors:

- For the highly contagious peculiarity and for the severity of the symptoms Crimean Congo Hemorrhagic fever is considered globally one of the most important emerging zoonosis
- The presence and the spread of *Hyalomma* species, and particularly of bird associated species belonging to *H. marginatum* group, in Europe, Asia and Africa and the presence of the disease in the Balkans are the main risk factors for introduction and spread of the disease in Europe.
- Although CCHF has been known from 1944 several aspects of the transmission cycle need to be better understood.
- For example, the role, if any, of ticks other than *Hyalomma marginatum marginatum* needs to be more carefully assessed, furthermore since in the global warming era the role of climatic factors will become increasingly important, geographic information systems and remote sensing using satellite are very useful tools to investigate the relationship among them and the influence on the disease dynamics.
- Development of predictive models validated by data collected during real epidemics will be an effective approach for prevention and control the disease.

Tropical Theileriosis introduction, list of the main vectors and role of ticks in the transmission

Tropical theileriosis is an infectious disease of cattle caused by the protozoan *Theileria annulata*, which is transmitted by ticks of the genus *Hyalomma*.
Fifteen *Hyalomma spp*. have been incriminated as vectors of tropical theileriosis, although some of these may be synonyms for identical species. Among the most important are *H. detritum*, *H. anatolicum*, *H. excavatum* and *H. dromedarii*. The infection is generally transmitted trans-stadially, but infected male ticks that accidentally become detached from one host may reattach to another and, thus, transmit the disease to more than one animal. Furthermore not all *Hyalomma spp*. that transmit *T. annulata* under experimental conditions are vectors in nature, because feeding on cattle is a necessary requirement. *Theileria annulata* is actually maintained in nature by a cattle–tick–cattle cycle, feeding of immature stages of some species of *Hyalomma* on hosts other than cattle does not allow the establishment of the *T. annulata* life cycle (Berkvens,1998).
Tropical theileriosis occurs in northern Africa, including the Sub-Saharan territories, Sudan and Eritrea, southern Europe, the Near and Middle East, Central Asia, India and northern China. The extent of its distribution in the Far East, where it overlaps with *Theileria sergenti* infection. (Pipano and Shkap, 2004)

HYALOMMA DETRITUM

Identification.
Adult *Hyalomma detritum* are medium-sized ticks with long mouthparts, a very dark-brown, smooth, shiny scutum, and long reddish or yellowish-brown legs which may have paler bands.
This tick species is the most abundant cattle ixodid found in the sub-humid and the semi-arid zones with a prevalence of 84% and 82.02% of tick population collected on cattle during one year, respectively. However, a small number of ticks is collected on cattle, in some farms, in the arid and humid zones. In the humid area, *H. detritum* population represents only 4% of tick sampling.
H. detritum, a stable dwelling tick, is strongly associated with cattle. However, it can be found in areas surrounding the cowshed. Nymphs of *H. detritum* are usually found in wall crevices and cracks, under the rocks and even under the dried manure where they hibernate in the farm.

Ecobiology .
H.detritum has a two-host life cycle with the adults feeding in summer and the larvae and nymphs in autumn. The detached engorged nymphs undergo a winter diapause and moult to adults the following summer. The life cycle is often associated with barns, stables and sheds, and livestock become infested when they are housed in these structures. This tick species is the most abundant cattle ixodid found in the sub-humid and the semi-arid zones (Boattour *et al.*, 1999).

Geographic range.
This *Hyalomma* is spread central Asia from northern India to middle east, in southern Balkans, southern Europe and along the Mediterranean coast of Africa as far as Algeria and Morocco in the

west. It is also present in Sub-Saharan Africa in North-Central Sudan, which it may have invaded from the Red Sea coast or via the Nile river valley (Manilla,1998).

Ethology.
Domestic cattle and horses are the most common hosts, but sheep, goats and camels may also be infested. All stages of development feed on the same host species. Adults attach on the inner thighs, udder, scrotum and perineum of cattle.

HYALOMMA ANATOLICUM

Identification.
The study of the ecology, development and epizootic role is very difficult by the presence of two subspecies: *Hyalomma. anatolicum anatolicum* and *Hyalomma. anatolicum excavatum*. The taxonomic status these ticks is not even uniformly agreed on today. Their occurrence within the same geographical area, the presence of hybrid forms, morphological variations and impossibility of distinguishing the larvae and nymphs of both subspecies complicate this work. Ecological conditions apparently determine which form will develop in a given location *(Apanaskievich, 2003,* Liebish *et al., 1989).*

Ecobiology and Ethology.
H. a. excavatum was always to undergo a three – host type of development while *H. a. anatolicum* usually developed as a two - host type.
The numerous *H a. anatolicum* immatures and adults that often parasitize livestock cause unthriftiness also wild ungulates *(*Ruiz-Fons *et al.*, 2006). Immatures of the subspecies *H a. excavatum* (a 3-host parasite) infest chiefly burrowing rodents in somewhat different biotopes in the same environments as *H. a. anatolicum*. Adults of both subspecies may infest the same animal. Distribution of *H a. excavatum* is somewhat more limited than that of *H a. anatolicum*, but its winter season population densities are often greater. In addition to livestock, deer and rabbits serve as hosts.

Geographic range.
H. anatolicum is common in the southern Mediterranean area and also in eastern Africa (Sudan, Somalia and Ethiopia) and central Asia (Rasulov, 2007, Ahmed *et al.*, 2007).

HYALOMMA ANATOLICUM ANATOLICUM

Ecobiology.

H. a. anatolicum no longer can be considered a field tick form. With the adaptation to cattle as their host animal, these ticks have become adapted to the biotope "stall" and have adopted a type of nest parasitism as a life style.

Ethology.
Cattle, buffalo and dromedaries usually function as hosts for *H. anatolicum anatolicum* Ecological conditions apparently determine which form will develop in a given location. Preliminary observations in the field in Egypt and in Syria indicate that the adults of the larger subspecies (*H. a. excavatum*) parasitize mainly on dromedaries and prefer an extremely arid environment. Populations of the smaller *H. a. anatolicum*, however, are found more often in irrigated areas. Here, cattle are the more available host species and the ticks become vectors of *T. annulata.*
Morphologically distinct specimens of *H. a. anatolicum* from cattle and of the *H. a. excavatum* from dromedaries parasitized in various sequences of mice, rabbits, cattle and dromedaries. Larvae were found to parasitize on the head (eyelids, ears), nymphs on the eyelids, between the bases of the horns and on the dorsal neck line back to the withers. Adults were usually located on the medial sides of the legs, on the scrotum or udder and the inguinal region. A large number of males were found on the feet of the cattle, crown ridge, pastern and between the cleats (Liebish *et al.*, 1989).

Seasonal dynamic.
The highest rate of the infestation of cattle by *H. a. anatolicum* occurred in February to March and in September. Larvae were especially active in March / April and in October. Nymphs were most common in May/June and October / November**.**

Control.
The following practical suggestions for the prophylaxis and control of tick infestation of cattle result from these observations:
The infection of the cattle *T. annulata* by *H. a. anatolicum* is not related to the pasturing of cattle. It can occur in the stalls and corrals even of intensive modern cattle farms.
The control of ticks with acaricides must include the treatment of the animals as well as the stalls**.**
The activity of *H. a. anatolicum* adults is of a bimodal nature. In order to prevent the development of egg laying females, the control measures must be carried out in April and October, when the larvae and nymphs are active.
There is some use of spray treatments of the walls of dairy houses to control *Hyalomma* ticks, but it is more effective in the long term to render the walls smooth with mortar (Latif and Walker, 2004).

HYALOMMA ANATOLICUM EXCAVATUM

Ethology.
Adults are esophilous mainly found on horses, camels, buffalo, antelope but also on dogs, fox and jackals. Endophilous immature stages feed mainly on rodents and lagomorphs**.**

Seasonal dynamic.
Depending on climatic conditions the life-cycle last 1or 2 years. Usually adults are active during between December and August, while immature stages are mainly found during spring.

HYALOMMA DROMEDARII

Identification.
Adult *Hyalomma dromedarii* are large ticks with long mouthparts. The scutum of the male is characterized by posterior grooves and ridges. The colour of these tick s varies from yellow-brown to nearly black. The legs are paler than the scutum and may be ringed by paler bands.

Ecobiology, geographic range and ethology.
Hyalomma dromedarii has a two or a three-host life cycle. The preferred hosts are camels, but cattle, sheep, goats and horses may also be infested. Adults attach on the inner thighs, udder and scrotum of camels. The larvae and the nymphs feed on small burrowing animals and hares, but the nymphs may also infest camels, cattle and horses.The larvae may feed and moult to nymphs on small mammal or on hare and the adults feed on large herbivores (Hoogstraal and Kaiser, 1958). Larvae may feed on small mammal hosts, drop off and moult to nymphs, which can then either attach to other small mammal hosts or feed on the same large animals as the adults. The life cycle appears to be continuous throughout the year. This tick is common wherever camels occur in the Far, Middle and Near East. It is also present in Mauritania in West Africa and in Morocco, Algeria, Tunisia and Libya in North Africa and is well-adapted to an arid and even desert environment. In north-eastern and East Africa it occurs in Sudan, Eritrea, northern, eastern and southern Ethiopia, northern Kenya and north-eastern Uganda (Norval and Horak, 2004).

Summary as provided by the authors:

- Bovine tropical theileriosis (*Theileria annulata* infection) is of great economic importance to several countries of Asia and Africa where millions of cattle are at risk of exposure to this disease.
- The presence of the vectors in southern Europe is the main risk factor for the spread Bovine tropical theileriosis.
- As with other tick-borne diseases, tropical theileriosis can be prevented by control or eradication of the *Hyalomma* vectors that are well adapted to living within the cattle housing.
- Future research identified by the authors to control theileriosis vectors will focus on the study of ecobiology and on the sensitivity to acaricides of some *Hyalomma* spp. and on development of adequate acraricide treatment regimes. The time schedule for acaricide treatment should take into account the effective residual activity of the acaricide and the very short period required for maturation of *T. annulata* sporozoites in attached ticks.

Tab.1 Ticks as vectors of CCHFV (Turrel, 2007).

	Detection of CCHFV from ticks collected in nature	**Replication and transmission of CCHFV by ticks that were inoculated intracoelomically in the laboratory**	**Replication and transmission of CCHFV by ticks that were orally exposed to CCHFV in the laboratory**	**Vertical transmission**
Amblyomma variegatum (Fabricius	Reported	Reported	Not reported	Reported
Dermacentor daghestanicus (Olenev)	Reported	Not reported	Not reported	Not reported
Dermacentor marginatus (Sulzer)	Reported	Not reported	Reported	Not reported
Dermacentor niveus (Neumann)	Reported	Not reported	Not reported	Not reported
Haemaphysalis parva (Neumann)	Reported	Not reported	Not reported	Not reported
Haemaphysalis punctata (Canestrini and Fanzago)	Reported	Not reported	Not reported	Not reported
Hyalomma anatolicum anatolicum (Koch)	Reported	Not reported	Not reported	Not reported
Hyalomma anatolicum excavatum (Koch)	Reported	Not reported	Not reported	Not reported
Hyalomma asiaticum asiaticum (Schulze and Schlottke)	Reported	Not reported	Not reported	Not reported
Hyalomma detritum detritum (Schulze)	Reported	Not reported	Not reported	Not reported
Hyalomma dromedarii (Koch)	Reported	Reported	Not reported	Not reported
Hyalomma impeltatum (Schulze and Schlottke)	Reported	Reported	Reported	Not reported
Hyalomma marginatum impressum (Koch)	Reported	Not reported	Not reported	Not reported
Hyalomma marginatum marginatum (Koch)	Reported	Not reported	Reported	Reported
Hyalomra marginatum rufipes (Koch)	Reported	Reported	Reported	Reported
Hyalomma marginatum turanicum (Pomerantsev)	Reported	Not reported	Not reported	Not reported
Hyalomma nitidum (Schulze)	Reported	Not reported	Not reported	Not reported
Hyalomma truncatum (Koch)	Reported	Reported	Reported	Not reported
Ixodes ricinus (Linnaeus)	Reported	Not reported	Not reported	Not reported
Rhipicephalus annulatus (Say)	Reported	Not reported	Not reported	Not reported
Rhipicephalus appendiculatus (Neumann)	Reported	Reported	Not reported	Not reported
Rhipicephalus bursa (Canestrini and Fanzago)	Reported	Not reported	Not reported	Not reported
Rhipicephalus (Boophilus)decoloratus (Koch)	Reported	Not reported	Not reported	Not reported
Rhipicephalus evertsi (Neumann)	Reported	Reported	Reported	Reported
Rhipicephalus guilhoni (Morel and Vassiliades)	Reported	Not reported	Not reported	Not reported
Rhipicephalus microplus (Canestrini)	Reported	Not reported	Not reported	Not reported
Rhipicephalus pulchellus (Gersticker)	Reported	Not reported	Not reported	Not reported
Rhipicephalus pumilio (Schulze)	Reported	Not reported	Not reported	Not reported
Rhipicephalus rossicus (Yakimov and Kol-	Reported	Reported	Reported	Reported

Yakimova)				
Rhipicephalus sanguineus (Latreille)	Reported	Not reported	Not reported	Not reported
Rhipicephalus turanicus (Pomerantsev)	Reported	Not reported	Not reported	Not reported
Argas persicus (Oken)	Reported	Not reported	Not reported	Not reported
Argas lahorensis (Neumann)	Reported	Not reported	Not reported	Not reported

Nairobi Sheep Disease (NSD) introduction, list of the main vectors and role of ticks in the transmission

Nairobi sheep disease (NSD) is a tick-transmitted viral disease of small ruminants, mainly of sheep, because they are usually more numerous in the areas where the tick vectors, which are principally of the genus *Rhipicephalus*, are found. Goats are kept in the drier semi-arid zones. The disease is characterized by fever, debility and prostration, an haemorrhagic gastroenteritis, abortion and a high mortality. Nairobi sheep disease virus (NSDV) of the family Bunyaviridae is one of the most pathogenic viruses for small ruminants in East Africa. Ticks, mainly of the genus *Rhipicephalus*, serve as invertebrate hosts and vectors of the virus . The common vector of NSDV in East Africa is the brown ear tick (*R. appendiculatus*), but other species, including *Rhipicephalus pulchellus*, *Rhipicephalus simus*, and the tropical bont tick (*Amblyomma variegatum*), can transmit the virus, albeit much less efficiently (Davies and Terpstra, 2004).

Rhipicephalus appendiculatus, in which trans-ovarian and trans-stadial transmission has been shown to occur, is by far the most efficient vector. Locally also *R. pulchellus* appears to be the principal tick vector as in northern Somalia and Ethiopia. Trans-ovarian and trans-stadial transmission of NSDV has been demonstrated to occur but it's not constant, depending on the strain of NSDV involved. Within the same generation of infected *R. appendiculatus* ticks, all stages remain infective, irrespective of the natural susceptibility of subsequent hosts or their immune status. For example, the virus is passed through successive generations of ticks, regardless of the character of the feeding animal hosts, whether they are susceptible and generate a viraemia, or are not susceptible or immune. The tick does not require an infective feed to transmit the virus to successive generations, as was once thought (De Vos,1981) .

The distribution and prevalence of NSDV antibodies in sheep and goats in Kenya and Uganda closely corresponds with the geographic distribution of *R. appendiculatus*. In such endemic areas, there is a situation of enzootic stability where clinical disease is rarely, if ever, seen in the indigenous sheep and goats. Most sheep and goats in endemic areas have antibody to the virus. The high frequency of antibody in endemic area in sheep and goat of different age, reflects a high exposure rate and infection at an early age when the lambs are still protected by maternal immunity. Outbreaks of NSD may occur in endemic areas following the introduction of susceptible animals or whenever tick control measures, which had been strictly applied, are allowed to lapse or fail for some reason (Davies and Terpstra, 2004).

The periodicity of NSD epidemics has varied in Kenya from 7 to 15 years, but the effects that the El Nino and Southern Oscillation phenomena have on weather patterns may alter this in future and epidemics may become more frequent.

East Coast Fever (ECF) introduction, list of the main vectors and role of ticks in the transmission

East Coast fever, which was introduced to Mozambique, Zimbabwe and South Africa in 1901/02, caused mortality of around 95 per cent in the herds of susceptible cattle (indigenous and exotic) to which it spread. It caused serious economic losses, affecting agriculture, mining and commerce, all of which still used ox-drawn transport.

East Coast fever in its classical form is a usually fatal disease of cattle caused by *Theileria parva*. It is transmitted principally by the brown ear tick *Rhipicephalus appendiculatus* and is characterized by the proliferation of lymphoblasts infected with theilerial schizonts throughout the body, particularly in the lymph nodes, lymphoid aggregates, spleen, kidneys, liver and lungs . The disease occurs widely through the range of its main vector in eastern, central, and southern Africa north of the Zambezi river (Loudsbury, 1904).

Theileria parva depends on its vector tick *R. appendiculatus* for transmission from host to host. The potential distribution of East Coast fever is thus restricted to those areas of eastern, central and southern Africa where cattle and tick coexist. In eastern and central Africa, this includes much of Kenya, Uganda, Rwanda, Burundi, the eastern part of the Democratic Republic of Congo, areas of southern Sudan bordering Uganda and much of Tanzania. In southern Africa its range is more limited, and it is confined to the northern and central regions of Malawi, the northern, eastern and central regions of Zambia, and the Tete Province of Mozambique, all lying to the north of the Zambezi River. The disease caused by *T. parva* in the Southern Province of Zambia has been historically referred to as Corridor disease(the buffalo associated form), but it seems likely that it is predominantly cattle-associated, rather than buffalo-associated (Lawrence and Perry, 2004).

The tick vector *R. appendiculatus* is widely distributed throughout the warmer, more humid areas of eastern, central and southern Africa (De Vos,1981).

Within its range its abundance varies considerably, being governed by soil moisture and temperature, presence of suitable habitat and availability of hosts. Areas of ecoclimatic suitability exist where the presence of the tick has yet to be recorded, illustrating that other factors also play a role in determining distribution. Among these is vegetation cover, which influences the microclimate of the habitat of the tick; overgrazing has a marked adverse effect on the tick population. Also important is the livestock production system employed, particularly with respect to how management affects exposure to ticks. Transmission of East Coast fever may be expected to occur freely in areas where ecological factors permit an average total population of not less than 10 to 15 adult ticks per ox (Lawrence and Perry, 2004).

RHIPICEPHALUS APPENDICULATUS

Identification
Brown ear tick, bruinoorbosluis (Afrik .)
Adults of *R. appendiculatus* are medium sized brown ticks with short mouthparts . The legs of the males increase markedly in size from the first to the fourth pair and engorged males have a slender caudal process.
Apart from its importance as vector of diseases, *R. appendiculatus* is also capable of inflicting directly considerable damage, presumably because of the action of a highly toxic secretion . The exact importance of this form of tick toxicosis is unknown, but due consideration should be given to this particular condition because of resultant loss of condition, retardation of growth and even death (Norval and Horak, 2004).

Ecobiology
Rhipicephalus appendiculatus is a three-host tick with a strictly seasonal, single annual life cycle in southern Africa .
This tick survives best in woodland and woodland savannah regions with good vegetation cover. It tends to disappear if overgrazing occurs and it does not survive on open plains. Its distribution may vary with rainfall .
Extensions in the range of the tick vectors occur beyond the usual endemic areas, whenever there are periodic cycles of years with excessive or prolonged rains. These result in vegetational and microclimatic changes that favour marked increases in *R. appendiculatus* populations (Mculloch *et al.,* 1968).

Geographic range
Rhipicephalus appendiculatus is an eastern, central and southern African tick .
Rhipicephalus species are widely distributed with current distributions overlapping within various geographical regions of the subcontinent. This does not necessarily mean that these species are not specialists with regard to their ecological requirements, e.g. *R. appendiculatus* is confined to parts of eastern, central and southeastern Africa *(*Olwoch *et al*,. 2007).
Its distribution extends from southern Sudan, Uganda, south-western Kenya, eastern Democratic Republic of the Congo, Rwanda and Burundi to northern, north-eastern, central and south-western Tanzania. Further south it is confined to the wetter areas, which include the highlands of Malawi, Zambia, Zimbabwe and the Angonia and Chimoio provinces of Mozambique. The extent of its distribution in the coastal areas of Mozambique is unknown. It is also present in eastern Botswana and in Swaziland. In South Africa it occurs in the Limpopo, North West, Gauteng and Mpumalanga provinces, along the east coast of KwaZulu-Natal and nearly throughout the southern Eastern Cape Province .
It was introduced into the south-eastern lowveld of Zimbabwe during the commencement of a wet cycle in 1973, and by 1982 it was estimated that more than 1 million ha of the lowveld was infested.

The tick started to disappear from this region towards the end of a dry cycle in 1983 and by 1985 it could no longer be found (Norval and Perry, 1990, Short and Norval, 1981, Walker, *et al.* 2000) .
In eastern Zambia, *R. appendiculatus* spread southwards between 1972 and 1982 and then westwards during the 1980s and 1990s. It is important to note that on the margins of *R. appendiculatus* distribution, the distribution may expand and contract with seasonal or secular changes in climatic suitability (Norval and Perry, 1990, Short and Norval, 1981).

Ethology
This species has a wide host range . Adults parasitize medium-sized to large ruminants while the immature stages feed on most ruminant species and a variety of other mammals, including equids, carnivores and hares.
Among domestic animals, cattle are the preferred hosts and can become very heavily parasitized with all stages of development. (Baker and Ducasse, 1967). Several wild ruminant species, such as impala *(Aepyceros melampus)*, African buffalo *(Syncerus caffer)*, eland *(Taurotragus oryx)*, male nyala *(Tragelaphus angasii)*, bushbuck *(Tragelaphus scriptus)*, greater kudu *(Tragelaphus strepsiceros)* and sable antelope *(Hippotragus niger)*, can also be heavily infested (Horak *et al*, 1995, Norval *et al.* 1982). Females of nyala usually harbour few adult ticks but they serve as good hosts for the immature stages (Lightfoot and Norval, 1981, Zeiger *et al.* 1998). Adults are mainly attached in the highest numbers in the inner part of the ears of their hosts but are also found on other parts of the body (Baker and Ducasse, 1967, Macleod *et al.*, 1977). The proportion that attaches to the ears varies between host species and is also dependent on the availability of attachment sites on the ears. Larvae and nymphs may attach to the ears as well as to other parts of the body such as the head, legs, neck and dewlap (Baker and Ducasse, 1967) .

Seasonal dynamic
These ticks are frequently seen questing for hosts on blades of grass during the early part of the wet season.
In equatorial Africa the warmer temperatures permit two cycles to be completed each year, and at these latitudes adult diapause does not occur. Only if two complete generations can be guaranteed each year can development proceed directly, otherwise the activity of each tick stage would occur at different seasons each year with no stage coinciding regularly with optimal climatic conditions. In countries close to the equator more than one life cycle can be completed annually and no clear pattern of seasonal abundance may be evident (Kaiser *et al., 1988,* Mculloch *et al., 1968).* In the relatively cool conditions of southern Africa each full direct cycle would take rather more than 6 months to complete and so a period of delay must be introduced to achieve one generation per year with each stage timed to ensure maximum overall survival.
In southern Africa latitudes adults are most abundant during the rainy period in summer (December to April), larvae in the late summer and cool period after the rains (April to August), and nymphs in the winter and early spring (June to October) (Randolph, 1993, Rechav, 1982).
The pattern of seasonal occurrence is regulated by the unfed adults, which enter diapause waiting for the rains start to engage in host seeking (Madder *et al*., 2002).

Surveillance and modelling

A practical means of designing cost-effective tick control strategies is to use models. An ecological model was originally developed in Australia for the one-host tick, *Boophilus microplus.* It has subsequently been modified for three-host ticks and given the name T3HOST. Ecological parameter values and the damage coefficient with respect to live-weight gain for *R. appendiculatus* have been fitted to T3HOSTb4 and it can now be used to simulate population dynamics and control strategies for this tick . These simulations allow the best strategies to be identified prior to the costly and time consuming process of field-testing.

For example, it has been estimated that the most cost-effective strategy for the control of *R. appendiculatus* on Zebù cattle at Lake McIlwaine in the highveld of Zimbabwe is intensive dipping for four months during the wet season (December to March) (Floyd *et al.*, 1987). The reason is that the adults, which cause losses in live-weight gain, are most abundant at this time. Extension of the dipping period could result in increased dipping costs progressively exceeding the value of increased live-weight gain. Shortening the dipping period could cause the value of decreased live-weight gain to progressively exceed the cost of dipping . Climate, geostatistics and satellite imagery have been used as predictive tools for the distribution and for the seasonal abundance of a number of economically important ticks. As more data become available models will be refined and will undoubtedly become increasingly important tools for the design of tick control strategies (Lessard *et al.*, 1990, Norval *et al.*, 1985). These tools could be useful for esophilous ticks on the contrary they are not complete for ticks that have endophilous behaviour

Control

Control measures against ticks and tick-borne diseases were only instituted on a large scale in southern Africa following the introduction of East Coast fever from East Africa. Considerable effort was therefore devoted to find the most suitable strategy to control *R. appendiculatus.* Early attempts at vaccination by the eminent microbiologist Robert Koch and later by Sir Arnold Theiler were largely unsuccessful. However, once it was shown by Lounsbury (1904) that the disease was transmitted by the brown ear tick, *R. appendiculatus*, more successful control measures based on tick control, quarantine procedures, pasture spelling, slaughter, and dipping in arsenic solutions were instituted. Dipping proved to be the most practical and effective measure. It was widely adopted and later made compulsory, but the control of *R. appendiculatus* by dipping only cattle has been shown to be a not easy task (Masika *et al.*, 1997) .

The various stages remain on the host for very short periods (larvae 4-7 d, nymphs 5-11 d, adult females 6-14 d), and thus the efforts of farmers to control this tick are further confounded; the 69 % of adult *R. appendiculatus* attach to the ear pinna, the part of the body which may not always be reached by standard dipping procedures. *R . appendiculatus* is therefore not only well adapted to its natural environment in East and southern Africa, but it is also well equipped to survive the attempts of man to control it (Norval and Horak, 2004).

Different strategies of control can be utilized whether if ECF is present or not. In the absence of ECF, adequate control of adults can usually be accomplished by localized application of acaricides to the ears or head. Larvae and nymphs are considerably less damaging to cattle than adults, and do not require treatment if adequate control of the adults is achieved (Kiwanuka *et al.*, 1998).

In general exotic cattle should receive acaricide protection throughout the summer months, while for Zebù *(Bos indicus)* cattle and indigenous Sanga breeds that are fairly resistant to the tick also fewer acaricide treatments can be effective.
Evidence for a genetic trait for resistance to multihost ticks, such as *R. appendiculatus*, in *B. indicus* breeds is not as strong as for one-host ticks as *Boophlilus* that is hypotesized to be proportionally related to the amount of zebu (*B. indicus*) genes in the breed (Mattioli *et al.*, 2000).
Generally breed tick resistance might vary with the species of infesting tick, heterospecific resistance appears to be low or even absent among different genera of ticks, while a certain degree of cross-resistance is expressed to tick species belonging to the same genus.
Heavy infestations with adult *R. appendiculatus* can also occur on horses, and these may require treatment with acaricides during the summer. Control on other domestic livestock species is unnecessary .
Regular acaricidal treatment of cattle on a mixed cattle and game ranch in Central Province, Zambia, resulted in a significant reduction in all stages of development of *R. appendiculatus* on sympatric impala and on the vegetation of the ranch. Should infestation with adult *R. appendiculatus* become a problem on wildlife in small reserves, control can be achieved by various methods based on the principle of self-application of acaricide (Lightfoot and Norval, 1981).
Although several agents are effective or partially effective for the biological control of ticks it is unlikely that many of these will be commercially available. Nevertheless, under natural conditions these agents may play a significant role in reducing tick numbers .
Domestic chickens are opportunistic predators of ticks .
The indigenous varieties in particular, if allowed to scavenge amongst cattle, can consume considerable numbers of ticks, especially if the cattle are penned to dwellings in the late afternoon and during the early morning.
Moreover the coexistence on the same pasture of wild birds as red and yellow-billed oxpeckers *(Buphagus erythrorhynchus* and *Buphagus africanus* also should be considered as control method. These birds in fact, are virtually obligatory predators of ixodid ticks, take large numbers of these parasites from both domestic cattle and from several wildlife species. The red-billed birds (*Buphagus erythrorhynchus*) favour *B. decoloratus* and *R. appendiculatus* as food items, whereas yellow-billed oxpeckers *(Buphagus africanus)* prefer the latter tick and *Amblyomma spp* (Bezuidenhout *et al.*, 1980). This preference is probably due by the bigger beak of yellow-billed oxpeckers. As an aid to tick control on both wildlife and domestic cattle, red-billed oxpeckers have been reintroduced to several regions in which they originally occurred in South Africa, but from which they had in recent times disappeared (Van Someren, 1951*)*.
Other arthropods can also to be used in the biological control of ticks:
chlacid wasps of the genus *Ixodipahgus* are obligatory parasitoids of ixodid ticks and most species will oviposit and develop only in the nymphal stage of the ticks. Several wasp larvae can successfully develop in a single engorged nymph, which is killed during this process. Two of the seven described species of these wasps occur in Africa, namely *Ixodiphagus hookeri* and *Ixodiphagus theilerae*.

In Kenya adults *Ixodiphagus hookeri*, were released over a period of one year into a field in which there were cattle naturally infested with *A. variegatum* and *R. appendiculatus* (Mwangi *et al.*, 1997).
In addition the field was seeded with nymphs of both tick species. During the period of wasp release 51 per cent of *A. variegatum* nymphs but no *R. appendiculatus* nymphs collected from the cattle were infested (Hu *et al.*, 1998).
Parasitoid entomopathogenic fungi have also been used in several countries for the control of agricultural pests and their use for the control of ticks is currently being investigated at various localities. In Kenya aqueous formulations of the spores of the fungi *Beauveria bassiana* and *Metarhizinnm rurisopliae* induced a high mortality and reduced fecundity and egg hatchability in *R. appendiculatus* feeding on cattle. These formulations also caused mortalities in all life stages of *A. variegatum* and *R. appendiculatus* in the vegetation. The comparative ease with which the spores of these fungi can be produced and artificially disseminated makes them promising potential agents for the control of ticks (Norval and Horak, 2004).

RHIPICEPHALUS PULCHELLUS

R. pulchellus can transmit Nairobi Sheep Disease Virus (NSD) albeit much less efficiently than *R. appendiculatus*

Identification
Zebra tick, yellow-backed tick
Adult *R. pulchellus* are medium-sized to large ticks with a characteristic dark brown-and-ivory pattern on the scutum of the male, while the scutum of the female is predominantly ivory-coloured with anterior dark markings.

Ecobiology and seasonal dynamic
Rhipicephalus pulchellus has a three-host life cycle . The adults appear to be most active during the rainy season.

Geographic range
It is one of the most common ticks present in the Horn of Africa, as well as in and to the East of the Rift Valley from Eritrea in the North to northeastern Tanzania in the south .

Ethology

The adults prefer cattle, on which they may occur in large numbers, as well as camels, sheep and goats as hosts. They attach primarily on the ears and the underside of the body, including the chest, belly, genital and peri-anal areas. Their preferred wild hosts are zebra, black rhinoceros *(Diceros bicornis)*, eland *(Taurotragus orix)* and gemsbok *(Oryx gazella)*. The immature stages feed on these animals as well as on hares .

Control

Strategic control of the adults can be achieved by acaricidal treatment during the rainy season (Walker *et al.*,2000, Norval and Horak, 2004).

Summary as provided by the authors:

- *R. appendiculatus* and disease transmitted is one of the most important cause of economic losses in EastAfrica.
- Since both species are strictly linked to the African environment, their introduction and spread outside Africa are unlikely.
- Being both a three host tick the improvement of the knowledge of ecology and ethology will be fundamental to control them.
- Geographic information systems and remote sensing using satellite are very useful tools to investigate the vectors dynamics that is on the basis for future control strategies.
- In the climate changing era, development and application of predictive models that integrate field data with climatic and environmental data will be an effective approach for prevention and control the disease transmitted by *R. appendiculatus.*

Cowdriosis (heartwater) introduction, list of the main vectors and role of ticks in the transmission

Cowdriosis is a disease of ruminants caused by the rickettsia *Ehrlichia ruminantium* and transmitted by various *Amblyomma* species. It is a major constraint to livestock production in infested areas, causing high mortalities in susceptible animals introduced from regions free from the vectors but also in local breeds of small ruminants, whereas cattle of local breeds are generally protected. In Europe, climatic conditions seem presently not suitable for cowdriosis vectors settlement, although the temperature threshold which prevents the ticks to survive seems undetermined. Some infected vectors could however be introduced attached to asymptomatic carrier ruminants, migrating birds or exotic reptiles.

The vectors of cowdriosis are ticks of the genus *Amblyomma* to which the previous genus *Aponomma* has recently been synonymised (Barker and Murrell, 2004). They are in the Family Ixodidae (hard ticks), subfamily Amblyomminae. Of the 142 *Amblyomma* species (Barker and Murrell, 2004), 12 are known to be able to transmit *E. ruminantium* although there were not all involved in natural outbreaks of the disease (Walker and Olwage, 1987). Two of the 12 potential or current vector species are American ticks (*A. cajennense* and *A. maculatum*) and could transmit cowdriosis if the pathogen would be introduced onto the continent (Barré *et al.*, 1987). This threat justified the recent eradication campaign implemented in many West Indies islands by the Caribbean Amblyomma Programme or CAP (Pegram *et al.*, 1996; Pegram *et al.*, 2001). *A. cajennense* appears however not to be a very efficient vector because of low susceptibility to *E.* ruminantium (Mahan *et al.*, 2000).

Among the 10 African Amblyomma vectors, *A. variegatum* is "undoubtedly the most important" (Walker and Olwage, 1987*)* because of its efficiency and large distribution. The other vector species are: *A. hebraeum, A. pomposum, A. lepidum, A. astrion, A. cohaerens, A. gemma, A. sparsum, A. marmoreum* and *A. tholloni*. *A. variegatum* and *A. hebraeum* are the two more studied vectors of cowdriosis.

Cowdriosis is not a contagious disease: it can naturally be transmitted only by attachment, during 3 or more days, of infected vectors, in which the rickettsia multiplies and migrates from gut to salivary glands. For experimental purpose, the disease can also be inoculated by infected blood or by cell culture.

VECTORS OF COWDRIOSIS

It is easy to identify an *Amblyomma* tick because of its big size, long palps, and ornamented scutum. It is more difficult to determine the species which identification relies mainly on eye form (flat or convex), coxa's spurs, and particularly on the colour and extent of the enamelled ornamentation, that can vary between specimens which explains the identification difficulties. As often happens, males are easier to identify than females, mainly because of larger scutum and more developed ornamentation.

Ecobiology.

Petney *et al.* (1987*)* reviewed the habitat and climatic needs or requirements of the different cowdriosis vectors. They mentioned thus that *A. pomposum and A. cohaerens* are found only at high altitude (1,200 to 1,700 m for the former, and 1,000 to 1,500 m for the latter), where the annual rainfall is higher than 800 mm or 650 mm, respectively. All the other vector species are found from see level and up to 1,000 m *(A. astrion),* 1,500 m *(A. hebraeum, A. lepidum, A. marmoreum, A. tholloni),* 1,800 m *(A. sparsum, A. gemma),* or even 2,600 m *(A. variegatum).*
Some vectors are found in dry habitat and others in more humid areas. *A. hebraeum, A. gemma, A. lepidum, A. sparsum* and *A. marmoreum* are thus found in regions with annual rainfall as low as 250 or 300 mm, and disappear when annual rainfall exceeds 750-800 mm (the 3 first species), 900 mm *(A. marmoreum),* or 1,250 mm *(A. sparsum).* On the other hand, *A. variegatum*, *A. tholloni* and *A. astrion* can not settle in areas with too low annual rainfall (lower than 400 to 500 mm, according to the authors) but can support up to 1,700 mm and even 2,800 mm for *A. variegatum.* It is perhaps because it can adapt to or support higher rainfalls better than other *Amblyomma* species that this latter species succeeded to settle in numerous Indian Ocean and Caribbean islands (see distribution below).
All species require ground covered by vegetation where they can find micro-habitats suitable for survival and moulting or egg laying. This is particularly the case for the stages dropping off the hosts during the dry season. For example, *A. variegatum* engorged nymphs, which infest their hosts in the beginning of the dry season, can not move more than about 2 meters to find favorable micro-habitats which are bush and grass roots (or root networks) retaining humidity during the dry season, and along which the ticks burrow up to depth of 10 cm (Stachurski, 2000a). Engorged females usually drop off during the rainy season but they also move only up to a few meters to find a suitable place to lay eggs (neck of a grass clump, wood stick, stones or plant debris under which they conceal, etc. [Barré, 1989]*).* Savannahs of short grass, without bush or tree cover, are therefore less favorable for *Amblyomma* survival.
The required conditions for *A. variegatum* are thus a minimum annual rainfall of about 500 mm (Morel, 1969) with at least 4 months of rainy season to enable the development of the eggs, and a temperature higher than 15°C but not exceeding 35°C (Barré, 1989). It is well known that a higher temperature increases the development rate of the engorged stages (Pegram and Banda, 1990), but it is not defined whether eggs (and/or larvae, which are the 2 most fragile stages) can survive, and how much time, with temperatures lower than 15°C, nor whether development can occur with temperatures varying every day around this threshold. Data regarding the influence of natural temperature variations on survival and development of the free stages are thus required to explain for example why the tick is present and abundant in the Adamawa province (Cameroon), up to 1,200 to 1,500 m above sea level, whereas it can apparently not settle in the Malagasy high plateaux, at the same altitude but with apparently colder climate. Those data seem also missing for the other species although they could be useful to understand the present and potential distributions of the ticks, at least for those *(A. variegatum, A. hebraeum, A. astrion, A. pomposum)* with wide host range. In particular, these data would be helpful to know whether some of the vectors could survive in some European regions with mild winter climate.
The recent northward spreading of *A. hebraeum* distribution area in Zimbabwe (see below) is due to interruption of dipping campaigns during the independence war, movements of wild infested

ruminants carrying the ticks in tick-free areas, but also to climate changes which occurred from the 1970s and increased the number of climate niches suitable for the tick (Peter *et al.*, 1998*;* Estrada-Peña *et al.*, 2008). *A. hebraeum* and *A. variegatum* have different climate requirements, the former withstanding drier environment and more marked seasonal drought (Petney *et al.*, 1987; Estrada-Peña *et al.*, 2008). This could explain why *A. hebraeum* is presently settling on the Zimbabwean highveld, what *A. variegatum* did not succeed to date.

Geographic range

The distribution of cowdriosis vectors in Africa was extensively reviewed by Walker and Olwage (1987) and Walker *et al.* (2003). Their maps are the main source for the below description and for the attached maps dealing with the distribution of the first 4 described species.

A. variegatum is the vector with the largest distribution. It occurs in Africa, south of the Sahel area, from Senegal to Ethiopia and to the extreme north-west of Somalia. It is prevalent in central and eastern Africa, and also in part of Botswana, Zimbabwe and Mozambique. In eastern Angola, southern Democratic Republic of Congo (DRC) and in Zambia, it overlaps with *A. pomposum;* in Zimbabwe, it overlaps with *A. hebraeum*, and in East Africa (from Sudan to Tanzania) it is present simultaneously with *A. lepidum*. From its original cradle, *A. variegatum* was introduced in the Yemen Arab republic (Mc Cartan *et al.*, 1987) and in different islands around Africa. It has thus been recorded in Capo Verde islands (Doss *et al.*, 1978, cited by Walker and Olwage, 1987) and in Indian Ocean islands: Madagascar, La Réunion, Mauritius, the Seychelles and the four Comoros islands (Grand Comore, Anjouan, Moheli, Mayotte).

A. variegatum has also been introduced in the West Indies. It is present since the beginning of the 19th century in Guadeloupe from where it was disseminated into Marie-Galante and Antigua during the 19th century, into Martinique in 1948, and into St Croix in 1967. It was then recorded in about 15 new islands up to the early 90s, from Puerto Rico in the north to St Vincent and Barbados in the south, as it was detailed by Barré *et al*. (1995) and Barré (1997). The present situation in most of the West Indies, described in the CAP web site (http://www.caribvet.net/information.php) and completed by the data given by CIRAD-Guadeloupe, is very dissimilar according to the countries. In some islands (French West Indies, Antigua, St Kitts and Nevis,…) the species is widespread and the current control strategy is to limit losses due to the tick (and associated diseases) and its dissemination through seasonal tick control because the implemented eradication programme failed or was never accurately carried out. Some islands (Anguilla, Montserrat, St Vincent) are considered as provisionally free of tick, and others have limited populations in hotspots where control is still implemented (Dominica, St Lucia, Barbados).

A. hebraeum did not succeed to date to greatly increase its distribution from its original area which covers the northern part and the east coast of the Republic of South Africa (RSA), east of Botswana, the main part of Zimbabwe and south of Mozambique. It seems however that, in Zimbabwe, the tick

slowly but regularly spreads northwards since three decades, because it is now established on the highveld (central plateau) where it was not found during the three first quarters of the 20th century (Norval, 1983). *A. hebraeum* and *A. variegatum* are both present in some areas of northern Zimbabwe but these are scarce, either because interspecific mating occurs and leads to sterile products (Norval *et al.*, 1994), either because the climatic requirements of both ticks or not similar (Estrada-Peña *et al*., 2008).
A. pomposum has a limited distribution, in west Angola, south of DRC and in Zambia. In Angola, where it coexists with five other cowdriosis vectors of narrower distribution (Gomes, 1993), it is the major vector of the disease. *A. lepidum* is present from Sudan (Chad border) to Ethiopia and Somalia except the driest part of the horn of Africa, and extents southwards until the northern half of Tanzania. In a large part of this distribution area, it coexists with *A. variegatum* but *A. lepidum* supports more arid condition (see above).
A. marmoreum is present in southern Africa, from Zimbabwe to South Africa with localised records in Botswana and Namibia. Its distribution is governed by that of its main host, the leopard tortoise *(Geochelone pardalis). A. sparsum* is profusely present in Kenya and Tanzania, and occurs in limited spots from Senegal, Chad, Ethiopia or Angola. *A. cohaerens* is present from central DRC to Ethiopia through Uganda, Burundi, Rwanda and south-west of Kenya. *A. astrion* is recorded in São Tomé and Principe, western Angola, Central African Republic, DRC and Congo Republic. A. gemma is present in eastern Africa, from Tanzania to Ethiopia, Djibouti and Somalia. *A. tholloni* is recorded from West Africa (Sierra Leone) to East Africa (Kenya) and to southern Africa (Mozambique and RSA) in almost every places where the African elephant is living.
For some ticks *(A. tholloni, A. marmoreum, A. sparsum)* the distribution is limited by that of their main host, i.e. elephant, leopard tortoise, reptiles and rhinoceros, respectively (Petney *et al.*, 1987). For *A. astrion* and *A. cohaerens*, the distribution is restricted to only a portion of that of the buffalo, which is their main host: other unknown factors (climatic requirements, predators, vegetation needs…) may explain that limited distribution. On the other hand, species like *A. variegatum, A. hebraeum, A. pomposum, A. lepidum and A. gemma* "have wide host preferences and it is unlikely that their distribution are in any way limited by host availability" (Petney *et al.*, 1987).

Ethology.
Petney *et al.* (1987) reviewed the hosts of the cowdriosis vectors. They considered that A. *variegatum* and *A. hebraeum* are the major vectors of the disease because they "use cattle as preferred hosts for their adults". As sheep and goats and also important hosts for the immature stages, and especially for the nymphs, these ticks also act as vectors for small ruminants. According to these authors, *A. astrion, A. cohaerens, A. gemma, A. lepidum* and *A. pomposum* are vectors of secondary importance because they "occur in only small numbers on domestic stock"; they can nevertheless be the major cattle tick in some restricted place, as it is for example the case for *A. lepidum* in Angola and *A. astrion* in São Tomé and Principe. The main host for *A. astrion* and A. *cohaerens* (except in Ethiopia where cattle are abundant) remains nevertheless the buffalo.
Adults of these seven *Amblyomma* species can probably infest a wide range of large wild ungulates (buffaloes, antelopes, gazelles, etc.) and various domestic animals: cattle, goats and sheep of course, but also donkeys, horses and sometimes pigs or dogs. For *A. variegatum* and *A. hebraeum*, host size

is crucial, greater animals being more infested than smaller one *(Norval and Lawrence, 1979; Barré et al*., 1988; Meltzer, 1996; Stachurski, 2000a): too small animals (less than 5-10-15… kg? It remains to be clarified) are therefore unlikely to be parasitized by adult ticks. Immature stages of these two species are by far less specific and can infest a wider range of vertebrates: birds (especially ground-dwelling birds like francolins or guinea-fowls, or birds associated to cattle like cattle egrets *[Bubulcus ibis]),* insectivores, reptiles, lagomorphs, carnivores… Birds like francolins or mammals like hedgehogs or hares do not move over long distances and might therefore not be involved in the dissemination of the ticks into tick-free countries or, all the more, into new continents. This is not the case of the migratory birds, and especially of cattle egrets as detailed by Barré *et al.* (1995). These birds are associated "with large herbivore and, as a result, they can become infested with immature ticks. After engorging on the egret, these ticks may detach […] on another island" because the birds have "strong migratory and dispersal tendencies" (Barré *et al.*, 1995). This involves mainly the scattering of juvenile birds and occurs generally over distances up to 100 km, despite some birds have been observed up to 200 to 400 km away from their labelling place (Corn *et al.*, 1993).

Some *Amblyomma* species do not usually parasite ruminants and are therefore unlikely to be involved in cowdriosis outbreaks. *A. tholloni* is thus the "elephant bont tick", and *A. marmoreum* the "South African tortoise tick", which infests also other reptiles like snakes and monitor lizards (Walker and Olwage, 1987*).* But, as the leopard tortoise is often imported by zoos or private reptile lovers, there is a real risk of introduction of infected ticks (immature stages of *A. marmoreum* can infest ungulates where they could get the infection) in cowdriosis-free countries. The same is true for *A. sparsum* which usual hosts are reptiles, snakes and rhinoceros but which can also infest cattle (Burridge *et al.*, 2000).

As it is the only cowdriosis vector which succeeded to set up outside its original distribution area, it is essential to consider the ways used by the tick *A. variegatum* to spread out. They have been compiled and extensively examined by Barré *et al*. (1995) who considered that "movement of (infested) animals is certainly the most efficient method of dissemination". As they are the most infested, sometimes by several tens of adults, ruminants and especially cattle represent the greatest risk of tick dissemination, in particular because each engorged female is able to lay up to 15-20,000 eggs once detached in a new suitable environment. Other domestic animals like dogs, cats or pigs may also, but rarely, be infested by adults, but are more frequently parasitized by immature ticks (larvae and nymphs): untreated pets traveling by plane or by boat could therefore transport ticks in new regions or countries. When the travel exceeds 7 to 12 days, no more engorged tick can be found on the infested animals because of the limited feeding period of the various stages: up to 8 or 9 days for larvae and nymphs (Yonow, 1995), and up to 12 days for the females, although greater engorgement periods, up to 28 days, have sometimes been noticed (Yonow, 1995) (male ticks can remain attached to cattle for several months (Norval *et al.*, 1992a) but they can not maintain the tick life-cycle after detachment). In that case, the greatest risk is not linked to the introduction of (previously) infested animals, but to the recycling of manure and litter used during the travel and which might harbor and shelter engorged ticks, moulted unfed stages, or not yet hatched eggs (Barré *et al.*, 1995). The initial introduction of *A. variegatum* in Guadeloupe (and probably also in most of the Ocean Indian islands) was thus due to importation of infested cattle, or of the tick-infested litter used during cattle transportation by ship from Senegal onto West Indies *(*Barré et *al.*, 1987), or from East Africa onto the Indian Ocean islands. Cattle transport between islands also explains the introduction of the tick at least in Marie-Galante, Antigua and Martinique. But from the late 1960s, the rapid increase in the number of infested islands in the Caribbean was linked to the presence and spreading of the cattle egret in the West Indies (Corn *et al.*, 1993; Barré *et al.*, 1995). The re-infestation of some countries, like Puerto Rico, after successful eradication campaign, might also be due to movement of this bird (Bokma and Shaw, 1993).

A. variegatum is thus the only "African vector of cowdriosis that has established itself extremely successfully outside the continent" (Walker and Olwage, 1987). It remains a threat for areas where the climatic conditions would be suitable for its permanent setting up, insomuch as it already succeeded to colonize new territories through movement of migratory birds which can not be controlled. However, Burridge *et al.* (2002) pointed out that introduction of cowdriosis onto the American mainland could occur "through animal movements include importation from Africa of tick-infested reptiles" (i.e. infested by *A. marmoreum* or *A. sparsum*) "and importation of livestock from islands in the Caribbean infested with *A. variegatum* ticks", but also through the introduction of "sub-clinically infected wild ungulates" from Africa. The risk would be, in that case, the adaptation of the disease in a new tick reservoir, *A. maculatum*.

The hunting strategy of *A. variegatum* ticks varies according to the stage. Like most of the hard tick larvae (if not all), *A. variegatum* larvae are grouped together in clusters of hundreds or thousands at the top of the grasses or other plants, several centimeters or decimeters high, where they are waiting for the hosts (Jongejan and Uilenberg, 1994). Larvae are moving up and down the grasses according to the climatic conditions (Pegram and Banda, 1990) and are not very active in the morning, probably because of the dew, and in the middle of the day, when it is too hot. When a grazing or walking host hits a larvae cluster, the ticks immediately attach in great number to the body part which strikes the infested clumps (head, ears and feet as far as cattle are concerned). But larvae clusters can be located by accustomed cattle which can avoid them by sidestepping.

Unlike other adult ticks (*Ixodes ricinus*, *Rhipicephalus appendiculatus,…) A. variegatum* adults are not waiting for their hosts at the top of the grasses but are hidden on the ground, beneath vegetation debris, from where they are emerging once activated by stimuli produced by cattle *(*Rechav, 1979; Norval *et al.*, 1987). These stimuli are mainly the carbon dioxide breathed out and the soil vibrations due to animal movements. Visual location of hosts by tick eyes is also involved in the activation process (Barnard, 1991). It was thought that the attraction-aggregation-attachment pheromones produced by males of *A. variegatum* (and of some other species like *A. hebraeum*) were essential for the ticks to locate the hosts and that carbon dioxide was a non-directional stimulus (Norval *et al.*, 1987), but capture of *A. variegatum* by dry ice traps (Barré *et al.*, 1997) and similar attractiveness for *A. variegatum* males of infested and non-infested cattle (Barré *et al.*, 1998) showed that this was not the case and that cattle stimuli alone are sufficient to activate and attract adult ticks. Cattle infestation by *A. variegatum* adults was identified as a two-steps process (Stachurski, 2000b). Once activated, the ticks crawl to the host and, when they reach it, they climb the hoof and attach temporarily and loosely to the inter-digital areas. Subsequently, when the animal lies down, the ticks move from this temporary attachment site to reach the predilection sites (groin and udder, chest and axilla, belly, perinea). Whereas they can attach in pasture to the feet of not infested cattle (Stachurski, 2000b), females are not able to reach predilection sites as long as there is no male attached since 3-4 days, time needed for the pheromones to be produced (Norval and Rechav, 1979). The pheromones are therefore essential for the second step, whereas the stimuli produced by the hosts are sufficient to induce tick attraction and attachment to the inter-digital areas. During this second phase, ticks can move from the feet of the animal which captured them in the field to the predilection sites of another animal. Host invasion by *A. variegatum* nymphs has not been accurately studied but evidences have been noticed indicating that the invasion process identified for the adult ticks may also be valid for the nymphs, except that an appreciable proportion (about 10-15%) of that ticks remains attached to the feet where they engorge, which is not the case for the adults.

Such observation was never mentioned for other cowdriosis vectors. But, since *A. hebraeum* are also hidden beneath the soil, under plant debris, and rapidly activated by cattle passing in the vicinity (Norval *et al.*, 1987) and since *Amblyomma* adults are activated by the same stimuli (Barnard, 1991), it is probable that the same invasion process takes place with other vectors, at least those which adults infest mainly great ungulates *(A. hebraeum, A. lepidum and A. pomposum but also A. astrion, A. cohaerens* and *A. gemma).*

Seasonal dynamic.

In regions with no real dry season (equatorial Africa, tropical islands like Guadeloupe and other West Indies), there is no pronounced seasonal variation of infestation: the three stages are present all the year long, with only a slight tick burden decrease during the months with lower rainfalls (Barré, *1989).* Various generations muddle and follow one another without interruption (Morel, 1981). On the other hand, in areas with a marked annual dry season lasting several months, *A. variegatum* exhibits only one generation yearly, each stage being present at very precise periods (Petney *et al.*, 1987).

Adults infest their hosts at the beginning of the rainy season, the males being present some weeks before the females because these latter can not attach before the former started to produce and emit pheromones (see above), and probably also because they need higher humidity at the soil level to get activated. From the middle of the rainy season, once the adult stocks present in the environment at the end of the dry season started to run out, adults disappear more or less rapidly from the hosts, some males remaining attached until the dry season if the animals are not treated. Larvae, issued from eggs needing 2-3 months incubation, attach to the hosts at the end of the rainy season but disappear from the environment after some 1-3 weeks of dry season because of quick desiccation, except in some shaded areas like gallery forests. Nymphs attach mainly at the beginning of the dry season, but can be found during 4-6 months, until the first rains. Each stage peaks about 4 weeks after the onset of its infestation period.

The seasonal variations are regulated by two mechanisms. First, it has been observed that females engorging before the rainy season, when the days are shorter, had delayed oviposition (morphogenic diapause). This diapause ended following the cooling effect of the first rainfalls on soil temperatures (Pegram *et al.*, 1988). Another mechanism regulating the adult activity was suspected (Norval *et al.*, 1992a) because 4-6 months sometimes elapsed between the activity peaks of nymphs and adults whereas nymphs moult into adults in 3-5 weeks,. A behavioural diapause was in fact observed: moulted adults have no host-seeking activity during the dry season, even when they are present in the pasture from the beginning of this season. The host-seeking activity starts only after the onset of the rains (Stachurski, 2000a). These two mechanisms enhance the survival probability of the desiccation-sensitive eggs and ensure that they are laid when the climatic conditions are more favourable for their survival (Norval *et al.*, 1992a). There is then one generation per year, and the beginning of the lifecycle is triggered off by the first rainfalls.

Norval *et al.* (1992a) mentioned that seasonal pattern is more clearly defined for *A. variegatum* than for *A. hebraeum*, although adults of the latter are also more abundant during the rainy season. There is also one generation per year, except in the extreme southern limits of its distribution, with lower temperatures and marked day-length variations. *A. hebraeum* sometimes needs more than one year to complete its lifecycle in these areas, only one stage succeeding to feed yearly, during the favourable periods of spring and summer (Norval, 1977).

There are fewer data for some species like *A. astrion, A. cohaerens, A. gemma*, and especially for the immature stages (Petney *et al.,* 1987). It however generally appears that, in regions with a two-season climate, adult ticks are attached to the hosts during the rainy season. This was observed for *A. cohaerens, A. lepidum* and *A. pomposum*. For the species very seldom attached to cattle (*A. tholloni, A. marmoreum* and *A. sparsum*), data are lacking because the usual hosts are not captured and examined regularly throughout the year. Vary few is known from *A. tholloni; A. marmoreum* (both adults and immatures) were collected on tortoises during the hot and wet months in Zimbabwe and South Africa; and *A. sparsum* adults were on the other hand mainly observed on hippopotamus and buffaloes during the dry season (Petney *et al.,* 1987).

Surveillance.

In regions and countries where the vectors of cowdriosis are present, abundance, seasonality and distribution of the ticks are assessed by regular monitoring of the usual hosts, in the event cattle and small ruminants for *A. variegatum* and *A. hebraeum*. For example, after regular acaricide treatment during at least 2 years of cattle herds in the Caribbean islands infested by *A. variegatum*, active surveillance was implemented by the CAP. Randomly selected herds were visited quarterly to verify freedom from the tick at country or regional levels. Selected animals were carefully examined and the number of ticks found was recorded. Such a monitoring can be refined according to tick biological characteristics: for example, more animals can be checked and visits can be increased during the tick peak activity period if there is a marked infestation seasonality.

Capture of unfed ticks in the environment is by far less efficient for *Amblyomma* ticks. Flags or blankets dragging methods are only useful for the ticks agglutinated at the top of the grasses, like the larvae (Spickett *et al.*, 1991), but not for nymphs and adults hidden at the soil level like those of *A. variegatum* or *A. hebraeum* (Norval *et al.*, 1987, 1992c). Dry ice traps, sometimes containing also pheromones, were tested on several occasions to capture these two species (Norval *et al.*, 1987, 1989, 1992c; Barré *et al.*, 1997). But such traps have two main drawbacks. The tick pick up rate is highly variable according trials, even when the climatic conditions are constant (Gray, 1985; Barré *et al.*, 1997), and the variations of the climatic conditions (wind, temperature, humidity, etc.) increase the variability of the capture rate. Moreover, such traps are active only at short distances (Rechav, 1979; Norval *et al*., 1987; Cuisance *et al.*, 1994). Barré *et al.* (1997) considered thus that a

CO_2 trap could pick up ticks in a 3.4 meters circle: capturing tick in pasture or savannah of hundreds hectares would require very numerous traps… Authors studying *A. variegatum* and *A. hebraeum* concluded therefore that the best traps to assess the density or the presence of these ticks in the environment were cattle (Norval *et al.*, 1987*;* Barré *et al.*, 1997), considered as tracer animals (Gray, 1985), insomuch as they cover daily long distances and can capture ticks on several hectares. This explains why the tick-free status of the Caribbean islands was assessed using cattle monitoring. Dermatophilosis, a cutaneous disease due to the actinomycete *Dermatophilus congolensis*, is regarded as a marker for the presence of *A. variegatum*. Uilenberg (1992) mentioned that the tick was found for the first time in Dominica in a herd examined because a new skin disease, later identified as dermatophilosis, has been observed. Such a marker is however not perfect since the disease is present, although with milder symptoms, in regions free from the tick.

As the "most efficient method" of vector dissemination in the transportation of infested hosts from tick-infested into tick-free areas, it is of course necessary to carefully examine all introduced animals coming from such regions, and/or to treat them with acaricide just before travelling. This should not be the case only for cattle but also for usual hosts of *Amblyomma* species potentially vectors, like *A. marmoreum* or *A. sparsum*. Reptiles, and especially tortoises, should therefore be treated before to be introduced in cowdriosis-free countries (Burridge *et al.*, 2000, 2001).

Regarding infested migratory birds, and particularly cattle egret, the surveillance is difficult to implement. The risk is not high, according to Corn *et al*. (1993) who found only one bird infested by nymphs in 300 examined, but it exists: in Burkina Faso, 12% of 26 egrets captured and examined were infested and carried in total 9 *A. variegatum* nymphs (Stachurski, 2000a). As birds are not infested by adult ticks, such introduced nymphs should find, after moulting, cattle, small ruminants or other ungulates to complete their lifecycle. Monitoring cattle reared near areas were migratory birds coming from tick-infested areas are known to stay temporally would probably be the best and cheapest surveillance method for this risk.

Summary as provided by the authors:

- Cowdriosis is a tick-borne disease of wild and domestic ruminants due to the rickettsia *Ehrlichia ruminantium* and transmitted by various tick species of the genus *Amblyomma*. In regions where the vectors are present, it is one of the major constraints to livestock production, causing high mortalities in susceptible animals introduced from regions or countries free from the vectors, but also in local breeds of small ruminants not always benefit of endemic stability.
- Cattle of local breeds, which susceptibility to the disease is lower than that of sheep and goats, are on the other hand generally protected by an immunity boosted by regular tick infestation, because tick infection rate by the pathogen is high enough to allow several asymptomatic infections each year. However, improved dairy or beef cattle reared in tick-free areas are very susceptible to cowdriosis and would suffer high mortality in case of introduction of infected ticks, especially in regions where climate would allow the ticks to settle: America mainland, tropical Asia, Caribbean Islands in some of which the tick (but unfortunately not the rickettsia except in Antigua, Guadeloupe and Marie-Galante) was sometimes introduced which led to more or less successful eradication campaigns.
- In Europe, climatic conditions seem presently not suitable for cowdriosis vectors settlement, although the temperature threshold which prevents the ticks to survive is apparently not determined.
- The risk exists however since some of the vectors could be introduced as infected larvae (attached to asymptomatic carrier ruminants) or, more probably, as infected nymphs (which got the infection as larvae when attached to susceptible animals) attached to ruminants, but also to migrating birds or to introduced exotic reptiles. Because of the highly variable genome of *E. ruminantium*, with strains exhibiting sometimes very poor cross-protection, development of vaccine (whether it is inactivated or attenuated or recombinant) is not yet achieved.
- Control of the disease in enzootic areas should therefore rely on enzootic stability for livestock reared in pasture, or on tick control (or prevention of tick infection) for animals continuously kept in farm buildings installed in tick-infected regions.

Babesiosis introduction, list of the main vectors and role of ticks in the transmission

Bovine babesiosis is a tick-borne infection produced by intracellular protozoan parasites in the genus *Babesia* belonging to the phylum Apicomplexa. The two economically more important species parasites producing disease in cattle are *Babesia bovis* and *Babesia bigemina*, affecting wild and domestic animals.

In cattle, the intra-erythrocytic parasites destroy host cells producing haemoglobinuria, anemia and fever. Symptoms appear after 2-3 weeks after tick infestation in the case of *B. bigemina*, and a bit longer for *B. bovis*. Generally, infections associated to *B. bovis* are more virulent and difficult to treat than that caused by *B. bigemina*, and usually are associated with fatal cerebral babesiosis caused by erythrocytes sequestration in capillary brain. Mortality rates are high in susceptible European cattle breeds, however in Africa asymptomatic chronic carriers are frequently found and don't exhibit clinical signs (M'Ghirbi *et al.*, 2008).

Parasite identification and diagnostics can be performed using traditional microscopic identification in blood smears, by serology and by molecular techniques as reverse line blot hybridisation (RLB) or polymerase chain reaction based methods (PCR). Published molecular techniques to detect *Babesia bovis* and *Babesia bigemina* show higher sensitivity and specificity than microscopic identification, where species identification is based on morphology, or serology, unable to distinguish between past exposure and present infection (M'Ghirbi *et al.*, 2008). Many authors have been using both the RLB (Georges *et al.*, 2001), (Oura *et al.*, 2004) and PCR techniques (Almeria *et al.*, 2001, Oliveira-Sequeira *et al.*, 2005 , Costa-Junior *et al.*, 2006, Martins *et al.*, 2008) for the detection of *Babesia* from blood and ticks because is a powerful tool to detect species in mixed infections and also detects low parasitemia rates.

Babesiosis associated with *B. bovis* and *B. bigemina* is currently endemic in tropical and subtropical regions around the world, being important in Australia, Asia, Africa, Central and South America as well as in southern Europe. *Babesia bigemina* and *B. bovis* have been reported from Switzerland (Hilpertshauser *et al.*, 2007), Spain (Almeria *et al.*, 2001), Portugal (Caeiro, 1999), Greece (Papadopoulos *et al.*, 1996) *Babesia bovis* is considered the most economically arthropod transmitted pathogen of livestock worldwide (Bock *et al 2004*, Howell *et al.*, 2007). The disease is associated with the geographic distribution of its vectors, being most common around the tropics. *B. bovis* and *B. bige*mina parasites are transmitted by *Ripichephalus* ticks of the genus *Boophilus.*

In laboratory assays strains of *Boophilus decoloratus* and *Boophilus microplus* were easily infected with *B. bigemina* and *Boophilus annulatus* was also infected although *Rhipicephalus evertsi* was difficult to infect (Buscher, *1988).* In the same assay, *R. appendiculatus, R. bursa* and *Hyalomma anatolicum excavatum* were refractory to infection. Major tick vectors for *B. bovis* are *Boophilus microplus, Boophilus annulatus* and *Boophilus geigyi*

Recent laboratory assays have found a positive correlation between the blood parasite levels in acute parasitemic cattle and kinete levels in the *Boophilus* ticks haemolymph after feeding on cattle.

The same assays showed no correlation between kinete levels in *Boophilus* ticks and infection rates on larval offspring. Larvae derived from adult females with low levels of kinete infection are able to transmit the parasite to the susceptible hosts even when haemolymph infection is undectectable (Howell *et al.*, 2007)

The parasites are transmitted and spread through the bites of infected *Boophilus* ticks. Ticks are infected when adult females bite and feed on infected cattle, after being infected they must pass the parasite to developing offspring to complete the transmission cycle infected larvae must feed on susceptible cattle. Adult and nymphal ticks transmit *B. bigemina*

In babesiosis endemic areas endemic stability is recommended when possible controlling tick population at non nuisance levels for cattle and allowing adequate low natural infection to occur.

Recent molecular and morphological studies of the genera *Rhipicephalus* Koch, 1844 and *Boophilus* Curtice, 1891 revealed that the five species of *Boophilus* make the genus *Rhipicephalus* paraphyletic. Thus, *Rhipicephalus* Koch, 1844 is not a monophyletic (natural) lineage and some species of *Rhipicephalus* are more closely related to the species of *Boophilus* than to other species of *Rhipicephalus*. *Boophilus* is retained as a subgenus of *Rhipicephalus* and all five species of *Boophilus* become members of *Rhipicephalus* (*Boophilus*).

RHIPICEPHALUS (BOOPHILUS) ANNULATUS

Identification

Although *Rhipicephalus (Boophilus) annulatus* and *Rhipicephalus (Boophilus) microplus* are very similar, the only specie found in Europe is *Boophilus annulatus*. Their distribution in Africa does not overlap. Both *Boophilus* ticks can be differentiated by several morphological characters.

Ecobiology

This tick is the typical one-host tick. Cattle infestation by *Boophilus annulatus* is approximately three weeks. Under favourable conditions of temperature and humidity six generations per year are possible, one every two months.

Geographic range

Boophilus annulatus survives in Meso-Mediterranean climates. In Europe and the Mediterranean region is abundant and widespread, several records have been performed from Spain (Estrada-Peña 2003, Castellà *et al.*, 2001, Almeria *et al.*, 2001), Italy (Caraccapa *et al.* 1999), and Greece (Papadopoulos *et al.*, 1996). This tick is common in northern Africa(M'Ghirbi *et al.*, 2008) and also in Mexico.

Seasonal dynamics

In the Mediterranean region with differentiated summer and winter seasons, its activity begins in late summer having a peak activity in autumn..

RHIPICEPHALUS (BOOPHILUS) MICROPLUS

Identification
The adults are slightly larger and red in color than those of *B. decoloratus*, but their general appearance is very similar.

Ecobiology
Boophilus microplus is a one host tick, and its life cycle is compatible with more than one generation per year. When moist and warm climatic conditions are favorable, *Boophilus microplus* is able to compete and even replace *Boophilus decoloratus* (Spickett *et al.*, 1978).

Geographic range
Probably the most distributed vector of *Babesia bigemina* worldwide in areas where climatic conditions assures a minimum average of rainfall.
The vector is established in South Africa, scattered in south and eastern coasts. It is also present in coastal regions of Kenya, Tanzania and Mozambique. In the interior of South Africa is scattered in certain localities, also in south and north-eastern Zimbabwe, estern and central provinces of Zambia, Malawi and the east and north of Lake Malawi in Tanzania.
Long term surveys performed in Zambia showed that *Boophilus microplus* replaced almost all *Boophilus decoloratus* between 1972 and 1982 (Berkvens *et al.*, 1998), and its westwards spread seems to continue (Jongejan *et al.*, 1988). The spread of *Boophilus microplus* in Zambia and Zimbabwe has been associated to high mortality in cattle due to *Babesia bovis* infection, in sub-Saharan Africa this tick is the only vector of the parasite (Jongejan *et al.*, 1988, Norval *et al.*, 1983)

Ethology
Preferred hosts of *Boophilus microplus* in sub-Saharan Africa are mainly cattle. Wild ungulates and other livestock are not usually parasitized by this tick (Horak *et al.*, 1986)

Seasonal dynamics
In Zimbabwe this tick is present in variable numbers throughout the year. In South Africa and south eastern Kwa-Zulu Natal is more abundant in cattle from mid to late summer (Baker *et al.*, 1989)

Control
Control of *Boophilus microplus* ticks is achieved by acaricidal treatment on host. As this tick feeds exclusively on cattle when livestock (cattle) are exposed to acaricidal treatment the tick does not have alternative hosts, this fact and their short cycle can leads to some acaricides resistance. *Bos indicus* cattle develop better resistance against *Boophilus microplus* than *Bos taurus*-type cattle and this helps to reduce acaricide treatments on *Bos indicus*-type cattle

RHIPICEPHALUS (BOOPHILUS) DECOLORATUS

Identification

Adults are small ticks with short mouthparts and thin legs. Engorged females are bluish-brown while males are brownish-yellow and smaller than females.

Geographic range

The tick is present in most of the moister areas of South Africa, unless in areas where *Boophilus microplus* has replaced this tick. It is present also in mountainous areas as Drakensverg and parts of Lesotho.

In parts of South Africa with an average annual rainfall less than 380mm the tick is absent as in the western Free State and western regions of Cape Town (Gothe, 1967) In Namibia is only present in few localized areas and in Botswana is only established in higher rainfall areas and few scattered northern localities. Other records have been performed from southern Mozambique, Zimbabwe, Angola, Zambia, Malawi, regions of Tanzania, Burundi, Uganda, western Kenya and in wet highlands and sub-highlands of Ethiopia, and several areas of central and west Africa.

Ecobiology

Boophilus decoloratus has one-host life cycle. The tick moults on the host from larvae to nymph and from nymph to adult (Arthur and Londt, 1973).The period on host, from the larvae attachment until the engorged female detaches, takes about three weeks. The free-host period, from the adult engorged female detachment until larval hatching and maturation takes about five weeks. Due to its short life cycle the tick has more than one generation annually. *Boophilus decoloratus* occurs in different vegetation types as coastal mosaic, grassland, bush land, Cape shrub land, woodland and montane vegetation.

Ethology

Preferred hosts of *Boophilus decoloratus* ticks are cattle, but horses as well as donkeys, sheep and goats are frequently parasitized. This tick is a common parasite in wild African ungulates .

Seasonal dynamics

In South Africa winter temperatures synchronizes the larval hatching with egg development and large number of larvae are present on the vegetation in spring when temperatures *rise* (Spickett, *et al.*,1992), and cattle are infested by adults during summer and autumn (Rechav and Kostrzewski,, 1991). In Zambia there is also a spring peak followed by a larger summer and winter peaks (Pegram *et al*, 1986). North of the equator, in Nigeria *Boophilus decoloratus* are abundant on cattle during autumn, and in Gambia peak burdens occur during the rainy season (Mattioli *et al.*, 1997). Higher burdens in South Africa are recorded from wild herbivores in spring, and in late summer and autumn burdens are low (Horak, 1984).

Control

Boophilus decoloratus can be easily controlled by acaricide treatment on cattle at three weekly intervals as it spends about three weeks to complete its parasitic cycle on host. Some species of cattle develop better resistance than others and they require fewer treatments.

Role of ticks in the transmission of anaplasmosis (gallsickness)

INTRODUCTION

Anaplasmosis o gallsicknes it's an infectious disease caused by a rickettsia, usually *Anaplasma centrale* or *An. marginale* that infect red blood cells of cattle causing severe anaemia. Transmission is by ticks of many species (particularly *Boophilus*) which serve also as biological vectors, *Anaplasma marginale* also can be readily transmitted during vaccination against other diseases unless a fresh or sterilised needle is used for injecting each animal. Similar transmission by means of unsterilised surgical instruments has been described (OIE, 2008).
This wide range of route of transmission allows to the disease to be present worldwide, the importance of biting insects and of different species of ticks in the natural transmission of anaplasmosis appears to vary greatly from region to region.

VECTORS OF ANAPLASMOSIS

Reviews based on careful study of reported transmission experiments list up to 19 different ticks as capable of transmitting *A. marginale* experimentally (Bradway *et al ,2001*, Marchette *et al.*, 1982). These are: *Argas persicus*, *Ornithodoros lahorensis*, *Boophilus annulatus*,
B. calcaratus, B. decoloratus, B. microplus, Dermacentor albipictus, D. andersoni, D. hunteri, D. occidentalis, D. variabilis, Hyalomma excavatum, H. rufipes, Ixodes ricinus, I. scapularis, Rhipicephalus bursa, R. evertsi, R. sanguineus and R. simus. Some of these reports, including those of *R. bursa*,
H. excavatum and *O. lahorensis*, were not entirely convincing, and that the ticks identified as *A. persicus* were probably either *A. sanchezi* or *A. radiatus.* Intrastadial or trans-stadial transmission is the usual mode, even in the one-host *Boophilus* species.
Male ticks may be particularly important as vectors; they can become persistently
infected and serve as a reservoir for infection (Kocan *et al.1992).* Experimental demonstration of vector competence does not necessarily imply a role in transmission in the field.
However, *Boophilus* species are clearly important vectors of anaplasmosis in countries such as Australia and countries in Africa, and some species of *Dermacentor* are efficient vectors in the United States of America (USA).
Various other biting arthropods have been implicated as mechanical vectors, particularly in the USA. Experimental transmission has been demonstrated with a number of species of *Tabanus* (horseflies), and with mosquitoes of the genus *Psorophora* (Kocan *et al.*, 2004, Ristic , 1968). In parts of southern Africa bleeding skin wounds caused by the filaria worm *Parafilaria bovicola* and the behaviour of face flies, such as *Musca xanthomeles*, *M. lusoria* and *M. nevilli*, which lap their meals, and also possibly other *Musca spp*., may be significant in this regard (Norval and Horak, 2004)
The main biological vectors of *A. centrale* appear to be multihost ticks peculiar to Africa, including *R. simus*. The common cattle tick *(B. microplus)* has not been shown to be a vector. This is of relevance where *A. centrale* is used as a vaccine in *B. microplus*-infested regions.

(OIE , 2008)

Summary as provided by the authors:

- Anaplasmosis is a well known present worldwide including Europe.
- It's very difficult to control for the presence of many route of transmission and a wide range of possible mechanical vectors.
- In endemic areas with permanent tick vector population, being difficult and expensive to achieve this goal and sometimes is restricted at keeping a low population of vectors to avoid large outbreaks.
- Good management and dipping is needed, although sometimes tick resistance against the dip compound is found *(Jonsson, 2000).*

References

Ahmed J., Alp H., Aksin M. & Seitzer U. 2007. Current status of ticks in Asia. *Parasitology Research* 101: 159-S162.

Almeria, S., Castella, J., Ferrer, D., Ortuno, A., Estrada-Pena, A. & Gutierrez, J. F. 2001. Bovine piroplasms in Minorca (Balearic Islands, Spain): a comparison of PCR-based and light microscopy detection. *Veterinary Parasitology* 99, 249-59.

Almeria, S., Castella, J., Ferrer, D., Sparagano & Estrada-Pena, A.2001. First report of *Babesia bovis* in Spain. *Veterinary Record* 149, 716-7.

Apanaskevich D.A ., 2003. Differentiation of closely related species *Hyalomma anatolicum* and *H. excavatum* (Acari: Ixodidae) based on a study of all life cycle stages, throughout entire geographical range. *Parazitologiia* 37(4):259-80.

Arthur, D. R. & Londt, J. G. H. 1973. The parasitic life cycle of B*oophilus decoloratus* (Koch 1844) (Acarina: Ixododae). *Journal of the Entomological Society of South Africa* 36, 87-116.

Baker, M .K . & Ducasse, F.B .W., 1967. Tick infestation of livestock in Natal. The predilection sites and seasonal variations of cattle ticks . *Journal of the South African Veterinary Medicai Association*, 38: 447-453 .

Baker, M. K., Ducasse, F. B., Sutherst, R. W. & Maywald, G. F. 1989. The seasonal tick populations on traditional and commercial cattle grazed at four altitudes in Natal. *Journal of South African Veterinary Association* 60, 95-101.

Barker, S.C. & Murrell, A. 2004. Systematics and evolution of ticks with a list of valid genus and species names. *Parasitology*, 129: S15-S36.

Barnard, D.R. 1991. Mechanisms of host-tick contact with special reference to *Amblyomma americanum* (Acari: Ixodidae) in beef cattle forage areas. *Journal of Medical Entomology*, 28: 557-564.

Barré, N. 1989. Biologie et écologie de la tique *Amblyomma variegatum* (Acarina : Ixodina) en Guadeloupe (Antilles Françaises). Thèse de Doctorat ès-sciences, Université de Paris-Sud-Orsay, France. 268 pp.

Barré, N. 1997. Les tiques des ruminants dans les Petites Antilles : biologie, importance économique, principes de lutte. *INRA Productions Animales*, 10: 111-119.

Barré, N., Uilenberg, G., Morel, P.C., Camus, E. 1987. Danger of introducing heartwater onto the american mainland: potential role of indigenous and exotic *Amblyomma* ticks. *Onderstepoort Journal of veterinary Research*, 54: 405-417.

Barré, N., Garris, G., Camus, E. 1995. Propagation of the tick *Amblyomma variegatum* in the Caribbean. *Revue scientifique et technique de l'Office international des Epizooties*, 14: 841-855.

Barré, N., Garris, G.I., Borel, G., Camus, E. 1988. Hosts and population dynamics of *Amblyomma variegatum* (Acari: Ixodidae) on Guadeloupe, French West Indies. *Journal of Medical Entomology,* 25: 111-115.

Barré, N., Garris, G.I., Lorvelec, O. 1997. Field sampling of the tick *Amblyomma variegatum* (Acari : Ixodidae) on pastures in Guadeloupe; attraction of CO2 and/or tick pheromones and conditions of use. *Experimental and Applied Acarology,* 21: 95-108.

Barré, N., Naves, M., Aprelon, R., Fargetton, M., L'Hostis, M. 1998. Attractivity of cattle infested by *Amblyomma variegatum* (Acari: Ixodidae) for conspecific adult ticks from the field in Guadeloupe. *Experimental and Applied Acarology*, 22: 297-308.

Berkvens D .L., Geysen D .M ., Chaka, G ., Madder, M . & Brandt, J .R.A ., 1998 . A survey of the ixodid ticks parasitising cattle in the Eastern Province of Zambia. *Medical and Veterinary Entomology*, 12, 234-240 .

Berkvens, D. L., Geysen, D. M., Chaka, G., Madder, M. & Brandt, J. R. 1998. A survey of the ixodid ticks parasitising cattle in the Eastern province of Zambia. *Medical and Veterinary Entomology* 12, 234-40.

Bezuidenhout, L .D . & Stutterheim, C.J ., 1980 . A critical evaluation of the role played by the red-billed oxpecker *Buphagus erythrorhynchus* in the biological control of ticks . *Onderstepoort Journal of Veterinary Research* , 47:51-75 .

Bock, R., Jackson, L., de Vos, A. & Jorgensen, W. 2004. Babesiosis of cattle. *Parasitology* 129 Suppl, S247-69.

Bokma, B.H. & Shaw, J.L. (1993). Eradication of a new focus of *Amblyomma variegatum* in Puerto Rico. *Revue d'Elevage et de Médecine vétérinaire des Pays tropicaux*, 46: 355-358.

Bouattour A., Darghouth M.A., Daoud A. 1999. Distribution and ecology of ticks (Acari: Ixodidae) infesting livestock in Tunisia: an overview of eighth years field collections. *Parassitologia* 41 Suppl 1:5-10.

Bradway D.S., Torioni De Echaide S., Knowles D.P, Hennager S.G., & Mcelwain T.F. 2001. Sensitivity and specificity of the complement fixation test for detection of cattle persistently infected with *Anaplasma marginale. Journal of Veterinary Diagnostic Investigation*, 13, 79-81.

Burridge, M.J., Simmons, L.A., Allan, S.A. 2000. Introduction of potential heartwater vectors and other exotic ticks into Florida on imported reptiles. *Journal of Parasitology*, 86: 700-704.

Burridge, M.J., Simmons, L.A., Peter, T., Mahan, S.M. 2001. Control and eradication of reptilian tick infestations, with particular reference to vectors of heartwater. "*International Joint Conference - Society for Tropical Veterinary Medicine and the Wildlife Disease Association*", Pilanesberg National Park, RSA.

Burridge, M.J., Simmons, L.A., Peter, T.F., Mahan, S.M. 2002. Increasing risks of introduction of heartwater onto the American mainland associated with animal movements. *Annals of the New York Academy of Sciences*, 969: 269-74.

Burridge, M.J., Simmons, L.A., Ahrens, E.H., Naudé, S.A.J., Malan, F.S. 2004. Development of a novel self-medicating applicator for control of internal and external parasites of wild and domestic animals. *Onderstepoort Journal of veterinary Research*, 71: 41-51.

Buscher, G. 1988. The infection of various tick species with *Babesia bigemina*, its transmission and identification. *Parasitology Reseach* 74, 324-30.

Caeiro, V. (1999). General review of tick species present in Portugal. *Parassitologia* 41 Suppl 1, 11-5.

Caracappa S. (1999) Livestock production and animal health in Sicily, Italy.*Parassitologia*. 1:17-23. Review.

Castellà J, Estrada-Peña A, Almería S, Ferrer D, Gutiérrez J, Ortuño A. 2001. A survey of ticks (Acari: Ixodidae) on dairy cattle on the island of Menorca in Spain. *Experimental and Applied Acarology* 25:899-908.

Corn, J.L., Barré, N., Thiebot, B., Creekmore, T.E., Garris, G.I., Nettles, V.F. 1993. Potential role of cattle egrets, *Bubulcus ibis* (Ciconiformes: Ardeidae), in the dissemination of *Amblyomma variegatum* (Acari: Ixodidae) in the Eastern Caribbean. *Journal of Medical Entomology*, 30: 1029-1037.

Costa-Junior, L. M., Rabelo, E. M., Martins Filho, O. A. & Ribeiro, M. F. 2006. Comparison of different direct diagnostic methods to identify *Babesia bovis* and *Babesia bigemina* in animals vaccinated with live attenuated parasites. *Veterinary Parasitology* 139, 231-6.

Cuisance, D., Barré, N., De Deken, R. 1994. Ectoparasites des animaux : méthodes de lutte écologique, biologique, génétique et mécanique. *Revue scientifique et technique de l'Office international des Epizooties*, 13: 1305-1356.

Cumming. G. 2008. The Tick Distributions Project <http://www.wec.ufl.edu/faculty/cummingg/Ticks/Appendix3< accessed on 16 October 2008

Davies F.G. & Terpstra C. 2004. *Nairobi Sheep Disease* in Infectious Diseases of Livestock J. A. W. COETZER & R C TUSTIN (eds) 2nd edition Oxford University Press pp 1071-1076.

de Castro, J.J. & Newson, R.M. 1993. Host resistance in cattle tick control. *Parasitology Today*, 9: 13-17.

De Vos A.J. 1981 Rhipicephalus appendiculatus: cause and vector of diseases in Africa. *Journal of South African Veterinary Association* 52: 315-22.

Estrada-Peña A. 2003 Climate change decreases habitat suitability for some tick species (Acari: Ixodidae) in South Africa. *Onderstepoort Journal of Veterinary Research;*70:79-93.

Estrada-Peña, A., Horak, I.G., Petney, T. 2008. Climate changes and suitability for the ticks *Amblyomma hebraeum* and *Amblyomma variegatum* (Ixodidae) in Zimbabwe (1974-1999). *Veterinary Parasitology*, 151: 256-267.

FAO. 1990. Report of the FAO expert consultation on revision of strategies for the control of ticks and tick-borne diseases, Rome, 25-29 september 1989. *Parassitologia*, 32: 3-12.

Fauna Europaea .2004. <Fauna Europaea www.faunaeur.org. accessed on 16 october 2008>
Floyd, R .B., Sutherst, R.W . & Maywald, G.F ., 1987 . Modelling tic k management. 111 . Designing control strategies for Rhipicephalus appendiculatus using T3110ST . III : SUTHERST, R .W., (ed .) . Ticks and Tick-borne Diseases. Proceedings ofan International Workshop, 17-21 February 1986, Nyanga, Zimbabwe. Canberra : ACIAR .

Georges, K., Loria, G. R., Riili, S., Greco, A., Caracappa, S., Jongejan, F. & Sparagano, O. 2001. Detection of haemoparasites in cattle by reverse line blot hybridisation with a note on the distribution of ticks in Sicily. *Veterinary Parasitology* 99, 273-86.

Gomes, A.F. 1993. The tick vectors of cowdriosis in Angola. *Revue d'Elevage et de Médecine vétérinaire des Pays tropicaux*, 46: 237-243.

Gothe, R. 1967. Ticks in the South African Zoological Survey Collection. 13. Gynanders of *Boophilus decoloratus* (Koch, 1844) and *Amblyomma hebraeum* Koch, 1844. *Onderstepoort*

Journal of Veterinary Research 34, 541-5.

Gray, J.S. 1985. A carbon dioxide trap for prolonged sampling of *Ixodes ricinus* L. populations. *Experimental and Applied Acarology*, 1: 35-44.

Hilpertshauser, H., Deplazes, P., Meli, M. L., Hofmann-Lehmann, R., Lutz, H. & Mathis, A. 2007. Genotyping of *Babesia bigemina* from cattle from a non-endemic area (Switzerland). *Veterinary Parasitology* 145, 59-64.

Hoogstraal H . & Kaiser, M .N ., 1958. The ticks (lxodoidea) of Egypt . *Journal of the Egyptian Public Health Association* 33, 51-85 .

Hoogstraal H . 1956 . African lxodoidea . *(Vol . I . Ticks of the Sudan . With special referens to Equatoria Province and with preliminary reviews o f the genera Boophilus, Margaropus and Hyalomma .)* Research Report NM 005 050. 29.07 . Department of the Navy, Bureau of Medicine and Surgery, Washington D .C .

Hoogstraal H. 1978 The epidemiology of tick-borne Crimean-Congo hemorrhagic fever in Asia, Europe, and Africa. *Journal of Medical Entomology* 15:307–417

Horak, I .G .1982. Parasites of domestic and wild animals in South Africa . XV. The seasonal prevalence of ectoparasites on impala and cattle in the northern Transvaal . *Onderstepoort Journal of Veterinary Research*, 49: 85-93.

Horak, I. G., De Vos, V. & De Klerk, B. D. 1984. Parasites of domestic and wild animals in South Africa. XVII. Arthropod parasites of Burchell's zebra, *Equus burchelli*, in the eastern Transvaal Lowveld. *Onderstepoort Journal of Veterinary Research* 51, 145-54.

Horak, I. G., Sheppey, K., Knight, M. M. & Beuthin, C. L. 1986. Parasites of domestic and wild animals in South Africa. XXI. Arthropod parasites of vaal ribbok, bontebok and scrub hares in the western Cape Province. *Onderstepoort Journal of Veterinary Research* 53, 187-97.

Horak, I .G ., Boomker, J . & Flamand, J .R. B., 1995 . Parasites of domestic and wild animals in South Africa. XXXIV. Arthropod parasites of nyalas in north-eastern KwaZulu-Natal. *Onderstepoort Journal of Veterinary Research,* 62: 171-179 .

Horak, I.G. 1998 . The relationships between ticks, hosts and the environment in the Kruger National Park . *In* : COONS, L . & ROTHSHILD, M . (eds) . The Second International Conferente on Tick-borne Pathogens at the Host-Vector Interface: a Global Perspective, August 28-September 1 1995, Kruger National Park, South Africa : proceedings and abstracts, 2 : 413-426 .

Horak I.G., Swanepoel R. & Gummow, B. 2001 The distribution of *Hyalomma spp*. and human cases of crimean-congo haemorrhagic fever in south africa Livestock Community and Environment. Proceedings of the 10th Conference of the Association of Institutions for Tropical Veterinary Medicine, Copenhagen, Denmark, 2001.

Howell, C .J ., Walker I .B . & Nevill E .M .1978 . Ticks, mites and insects infesting domestic animals in South Africa. Part 1 . *Descriptions and biology Department ofAgricultural Technical Services, Republic of South Africa, Science Bulletin* No. 393 .

Howell, J. M., Ueti, M. W., Palmer, G. H., Scoles, G. A. & Knowles, D. P. 2007. Persistently infected calves as reservoirs for acquisition and transovarial transmission of *Babesia bovis* by *Rhipicephalus (Boophilus) microplus*. *Journal of Clinical Microbiology* 45, 3155-9.

Hu, R ., Hyland, K. E. & Oliver, J. H., 1998 . A review on the use of *lxodiphagus* wasps (Hynlenoptera : Encyrtidae) as natural enemics for the control of ticks (Acari: ixodidae). *Systernatic and Applied Acarology* , 3:19-28.

Jongejan, F., Perry, B. D., Moorhouse, P. D., Musisi, F. L., Pegram, R. G. & Snacken, M. 1988. Epidemiology of bovine babesiosis and anaplasmosis in Zambia. *Tropical Animal Health Production* 20, 234-42.

Jongejan, F. & Uilenberg, G. 1994. Ticks and control methods. *Revue scientifique et technique de l'Office international des Epizooties*, 13: 1201-1226.

Jonsson, N. N., Mayer, D. G. & Green, P. E. 2000. Possible risk factors on Queensland dairy farms for acaricide resistance in cattle tick (*Boophilus microplus*). *Veterinary Parasitology* 88, 79-92.
Kaiser, M. N., Sutherst, R .W ., Bourne, A . S ., Gorissen, I . & Floyd, R . 1988. Population dynamics of ticks on Ankole cattle in five ecological zones in Burundi and strategies for their controL. *Preventive Veterinary Medicine*, 6: 199-222.

Kiwanuka, A ., Stewart, C. J. , Bryson, N. R., De Waal, D. T., Tice, G. A., Schoeman, N .S . & Pettey, K. P. 1998 . Participatory research and extension approach to tick contro) in a developing area of South Africa . In : COONS , L . & ROTHSHILD.D,M . (eds) . The Second lnternational Conference on Tick-borne Pathogens *at Host-Vector interface: a Global Perspective*, August 28-September 1 1995, Kruger National Park, South Africa : proceedings and abstracts, 2: 481-491 .

Kocan K.M., Goff W.L., Stiller D., Claypool P.L., Edwards W., Ewing S.A., Hair J.A. & Barron S.J.1992. Persistence of Anaplasma marginale (Rickettsiales: Anaplasmataceae) in male *Dermacentor andersoni* (Acari: Ixodidae) transferred successively from infected to susceptible cattle. *Journal of. Medical. Entomology*,. 29, 657–668.

Kocan K.M., De La Fuente J., Blouin E.F. & Garcia-Garcia J.C. 2004. *Anaplasma marginale* (Rickettsiales: Anaplasmataceae): recent advances in defining host-pathogen adaptations of a tick-borne rickettsia. Parasitology, 129, 285–300.

Latif A.A. & Walker A.R. 2004 An introduction to the biology and control of ticks in Africa in *Ticks of Veterinary and Medical Importance :Africa* ICTTD-2 (eds)

Lawrence, J.A., Foggin, C.M., Norval, R.A.I. 1980. The effect of war on the control of the diseases of livestock in Rhodesia (Zimbabwe). *Veterinary Record*, 107: 82-85.

Laurence J.A., Perry .D. & Williamson S.M. 2004 *East Coast fever* in Infectious Diseases of Livestock J. A. W .COETZER & R .C. TUSTIN (eds) 2nd edition, Oxford University Press pp 448-467.

Lefrançois T. & Vachiéry N. 2008. CIRAD Guadeloupe, personal communication.

Lessard, P ., L 'Eplattenier, R ., Norval, R.A .I ., Kundert, K ., Dolan, T.T. , Croze, H., Walker, J .B ., Irvin, A. D. & Perry, B .D . 1990 . Geographical information systems for studying the epidemiology of cattle diseases caused by *Theileria parva* . *Veterinary Record,* 126: 255-262 .

Liebish A., Rahaman M.S. & Hoogstaal H. 1989 Tick fauna of Egypt with special reference to studies on *Hyalomma anatolicum anatolicum* the natural vector of Theilerioses. *Progress in Acarology* vol. 1: 55-58.

Lightfoot, C.J. & Norval, R.A.I. 1981. Tick problems in wildlife in Zimbabwe. 1 .The effects of tick parasitism on wild ungulates . *South African Journal of Wildlife Research,* 11: 41-45.

Lounsbury, C. P. 1904 . Transmission of African coast fever. *Agricoltural Journal*, Cape Town, 24: 428-432.

Macleod J., Colbo, M .H ., Madbouly, M. H. & Mwanaumo, B. 1977 . Ecological studies of ixodid ticks (Acari : Ixodidae) in Zambia . III Seasonal activity and attachment sites on cattle, with notes on other hosts. *Bulletin of entomological Research,* 67: 161-173.

Madder M., Speybroeck N., Brandt J., Tirry L. , Hodek I. & Berkvens D. 2002 Geographic variation in diapause response of adult Rhipicephalus appendiculatus ticks *Experimental and Applied Acarology* ,27: 209-21.

Mahan, S.M., Peter, T.F., Simbi, B.H., Kocan, K., Camus, E., Barbet, A.F., Burridge, M.J. 2000. Comparison of efficacy of American and African *Amblyomma* ticks as vectors of heartwater (*Cowdria ruminantium*) infection by molecular analyses and transmission trials. *Journal of Parasitology,* 86, 44-9.

Manilla G. 1998 *Subfam. Hyalomminae* In Ixodida –Fauna d'Italia ed Calderini, Bologna pp 174-200.

Marchette N. & Stiller D. 1982 Chapter 11: *The Anaplasmataceae, Bartonellaceae, and Rochalimaea quintana.* In: Ecological Relationships and Evolution in the Rickettsiae, Vol. 11, Marchette N.J., ed. CRC Press, Boca Raton, Florida, USA, 98–106.

Martins, T. M., Pedro, O. C., Caldeira, R. A., do Rosario, V. E., Neves, L. & Domingos, A. 2008. Detection of bovine babesiosis in Mozambique by a novel seminested hot-start PCR method. *Veterinary Parasitology,* 153, 225-30.

Masika P. J. , Sonandi A. & Van Averbeke W. 1997 . Tick control by small-scale cattle farmers in the central Eastern Cape Province, South Africa . *Journal of the* South *African Veterinary Association,* 68: 45-48.

Matthysse I .G . & Colbo M. I. 1987. The lxodid ticks of Uganda together with Species Pertinent to Uganda because of their Present Known Distribution. College Park, MD : Entomological Society of America .

Mattioli R.C., Ianneh, L ., Corb, N ., Faye, J.A ., Pandey V .S . & Verhulst A. 1997. Seasonal prevalence of ticks and tick-transmitted hemoparasites in traditionally managed N'dama cattle with reference to strategic tick control in The Gambia . *Medical and Veterinary Entomology,* 11: 342-348.

Mattioli R.C., Pandey V. S. , Murray M., Fitzpatrick J. L. 2000. Immunogenetic influences on tick resistance in African cattle with particular reference to trypanotolerant N'Dama *(Bos taurus)* and trypanosusceptible Gobra zebu *(Bos indicus*) cattle. *Acta Tropica,* 75: 263–277.

McCartan, B.M., Hunter, A.G., Pegram, R.G., Bourne, A.S. 1987. Tick infestations on livestock in the Yemen Arab Republic and their potential as vectors of livestock diseases. *Tropical Animal Health & Production*, 19, 21-31.

Mcculloch B., Kalaye W.J., Tungaraza R ., Suda B ' Q .J . & Mbasha, E. M. S.,1968 A study of the life history of the tick *Rhipicephalus appendiculatus*- the main vector of East Coast fever- with reference to its behaviour under field conditions and with regard to its control in Sukumaland, Tanzania . *Bulletin of Epizootic Diseases of Africa,* 16: 477-500 .

Meltzer, M.I. 1996. A possible explanation of the apparent breed-related resistance in cattle to bont tick (*Amblyomma hebraeum*) infestations. *Veterinary Parasitology*, 67: 275-279.

Merck & Co., Inc.Whitehouse Station, Nj Usa. 2008. *Hyalomma spp.* www.merckvetmanual.com/mvm/index.jsp?cfile=htm/bc/72111.htm acessed on 7th August 2008.

M'Ghirbi, Y., Hurtado, A., Brandika, J., Khlif, K., Ketata, Z. & Bouattour, A. 2008. A molecular survey of Theileria and Babesia parasites in cattle, with a note on the distribution of ticks in Tunisia. *Parasitology Reseach*, 435-442.

Morel, P.-C. 1969. Contribution à la connaissance de la distribution des tiques (Acariens, Ixodidae et Amblyommidae) en Afrique éthiopienne continentale. Thèse de Doctorat ès-Sciences, Université de Paris-Sud-Orsay, France. 388 pp.

Morel, P.-C. 1981. Maladies à tiques du bétail en Afrique. *In* Précis de parasitologie vétérinaire tropicale. Paris, France, Ministère de la Coopération et du Développement - Institut d'Elevage et de Médecine Vétérinaire des pays Tropicaux: 473-717.

Mwangi E.N., Hassan S. M ., Kaaya G .P . & Essijman S. 1997. The impact of *Ixodiphagus hookeri*, a tick parasitoid, on *Amblyonnna variegatum* (Acari : lxodidae) in a field trial in Kenya . *Experimental and Applied Acarology*, 21:117-126.

Norval R .A.I ., 1982 .The ticks of Zimbabwe. IV . The genus Hyalomma *Zimbabwe Veterinary Journa*l, 13: 2-10

Norval, R.A.I. 1977. Ecology of the tick *Amblyomma hebraeum* Koch in the Eastern Cape Province of south Africa. I. Distribution and seasonal activity. *Journal of Parasitology*, 63: 734-739.

Norval, R.A.I. & Lawrence, J.A. 1979. The control of heartwater in Zimbabwe-Rhodesia. *Zimbabwe Rhodesia Agricultural Journal*, 76: 161-165.

Norval, R.A.I. & Rechav, Y. 1979. An assembly pheromone and its perception in the tick *Amblyomma variegatum* (Acarina : Ixodidae). *Journal of Medical Entomology*, 16: 507-511.

Norval R. A. I., Walker J. B. & Colborne J. 1982. The ecology of *Rhipicephalus zambeziensis* and *Rhipicephalus appendiculatus* (Acarina: Ixodidae) with particular reference to Zimbabwe. *Onderstepoort Journal of Veterinary Research*, 49: 181-190 .

Norval, R. A., Fivaz, B. H., Lawrence, J. A. & Daillecourt, T. 1983. Epidemiology of tick-borne diseases of cattle in Zimbabwe. I. Babesiosis. *Tropical Animal Health Production* 15, 87-94.

Norval, R.A.I. 1983. The ticks of Zimbabwe. VII. The genus *Amblyomma*. *Zimbabwe Veterinary Journal*, 14: 3-18.

Norval R.A.I., Fivaz B. H ., Lawrence J.A . & Brown A. 1985. Epidemiology of tick-borne diseases of cattle in Zimbabwe. III . *Tlleileria parva* group . *Tropical* Animal *Health and Production*, 17, 19-28.

Norval, R.A.I., Yunker, C.E., Butler, J.F. 1987. Field sampling of unfed adults of *Amblyomma hebraeum* Koch. *Experimental and Applied Acarology*, 3: 213-217.

Norval, R.A.I., Butler, J.F., Yunker, C.E. 1989. Use of carbon dioxide and natural or synthetic aggregation-attachment pheromone of the bont tick, *Amblyomma hebraeum*, to attract and trap unfed adults in the field. *Experimental and Applied Acarology*, 7: 171-180.

Norval R.A.I. & Perry B. D. 1990. Introduction, spread and subsequent disappearance of the brown ear-tick, *Rhipicephalus appendiculatus*, from the southern lowveld of Zimbabwe . *Experimental and Applied Acarology*, 9: 103-111 .

Norval, R.A.I., Andrew, H.R., Yunker, C.E., Burridge, M.J. 1992a. Biological processes in the epidemiology of heartwater. *In* Tick vector biology. Medical and veterinary aspects. Edited by B. Fivaz, T. Petney & I. Horak. Berlin, Springer-Verlag: 71-86.

Norval, R.A.I., Barrett, J.C., Perry, B.D., Mukhebi, A.W. 1992b. Economics, epidemiology and ecology: a multidisciplinary approach to the planning and appraisal of tick and tick-borne disease control in southern Africa. *In* Tick vector biology. Medical and veterinary aspects. Edité par B. Fivaz, T. Petney & I. Horak. Berlin, Springer-Verlag: 35-54.

Norval, R.A.I., Peter, T., Meltzer, M.I. 1992c. A comparison of the attraction of nymphs and adults of the ticks *Amblyomma variegatum* and *A. hebraeum* to carbon dioxide and the male-produced aggregation-attachment pheromone. *Experimental and Applied Acarology*, 13: 179-186.

Norval, R.A.I., Perry, B.D., Meltzer, M.I., Kruska, R.L., Booth, T.H. 1994. Factors affecting the distributions of the ticks *Amblyomma hebraeum* and *A.variegatum* in Zimbabwe: implications of reduced acaricide usage. *Experimental and Applied Acarology*, 18: 383-407.

Norval, R.A.I., Sonenshine, D.E., Allan, S.A., Burridge, M.J. 1996. Efficacy of pheromone-acaricide-impregnated tail-tag decoys for controlling the bont tick, *Amblyomma hebraeum* (Acari : Ixodidae), on cattle in Zimbabwe. *Experimental and Applied Acarology*, 20: 31-46.

Norval R.A.I. & Horak I.G. 2004 . *Ticks* in Infectious Disease of Livestock COETZER J. A. W. & R. C .TUSTIN (eds) 2nd edition Oxford University Press pp 3-42.

OIE – World Organization for Animal Health 2008 Chapter 2.4.1.*Anaplasmosis* in OIE – Manual of Diagnostic Tests and Vaccines for Terrestrial Animals pp 555-610.

Oliveira-Sequeira, T. C., Oliveira, M. C., Araujo, J. P., Jr. & Amarante, A. F. 2005. PCR-based detection of Babesia bovis and Babesia bigemina in their natural host *Boophilus microplus* and cattle. *International Journal of Parasitology,* 35: 105-11.

Olwoch, J.M., Van Jaarsveld, A.S., Scholtz, C.H. & Horak, I.G. 2007. Climate change and the genus *Rhipicephalus* (Acari: Ixodidae) in Africa. *Onderstepoort Journal of Veterinary Research,*74:45–72.

Oura, C. A., Bishop, R. P., Wampande, E. M., Lubega, G. W. & Tait, A. 2004. Application of a reverse line blot assay to the study of haemoparasites in cattle in Uganda. *International Journal of Parasitology* 34, 603-13.

Papadopoulos, B., Brossard, M. & Perie, N. M. 1996. Piroplasms of domestic animals in the Macedonia region of Greece. 2. Piroplasms of cattle. *Veterinary Parasitology,* 63: 57-66.

Pegram R .G ., Hoogstraal, H . & Wassef, H .Y.1981 . Ticks (Acari : Ixodoidea) of Ethiopia. I . Distribution, ecology and host relationships of species infesting livestock . *Bulletin of Entomological Research,* 71: 339-359 .

Pegram, R. G., Perry, B. D., Musisi, F. L. & Mwanaumo, B. 1986. Ecology and phenology of ticks in Zambia: seasonal dynamics on cattle. *Experimental and Applied Acarology,* 2: 25-45.

Pegram, R.G., Mwase, E.T., Zivkovic, D., Jongejan, F. 1988. Morphogenic diapause in *Amblyomma variegatum* (Acari: Ixodidae). *Medical and Veterinary Entomology,* 2: 301-307.

Pegram, R.G. & Banda, D.S. 1990. Ecology and phenology of cattle ticks in Zambia: development and survival of free-living stages. *Experimental and Applied Acarology,* 8: 291-301.

Pegram, R.G., Dupre, P., Hansen, J.W., Gersabeck, E.F. 2001. Eradication of the Tropical Bont Tick in the Caribbean: is the Caribbean *Amblyomma* Program in a crisis? "*International Joint Conference - Society for Tropical Veterinary Medicine and the Wildlife Disease Association*", Pilanesberg National Park, RSA.

Pegram, R.G., Tatchell, R.J., de Castro, J.J., Chizyuka, H.G.B., Creek, M.J., McCosker, P.J., Moran, M.C., Nigarura, G. 1993. Tick control: new concepts. *World Animal Review,* 74/75: 2-11.

Pegram, R.G., Rota, A., Onkelinx, R., Wilson, D.D., Bartlette, P., Nisbett, B.S., Swanston, G., Vanterpool, P., de Castro, J.J. 1996. Eradicating the tropical bont tick from the Caribbean. *World Animal Review*, 87: 56-65.

Peter, T.F., Perry, B.D., O'Callaghan, C.J., Medley, G.F., Shumba, W., Madzima, W., Burridge, M.J., Mahan, S.M. 1998. The distribution of heartwater in the highveld of Zimbabwe, 1980-1997. *Onderstepoort Journal of Veterinary Research*, 65:177-87.

Petney, T.N., Horak, I.G., Rechav, Y. 1987. The ecology of the african vectors of heartwater, with particular reference to *Amblyomma hebraeum* and *A.variegatum*. *Onderstepoort Journal of veterinary Research*, 54: 381-395.

Pipano E. & Shkap V. 2004 *Theileria annulata theileriosis* in Infectious Diseases of Livestock J. A. W .COETZER & R .C. TUSTIN (eds) 2nd edition, Oxford University Press pp 486-497.

Randolph S.E. 1993. Climate, satellite imagery and the seasonal abundance of the tick *Rhipicephalus appendiculatus* in southern Africa: a new perspective. *Medical and Veterinary Entomolog*,. 7:243-58.

Rasulov I. 2007. Ticks status in Central Asia with a special emphasis on Uzbekistan *Parasitology Research* 101 Suppl 2:183-6.

Rechav, Y. 1979. Migration and dispersal patterns of three african ticks (Acari: Ixodidae) under field conditions. *Journal of Medical Entomology*, 16: 150-163.

Rechav Y. 1982. Dynamics of tick populations (Acari : Ixodidae) in the eastern Cape Province of South Africa . *Journal of MedicaL Entomology* , 19: 679-700 .

Rechav Y., Zeederberg M .E . & Zeller, D .A . 1987. Dynamics of African tick (Acari : Ixodoidea) populations in a natural Crimean-Congo hemorrhagic fever focus . *Journal of Medical Entomology*, 24: 575-583.

Rechav, Y. & Kostrzewski, M. W. 1991. Relative resistance of six cattle breeds to the tick *Boophilus decoloratus* in South Africa. *Onderstepoort Journal of Veterinary Research*, 58, 181-6.

Ristic M. 1968. Chapter 23: Anaplasmosis. In: Infectious Blood Diseases of Man and Animals, Vol. 11, Weinman D. & Ristic M., eds. Academic Press, New York, USA, 473–542.

Ruiz-Fons F, Fernández-De-Mera Ig, Acevedo P, Höfle U, Vicente J, De La Fuente J, Gortazár C. 2006 Ixodid ticks parasitizing Iberian red deer (*Cervus elaphus hispanicus*) and European wild boar (*Sus scrofa*) from Spain: geographical and temporal distribution. *Veterinary Parasitology* 140(1-2):133-42. Epub 2006 May.

Santos Dias, J.A .T. 1993. Some data concerning the ticks (Acarina-Ixodoidea) presently known in Mozambique *Garcia de Orta, Séries Zoologica, Lisboa*, 18 (1991): 27-48.

Short N. J. & Norval. R. A. 1981. The seasonal activity of R*hipicephalus appendicultus* Neumann 1901 (Acarina : lxodidae) in the highveld of Zimbabwe Rhodesia . *Journal of Parasitology*, 67: 77-84 .

Sonenshine, D.E., Allan, S.A., Norval, R.A.I., Burridge, M.J. 1996. A self-medicating applicator for control of ticks on deer. *Medical and Veterinary Entomology*, 10: 149-154.

Spickett, A. M. & Malan, J. R. 1978.Genetic incompatibility between *Boophilus decoloratus* (Koch, 1844) and *Boophilus microplus* (Canestrini, 1888) and hybrid sterility of Australian and South African *Boophilus microplus* (Acarina: Ixodidae). *Onderstepoort Journal of Veterinary Research* ,45: 149-53.

Spickett, A.M., Horak, I.G., Braack, L.E.O., Van Ark, H. 1991. Drag-sampling of free-living ixodid ticks in the Kruger National Park. *Onderstepoort Journal of veterinary Research*, 58: 27-32.

Spickett, A. M., Horak, I. G., Van Niekerk, A. & Braack, L. E. 1992. The effect of veld-burning on the seasonal abundance of free-living ixodid ticks as determined by drag-sampling. *Onderstepoort Journal of Veterinary Research* ,59: 285-92.

Stachurski, F. & Lancelot, R. 2006. Foot-bath acaricide treatment to control cattle infestation by the tick *Amblyomma variegatum*. *Medical and Veterinary Entomology*, 20: 402-412.

Stachurski, F. 2000a. Modalités de la rencontre entre la stase adulte de la tique *Amblyomma variegatum* (Acari, Ixodida) et les bovins : applications potentielles à la lutte contre ce parasite. Thèse de Doctorat ès Sciences, Université de Montpellier II (Sciences et Techniques du Languedoc). 264 pp.

Stachurski, F. 2000b. Invasion of West African cattle by the tick *Amblyomma variegatum*. *Medical and Veterinary Entomology*, 14: 391-399.

Stachurski, F. 2006. Attachment kinetics of the adult tick *Amblyomma variegatum* to cattle. *Medical and Veterinary Entomology*, 20: 317-324.

Stachurski, F. 2007. Poor inheritance of low attractiveness for *Amblyomma variegatum* in cattle. *Veterinary Parasitology*, 146: 321-328.

Swanepoel, R. 1998. Crimean-Congo haemorrhagic fever. In: *Zoonoses* S.R. Palmer, E.J. L. Soulsby, and D.I.H. Simpson(eds), Oxford: Oxford University Press. 461-470.

Swanepoel, R., Leman, P.A., Burt, F.J., Jardine, J., Verwoerd, D.J., Capua, I., Brückner, G.K. & Burger, W.P. 1998. Experimental infection of ostriches with Crimean-Congo haemorrhagic fever virus. *Epidemiology and Infection*, 121: 427-432.

Tonbak S., Aktas M., Altay K., Azkur Ak, Kalkan A., Bolat Y., Dumanli N., Ozdarendeli A. 2006. Crimean-Congo hemorrhagic fever virus: genetic analysis and tick survey in Turkey *Journal of Clinical Microbiology*, 44:4120-4.

Turrel M.J. 2007 *Role of Ticks in the Transmission of Crimean Congo Haemorrhagic Fever Virus* in “Crimean Congo Haemorrhagic Fever-A global perspective” Ergonul O. and Whitehouse C.A. (eds) Springer pp43-55.

Uilenberg, G. 1984. An historical account of tick and tick-borne disease control in East Africa with emphasis on tick-borne diseases. Implications for centres in West Africa. "FAO seminar on African centres for tick and tick-borne disease control", Ouagadougou, 26-29 November 1984. FAO, Rome. 9 pp.

Uilenberg, G. 1992. Veterinary significance of ticks and tick-borne diseases. *In* Tick vector biology. Medical and veterinary aspects. Edité par B. Fivaz, T. Petney & I. Horak. Berlin, Springer-Verlag: pp 23-33.

Van Someren V .D. 1951. The red-billed oxpecker and its relation to stock in Kenya . *East African Agricultural journal*, 17: 1-11.

Walker J. B., Keirans J. E. & Horak I. G. 2000. The Genus *Rhipicephalus* (Acari, Ixodidae): a Guide to the Brown Ticks of the World. United Kingdom: Cambridge University Press .

Walker, A.R., Bouattour, A., Camicas, J.-L., Estrada-Peña, A., Horak, I., Latif, A.A., Pegram, R.G., Preston, P.M. 2003. Ticks of domestic animals in Africa: a guide to identification of species. Edinburgh, Bioscience Reports. 221 pp

Walker J. B. 1974 . The Ixodid Ticks of Kenya. A Review of present Knowledge of their Hosts and Distribution. London: Commonwealth Institute of Entomology.

.

Walker, J.B. & Olwage, A. 1987. The tick vectors of *Cowdria ruminantium* (Ixodoidea, Ixodidae, genus *Amblyomma*) and their distribution. *Onderstepoort Journal of veterinary Research*, 54: 353-379.

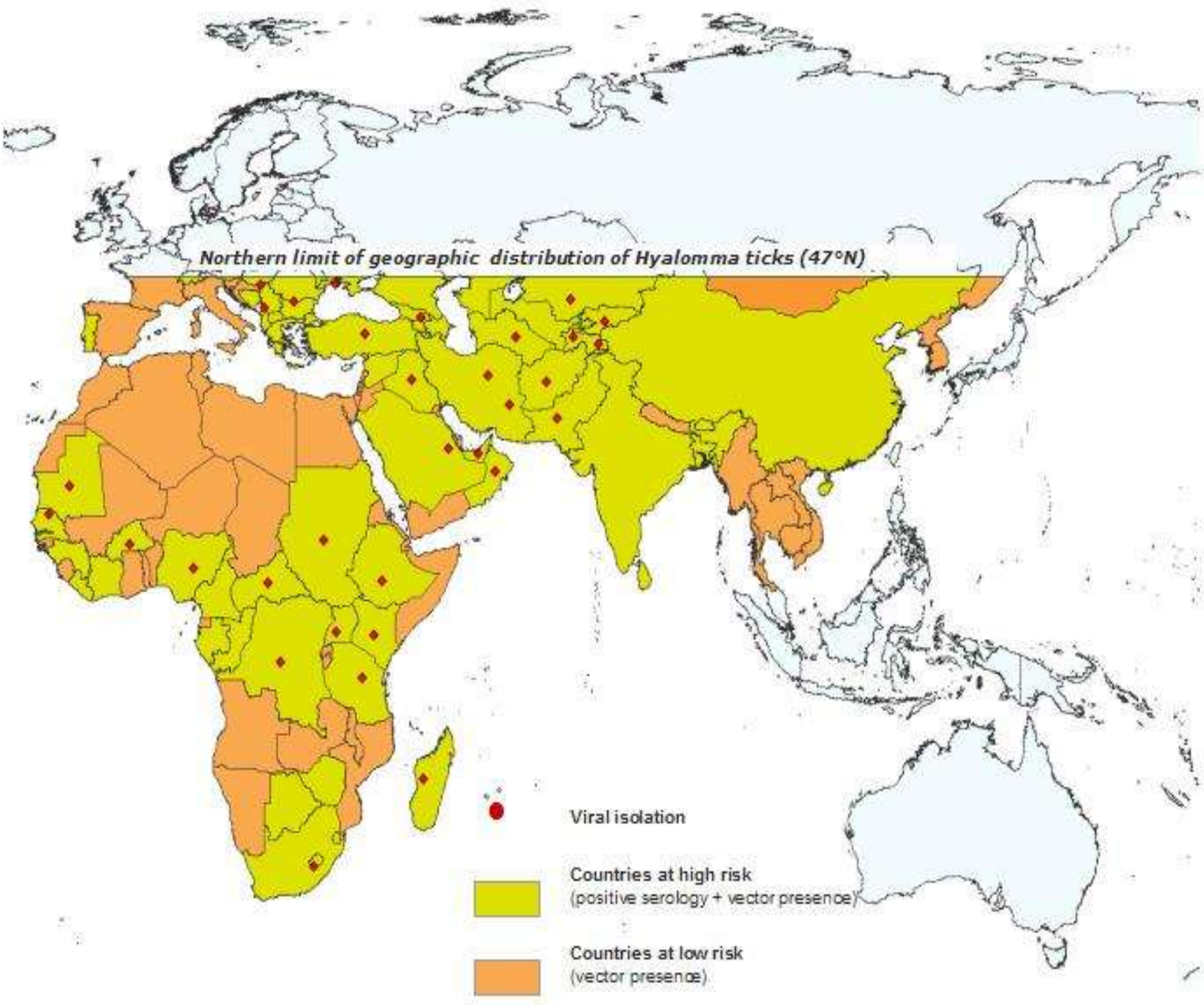
WHO. Crimean-Congo haemorrhagic fever (CCHF) <www.who.int/csr/disease/crimean_congohf/en/> accessed on 16 october 2008

Yonow, T. 1995. The life-cycle of *Amblyomma variegatum* (Acari: Ixodidae): a literature synthesis with a view to modelling. *International Journal for Parasitology*, 25: 1023-1060.

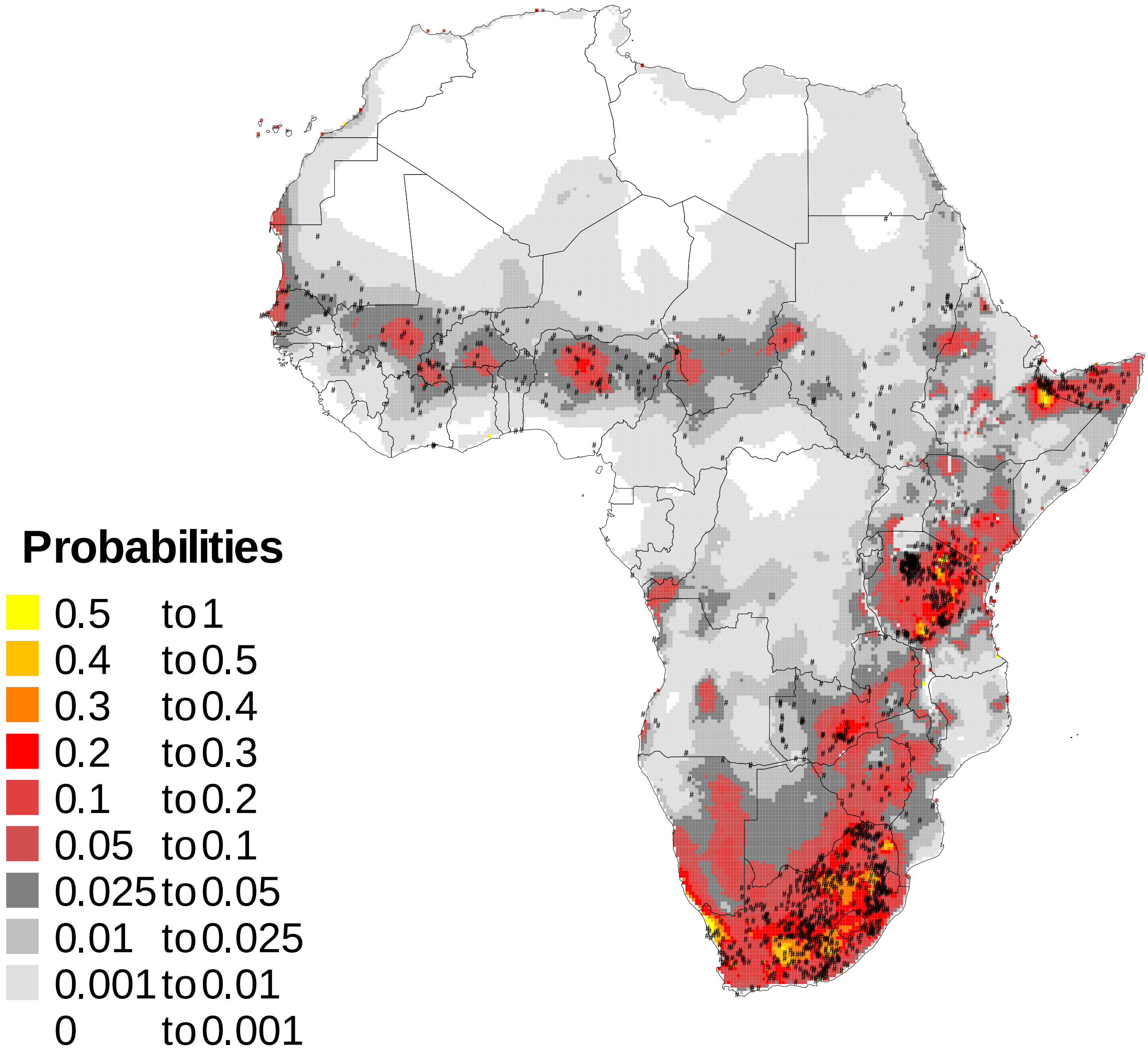
Young, A.S., Groocock, C.M., Kariuki, D.P. 1988. Integrated control of ticks and tick-borne diseases of cattle in Africa. *Parasitology*, 96: 403-432.

Zieger U. Horak I.G. Cauldwell A.E. & Uys A .C. 1998 . Ixodid tick infestations of wild birds and mammals on a game ranch in Central Province, Zambia. *Onderstepoort Journal of Veterinary Research*, 65: 113-124.

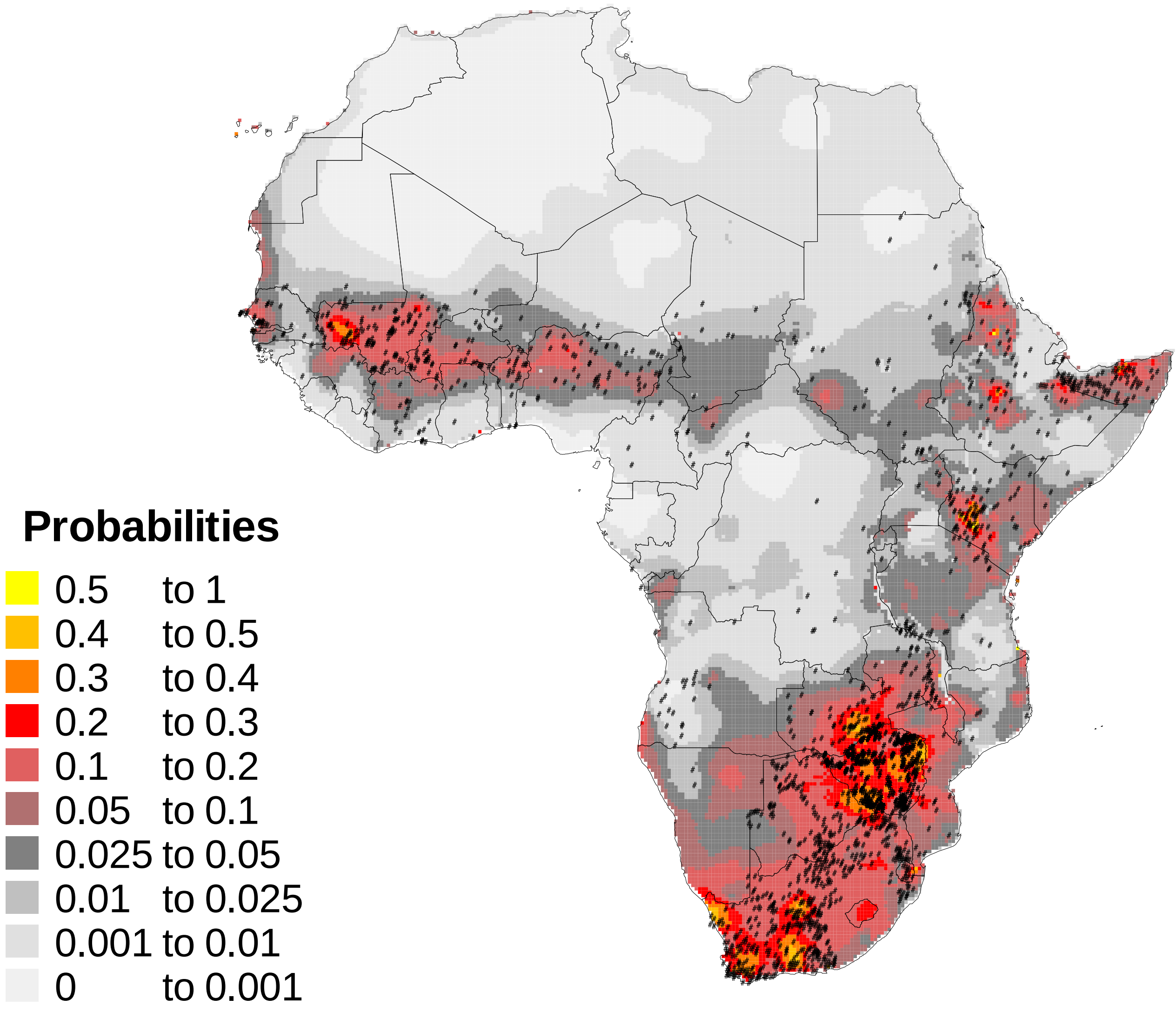
ANNEX I- MAPS ON TICK DISTRIBUTION



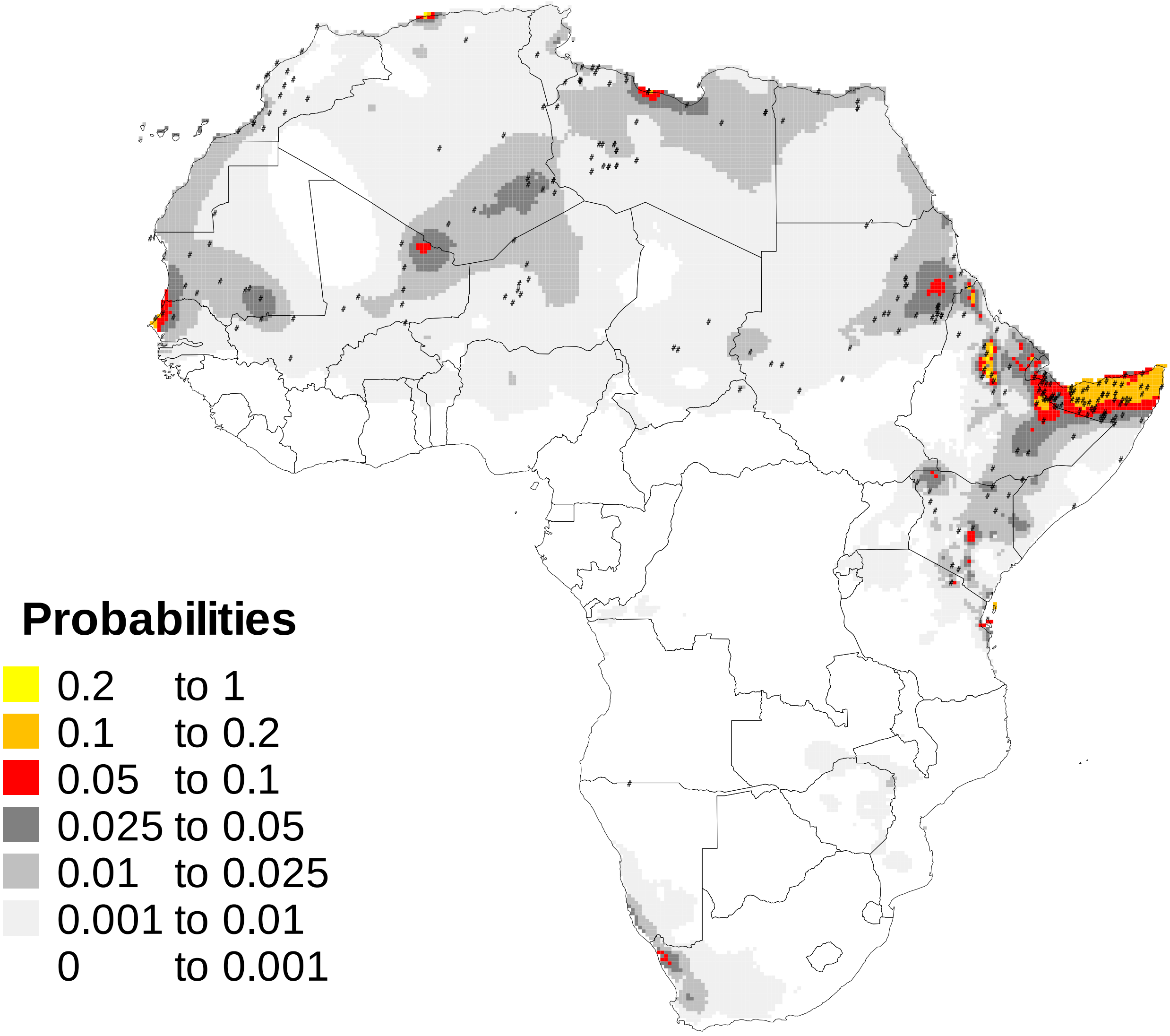
DISTRIBUTION OF CCHF AND ITS VECTORS FROM WWW.WHO.INT/CSR/DISEASE/CRIMEAN_CONGOHF/EN/


Probabilities
0.5 to 1
0.4 to 0.5
0.3 to 0.4
0.2 to 0.3
0.1 to 0.2
0.05 to 0.1
0.025 to 0.05
0.01 to 0.025
0.001 to 0.01
0 to 0.001

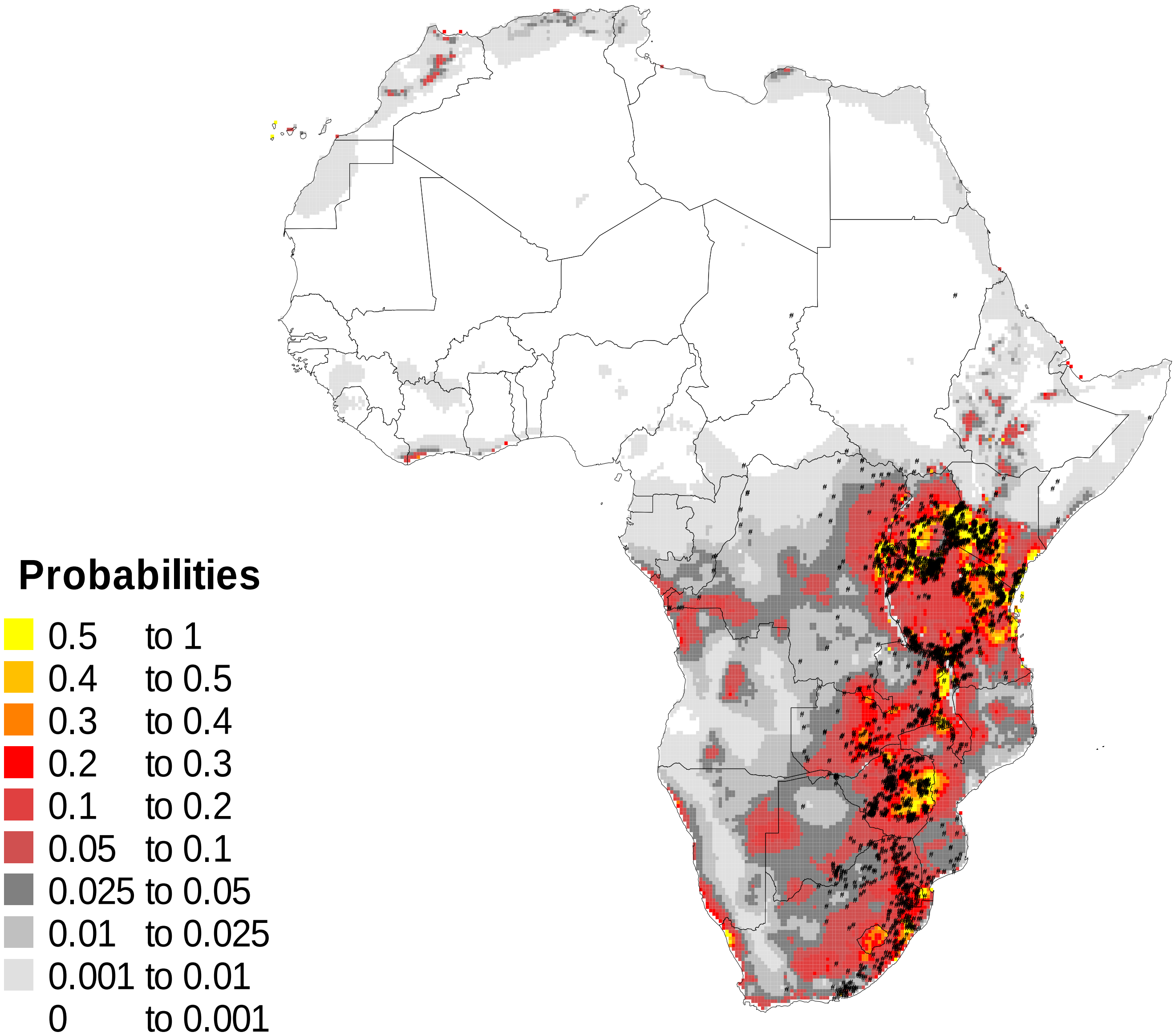
KNOWN AND PREDICTED DISTRIBUTIONS OF *HYALOMMA MARGINATUM RUFIPES* IN AFRICA FROM WWW.WEC.UFL.EDU/FACULTY/CUMMINGG/TICKS/APPENDIX3_FILES/FRAME.HTM


Probabilities
0.5 to 1
0.4 to 0.5
0.3 to 0.4
0.2 to 0.3
0.1 to 0.2
0.05 to 0.1
0.025 to 0.05
0.01 to 0.025
0.001 to 0.01
0 to 0.001

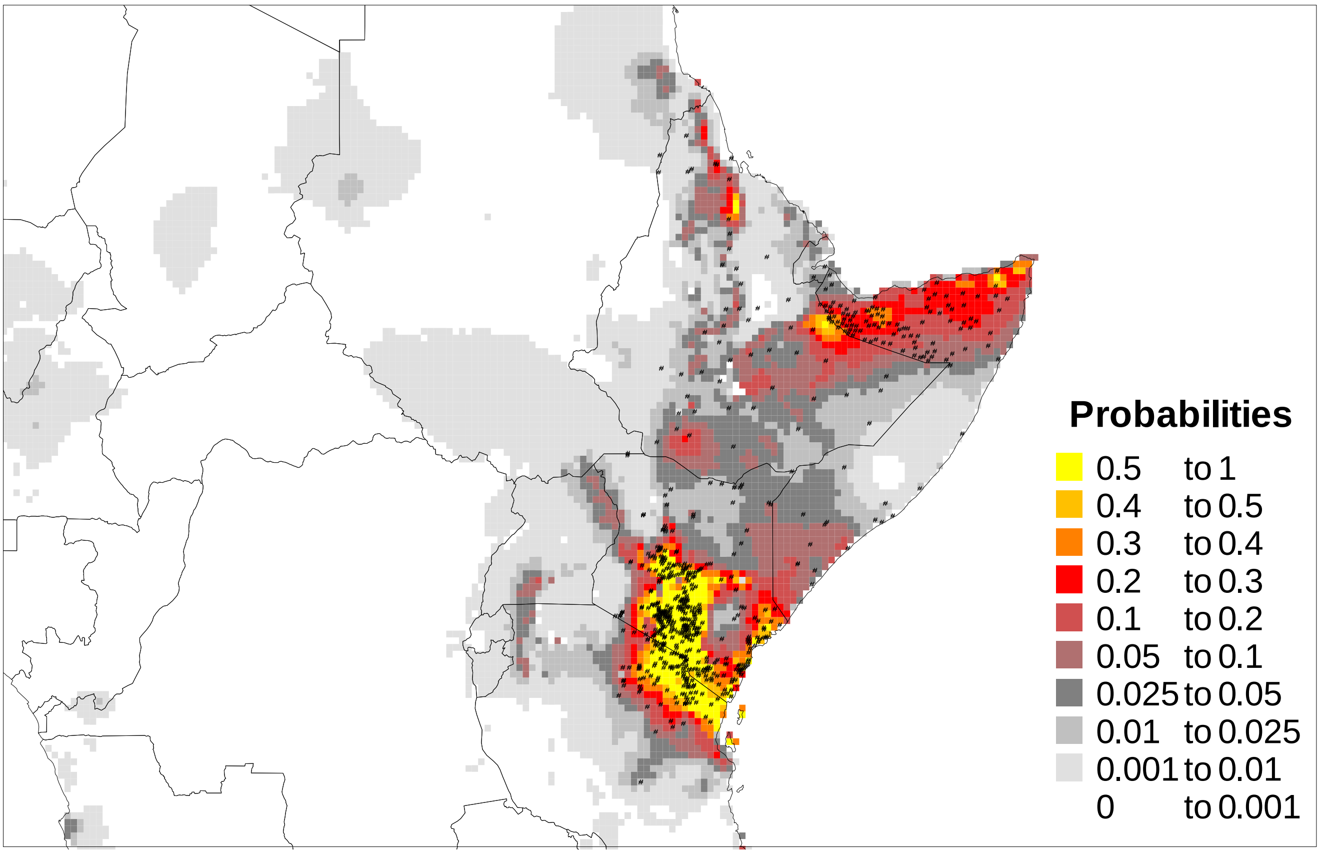
KNOWN AND PREDICTED DISTRIBUTIONS OF *HYALOMMA TRUNCATUM* IN AFRICA FROM WWW.WEC.UFL.EDU/FACULTY/CUMMINGG/TICKS/APPENDIX3_FILES/FRAME.HTM


Probabilities
0.2 to 1
0.1 to 0.2
0.05 to 0.1
0.025 to 0.05
0.01 to 0.025
0.001 to 0.01
0 to 0.001

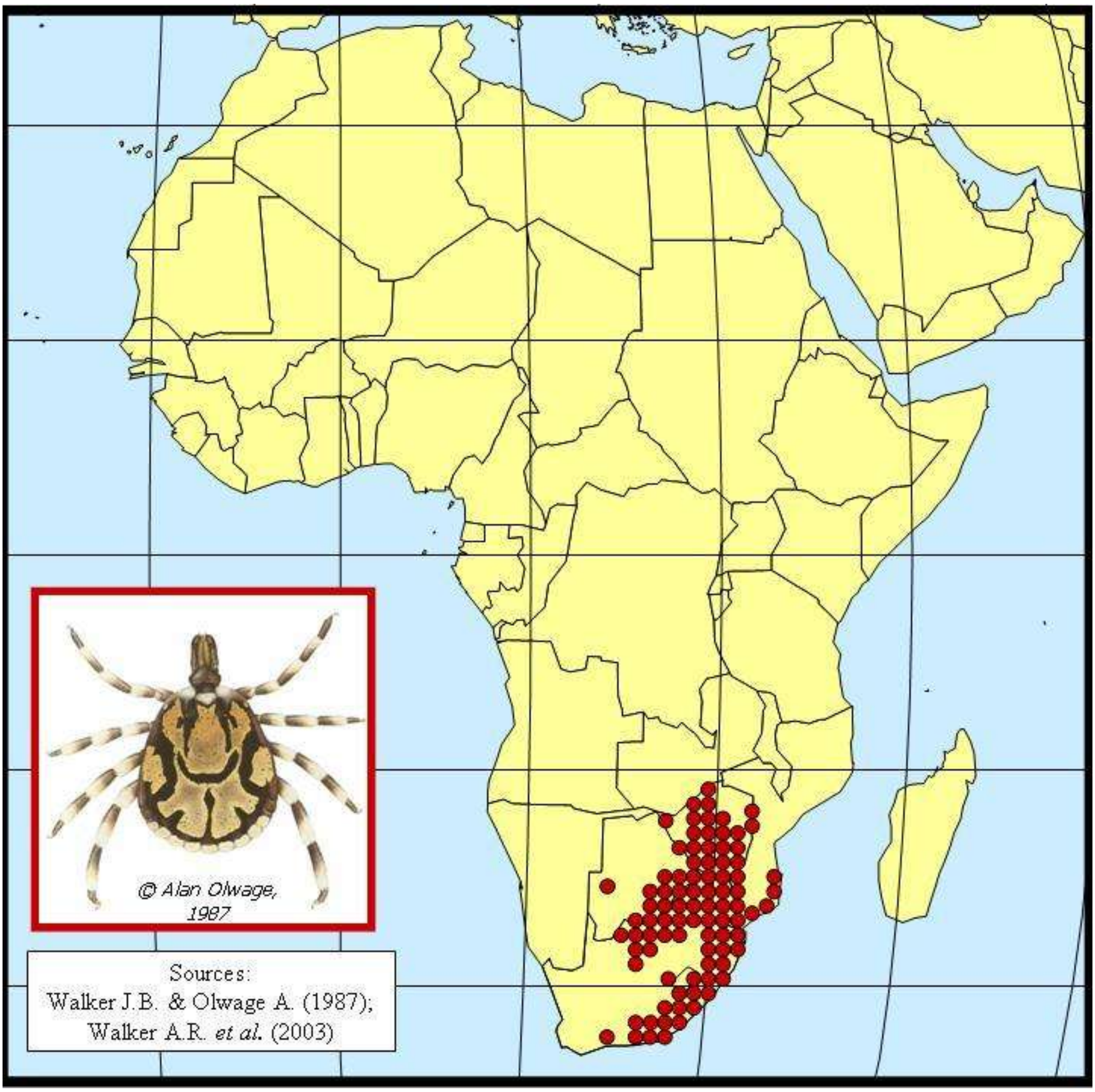
KNOWN AND PREDICTED DISTRIBUTIONS OF *HYALOMMA DROMEDARII* IN *AFRICA* FROM *HTTP://WWW.WEC.UFL.EDU/FACULTY/CUMMINGG/TICKS/APPENDIX3*


Probabilities
0.5 to 1
0.4 to 0.5
0.3 to 0.4
0.2 to 0.3
0.1 to 0.2
0.05 to 0.1
0.025 to 0.05
0.01 to 0.025
0.001 to 0.01
0 to 0.001

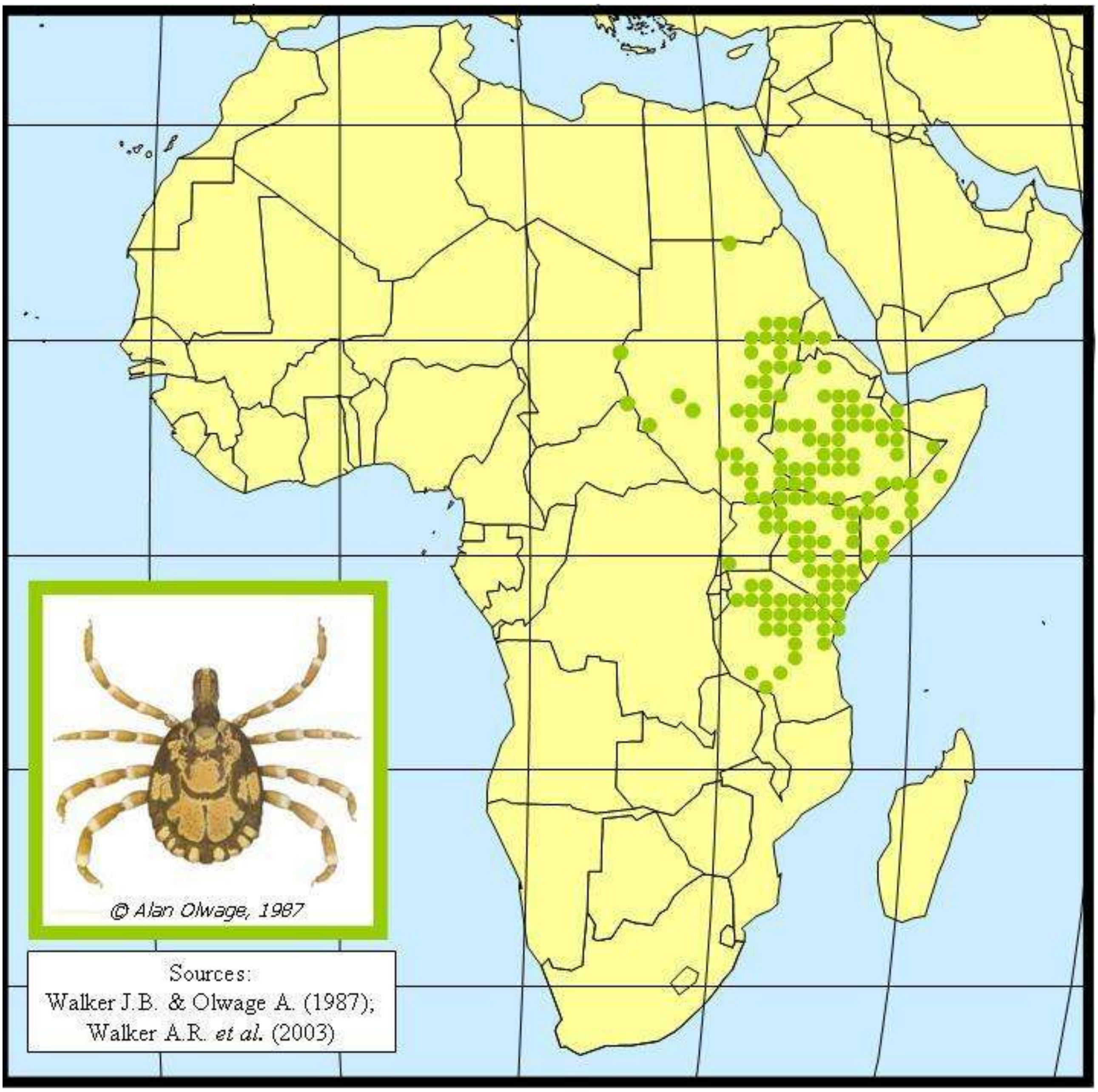
KNOWN AND PREDICTED DISTRIBUTIONS OF *RHIPICEPHALUS APPENDICULATUS* IN AFRICA FROM [HTTP://WWW.WEC.UFL.EDU/FACULTY/CUMMINGG/TICKS/APPENDIX3](http://www.wec.ufl.edu/faculty/cumminggg/Ticks/Appendix3)



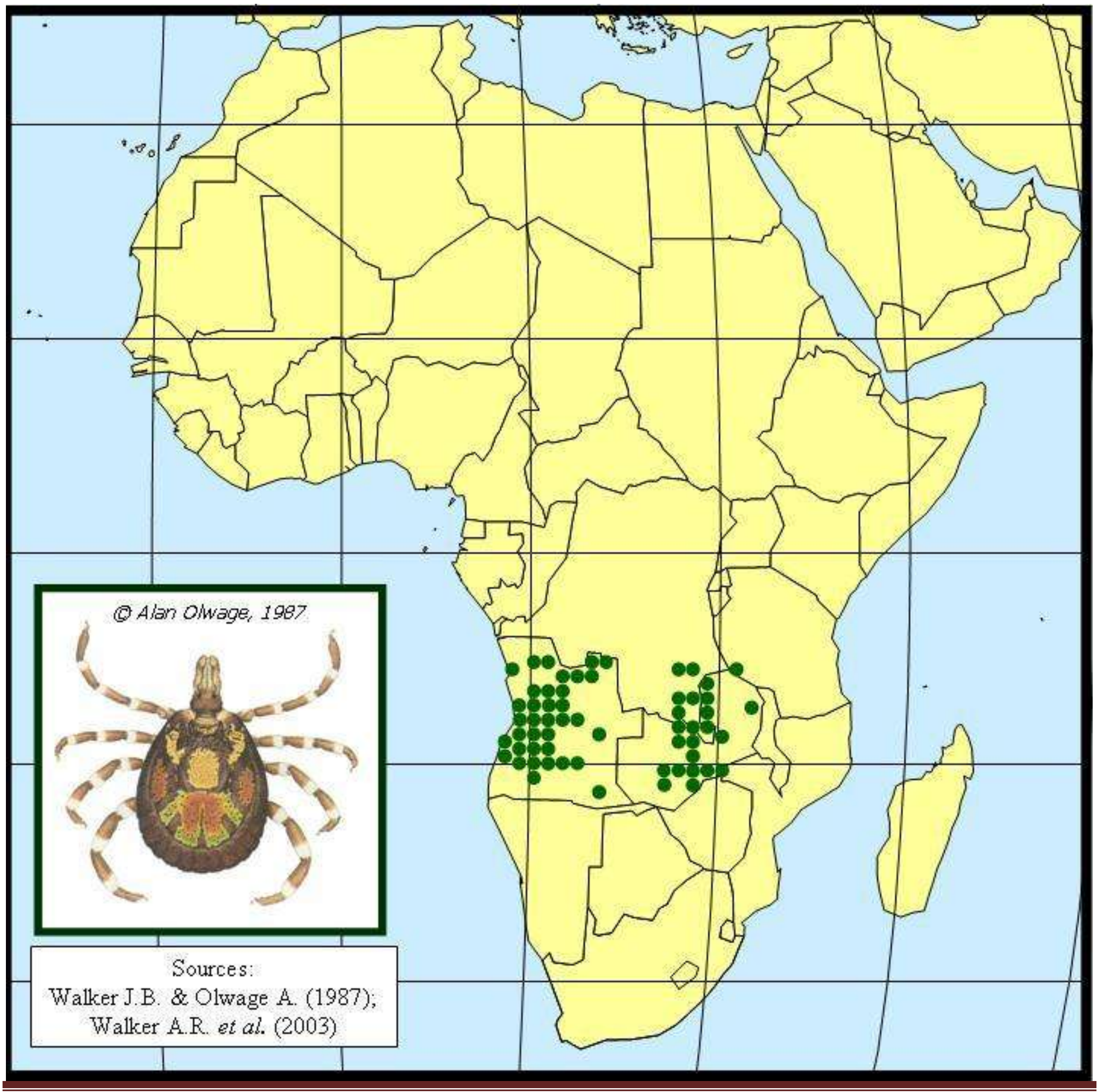
KNOWN AND PREDICTED DISTRIBUTIONS OF RHIPICEPHALUS PULCHELLUS IN AFRICA FROM [HTTP://WWW.WEC.UFL.EDU/FACULTY/CUMMINGG/TICKS/APPENDIX3](http://www.wec.ufl.edu/faculty/cumminggg/Ticks/Appendix3)



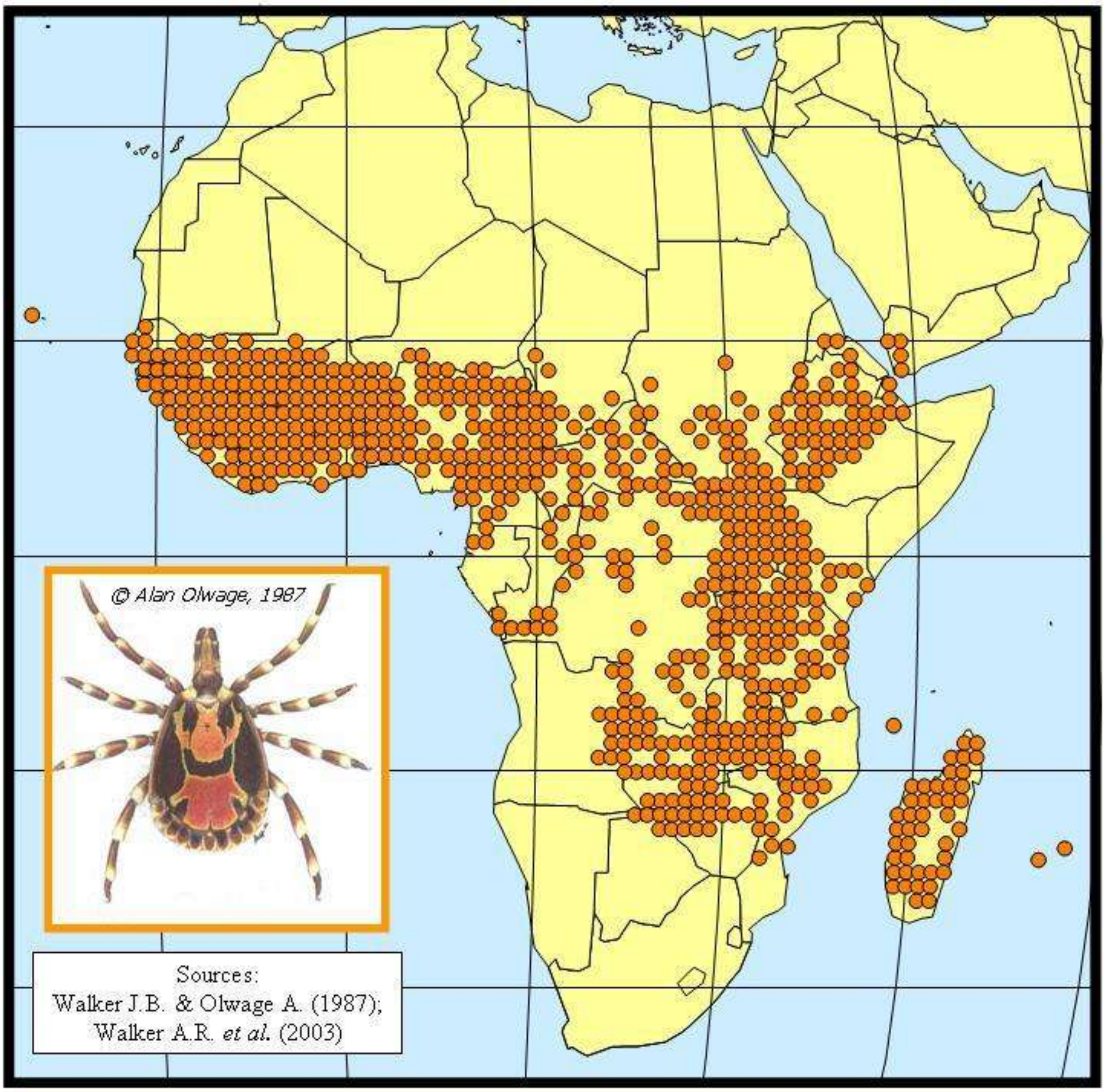
DISTRIBUTION OF *A.HEBRAEUM* FROM WALKER J.B. & OLWAGE A. (1987) AND WALKER A.R. *ET AL* (2003)



DISTRIBUTION OF *A.LEPIDUM* FROM WALKER J.B. & OLWAGE A. (1987) AND WALKER A.R. *ET AL* (2003)


© Alan Olwage, 1987
Sources:
Walker J.B. & Olwage A. (1987);
Walker A.R. *et al.* (2003)

DISTRIBUTION OF *A.POMPOSUM* FROM WALKER J.B. & OLWAGE A. (1987) AND WALKER A.R. *ET AL* (2003)



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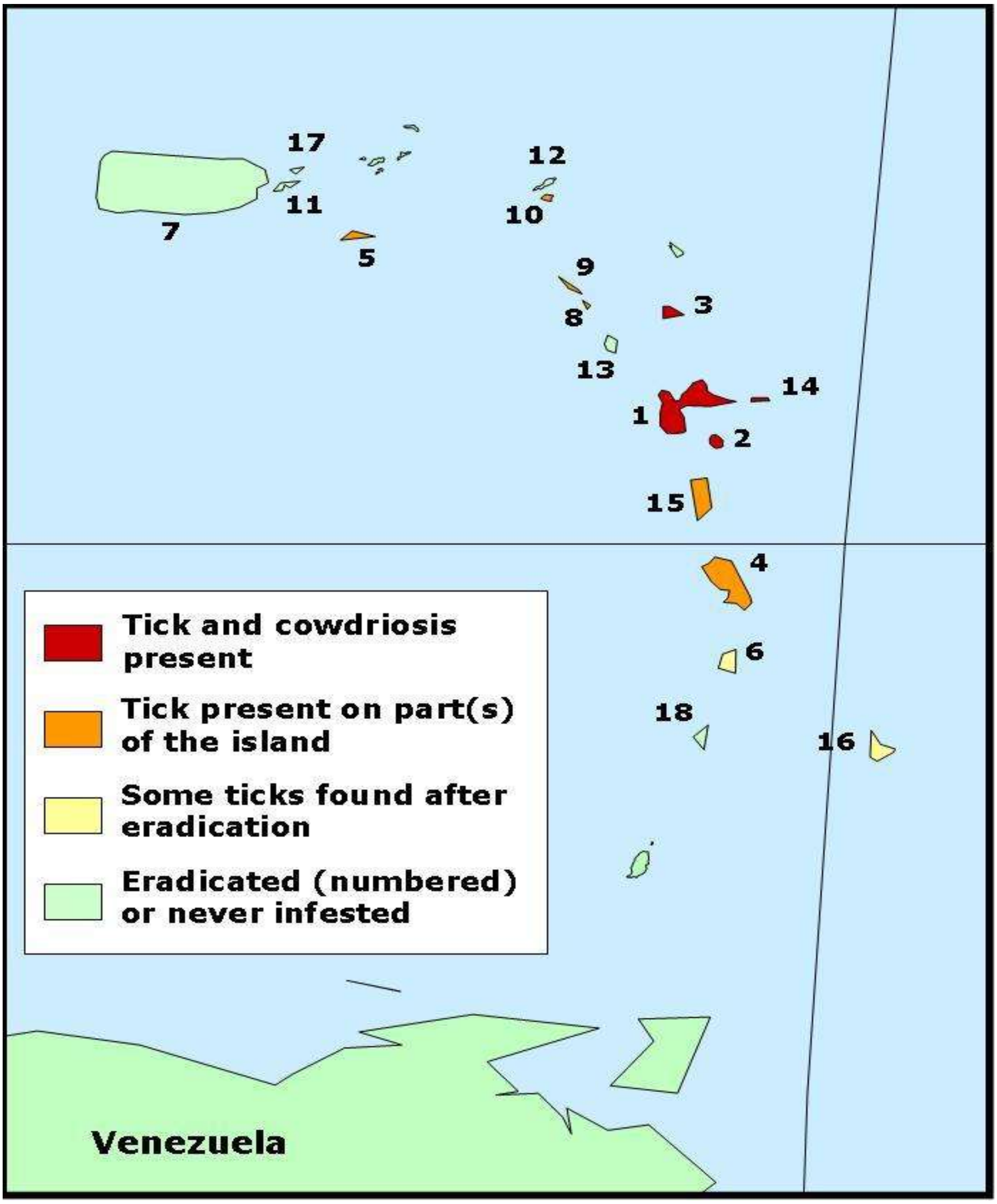
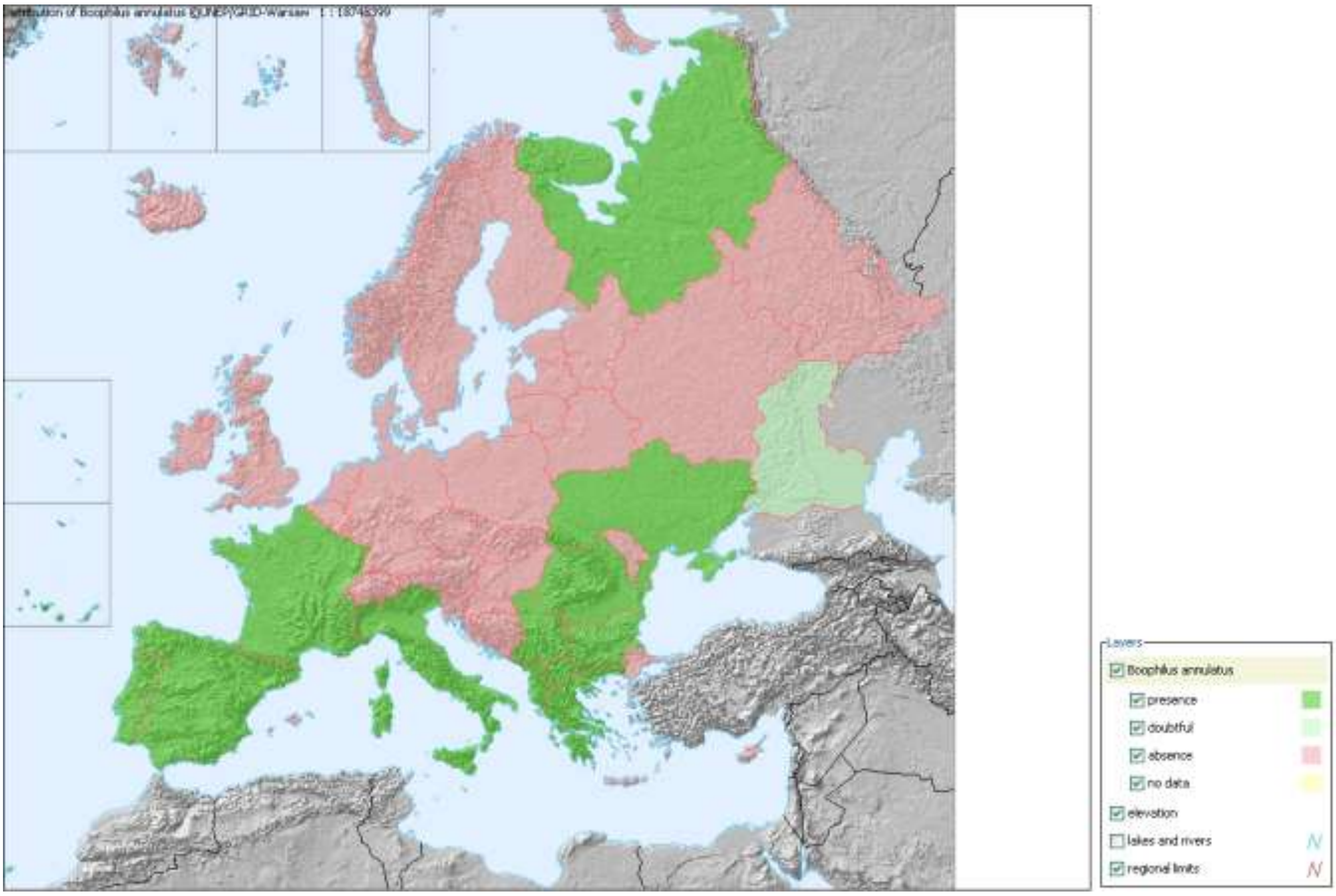
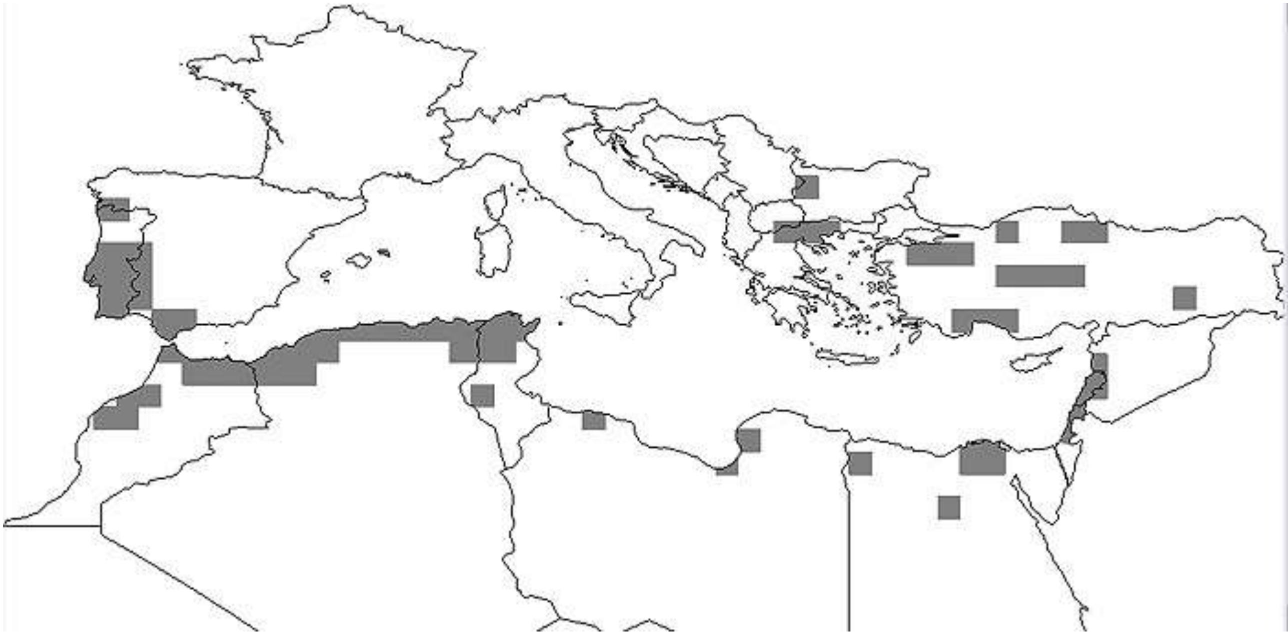


1 Guadalupe, 2 Maria Galante, 3 Antigua, 4 Martinica, 5 Saint Croix, 6 Saint Lucia, 7 San Juan, 9 Saint Kitts, 8 Nevis, 10 Saint Martin, 11 Vieques, 12 Anguilla, 13 Montserrat, ,14 La Desirade, 15 Dominica, 16 Barbados, 17 Culebra,18 Saint Vincent.

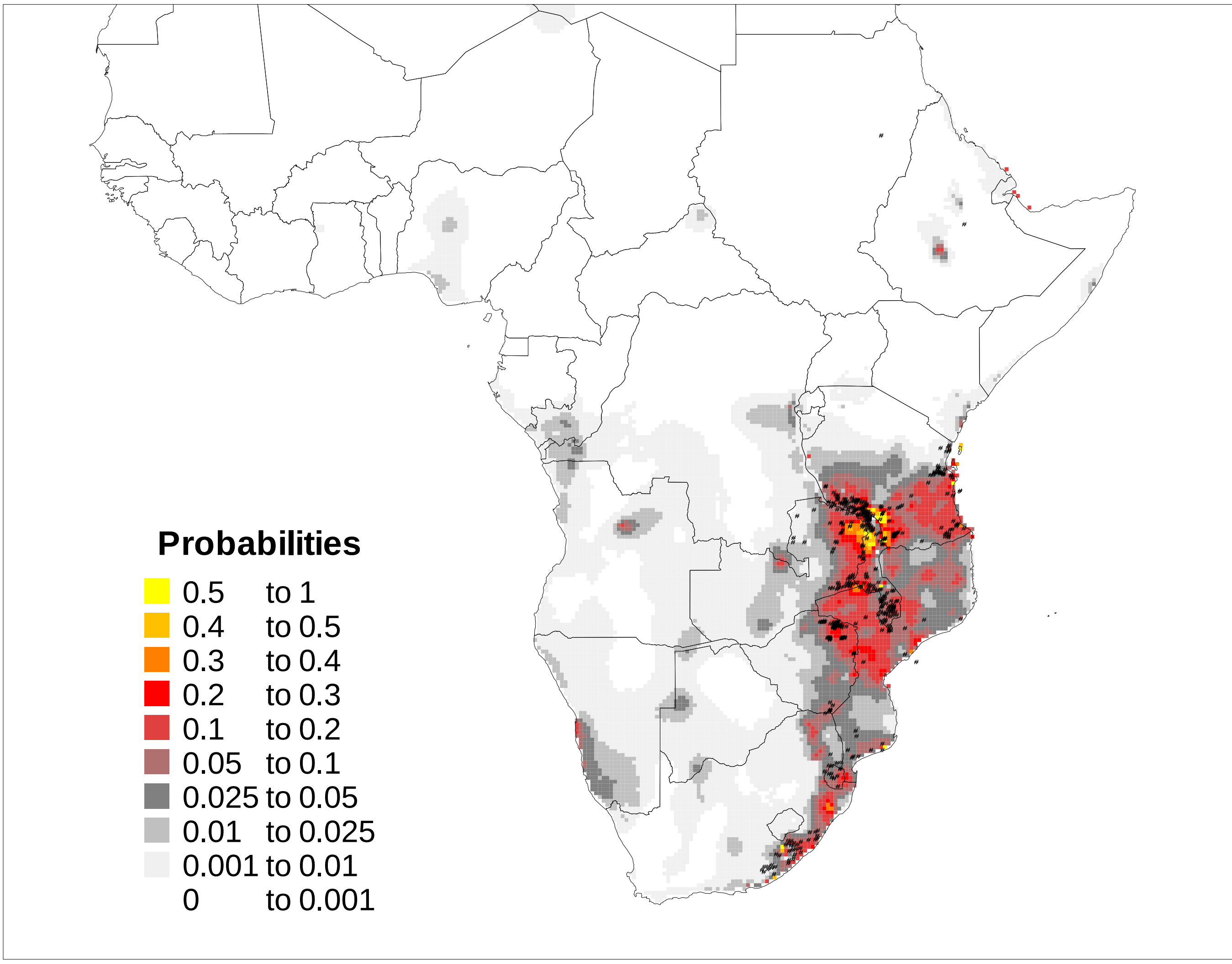
DISTRIBUTION OF *AMBLYOMMA VARIEGATUM* AND COWDRIOSIS IN THE CARIBBEAN FROM BARRÉ N., GARRIS G. & CAMUS E. (1995), BARRÉ N. (1997) AND LEFRANÇOIS T. AND VACHIÉRY N., (2008).



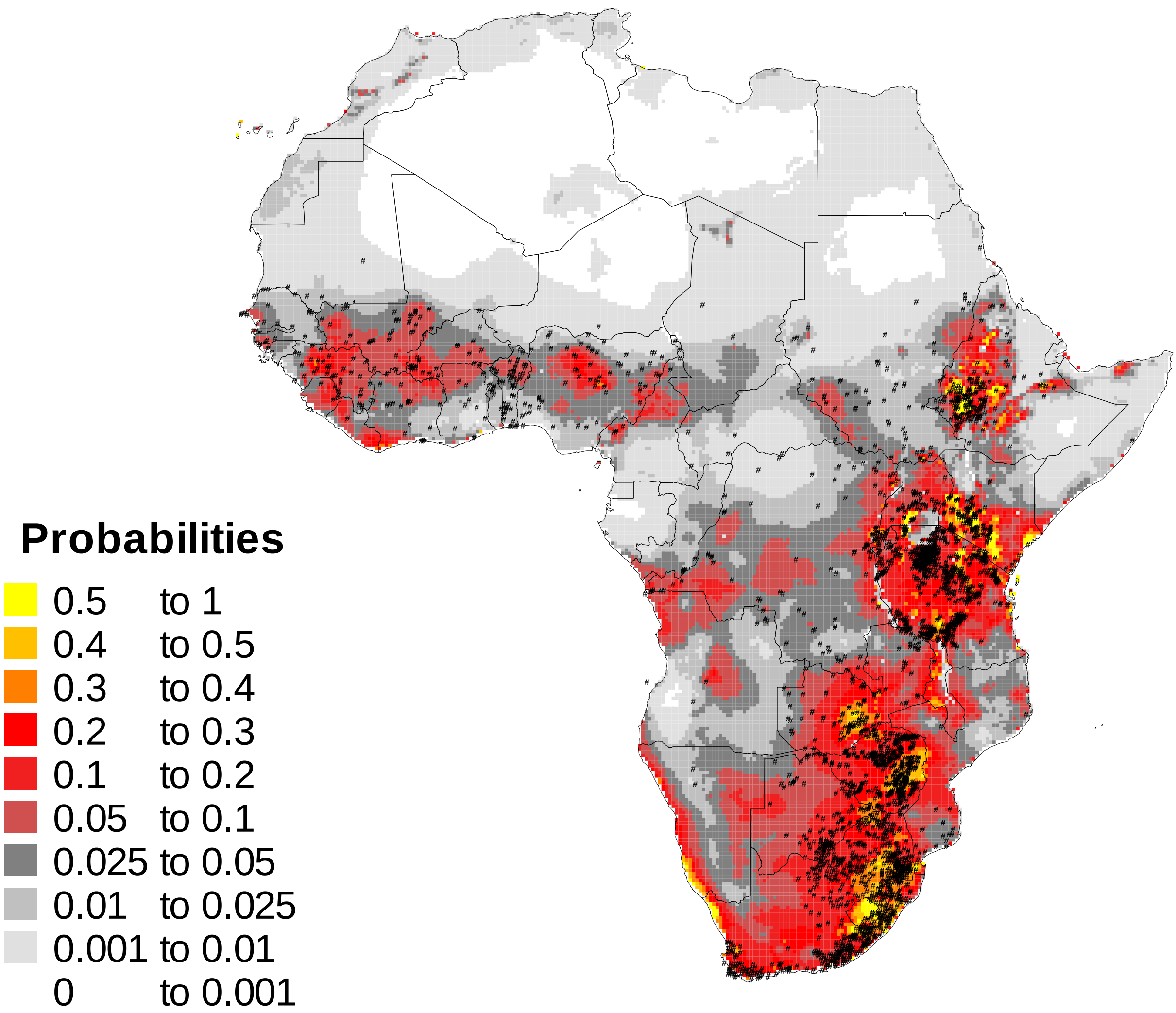
DISTRIBUTION OF *RHIPICEPHALUS (BOOPHILUS) ANNULATUS* IN EUROPE FROM FAUNA EUROPAEA WEB SERVICE (2004) FAUNA EUROPAEA HTTP://WWW.FAUNAEUR.ORG.



DISTRIBUTION OF *RHIPICEPHALUS (BOOPHILUS) ANNULATUS* IN MEDITERRANEAN FROM ICTTD-2


Probabilities
0.5 to 1
0.4 to 0.5
0.3 to 0.4
0.2 to 0.3
0.1 to 0.2
0.05 to 0.1
0.025 to 0.05
0.01 to 0.025
0.001 to 0.01
0 to 0.001

KNOWN AND PREDICTED DISTRIBUTIONS OF *RHIPICEPHALUS (BOOPHILUS) MICROPLUS* IN AFRICA FROM *http://www.wec.ufl.edu/faculty/cummingg/Ticks/Appendix3*



KNOWN AND PREDICTED DISTRIBUTIONS OF *RHIPICEPHALUS (BOOPHILUS)DECOLORATUS* IN AFRICA FROM *http://www.wec.ufl.edu/faculty/cummingg/Ticks/Appendix3*