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TICKS AND TICKBORNE DISEASES AFFECTING MILITARY PERSONNEL

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NOTICES

This final report was submitted by personnel of the Epidemiology Services Branch, Epidemiology Division, USAF School of Aerospace Medicine, Human Systems Division, AFSC, Brooks Air Force Base, Texas, under job order SUPTXXEK.

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This special report contains a worldwide overview of the tick species and tickborne diseases potentially affecting military operations. Chapters on history of tickborne disease, biology/ecology of ticks, major tickborne diseases, species discussions, and management of tick problems during deployments are included. Photographs and/or drawings are provided for the medically important species occurring worldwide. This report serves as a guide for physicians, environmental health, veterinary, and pest management personnel.

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PREFACE

Tick problems are apparently increasing in many areas of the world due to intense management of certain wild and domestic animals, as well as human development of previously wild areas. Direct effects of tick bites (annoyance) are compounded by disease transmission in many geographic areas. Besides Acquired Immunodeficiency Syndrome (AIDS), Lyme disease is now the most important "new" disease facing us today. Tick specialists, which sometimes have been considered curiosities or eccentrics, are back in the Limelight (or should I say "Lymelight"). As for the future, the status of ticks and tickborne disease at best looks unchanged and likely will increase in importance as tick/human contact increases. This report was written in an effort to minimize the effects of ticks and tickborne diseases on military personnel by providing information on the species present in an area, notes on their biology, guidance for control strategies, and descriptions of tickborne diseases.

Many individuals have been instrumental in the preparation of this report. I received encouragement and helpful advice from Lt Col D. Pinkovsky, Capt T. L. Carpenter, Dr Chad P. McHugh, Col William H. Wolfe, and Col Alan H. Mumm, all of the U.S. Air Force School of Aerospace Medicine (USAFSAM), Epidemiology Division. Steve Bloemer, Tennessee Valley Authority (TVA) Land Between the Lakes, Kentucky; Dr Fivaz, Rhodes University, Grahamstown, South Africa, and Dr Mumcuoglu, Hebrew University, Israel, provided a few key specimens or photographs. Mr Ray Blancarte, USAFSAM/TSY, prepared the tick drawings, and Mr Al Young (also from USAFSAM/TSY) designed the cover. Ms Janina D. Casias and Patricia C. Miller, USAFSAM/EKEN, typed numerous versions of the manuscript. The section, "Definition of Terms Used for Diagnostic Characters," and Figures 70 and 71 were taken from the United States Department of Agriculture (USDA) publication by Strickland et al. (1976).

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CHAPTER 1

HISTORICAL ACCOUNTS OF TICKS AFFECTING MILITARY OPERATIONS

Documented cases of ticks and tickborne diseases affecting military personnel are scarce. However, military personnel throughout history have probably been afflicted by various tickborne diseases such as boutonneuse fever, relapsing fever, tickborne encephalitis, Siberian tick typhus, and others. An epizootic of tropical canine pancytopenia (TCP) affected military working dogs (MWD) in Southeast Asia during the 1960s, with at least 160 MWD killed by the disease (Walker et al., 1970). Outbreaks of TCP were associated with severe dog tick infestations and prevalence of the disease decreased or disappeared in some kennels after rigid tick control measures were enforced (Mac Vean, 1968). Other undocumented cases of tick problems have likely occurred. The lack of documentation of tick problems may be due to the fact that infestations are usually geographically localized with small areas being extremely infested and other great expanses being virtually tick free. However, in a problem tick area, ticks can be so severe that outdoor activity is almost unbearable.

Ticks generally affect military operations in two ways: (1) directly, by tick bite and the accompanying psychological stress, and (2) indirectly, by disease transmission. Various bacteria, rickettsiae, viruses, and protozoans are transmitted to people via tick bites (see Chapter 4). Relatively few ticks may be in an area with disease transmission occurring, or millions of ticks may be in an area with little or no disease transmission occurring. Either way is bad enough by itself. However, when both conditions occur simultaneously (e.g., numerous ticks and high probability of disease transmission), military operations may be severely limited by incapacitating disease among some personnel as well as other troops hampered from performing their duty by annoyance from ticks.

Two military training operations (one historical, one more contemporary) that have been affected by ticks and tickborne disease are presented here. Hopefully, by careful study of the ecological and man-made conditions involved in tick infestations, we can develop effective methodologies to deal with them (see Chapter 3).

Camp Bullis Tick Infestation

In the 1940s, a mysterious disease at Camp Bullis, Texas (near San Antonio) was characterized by low white blood cell counts, fever, and severe occipital headache in more than 1,000 soldiers who had been involved in training (Woodland et al. 1943; Anigstein and Anigstein, 1975). The disease, subsequently named Bullis fever, was shown to have a rickettsial etiology (Anigstein and Bader, 1943; Livesay and Pollard, 1943) transmitted by ticks or chiggers. Since Amblyomma americanum was extremely abundant in the area, it was strongly suspected to be the vector (Brennan, 1945). Pollard et al. (1946) isolated what they believed to be the causative agent from field caught A. americanum and showed that both the tick strain and the human strain (from blood of an infected patient) induced a typical Bullis fever syndrome in inoculated susceptible individuals. Further, cross immunity was demonstrated indicating that the two strains were identical. The exact nature of the Bullis fever rickettsia was not determined, but isolates from infected patients were unrelated serologically to either Rocky Mountain Spotted Fever (RMSF) or Q fever (Livesay and Pollard, 1944). Although no cases of Bullis fever have been reported since the late 1940s, Anigstein and Anigstein (1975) suggested that the Bullis fever agent be named Rickettsia texiana based on retrospective analysis of the data. The author has proposed that Bullis fever and the recently described human ehrlichiosis (see Chapter 4) may be the same disease (Goddard, 1988).

Amblyomma americanum (the lone star tick), the suspected vector in the Bullis fever cases, is a 3-host woodland species that is one of the most annoying and economically important ticks in the United States (U.S.) because of its aggressive and mostly nonspecific feeding habits and high population densities.

The lone star tick has unusually long mouthparts, thus producing painful bites. In several cases among the troops at Camp Bullis, scars (some of them still unhealed lesions) were observed for as long as 2 years following removal of the tick (Brennan, 1945). First stage lone star ticks (often called larvae or seed ticks) are smaller than the head of a pin and occur by the thousands in infested areas during late summer. Often, it is these seed ticks that cause the most annoyance because they escape detection and usually get on people in high numbers.

The tick infestation was so intense at Camp Bullis in the 1940s that it prompted Dr J.M. Brennan, a prominent medical entomologist at the time, to make this assessment of the problem: "There is no record in literature of a greater concentration of the lone star tick elsewhere in the United States than at Camp Bullis." Some examples of the extreme tick infestation noted by Brennan, 1945 are: (1) an Army officer stated that on one occasion 294 ticks were detached from an enlisted man, (2) 910 adult ticks were removed from the head of a deer, (3) 1,160 nymphal ticks were removed from another deer head, (4) a gray fox was infested with 3,064 ticks, and (5) on July 24, 1943, 4 men collected 4,086 adult lone star ticks beneath a small juniper tree (can you imagine taking a 10-min nap under that tree!).

Later, on 13 June 1951, members of the 4th Army Area Medical Laboratory removed 2,951 larvae, 50 nymphs, and 79 adults from a jack rabbit shot on the Bullis reservation. Also in early July 1951, members of a preventive medicine survey unit at Camp Bullis removed 1,150 ticks from a soldier who had sat in a tick-infested thicket for 2 h (Webb, 1952).

All of these examples illustrate the severity of the tick problem at Camp Bullis in the 1940s-1950s. Fortunately, the tick infestation there now is not as bad. This decrease is probably due to the arrival of the imported fire ant, Solenopsis invicta, in the area. Some studies have shown a marked decrease in tick populations in areas recently infested by fire ants. This decrease is due to fire ants feeding on tick eggs and larvae. However, you have to ask yourself, "Which is worse, fire ants or ticks?"

Needless to say, in an area infested with ticks to the degree that Camp Bullis was in the 1940s (regardless of the disease transmission potential), troops are not going to be able to execute their military duties at an optimal level. There is probably some tolerance threshold (see Chapter 3) beyond which duty performance is significantly affected and thus drastic tick control measures are warranted, and the author thinks everyone would agree that 1,150 ticks on one soldier is above that tolerance threshold.

Little Rock AFB Tick Infestation

An ongoing tick infestation affecting military training is in the Volant Scorpion training area at Little Rock Air Force Base (AFB), Arkansas. Members of the United States Air Force (USAF) Military Airlift Command's 1314th Ground Combat Readiness Evaluation Squadron, also known as Volant Scorpion, train and evaluate security police forces in maintaining the security of tactical airfields during time of war. Volant Scorpion consists of a cadre of approximately 50 personnel, and trains about 2,000 troops each year. The 2-week course, offered year-round, is conducted on 1,100 acres on the east side of Little Rock AFB and over 25,000 acres at nearby Camp Robinson (an Arkansas National Guard Installation).

Little Rock AFB has a history of lone star tick infestation, but since 1987 the problem has been especially intense (Goddard, 1987). In a survey of 13 sites on Little Rock AFB and Camp Robinson, tick counts at some sites were as high as 24,000 ticks collected per drag cloth hour (Goddard, 1987); and deer sampled had as many as 2,550 ticks per ear (Goddard et al. 1988). Accordingly, Volant Scorpion personnel sometimes acquire numerous tick bites during exercises. Because of their extensive sneaking and crawling through brushy areas, personnel playing the aggressors are especially attacked by ticks.

The interest in the tick problem at Little Rock AFB was heightened when three clinical cases of ehrlichiosis (see Chapter 4 for a discussion of the disease) were identified in 1988. In a subsequent serological screening of the Volant Scorpion cadre, three other persons were found to have elevated antibody titers to <u>Ehrlichia canis</u>. In addition, 10/12 MWDs on temporary duty (TDY) to the Volant Scorpion training course tested positive for <u>E. canis</u> in early 1988 after completion of training. All the dogs had tested negative for ehrlichiosis in recent tests at their home bases. As of this writing, USAFSAM Epidemiology Division personnel were conducting an epidemiological investigation of this problem.

Goddard and McHugh (1989) conducted a study in the Volant Scorpion squadron at Little Rock AFB to assess the impact of the tick infestation on performance of military duties. The study involved a questionnaire (Table 1) completed by Volant Scorpion participants upon completion of training. Students were asked to estimate the number of attached ticks they found as an objective measure of the tick problem. Two questions (Nos. 3 and 5) required a more subjective assessment of the tick problem. Information was also requested on personal protective measures used by students and on the medical pests encountered.

TABLE 1. QUESTIONNAIRE ADMINISTERED TO VOLANT SCORPION TRAINEES, MAR-AUG 1988.

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1. What was your course number and dates attended?

2. What was the most bothersome pest you encountered during this training?
   A) Mosquitoes
   B) Ticks
   C) Chiggers
   D) Snakes
   E) No pests were encountered

3. How would you rank the tick problem in the training area?
   A) Slight
   B) Moderate
   C) Bad
   D) Extremely bad
   E) Non existent

4. Approximately how many ticks attached to you during your training?
   A) <10
   B) 10-24
   C) 25-49
   D) 50-99
   E) >100

5. How significant was the effect of ticks and tick bites on the execution of your duties during this training?
   A) Insignificant
   B) Significant
   C) Very Significant (they greatly interfered with my duties)
   D) Not Applicable - no ticks seen

6. Which of the following personal protection techniques did you use to protect against tick bites? (Answer all that apply.)
   A) Bloused fatigues
   B) Used diethyl-toluamide (DEET) repellent (Army green standard issue)
   C) Permanone repellent
   D) Other repellents
   E) None

The questionnaire was intentionally short because troops at the end of training are tired and generally unwilling to complete paperwork of any kind. The questionnaire was given to 9 classes from mid-March to mid-August 1988 (roughly one tick season). Completed questionnaires were returned to the USAFSAM Epidemiology Division at Brooks AFB, Texas, and responses were analyzed using Statistical Analysis System (SAS) software.

Class size ranged from 44 to 370 students. Classes were composed almost exclusively of males; females only infrequently attended the Volant Scorpion program. Overall response was 73.9% (956 questionnaires from 1,293 students). Class response ranged from 54 to 100% with the 2 largest classes having the lowest response rates. No attempt was made to resurvey nonresponders, and the effect of this nonresponse on the study is not known.

With the exception of the last 2 classes, 35-50% of each class reported that ticks were the worst pest encountered during Volant Scorpion training (Table 2). In those 2 classes, the most common response for worst pest encountered was "chiggers"; however, larval lone star ticks (which peak in numbers during those months) are extremely small and may easily be mistaken for chiggers.

When asked to rank the severity of the tick problem, 5 of the 9 classes had >60% of the responses indicating "bad" or "extremely bad." Most classes in which the students ranked the problem as "bad" or "extremely bad" were conducted from April to June. This response is not unusual as ticks are seasonal pests and most adult lone star tick feeding occurs in the spring and early summer. There was a class in the spring (28 Apr-11 May) in which both tick numbers and the severity of the tick problem were reported as low. Weather data revealed no unusually cool or wet weather during that class. Training is accomplished at various sites on Little Rock AFB and Camp Robinson and is not conducted at the same locations for all classes. Whether training during that class was conducted in an area(s) with fewer ticks (such as open meadows, on top of high hills, in recently burned areas, etc.) is unknown.

In 6 of the 9 classes, approximately 40% or more students received >10 ticks during training. Class 88-10 (May 30-June 12) had 65% of respondents reporting at least 10 tick bites. Ten people, mostly in the first 4 classes, reported >100 ticks attached to them during the 2-week training period.

There was a direct relationship between number of tick bites received and the perceived severity of the tick problem, suggesting that despite some personal squeamishness about ticks, the respondents were able to remain fairly objective in their assessment of the tick problem. Table 3 shows a breakdown of data comparing the rating of the tick infestation vs. the number of tick bites received. When the ranking "extremely bad" is plotted against the number of tick bites, a clearer pattern of the perception of the tick problem can be observed (Fig. 1). Of those troops who received less than 10 tick bites, only 6.5% felt this represented an extremely bad problem. When 10-24, 25-49, or 50-100 tick bites were received, the percentage who rated the problem as extremely bad increased to 25.5, 44.0, and 69.6%, respectively.

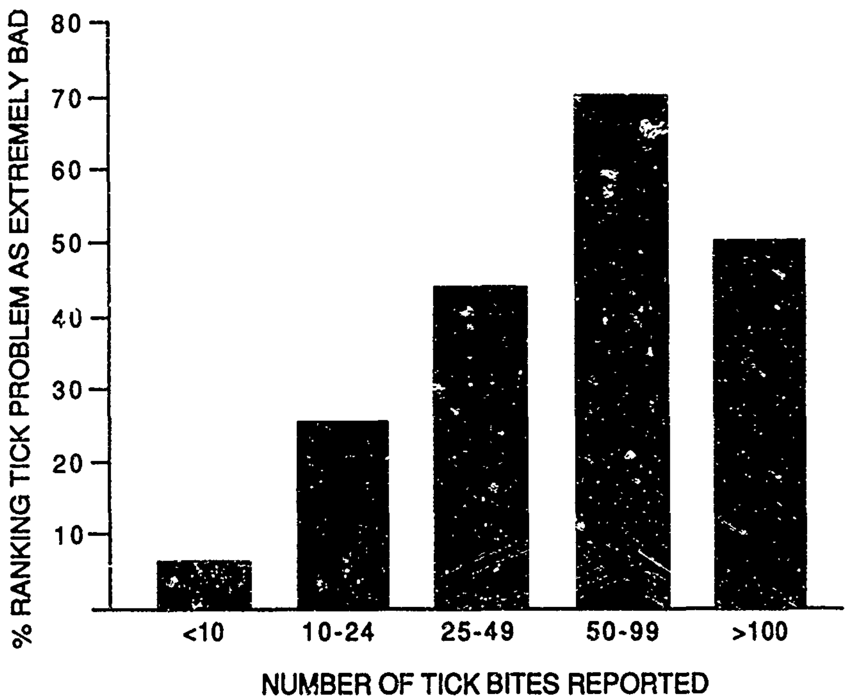

Figure 1. Comparison of number of tick bites received by Volant Scorpion students vs. those students who considered the problem to be extremely bad.

TABLE 2. TICK BITE SURVEY RESULTS, LITTLE ROCK AFB ARKANSAS, MAR-AUG 1988.

Response	Class								
	88-5[a]	88-6[b]	88-7[c]	88-8[d]	88-9[e]	88-10[f]	88-11[g]	88-12[h]	88-13[i]
Said ticks were worst pest encountered	34%	50%	46%	40%	40%	40%	49%	11%	18%
Rated tick problem as at least bad	26%	41%	72%	25%	61%	71%	62%	36%	60%
Got >10 ticks on them during training	9%	42%	52%	19%	43%	65%	38%	19%	45%
Said ticks had at least a significant effect on duty performance	27%	44%	45%	18%	26%	55%	30%	30%	34%
Used repellents other than Permanone	23%	48%	56%	53%	55%	55%	70%	68%	70%
Used Permanone repellent	1%	11%	4%	7%	3%	12%	94%	64%	55%
Said ticks greatly interfered with duty performance	3%	16%	6%	1%	3%	9%	0%	6%	6%

[a] March 11-24, 138 responses out of 160 students in class.
[b] March 27-April 9, 104 responses out of 192 students in class.
[c] April 12-25, 139 responses out of 142 students in class.
[d] April 28-May 11, 100 responses out of 102 students in class.
[e] May 14-27, 72 responses out of 96 students in class.
[f] May 30-June 12, 86 responses out of 120 students in class.
[g] June 15-28, 37 responses out of 44 students in class.
[h] July 15-30, 213 responses out of 370 students in class.
[i] August 6-19, 67 responses out of 67 students in class.

TABLE 3. RATING OF THE SEVERITY OF TICK INFESTATION AND THE NUMBER OF ATTACHED TICKS REPORTED BY STUDENTS AT VOLANT SCORPION, CLASS 88-5 THROUGH 88-13 (11 MARCH 88-19 AUGUST 88).

	Number and percentage of tick bites				
Rating of tick infestation	<10	10-24	25-49	50-99	>100
Nonexistent (No Problem)	17(3)	0(0)	1(1)	0(0)	1(10)
Slight	183(29)	2(1)	2(3)	0(0)	1(10)
Moderate	233(37)	51(25)	11(15)	1(4)	2(20)
Bad	158(25)	102(49)	28(37)	6(26)	1(10)
Extremely bad	41(6)	53(25)	33(44)	16(70)	5(50)
Total	632	208	75	23	10

Approximately one-third of each class reported that ticks had a significant impact on the performance of their military duties. Of those students receiving >50 ticks during training, 66% (21/32) felt that ticks had a significant impact on their duty performance. On the other hand, 20.7% (130/629) of students who reported <10 ticks also considered tick effects significant. Although only 6.5% felt that less than 10 ticks was an extremely bad tick problem, one-fifth of the class felt this level of tick infestation significantly, or very significantly, impacted their performance of duty. The manner in which this interference was expressed was not determined, but likely it was the psychological distress and preoccupation with attached ticks which distracted troops from their duties.

The use of chemical repellents by class members was widespread and increased as the season progressed. The use of repellents may have been due to recommendations by the cadre (the cadre did recommend use of Permanone repellent to the last few classes) or feedback from previous classes reaching incoming troops. The use of nonchemical, mostly folklore, tick-repellent methods was occasionally noted on questionnaires. These methods included pantyhose, flea/tick collars, Avon Skin-so-Soft, vitamin C, and double-sided tape.

Permanone tick repellent, one of the best available repellents, has been recommended for Volant Scorpion participants previously by USAFSAM entomologists (Goddard, 1987). A few Volant Scorpion students used this repellent (1-10%) in classes 88-5 through 88-10, but upon the strong recommendation of the cadre, a majority of students reported Permanone use during the last 3 classes.

In class 88-11, which reported the highest Permanone use, no responders reported that "ticks greatly interfered with performance of military duties." However, there was no significant difference (chi-square, P = .05) in the number who reported an impact of ticks on duty performance between the 3 classes with highest Permanone use (88-11, 88-12, 88-13) and all the other classes.

In addition, in a statistical comparison (chi-square, P =.05) of Permanone use alone vs. no repellents, the use of Permanone made no significant difference in actual tick numbers acquired during training. The failure to demonstrate an effect of Permanone on tick bites was surprising and may represent a failure of the compound, inadequate application technique, or behaviors such as crawling through brushy areas which may have exposed untreated areas (hands, face, hair) to ticks. Recall bias may also have influenced the responses. Persons who used the repellent may have been those who were the most concerned or alarmed by ticks and may have overestimated how many got on them. Conversely, the troops who did not use repellents may have been unconcerned by tick bites and thus underreported how many bites were received during training.

This subjective study indicated that the heavy tick infestation at Little Rock AFB had an adverse effect on the training of military personnel. Over one-third of all respondents reported a significant or very significant impact on duty performance. Even 9 or fewer ticks were sufficient to adversely impact one-fifth of the troops. Use of Permanone alone had no demonstrable effect on the number of tick bites reported. In my opinion, failure to demonstrate effectiveness in this case is largely due to improper application technique. My own experience has found Permanone very effective if properly applied. In a recent U.S. Army study (Evans, 1989), 98% protection from ticks was attained by thoroughly spraying both front and back of battle dress uniform pants and shirt with Permanone.

Two effects may help alleviate the impact of ticks on military personnel: (1) proper application techniques of repellents will help reduce the number of tick bites and the potential for tickborne disease transmission, and (2) an educational effort to increase troop awareness of ticks, their biology, their role in disease transmission, and the effective use of repellents may help personnel put the tick problem in perspective. If the impact of tick bites is largely emotional distress, even a modicum of information may reduce troop aversion to ticks, reduce the psychological impact of attachment, and allow troops to concentrate on military duties.

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CHAPTER 2

BASIC TICK BIOLOGY AND ECOLOGY

The 3 families of ticks recognized in the world today are: (1) Ixodidae (hard ticks), (2) Argasidae (soft ticks), and (3) Nuttalliellidae (a small, curious, little-known group with some characteristics of both hard and soft ticks). The terms hard and soft refer to the presence of a dorsal scutum or "plate" in the Ixodidae, which is absent in the Argasidae.

Hard ticks display sexual dimorphism (males and females look obviously different, Fig. 2) and the blood-fed females are capable of enormous expansion. Their mouthparts are anteriorly attached and visible from dorsal view (Fig. 3b). When eyes are present, they are located dorsally on the sides of the scutum.

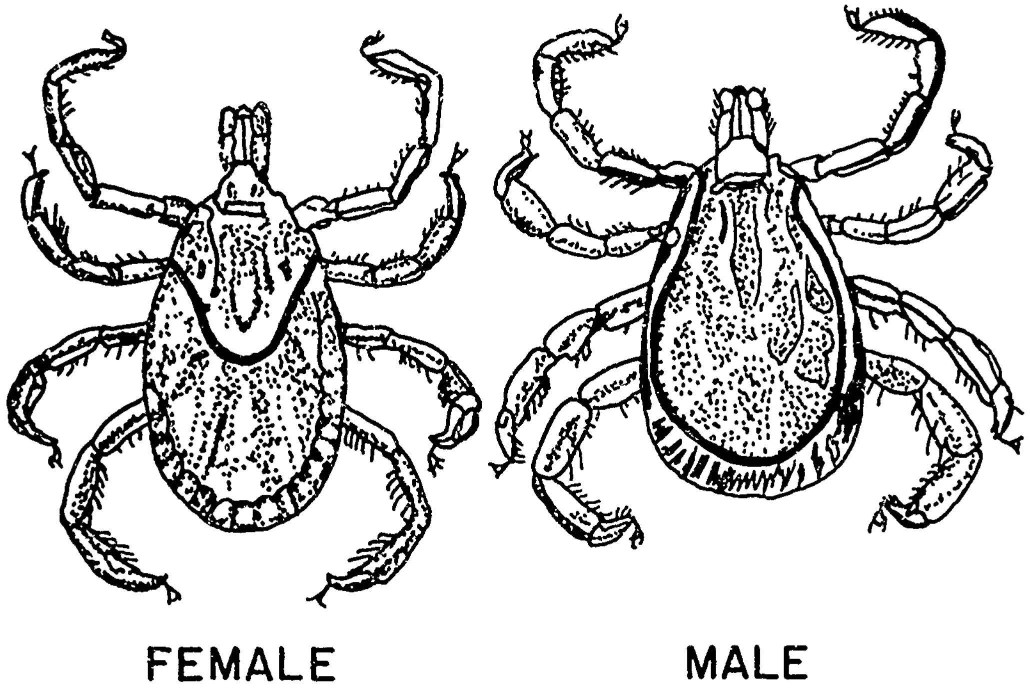

Figure 2. Female and male hard ticks.

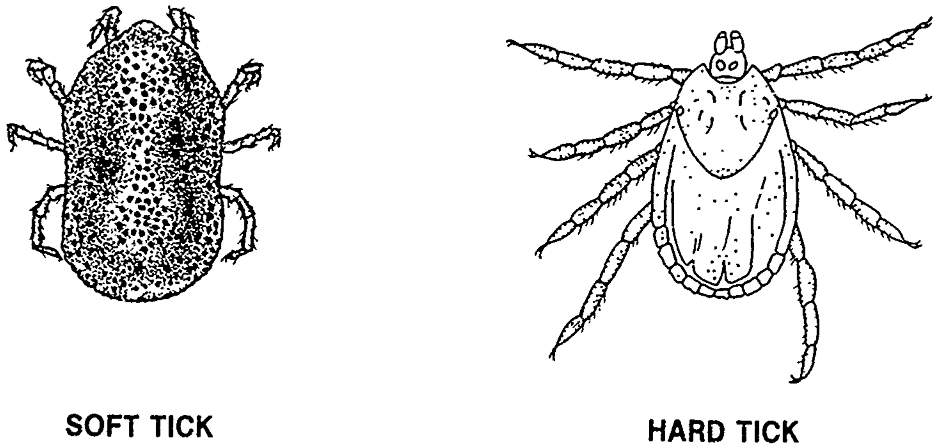

Figure 3. Comparison of soft and hard ticks.

Soft ticks are leathery and nonscutate, without obvious sexual dimorphism. Their mouthparts are subterminally attached (in adult and nymphal stages) and not visible from dorsal view (Fig. 3). Eyes, when present, are located laterally in folds above the legs.

There are major differences in the biology of hard and soft ticks. Some hard tick species have a 1-host life cycle in which case engorged larvae and nymphs remain on the host after feeding; they then molt, and the subsequent stages reattach and feed. The adults mate on the host, and only engorged females drop off to lay eggs on the ground. While some hard ticks complete their development on only 1 or 2 hosts, most commonly encountered ixodids have a 3-host life cycle. In this case, adults mate on a host (except for some Ixodes spp.) and the fully fed female drops from a host animal to the ground and lays from 5,000 to 18,000 eggs, after which she dies. The eggs hatch in about 30 days into a 6-legged seed tick (larval) stage, which feeds predominantly on small animals. The fully fed seed ticks drop to the ground and transform into 8-legged nymphs. These nymphs seek an animal host, feed, and drop to the ground. They then molt into adult ticks, thus completing the life cycle. Figure 4 shows all the motile life stages of hard ticks.

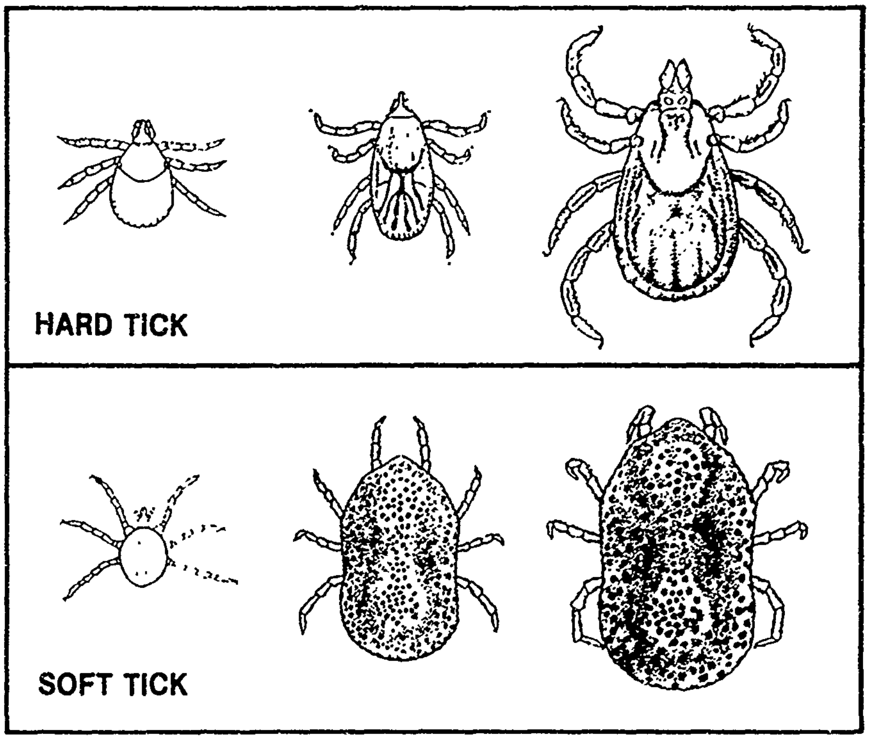

Figure 4. Motile life stages of hard ticks and soft ticks.

Many hard tick species "quest" for hosts, whereby they climb blades of grass or weeds and remain attached, forelegs outstretched, awaiting a passing host. They may travel up a blade of grass (to quest) and back down to the leaf litter where humidity is high (to rehydrate) several times a day. Also, hard ticks will travel toward a CO_2 source. Adult ticks are more adept at traveling through vegetation than the minute larvae. Studies have shown that adult lone star ticks may travel up to 10 m (33 ft) to a CO_2 source, but other species such as Ixodes dammini will only travel distances of 1-2 m (3.3 - 6.6 ft) toward a CO_2 source.

Ticks feed by using their chelicerae to cut a small hole into the host epidermis and inserting the hypostome into the cut, thereby attaching the tick to the host. Blood flow is presumably maintained with the aid of an anticoagulant from the salivary glands. Some hard ticks secure their attachment to the host by forming a cement cone around the mouthparts and surrounding skin. Two phases are recognized in the feeding of nymphal and female hard ticks: (1) a growth feeding stage characterized by slow continuous blood uptake, and (2) a rapid engorgement phase occurring during the last 24 h or so of attachment.

Ticks communicate with each other by both physical and chemical means. Chemicals released by individuals of a species that alter the behavior of other individuals of the same species are called pheromones. Assembly, aggregation/attachment, and sex pheromones are known to occur in several species of ticks. Sonenshine (1985) provides an excellent review of the subject. Assembly pheromones serve to induce clustering of free-living ticks in the environment and are known from at least 14 species of Argasidae and 6 species of Ixodidae. Aggregation/attachment pheromones regulate attachment to the host body sites where conspecific males have attached and fed. Males produce the pheromone to attract females, resulting in the formation of tight clusters of conspecific feeding ticks. Sex pheromones alter the behavior of one or both members of the mating pair. There are different types of sex pheromones, but probably the best known example is the attractant sex pheromone, 2,6-dichlorophenol (2,6-DCP) which has been shown to be attractive to numerous ixodid tick species. The compound serves as an excitant, inducing males to detach, as well as a locating signal of the emitting source, thus guiding the male to the sexually active female.

The biology of soft ticks differs from hard ticks in several ways (see Fig. 4 for life stages). Adult female soft ticks feed and lay eggs several times during their lifetime. Soft tick species may also undergo more than one nymphal molt before reaching the adult stage. With the exception of larval stages of some species, soft ticks do not firmly attach to their hosts for several days like the Ixodidae. They are adapted to feeding rapidly and leaving the host promptly.

The expansion capability of hard ticks sometimes causes confusion among nonspecialists. I have often been sent fully engorged hard ticks removed from dogs with instructions to "identify enclosed soft tick"; This misconception is because engorged ixodids do sometimes appear "soft." Another common misconception is that flat, unengorged hard ticks and engorged hard ticks represent different species. Ranchers often speak of 2 "species" on their cattle: "the large swollen species" and the "small flat, brown species."

Hard ticks and soft ticks occur in different habitats. In general, hard ticks occur in brushy, wooded or weedy areas containing numerous deer, cattle, dogs, small mammals, or other hosts. Soft ticks are generally found in animal burrows or dens, bat caves, dilapidated or poor quality human dwellings (huts, cabins, etc.), or animal rearing shelters. Many soft tick species thrive in hot and dry conditions, whereas ixodids are more sensitive to dessication and, therefore, are usually found in areas providing protection from high temperatures, low humidities, and constant breezes.

Ticks, being sensitive to dessication, therefore, must practice water conservation and uptake. Their epicuticle contains a wax layer which prevents water movement through the cuticle. Water can be lost through the spiracles; therefore resting ticks keep their spiracles closed most of the time (opening them only 1 or 2 times/hour). Tick movement and its resultant rise in CO_2 production cause the spiracles to open about 15 times/hour with a corresponding water loss.

Development, activity, and survival of hard ticks is influenced greatly by temperature and humidity within the tick's micro-habitat. Lancaster (1957) found that lone star tick eggs reared in an environment of <75% humidity would not hatch. Lees (1946) showed that Ixodes ricinus died within 24 h if kept in a container of 0% relative humidity (RH), but survived 2-3 months at 90% RH. The tick Hyalomma savignyi survived almost 7 months at 17.5 °C (63.5 °F) but less than 3 weeks at 37 °C (98.6 °F) (Feldman-Muhsam 1947).

Because of their temperature and humidity requirements, as well as host availability, hard ticks tend to congregate in areas providing those factors. Ecotonal areas (interface areas between forests and fields) are excellent habitat for hard ticks. Hair and Howell (1970) found that open meadows/prairies, along with climax forest areas, supported the fewest lone star ticks. Ecotone areas and small openings in the woods were heavily infested. In a study by Semtner et al. (1971), lone star tick populations decreased with an increase in distance from the ecotone. Fleetwood et al. (1984) found that inner ecotone areas (next to the interior woods or thickets) yielded significantly higher numbers of nymphal and adult ticks than did the outer ecotone areas. Studies conducted by Sonenshine et al. (1966) and Sonenshine (1979) demonstrated that American dog ticks tend to be especially abundant along trails, roadsides, and the forest boundaries surrounding old fields or other clearings. Another of Sonenshine's studies showed that ticks were at least twice as abundant in the old field-forest edge as in adjacent clearings (Sonenshine and Levy, 1972).

Deer and small mammals thrive in ecotonal areas, thus providing blood meals for ticks. In fact, deer are often heavily infested with hard ticks in the spring and summer months (Fig. 5). The optimal habitat of white-tail deer has been reported to be the forest ecotone since the area supplies a wide variety of browse and frequently offers the greatest protection from their natural enemies (Bartlett, 1938). Many favorite deer foods are also found in the low trees of an ecotone. According to Dalke (1941) these trees include greenbrier, sassafras, grape, oaks, and winged sumac.

Studies have shown that ticks are sometimes associated with certain vegetation types. Semtner et al. (1971) found that highest numbers of adult and nymphal lone star ticks generally occurred in the persimmon-sassafras-winged elm woods. A distinct association between the Rocky Mountain wood tick and several species of shrubs has been demonstrated (Wilkinson, 1967). Other species of ticks such as the American dog tick are associated with vegetative habitats that are fairly identifiable (Sonenshine et al. 1966).

Figure 5. Deer heavily infested with lone star ticks. (TVA photo by Denise Schmittou).

These studies emphasize that ticks are not evenly distributed in the wild, but instead are localized in areas providing their necessary temperature, humidity, and host requirements. These biologic characteristics of ticks, when known, may enable us to avoid the parasites in many military operations.

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CHAPTER 3

MANAGEMENT OF TICK PROBLEMS ON MILITARY DEPLOYMENTS

In Chapter 1, I discussed the fact that tick infestations have impacted military operations in the past and continue to do so. What then can be done when heavy tick infestations are encountered? Control of ticks in a large area is often impractical because of financial and environmental considerations of large scale pesticide application. However, several options are available for management of severe tick infestations (not all of which are applicable in every situation), beginning with an education program.

Education

In the tick bite study conducted at Little Rock AFB, Arkansas, Goddard and McHugh (1989) found that not everyone reacted the same way to tick bites. For some troops, 1-10 ticks significantly affected their military duty performance during Volant Scorpion training, while for others, it took as many as 50-100 ticks to produce the same effect. This disparity was probably due to the backgrounds of those troops involved. A person from Oklahoma or Kentucky who grew up in a rural environment is likely not as concerned about ticks as a recruit from New York City or Los Angeles; this is where an effective education program is needed. People who never have been exposed to the out-of-doors and these blood-sucking parasites will greatly benefit from a briefing on ticks, including pictures of the life stages, discussions on their biology, the diseases they may transmit, and proper personal protection measures against them.

Accomplished properly, an education program about ticks can reduce the psychological stress factor of ticks and tick bites. Hopefully, the briefings will put a tick problem in proper perspective concerning just how bad the problem is in the training area; what are the chances of disease transmission by tick bites; and just how effective are the current personal protection techniques. For an example of personal protection, Schreck et al. (1986) demonstrated in a research study that military field uniforms treated with 0.5% permethrin provided 100% protection to humans against all life stages of _Ixodes dammini_. While we as preventive medicine personnel cannot promise 100% protection from ticks, it is comforting to offer incoming troops these kinds of data.

Host Management

Another little-used tool for tick control is host management, and especially for deer. Since 1900, the United States' deer population has exploded from under 300,000 to 15 million. Unfortunately, some of our most pestiferous tick species such as the lone star tick, *Amblyomma americanum*, and Dammin's northeastern ixodid, *Ixodes dammini*, use white-tailed deer as a primary food source. There seems to be a correlation between deer numbers and tick numbers. Invariably, wherever there is a tremendous tick population, there is high deer density (with the exception of some domestic animal farms or productions). When I first visited Little Rock AFB to investigate the tick problem in 1987, I asked base personnel if there were any deer on base. "Interesting that you would ask that," one replied, "We had over 50 deer road kills on base last year and a C-130 even hit one upon landing." The association between deer numbers and tick populations is because (at least with *A. americanum* and *I. dammini*) numerous deer in an area increase the chances that an adult tick will obtain a blood meal and reproduce. Conversely, if deer numbers are drastically reduced, many unfed female ticks will starve. This reduction has been experimentally demonstrated: when deer were removed from a tick infested area on Cape Cod, Massachusetts, larval ticks became less abundant beginning the next summer following deer removal, indicating that the adults of *Ixodes dammini* generally failed to feed and reproduce (Wilson et al. 1988). However, Wilson et al. (1984) demonstrated that halving the indigenous deer herd may not measurably affect tick density. These two studies, along with some work done at the Tennessee Valley Authority (TVA) Land Between the Lakes, in Kentucky (Bloemmer, 1988), indicate that deer reduction does, in fact, reduce tick numbers in an area but the reduction may not be linear. For example, a 25% reduction in deer may not result in a 25% reduction in ticks.

Deer reduction (within state and local guidelines) is a useful tool in an overall tick management program and should be considered before tick infestations become severe. Often, military installations are closed to hunting, and deer numbers increase dramatically. Base preventive medicine or veterinary personnel may help to avert the corresponding rise in tick populations by advocating effective ongoing deer management. Proper coordination with the state department of natural resources or wildlife department personnel can result in special hunts, trapping and relocation efforts, etc. Environmental modification and high fencing, although expensive, may also help by discouraging deer immigration.

Vegetation Management

Vegetation management may reduce tick numbers. Some legumes produce viscous secretions from glandular trichomes on the stems which trap and kill larval ticks as they attempt to quest for hosts. However, Norval et al. (1983) in Zimbabwe showed that legumes in the genus Stylosanthes were repellent to ticks with larval ticks selectively avoiding them. Hoch et al. (1971b) have demonstrated that herbicidal treatment or mechanical removal of vegetation in woodlots results in higher temperatures in the tick habitat, causes a lower relative humidity in the area, and reduces available soil moisture. All of these factors lead to higher tick mortality. In another study, mechanical clearing of all undergrowth and enough of the larger vegetation to allow penetration of 70-80% of sunlight significantly lowered lone star tick populations (all stages). Lone star tick larvae were reduced by 85% 1 year posttreatment by this means (Hoch et al. 1971a). Mowing with a bush hog rotary mower in tick habitat (on Great Island, Massachusetts) reduced adult Ixodes dammini populations by 70% seven months after the mowing (Wilson, 1986).

Controlled burning of habitat may also reduce tick numbers. This method is an old practice. Ranchers and foresters periodically burn fields, woodlots, etc. to modify habitats and this likely reduces tick population numbers (at least temporarily). This method also has been experimentally demonstrated: On Great Island, Massachusetts, burning tick-infested areas reduced adult I. dammini populations by 38% 6 months after the burn (Wilson, 1986).

Because of reinfestation possibilities due to animal use of uncleared areas, acaricides provide no lasting solution to a tick problem, whereas vegetation management (clearing, burning, etc.) may alter the behavior of tick hosts that normally depend on cover for survival (Hoch et al. 1971a). However, vegetation clearing by mechanical or chemical means may not produce similar results. Hoch et al. (1971a) found that even though herbicidal treatment of woodlots creates an environment that is generally unfavorable for lone star tick larvae, it was not as effective as mechanical clearing.

Furthermore, vegetation management is not a panacea. In studies in Oklahoma, mechanical and herbicidal clearing of vegetation produced a significant impact on lone star tick larvae but little effect on nymphs and adults (Clymer et al. 1970; Hoch et al. 1971a). Also, the indirect, long-term impact of burning on tick abundance is not clear. Burning may actually produce contradictory effects on hosts and ticks because burning typically improves deer browse in an area. This type of vegetation management suggests that deer abundance may ultimately increase at a burn site, thus reinfesting the area with replete adult ticks acquired elsewhere (Wilson, 1986).

Training Site Selection

Camp site and/or training site selection is important in avoiding tick-infested areas. Knowing what we know about tick habitat preferences (Chapter 2), troops on maneuvers should avoid ecotonal areas such as forest boundaries surrounding old fields or other clearings. Obviously, this avoidance is not always possible and other overriding considerations may come into play; however, commanders often consult environmental health or preventive medicine personnel for advice concerning locations for bivouacs, Continuing Medical Readiness Training, etc.

Tick sampling is important in such situations. Tick populations can be assessed in an area by dragging a white cloth over vegetation (Fig. 6) or by dry ice trapping (Fig. 7). Dragging for ticks is successful because of tick questing

Figure 6. Drag cloth method of tick collecting.

behavior on vegetation. Dry ice attracts ticks because they come toward a CO_2 source. Dragging is accomplished by pulling a white cloth (approximately 1 m (3.3 ft) wide x 2 m (6.6 ft) long, attached to a wooden dowel) through the weeds or brush, and checking the cloth every 7 m (approx 20 ft) or so for ticks. Dry ice trapping involves placing a piece of dry ice (1/4-1 lb block) in the middle of a 1-m^2 (10.8 ft^2) white cloth placed in the area to be sampled. After an hour, ticks crawling on the cloth are counted. For comparison purposes, tick numbers are often quoted as "ticks/drag cloth hour" or "ticks per 1 h dry ice sample." If tick sampling in an area reveals 5 ticks/drag cloth hour on top of a wooded hill as compared to 125 ticks/hour in a subclimax forest near a meadow, the choice for a training or bivouac site should be obvious.

Figure 7. Dry ice trapping for ticks.

Human tolerance thresholds for tick numbers have been established for recreational areas and may also be useful for military training areas. Mount (1981) proposed an arbitrary tolerance threshold of one tick/dry ice sample. This threshold was based on several years of observation in 5 recreational areas in eastern Oklahoma. In another study, Mount and Dunn (1983) proposed a threshold of 0.65 ticks/1 h dry ice sample for recreational areas. The 0.65 density threshold was based on the established relationship between CO_2 and human subject attraction of lone star ticks and an assumption that most human visitors to recreational areas will not spend more than 1 h/day in tick habitats. This threshold was also formulated in line with the ultimate goal of tick management in recreational areas--zero probability of tick attack on human visitors. A tolerance threshold for military training sites need not be 0.65 ticks/CO_2 sample due to the nature of our mission; perhaps a threshold of <10 ticks/1-pound dry ice sample/hour would be more feasible.

Area Control

To reduce tick numbers in a small infested area, entomology or pest control personnel can spray the area with an insecticide (actually an acaricide in this case) such as chlorpyrifos or diazinon. If used properly, this treatment can provide seasonlong tick control. At least 2 treatments are needed for control: 1 in the spring for the adult and nymphal stages and 1 in late summer for the emerging larval stage. Surveillance is critical to determine times of application. Drag cloth or dry ice sampling can indicate if another springtime application is necessary for adult/nymph control or if another late summer treatment is needed for larval control. In a low to moderate tick infestation, 1 treatment in spring and 1 treatment in fall will provide seasonlong control. Heavy infestations may require 2 or more treatments in spring and again in fall. Pesticides of choice, national stock numbers (NSNs), dilution rates, and comments concerning such treatments are outlined in the Armed Forces Pest Management Board's Technical Information Memorandum Number 24, entitled, "Contingency Pest Management Pocket Guide."

Effectiveness of acaricides is dependent on tick activity. Applications of acaricides in cold weather when ticks are inactive will achieve only minimal results. Tick activity may also vary with time of day. Pest management personnel should strive to know as much as possible about the population dynamics of the tick species they are trying to control to use acaricides effectively. One problem with local area spraying for tick control is the size of area to be treated. Pest control personnel can easily treat small camps or training areas (up to about 10 acres), but large-area spraying such as by aircraft is a complicated and environmentally sensitive issue.

Aerial Spray

For an aerial dispersal of acaricide, an aerial spray validation statement is required as well as an environmental assessment and proper coordination with local, state, and sometimes federal officials. Roberts et al. (1980) and Mount (1981) confirmed the efficacy of diazinon granules for control of lone star ticks. Mount (1984) used 14% diazinon granules at 7 lb/acre in an aerial spray treatment for tick control in Oklahoma and attained 97% control of lone star nymphs and 82%

control of adults. Mount's study (1984) using a Cessna AgCat with a gravity granule spreader demonstrated that there was no significant loss of efficacy from overstory filtration when granules were applied by air. Thus, aerially dispersed granules (at 7 lb/acre) offer an efficient method of area control of ticks in wooded habitat. Moreover, granular applications by aircraft provided rapid coverage with satisfactory placement of acaricide, even during moderate winds (3.2-11 kph). In contrast, the Army used diazinon 14G granules for tick control at Ft A.P. Hill, Virginia with less desirable results (Sardelis et al. 1989). A helicopter-transported granular spreader calibrated at 4 lb of granules/acre was used to treat a 700-acre site near Richmond, Virginia. Distribution of the granules was uneven with some areas receiving around 4 lb/acre and others as much as 7 lb/acre. Posttreatment surveillance indicated that approximately 90% control was achieved in areas receiving the 7 lb/acre dosage. The limited tick control achieved in this study (only 50% overall) may be attributed to the lower acaricide dosage used and/or poor penetration of dense overstory vegetation. Therefore, in an aerial spray project, careful attention should be given to attaining the uniform distribution of 7 lb/acre necessary to achieve 80-90% tick control using diazinon 14G.

Other Methods of Tick Control

Some innovative, highly specific tick control measures are being actively developed. Since white-footed mice are reported to be the primary reservoir of Lyme disease spirochetes (and thus the source for infecting immature Ixodes dammini), EcoHealth Inc., of Boston, has developed a permethrin treated cotton product for tick control. The product, called "Damminix," consists of biodegradable cardboard tubes containing cotton balls treated with 7.4% permethrin. The tubes (recommended to be distributed 50/acre) are placed 9 m (10 yd) apart in a grid pattern in the area to be protected and the cotton is subsequently gathered up by the white-footed mice for nests. The treated cotton kills immature ticks but does not harm the mice. EcoHealth claims that the product, if properly applied, can reduce the risk of being bitten by an infected tick by 97% on treated property. Another innovative application of technology is combining pheromones with pesticides. Sonenshine et al. (1985) evaluated a product containing the sex pheromone 2,6-dichlorophenol combined with propoxur insecticide for tick control on dogs. The compound persisted in the fur of treated dogs for at least 18 days and was much more effective in reducing mating among the surviving ticks than the treatments without pheromone. The pheromone-pesticide mixture also killed significantly more ticks than the treatment without pheromone. This increased effectiveness was due almost entirely to the greater kill of male ticks. Sonenshine et al. (1985) cautioned against raising unwarranted expectations regarding the potency of the pheromone-aided treatments for tick control. They stated that the inclusion of pheromone will probably not result in very great reductions in the numbers of attached feeding ticks and only modest increases in tick mortality. The primary effect to be expected is the reduction of mating, with long-term benefits expressed in the form of declining tick populations. These benefits are most likely to be limited to closed environments (homes, barns, kennels) where the tick population is restricted and will repeatedly encounter the same pheromone-treated hosts.

Experiments have also been conducted using baited pesticide treatment stations for reducing natural populations of American dog ticks, Dermacentor variabilis. Sonenshine and Haines (1985) demonstrated that small mammals attracted to a baited container coated themselves with dust or oil containing small quantities of pesticide, resulting in highly significant reductions in the numbers of immature ticks on animals in the treated area as compared to animals in the control area. In one experiment, they used Sherman live traps modified with felt-covered wheels that coated small mammals with carbaryl-laden talc dust as they entered the trap to reach bait at the rear. Doors were removed from the traps to allow free entry and exit by the animals. In the second experiment, plastic tubes containing felt-covered, diazinon-impregnated strips were used. Small animals entered the tubes to reach the bait and coated themselves with the pesticide. Sonenshine and Haines (1985) concluded that the plastic tube/diazinon technique was more practical, in terms of labor, cost of materials, and simplicity, than the first method using dust boxes. They also proposed that baited pesticide treatment stations appear to be suitable for use in areas close to suburban or urban developments, since relatively small quantities of pesticide are required.

Personal Protection

Personal protection measures against ticks are perhaps the most effective means of managing a tick problem. Simple efforts such as blousing fatigues can help; blousing forces ticks to crawl up the outside of one's pants thus making them easier to spot and remove. Blousing the fatigues and treating the pants legs with various repellents (the extended duration DEET, Off, 6-12, etc.) will help keep ticks off, but the most effective repellent available at this time is Permanone (0.5% permethrin). Permanone is actually a toxicant (not a repellent) and is available for clothing treatment (not intended to be sprayed directly upon the skin). Permanone can be sprayed onto a set of fatigues and will remain effective for at least 1 month and through several washes. Availability of Permanone is somewhat limited since it is not labeled for use in all states (as of this writing). In states where it is legal, Permanone can be purchased locally with permission from the major command (MAJCOM) pest management professional.

Permanone, in itself, is not a cure-all for tick problems, especially in situations where personnel are crawling through vegetation and may get ticks on untreated areas such as the arms or head. The repellent works well if used properly. In all field work accomplished at Little Rock AFB (which is heavily tick infested) during 1987 and 1988, I used Permanone and never acquired a tick!

Other protection techniques are sometimes used against ticks. Wide masking tape placed around the ankles or thighs, leaving the sticky side exposed, works quite well against ticks crawling up the legs (Fig. 8). Obviously, white or beige tape on pants legs is not in accordance with standard uniform wear, but perhaps a camouflaged version of double-sided sticky tape could be developed for tick or chigger protection.

Figure 8. "Taping up" with masking tape for tick protection.

Many unorthodox (or questionable, at least) methods of tick protection are commonly used by military personnel. Flea collars worn around the ankles, Avon Skin-so-Soft, vitamin C, garlic, sulfur powder, panty hose, and others have been reported to me as "great tick repellents." While these efforts may possibly provide some degree of protection, blousing fatigues with proper use of Permanone is much more effective. Besides, using pet products such as flea collars may be dangerous due to absorption of pesticide through the skin; they have not been Food and Drug Administration (FDA) approved for human wear.

Tick Removal

"What is the best way to remove a tick after it gets on you?" The answers are varied depending on who you ask and what part of the country you are in because many folklore methods are available. Hard ticks attach themselves firmly to a host for a feeding period of several days and are especially difficult to remove. Methods such as touching attached ticks with a hot match, coating them with mineral oil, petroleum jelly or some other substance, and/or "unscrewing" them are but a few of the home remedies that supposedly induce them to "back out."

The "theory" behind coating a tick with fingernail polish, petroleum jelly, or mineral oil is that covering the tick's spiracles (breathing openings) supposedly will cause it to back out to breathe or escape the discomfort; this is erroneous. Ticks can survive for hours with closed spiracles and certainly don't breathe via the mouthparts. Even if coating a tick with a substance causes it to back out, the time required to accomplish this is unacceptable (usually 1-4 h).

Since the lengthy feeding period is an important factor in disease transmission by ticks, it is crucial that a tick be removed as soon as possible to reduce chances of infection by disease organisms. During several years of field research with ticks, I often had to remove them from myself or others, and pulling them straight off with blunt forceps (tweezers) seemed to work best (Fig. 9). There has been some research in this area. A study by J.H. Theis (1968) advocated tick removal by the use of forceps or protected fingers using a steady retracting pressure. Recently, Glen Needham (1985) at Ohio State University did a very good research study of this problem. He evaluated 5 methods commonly used for tick removal: (1) petroleum jelly, (2) fingernail polish, (3) 70% isopropyl alcohol, (4) hot kitchen match, and (5) forcible removal with forceps. Needham found that the commonly advocated methods are either ineffective, or worse, actually created greater problems. If petroleum jelly or some other substance causes the tick to back out on its own (and most often it does not), the cement surrounding the mouthparts used for attachment remains in the skin where it continues to cause irritation. Touching the tick with a hot match may cause it to burst, increasing risk of disease pathogen exposure. Furthermore, hot objects may induce ticks to salivate or regurgitate infected fluids into the wound (Barker et al. 1973). "Unscrewing" a tick is likely to leave broken mouthparts in the host's skin.

Needham recommended the following procedure for tick removal: (a) use blunt forceps or tweezers; (b) grasp the tick as close to the skin surface as possible and pull upward with steady, even pressure; (c) take care not to squeeze, crush, or puncture the tick; (d) do not handle the tick with bare hands because infectious agents may enter via mucous membranes or breaks in the skin; and (e) after removing the tick, disinfect the bite site and wash hands thoroughly with soap and water.

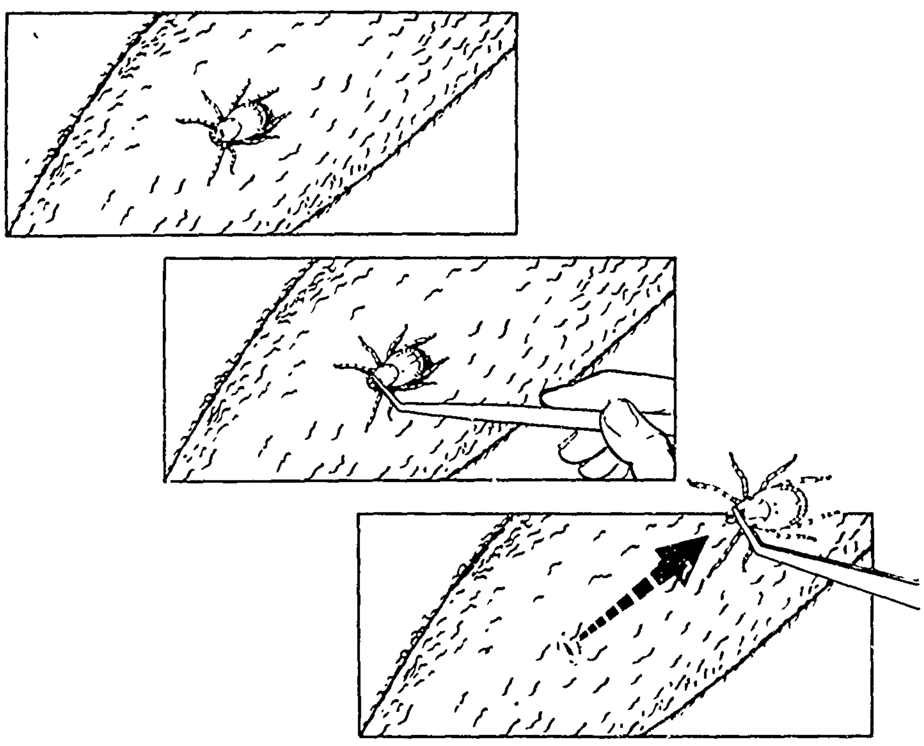

Figure 9. Recommended method for tick removal: grab tick with forceps as close to the skin as possible and pull straight off.

Rocky Mountain spotted fever and Lyme disease (the 2 most important tickborne diseases in the U.S.) are usually successfully treated with antibiotics in their initial stages;

therefore, early diagnosis is imperative. For this reason, marking the day of a tick bite on a calendar is a good idea. If unexplained disease symptoms occur within 2 weeks from this day, a physician should be specifically informed of the tick bite. This method has proven to be very helpful in diagnosis of tickborne disease. Although there are a number of well-known tick removal methods (mostly folklore), the best one seems to be the simplest--pull them straight off with blunt forceps and disinfect the bite site.

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CHAPTER 4

MAJOR HUMAN TICKBORNE DISEASES

Ticks are of significant medical and veterinary importance, and knowledge of species present in a given area is important to physicians, veterinarians, the military, and livestock personnel. In fact, ticks are the most important vectors of disease pathogens to domestic animals throughout the world and are second only to mosquitoes as transmitters of disease agents to man. Ticks may harbor and transmit to people various disease agents such as protozoa, viruses, bacteria, rickettsiae, and toxins.

Several factors are unique to ticks, enabling them to survive adverse conditions and transmit disease: they are highly sclerotized (a protective, chitinous covering); can attach firmly while feeding and do not dislodge easily; can withstand long periods of starvation; have a wide host range (which ensures more certain sources of blood); are able to deposit large numbers of eggs; feed slowly, permitting wide dispersion while attached to a host; and are relatively free from natural enemies. Another critically important factor in disease transmission by ticks is their ability to transovarially transmit some disease agents from generation to generation; thus, ticks themselves may serve as reservoirs for a particular pathogen.

Patterns of tickborne diseases are ever-changing. In the U.S., for example, just 15 years ago, Lyme disease (LD) was virtually unknown and the incidence of Rocky Mountain spotted fever (RMSF) was steadily increasing. Presently, however, reported cases of RMSF are declining each year while LD is steadily increasing. In contrast, Bullis fever, a mysterious tickborne disease occurring in hundreds of troops at Camp Bullis, Texas during the 1940s, has essentially disappeared with no cases reported since that time (Woodland et al. 1943; Anigstein and Anigstein, 1975). In the last several years the agent of canine ehrlichiosis or a closely related organism has also been found to infect humans (Anonymous, 1986 and 1987a; Fishbein et al. 1987).

The ecology and dynamics of many tickborne diseases have been well researched. Occasional literature reviews and perspectives have been written concerning several of these maladies individually, or by tick species (Burgdorfer, 1975 and 1977; Goddard, 1987; Spielman et al. 1985). Hoogstraal (1981) summarized some changing patterns of tickborne diseases, but his review predated the current understanding of LD, the decline in RMSF cases, and the advent of human cases of ehrlichiosis in the U.S.

Lyme Disease

General. Lyme disease, probably more accurately named Lyme borreliosis, is a multisystem spirochetosis occurring in the U.S., Europe, the USSR, Japan, China, and Australia (Steere et al. 1977; Steere and Malawista, 1979; Kawabata et al. 1987; Ackerman et al. 1980; Stewart et al. 1982; Dekonenko et al. 1988). In Europe, it is more often referred to as erythema chronicum migrans or ECM disease. The disease was named after the Connecticut community of Old Lyme, where outbreaks of arthritis in 1974 and 1975 were diagnosed as juvenile rheumatoid arthritis. Two persistent housewives living in Lyme questioned this diagnosis and the rheumatology department of Yale University Medical School conducted detailed clinical and epidemiologic investigations that eventually led to the description of a new disease entity called Lyme arthritis or Lyme disease (Steere et al. 1977).

The disease is characterized by an initial flu-like syndrome and a migrating annular "red ring" lesion (ECM). After several weeks or months various types of arthritic, neurologic, or cardiac abnormalities may occur (Steere et al. 1983). The neurologic abnormalities occur roughly 4 weeks after the tick bite and may include aseptic meningitis, encephalitis, chorea, cerebellar ataxia, and myelitis. The arthritis associated with LD is usually of sudden onset and is monoarticular, oligoarticular, and occasionally migratory. The knee seems to be the joint most commonly affected. Sometimes unexplained cases of facial paralysis or paresis are due to LD. Lyme disease is rarely fatal, but its course can be long and debilitating.

Natural history. The disease is caused by a spirochete transmitted to man primarily by the deer tick, Ixodes dammini, in the U.S., and the European castor bean tick, I. ricinus, in Europe. In Japan, the eastern USSR, and China, I. persulcatus is the likely vector. Research in 1982 confirmed the spirochetal etiology of the disease and the agent was named Borrelia burgdorferi in honor of the man primarily responsible for identifying the causative agent of the disease, Dr. Willy Burgdorfer (Burgdorfer et al. 1982; Johnson et al. 1984).

The primary vector in the U.S., I. dammini, occurs in the New England states and New York, south into New Jersey, Virginia, and Maryland; there are also established populations of I. dammini in Wisconsin and Minnesota. Recent unpublished reports indicate that the species is extending its range southward from Wisconsin and Minnesota into Iowa, Illinois, and Indiana. The majority of cases of LD in the U.S. occur in the Northeast and upper Midwest (corresponding to the distribution of I. dammini). In the Pacific Coast states, Ixodes pacificus has been shown to be a vector of LD spirochetes, and I. scapularis is a likely vector in the southern U.S. Several other species, such as Amblyomma americanum and Dermacentor variabilis, have been found to be infected with LD spirochetes (Schulze et al. 1984; Anderson et al. 1985), but their vector potential is probably slight (Piesman and Sinsky, 1988). The agent has also been recovered from horse flies and mosquitoes, thus indicating that transmission by other blood-feeding arthropods may be possible.

Epidemiology. A lack of reporting of LD in some areas combined with only sporadic reporting in others prohibits an accurate assessment of case numbers of LD. However, approximately 1,500 cases of LD were reported in the U.S. in 1984 (WHO, 1986), and recent estimates are as high as 5,000-15,000 new cases per year. Most reported cases of LD in the U.S. are from Connecticut, New York, Rhode Island, and New Jersey; however, cases have also been reported from many other states, particularly Wisconsin, Minnesota, and California.

Cases of Lyme disease are most often seen in the summer months (June and July) corresponding to tick activity. Since nymphal I. dammini are very small and may go unnoticed, not all patients have a known history of tick bite. In a study of a focal epidemic of LD in coastal Massachusetts, the risk of infection correlated with proximity to a nature preserve containing a deer population fourfold higher than the carrying capacity of the land (Lastavica et al. 1989). In general, persons at greatest risk of LD are those who by reason of occupation or recreation, spend considerable time in tick-infested woods.

Current status. Lyme disease is apparently extending its geographic range and has become the most prevalent tickborne disease in the U.S. The 1,500 cases reported in 1984 (WHO, 1986) and estimated 5,000 cases in 1988 represent a sharp increase from the 226 cases reported in 1980 (CDC, 1984a, see Figure 10). One factor contributing to this increase is that the infection rate of ticks with the causative agent is very high (50-70% ticks infected in some areas) compared to that of other disease organisms in their respective vectors (Magnarelli et al. 1986; Burgdorfer and Keirans, 1983). However, some increase in reporting of LD is likely due to increased awareness and recognition by health care providers.

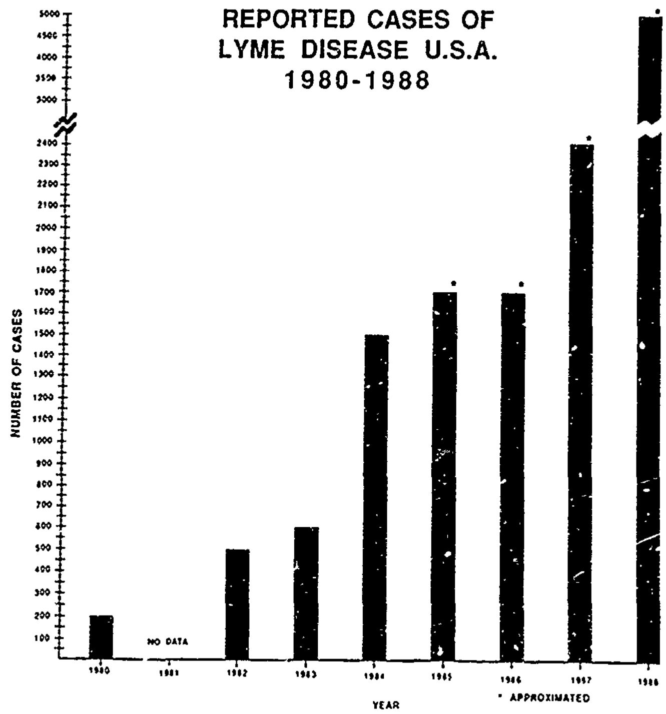

Figure 10. Reported cases of Lyme disease in the U.S. 1980-88.

Rocky Mountain Spotted Fever

General. Rocky Mountain spotted fever is one of the most severe of all infectious diseases and is characterized by headache, chills, fever, and a rash which characteristically begins on the extremities, especially the soles and palms. In some cases of RMSF there may be convulsions, coma, and death (Burgdorfer, 1975). Although treatable with broad spectrum antibiotics, about 5% of cases reported in the U.S. are fatal.

Natural history. The causative agent of RMSF, Rickettsia rickettsii, is transmitted to man by several species of ticks. In the U.S., 2 of the most important vectors are the Rocky Mountain wood tick Dermacentor andersoni, in the West, and the American dog tick, D. variabilis, in the East. When infected ticks feed, rickettsiae are transmitted to the host via salivary secretions. Transmission may also occur when persons manually detick pets since tick body fluids are infective.

In nature, the disease agent occurs in cycles among small mammals with ticks acting as transmitters; man is infected as an accidental or dead-end host only. Ticks themselves may also serve as reservoirs of the disease because R. rickettsii is transovarially (parent to progeny via egg) transmitted from generation to generation in ticks (Burgdorfer and Brinton, 1975). However, not all ticks are infected with RMSF organisms; within a vector species (e.g., D. variabilis) usually only about 1-5% are infected (Burgdorfer, 1975).

Epidemiology. In the U.S., RMSF accounts for the majority of all reported cases of rickettsial diseases. Approximately 700 to 1,000 cases of RMSF are reported in the U.S. annually (CDC, 1982, 1985, and 1987a), but the disease also occurs in Canada, Mexico, and Central and South America (although sometimes under different names). RMSF occurs throughout most of the U.S. with its highest incidence in North Carolina and Oklahoma. Actually the name "Rocky Mountain" spotted fever is a misnomer since more cases occur in the eastern U.S. than in the Rocky Mountain area. Although RMSF occurs year-round, most cases occur from April through September when environmental conditions are optimal for tick activity. Persons at greatest risk are the very young, the old, and blacks.

Current status. Since 1984, the annual number of reported cases of RMSF has been declining (Fig. 11). There were 1,126 cases reported in 1983 (CDC, 1984b); and 848, 700, and 746 cases, in 1984 (CDC, 1985), 1985 (CDC, 1986), and 1986 (CDC, 1987) respectively. The 1987 figure was even lower at 586 (CDC, 1988). How much of this decline is real and/or a lack of reporting is not clear. One factor contributing to this decline may be the use of broad spectrum antibiotics to treat a number of diseases. Several disease entities (various types of typhus, meningococcemia, etc.) are presumptively treated with tetracyclines or chloramphenicol and, with good responses, no further followup is performed. With the recent emphasis on LD, interest in serological confirmation and reporting of RMSF may also have waned.

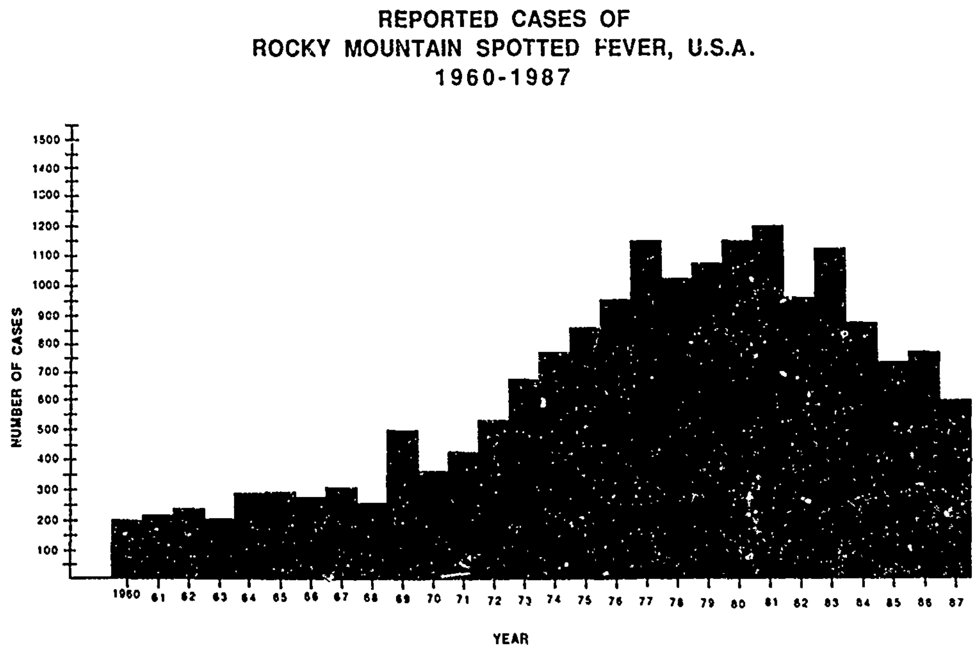

Figure 11. Reported cases of RMSF in the U.S., 1960-87.

Boutonneuse Fever

General. Boutonneuse fever (BF) is a rickettsial disease resembling a mild form of RMSF and is characterized by mild to moderately severe fever, a rash usually involving the palms and soles, and a black button-like lesion (eschar) at the site of tick bite. The fatality rate is < 3%, even without treatment.

Natural history. The causative agent of BF is Rickettsia conori, a member of the spotted fever group rickettsiae. Several tick species serve as vectors of the agent to humans, but especially Rhipicephalus sanguineus, R. appendiculatus, Amblyomma hebraeum, and Haemaphysalis leachi. Reservoirs of R. conori involve both ticks and small rodents. Dogs are important because they bring ticks into close contact with humans.

Epidemiology. Boutonneuse fever occurs throughout Southern Europe, the Mediterranean area, Africa, and India. In temperate areas, highest incidence occurs during the warmer months when ticks are numerous; in tropical areas the disease occurs throughout the year. Persons at risk are those frequently exposed to infected ticks, especially susceptible travelers entering endemic areas.

Current status. There seems to be an expansion of the Southern European endemic zone towards the north due to tourists' pet dogs acquiring infected ticks in Southern Europe and returning home where the ticks colonize (Benenson, 1985). Broad spectrum antibiotics are an effective treatment for this disease.

Siberian Tick Typhus
(North Asian Tick Typhus)

General. Siberian tick typhus is a disease very similar clinically to Rocky Mountain spotted fever with fever, headache, and rash. The disease can be mild to severe, but is seldom fatal.

Natural History. The causative agent of the disease is Rickettsia sibirica, very closely related to R. rickettsii (so much that some authors maintain that they are identical); however, Rickettsia sibirica is less virulent than R. rickettsii. Various hard tick species are vectors or reservoirs, but especially Dermacentor marginatus, D. silvarum, D. nuttalli, He. concinna, and Hy. asiaticum. Rickettsia sibirica cycles among ticks and small mammals and has been recovered from several species of rodents. Ticks removed from sheep, cattle, dogs, and birds have been found infected.

Epidemiology. Between 200 and 600 cases of Siberian tick typhus are recorded annually at Krasnoyarsk, USSR (Hoogstraal, 1967). The disease was first recognized in the Siberian forests and steppes in the 1930s, but now is known to occur in many areas of Asiatic Russia and on islands in the Sea of Japan. Cases occur most frequently during spring and summer, corresponding to tick activity. Persons regularly exposed to ticks (especially the Dermacentor spp.) in the endemic areas are at greatest risk.

Current status. Almost 19,000 cases of Siberian tick typhus were reported between 1935 and 1970, and the agent is much more widely distributed than previously believed (Hoogstraal, 1981). As further development of forest lands continues in the Soviet Union, the incidence of Siberian tick typhus may increase accordingly.

Tularemia

General. Tularemia is characterized by flu-like symptoms with an initial bout of severe fever, then temporary remission, followed by another period of fever for about 2 weeks. In addition, there is often a local lesion at the bite site (if vectorborne), conjunctivitis, and enlarged lymph nodes.

Natural history. The causative agent of tularemia is the bacterium, Francisella tularensis, which is transmitted to man by various avenues (food, water, etc.) as well as by several species of ixodid ticks and possibly other blood-sucking insects (Hopla, 1960, 1974, 1977). Two of the primary tick vectors in North America are Amblyomma americanum and Dermacentor variabilis. Ixodes ricinus is known to transmit the causative agent in Central and Western Europe, and Dermacentor nuttalli in the USSR. As recently as 1984, 20 persons on the Lower Brule and Crow Creek Indian reservations in South Dakota were diagnosed with glandular tularemia (Markowitz et al. 1985). An investigation indicated that the cases were contracted via bites of infected Dermacentor variabilis ticks (Markowitz et al. 1985). The disease may also be contracted by skinning infected rabbits or rodents.

Epidemiology. Tularemia is widespread over much of Europe, the USSR, Asia Minor, Japan, the U.S., Canada, and parts of Mexico; approximately 150-300 cases are reported in the U.S. annually (CDC, 1982, 1985, 1987a). The seasonal incidence of tularemia in the U.S. reflects two modes of transmission; reported cases increase during fall and winter in the East and Midwest due to the skinning of rabbits during hunting season and during the summer in the Southwest and West as a result of tick bites.

Current status. In the U.S., reported case numbers of tularemia have been as high as 1,400 in 1947, but since about 1960 have remained at approximately 150-250 per year. Assuming a fairly constant rate of exposure to the agent and a susceptible population, this relatively stable incidence of tularemia may indicate a degree of enzootic stability of the disease in nature (at least in the U.S.).

Colorado Tick Fever

General. Colorado tick fever (CTF) is an acute, febrile, dengue-like disease sometimes accompanied by a rash. Often a brief remission period is followed by a second bout of fever. In children, encephalitis and severe bleeding may occasionally develop (Goodpasture et al. 1978).

Natural history. The causative agent of CTF is an arbovirus in the genus Orbivirus of the family Reoviridae; CTF is the only commonly occurring tick-transmitted viral disease in the U.S. Rocky Mountain wood ticks, Dermacentor andersoni, are the primary vectors of the disease to humans, although D. occidentalis have also been found naturally infected in Oregon and California (Goodpasture et al. 1978; Eklund et al. 1955). The virus circulates in nature among small rodents and is especially prevalent in areas of reforestation where small mammals and ticks are most abundant. Transstadial passage (tick stage to tick stage) of the virus occurs in D. andersoni and unfed nymphs overwinter the virus.

Epidemiology. Colorado tick fever occurs in all the mountain states of the western U.S. as well as in British Columbia, Canada. Approximately 200-400 cases of CTF are reported in the U.S. annually with peak incidence during April and May at lower altitudes and during June and July at higher elevations. Persons at greatest risk are those who regularly engage in outdoor activities in the Rocky Mountain area.

Current status. No significant changes have recently been reported in either incidence or geographic distribution of CTF, but because the disease is relatively benign, the true incidence cannot be assessed. Many cases never come to the attention of a physician and, if they do, may not be recognized as CTF.

Tickborne Relapsing Fever

General. Relapsing fever in man is characterized by acute onset of fever about 1 week after the bite of an infected soft tick. Since soft ticks generally feed for only a short period of time (unlike hard ticks which are securely attached for several days), the victim may be unaware of any recent tick bites. Fever may last 4-5 days followed by an afebrile period of similar length. This pattern may recur through several fever episodes.

Natural history. The causative agent of relapsing fever is a spirochete, Borrelia recurrentis, or various tick-adapted strains of this organism (many authors maintain that each tick-adapted strain is a distinct species) (Felsenfeld, 1979; Burgdorfer, 1986). Although relapsing fever is transmitted by lice, soft ticks of the genus Ornithodoros are also involved in the transmission of the disease. Rodents serve as natural sources of infection for ticks, and transmission is by the bite of ticks of either sex in all active stages. Fluids from the tick's coxal glands released while feeding are important in disease transmission because spirochetes present in the fluid may be introduced into the bite wound or penetrate unbroken skin.

Epidemiology. Relapsing fever is essentially worldwide in distribution (Felsenfeld, 1979). Several hundred cases are reported annually worldwide and approximately 30-50 cases are diagnosed in the U.S. each year (primarily in Washington, Oregon, and Northern California). Greatest at risk are persons coming in contact with Ornithodoros-infested areas such as cattle barns, ruined buildings, clay fences, storerooms, and uninhabited houses or cabins.

Current status. The incidence of relapsing fever in the U.S. may be increasing due to increased development (condominiums, vacation cabins, etc.) of rural areas of the Northwest. The threat of relapsing fever outbreaks is ever present even in our well-developed American society. For example, in 1969, 11 cases were reported in a troop of 42 boy scouts using mountain cabins near Spokane, Washington (Burgdorfer, 1986). Again, in 1973, 62 cases were reported in tourists and park employees who slept in infested cabins in Grand Canyon North Rim Park (Boyer et al. 1977).

Tickborne Encephalitis
(Including Russian Spring-Summer Encephalitis and Central European Tickborne Encephalitis)

General. Viruses causing Central European tickborne encephalitis (CETBE) and Russian Spring-Summer Encephalitis

(RSSE) are closely related and thus discussions of the two will be combined here. The disease caused by RSSE virus is characterized by violent headache, high fever, nausea, and vomiting. Delirium, coma, paralysis, and death may follow; the mortality rate is about 25-30%. CETBE usually has a longer course than RSSE, but fatality and severe residua are less frequent than for RSSE.

Natural history. The causative agents of RSSE and CETBE are members of the flavivirus complex, which are transmitted to people by Ixodes ticks. Ixodes persulcatus is the main vector of RSSE and I. ricinus of CETBE. Other ixodid ticks may be secondarily important vectors of the tickborne encephalitis (TBE) complex such as Haemaphysalis concinna, Dermacentor marginatus, D. silvarum, and I. lividus. Immature I. persulcatus feed on a wide variety of small forest mammals and birds, while adults feed primarily on large wild and domestic animals. Ixodes ricinus feed on many vertebrates and CETBE virus has been found in rodents and the European mole, Talpa europaea (Harwood and James, 1979). Transovarial passage of TBE viruses occurs in ticks, and the viruses also circulate in nature between ticks and wild vertebrate hosts in endemic foci. Dorontsova and Chudinov (1971) reported foci of TBE in planted protective forest belts of the Western Siberian Railway, and in Austria, foci occur in dense, moist, young mixed forests associated with high rodent populations (Radda et al. 1974).

Epidemiology. Numerous cases of TBE occur throughout Europe each year, but since infection may also be acquired via drinking infected milk and uncooked milk products, actual tick-transmitted case numbers are hard to ascertain. RSSE is mainly associated with the taiga forest of the Soviet Union but has been reported in other parts of Eastern and Central Europe. CETBE has been recognized in Poland, Austria, Bulgaria, Hungary, Yugoslavia, East and West Germany, Switzerland, Finland, Sweden, Denmark, France, and Romania (Gresikova and Beran, 1979). Peak incidence of RSSE is in May and June, and cases of CETBE occur from late spring until early autumn. Persons at greatest risk are those who have exposure to large numbers of infected ticks, generally those living in rural or forested areas.

Current status. Prior to WWII, RSSE was considered to be an occupational disease of forest workers, but in recent years the risk of acquiring the disease has expanded to include most of the general population. Hoogstraal (1981) reported RSSE prevalence at 1.8 per 100,000 which is probably due to urbanites making weekend trips to the forests for relaxation and outdoor activities. Considering this ongoing interest in nature and outdoor activities, incidence of TBE may be on the increase.

Crimean-Congo Hemorrhagic Fever

General. Crimean-Congo Hemorrhagic Fever (CCHF) is characterized by sudden onset of fever, weakness, malaise, irritability, headache, myalgia, and anorexia. Sometimes vomiting, abdominal pain, and diarrhea accompany infection and a petechial rash is usually observed, beginning on the chest or abdomen and spreading to the rest of the body. The fatality rate ranges from 2 to 50%.

Natural history. CCHF is caused by a Nairovirus that is transmitted to people by the bite of several species of hard ticks, especially *Hyalomma marginatum* and *Hy. anatolicum*. These species are especially important in epidemics of CCHF because of their great numbers and aggressiveness. The agent of CCHF occurs in cycles in nature among hares, birds, rodents, and the *Hyalomma* tick species. Infection can also occur by crushing infected ticks, and nosocomial transmission from patients to medical personnel has been reported.

Epidemiology. Case numbers of CCHF are hard to assess, but hundreds of cases may occur annually (many of which are clinically inapparent). The disease occurs primarily in the Crimean and Caspian Sea regions of the USSR, as well as Bulgaria, Yugoslavia, Iraq, Pakistan, and China. A few cases have been recognized in Mauritania and South Africa. Most cases are diagnosed from June-September, the period of vector activity. Persons at greatest risk are those living and working in rural areas of the endemic zones.

Current status. Cases of CCHF from Iraq (Hooogstraal, 1981), South Africa (Swanepoel et al. 1983), and Mauritania (Saluzza et al. 1985), represent areas where the disease had not previously been reported. Treatment of the disease is usually only supportive, although convalescent serum is reported to be useful.

Kyasanur Forest Disease
Omsk Hemorrhagic Fever

General. Kyasanur Forest Disease (KFD) and Omsk Hemorrhagic Fever (OHF) are related and thus are considered together here. Clinical manifestations include sudden onset of fever, headache, severe muscle pains, and prostration. In many cases there are accompanying symptoms such as conjunctivitis, diarrhea, and vomiting. Severe cases are marked by hemorrhages and bleeding from gums, nose, gastrointestinal tract, uterus, and lungs. Fatality is about 5%.

Natural history. The causative agents for these two diseases are closely related viruses in the flavivirus complex. Humans are primarily infected with the Omsk virus by handling infected muskrat carcasses or by contact with contaminated water. Ticks do not presently appear to be important vectors of OHF but possible vectors are Dermacentor pictus and D. marginatus. The virus of KFD is transmitted to humans primarily by nymphal Haemaphysalis spinigera. Many small rodents serve as hosts for immature Haemaphysalis ticks and peak infestations occur in the dry month of November. Haemaphysalis spinigera nymphs are active in India during the dry season just when people come to the ticks' habitats to gather firewood.

Epidemiology. KFD occurs primarily in the areas of Mysore and Karnataka States, India. In Mysore State, 25-250 acute cases were diagnosed annually from 1967-1975. Since then, the incidence of the disease has apparently increased with over 1,000 cases reported from 1976-1978 (Hoogstraal, 1981), and 1,142 cases with 104 deaths in 1983 (Benenson, 1985). The disease occurs principally in young males exposed in the forest during the dry season of November to June. The OHF has historically been seen mostly in rural workers and children exposed to muskrats, contaminated water, or infected ticks in the Omsk Oblast of Siberia, but recently has only occurred in the Novosibirsk region.

Current status. KFD appears to be increasing both in incidence and geographic distribution. This increase is due to increased human population in the endemic area, practices such as gathering firewood and other forest products, and an increase in tick numbers related to cattle now grazing in and beside the forests. Specific treatments for both OHF and KFD are lacking, although an experimental vaccine has been used to prevent KFD in endemic areas of India (Benenson, 1985).

American Babesiosis

General. Human babesiosis is a malaria-like disease of varying severity, which becomes clinically apparent 1-4 weeks after exposure. The disease is characterized by fatigue, anorexia, fever, chills, headache, and generalized myalgia.

Natural history. The infecting organism of American human babesiosis is the rodent piroplasm (protozoan), Babesia microti, associated with the white-footed mouse (Dammin et al. 1981). The vector to humans is exclusively Ixodes dammini that appears to be abundant only where numerous deer are found. According to Hoogstraal (1981) the I. dammini-B. microti associated disease is an ecologically unique, localized phenomenon: a benign zoonotic infection of rodents and ticks flaring into an outbreak infecting humans where environmental changes provide numerous hosts and shelters for dense populations of ticks.

Epidemiology. American human babesiosis occurs primarily in the Massachusetts and New York area of the U.S., but particularly on Nantucket Island (Spielman et al. 1985). The present limited focus of American babesiosis may be related to deer abundance and increasing contact of humans outdoors with vegetation harboring rodents and ticks. Annual case numbers are difficult to ascertain but over 100 cases of human babesiosis have been reported in the U.S. since 1969 (Piesman et al. 1986). Age of the patient affects the clinical course of disease with the most seriously ill patients usually being more than 60 years old. Few clinical cases have been diagnosed in spleen-intact persons below age 50 (Spielman et al. 1985).

Current status. The incidence of human Babesia microti infections appears to be stable.

Tick Paralysis

General. Ticks may cause a paralysis in humans that is reversible when the ticks are removed. The characteristic symptom is an ascending flaccid paralysis which may terminate fatally if ignored.

Natural history. Most experts believe that tick paralysis is caused by a toxin in the salivary glands transmitted to people when the ticks feed (Gregson, 1973). Although the host's head region is the most common site of attachment, location of ticks may not be important in cases of paralysis because the malady has occurred from attachment to various parts of the body. The rapid recovery of patients after removal of the causative tick suggests that toxins may be rapidly excreted or metabolized.

Epidemiology. The disease occurs in various regions of the world and affects man, other mammals, and sometimes even birds. In the Western Hemisphere, the greatest number of tick paralysis cases have occurred in North America and are due to the tick, Dermacentor andersoni, with highest incidence occurring near the border of British Columbia, Canada, and the northwestern U.S. (Gregson, 1973). Central and South America are largely free of tick paralysis although isolated reports have come from Venezuela and Uruguay. Tick paralysis occurs in humans in North America mainly in April, May, and June (Gregson, 1973), and approximately 300-400 cases have been documented in the British Columbia-Montana area since 1900. Local residents of that area, particularly preschool children, who have access to tick-infested areas, are at greatest risk (Eklund et al. 1955; Gregson, 1973). Age appears to be a factor in the incidence of paralysis although this may be partly due to the fact that adults detect and remove ticks faster than children (Gregson, 1973).

Current status. Neither the incidence nor geographic distribution of tick paralysis has changed significantly over the past decade.

Human Ehrlichiosis

General. Canine ehrlichiosis is a rickettsial disease of dogs that consists of a mild or severe febrile (acute) phase which may be followed by a chronic, highly fatal phase 2 to 4 months later. Whether or not human cases of "canine ehrlichiosis" are indeed caused by Ehrlichia canis is unknown at this time, but cases of suspected E. canis infection have been characterized by many spotted fever-type manifestations such as fever, anorexia, myalgia, arthralgia, headache, and nausea, and often referred to as "spotless" spotted fever. In addition, most patients have leukopenia, thrombocytopenia, and mildly high hepatic enzyme activities.

Natural history. The disease in dogs is caused by Ehrlichia canis, an obligate intracellar rickettsia that parasitizes leukocytes of wild and domestic Canidae, and the brown dog tick, Rhipicephalus sanguineus, is the primary vector and reservoir. Other possible reservoirs include rodents, wild canids, and chronically infected dogs. Of all tick species, the brown dog tick probably has the most widespread distribution in the world today and is commonly found infesting homes of dog owners. The ticks may transmit E. canis to dogs for up to 5 months after engorgement. Transstadial transmission of the agent occurs in R. sanguineus but transovarial transmission apparently does not.

Epidemiology. Little is known at this time about the epidemiology of human (canine) ehrlichiosis, but the disease in dogs occurs throughout many regions of the world and is widespread in the southern half of the U.S. Recently, human cases of the malady have been increasingly diagnosed. In 1986, the first confirmed human case of canine ehrlichiosis was reported from Arkansas (Anonymous, 1986a), with at least six additional cases subsequently being confirmed in Texas in 1986 (Anonymous, 1987b). In Oklahoma in 1987, health department personnel reviewed numerous sera samples of suspected spotted fever cases that had tested negative for RMSF and found 16 sera significantly positive for E. canis (Anonymous, 1987a). These reports suggest that many suspect cases of RMSF or murine typhus may actually be ehrlichiosis.

Persons at greatest risk of contracting ehrlichiosis are those who regularly come into contact with tick-infested dogs.

Current status. If E. canis, or a very closely related agent, is becoming adapted to the human host, the incidence of human ehrlichiosis is likely to increase in many parts of the world. Various tick species may be involved in human cases of ehrlichiosis. Although R. sanguineus is the vector of E. canis to dogs, it is usually discounted as a vector to humans because it has historically only rarely bitten humans in the U.S. I recently found evidence indicating that this species may be becoming anthropophilic and increased human biting by this species is likely (Goddard, 1989). This biting may also lead to an increase in the incidence of human ehrlichiosis.

DISCUSSION

This chapter has described the changing incidence of certain tickborne diseases on one hand and the apparent stability of others. The RMSF case numbers are declining whereas LD incidence is increasing. Siberian tick typhus, relapsing fever, and tickborne encephalitis case numbers may be increasing due to development of forest lands and an increased interest in nature and outdoor activities. Case numbers of Kyasanur forest disease are apparently increasing in the area of Mysore State, India, due to the rapidly increasing human population in the endemic area. Crimean-Congo hemorrhagic fever is continuing to be recognized in new geographic areas. Human ehrlichiosis incidence may well increase, especially if the U.S. population of Rhipicephalus sanguineus (the primary vector to dogs) is becoming more anthropophilic. In contrast, reported case numbers of tularemia, Colorado tick fever, babesiosis, and others have remained relatively stable over the past decade.

Two important factors affecting the true incidence of disease in the human population are: (1) the amount of exposure of the population to an agent; and (2) the overall susceptibility of the population. Since tickborne diseases in the U.S. do not occur in high numbers each year, we may assume that the population generally remains susceptible. The amount of exposure to disease agents has changed somewhat over time with increased interest in outdoor recreation activities as well as rapid suburbanization of many tick-infested areas. Besides these factors, changing levels of disease in the enzootic cycles may also influence the level of human exposure.

There are additional factors affecting the reported, or apparent, incidence of many of these diseases. One such factor is diagnostic bias which includes anything that would interfere with accurate recognition and/or reporting of a tickborne disease. Factors such as preconceived ideas concerning tickborne diseases or simply a lack of physician awareness about which diseases occur in any one area may influence a diagnosis. In addition, presumptive diagnoses are sometimes made when any typhus-like symptoms are present in a patient and a course of broad spectrum antibiotics is usually prescribed. While this practice in itself is not necessarily bad, it does significantly hinder assessment of the incidence of tickborne diseases. Lyme disease may be somewhat exempt from this bias in that its characteristic symptom, ECM, is often pathognomonic.

Disease agents harbored and transmitted by ticks are here to stay and have by no means been "conquered" by man. We can expect to see further changes in the status of tickborne disease in the future, especially with such demographic changes occurring in our society as large-scale movements of the population to suburban or recently developed rural areas. Furthermore, we should be careful not to underestimate the extent or effects of tickborne diseases as they relate to our military mission.

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CHAPTER 5

BIOLOGY, DISTRIBUTION, AND MEDICAL IMPORTANCE OF COMMON TICKS POTENTIALLY AFFECTING MILITARY OPERATIONS

Many of the approximately 850 tick species worldwide are of little or no medical or veterinary importance. Some species are extremely host specific, whereas others are quite anthropophilic and/or nonspecific in their feeding habits. A couple of our worst pest species, *Amblyomma americanum* and *Amblyomma cajennense*, are very nonspecific in feeding and will bite almost any vertebrate. I make no attempt here to present all tick species affecting man and his domestic animals worldwide. Included here are only discussions of the most common, medically important tick species that can potentially affect military operations. Specific references for each country are not given (with a few exceptions); the reader is referred to other works for that information (Hoogstraal 1956; Travis et al. 1967 and 1968; Doss et al. 1978; Goddard, 1987a). Line drawings of each species are included with three exceptions, in which case photographs are provided. In addition, photographs were produced/obtained of as many of the species as possible and are provided in the Appendix. Diagnostic characters are provided for the adult specimens only because immatures of many species are extremely difficult to identify and should be attempted only by a specialist. See the "Definition of Terms used for Diagnostic Characters" section for illustrations and definitions used herein.

ARGASIDAE (SOFT TICKS)

The Genus *Ornithodoros*

MORPHOLOGICAL CHARACTERISTICS OF THE GENUS *ORNITHODOROS*

Capitulum subterminally attached; hypostome well developed and alike in both sexes; integument with varying arrangements of discs and mammillae; body more or less flattened but strongly convex dorsally when distended; integumental patterns continuous over sides from dorsal to ventral surfaces.

Ornithodoros coriaceus Koch

Pajaroella Tick

Medical Importance: Although not positively linked to disease transmission, this species produces a "venomous bite" that is reported to be very painful (Failing et al. 1972). There are many tales about the seriousness of the bite, and the tick is said to be feared like a rattlesnake by certain native Mexicans.

Distribution: This species (Figs. 12, 13) occurs along the Pacific Coast of California into Oaxaca and Chiapas States, Mexico. However, collections have recently been made in extreme southern Oregon (Keirans, 1987).

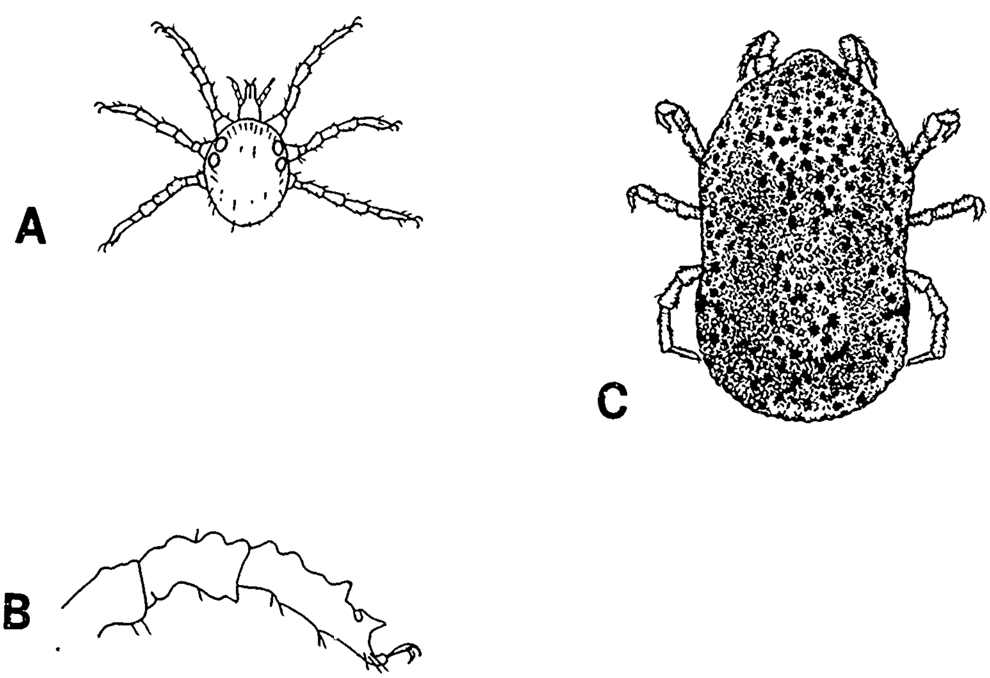

Figure 12. Larva (a), foreleg (b), and adult (c) of Ornithodoros coriaceus.

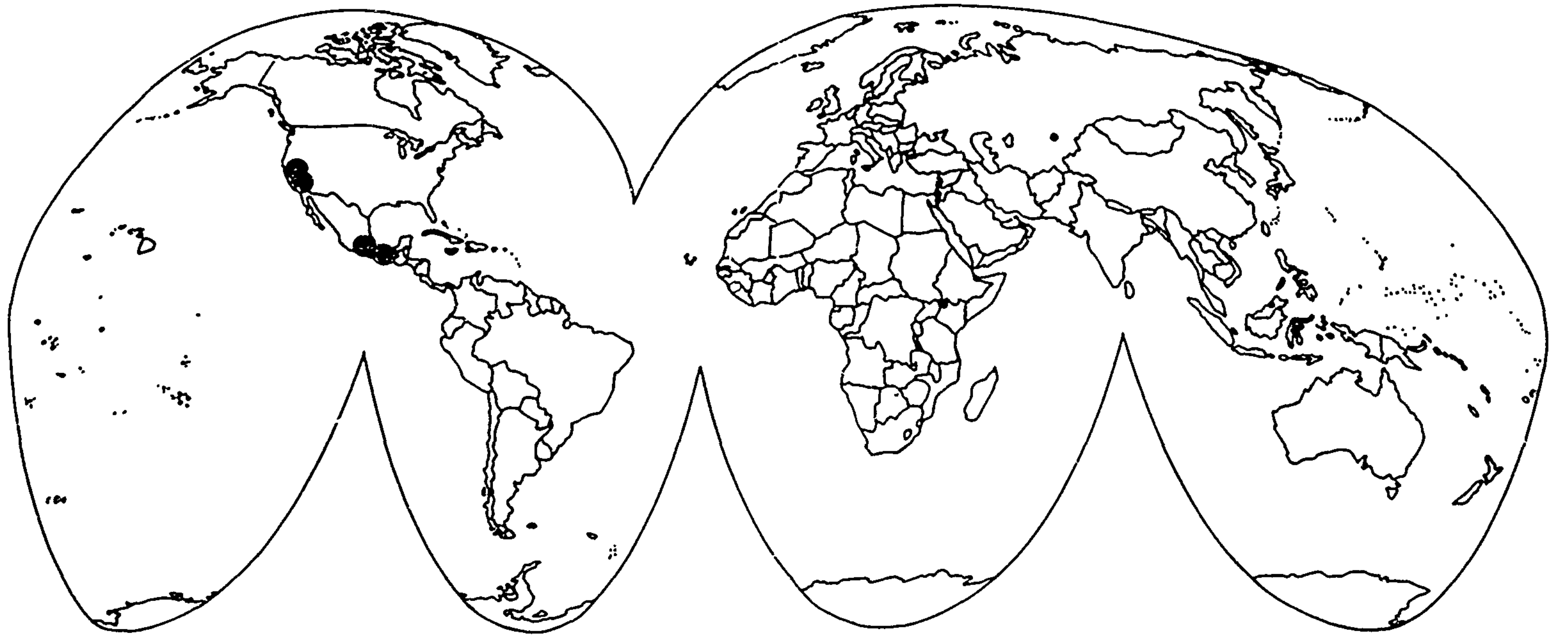

Figure 13. Geographic Distribution of <u>Ornithodoros coriaceus</u>.

Hosts: Man, deer, and swallows.

Seasonality: Varies with geographic location, hosts, and habitat. In warmer areas, it may be active throughout the year.

Diagnostic Characters: Two pairs of eyes present on lateral margins near coxae I and II; cheeks (flaps at the sides of the mouthparts) absent; dorsal humps on Tarsus I present.

Remarks: Ornithodoros coriaceus is a large soft tick species often found in the soil in deer and cattle bedding areas. Larvae may attach and remain on the host for about 7 days. There may be 3 to 6 nymphal stages and the time required to reach adult stage is about 4 months.

Ornithodoros hermsi Wheeler, Herms, and Meyer

No Common Name

Medical Importance: Ornithodoros hermsi is the primary vector of relapsing fever spirochetes in the Rocky Mountain and Pacific Coast states, U.S.

Distribution: This species (Figs. 14, 15) occurs in the U.S. in the states of California, Nevada, Idaho, Oregon, Utah, Arizona, Washington, and Colorado, as well as in British Columbia, Canada.

Host: Rodents and man.

Seasonality: Varies with geographic location, hosts, and habitat.

Diagnostic Characters: Cheeks absent; dorso-ventral grooves present; dorsal humps on Tarsi I absent.

Remarks: Ornithodoros hermsi is often found infesting corners and crevices of vacation or summer cabins. Larvae only remain attached to a host for about 15-20 minutes. There are usually 4 nymphal molts, and the cycle from egg to egg is about 4 1/2 months.

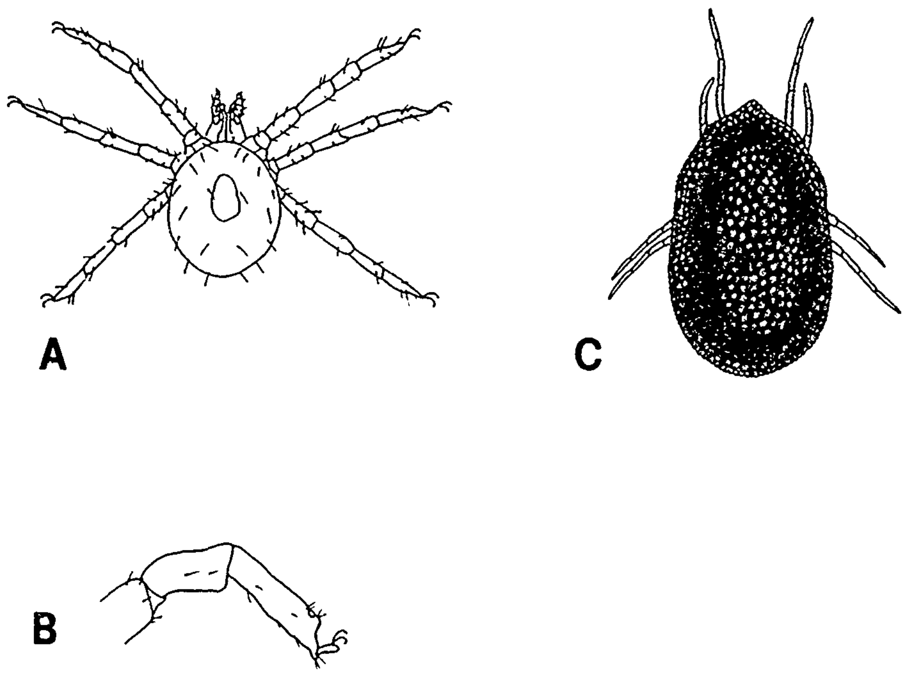

Figure 14. Larva (a), foreleg (b), and adult (c) of Ornithodoros hermsi.

Ornithodoros moubata (Murray)

Eyeless Tampan

Medical Importance: This species is a known vector of African tick-borne relapsing fever spirochetes in east, central, and south Africa.

Distribution: Ornithodoros moubata (Figs. 16, 17) occurs throughout east Africa and the northern portions of south Africa, extending into the drier parts of central Africa.

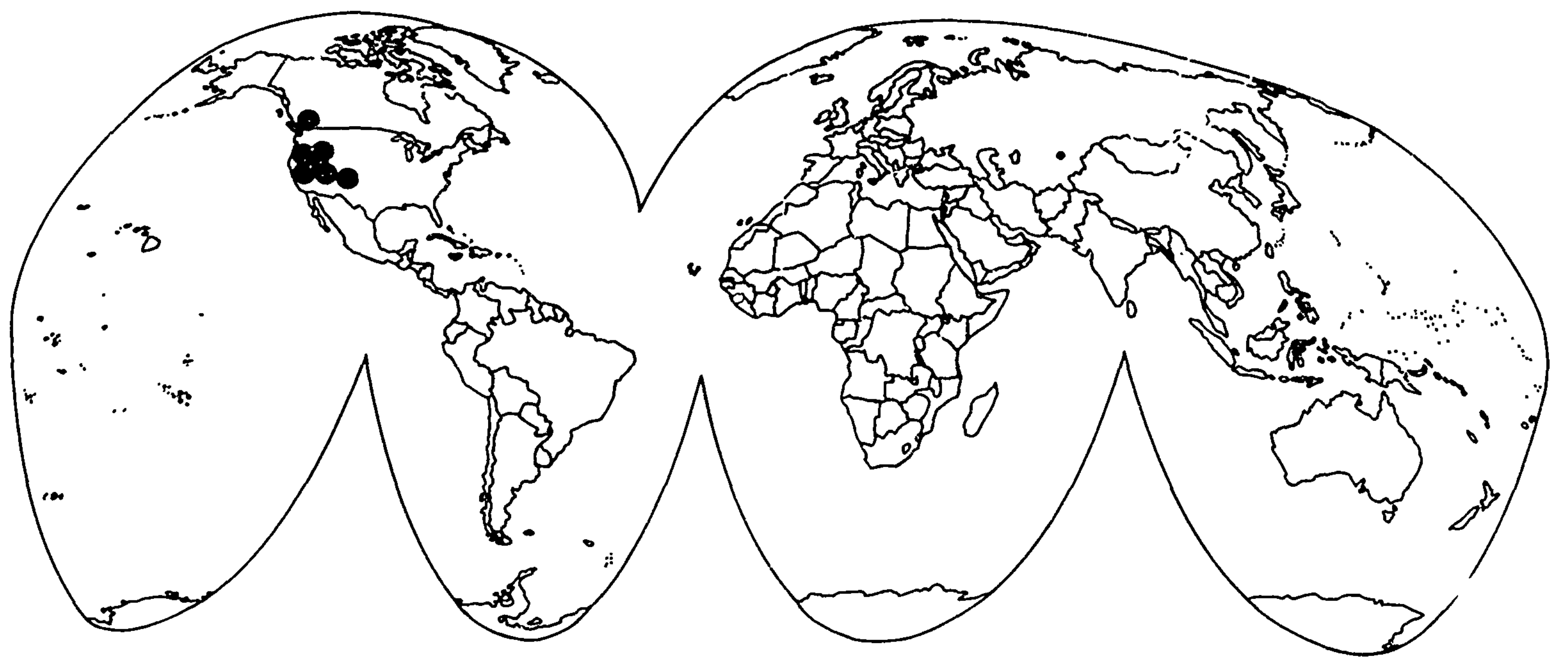

Figure 15. Geographic Distribution of <u>Ornithodoros</u> <u>hermsi</u>.

Hosts: Humans, warthogs, domestic pigs, antbears and porcupines.

Seasonality: Varies with geographic location, hosts, and habitat.

A B

Figure 16. Dorsal (a) and ventral (b) view of Ornithodoros moubata.

Diagnostic Characters: Mammillated integument; cheeks absent; eyes absent; dorsal protuberances on tarsi present. Ornithodoros moubata probably represents a species complex (Walton, 1962 and 1979; Van der Merwe, 1968). Both workers described various species and subspecies within the complex, but placed both wild and domestic populations within their taxa. From a medical point of view, it would have been better to make a taxonomic distinction between wild and domestic populations since domestic O. moubata play the major role in transmission of relapsing fever spirochetes.

Remarks: Ornithodoros moubata is often found in cracks in walls and in the earthen floors of huts. An O. moubata female usually lays 6 or 7 batches of eggs (several hundred per batch) during her lifetime. Larvae do not feed; nymphs engorge in about 20-25 min. There are usually 4 nymphal molts for males and 5 for the females. This species is able to live up to 5 years without feeding (Walton, 1960).

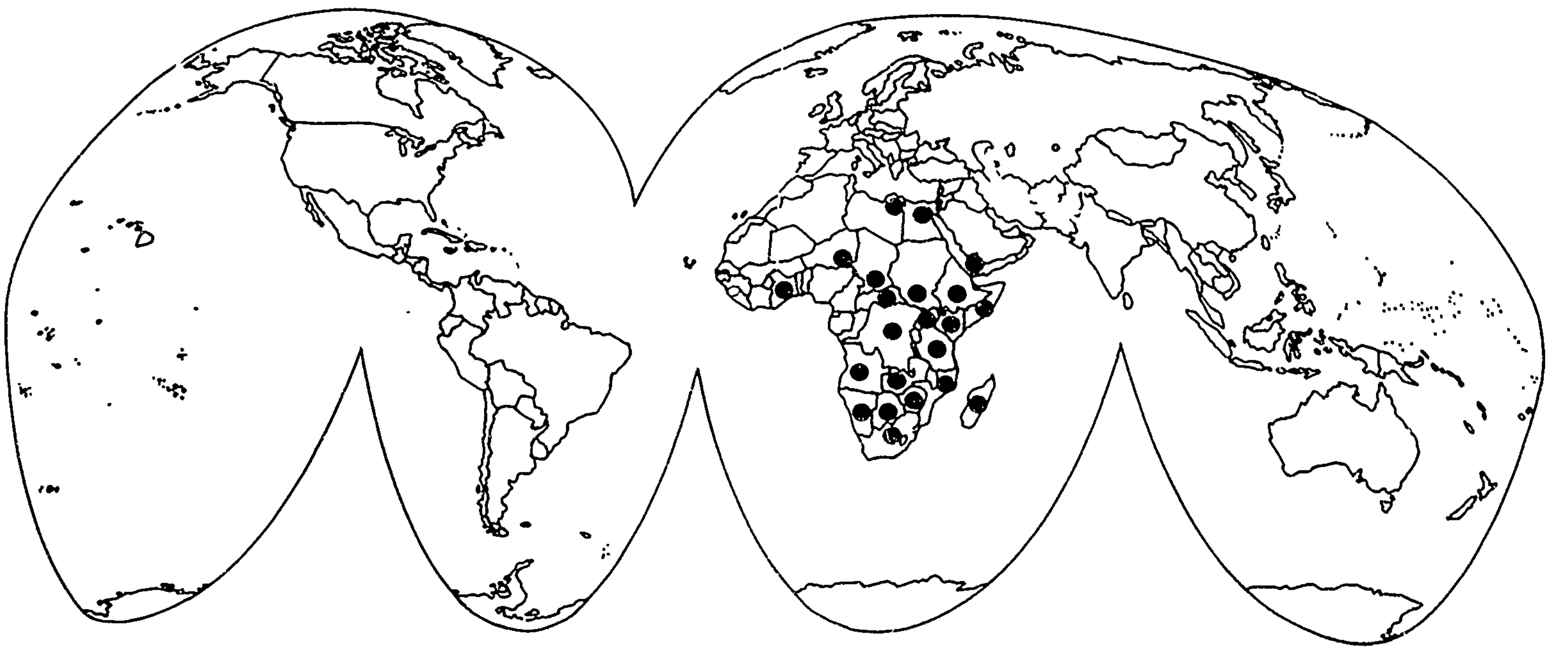

Figure 17. Geographic Distribution of _Ornithodoros_ _moubata_.

Ornithodoros rudis (=venezuelensis) Karsch

No Common Name

Medical Importance: This species is the most important vector of relapsing fever spirochetes in Panama, Colombia, Venezuela, and Ecuador.

Distribution: Ornithodoros rudis (Figs. 18, 19) occurs in Panama, Paraguay, Colombia, Venezuela, Peru, and Ecuador.

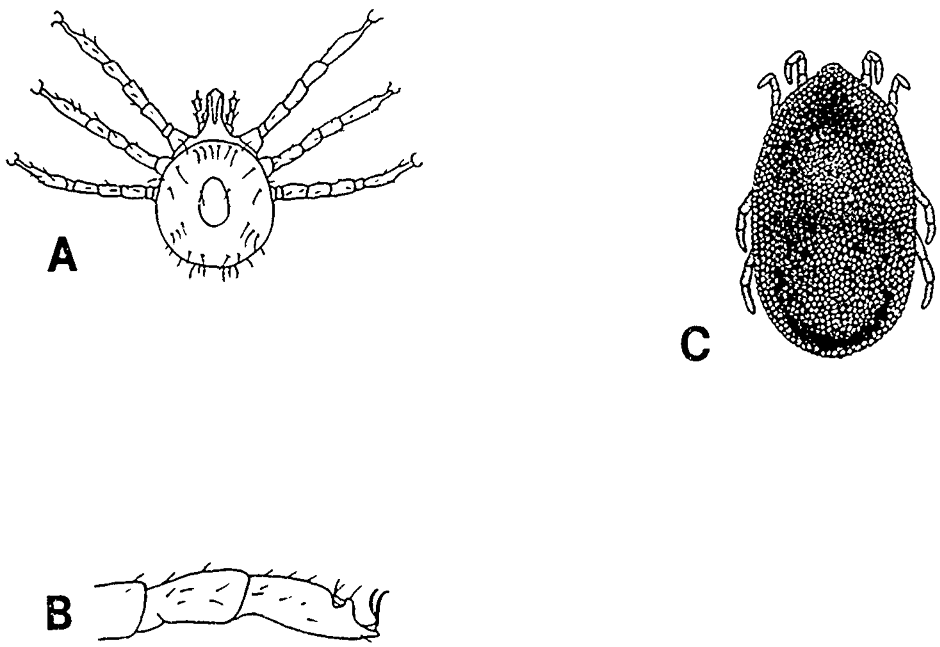

Figure 18. Larva (a), foreleg (b), and adult (c) of Ornithodoros rudis.

Hosts: Domestic birds and man.

Seasonality: Varies with geographic location, hosts, and habitat. This species may be active in warmer areas throughout the year.

Diagnostic Characters: Cheeks present; dorsal humps on legs absent, discs small and inconspicuous.

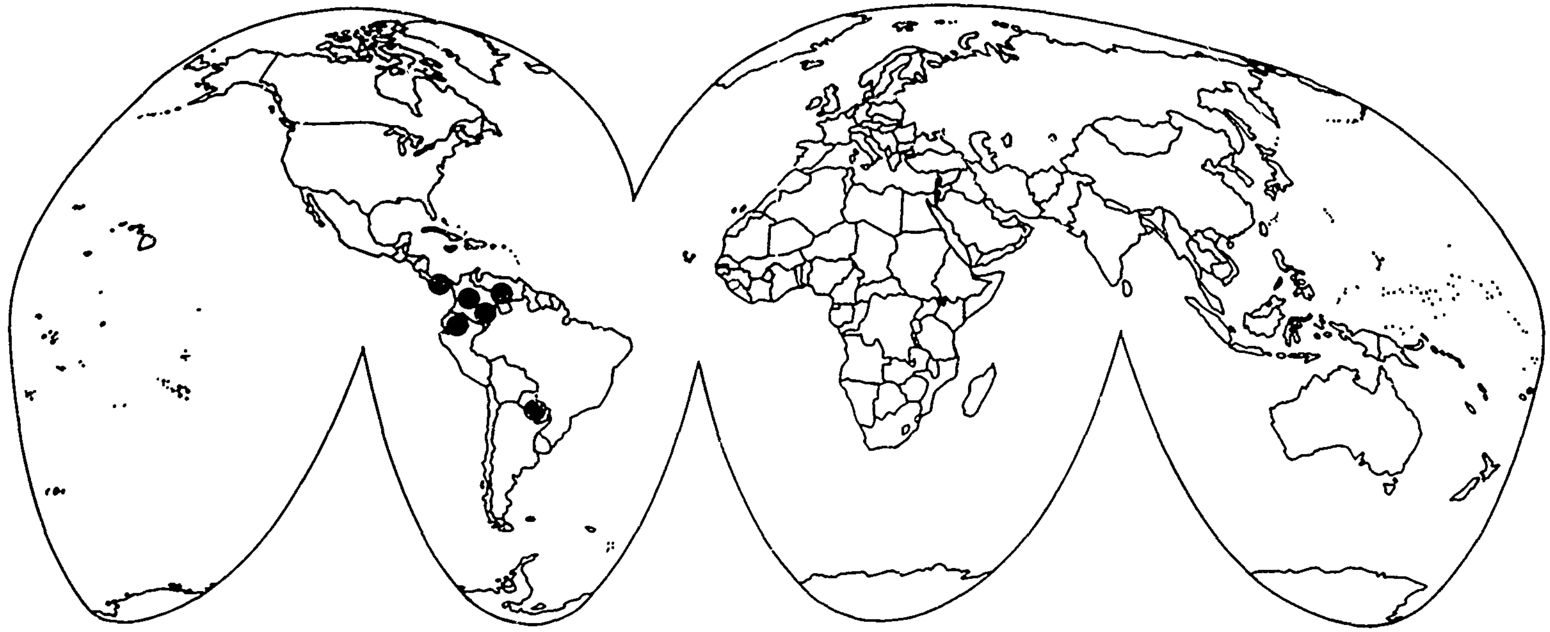

Figure 19. Geographic Distribution of Ornithodoros rudis.

Remarks: Ornithodoros rudis appears to be especially adapted as a parasite of humans, but feeds on other animals as well. This species is a night feeder with the larval stages engorging rapidly. There are 3 to 4 nymphal stages, and the developmental time from larvae to adult is about 3 months.

Ornithodoros talaje (Guerin-Meneville)

No Common Name

Medical Importance: This species transmits the agent of relapsing fever to man in Guatemala, Panama, and Colombía.

Distribution: Ornithodoros talaje (Figs. 20, 21) has been reported in the U.S. in the states of Florida, Texas, Arizona, Nevada, Kansas, New Mexico, and California. However, Hoogstraal (1985) maintains that in the U.S. it has only been reported from Kansas and California. It occurs in Mexico in the states of Baja California, Chiapas, Guerrero, Morelos, Oaxaca, Puebla, Sinaloa, Sonora, Veracruz, and Yucatan. This species has also been reported from Venezuela, Uruguay, Brazil, French Guiana, Panama, Ecuador, and Chile. Hoffmann (1962) notes that this species has also been reported from Guatemala, Colombia, Argentina, and the Galapagos Islands, although according to Keirans et al. (1984), the O. talaje reported from the Galapagos Islands actually is O. galapagensis.

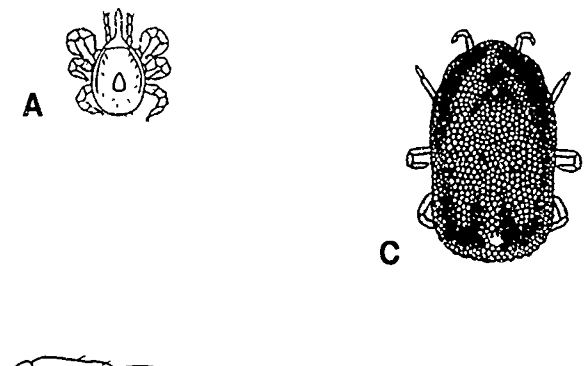

Figure 20. Larva (a), foreleg (b), and adult (c) of Ornithodoros talaje.

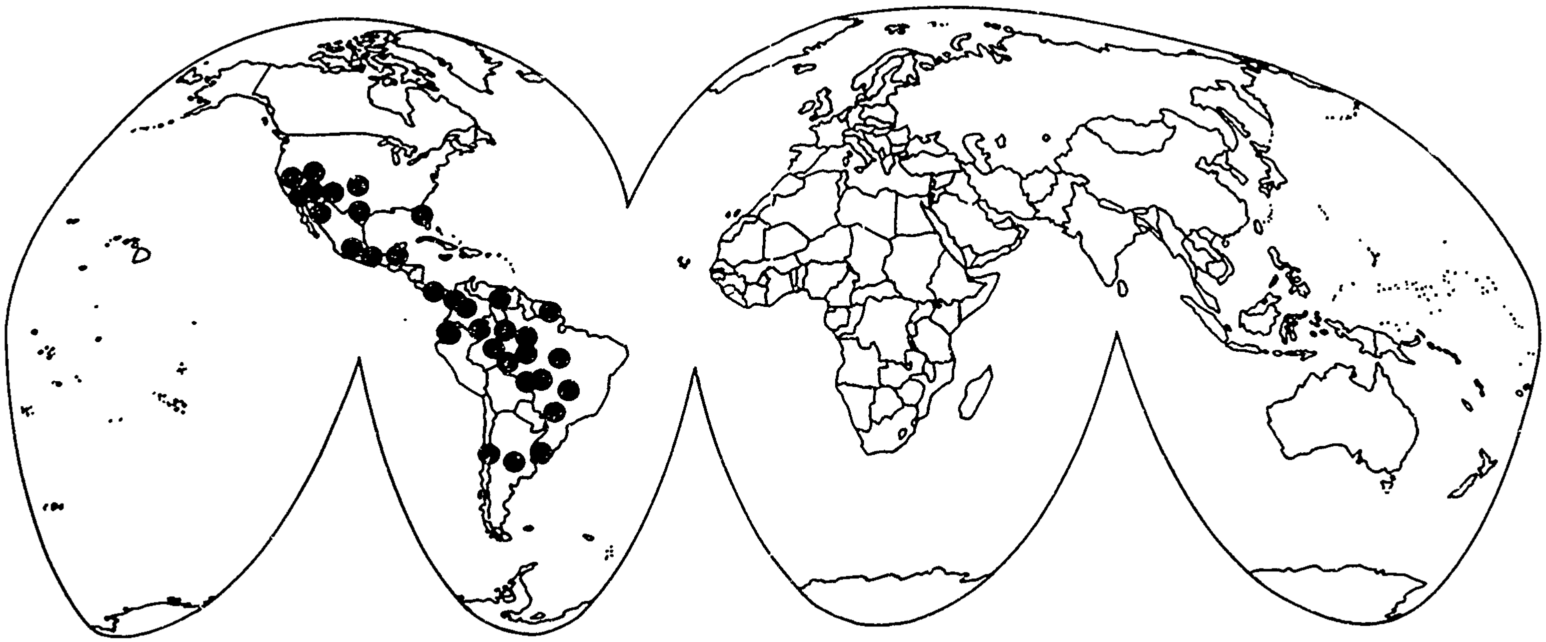

Figure 21. Geographic Distribution of <u>Ornithodoros</u> <u>talaje</u>.

Hosts: Rodents (principally) and man, as well as birds, bats, pigs, cattle, horses, opossums, and snakes.

Seasonality: Varies with geographic location, hosts, and habitat. This species may be active in warmer geographic areas throughout the year.

Diagnostic Characters: Large cheeks present; discs large and noticeable, legs with surfaces micromammillated.

Remarks: According to Dunn (1923), Ornithodoros talaje adults are seldom observed in dwellings and are not avid parasites of man. The larvae remain attached to a host for several days. There are 3 to 4 nymphal stages and developmental time from larvae to adult is about 8 months.

Ornithodoros turicata (Duges)

Relapsing Fever Tick

Medical Importance: Ornithodoros turicata may produce an intense irritation and edema at the bite site in humans. This species also serves as a vector of relapsing fever spirochetes in portions of Kansas, Oklahoma, Texas, and other southwestern states.

Distribution: This species (Figs. 22, 23) occurs in the U.S. in the states of Texas, New Mexico, Oklahoma, Kansas, California, Colorado, Arizona, Florida, and Utah. It has been reported from Mexico in the states of Aguascalientes, Coahuila, Gunanjuato, Morelos, Queretaro, San Luis Potosi, and Sinaloa. This species has also reportedly been found in Venezuela, Honduras, Bolivia, Chile, and Argentina. However, Hoogstraal (1985) reported that the records of this species from Central and South America are probably incorrect.

Hosts: Specimens have been collected from rattlesnakes, turtles, birds, rodents, rabbits, sheep, cattle, horses, pigs, and man.

Seasonality: Varies with geographic location, hosts, and habitat. This species may be active in warmer geographic areas throughout the year.

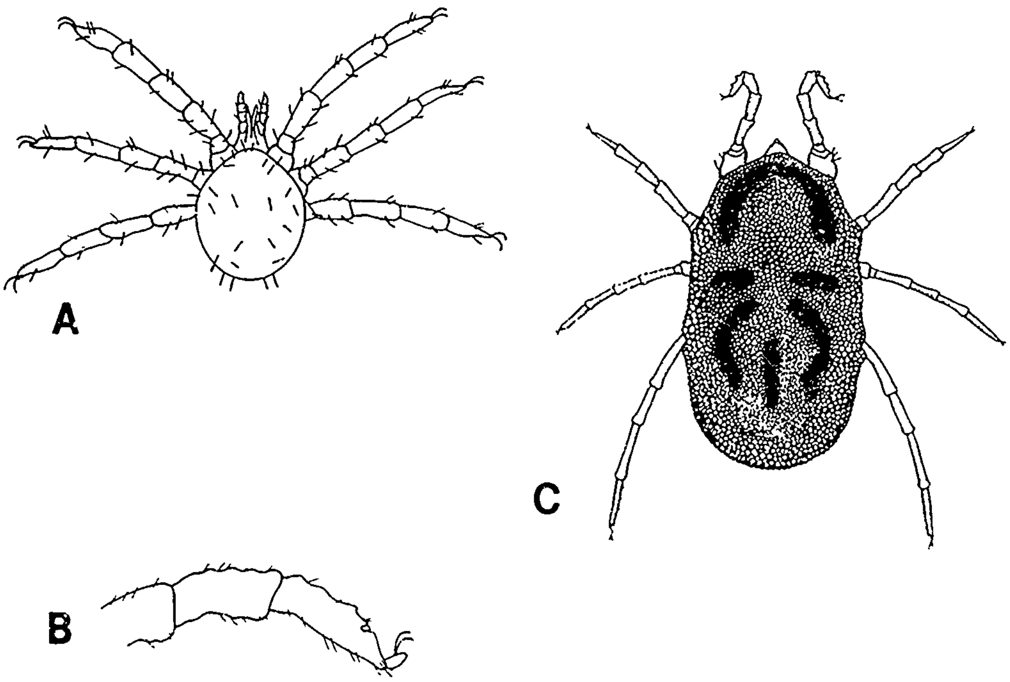

Figure 22. Larva (a), foreleg (b), and adult (c) of Ornithodoros turicata.

Diagnostic Characters: Cheeks absent; dorso-ventral grooves present, dorsal humps present on tarsus I; subapical dorsal protuberance absent from leg IV, dorsal humps absent from tarsus IV; mammillae large, relatively few in number, not crowded together.

Remarks: Ornithodoros turicata is often found in burrows used by rodents or burrowing owls. Cooley and Kohls (1944) report the bite to be painless but followed in a few hours by intense local irritation and swelling. Subsequently, subcutaneous nodules may form which persist for months. There are 3 to 5 nymphal stages and the time required for development from larva to adult is approximately 6 months.

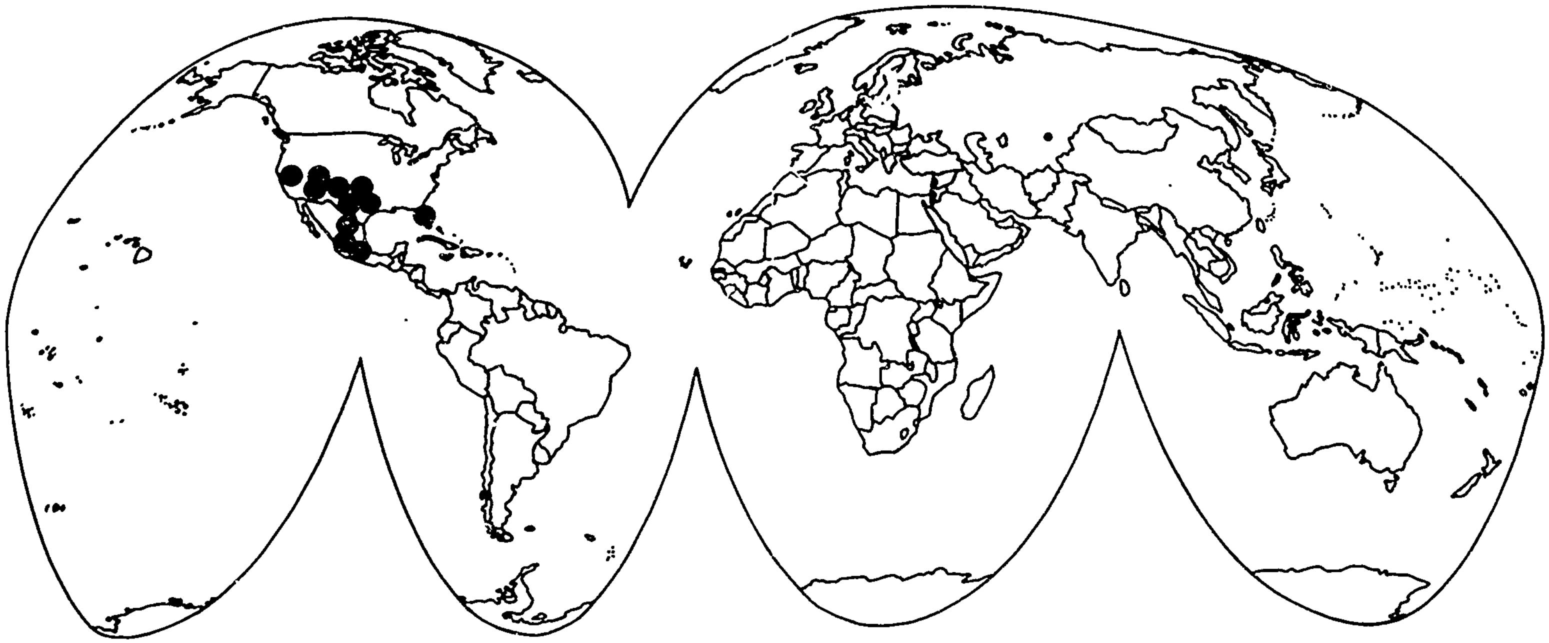

Figure 23. Geographic Distribution of Ornithodoros turicata.

IXODIDAE (HARD TICKS)

The Genus _Amblyomma_

MORPHOLOGICAL CHARACTERISTICS OF THE GENUS _AMBLYOMMA_

Palpi long, segment 2 at least twice as long as wide; generally ornate specimens; eyes and festoons present; adanal shields absent in males; spiracular plates subtriangular or comma-shaped.

Amblyomma americanum (Linnaeus)

Lone Star Tick

Medical Importance: This species transmits the pathogen of tularemia to man and is reported to transmit the agents of Lyme disease and RMSF. However, recent studies have indicated that _Amblyomma americanum_ may not be an important vector of RMSF (Goddard and Norment, 1986; Goddard, 1987b) or LD (Piesman and Sinksy, 1988).

Distribution: This species (Figs. 24, 25) occurs in the U.S. in central Texas east to the Atlantic Coast and north to approximately Iowa and New York. It has been reported from Mexico in the northern states of Coahuila, Nuevo Leon, and Tamaulipas. It has also been occasionally reported from Panama, Venezuela, Argentina, Guatemala, Guayana, and Brazil. However, Central and South American records of this species may not be valid.

Hosts: _Amblyomma americanum_ is extremely aggressive and nonspecific in its feeding habits. All three motile life stages of this species will feed on a wide variety of mammals (including humans) and ground-feeding birds.

Seasonality: _Amblyomma americanum_ adults and nymphs are generally active from early spring through midsummer with larvae being active from late summer into early fall.

Diagnostic Characters: Males with internal spur of coxa I moderately long and scutum with inverted horseshoe markings at posterior edge; females with external spur of coxa I distinctly longer than internal, and scutum with distinct, single white spot.

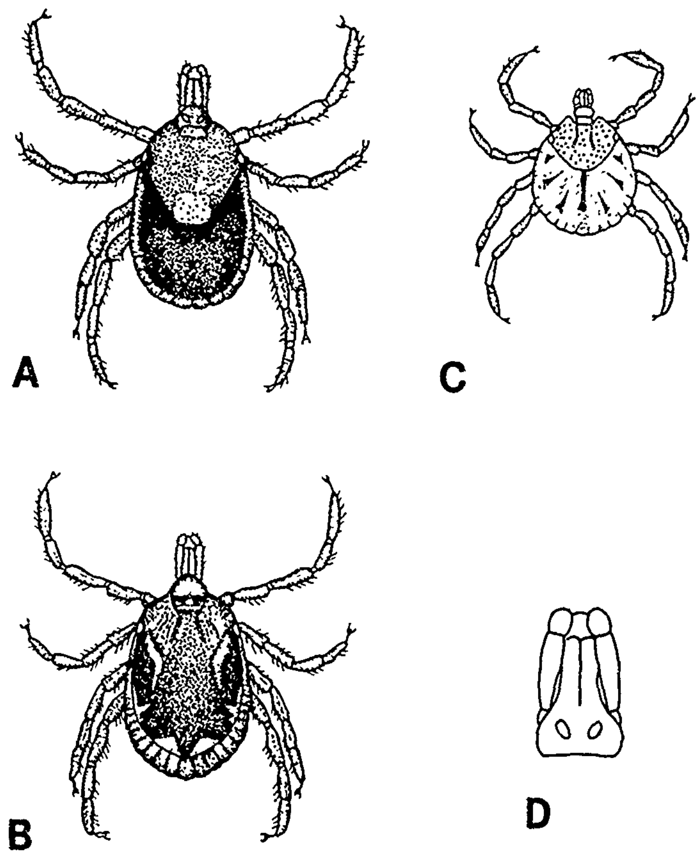

Figure 24. Adult female (a), male (b), nymph (c), and dorsal view of capitulum (d) of Amblyomma americanum.

Remarks: Amblyomma americanum is probably the most annoying and commonly encountered tick occurring in the southern U.S. In some rural areas almost every person has been bitten by these ticks at one time or another. Lone star ticks are most often found in interfacing zones between forested and open (meadow) areas, especially where there is an abundance of deer or other hosts. They seldom occur in high numbers in the middle of pastures or meadows because of low humidities and high daytime temperatures present in those areas. Larvae may survive from 2 to 9 months; nymphs and adults 4 to 15 months each. Females usually deposit 3,000-8,000 eggs.

The female lone star tick is often falsely referred to as the "spotted fever tick" because of the single white spot visible on its back. However, this spot has nothing to do with the presence or absence of RMSF organisms. Amblyomma americanum adults have very long mouthparts and can produce painful bites.

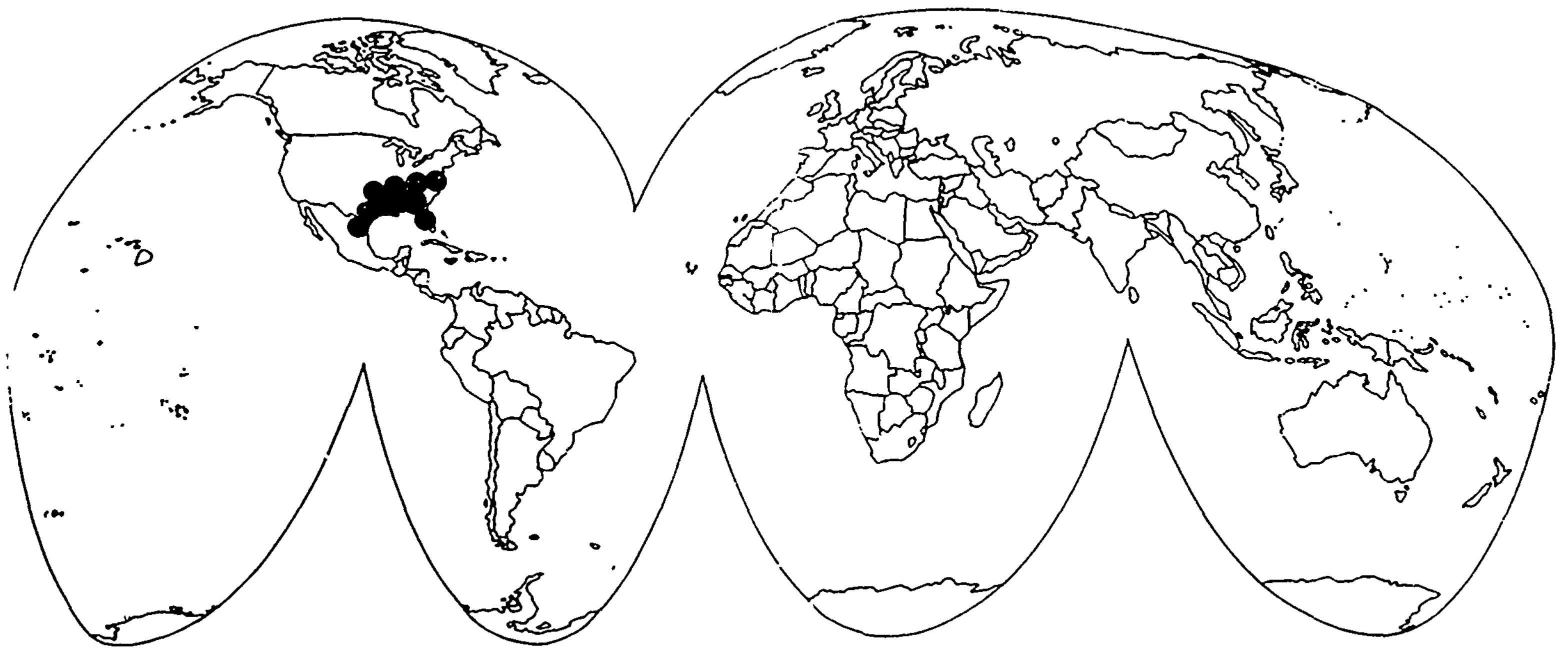

Figure 25. Geographic Distribution of Amblyomma americanum.

Amblyomma cajennense (Fabricius)

Cayenne Tick

Medical Importance: Amblyomma cajennense is probably the most commonly encountered and aggressive of all Central and South American ticks. This species is considered a vector of RMSF rickettsiae in Mexico, Panama, Colombia, and Brazil.

Distribution: Amblyomma cajennense (Figs. 26, 27) occurs from extreme southern Texas, south throughout Mexico and Central America into parts of South America. Specific countries include: most of Mexico, Panama, several Caribbean islands including Cuba and Jamaica, Brazil, Honduras, Venezuela, Costa Rica, Uruguay, Ecuador, Nicaragua, and Bolivia. Hoffmann (1962) states that it also occurs in Guatemala, Colombia, Guayana, Paraguay, and Argentina.

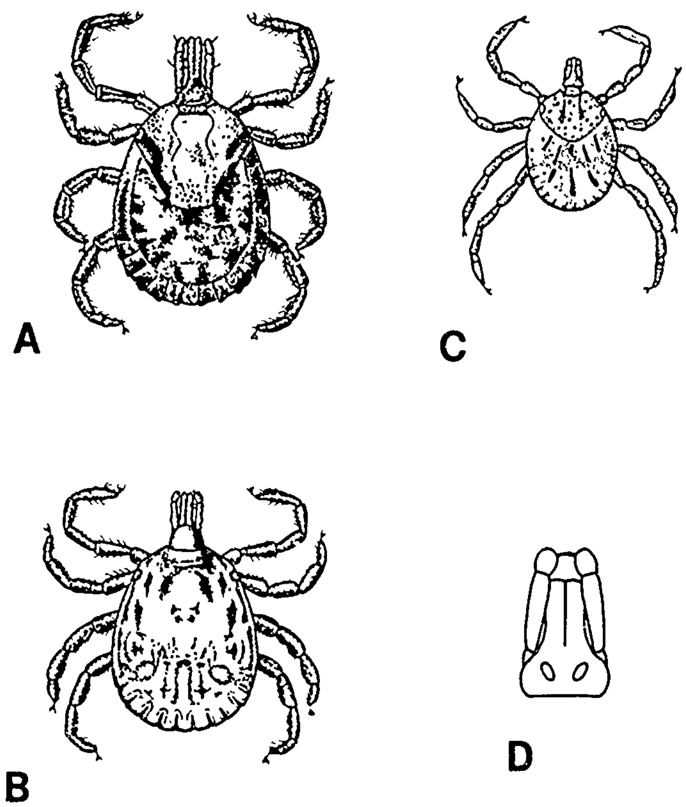

Figure 26. Adult female (a), male (b), nymph (c), and dorsal view of capitulum (d) of Amblyomma cajennense.

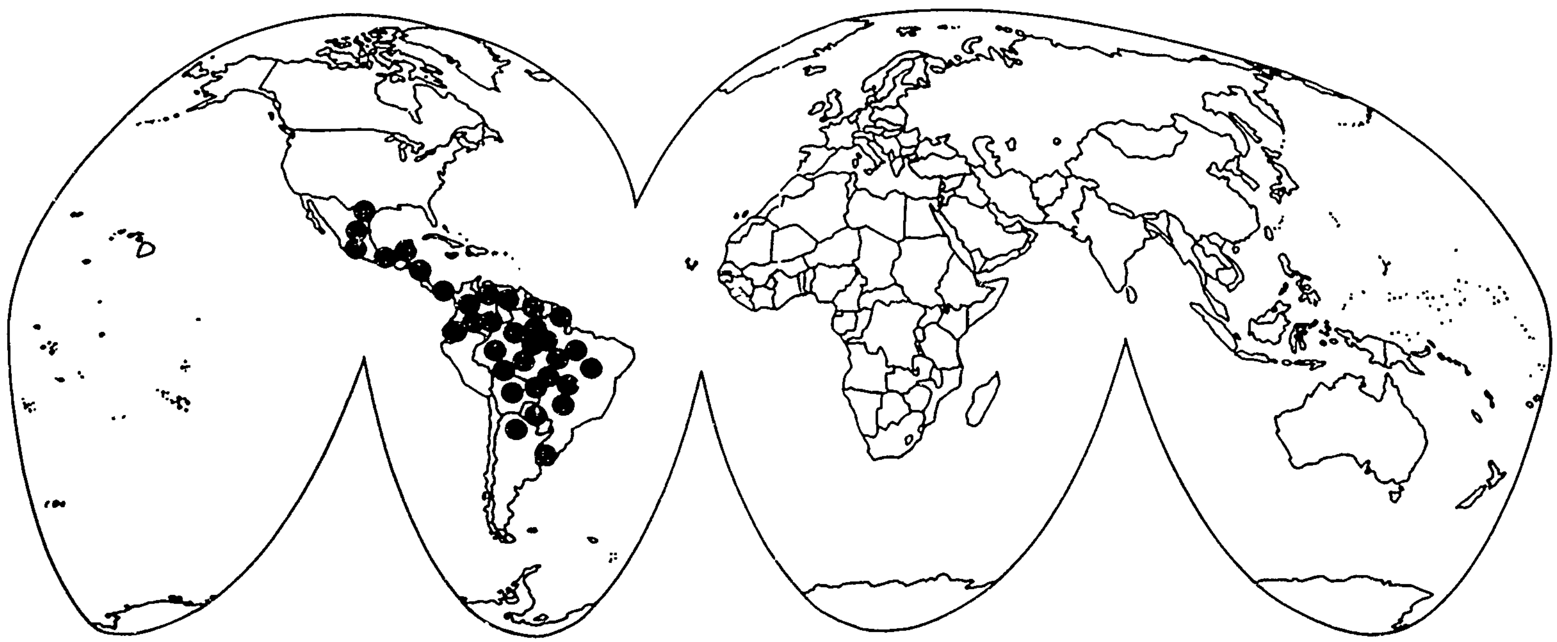

Figure 27. Geographic Distribution of Amblyomma cajennense.

Hosts: All active stages commonly attack man, domestic and wild animals, and ground-frequenting birds.

Seasonality: Amblyomma cajennense may be active in tropical areas year-round; however, in the cooler areas at the northernmost and southernmost extent of its distribution, there may be reduced activity in midwinter.

Diagnostic Characters: Males with internal spur of coxa I moderately long and scutum with weblike ornamentation radiating from the center; females with external spur of coxa I distinctly longer than internal; scutum with extensive ornamentation and festoons with tubercules at posterior edge.

Remarks: Amblyomma cajennense is very similar to A. americanum in its aggressiveness and nonspecific feeding habits. Basically, where the southernmost distribution of A. americanum stops, A. cajennense picks up and continues southward throughout Central and South America. Longevity of larvae, nymphs, and adults, as well as numbers of eggs laid by engorged females, is similar to that of A. americanum. As with A. americanum, A. cajennense have long mouthparts and produce painful bites.

Amblyomma hebraeum Koch

Bont Tick

Medical Importance: Amblyomma hebraeum is one of several ixodid vectors of Rickettsia concri, the agent of boutonneuse fever.

Distribution: This species (Figs. 28, 29) is distributed throughout southern Africa. Specific countries include Angola, Botswana, Cameroon, Mozambique, Madagascar, Kenya, Nigeria, Somalia, South Africa, Swaziland, Tanzania, Zaire, Zambia, and Zimbabwe. Amblyomma hebraeum has been accidentally introduced into the United States on several occasions (primarily on rhinoceroses) but each time has been successfully eliminated.

Hosts: Immatures of this species feed on many medium- and large-sized mammals, particularly wild hares. Adults parasitize a variety of domestic and wild mammals but seem to prefer cattle and antelopes. All life stages will bite people.

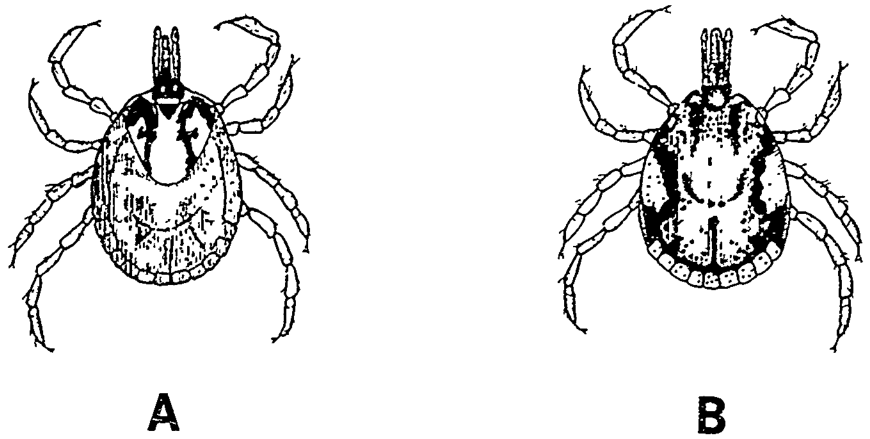

Figure 28. Adult female (a) and mal~ (b) Amblyomma hebraeum.

Seasonality: This species is active in spring, summer, and fall months. In South Africa, the adults are most abundant on hosts during the late summer and autumn (Strickland et al. 1976).

Diagnostic Characters: Males with black or brown stripes and spots on a pale greenish-white background; all festoons pale except external ones; eyes small, circular, slightly convex; legs with yellow banding at distal ends of each segment; coxa I with 2 unequal spurs; short stout spur present on coxa IV; females with scutum longer than broad; cervical grooves deep anteriorly; extensive pale coloration (except scapulae dark colored); eyes pale, circular, bulging.

Remarks: Larval A. hebraeum, like their U.S. cousins, lone star ticks, are troublesome pests of people. They attach themselves in large numbers on the legs and about the waist causing intense irritation, rash-like lesions, and occasionally pustules. Unfed larvae may live for up to 11 months, nymphs for 8 months or more, and adults 22 months or longer. Females deposit about 15,000 eggs.

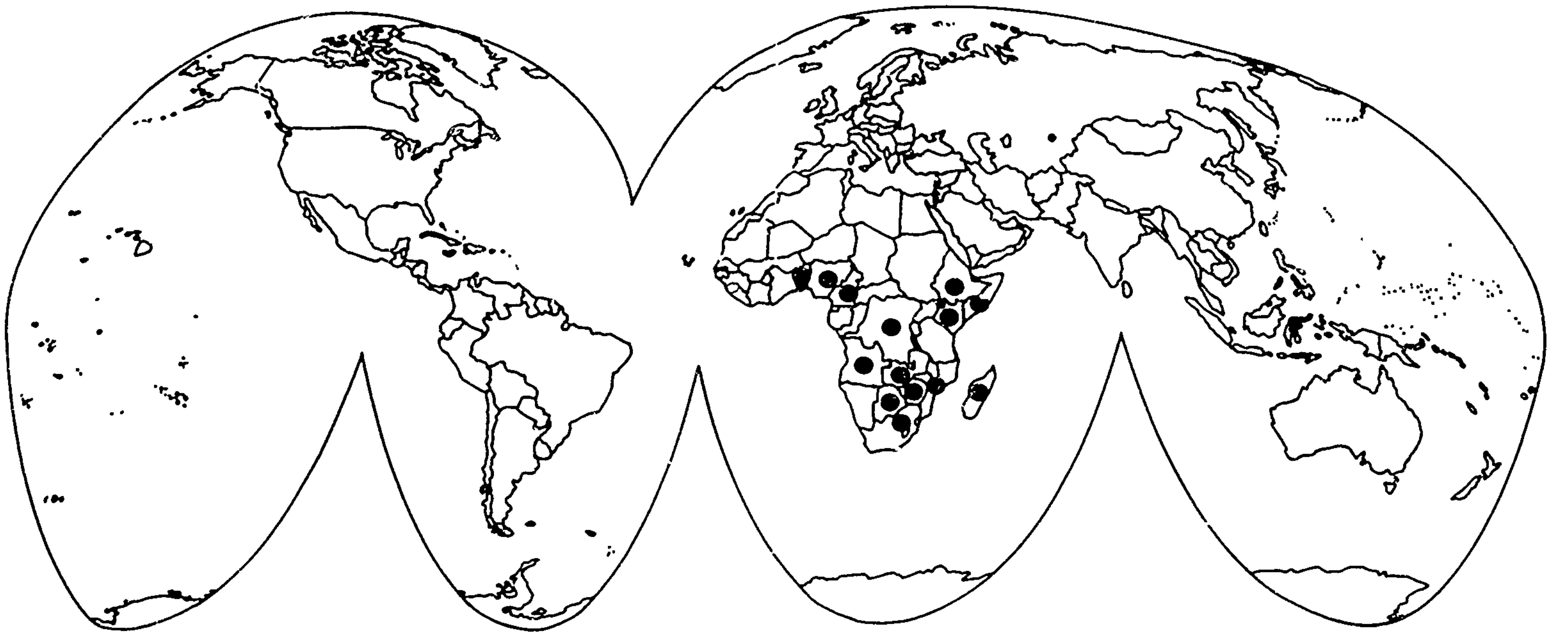

Figure 29. Geographic Distribution of *Amblyomma hebraeum*.

The Genus Haemaphysalis

MORPHOLOGICAL CHARACTERISTICS OF THE GENUS HAEMAPHYSALIS

Small inornate ticks; sexual dimorphism only slight; eyes absent; festoons present; palpi with second segment projecting beyond the lateral margin of the basis capituli; basis capituli rectangular; ventral plates or shields absent in males; spiracular plates usually rounded or comma-shaped in males, rounded or oval in females.

Haemaphysalis concinna Koch

No Common Name

Medical Importance: *Haemaphysalis concinna* is a vector of the Siberian tick typhus rickettsia and viruses in the tick-borne encephalitis complex.

Distribution: This species (Figs. 30, 31) is widely distributed in forests of temperate Eurasia. Specific countries include most of Central Europe, the USSR, China, Japan, Korea, and Vietnam.

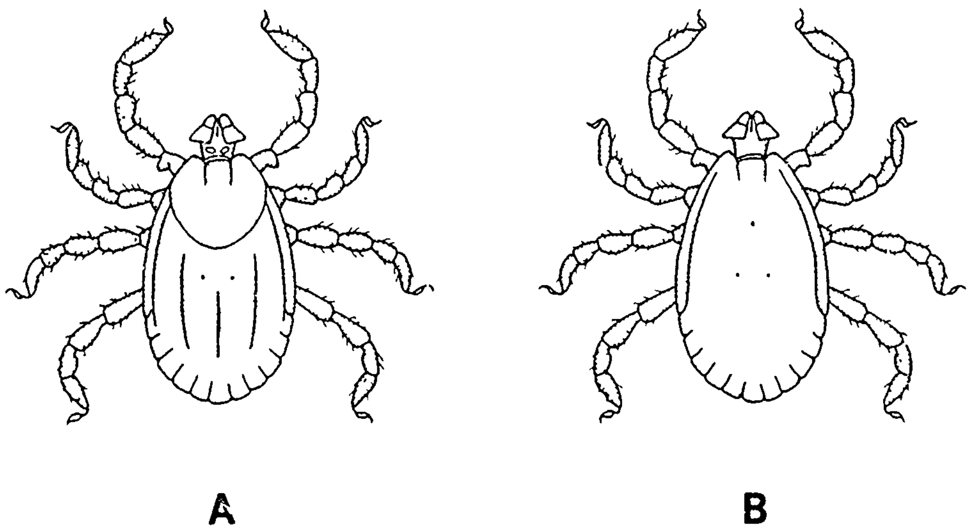

Figure 30. Female (a) and male (b) *Haemaphysalis concinna*.

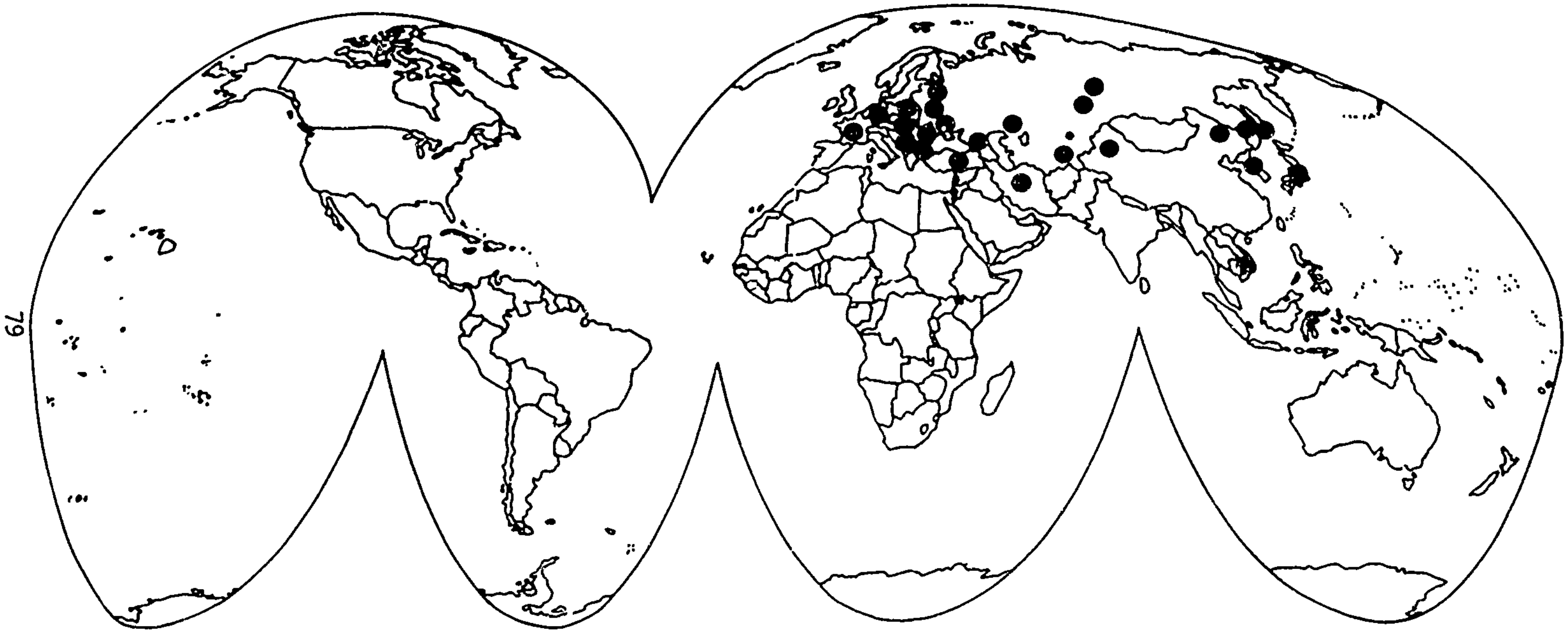

Figure 31. Geographic Distribution of *Haemaphysalis concinna*.

Hosts: Adult He. concinna feed on large wild and domestic mammals; immatures infest smaller mammals and birds, sometimes even reptiles. Both adults and nymphs will bite people.

Seasonality: All stages of He. concinna are active from spring to autumn; peak adult activity is in June.

Diagnostic Characters: Palpal article 3 lacking dorsal spur; males with lateral grooves present; palps pincer-like, article 3 long and incurved; females with scutum not usually longer than broad; palpal article 3 narrower than article 2; scutum broadest in middle; hypostome 6/6.

Remarks: This species is found chiefly in deciduous and mixed forests, grass tussock swamps, birch-aspen grooves, and alpine taiga forests. In studies in the Maritime territory of the USSR, H. concinna was reported to be abundant in low lying areas with high humidities.

Haemaphysalis leachi (Audouin)

(Including H. l. muhsami)

Yellow Dog Tick

Medical Importance: This species is a vector of the boutonneuse fever rickettsia. In addition, human infection with the rickettsia may also be acquired by contamination of the skin and eyes with infectious tick fluids from crushing this species while deticking dogs.

Distribution: Haemaphysalis leachi (Figs. 32. 33) occurs primarily in tropical and southern Africa (although there are records from Algeria, Libya, and Egypt). Records of this species from India and Southeast Asia probably represent related but distinct species.

Hosts: Immatures of H. leachi usually parasitize field rodents; adults commonly bite domestic dogs but will bite people readily. The subspecies H. leachii muhsami prefers small carnivores (mongooses, wildcats, etc.) instead of canines.

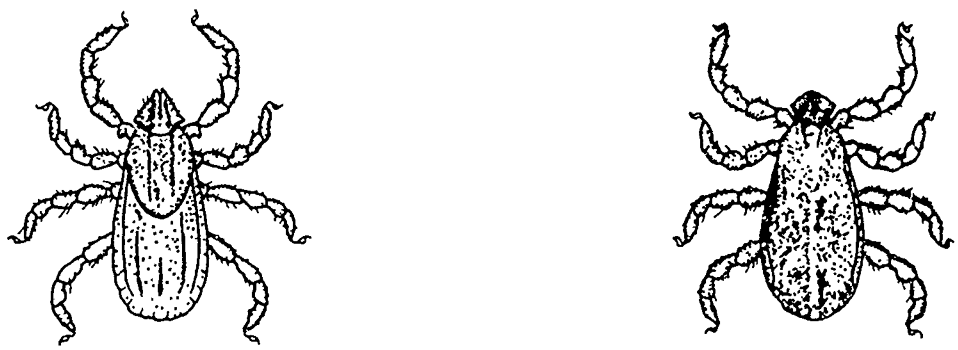

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Figure 32. Female (a) and male (b) *Haemaphysalis leachi*.

Seasonality: This species is most active from late spring to early fall.

Diagnostic Characters: *Haemaphysalis l. muhsami* smaller than *H. l. leachi*; males with palpal segment 2 without dorsal retrograde spur; trochanter 1 without ventral spur; palpal lateral margins straight or slightly concave (*leachi*); palpal lateral margins concave (*muhsami*); coxae each with a distinct, overlapping spur (*leachi*); cornua short and wide (*muhsami*) or elongate (*leachi*); Females with palpal segment 3 with basal margin dorsally forming a straight line with no spur or angle; coxae with overlapping spur on at least two pairs; well-developed cornua; *muhsami* with palpal spurs reduced and tarsi short, sometimes humped; *leachi* tarsi elongate and tapering; palpal spurs large and definite.

Remarks: Very common on dogs; in some areas *H. leachi* is more prevalent on dogs than *Rhipicephalus sanguineus*. Usually two generations are produced each year. Unfed larvae may survive at least 169 days, nymphs 52 days, and adults 210 days (Hoogstraal, 1956). Females lay up to 5,000 eggs.

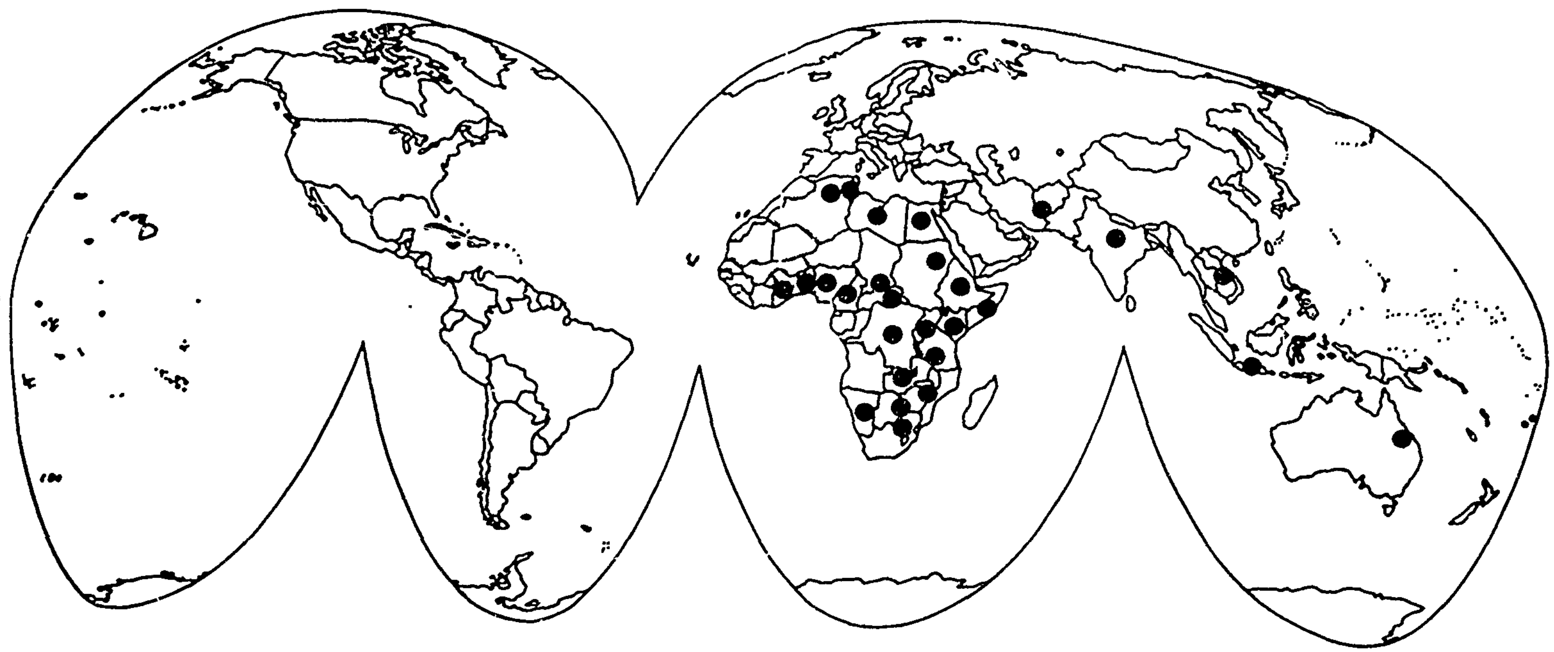

Figure 33. Geographic Distribution of <u>Haemaphysalis</u> <u>leachi</u>.

Haemaphysalis spinigera Neumann

No Common Name

Medical Importance: *Haemaphysalis spinigera* is the primary vector of the virus of Kyasanur Forest disease.

Distribution: This species (Figs. 34, 35) is widely distributed in central and southern India, but has also been reported from southeast Asia and Indonesia.

Hosts: Immature *H. spinigera* parasitize a wide range of small mammals and birds, whereas adults prefer large mammals such as cattle, monkeys, bears, and tigers. Nymphal *H. spinigera* avidly bite humans.

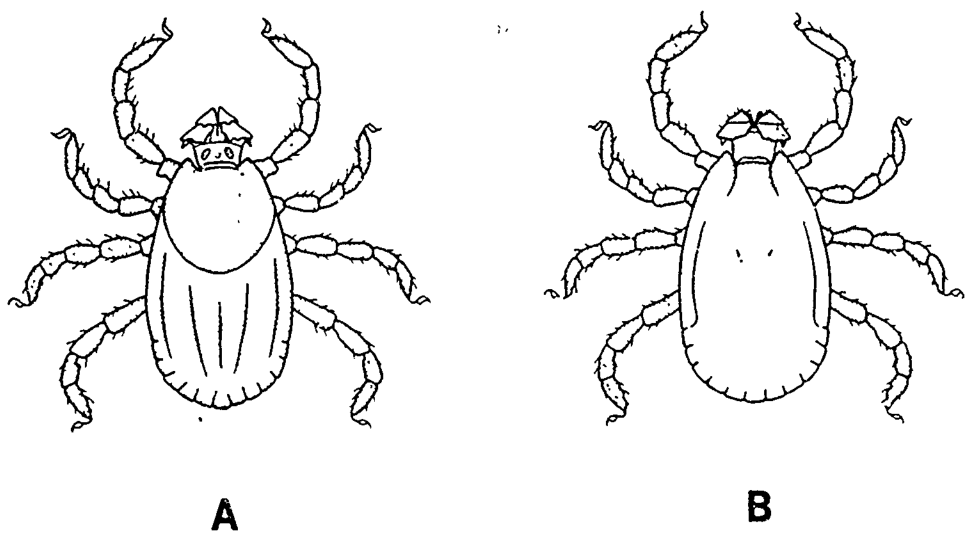

Figure 34. Female (a) and male (b) *Haemaphysalis spinigera*.

Seasonality: This species is generally active in the spring, summer and fall; however, the immatures peak in numbers from September-November.

Diagnostic Characters: Males with lateral grooves present; coxae II and III with spurs poorly developed; coxae I and IV with long spurs (although the Australian and New Guinea forms

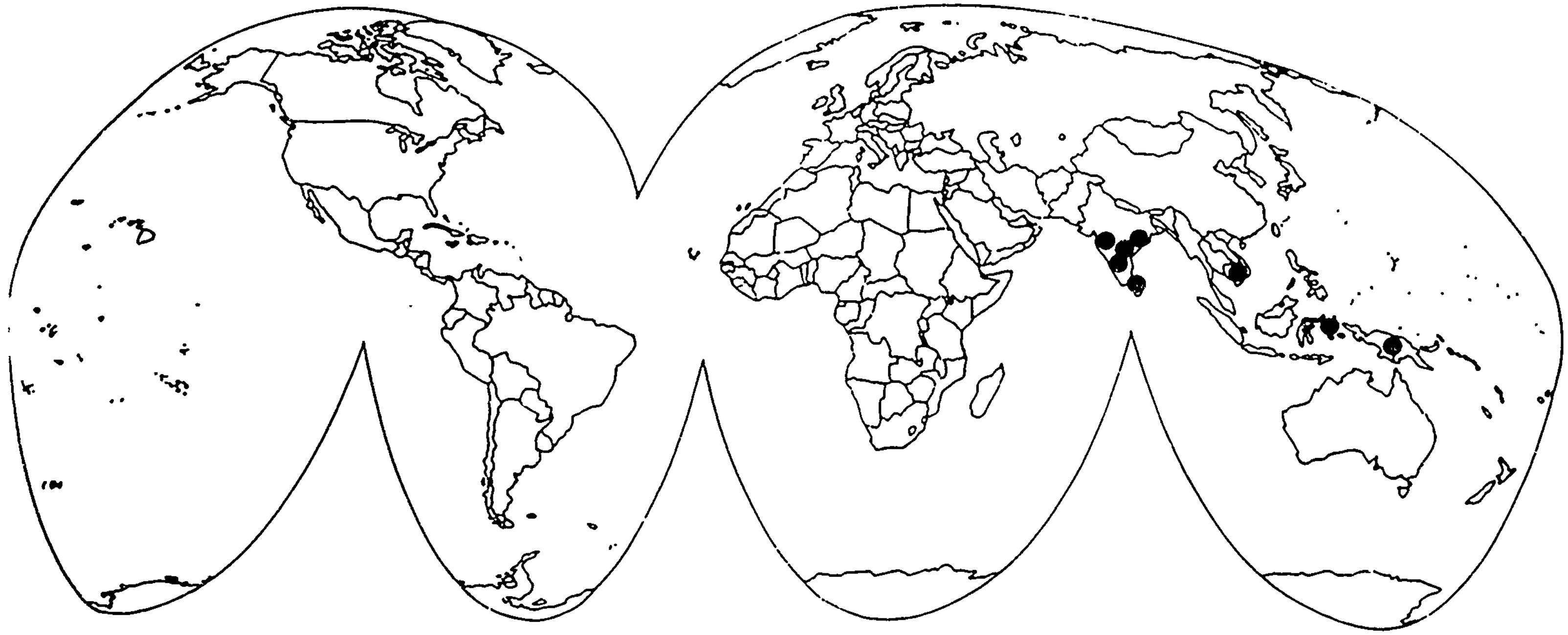

Figure 35. Geographic Distribution of Haemaphysalis spinigera.

have only coxa IV with a long spur); females with spurs absent from trochanters, palpal articles 3 with distinct dorsal spine; palpal articles 2 and 3 not equal.

Remarks: According to Harwood and James (1979), humans in the KFD endemic areas (Mysore State, India) turn from agricultural pursuits to wood gathering in the forests during the season of peak immature He. spinigera activity. This activity greatly increases human-tick contact. Hoogstraal (1981) reported that He. spinigera populations have increased in India because of recent increased cattle grazing practices in and beside the forests. In addition, immatures thrive on the numerous small vertebrates hiding in dense lantana thickets where sections of forests have been cleared.

The Genus Hyalomma

MORPHOLOGICAL CHARACTERISTICS OF THE GENUS HYALOMMA

Scant ornamentation, sometimes bands present on legs; eyes present; irregular festoons, partially coalesced; palpi long, segment 2 approximately twice as long as segment 3; basis capituli subtriangular dorsally; coxa I deeply cleft; males with adanal and accessory shields; spiracular plate comma-shaped.

Hyalomma asiaticum Schulze and Schlottke

The Asiatic Hyalomma

Medical Importance: Hyalomma asiaticum is a vector of the agent of Siberian tick typhus.

Distribution: This species (Figs. 36, 37) occurs in many places in the southern USSR, China, Afghanistan, Pakistan, Iran, and Iraq.

Hosts: Adult Hy. asiaticum parasitize all domestic animals, especially camels, cattle, horses, and sheep. People, hares, boars, and hedgehogs are less frequently attacked. Immatures feed on hedgehogs, rodents, hares, cats, and dogs.

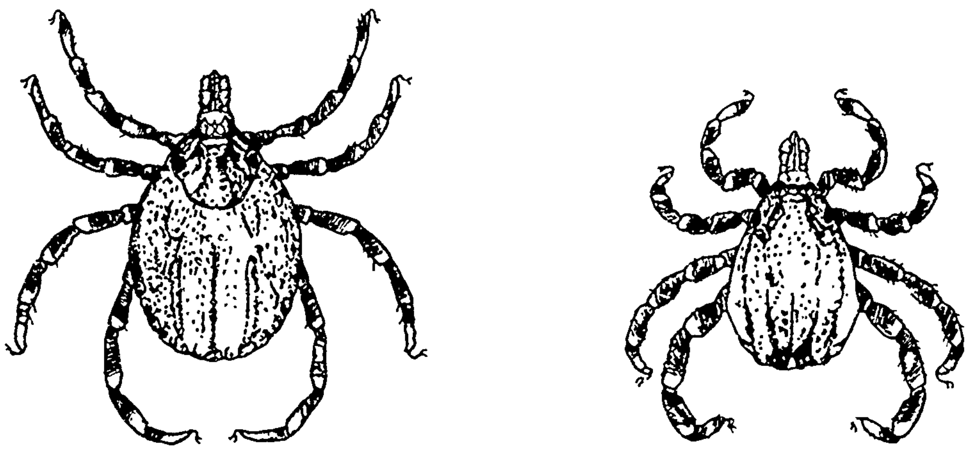

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Figure 36. Female (a) and male (b) Hyalomma asiaticum.

Seasonality: This species is most active in spring and summer throughout its range.

Diagnostic Characters: Similar to Hy. anatolicum; males with scutum having deep cervical grooves reaching to midlength a few large punctations present; adanal shields straight, their inner margins parallel; subanal shields situated on the median axis of the adanals; females with genital apron longitudinally oval, bulging in profile; scutum longer than wide; deep long cervical grooves and few punctations; legs with white or yellowish rings.

Remarks: In southwestern Kirghiz (USSR), foci of Siberian tick typhus occur where the southern steppes give way to a foothill semidesert zone. In these areas Hy. asiaticum is associated with red-tailed jirds along dry waterways overgrown with shrubs and along irrigation canals (Hoogstraal, 1967).

Hyalomma anatolicum Koch

(Including Hy. a. anatolicum and Hy. a. excavatum)

The Small Anatolian Hyalomma

Medical Importance: Hyalomma anatolicum is a vector of the virus of Crimean-Congo hemorrhagic fever.

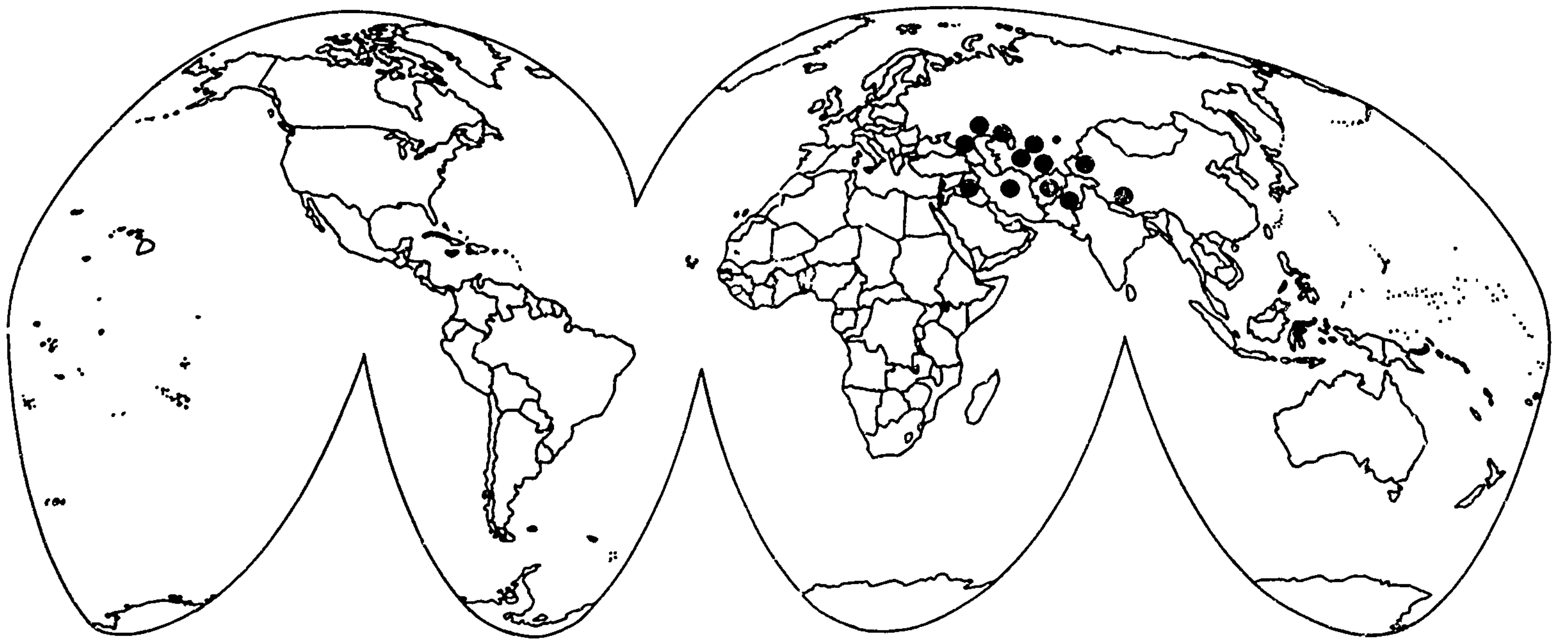

Figure 37. Geographic Distribution of Hyalomma asiaticum.

Distribution: This species (Figs. 38, 39) is found throughout northern Africa, portions of the Near East, Asia Minor, southern Europe, southern Russia, and India.

Hosts: All stages of Hy. anatolicum have been observed feeding on hares in a forest near Casablanca (Hoogstraal, 1956). This species also is an avid parasite of man and many domestic animals.

Seasonality: Varies with latitude throughout the range of Hy. anatolicum. In general, adults infest domestic animals from March-October, and larvae and nymphs from July-September. All stages are most numerous in early August.

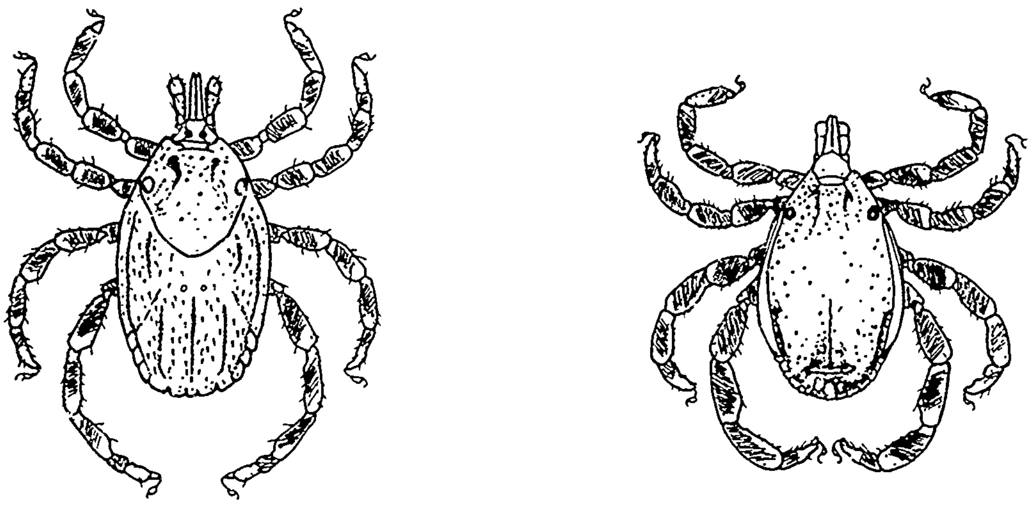

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Figure 38. Female (a) and male (b) Hyalomma anatolicum.

Diagnostic Characters: Small ticks; males with center of subanal shields in line with the axis of the adanal shields; lateral grooves not extending beyond the posterior 3rd of the scutum; females with scutum longer than wide and genital apron circular or triangular, bulging in profile.

Remarks: Engorged larvae and unfed adults are the usual overwintering stages. They hibernate in cracks and crevices in wooden animal shelters in the Russian climate and in rodent burrows in African desert conditions. Larvae may survive up to 241 days, nymphs up to 246 days, and adults over 1 year.

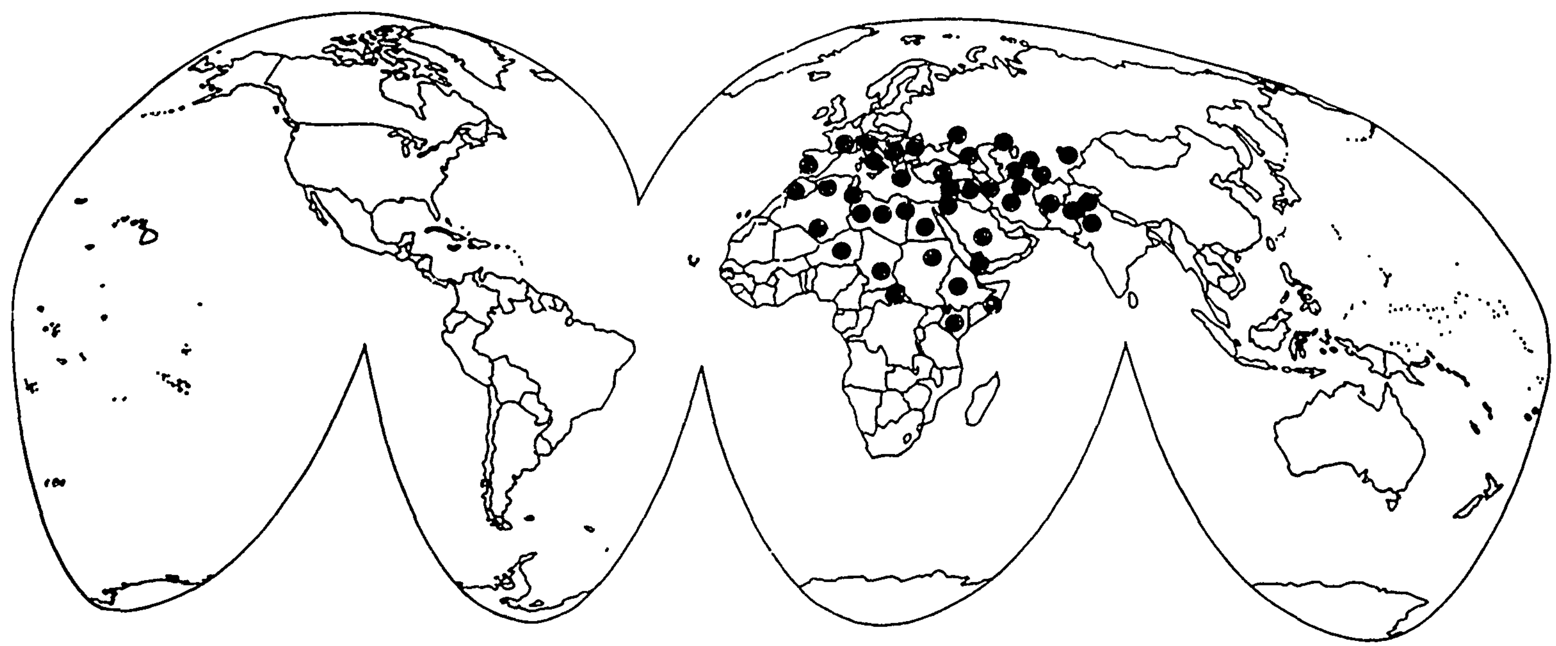

Figure 39. Geographic Distribution of _Hyalomma_ _anatolicum_.

Hyalomma marginatum Koch

(Including several subspecies)

Several Common Names

Medical Importance: Ticks of the Hyalomma marginatum complex are efficient vectors of the Crimean-Congo hemorrhagic fever virus.

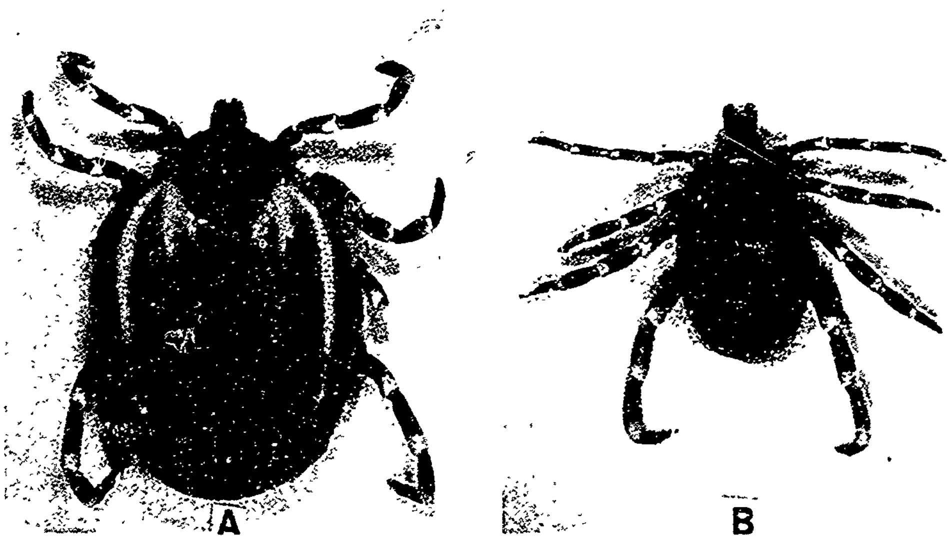

Figure 40. Female (a) and male (b) Hyalomma marginatum. (Specimen courtesy Dr. B. Fivaz, Rhodes Univ. Grahamstown, South Africa)

Distribution: This species (Figs. 40, 41) is most common in southeastern Europe and southern Russia. It also occurs in India and Indochina, westward throughout southern Europe, into the Near East and Africa. Specific countries include Egypt, Libya, Tunisia, Morocco, Algeria, Nigeria, Sudan, Kenya, South Africa, Cameroon, Southwest Africa, Mauritania, Senegal, Israel, Syria, Lebanon, Jordan, Turkey, Cyprus, Iran, Iraq, Yemen, Spain, Portugal, France, Italy, Yugoslavia, Romania, Greece, Bulgaria, Russia, India, and China.

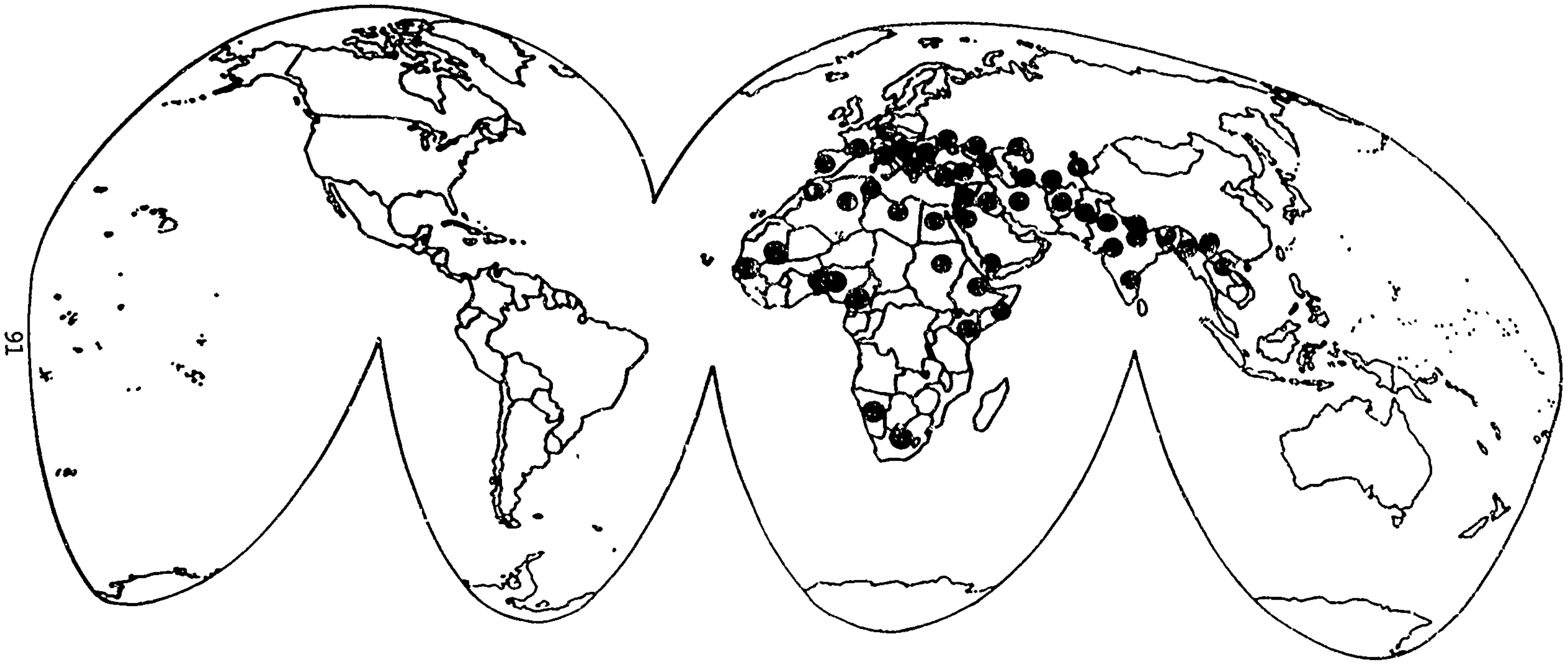

Figure 41. Geographic Distribution of *Hyalomma marginatum*.

Hosts: Adults attack humans and most domestic animals, especially cattle and horses. The immatures may also be found on domestic animals but prefer small wild mammals and birds.

Seasonality: According to Hoogstraal (1956), adult *H. marginatum* are rarely seen in winter throughout much of their distribution but begin to appear in March and continue until October. Maximum tick densities are reached in April, May, and June. The nymphs are active throughout the summer.

Diagnostic Characters: Usually large, inornate ticks; scutum in females covered by mostly shallow punctations, large ones restricted to anterior half, small ones widely scattered; genital apron large with a bulging profile, resembling a widely transverse oval or triangle.

Remarks: *Hyalomma* ticks are extremely hardy ticks, often existing under varied conditions of cold, heat, and aridity. *Hyalomma marginatum* often occurs in high numbers and is an aggressive human parasite. This species may act as either a 2-host or 3-host tick. Nuttall (1915) reported that unfed adults could survive over 2 years. Females deposit between 4,000-15,000 eggs.

The Genus *Dermacentor*

MORPHOLOGICAL CHARACTERISTICS OF THE GENUS *DERMACENTOR*

Usually ornate specimens; basis capituli rectangular dorsally; eyes and festoons present; males with coxae I to IV increasing in size progressively, no ventral plates or shields; Coxa I bifid in both sexes; spiracular plates sub-oval or comma-shaped.

Dermacentor andersoni Stiles

Rocky Mountain Wood Tick

Medical Importance: This species is the primary vector of RMSF in the Rocky Mountain states and also is known to transmit the causative agents of Colorado tick fever and tularemia. In addition, Dermacentor and~rsoni produces cases of tick paralysis in the U.S. and Canada each year.

Distribution: Dermacentor andersoni (Figs. 42, 43) is found from the western counties of Nebraska and the Black Hills of South Dakota to the Cascade and Sierra Nevada Mountains. It is also reported from northern Arizona and northern New Mexico, U.S., to British Columbia, Alberta, and Saskatchewan, Canada.

Hosts: Immatures prefer many species of small mammals such as chipmunks and ground squirrels, whereas the adults feed mostly on cattle, sheep, deer, man, and other large mammals.

Seasonality: Larvae feed throughout the summer and adults usually appear in March, disappearing by July. Nymphs may continue to be present although in diminishing numbers until late summer.

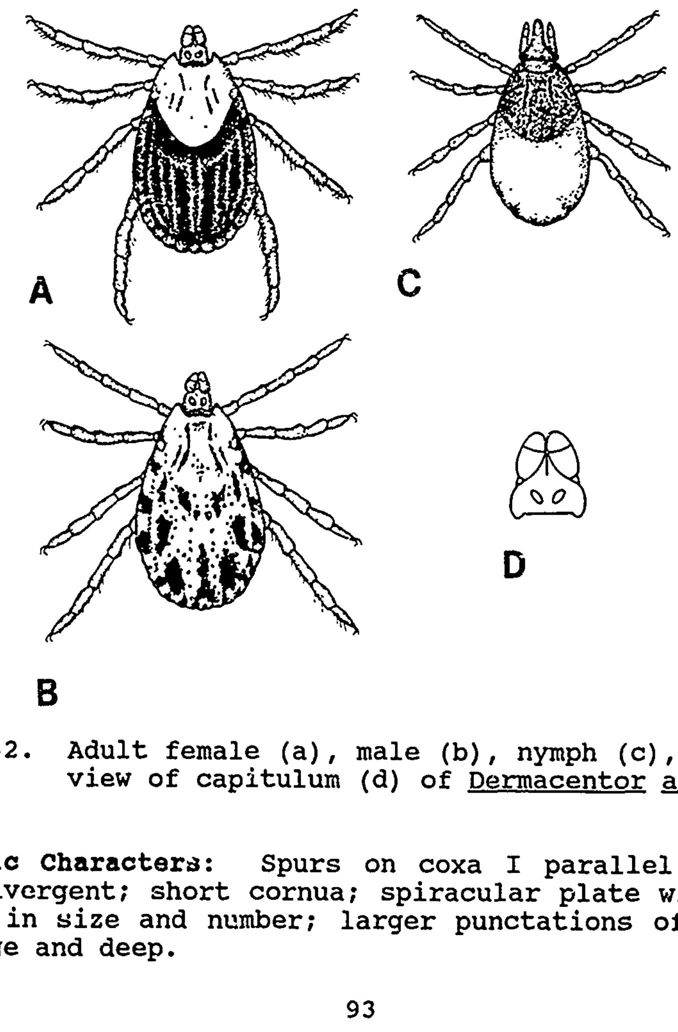

Figure 42. Adult female (a), male (b), nymph (c), and dorsal view of capitulum (d) of Dermacentor andersoni.

Diagnostic Characters: Spurs on coxa I parallel or only a little divergent; short cornua; spiracular plate with goblets moderate in size and number; larger punctations of the scuta very large and deep.

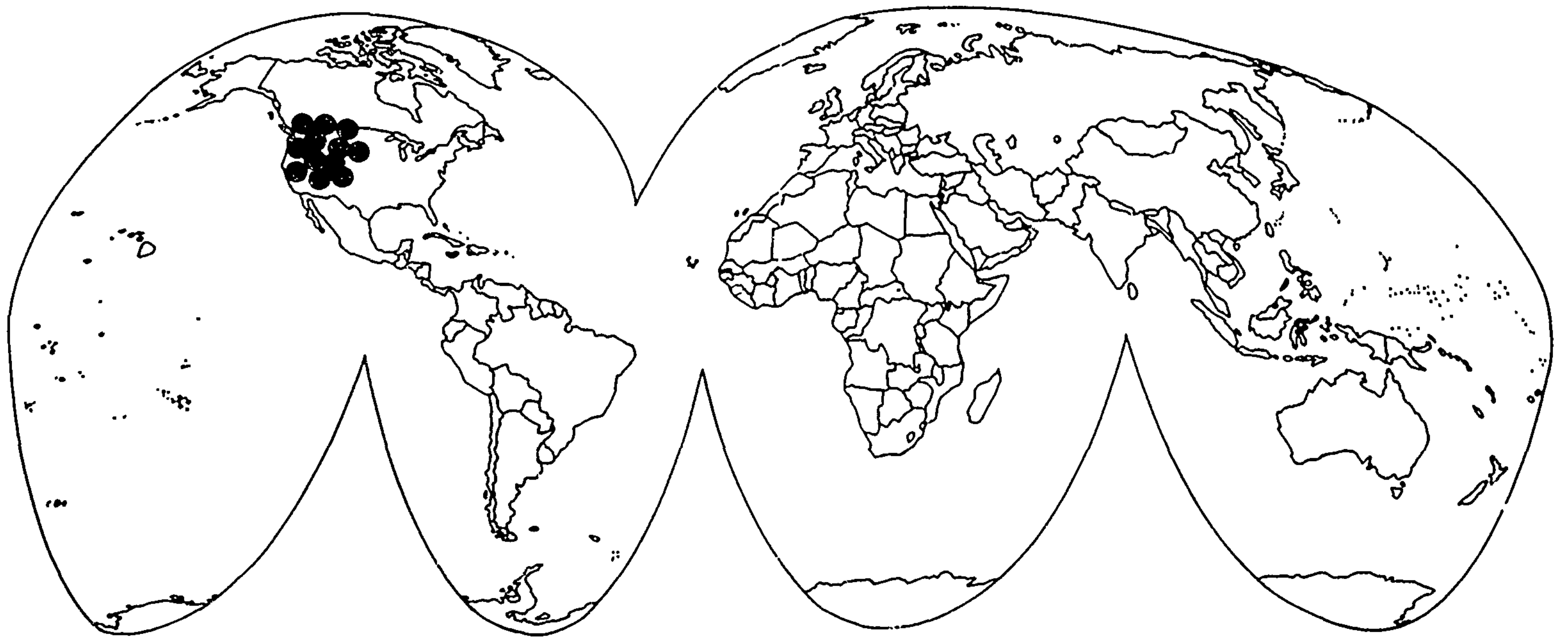

Figure 43. Geographic Distribution of *Dermacentor andersoni*.

Remarks: Dermacentor andersoni is especially prevalent where there is brushy vegetation to provide good protection for small mammalian hosts of the immatures and with sufficient forage to attract large hosts required by the adults. Unfed larvae may live for 1 to 4 months, nymphs for 10 months or more, and adults 14 months or longer. Females deposit about 4,000 eggs.

Dermacentor marginatus Sulzer

No Common Name

Medical Importance: Dermacentor marginatus is one of the primary vectors of the Siberian tick typhus rickettsia in Russia, as well as a vector of viruses in the tick-borne encephalitis complex. It is possibly a vector of the Omsk hemorrhagic fever virus.

Distribution: This species (Figs. 44, 45) occurs in many areas of western and central Europe and Russia. Specific countries include Afghanistan, Albania, Bulgaria, Czechoslovakia, Portugal, Spain, France, Germany, Greece, Hungary, Romania, Switzerland, Iran, Iraq, Poland, Italy, Turkey, Yugoslavia, and the USSR.

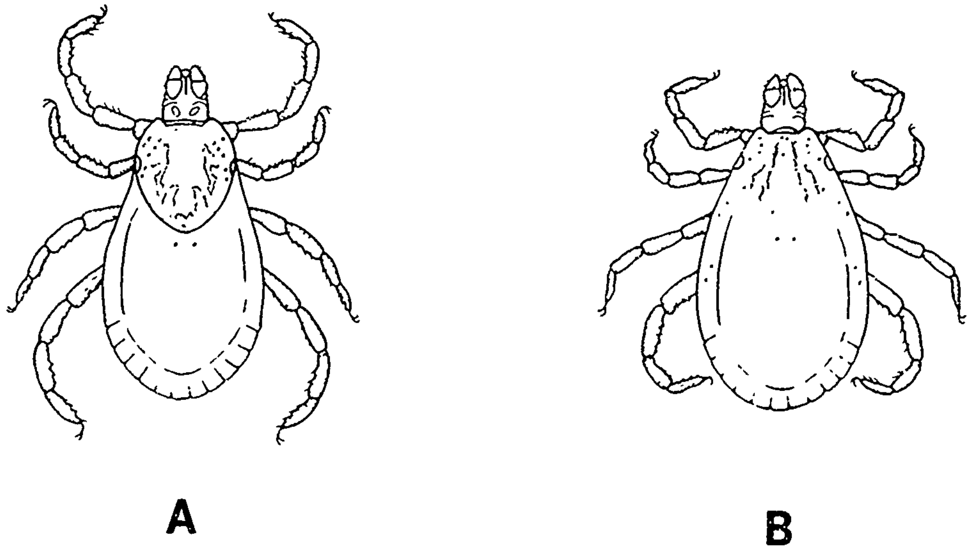

Figure 44. Female (a) and male (b) Dermacentor marginatus.

Hosts: Adult D. marginatus parasitize horses, cattle, sheep, man, dogs, buffalo, swine, camels, and hedgehogs. Immatures feed most frequently on small mammals (especially rodents).

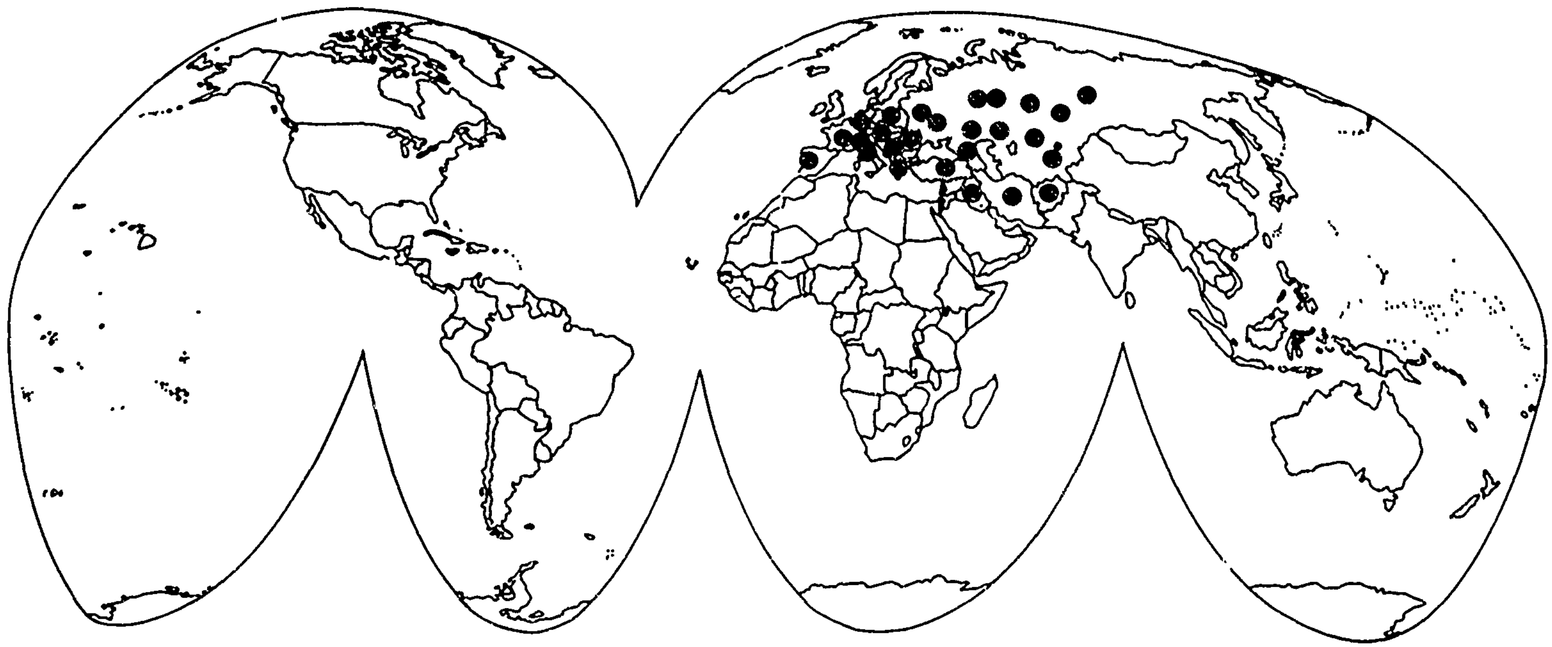

Figure 45. Geographic Distribution of Dermacentor marginatus.

Seasonality: Adults of this species are generally active in the spring and again in the autumn. Larvae usually peak in activity in June and July; nymphs in July and August.

Diagnostic Characters: Males with spurs on coxa I parallel or only slightly divergent; strongly thickened margin present at the base of the dorsal prolongation of the spiracular plate; 2nd palpal segment with weakly defined spur on posterodorsal margin ; mixture of both large and small punctations; moderate cornua; females possess winglike lateral extensions on genital opening and trochanters II and III with small ventral spurs.

Remarks: Dermacentor marginatus inhabits shrubby areas, low forests, marshes in lowlands, alpine steppes, and semidesert areas. In southeastern France, D. marginatus was found in close association with woods where Quercus pubescens predominated (Gilot and Pautou, 1983).

Dermacentor nuttalli Olenev

No Common Name

Medical Importance: Dermacentor nuttalli is one of several known vectors of Siberian tick typhus. It is also a vector of the agent of tularemia in the USSR.

Distribution: This species (Figs. 46, 47) occurs through central and eastern Siberia, Asiatic Russia, northern Mongolia, and China. It has also occasionally been reported from the western USSR.

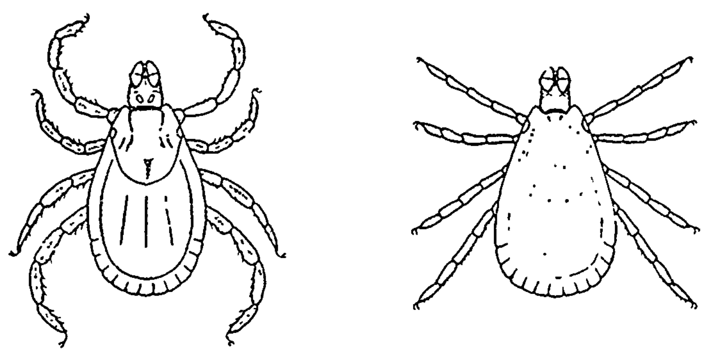

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Figure 46. Female (a) and male (b) Dermacentor nuttalli.

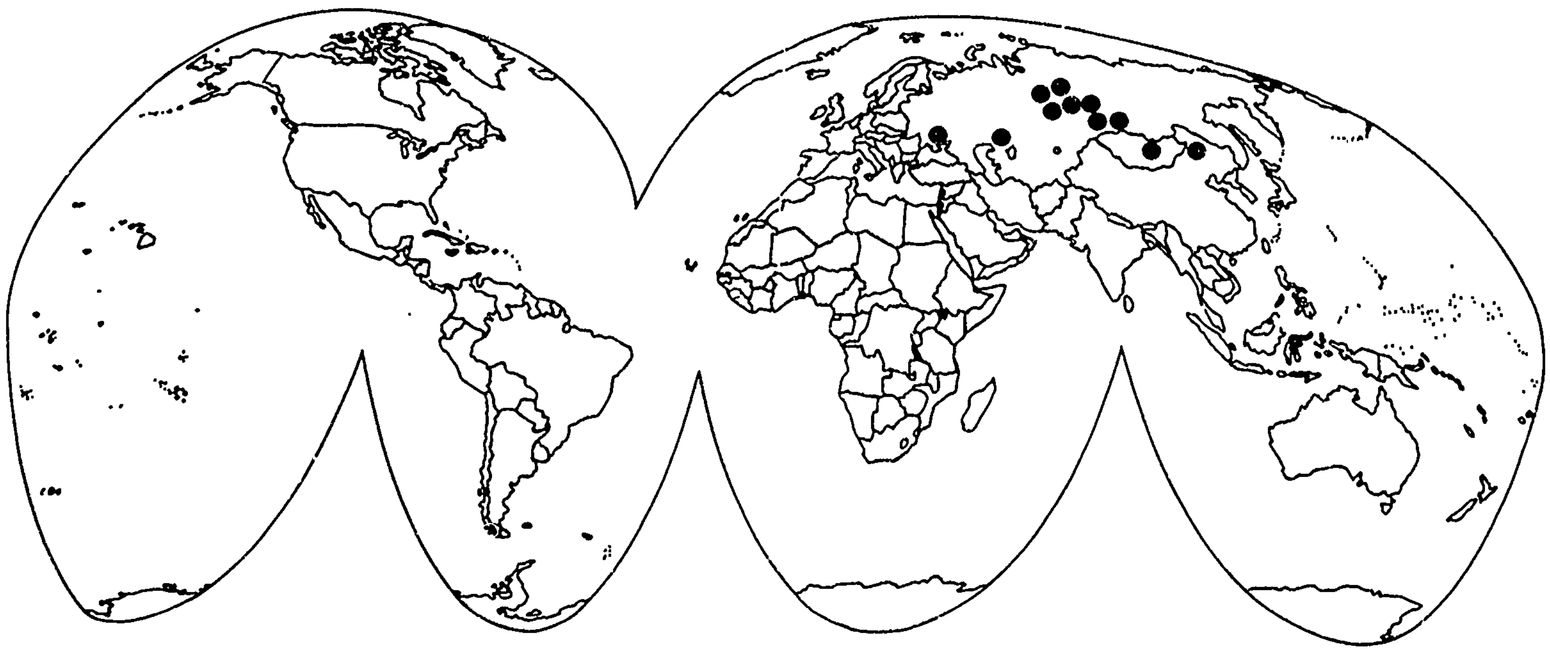


Figure 47. Geographic Distribution of Dermacentor nuttalli.

Hosts: Immatures of D. nuttalli generally parasitize small mammals such as field mice, rats, marmots, hamsters, hares, cats, and dogs. Adults feed predominantly on larger hosts such as horses, cattle, camels, sheep, dogs, and man.

Seasonality: Larvae and nymphs are active from mid-June to mid-August with adults being active primarily in the spring (peaking in mid-May). Splisteser and Tyron (1986) reported high population numbers of adult D. nuttalli in the steppe regions of Mongolia from mid-March to late-May.

Diagnostic Characters: Males with spurs on coxa I parallel or only slightly divergent; dorsal prolongation of spiracular plate narrow, not reaching edge of scutum; external spurs of coxa IV short, not protruding beyond the edge of the coxa; festoons of similar size; females have no internal spurs on coxa IV; ventral spurs lacking on basis capituli; cornua absent; strong spurs present on ventral surface of leg segments; palpi protuberant laterally.

Remarks: This species seems to be especially associated with high grasslands. They are generally not found in dense forests, river lowlands, or hilly wooded country. Unfed adults usually overwinter in cracks in the soil, and occasionally in the burrows of rodents. They cease questing and become inactive at temperatures below 10 ^{0}C (50 ^{0}F) (Splisteser and Tyron, 1986).

Dermacentor occidentalis Marx

Pacific Coast Tick

Medical Importance: Dermacentor occidentalis may transmit the agents of tularemia, RMSF and Colorado tick fever; it may also produce tick paralysis.

Distribution: This species (Figs. 48, 49) occurs along the Pacific Coast and inland for several hundred miles from Oregon to the southern tip of California. Hoffmann (1962) also reported this species from the state of Sonora, Mexico.

Hosts: Immatures feed primarily on small mammals with the adults preferring larger domestic animals, deer, and man.

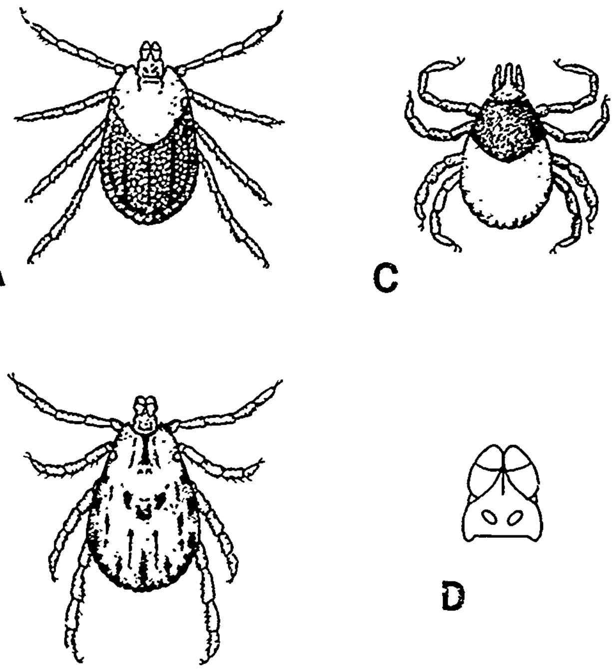


Figure 48. Adult female (a), male (b), nymph (c), and dorsal view of capitulum (d) of Dermacentor occidentalis.

Seasonality: Larvae and nymphs are active in the spring and summer, whereas adults may be active year-round with peaks in April and May.

Diagnostic Characters: Spurs on coxa I parallel or only a little divergent; long cornua; speckled ornamentation, especially on scuta and legs.

Remarks: As the common name implies, D. occidentalis is confined to the Pacific Coast. Adult D. occidentalis are most numerous on hosts during the rainy season. Unfed larvae and nymphs may live up to 4 months each and adults can live up to 11 months. Females lay 3,000-4,000 eggs.

Dermacentor silvarum Olenev

No Common Name

Medical Importance: Dermacentor silvarum is a vector of the Siberian tick typhus rickettsia in the far eastern areas of

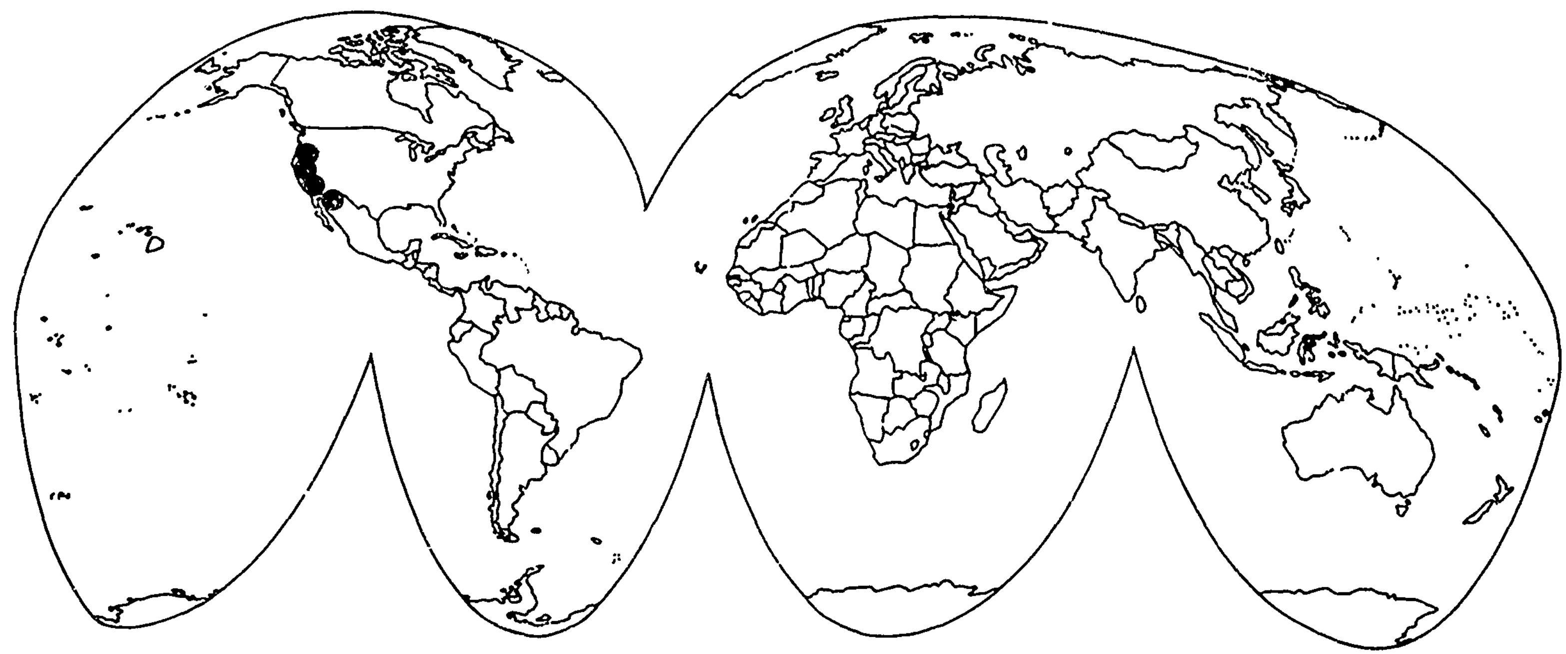


Figure 49. Geographic Distribution of *Dermacentor occidentalis*.

the Soviet Union and northern Mongolia, as well as viruses in the tick-borne encephalitis complex.

Distribution: This species (Figs. 50, 51) occurs primarily in eastern and far eastern Russia and northern Mongolia. However, it has also been reported from the western USSR, Romania, and Yugoslavia.

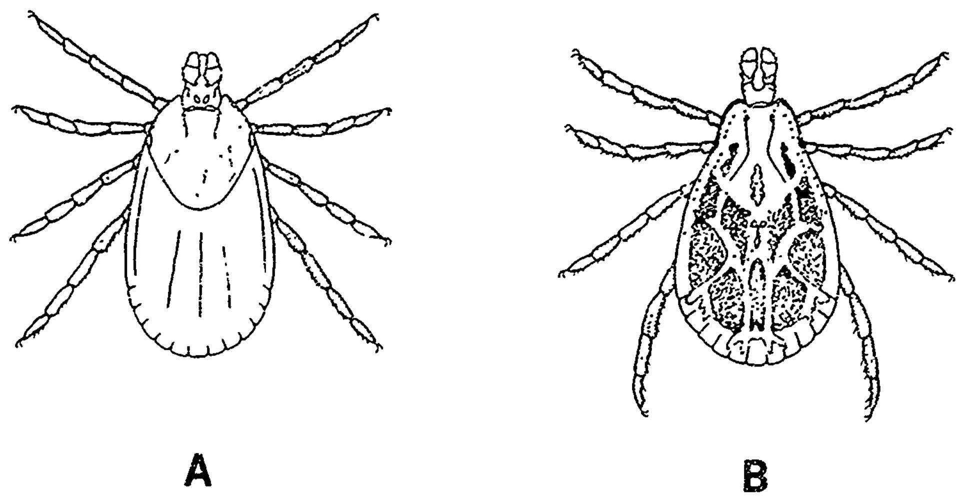


Figure 50. Female (a) and male (b) Dermacentor silvarum.

Hosts: Adult specimens have been collected from man, horses, cattle, sheep, dogs, fox, and deer. Larvae and nymphs feed on numerous species of small mammals.

Seasonality: There is a bimodal pattern of seasonal activity of adult D. silvarum with one peak in early June and the other in early September (Pomerantzev and Serdyukova, 1947). Larvae are most active in June and July and nymphs from June to mid-August.

Diagnostic Characters: Males with spurs on coxa I parallel or only slightly divergent; trochanter I with prominent dorsal spur; dorsal prolongation of spiracular plate wide and reaching to the edge of the scutum; females have coxa IV without internal spurs; ventral spurs lacking on basis capituli; cornua present; genital opening with wing-like lateral extensions; external spur of coxa IV reaches beyond posterior margin of coxa.

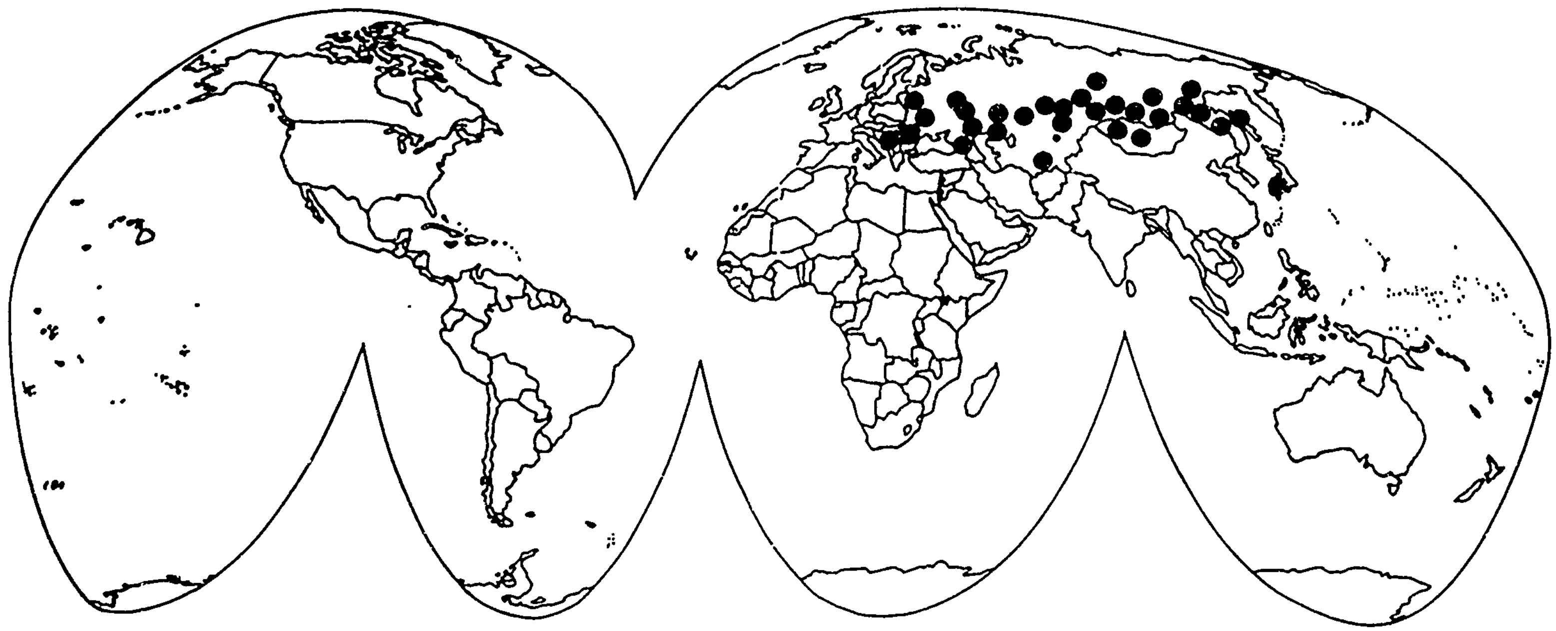


Figure 51. Geographic Distribution of Dermacentor silvarum.

Remarks: Dermacentor silvarum is an inhabitant of forest steppe zones, and is most numerous in birch-aspen marshes, glades in mixed forests, cultivated areas in taiga forests, and other localized dense shrub areas and secondary growth forest.

Dermacentor variabilis (Say)

American Dog Tick

Medical Importance: The American dog tick is one of the most medically important ticks in the U.S.; it is the primary vector of RMSF in the East. It also transmits tularemia and may cause tick paralysis.

Distribution: This species (Figs. 52, 53) occurs throughout the U.S. except in parts of the Rocky Mountain region. It is also established in Nova Scotia, Manitoba, and Saskatchewan, Canada, and has been reported in Mexico from the following states: Chiapas, Gunajuato, Hidalgo, Oaxaca, Puebla, San Luis Potosi, Sonora, Tamaulipas, and Yucatan.

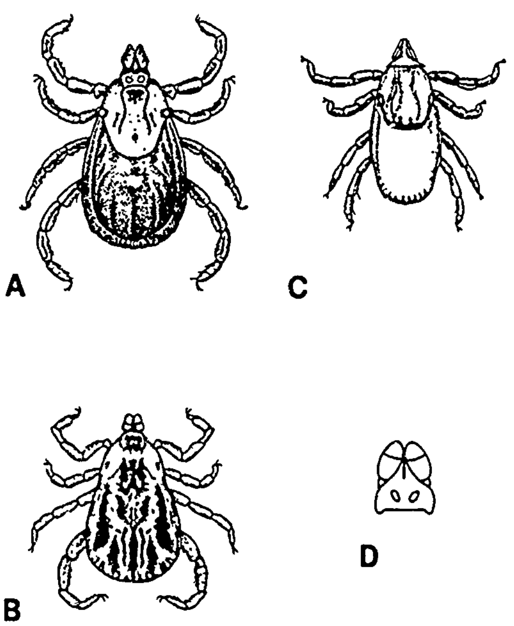


Figure 52. Adult female (a), male (b), nymph (c), and dorsal view of capitulum (d) of Dermacentor variabilis.

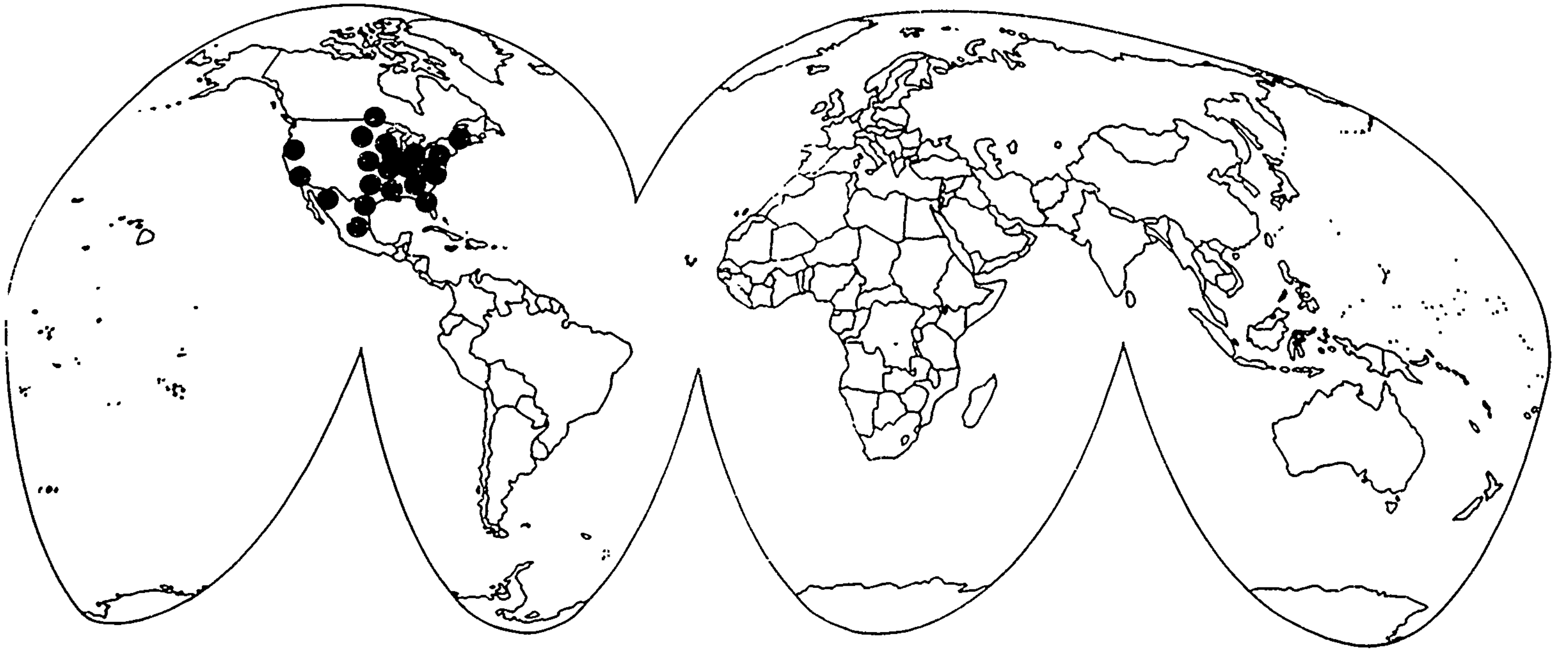


Figure 53. Geographic Distribution of *Dermacentor variabilis*.

Hosts: Immatures feed primarily on small mammals (particularly rodents), and adults prefer the domestic dog. However, adult D. variabilis will readily bite humans.

Seasonality: Adults are active from about mid-April to early September; nymphs predominate from June to early September and larvae are active from about late March through July.

Diagnostic Characters: Spurs on coxa I parallel or only a little divergent; short cornua; spiracular plate with goblets very numerous and small.

Remarks: Since D. variabilis is the principal vector of RMSF in the central and eastern U.S., it should be avoided whenever possible. One important mode of transmission of RMSF is by deticking dogs. Hand-picking infected D. variabilis from dogs is dangerous because infected tick secretions on the hands may be transmitted through contact with the eyes, mucous membranes, etc. Unfed larvae may live up to 15 months, nymphs 20 months, and adults up to 30 months or longer. Females deposit 4,000-6,500 eggs.

The Genus Ixodes

MORPHOLOGICAL CHARACTERISTICS OF THE GENUS IXODES

Inornate ticks; eyes and festoons absent; anal groove curving around the anus anteriorly; venter of males covered with seven nonprojecting, armor-like plates; sexual dimorphism much pronounced, especially regarding the capitulum.

Ixodes dammini Spielman, Clifford, Piesman and Corwin

Dammin's Northeastern Deer Ixodid

Medical Importance: Ixodes dammini transmits the causative agent of Lyme disease in the New England and midwestern areas of the U.S. and has also been incriminated as a vector of the protozoan, Babesia microti, on Nantucket Island, Massachusetts.

Distribution: This species (Figs. 54, 55) occurs in the New England states and New York, south into New Jersey, Virginia, and Maryland; there are also established populations of I. dammini in Wisconsin and Minnesota as well as Ontario, Canada. There have been recent reports (1987-88) of I. dammini from Michigan, Iowa, Illinois, and Indiana; Spielman et al. (1985) proposed that the species is extending its range.

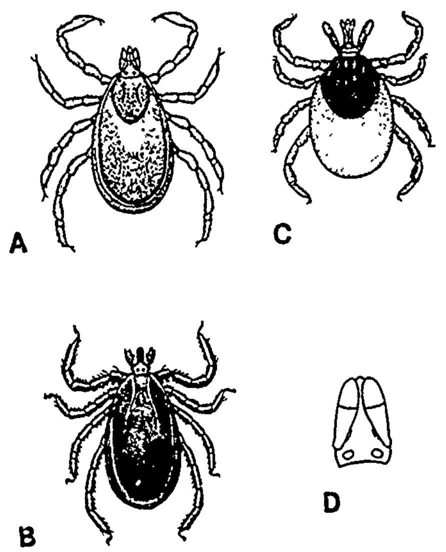


Figure 54. Adult female (a), male (b), nymph (c), and dorsal view of capitulum (d) of Ixodes dammini.

Hosts: Immatures feed on a wide variety of small mammals (especially rodents), birds, deer, dogs and man. Adults feed primarily on deer.

Seasonality: Larvae are active from July through September, nymphs are active from May through July, and adults are most active in the fall, winter, and early spring.

Diagnostic Characters: Very similar to I. scapularis, but the adult female I. dammini possess a shorter and broader internal spur on coxa I and the auriculae are more pronounced and protruding; male I. dammini spiracular plates are distinctly shorter than those of I. scapularis.

Remarks: In contrast to nymphal I. scapularis, I. dammini nymphs bite people aggressively. This behavioral difference is very important in the epidemiology of Lyme disease.

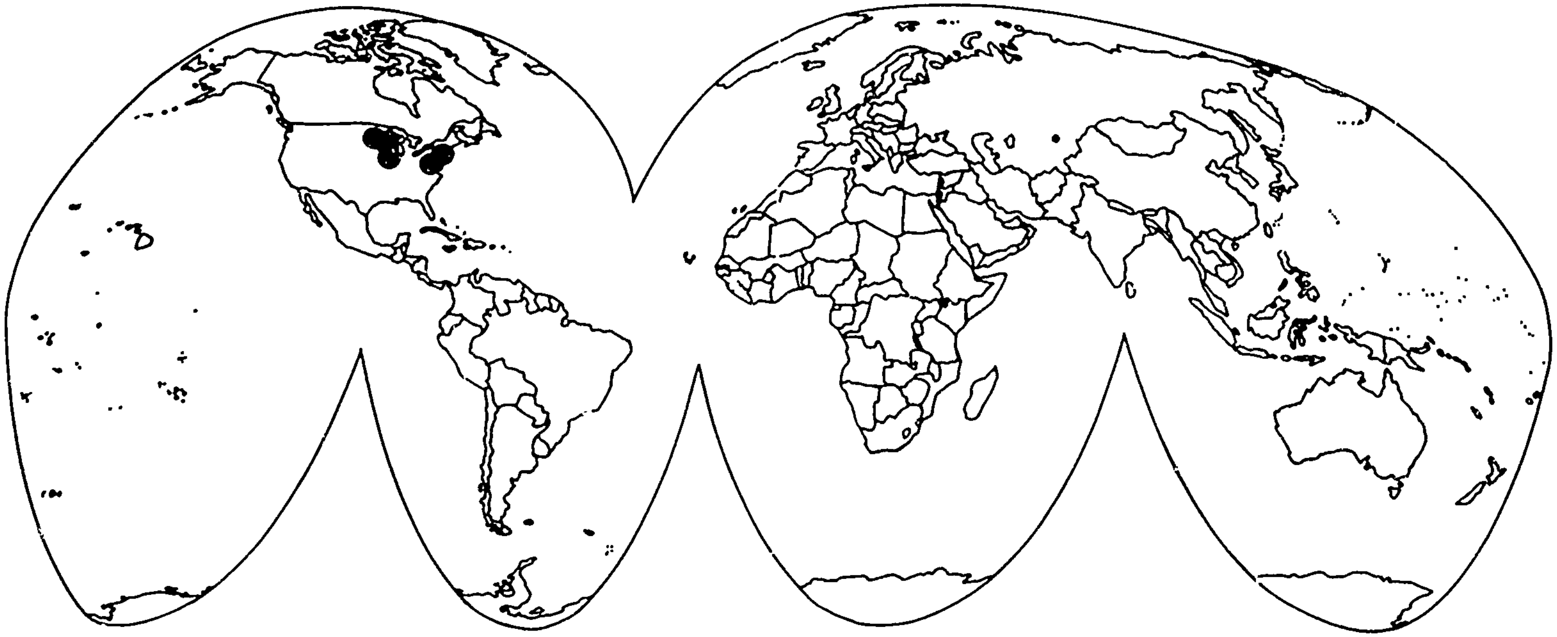


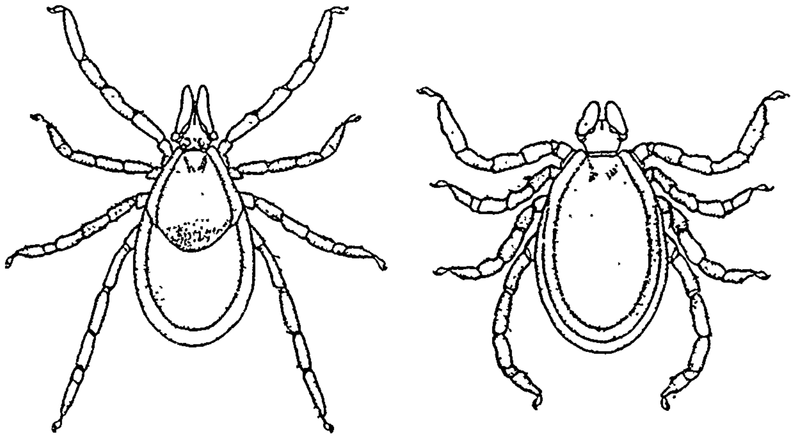
Figure 55. Geographic Distribution of <u>Ixodes</u> <u>dammini</u>.

Ixodes holocyclus Neumann

The Australian Paralysis Tick

Medical Importance: *Ixodes holocyclus* is the primary cause of tick paralysis cases in Australia.

Distribution: This species (Figs. 56, 57) occurs primarily in New Guinea and along the eastern coastal areas of Australia.



A B

Figure 56. Female (a) and male (b) *Ixodes holocyclus*.

Hosts: *Ixodes holocyclus* parasitizes man, other mammals, and birds; it seems to especially prefer sheep, cattle, dogs, cats, and bandicoots.

Seasonality: This species is active in the warmer months of the year.

Diagnostic Characters: Anal grooves curving towards each other in the anterior midline where they meet (females) or nearly meet (males); males with cervical grooves short; legs I and IV reddish with barred appearance; legs II and III yellowish; coxae contiguous, external spur on coxa I the largest; females with scutum broadest posterior to middle; cervical grooves short and superficial; numerous punctations of varying sizes; coxae large, trapezoid, longer than broad; external spurs present on coxae I-IV, that on coxa I being the largest.

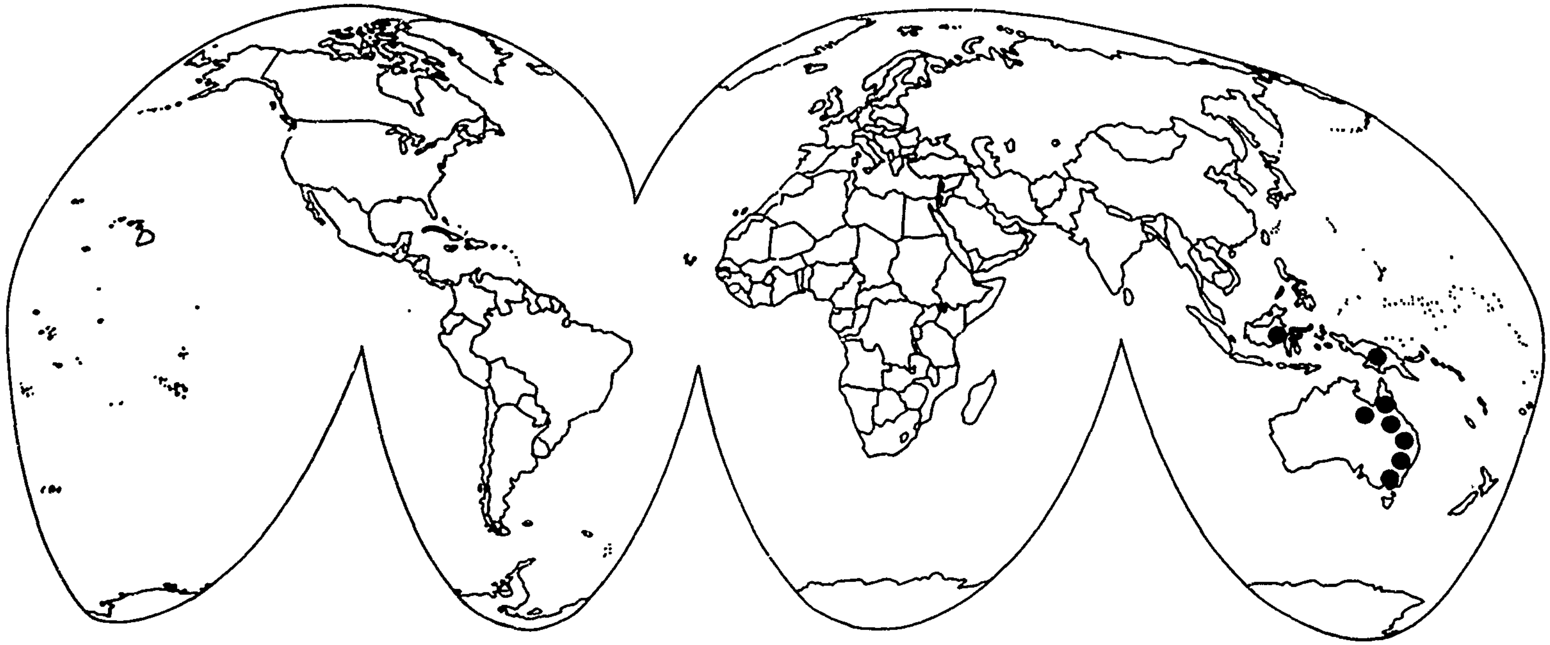


Figure 57. Geographic Distribution of Ixodes holocyclus.

Remarks: This species occurs primarily in the heavily vegetated rain forest areas of eastern coastal Australia. The bandicoot is a natural host for I. holocyclus, and bandicoot populations are increasing near urban areas due to control campaigns against dingoes and foxes (Bagnall and Doube, 1975).

Ixodes pacificus Cooley and Kohls

Western Black-legged Tick

Medical Importance: Ixodes pacificus has been shown to be a vector of Lyme disease spirochetes.

Distribution: This species (Figs. 58, 59) occurs along the Pacific coastal margins of British Columbia, Canada, and the U.S., possibly extending into Baja California and other parts of Mexico.

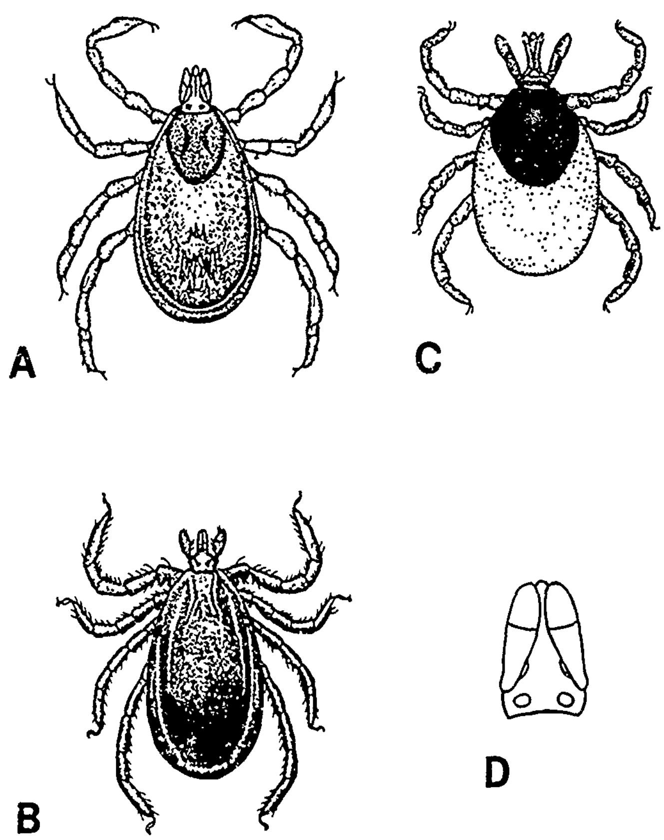


Figure 58. Adult female (a), male (b), nymph (c), and dorsal view of capitulum (d) of Ixodes pacificus.

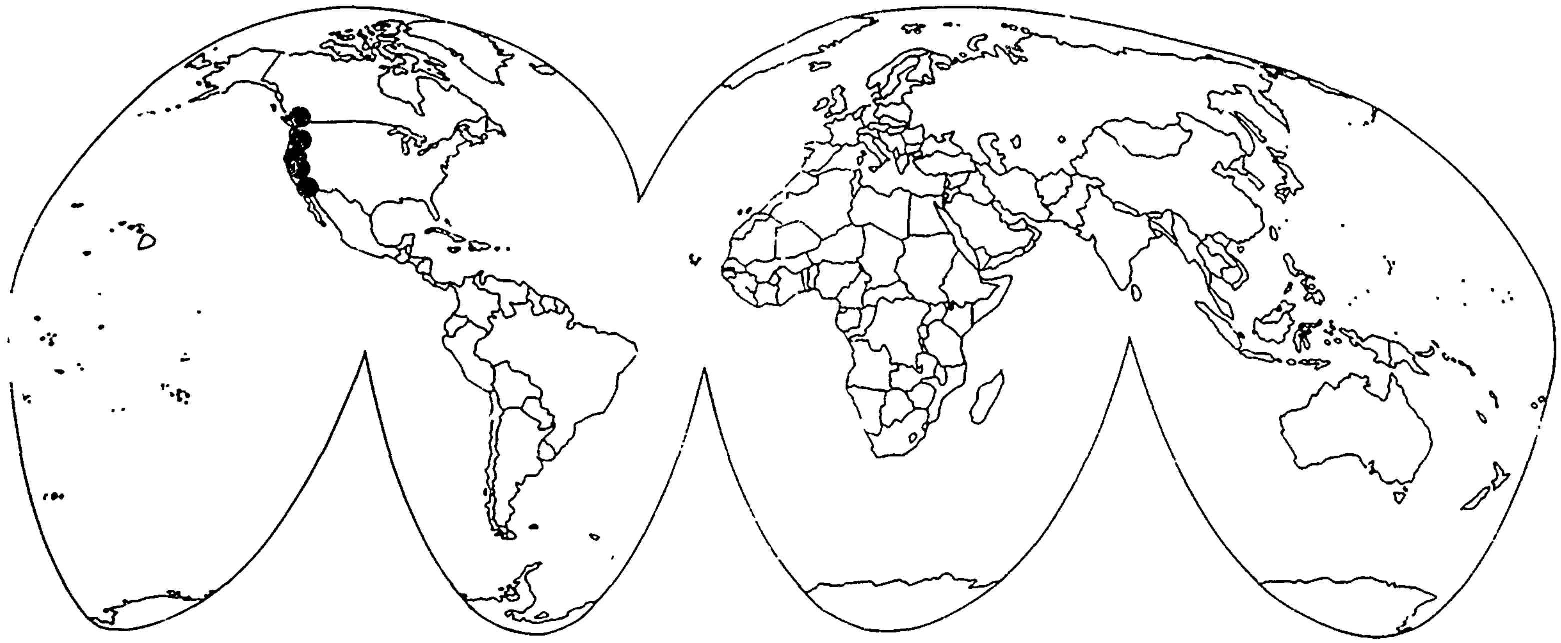


Figure 59. Geographic Distribution of <u>Ixodes</u> <u>pacificus</u>.

Hosts: Ixodes pacificus immatures feed on numerous species of small mammals, birds, and lizards. Adults feed primarily on Columbian black-tailed deer.

Seasonality: Adults are primarily active from fall to late spring with immatures active in the spring and summer.

Diagnostic Characters: Very similar to I. scapularis and I. dammini; cornua absent; male with long, thin internal spur on coxa I; spiracular plate oval (smaller than in I. scapularis).

Remarks: Adult Ixodes pacificus, like I. scapularis and I. dammini, have long mouthparts, enabling them to be especially painful parasites of man. Adults are most abundant in the early spring. Infection rates of I. pacificus with Lyme disease spirochetes are usually in the range of 1-5% compared to rates of 25-75% in I. dammini. This effect may be related to host preferences of the immatures. Ixodes pacificus immatures feed predominantly on the western fence lizard (which is refractory to Borrelia burgdorferi infection). Ixodes dammini larvae feed on white-footed mice which are excellent reservoirs of the spirochetes, producing spirochetemias high enough to infect feeding ticks.

Ixodes persulcatus Schulze

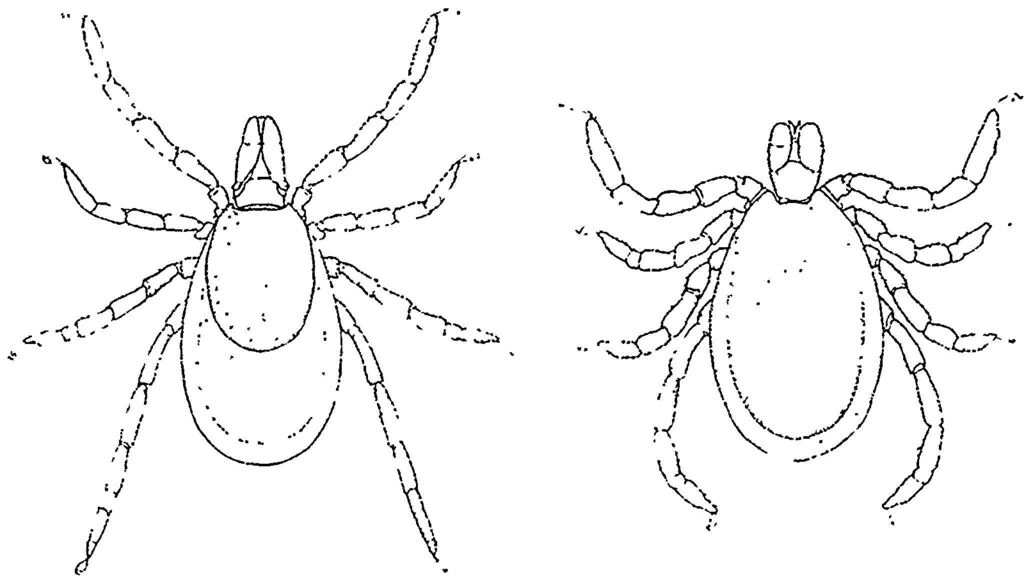
Taiga Tick

Medical Importance: Ixodes persulcatus is a vector of the virus of Russian spring summer encephalitis and the Lyme disease spirochete (in the Far East).

Distribution: This species (Figs. 60, 61) occurs in central and eastern Europe, the USSR, China, and Japan.

Hosts: Larval and nymphal I. persulcatus feed on a wide variety of small forest mammals and birds. The adults parasitize larger wild and domestic mammals. The species readily bites people.

Seasonality: Ixodes persulcatus is found on hosts in the late spring and summer months. Zemskaya (1984) found that, after overwintering, adult I. persulcatus usually resumed their activity in the eastern part of the Russian Plain during the last 10 days of April when upper soil layers warmed up to 5-10 ^{0}C (41 - 50 ^{0}F) and remained active for 65-95 days.



A B

Figure 60. Female (a) and male (b) Ixodes persulcatus.

Diagnostic Characters: Similar to I. ricinus; males with auriculae; basis capituli without dorsal cornua; hypostome with well-developed lateral teeth; punctations evenly distributed over scutum; coxae II-IV without spurs; internal spur on coxa I short; females with cornua absent or poorly developed; auriculae spur-like; hypostome with sharp tip; shallow, poorly developed cervical grooves; external spurs present on coxae II-IV; well-developed internal spur on coxa I.

Remarks: Ixodes persulcatus apparently is more cold hardy than I. ricinus, thus inhabiting harsher, more northern areas. According to Harwood and James (1979) I. persulcatus inhabits small-leaved forests near primary coniferous forests, such as spruce-basswood combinations (commonly referred to as taiga).

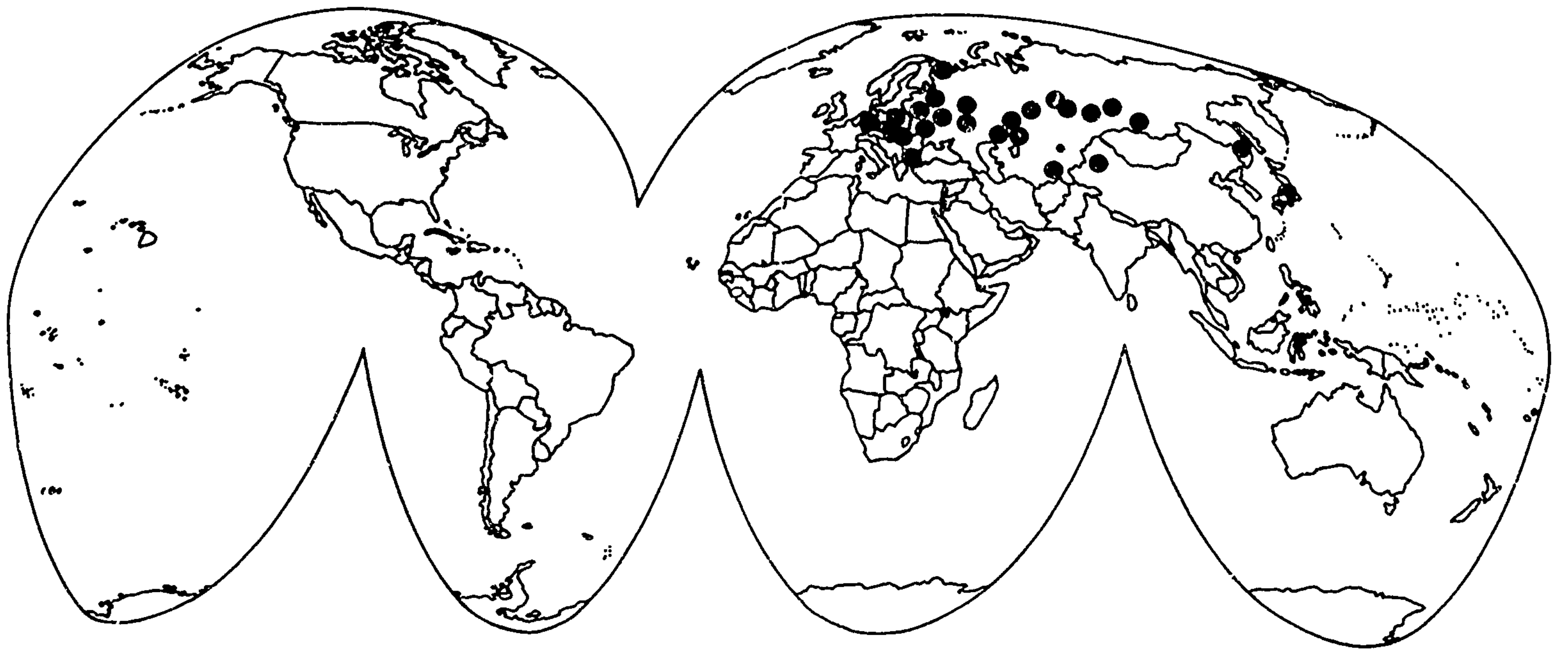


Figure 61. Geographic Distribution of *Ixodes persulcatus*.

Ixodes ricinus (Linnaeus)

European Castor Bean Tick

Medical Importance: This species is the primary vector of Lyme disease spirochetes in Europe and is also known to transmit the viruses of the tick-borne encephalitis complex.

Distribution: Ixodes ricinus (Figs. 62, 63) is common throughout most of Europe, including the British Isles. It is also found in scattered locations in northern Africa and parts of Asia.

A B

Figure 62. Female (a) and male (b) Ixodes ricinus.

Hosts: Immatures have been recorded from lizards, small mammals, and birds, whereas the adults feed mostly on sheep, cattle, dogs, horses, and deer. The adults are avid parasites of humans.

Seasonality: In the temperate regions of its range, I. ricinus is most active in spring and autumn. Two peaks of activity may be observed: one in late March to early June and one from August to October. In northern Africa it is most active in winter (Strickland et al. 1976).

Diagnostic Characters: Very similar to I. dammini, I. pacificus, and I. scapularis; males of I. ricinus possess very large lateral denticles on their hypostomes and the demarcation between the median plate and the anal and adanal

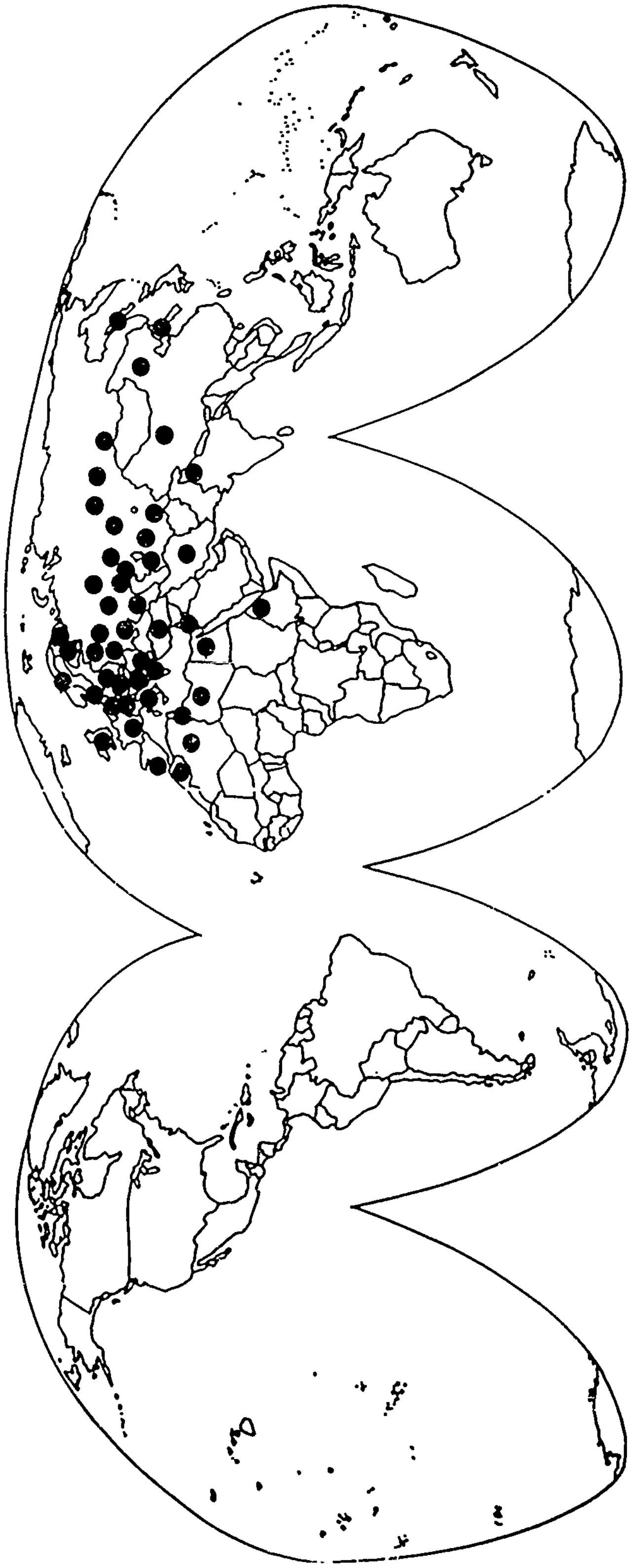


Figure 63. Geographic Distribution of Ixodes ricinus.

plates is a flat-bottomed "V"; females have a narrow hypostome, with lateral denticles widely separated.

Remarks: Ixodes ricinus is one of the most commonly encountered ticks in central and western Europe. As long as 3 years is usually required to complete the life cycle with larvae feeding the 1st year, nymphs the 2nd year, and adults the 3rd year. Females deposit 2,000-3,000 eggs.

Ixodes scapularis Say

Black-legged Tick

Medical Importance: Ixodes scapularis may transmit RMSF to humans and has been found naturally infected with Lyme disease spirochetes. Whether or not it is an efficient natural vector of Lyme disease spirochetes is unknown at this time, but Piesman and Sinksky (1988) demonstrated that I. scapularis can maintain an infection of the spirochetes and transmit them efficiently to hamsters in the laboratory.

Distribution: This species (Figs. 64, 65) occurs in the southern Atlantic Coast states and throughout the South including Texas and Oklahoma. It has also been reported from the Mexican states of Jalisco and Tamaulipas.

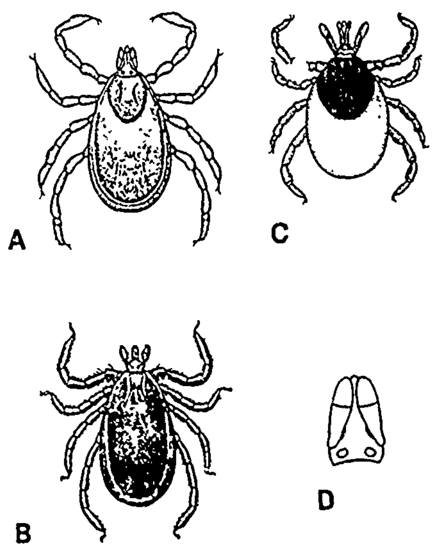


Figure 64. Adult female (a), male (b), nymph (c), and dorsal view of capitulum (d) of Ixodes scapularis.

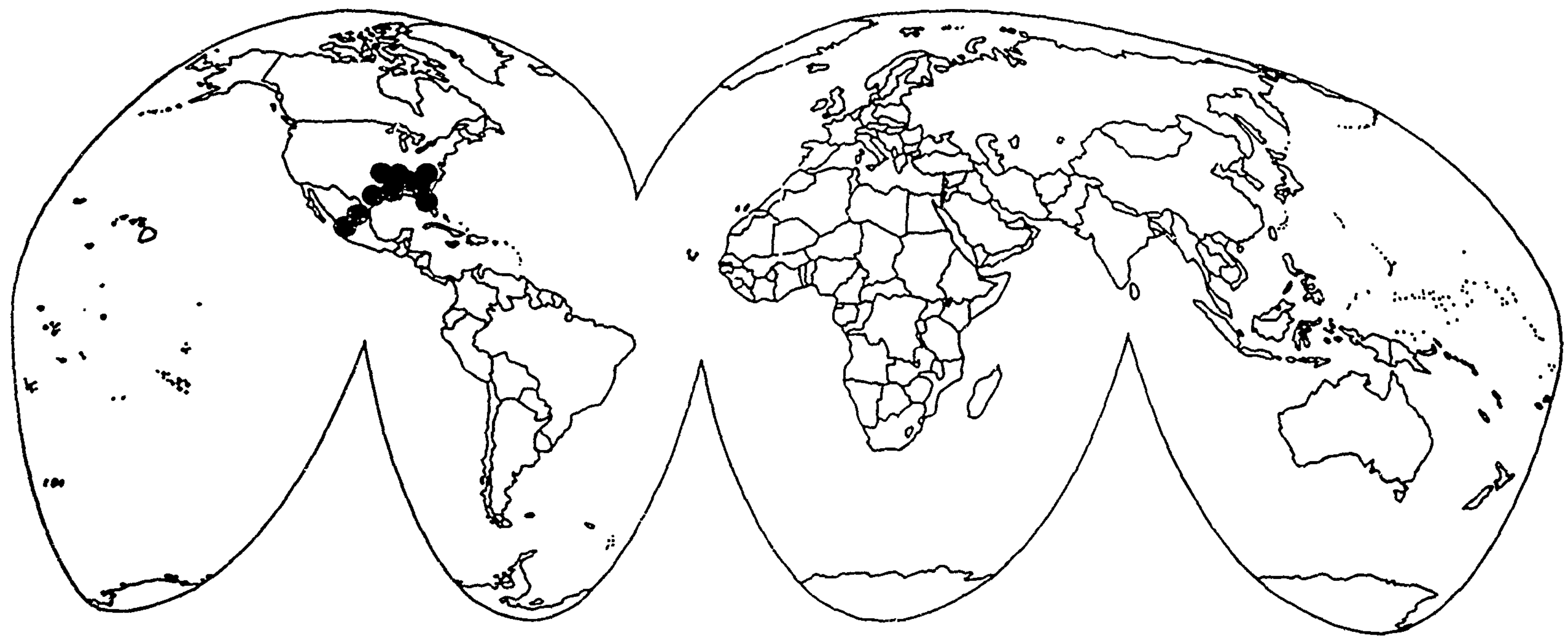


Figure 65. Geographic Distribution of Ixodes scapularis.

Hosts: Immatures feed on lizards and small mammals; adults prefer deer but will bite people. In Mexico, there are additional host records from dogs, cattle, and jaguar.

Seasonality: In the U.S. adults are active in the fall, winter, and spring whereas immatures are active in the spring and summer.

Diagnostic Characters: Very similar to I. dammini and I. pacificus; cornua small, but definite; male with long, thin internal spur on coxa I; spiracular plate elongated.

Remarks: Ixodes scapularis congregates along paths, trails, and roadways in various types of forested areas such as those exhibiting mature pine-hardwoods with dogwood, wild blueberry, huckleberry, and sweetgum. I. scapularis inflicts a painful bite. The majority of hard ticks acquired by persons in the south central and southeastern states in the winter months are of this species.

The Genus Rhipicephalus

MORPHOLOGICAL CHARACTERISTICS OF THE GENUS RHIPICEPHALUS

Usually inornate specimens; basis capituli hexagonal dorsally; eyes and festoons present; coxa I deeply cleft; males with adanal shields and usually accessory shields; spiracular plates comma-shaped.

Rhipicephalus appendiculatus (Neumann)

Brown Ear Tick

Medical Importance: Rhipicephalus appendiculatus is one of several vectors of the boutonneuse fever rickettsia.

Distribution: This species (Figs. 66, 67) occurs throughout southern Africa up to about 10°N Latitude.

Hosts: Cattle primarily (for the adult ticks as well as immatures), but also man, domestic animals, and wild game such as antelope and buffalo.

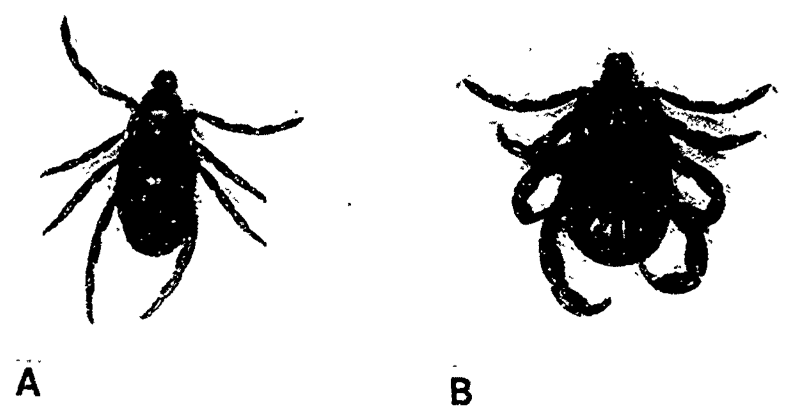


Figure 66. Female (a) and male (b) _Rhipicephalus appendiculatus_ (Specimen provided by Dr. K.Y. Mumcuoglu, Hebrew Univ., Jerusalem)

Seasonality: Larval _R. appendiculatus_ are most abundant on hosts from May-July, whereas nymphs occur on hosts from June-September. Adults are most active from November to March.

Diagnostic Characters: Males with distinctly pointed dorsal projection on coxa I; lateral grooves distinct; scutal punctations scattered, not in rows, few and well spaced centrally; females with eyes flat (not obviously convex); palpi subtriangular; scutum with numerous, widely spaced punctations; lateral grooves superficial, not deep.

Remarks: There may be 1-3 generations of _R. appendiculatus_ occurring annually, depending on the length and number of rainy seasons in their range. This species seems to be especially sensitive to dessication and during a series of dry years this parasite tends to die out. Unfed larvae may survive as long as 10 months, nymphs 15 months, and adults 24 months. Females lay up to 6,000 eggs.

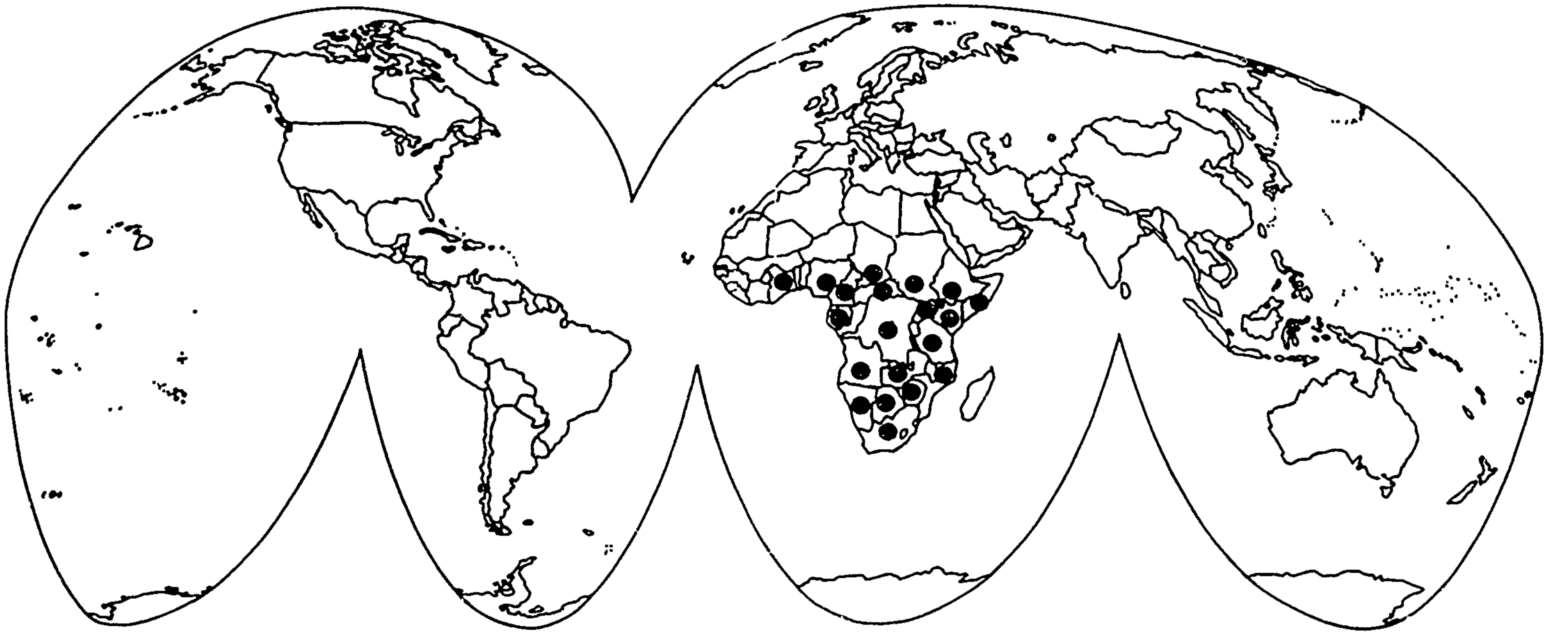


Figure 67. Geographic Distribution of <u>Rhipicephalus</u> <u>appendiculatus</u>.

Rhipicephalus sanguineus (Latreille)

Brown Dog Tick

Medical Importance: Rhipicephalus sanguineus is reported to transmit the agent of RMSF in Mexico and may be a vector of human cases of canine ehrlichiosis. In southern Europe and Africa, the species is a known vector of Rickettsia conorii, the causative agent of boutonneuse fever. Viloria (1954) reported a case of tick paralysis in a dog in Venezuela caused by this species.

Distribution: This species (Figs. 68, 69) is probably the most widely distributed of all ticks, being found almost worldwide. In the Western Hemisphere there are records from most of the U.S. and the southeastern and southwestern parts of Canada. It has been reported from most of Mexico, Argentina, Venezuela, Colombia, Brazil, Nicaragua, Panama, Uruguay, Paraguay, Surinam, British Guiana, French Guiana, Peru, Costa Rica, and the Caribbean islands of Cuba, Jamaica, and the Bahamas. Keirans (1987) reported this species from the Galapagos Islands. It is also widely distributed throughout Eurasia, Africa, and the Australian region.

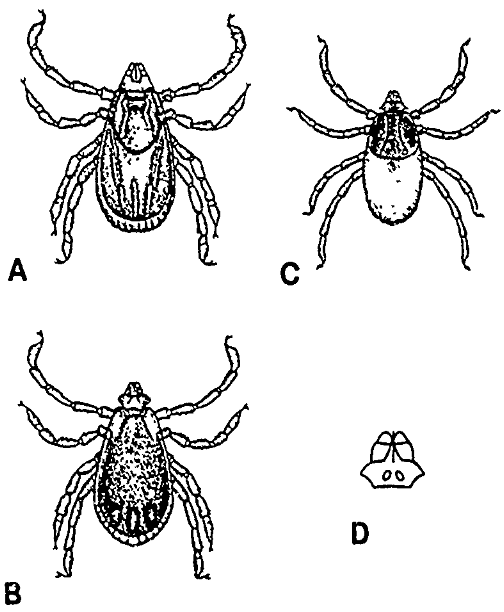


Figure 68. Adult female (a), male (b), nymph (c), and dorsal view of capitulum (d) of Rhipicephalus sanguineus.

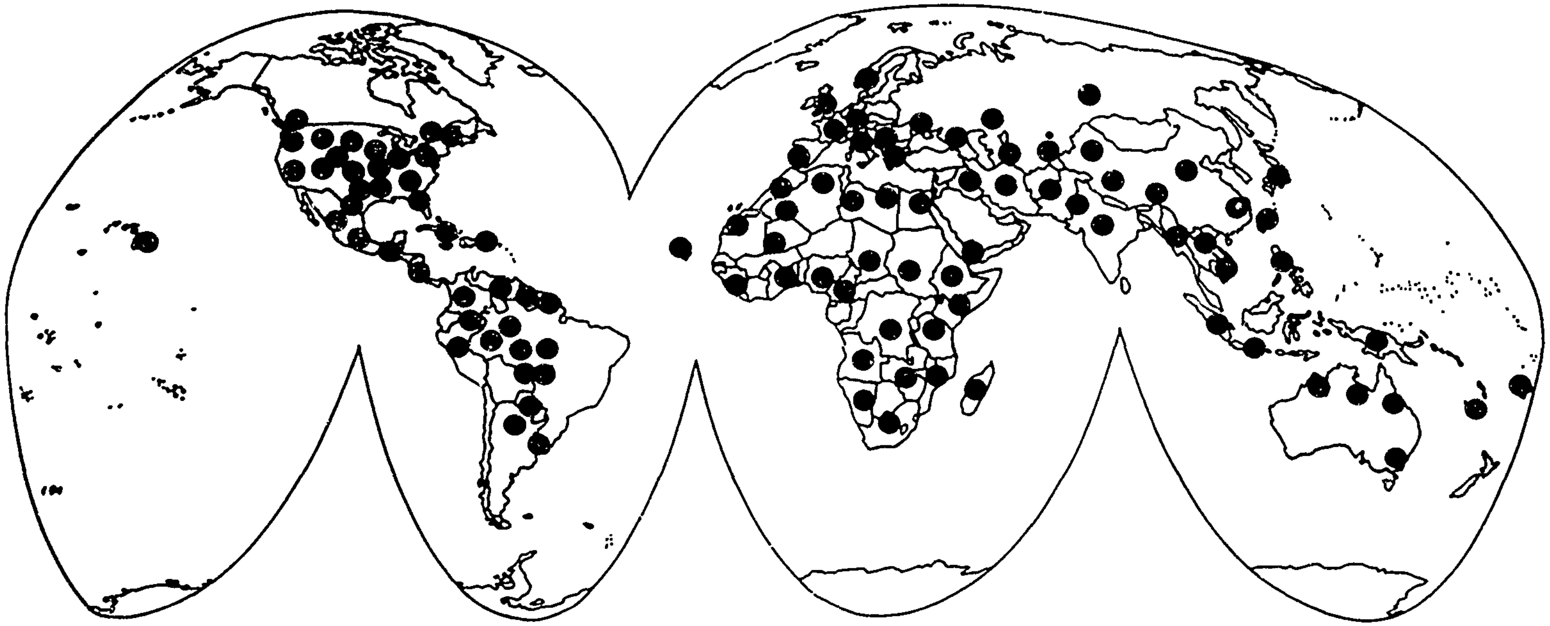


Figure 69. Geographic Distribution of _Rhipicephalus_ _sanguineus_.

Hosts: The dog is the principal host for <u>Rhipicephalus sanguineus</u> although in the immature stages it sometimes attacks numerous other animals. Man has historically only occasionally been bitten by this species in the U.S., but recent evidence indicates that it is becoming more anthropophilic (Goddard, 1989).

Seasonality: <u>Rhipicephalus sanguineus</u> may be active in the warmer parts of its range year-round; however, in temperate zones adults and immatures are primarily active from late spring to early fall.

Diagnostic Characters: Eyes flat; females with moderate to large number of medium sized, noncontiguous punctations; males have coxa I without a distinctly pointed projection; posteromedian and paramedian grooves pronounced, deep, and wide.

Remarks: <u>Rhipicephalus sanguineus</u> is the tick most often found indoors in and around pet bedding areas. This tick has a strong tendency to crawl upward and is often seen climbing the walls of infested houses. <u>Rhipicephalus sanguineus</u> is associated with homes and yards of pet owners and is seldom found out in the middle of a forest or uninhabited area. Unfed larvae may survive as long as 8 1/2 months, nymphs 6 months, and adults 19 months. Females usually lay 2,000-4,000 eggs.

<u>DEFINITION OF TERMS USED FOR DIAGNOSTIC CHARACTERS</u> (Figs. 70, 71)

Accessory Shields: Paired, projecting, sclerotized structures on the venter, lateral to the adanal shields in males of some species of hard ticks.

Adanal Shields: Paired, projecting, sclerotized structures on the venter, lateral to the anus in males of some hard tick species.

Anterior: Toward the front end.

Auriculae: Paired extensions or "ears" at the sides of the venter of the basis capituli; may be like "horns," flattened extensions, or ridges that are mild or sometimes absent.

Basis Capitulum: Basal portion of capitulum on which the mouthparts are attached. May be of various shapes (hexagonal, rectangular, subtriangular, etc.) in hard ticks.

Bifid: Clearly divided into 2 parts.

Cervical Grooves: Pair of grooves in the scutum extending posteriorly from the inner angles of the scapulae.

Cheeks: Paired flaps at the sides of the mouthparts, which may be either fixed or movable.

Chelicerae: Paired structures lying dorsally to the hypostome, which complete the cylindrical mouthparts that are inserted when the tick feeds.

Cornua: Small projections extending from the dorsal, posterolateral angles of basis capituli.

Coxae: (sing. Coxa) Small sclerotized plates on the venter representing the first segment of the leg to which the trochanters are movably attached. From anterior to posterior, the coxae are designated by Roman numerals I, II, III, and IV. Bifid coxae are those that are cleft, divided, or forked.

Dentition: Refers to the presence of denticles (teeth) on the ventral side of the hypostome. The numerical arrangement of the rows of denticles is expressed by dentition formulas. Thus, dentition 3/3 means that there are three longitudinal rows of denticles on each side of the median line of the hypostome.

Discs: Limited areas or spots which are the external evidence of modification of the structure of the body wall at the points of attachment of the dorso-ventral muscles. They are usually in a symmetrical pattern and may or may not be evident on the underside.

Dorsal: Pertaining to the back or top of the body.

Dorsal Humps: Humps or elevations on the dorsal walls of the articles of the legs but not including the subapical dorsal protuberance.

Eyes: Eyes, when present, are located on the edges of the scutum about even with the site of leg I attachment in hard ticks. Soft ticks may have eyes on their lateral margins near Coxae I and II.

Festoons: Uniform rectangular areas, separated by distinct grooves, located on the posterior margin of most genera of hard ticks. Very distinct areas in unengorged specimens but may not be visible in fully engorged females.

Goblets: Small, round structures located in the spiracular plate.

Grooves: Linear depressions or furrows, primarily on the ventral surface.

Hood: The anterior projection of the integument in soft ticks above and covering the mouthparts.

Hypostome: Median ventral structure of the mouthparts that lies parallel to and between the palps. It bears the "recurved teeth" or denticles.

Inornate: Absence of a color pattern on the scutum.

Integument: Outer covering or cuticle of the tick's body.

Lateral Groove: The groove running along the sides of the scutum in both sexes.

Mammillae: Elevations of various forms found on the integument in Ornithodoros species.

Micromammillae: Very small, rounded elevations of nearly uniform size on the surface of the legs and sometimes the capitulum.

Ornate: Definite enamel-like color pattern superimposed on the base color of the integument in hard ticks.

Palps: (Pl. palpi) Paired articulated appendages located to the front and sides of the basis capituli and lying parallel with the hypostome.

Posterior: Toward the rear end.

Protuberance: Any elevation above the surface of the integument.

Punctuations: Pits in the surface of the cuticle, frequently present on the scutum and sometimes on the basis capituli of some hard tick species.

Scapula: (Pl. scapulae) Anterior angles or "shoulders" of the scutum.

Scutum: The sclerotized dorsal plate posterior to the capitulum in hard ticks. It covers almost the entire dorsal surface in the male and about one-half the dorsal surface in the unengorged female.

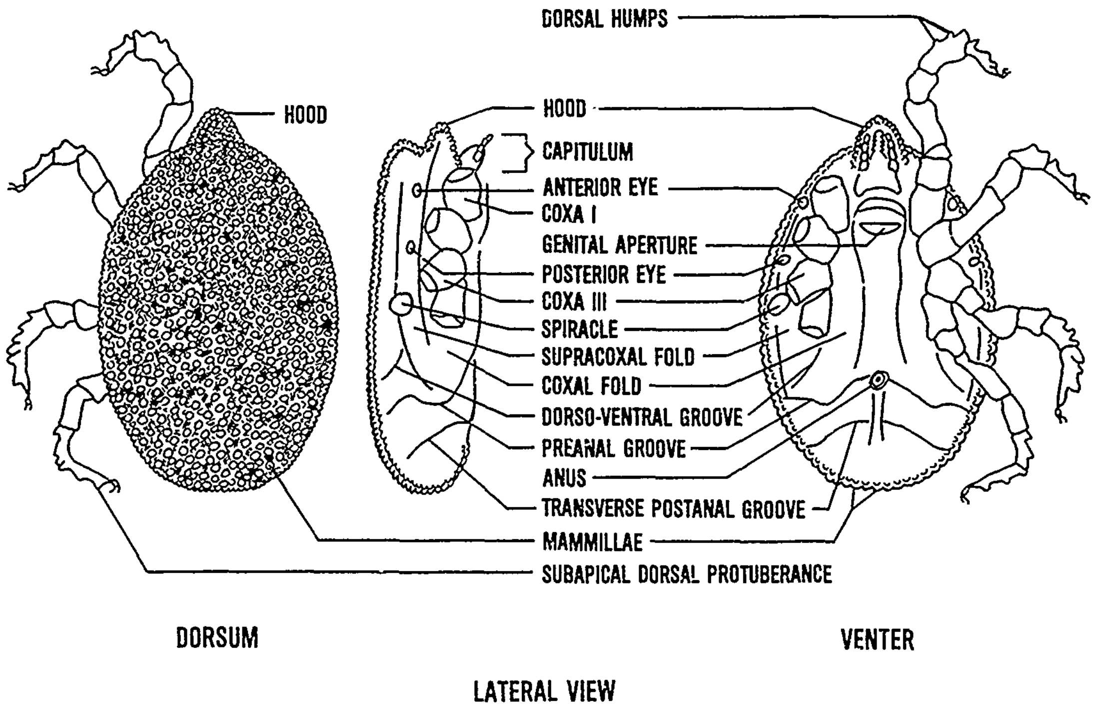
Spiracular plates: Paired plates located ventrolaterally that are the external openings of the respiratory system.

Spurs: Coxal spurs are projections from tne posterior surface or posterior margin of the coxae; they may be rounded or pointed, small or large. Projections on the median side are called internal spurs; those on the lateral side are called external spurs.

Subapical Dorsal Protuberance: The protuberance sometimes present distal of the Haller's organ (on tarsus) and when much drawn out produces the bifurcate termination of the tarsus. Distinctly different from the dorsal humps.

Tarsus: (Pl. tarsi) The terminal leg segment.

HYPOTHETICAL SOFT TICKS WITH KEY CHARACTERS LABELED



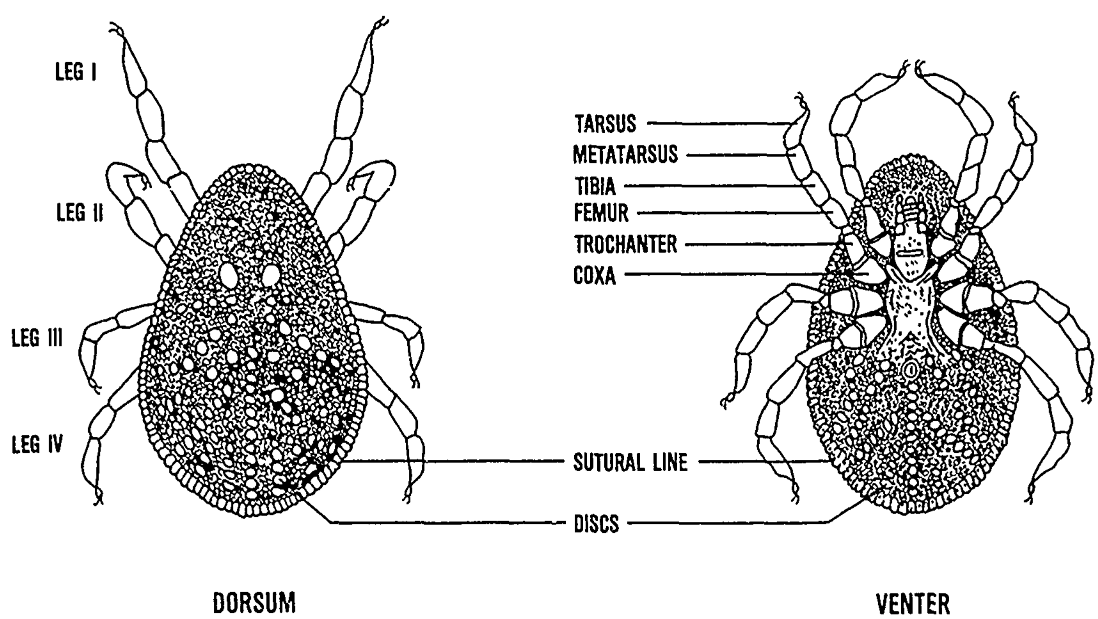


Figure 70. Diagnostic characters of soft ticks (from Strickland et al. 1976).

HYPOTHETICAL MALE AND FEMALE HARD TICKS WITH KEY MORPHOLOGICAL CHARACTERS LABELED

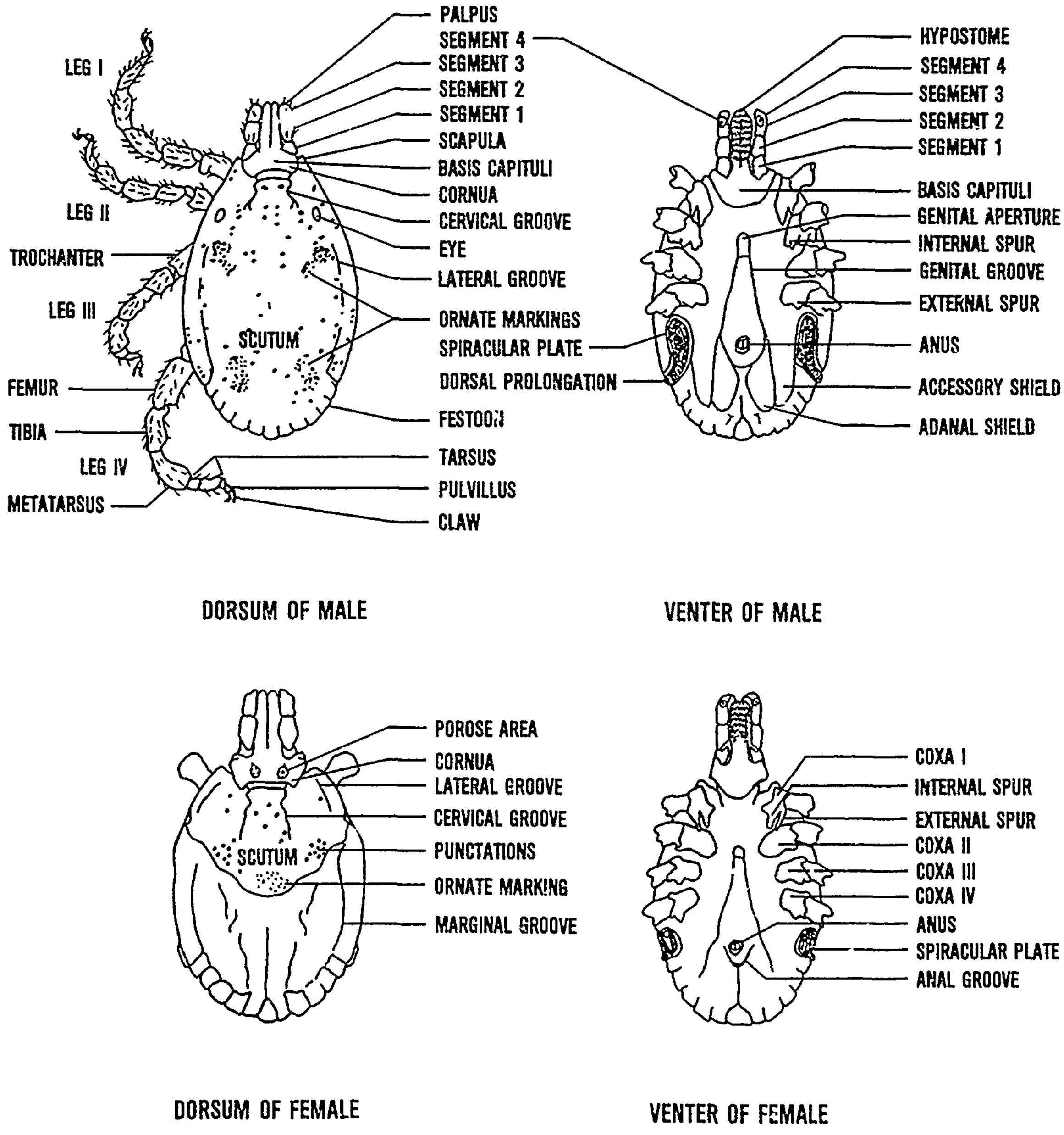


Figure 71. Diagnostic characters of hard ticks (from Strickland et al. 1976).

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APPENDIX

SPECIMEN PHOTOGRAPHS

Female and male Amblyomma americanum.

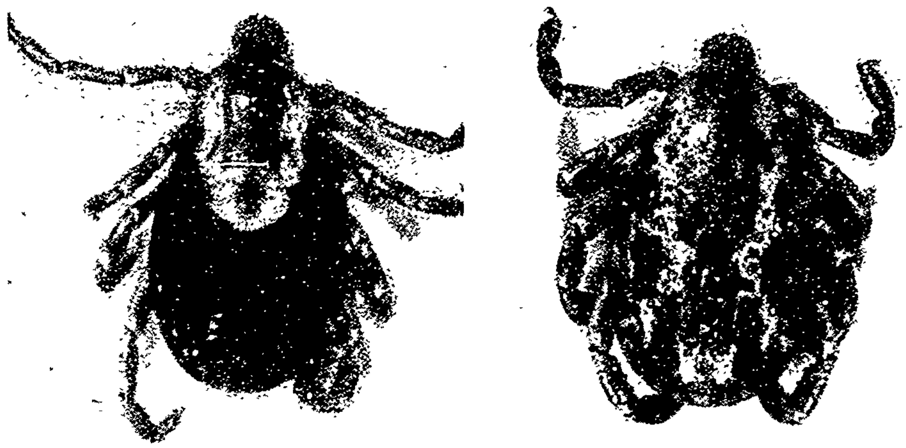
Female and male Amblyomma cajennense.

Female and male Amblyomma hebraeum.

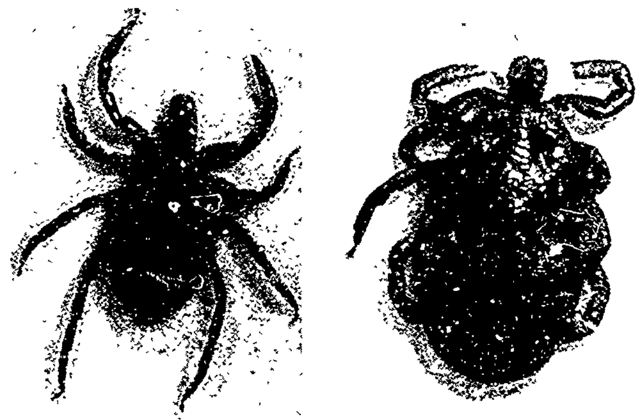
Female and male _Haemaphysalis_ _leachi_.

Female and male _Hyalomma_ _marginatum_.
(Specimen provided by Dr. B. Fivaz,
Rhodes Univ., Grahamstown, South Africa)

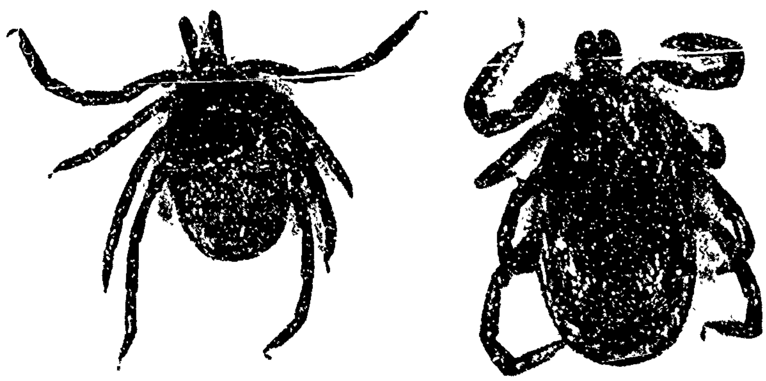
Female and male _Dermacentor_ _andersoni_.



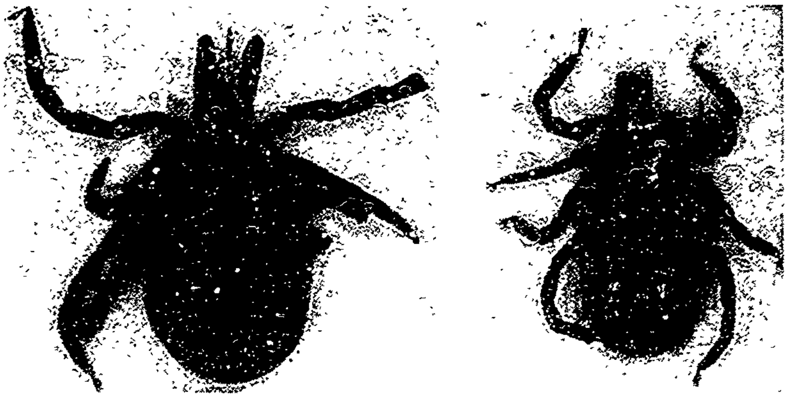
Female and male Dermacentor variabilis.



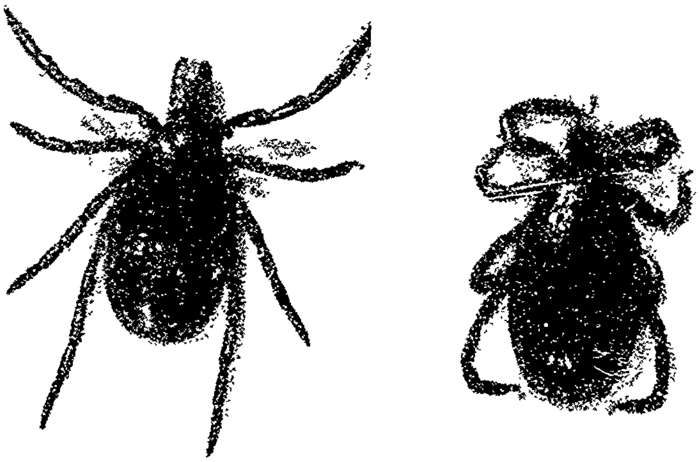
Female and male Ixodes dammini.



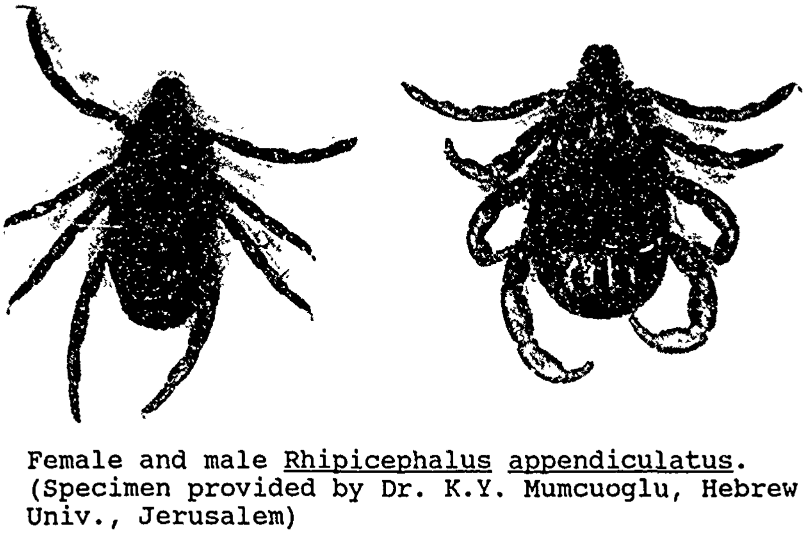
Female and male Ixodes pacificus.



Female and male *Ixodes ricinus*.



Female and male *Ixodes scapularis*.



Female and male *Rhipicephalus appendiculatus*.
(Specimen provided by Dr. K.Y. Mumcuoglu, Hebrew Univ., Jerusalem)

Male and female Rhipicephalus sanguineus.