Ticks and control methods

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Summary: Ticks are the most important ectoparasites of livestock in tropical and sub-tropical areas, and are responsible for severe economic losses both through the direct effects of blood sucking and indirectly as vectors of pathogens and toxins. Feeding by large numbers of ticks causes reduction in live weight gain and anaemia among domestic animals, while tick bites also reduce the quality of hides. However, the major losses caused by ticks are due to the ability to transmit protozoan, rickettsial and viral diseases of livestock, which are of great economic importance world-wide.

The authors review general aspects of tick biology, the taxonomy, pathogenic effects and vector role of these species, and methods for the control of ticks. The distribution of ticks is continuously changing, as illustrated by the spread of the African tick Amblyomma variegatum in the Caribbean, where a large-scale eradication campaign is now under way.


INTRODUCTION: TICKS AND TICK-BORNE DISEASES

Ticks and tick-borne diseases are an important cause of losses to the livestock industry, in particular the production of cattle and small ruminants in tropical and sub-tropical areas. World-wide losses due to diseases transmitted by ticks and the costs of tick control have been estimated to be in the range of several billion ($10^{9}$) US dollars annually (17, 33). The importance of ticks is principally due to the ability to transmit a wide spectrum of pathogenic microorganisms, such as protozoa, rickettsiae, spirochaetes and viruses. In Africa, tick-borne protozoan diseases (e.g. theileriosis and babesiosis) and rickettsial diseases (e.g. anaplasmosis and heartwater [cowdriosis]) are the main health and management problems of domestic ruminants (61, 62). The biology of the various tick species is discussed below, as well as the life cycle, taxonomy and pathogenic effects of these parasites, their role as vectors, and the control methods available. Only the most important ticks and tick-associated diseases can be briefly discussed within the limits of this review; some species which may be of genuine significance in certain areas have been reluctantly omitted.

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Ticks

Ticks are ectoparasites of livestock, which are classified (together with mites) in the order Acari. All ticks are obligate ectoparasites of vertebrates. They have four pairs of legs as nymphs and adults, and the body is divided into the capitulum (which bears the mouthparts) and the opisthosoma. There are at least 840 tick species in two major families, namely the Ixodidae or 'hard' ticks (so called by virtue of their hard dorsal shield) and the Argasidae or 'soft' ticks (due to their flexible leathery cuticle). The family Ixodidae comprises approximately 80% of all tick species, including the species of greatest economic importance. However, argasid ticks also play a significant role as vectors of diseases, especially in poultry.

Ixodidae

There are three active stages in the life cycle of a hard tick: larvae, nymphs and adult ticks. Each instar takes a blood meal only once and long periods are spent on vegetation between blood meals. Most ticks require three different hosts to complete one full cycle. These three-host ticks detach on completion of feeding, drop from the host, moult and wait for another host (Fig. 1a). However, in some tick species, the engorged larvae remain on the host, where they moult rapidly to become nymphs, continue to feed and then drop as engorged nymphs. These two-host ticks include *Rhipicephalus evertsi* and some *Hyalomma* species (Fig. 1b). In one-host ticks, the nymphs also remain on the same host and continue to feed as adults. *Boophilus* spp. are typical one-host ticks (Fig. 1c). After the female drops from the host, she seeks a sheltered place for oviposition, where she lays a single batch of several thousand eggs and then dies. Males usually remain much longer on the host, where they may mate repeatedly. As long

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**Fig. 1a**

Life cycle of a three-host *Amblyomma* tick

Courtesy of the Wellcome Foundation
Life cycle of a two-host *Hyalomma* tick
Courtesy of the Wellcome Foundation

Life cycle of a one-host *Boophilus* tick
Courtesy of the Wellcome Foundation
periods often elapse between the different feeding periods, ticks are well adapted for long-term survival, maintaining their water balance by taking up moisture from the atmosphere.

Hungry ticks accumulate near the tips of grasses and other plants. Figure 2 shows adult *Rhipicephalus appendiculatus* ticks waiting on the grass at a small game ranch in north-eastern Zimbabwe. When a host approaches, the ticks seek to attach themselves by waving their first pair of legs in the air. Chemoreceptors are present in Haller's organ, which is located in the front pair of legs (Fig. 3). Once the host has been mounted, the tick pierces the skin with its chelicerae and inserts the barbed hypostome (Figs 4 and 5) to secure initial attachment to the host. Cement is then secreted in the saliva to further secure attachment. Ixodid ticks remain on the host for several days, sometimes weeks or (for males) even months. The ticks create a feeding lesion in the dermis of the host by inducing an acute inflammatory reaction, and then feed on the blood which enters this lesion. The tick must ingest enough blood in a single meal to support survival at the next stage or to enable the female to produce thousands of eggs.

Ixodid ticks ingest very large quantities of blood, amounting to several hundred times their unfed weight. Surprisingly, tick feeding is generally very wasteful, as large amounts of haemoglobin are passed into the faeces unchanged; the quantity of blood passed in the faeces during feeding can equal or even exceed the final engorgement weight of the tick (4). In addition, water and salts contained in the ingested blood are
Haller's organ, situated on the tarsus of leg 1 of an Amblyomma variegatum nymph

This organ consists of a posterior capsule (P. cap.), evident only as a dark slit-like opening in its roof, and an anterior pit (A.p.) containing several sensilla. The organ has a primary function in the location of a suitable host by detecting host odours, and plays an important role in the perception of tick pheromones.

Courtesy of C.J.A.H.V. van Vorstenbosch

eliminated before feeding ceases. In ixodid ticks, up to 60-70% of the excess water in the blood meal is re-injected into the host by salivation during feeding (58). As a result, the actual uptake of blood can be two to three times the weight of the engorged female. As an engorged R. appendiculatus female weighs approximately 0.4 g and an engorged Amblyomma variegatum as much as 4.0 g, large numbers of ticks can cause severe economic losses due to reduction in live weight gain (47).

Argasidae

The life cycle and feeding pattern of the soft ticks are different from those of the hard ticks. The Argasidae are multi-host ticks; there are several nymphal stages and the adults also feed repeatedly. Feeding can last from a few minutes to hours, or even days for the larvae of some species. Most argasid ticks live in nests or burrows, although there are exceptions. Adults usually mate in the nest or burrow. Mated females take small, repeated blood meals to support the production of small batches of eggs. The occurrence of several nymphal instars and frequent adult blood meals contributes to an unusually long life span (several years) and high resistance to starvation. These species are extremely hardy and can survive in hot, dry conditions for long periods without a blood meal. Argasid ticks also concentrate their blood meal by eliminating excess water via the coxal apparatus, which is located in the proximal part of the front pair of legs.

There are approximately 170 species of soft ticks. Species of medical or veterinary importance belong to the genera Argas, Ornithodoros and Otobius.
HYP: hypostome (situated ventrally, this is armed with rows of curved teeth to secure attachment to the host skin)
P.a.I: palpal article 1 (contains multipurpose sensory sensilla)
P: palp

**FIG. 4**

Scanning electron micrographs (at two different magnifications) of the frontal aspect of the mouthparts of an *Amblyomma variegatum* male

Courtesy of C.J.A.H.V. van Vorstenbosch
F.c.: food canal (enclosed between the dorsal surface of the hypostome and ventral surfaces of the chelicerae)

P: palp
ch.d.: cheliceral digits
ch.s.: cheliceral shaft
HYP: hypostome

**FIG. 5**

Scanning electron micrographs (at two different magnifications) of the mouthparts of an *Amblyomma variegatum* female

Courtesy of C.J.A.H.V. van Vorstenbosch
The *Argas persicus* group are typical fowl ticks found on poultry throughout the tropics and sub-tropics.

Ticks of the *Ornithodoros moubata* complex are important in parts of Africa, where they feed on domestic and wild pigs, and also on humans. Another species, *O. savignyi*, lives in sandy soil at the shaded resting sites of livestock in semi-desert areas of the Old World, and feeds on the legs of cattle, sheep, goats and camels. Massive infestations of these ticks can build up as shown in Figure 6.

The spinose ear tick *Otobius megnini* is widespread in America and now also occurs in Africa and India. Larvae of this tick attach within the ear canal, feed and moult into nymphs. The nymphs remain in the same site for several weeks. The adults do not feed and mating takes place off the host, followed by the laying of eggs.

**Disease relationships of soft ticks**

*A. persicus* and related species transmit *Borrelia anserina*, the cause of spirochaetosis in poultry. Massive infestations by *Argas* spp. on poultry can cause paralysis and death by exsanguination. *Ornithodoros moubata* is the original vector of African swine fever virus, of which *O. erraticus* has become a new vector in the Iberian peninsula. *O. moubata* and several other *Ornithodoros* species which hide in huts and houses also transmit spirochaetes, causing relapsing fever in humans. Heavy infestations by the spinose ear tick are irritating (the nymphs are covered with spines), cause damage and stress, and predispose to myiasis.

**MAIN GENERA OF IXODID TICKS**

The main characteristics of seven main genera of ixodid ticks (*Boophilus*, *Dermacentor*, *Haemaphysalis*, *Hyalomma*, *Ixodes*, *Rhipicephalus* and *Amblyomma*) are given below, with special reference to their disease relationships. For a detailed account of the biology of ticks, the reader is referred to an excellent publication by Sonenshine (54).

*Boophilus*

The genus *Boophilus* contains only five species of small ticks, all of which are one-host ticks and take approximately three weeks to complete their blood meal, preferably on cattle (except for *B. kohlsi*, a Near/Middle Eastern species with a predilection for small ruminants). *Boophilus* spp. have short palps which are ridged dorsally and laterally, and they possess eyes which are sometimes difficult to discern (see Appendix). *Boophilus* ticks have short mouthparts which are unable to penetrate very deeply into the skin. However, damage to hides is considerable as the preferred feeding sites are often of good leather potential. *B. microplus* is the most important species. Originating from South-East Asia, this species has spread to countries throughout the tropics including Australia and the countries of East and Southern Africa, and South and Central America. *B. annulatus* is present in the Mediterranean region, and occurs in southern Ukraine and Russia as well as in the Near and Middle East; this species has also extended its distribution southwards into Africa in a belt from West Africa to southern and central Sudan (22). Furthermore, *B. annulatus* has been introduced into Mexico on livestock, subsequently spreading into much of the southern United States of America (USA), before being successfully eradicated, together with *B. microplus*. However, continued surveillance is required to prevent reintroduction of these ticks from Mexico. To date, a third species, *B. decoloratus*, has remained confined to Africa. It is interesting to note that *B. decoloratus* competes with *B. microplus*, which is thus
Massive infestation of soft ticks (Ornithodoros savignyi) on a bovine leg, in northern Nigeria

Courtesy of B.E.C. Schreuder
excluded from large areas of Africa (40, 56). Finally, *B. geigyi* is common on cattle and small ruminants in West Africa, but has also been transported eastwards as far as southern Sudan (29).

**Disease relationships**

*Boophilus* ticks are the main vectors of bovine babesiosis caused by the protozoan parasites, *Babesia bigemina* and *Babesia bovis*. *B. bigemina* is only moderately pathogenic for adult cattle, but is the most widely distributed of the *Babesia* spp., as it is transmitted by both *B. microplus* and *B. annulatus*, as well as *B. decoloratus* and probably *B. geigyi*. *Babesia bovis* is highly pathogenic for European breeds of cattle. This parasite also occurs on all continents, but its distribution in Africa is restricted, as *B. bovis* cannot be transmitted by *B. decoloratus*. *Boophilus* ticks, together with many other tick species, transmit *Anaplasma marginale*, the rickettsia which causes anaplasmosis of cattle on all continents including several temperate regions. As *Boophilus* spp. are one-host ticks, these ticks may become very numerous in cattle herds, especially in herds with a low degree of resistance to the infestation, and cause considerable direct damage due to the continual loss of blood and effects on the host metabolism.

**Dermacentor**

The genus *Dermacentor* comprises approximately 30 species. These ticks have ornate scuta, short palps, eyes and usually follow a three-host cycle (exceptions include the American *D. pictus* [so-called 'winter tick'] and *D. nitens* [see below], which are both one-host ticks). *Dermacentor* spp. occur on all continents, except Australia. In Eurasia, several species (e.g. *D. marginatus* and *D. reticulatus*) infest livestock and other domestic animals. In North America, *D. variabilis* and *D. andersoni* are also important ectoparasites of livestock. *Dermacentor* (or *Anocentor*) *nitens*, the tropical horse tick, is present in an area which extends from the southern USA through to Central and South America. *D. nitens* is a one-host tick, originally found on deer in South America, and has a predilection for the ears of the host. In Africa, *Dermacentor* ticks do not play a significant role for livestock.

**Disease relationships**

In temperate regions, *Dermacentor* spp. are important vectors of bovine and probably small ruminant anaplasmosis, and also of equine babesiosis. Several species are also important in human medicine as vectors of rickettsial diseases. For example, *D. andersoni* is notorious as a vector of the causal agent of the human disease Rocky Mountain spotted fever (caused by *Rickettsia rickettsi*) in North America, and also causes tick paralysis in livestock. *D. marginatus* is a reservoir of Q fever (*Coxiella burnetii*) in Europe. *D. reticulatus* is the main vector of European canine babesiosis (*Babesia canis*). *D. nitens* causes loss of condition when large numbers feed on horses, as well as predisposing to attack by myiasis flies and being the vector of *Babesia caballi* of horses in the western hemisphere.

**Haemaphysalis**

The genus *Haemaphysalis* contains approximately 155 species. They are easy to differentiate from other genera by the characteristic lateral projection of palpal article 2 beyond the margins of the basis capituli (see Appendix). All *Haemaphysalis* spp. are eyeless, three-host ticks. Only a few species have adapted to domestic livestock. For example, *H. bispinosa* occurs on cattle on the Indian subcontinent. *H. longicornis* is an East Asian species, occurring on cattle and other domestic animals, and has been introduced into Australia, New Zealand and New Caledonia. In Australia,
H. longicornis maintains itself by parthenogenesis (reproducing without males), whereas normal bisexual populations of the same tick exist in eastern Asia, side-by-side with parthenogenetic populations; the reason for this difference is unknown. In Europe, H. punctata is common on ruminants.

**Disease relationships**

Haemaphysalis spp. are of importance to livestock in Europe and Asia. H. punctata is the vector of Babesia major in cattle and B. motasi in small ruminants in Europe, and H. longicornis transmits B. ovata of cattle in Japan and elsewhere in eastern Asia, as well as bovine theileriosis (caused by Theileria buffeli, for which T. orientalis may be a synonym, while the name T. sergenti [commonly used in Japan] is invalid for any Theileria species; 37). Haemaphysalis spp. are also involved in the epidemiology of human rickettsioses.

**Hyalomma**

Hyalomma spp. are medium to large sized ticks with long palps and eyes typically in sockets (see Appendix). Hyalomma species parasitise domestic and wild mammals and birds, and are abundant in semi-arid zones. The genus *Hyalomma* comprises approximately 30 species, most of which follow a three-host life cycle. However, some species undergo either a two-host or a three-host cycle, depending on the host species. Adult *Hyalomma* ticks actively run out from their resting sites when a host approaches, unlike most other ixodid ticks, which wait on vegetation. One species, *H. scupense* (possibly a subspecies of *H. detritum*, according to some scientists), usually has a one-host cycle and occurs on cattle in southern Europe and south-western Russia. As an exception to the situation for other tick species, this tick may overwinter on the host.

**Disease relationships**

The long mouthparts of *Hyalomma* ticks cause large feeding lesions, which are often exposed to secondary bacterial infections. Lameness is often associated with these ticks. Some populations of *H. truncatum* in Africa cause a toxic syndrome known as sweating sickness, the aetiology of which remains unclear. Numerous *Hyalomma* ticks transmit *Theileria annulata*, the causative protozoan pathogen of tropical theileriosis. The distribution of this disease ranges from China in the east to Spain and Mauritania in the west. *H. anatolicum anatolicum* and *H. detritum* are the most important vectors of *T. annulata*, and occur in Central Asia, southern Russia and other parts of Southern Europe, the Near and Middle East, and Northern Africa. All stages of these ticks have adapted to cattle, explaining their importance as vectors, as theileriosis is transmitted only trans-stadially. *H. dromedarii*, the camel tick, is distributed from India to Africa just south of the Sahara, and has recently been shown to act as a field vector of *T. annulata* in Mauritania, where neither *H. anatolicum anatolicum* nor *H. detritum* occurs (25). *H. marginatum marginatum* may be the main vector of theileriosis in parts of Spain (20). An estimated 250 million domestic cattle are at risk from this disease over the entire distributional range (57).

Crimean-Congo haemorrhagic fever virus is an important zoonotic disease agent in humans in Europe, Asia and Africa, which is mainly transmitted by *Hyalomma* ticks.

**Ixodes**

*Ixodes* spp. form the largest genus of hard ticks and belong to a separate branch of the Ixodidae, the Prostriata. The 250 species belonging to the genus *Ixodes* are characterised by the anal groove curving anteriorly to the anus (see Appendix). This
easily differentiates *Ixodes* from the other genera of hard ticks (Metastrongylidae), in which this groove curves posteriorly around the anus. The scutum of *Ixodes* spp. lacks ornamentation and there are no eyes. Most species inhabit nests or burrows. Relatively few *Ixodes* species parasitize larger mammals, but the genus is widely distributed throughout wooded or grassy environments. The most important species in North America is *I. scapularis* (for which *I. dammini* is now considered to be a synonym; 43), while the most common species in Europe and Asia are *I. ricinus* and *I. persulcatus*. *Ixodes* spp. are not of economic importance in the tropics, except *I. rubicundus* on sheep and goats in Southern Africa. In Australia, *I. holocyclus* usually occurs on bandicoots, but can also feed on domestic animals, tropical bats (*Pteropus* spp.) or humans.

**Disease relationships**

Both *I. rubicundus* in South Africa and *I. holocyclus* in Australia can induce paralysis when they feed on animals or humans. The indiscriminate feeding behaviour of *I. ricinus* means that this species is found on many different hosts and is thus an important vector of a large number of disease pathogens in Europe. These include *Babesia divergens* in cattle, *Ehrlichia phagocytophila* (tick-borne fever) in domestic ruminants, and louping ill virus in sheep.

*Ixodes* ticks are of great importance as vectors of human diseases. Lyme disease (borreliosis) is transmitted in Europe by *I. ricinus*, in Eastern Europe and Asia by *I. persulcatus* and in North America by *I. scapularis*. The species *I. ricinus* and *I. persulcatus* are also vectors of tick-borne encephalitis virus in humans.

**Rhipicephalus**

The genus *Rhipicephalus* comprises approximately 70 species. These are small to medium sized ticks with short, broad palps; most species are inornate. When viewed from the dorsal aspect, the basis capituli has a distinct hexagonal shape with protruding lateral margins. Males have ventral plates near the anus. Both sexes have eyes and festoons (see Appendix). Most *Rhipicephalus* spp. are found on mammals on the African continent. These are usually three-host ticks, although some have a two-host cycle (e.g., *R. evertsi*).

Taxonomic identification of rhipicephalid group ticks may cause difficulties, and the reader is referred to revisions of several taxa of *Rhipicephalus* ticks (46). For example, *R. sanguineus sensu stricto* has a very strict host specificity and occurs almost exclusively on dogs and some wild carnivores. However, *R. sanguineus* group ticks are often collected from domestic ruminants (29). Such ticks are easily misidentified as *R. sanguineus*, but in fact belong to other species, such as *R. turanicus*, *R. guilhoni* and others which are far less host-specific (36, 46). This illustrates that accurate identification of prevalent tick species is essential to ascertain their potential capacity as vectors. Morphological differences between closely-related tick species may be slight, but such ticks can differ dramatically in their capacity to harbour and transmit an infectious agent (23).

*R. appendiculatus*, the brown ear tick, is the most important rhipicephalid tick in East and Southern Africa, where it occurs on a wide variety of domestic and wild ruminants. This tick prefers to feed on the ears of the hosts at any stage of the life cycle.

**Disease relationships**

*R. appendiculatus* (as well as the closely related *R. zambeziensis*) is a vector of *Theileria parva*, causative agent of East Coast fever and related disorders. A thorough, comprehensive review on the epidemiology of theileriosis in Africa was recently
published by Norval et al. (42). *Rhipicephalus* species are also important, for example as vectors of ovine babesiosis (*B. ovis*, transmitted by the two-host tick *R. bursa*) and ovine ehrlichiosis (*Ehrlichia ovis*, of which both *R. bursa* and *R. evertsi* are vectors). *R. bursa* is probably also one of the main vectors of anaplasmosis of small ruminants. *R. sanguineus sensu stricto* is a vector of *Babesia canis* in dogs and also of *Ehrlichia canis*, the cause of tropical pancytopaenia in dogs, a severe rickettsial disease which occurs world-wide. This species is also a vector of classical tick-bite fever in humans (due to *Rickettsia conorii*).

**Amblyomma**

The genus *Amblyomma* comprises over 100 species characterised by long mouthparts and, usually, beautifully-coloured 'ornamented' scuta. The eyes are usually not housed in sockets. These three-host ticks are widespread in tropical and sub-tropical zones, where they parasitise a wide variety of mammalian hosts, and also reptiles and amphibians. The immatures stages of some species infest birds, which can play an important role in dispersing the ticks.

*A. variegatum* is the most important species on the African continent, being well adapted to domestic livestock and having the widest distribution: throughout tropical sub-Saharan Africa, Madagascar, Reunion Island, Mauritius and other islands near Africa (67). Figure 7 shows a typical cluster of *A. variegatum* males and females feeding on the back of a sheep.

![Typical cluster of male and female Amblyomma variegatum on the back of a sheep](image)

Females of this species will not attach unless attracted by aggregation/attachment pheromones produced by feeding males

Photograph F. Jongejan
A. hebraeum is another important pest of livestock, which inhabits the south-eastern part of the African continent. The following *Amblyomma* species are also commonly found on domestic ruminants in Africa (67):

- A. lepidum and A. gemma (in parts of eastern and north-eastern sub-Saharan Africa)
- A. pomposum (mainly in Angola)
- A. cohaerens (which has adapted from buffalo to cattle, mainly in Ethiopia).

In addition to widespread distribution in Africa, *A. variegatum* has been introduced into the Caribbean region, presumably in the 18th or 19th century with cattle from West Africa. To date, *A. variegatum* is the only African *Amblyomma* tick to have successfully established itself outside the African continent (67). On the American continent, several species (including *A. americanum*, *A. cajennense* and *A. maculatum*) are of economic significance, as the adults prefer to feed on cattle.

**Disease relationships**

*Amblyomma* ticks are vectors of cowdriosis (heartwater) of cattle and small ruminants, one of the most important tick-borne diseases in Africa; the reader is referred to a recent review of the disease (64). Heartwater is caused by the rickettsia *Cowdria ruminantium* and is characterised in typical cases by high fever, respiratory distress, nervous symptoms and hydropericardium. Severe forms of cutaneous dermatophilosis (due to the bacterium *Dermatophilus congolensis*) are also associated with the presence of this tick (although it is not a vector), and this disease has decimated livestock on Caribbean islands newly invaded by *A. variegatum* (9, 63).

In addition to its presence in sub-Saharan Africa, heartwater has also been confirmed on three different islands in the Caribbean, namely Guadeloupe (48), Marie-Galante (63) and Antigua (8). The presence of *A. variegatum* on most of the islands in this region constitutes a serious threat for livestock on the American mainland. It has been predicted that the tick – once introduced onto the American mainland, either north or south – would find the ecological niches required for its establishment (6). As a consequence, containment of *A. variegatum* is of major importance to the livestock industry. The actual distribution of heartwater and *A. variegatum* in the Caribbean has recently been reviewed by Camus *et al.* (11) (Fig. 8).

Thirteen species of *Amblyomma* are known to be able to transmit cowdriosis. Ten of these species are of African origin, but three American species, *A. maculatum*, *A. cajennense* and *A. dissimile*, have also been shown to be capable of transmitting the disease under experimental conditions (27, 60). Not all of these vectors are of equal significance in the natural transmission of cowdriosis in the field. For example, should the disease reach the American mainland, the American reptile tick (*A. dissimile*) is not likely to play a significant role, as this species does not usually feed on domestic ruminants. Nevertheless, it has been shown in South Africa that reptiles can be infected with cowdriosis (7). *A. maculatum*, the Gulf Coast tick, and *A. cajennense* are widespread and common on cattle. However, while *A. maculatum* has been shown to be an efficient experimental vector, *A. cajennense* is a poor vector.

A number of other American *Amblyomma* species have been tested as potential vectors of cowdriosis, but with negative results to date. These include *A. rotundatum*, another tick which feeds on amphibians and reptiles in Central and South America, and which has also become established in southern Florida (44). However, as none of the stages of this tick fed on infected goats or sheep, it is unlikely that it can play a role in the epidemiology of the disease (F. Jongejan and J.I. Oliver, unpublished findings, 1994).
Distribution of *Amblyomma variegatum* in the Lesser Antilles

Figures indicate percentages of animals seropositive for *Cowdria ruminantium* determined by enzyme-linked immunosorbent assay

Courtesy of Camus *et al.* (11)
Plans for eradicating *A. variegatum* in the Caribbean were prepared almost a decade ago. Studies on the economic impact of the presence of *A. variegatum* in the area and estimates of the cost of eradication have clearly shown that the cost/benefit ratio of the eradication programme is highly favourable. This is obviously true if one considers the threat of the tick invading the American mainland – as this would be followed by tremendous losses and control expenditures – but eradication will also be cost-effective even if only the benefits for currently-infested islands are taken into account. The present annual losses (including the cost of tick control) due to the presence of the tick on Guadeloupe alone have been estimated at some US$1.5 million (10), while the loss of potential production is far higher. For example, of the 75,000 cattle on the island, over 90% are very resistant Creole cattle, while only 1% is made up of far more productive but susceptible exotic breeds. This composition is caused by selective pressure maintained by the effects of the ticks, and the occurrence of cowdriosis and severe dermatophilosis on the island since the tick was introduced. The island of Nevis provides an example of a different kind. *A. variegatum* first appeared on Nevis in the 1970s, and within ten years the tick had caused the disappearance of some 75% of the cattle population, mainly due to severe dermatophilosis (21).

Although eradication is certainly feasible from a technical point of view, this will not be easy to implement. Each island must be studied separately, as differences exist in management, owner attitudes, presence of wild hosts, etc. However, eradication should proceed simultaneously on the various infested islands to prevent re-infestations. Re-infestations have been observed on Puerto Rico, Saint Croix, Dominica and Barbados. The spread of immature ticks with infested cattle egrets migrating between different islands appears to be an important factor (13).

France and the European Union have recently approved financing to start the programme this year on Guadeloupe and other French islands. International organisations and other donors are expected to start the programme this year on the other infested and threatened islands. These developments are very encouraging in view of the huge stakes involved. The total estimated programme cost of US$30 million is modest compared with the direct benefit gained by eradication and the potential losses which would be faced were *A. variegatum* to spread to the mainland or to the Greater Antilles.

**DETECTION OF PARASITES IN Ticks**

Infection rates of parasites in ticks constitute an important epidemiological parameter. Techniques for detecting infections in ticks have evolved from using conventional staining methods (e.g. 24, 66), through more specific DNA probes (e.g. 12, 19, 65) to the very sensitive means of determining infection rates in ticks by deoxyribonucleic acid (DNA) amplification using the polymerase chain reaction (PCR). This technique – which uses specific oligonucleotide primers and *Taq* DNA polymerase to synthesise a large number of copies from a single DNA template (52) – has very rapidly become a standard laboratory technique, and is more sensitive than nucleic acid hybridisation. For example, PCR has been shown to be a valuable tool for the detection of *Borrelia burgdorferi* in *Ixodes* ticks (26, 49), *Anaplasma marginale* in *Dermacentor* spp. (55), *Theileria annulata* in *Hyalomma* spp. (15) and *Cowdria ruminantium* in *Amblyomma* spp. (28). In general, one can differentiate between closely-related parasites within ticks, which is not possible using conventional staining techniques (66). Another great advantage is that PCR can be performed on ethanol-
preserved specimens. This versatility of PCR makes the technique highly valuable in field studies, by reducing the risks involved in the maintenance and transportation of infected live ticks. PCR detection of parasites in ticks has become another biotechnological tool in the epidemiology of tick-borne diseases. However, this tool should be handled with great care and strict precautions, due to the ever-present danger of extraneous DNA contamination giving false positive results.

**TICK CONTROL**

Within the limits of this review, it is possible to outline only briefly various aspects of tick control and several new developments.

Eradication of ticks is generally not feasible, except on islands, where successful campaigns have sometimes been implemented. On large islands and on continents, the situation is quite different and eradication of ticks is not a realistic goal in most cases, although the eradication of *Boophilus* spp. from the USA remains a notable exception. In this case, eradication has been possible through stringent application of legislative measures and particularly because these are one-host ticks with a distinct preference for cattle; luck may also have played a role, in that acaricide resistance has not been a complicating factor during the campaign. However, it is now becoming increasingly difficult to prevent the ticks re-establishing themselves from Mexico. Acaricide resistance is perhaps one of the main reasons for the failure to eradicate *Boophilus microplus* in New South Wales. Wild animals frequently act as reservoir hosts for economically important ticks, and for this reason (among others) it is generally unrealistic to consider eradicating ticks – including those in temperature regions, such as *Ixodes ricinus* – which parasitise many animals in addition to domestic livestock.

Control of tropical tick-borne diseases – especially in more susceptible and productive exotic or upgraded breeds of livestock – still depends mainly on intensive tick control using acaricides. However, these chemicals are toxic, leave residues in meat and milk, and cause environmental pollution (16). Moreover, acaricides are costly and require expenditure in foreign currencies, thus constituting a major economic strain on the development of the livestock industry, particularly in many African countries (72). Finally, the resistance of ticks to acaricides poses an increasing threat to livestock production (68).

Intensive (and thus expensive) dipping or spraying programmes have been largely unsuccessful in eradicating ticks and tick-borne diseases. Moreover, disruption of cattle dip services has had dramatic consequences, for example in Zimbabwe, where the pre-independence war between 1973 and 1978 was followed by epizootics of tick-borne diseases and the death of an estimated one million head of cattle. This heavy mortality arose from lack of immunity to tick-borne diseases, as a result of previous efficient disease control through dipping (39). Integrated tick control strategies have been advocated, based on host resistance to ticks and the diseases they transmit, strategic tick control (taking into account the seasonal dynamics of tick infestation), the availability of vaccines against tick-borne diseases and cost/benefit analyses of acaricidal application. Moreover, accurate data on tick ecology (e.g. geographical distribution, seasonal occurrence and host preference) are also required (45), together with data on the prevalence of tick-borne diseases within both traditional and commercial livestock production systems. Epidemiological data on tick-borne diseases should be related to tick ecological data as a basis for a recommended tick control programme.
Chemical control

The conventional method for tick control is the treatment of animals by dipping or spraying with acaricides. Spraying can be performed using motorised spray-races or hand-sprays. 'Pour-on' formulations, and acaricide-impregnated ear-tags and bands have also been developed, and some systemic acaricides are available. For example, the present eradication campaign against *A. variegatum* in the Caribbean may use fortnightly pour-on applications of pyrethroids on livestock for prolonged periods. Although this method might select more quickly for acaricide resistance than short-interval dipping or spraying, it has been chosen due to cattle management practices in the Caribbean. In any case, this campaign is meant to last for a definite period of time only, but continuous monitoring for resistance during the campaign is still deemed essential.

In general, it is more efficient to allow livestock to collect ticks and then kill the parasites on the host, rather than to apply acaricides to pastures (a practice which is also potentially much more harmful to the environment). However, in the case of soft ticks (which remain in crevices in animal housing facilities) indoor spraying using acaricides with a long residual effect is useful. This is also true for *R. sanguineus*, *H. anatiolicum anatiolicum* and *H. detritum*. The use of acaricides in tick control has been comprehensively reviewed by the Food and Agriculture Organisation of the United Nations (17).

Host resistance to ticks

For many years, acquired resistance to ixodid ticks has been recognised as a possible biological control method (59). Such resistance, acquired after repeated infestations by ticks, is immunologically mediated (2). Acquired immunity is expressed by a reduction in the number of ticks which attach to the host, reduced engorgement weights, and reduced egg and larval production resulting in significantly reduced tick populations (69). The acquisition of this type of resistance varies with the tick species and the type of breed, and between individuals, probably depending on natural selection of animals exposed to the tick in question over many generations. In Australia, *Bos indicus* herds contain a much higher proportion of individuals capable of acquiring resistance to ticks than (European) *Bos taurus* breeds. The heritability of this characteristic is high. For example, the Australian Milking Zebu and the Australian Friesian Sahiwal have been selected by breeding for their ability to acquire effective resistance against *B. microplus* (53). Such biological control of ticks by selecting for tick-resistant cattle to control populations of the one-host tick *B. microplus* has become an accepted practice in Australia (53). However, despite the use of tick-resistant cattle in this part of the world, the annual cost of production losses caused by ticks and the expense of tick control is still estimated at AUS$100-150 million (approximately US$75-115 million) (71). On the other hand, resistance to the local ticks among West African *Bos taurus* breeds is equal to, if not greater than that among West African zebu cattle (35). For further details, the reader is referred to a recent review on host resistance in relation to cattle tick control (14).

Interestingly, immunity is not acquired against all species of ticks. For instance, no immunity was induced after repeated infestation of goats by *A. variegatum* nymphs (5, 30) or of sheep by *A. hebraeum* nymphs (38). Also, engorgement weights of adult *A. hebraeum* did not decline after repeated feeding on cattle or sheep (41). It has even been reported that engorgement weights of *A. variegatum* fed on cattle were higher in the fourth successive infestation than those obtained during the first feeding (51). Immunosuppressive components in tick saliva may be responsible for this result.
Evidence for immunosuppression was also found when adult *A. variegatum* ticks were fed on sheep which had been experimentally infected with dermatophilosis. A significant systemic effect of the tick on the progression of the disease was found, measured by reduced cell-mediated and humoral immune responses (32). The mechanisms involved are not yet known, but components in tick saliva of adult *A. variegatum* are mediators in the development of severe forms of dermatophilosis in animals infested by this tick. However, this apparent immunosuppressive effect appears to be specific for dermatophilosis, there being no evidence that this tick induces similar effects where other diseases are concerned.

Anti-tick vaccines

Unchanged γ-immunoglobulins in the blood of the host can cross the intestinal wall into the haemolymph of ticks. This observation is at the origin of the idea of inducing artificial resistance against ticks through the use of ‘concealed’ antigens, which do not normally contact the host (18).

The development of an anti-tick vaccine against *B. microplus* is a major new approach in the control of ticks in Australia. This type of vaccination makes use of tick gut antigens, rather than salivary antigens, as the targets for the immune response. This approach has already been demonstrated to work in principle by Allen and Humphreys (3), who succeeded in inducing immunity against *D. andersoni* in guineapigs and cattle, using extracts of the midgut and reproductive organs of adult ticks. Agbede and Kemp (1) were able to immunise cattle against *B. microplus* using extracts derived from the internal organs of adult female ticks. They showed that this immunity was not mediated by a hypersensitivity reaction, that vaccination caused death of adults rather than larvae, and that many of these ticks had gut damage. It was concluded that these antigens, normally located on the plasma membrane of tick gut cells used in this type of vaccination, were concealed from the host immune response. The immunity induced with these antigens appears to be based on specific action of host immunoglobulins resulting in damage of the tick gut during feeding (31). Recombinant DNA technology provided a breakthrough in the production of sufficient amounts of the relevant protein. A membrane-bound tick gut glycoprotein was isolated from *B. microplus*, and the gene coding for this protein was expressed in *Escherichia coli*. The recombinant protein was shown to be capable of inducing a high degree of protection in cattle against infestation with *B. microplus* (50). The vaccine based on this recombinant protein holds great promise (70) and has recently been released on the market. Confirmation of the success and economic viability of this vaccine would considerably raise the hopes of obtaining similar vaccines for use in future integrated programmes against other species of ticks and tick-borne diseases. Biological control of ticks using anti-tick vaccines should reduce the reliance on acaricides and allow more widespread exploitation of tick-susceptible cattle.

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TIQUES ET MÉTHODES DE LUTTE. – F. Jongejan et G. Uilenberg.

Résumé : Les tiques sont les ectoparasites les plus importants des animaux en zones tropicale et subtropicale. Elles sont à l’origine de graves pertes économiques, tant par leur action hématophage directe qu’indirectement, en tant que vecteurs d’agents pathogènes et de toxines. Chez les animaux domestiques très parasités, on observe une baisse de la croissance pondérale et une anémie. Les traces de piqûres de tiques compromettent également la qualité des cuirs. Mais les pertes les plus importantes sont celles qui résultent de l’action des tiques en tant que vecteurs de protozooses, de rickettsioses ou de maladies virales, dont l’impact économique est considérable dans toutes les régions du monde.

Les auteurs passent en revue la biologie, la taxonomie, le rôle pathogène et le rôle en tant que vecteurs des différentes espèces de tiques, ainsi que les méthodes de lutte existantes. La répartition géographique des tiques ne cesse d’évoluer, comme en témoigne le cas de la tique africaine Amblyomma variegatum qui s’est propagée aux Antilles, où une importante campagne d’éradication est actuellement en cours.


* * *

GARRAPATAS Y MÉTODOS DE LUCHA. – F. Jongejan y G. Uilenberg.

Resumen: Las garrapatas son los ectoparásitos más importantes de los animales en las zonas tropical y subtropical. Producen graves pérdidas económicas por su acción hematofaga directa así como también indirectamente, al actuar como vectores de agentes patógenos y de toxinas. En los animales domésticos muy parasitados se observa una baja del crecimiento ponderal y anemia. Las huellas de picaduras de garrapatas deterioran la calidad de los cueros, pero las pérdidas más importantes se deben a la acción de las garrapatas como vectores de protozoosis, de rickettsiosis o de enfermedades virales, de gran impacto económico en el mundo entero.

Los autores pasan revista a la biología, la taxonomía, la acción patógena y la acción como vectores de las diferentes especies de garrapatas, así como a los métodos de lucha actualmente existentes. La distribución geográfica de las garrapatas no deja de evolucionar, como lo muestra el caso de la Amblyomma variegatum africana que se ha propagado a las islas del Caribe – donde se está llevando a cabo ahora una campaña de erradicación de esta garrapata.


* *

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### Appendix

**Key to the genera of adult Ixodidae**  
(Adapted from 34)

<table>
<thead>
<tr>
<th>Description</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>anal groove curves around in front of anus; inornate; eyes absent</td>
<td><em>Ixodes</em></td>
</tr>
<tr>
<td>anal groove located behind anus or absent</td>
<td></td>
</tr>
<tr>
<td>eyes absent</td>
<td></td>
</tr>
<tr>
<td>palps narrow, elongated; article 2 at least twice as long as wide (ectoparasites on reptiles)</td>
<td><em>Aponomma</em></td>
</tr>
<tr>
<td>palps conical, short; article 2 projects beyond lateral margin of basis capitulum</td>
<td><em>Haemaphysalis</em></td>
</tr>
<tr>
<td>eyes present</td>
<td></td>
</tr>
<tr>
<td>palps wider than long, or slightly longer than wide</td>
<td></td>
</tr>
<tr>
<td>small/moderate; mostly inornate; basis capitulum not rectangular dorsally</td>
<td><em>Dermacentor</em></td>
</tr>
<tr>
<td>festoons absent; spiracular plates round or oval; anal grooves faint or obsolete; inornate; males very small</td>
<td></td>
</tr>
<tr>
<td>palps very short and ridged dorsally and laterally; males with normal legs</td>
<td><em>Boophilus</em></td>
</tr>
<tr>
<td>palps short and not ridged; massive, beady leg segments in males</td>
<td><em>Margaropus</em></td>
</tr>
<tr>
<td>festoons present; spiracular plates with tail-like projection; anal grooves distinct; males of moderate size</td>
<td><em>Rhipicentor</em></td>
</tr>
<tr>
<td>no ventral shields in males; coxa IV of male greatly enlarged; palpal article 1 with dorsal spur; inornate</td>
<td></td>
</tr>
<tr>
<td>anal grooves present in males and (usually) accessory shields; coxa IV of male normal size; no spur on palpal article 1 of male and female; usually inornate</td>
<td><em>Rhipicephalus</em></td>
</tr>
<tr>
<td>palps much longer than wide</td>
<td></td>
</tr>
<tr>
<td>ventral plates absent in males; palpal article 2 at least twice as long as article 3; festoons well developed and regular; scutum usually ornamented</td>
<td><em>Amblyomma</em></td>
</tr>
<tr>
<td>ventral plates present in males; palpal article 2 less than twice as long as article 3; festoons less well developed and irregular; scutum inornate</td>
<td><em>Hyalomma</em></td>
</tr>
</tbody>
</table>

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REFERENCES


