Insects of Virginia No. 13

TICKS OF VIRGINIA
(Acari: Metastigmata)

by

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ABSTRACT

Thirteen species of ticks, representing five genera of the Ixodidae, are known from Virginia. In addition, two other species (*Ornithodoros kelleyi*, a species of the Argasidae, and the ixodid *Haemaphysalis chordeilis*) are believed to occur in the state. The medical and veterinary importance of ticks, their life cycles, and their morphology are reviewed. Collection methods and techniques of study are described. Procedures for control of ticks, concerned primarily with protection of people and their pets, are discussed. Taxonomic keys to all of the life stages and illustrations of the female, nymph, and larva of each species are provided. Diagnostic descriptions are also given for each species. Finally, host associations, seasonal activity, known distribution, Virginia records, and disease associations are reviewed in each case.

ACKNOWLEDGMENTS

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INTRODUCTION

Ticks are parasitic, blood sucking members of the Acari associated with virtually all terrestrial vertebrates except Amphibia. Thirteen species are known to occur in Virginia, and two others are suspected to occur here. The American Dog Tick, *Dermacentor variabilis,* and the Lone Star Tick, *Amblyomma americanum,* are important vectors of disease and inflict serious physical injury. The Brown Dog Tick, *Rhipicephalus sanguineus,* is a major pest of dogs. Other species are less directly important to man but are harmful to wildlife and are implicated in the transmission of disease in nature.

The work reported here was undertaken to bring together the diverse technical knowledge of Virginia ticks. Taxonomic keys, diagnostic descriptions, illustrations, and pertinent information on the bionomics of each species are presented. It is hoped that this bulletin will provide a practical reference for physicians, veterinarians, health officials, county extension agents, students, and others concerned with Virginia ticks.

BIOLOGY

The life cycle of hard ticks (Ixodidae) includes three active life stages: larva, nymph, and adult. Sexual dimorphism is evident only in the adult stage. In the three-host life cycle pattern, each stage feeds on a different host; this is the most common pattern among Virginia ticks. The 6-legged larvae may seek animal hosts shortly after hatching, or may overwinter by diapausing in an unfed state. Feeding requires several days, with marked variability among species and even among individuals of the same species occurring on different hosts. Engorged larvae, having consumed many times their original weight in host blood, drop off the host and shelter in vegetation, forest or meadow floor, or in nests or burrows. Engorged ticks remain quiescent while digesting their meals. After new cuticle growth is completed, the old cuticle is shed and the 8-legged nymph emerges. The feeding behavior of the nymph resembles that of the larvae. The unfed nymphs seek hosts, feed for several days, drop off after repletion, then metamorphose into adults. Unfed adults are sexually distinct, as described below. Both males and females seek hosts independently. In most species of *Ixodes,* mating occurs in nests or vegetation, and the male does not feed. In others (e.g., *Ixodes scapularis*), both sexes feed. In other genera, mating occurs only on the host and then only after several days of continuous feeding. A female pheromone regulates mating. In *Amblyomma maculatum,* an aggregation pheromone (produced by the male) regulates attachment and feeding of other individuals. In all hard ticks, except species of *Ixodes,* mating must occur before the female will feed to repletion. Following engorgement, the replete female drops off, shelters in a protected location and lays eggs. The entire egg mass, involving thousands of eggs, is deposited over a period of 2 or 3 weeks. The spent female dies after the termination of oviposition.

Some ixodid species (e.g., *Dermacentor albipictus*) have a one-host life cycle pattern. In this case, engorged larvae and nymphs do not drop off the host after feeding; they remain attached, molt, and the subsequent stages reattach and feed. The adults then mate on the host, and only engorged females drop off to lay eggs on the ground.

The life cycle of soft ticks (Argasidae) includes the larva, nymphal stages, and the adult. Sexual dimorphism is slight, and occurs only in adults. Feeding is rapid and usually is completed in less than 1 hour (in some species, larvae feed for days or even weeks). Molting occurs off the host, usually in animal nests or burrows. Mating usually occurs off the host. After each feeding, females deposit small egg clutches containing up to several hundred eggs. Males and females may feed and mate several times, and females may lay eggs after each feeding.

MEDICAL AND VETERINARY IMPORTANCE

Few ectoparasites are as harmful to man and other animals as the tick. Rocky Mountain Spotted Fever (RMSF) is the most serious tick-borne disease in the United States. Following a nationwide decline during the 1950's, incidences of this disease have dramatically increased, contrary to the general trend for vector-borne diseases. North Carolina and Virginia ranked first and second, respectively, in numbers of cases of this disease among the states reporting. In 1969, Virginia had the highest incidence rate (1.94/100,000 population) of any state in the United States, with 91 cases and 4 deaths; in 1976, 100 cases and 4 deaths were recorded. Despite the availability of vaccines and highly effective antibiotics against the causative agent, *Rickettsia rickettsii,* fatality rates from RMSF have remained at approximately 7% of all cases reported (Hattwick et al., 1976). In the Southeastern United States, the maximum number of cases have been reported to occur in July. Changing patterns of land use, life styles, occupations, and the redistribution of population may have contributed to the increased incidence of the disease. Cropland decreased from 6.0 million acres in 1942 to 3.2 million in 1959 (Larson and Bryan, 1959). In the Piedmont physiographic province, a large proportion of the cases occur because much of this land has reverted to forest which is kept in an early seral state by intensive logging. These small woodlots, interspersed with logging trails, rural roads, and numerous clearings provide ideal habitats for the American Dog Tick, *Dermacentor variabilis,* the major vector of RMSF. Suburbanization, at least in

its early stages, is also thought to have contributed to increased incidences of RMSF, because it exposes populations daily to tick infested habitats (Atwood et al., 1965).

RMSF is a zoonotic disease, i.e., capable of spreading in wildlife without involving man. Ticks, which are apparently unharmed by the rickettsia, are the only known reservoir. The rickettsia is perpetuated in the overwintering tick population. Infected wild mammals act as amplifiers of the disease by providing a common blood pool for transfer of pathogens from infected to uninfected ticks feeding on the same rickettsemic animal. Meadow voles and white footed mice, hosts of the vector tick, are important in the transmission of the disease to man because these rodents are found in close proximity to human habitation. The limited range of these small mammals tends to localize the area of the disease. Another important factor affecting the number of human cases of RMSF is the natural incidence of infection in the vector ticks. Walter Reed Army Medical Center (Sonenshine et al., 1966) estimated the incidence of infection in ticks (*D. variabilis*) collected near Montpelier, Virginia at 4.9% in 1964 and 5.1% in 1965. Estimates for the same species collected from animals in Arkansas, Alabama, Tennessee, and South Carolins ranged from 4.9% to 10.4% (Burgdorfer, 1975). However, Price (1954) reported only 0.4% infection among Maryland ticks he examined. Spotted fever group rickettsia have also been isolated frequently from the Lone Star Tick *A. americanum*. However, recent work summarized by Burgdorfer (1975) indicates that many isolates from Brown Dog Ticks, *R. sanguineus,* are non-pathogenic, but at least one isolate from Brown Dog Ticks contained a spotted fever group rickettsia distinct from *R. rickettsii*. The available evidence suggests that the dominant vector of RMSF is the American Dog Tick, though the Lone Star Tick cannot be disregarded as a potentially important vector also.

Although RMSF is the most important tick-borne disease in Virginia, others also occur. Tularemia, a bacterial infection, occurs in the state; eight cases were reported in Virginia in 1975, the highest number for any of the South Atlantic States. This disease may be contracted from the bite of an infected vector, or by directly handling infected rabbits or other wildlife. Tularemia is common among lagomorphs (rabbits, hares, pikas), especially cottontail rabbits, and is perpetuated among these animals by the Rabbit Tick, *Haemaphysalis leporispalustris*. Tick paralysis, a condition caused by the attached tick itself, occurs in many parts of the world. In the Eastern United States, *D. variabilis* is the only species associated with human cases. Such cases have been reported from Virginia, North Carolina, South Carolina, Georgia, Kentucky, Tennessee, and New York (Gregson, 1973). Unless the offending tick is removed, the patient's paralysis intensifies and terminates in death. Removal of the tick before the terminal stages of the paralysis reverses the paralytic deterioration and results in a complete cure. *Ixodes cookei,* a common parasite of wild carnivores in Virginia has been implicated in the transmission of Powassan virus in New York State (Whitney and Jamnback, 1965), while a tick closely related to *Ixodes scapularis* has been implicated in the transmission of babesiosis in Massachusetts (McEnroe, 1977; Spielman and Piesman, 1978). Both *I. cookei* and *I. scapularis* have been reported as biting man (Bishop and Trembley, 1945). Other microbial agents among the tick species of the Eastern United States with known or potential pathogenic effects on man have been isolated. *Coxiella burnetti,* the causative agent of Q fever and the Bullis fever agent, along with the Lone Star virus, are included.

In addition to disease transmission, ticks inflict serious physical injury on man, domestic animals, and wildlife. In some cases, large numbers of ticks accumulate on wildlife and may cause their death. Bishop and Trembley (1954) describe examples of white tailed deer so heavily infested with Lone Star Ticks that the deer's ears are hidden. Bolte et al. (1970) report severe injury and death among fawns in heavily infested deer herds in eastern Oklahoma. The irritating effects of tick bites contribute to lesions, inflammatory reactions, and violent scratching as the infested animals seek relief. The problem is especially severe among cattle infested with Gulf Coast Ticks for screwworm infestation can occur on the wounds. The Brown Dog Tick, now spread throughout the entire continent, breeds in homes, kennels, and other man-made habitations. Pet owners, in addition to being concerned about the ticks attached to their dogs, complain of having ticks (often in great numbers) crawling on furniture, rugs, and walls of their homes. Once established, such infestations are difficult to control and may require that the home be treated with pesticide and the pets removed from the premises for treatment.

COLLECTING

Some species of ticks can be collected from vegetation by flagging. The flag simulates the passing host and makes use of the fact that certain species or life stages which wait for moving, active hosts will cling to the flag. Tick flags consist of a sheet of cloth approximately 1 m wide attached to a pole; the free edge of the cloth farthest from the pole is weighted to insure maximum contact with the vegetation. Virginia species commonly collected on tick drags include *D. variabilis* (adults only) and *A. americanum* (all stages). Occasionally, *I. scapularis* is collected in this manner. Nest-inhabiting stages may be collected by placing some of the nest material in a Berlese funnel. CO_2 traps are also widely used as an aid in collecting unfed ticks in the natural habitat.

Most ticks are found attached to their hosts. Fully engorged ticks are easily seen, but flat, unengorged ticks, particularly larvae, are more difficult to find. The host's fur should be combed carefully for these ticks; eyelids, ears, and even the tail may harbor ticks. Attached ticks can be removed with fine forceps, but one must be careful not to destroy valuable taxonomic characters, such as mouthparts, legs, etc.

Ticks are preserved in 70% ethyl alcohol. Complete collection data, e.g., host information, exact locality, date, and the name of the collector are essential. Other data, e.g., altitude and nest associations, may also be helpful. Specific identification of ticks can be greatly facilitated by precise knowledge of these important data.

PREPARING SPECIMENS FOR STUDY

Adults and nymphs preserved in alcohol can be identified with the aid of a stereoscopic microscope without further preparation. A good quality microscope capable of magnifying at least 90 to 100 X is highly desirable; an ocular micrometer is also valuable for use in identifying ticks. Larvae, however, require clearing and mounting on slides before they can be identified. The larvae should be cleared by immersion in 70% lactic acid or 5% KOH at 60°C until they retain only a faint amber color. Care should be exercised to avoid overclearing, especially when using KOH. The cleared specimens should be washed with distilled water and mounted on slides using Hoyer's mounting medium. Hoyer's medium consists of the following: 1) distilled water, 50 grams; 2) gum arabic (crystals), 30 grams; 3) chloral hydrate, 200 grams; and 4) glycerine, 20 grams. The gum arabic must be crystalline. Powdered gum arabic is unsuitable as the tiny flakes resist wetting. Acquisition of chloral hydrate requires special licensing or the signature of a physician, because it is a controlled drug. The ingredients should be mixed in the order listed and filtered until a clear viscous fluid is obtained. To mount the specimens, the washed larvae should be placed on a clean slide and one or two drops of fresh Hoyer's medium placed directly on them. A No. 1 coverglass is floated onto the droplet until the medium spreads uniformly. If small amounts of mounting medium are used, the pressure of the coverglass will compress the specimen to make it easier to study. The finished mount should be labelled and heated in a drying oven at 60-65°C until the medium hardens. The heat will also cause the larvae to expand and extend their appendages. This greatly enhances the quality of the slide preparation making identification easier. Drying may be accomplished overnight, though the mounted specimens may be left in the drying oven for several days without harm. After drying, the coverglass should be ringed with lacquer to prevent absorption of atmospheric moisture. Unless this is done, the mounts deteriorate, with the formation of numerous crystalline deposits that may obscure the specimen. Krantz (1970) recommends "ZUT" or Euparal®. Clear nail polish is also quite suitable for ringing slides.

CONTROL

The USDA cattle fever tick eradication program is the only formal program of tick control in the United States today. A study to develop improved techniques for tick control was done by Clymer et al. (1970) in eastern Oklahoma. Hair and Howell (1970) discussed techniques for control of Lone Star Ticks in recreational areas, including use of Gardona®. Effective control was achieved with this relatively low toxicity insecticide with as little as 2 or 3 applications of 1 lb. Gardona as a 75% wettable powder/acre. Environmental alterations, especially reduction in brushy understory and thinning of the forest canopy were carried out by these workers in Oklahoma and contributed to the reduction of the tick population. In Canada, McKiel et al. (1967) used a combination of herbicides and chlorinated hydrocarbons for control of the American Dog Tick along roadsides. The U. S. Public Health Service Center for Disease Control, recommended application of chlordane, toxaphene or Gardona in dusts, emulsions, or suspensions to obtain area control of ticks (Pratt and Littig, 1974).

In Virginia, 3 species of ticks require control; namely, the Brown Dog Tick, *R. sanguineus*; the American Dog Tick, *D. variabilis*; and the Lone Star Tick, *A. americanum*. Control of Brown Dog Ticks is practiced by pet owners, kennel operators, and veterinarians on an individual basis, using insecticidal collars, shampoos, dustings or other methods to apply insecticides to the pet dogs that serve as the primary host of this tick. In mild cases, these methods are usually sufficient to suppress the infestations. In severe cases, where massive infestations have inundated the household where pets are kept, the aid of a veterinarian and exterminator may be required. Pets should be kept out of the house until the ticks therein are destroyed, to prevent reproduction of these parasites. Unfortunately, such procedures may entail considerable expense, and there is no guarantee against reinfestation if the pets are returned to the household, unless a continuing control program is maintained.

The American Dog Tick and Lone Star Tick are serious pests in rural and suburban areas of Virginia, especially along wooded roadsides, trails, parks, campgrounds, and other recreational areas. Since no area control programs for suppression of these pests exist, precautions are the only effective means of avoiding contact with the ticks. Persons entering infested areas can protect themselves

against ticks by wearing full-length trousers, full-length sleeved shirts and full-length boots. The trouser legs should be enclosed in the boots; taping the tops of the boots where the trousers are inserted helps to eliminate openings through which ticks can crawl into the clothing. Tick repellants applied to the clothing can provide protection for up to several hours. Commercial preparations containing "Deet" (Diethyl toluamide) are effective and generally available for sale during spring and summer. Frequent examination of one's clothing will enable a person to discover ticks before they can become attached to the body. Ticks that attach, despite these precautions, should be removed as soon as possible to minimize risk of disease. Ticks can be removed with little injury to the body. People often overreact to the presence of an attached tick and resort to remedies for its removal that may result in greater injury than the tick bite itself. Attached adult ticks can be removed by grasping them firmly, twisting them and pulling simultaneously; this breaks the cement bond by which their mouthparts are attached. Violent tugging should be avoided as it may break the body away from the mouthparts, leaving the latter in the wound. Immature ticks, especially Lone Star Tick larvae and nymphs, may be more difficult to find until they become engorged. Even then, their small size and firm attachment makes it difficult to dislodge them. The use of forceps will enable a person to obtain a firm grip and twist them off.

Additional information on the control of ticks on pets and vegetation is available at VPI&SU County Extension offices.

GENERAL MORPHOLOGY OF VIRGINIA TICKS
(Figs. 1, 2 a&b, 3, 4, 5, 6, 7, 8)

As members of the class Arachnida, subclass Acari, ticks have 4 pairs of walking legs (as adults), a pair of palpi, and a pair of chelicerae. Ticks are characterized by the presence of a prominent holdfast, the hypostome, almost always armed with posteriorly directed denticles (teeth). A spiracular plate (=stigmal plate) surrounding the respiratory pore (spiracle) occurs on each side of the body between the third and fourth pairs of coxae, or posterior to the fourth pair of coxae in nymphs and adults. The cutting organs used to penetrate the host skin are termed chelicerae and are armed with laterally directed denticles. The palps have 4 segments, termed articles; in most hard ticks (Ixodidae), the terminal segment (article IV) is recessed in a cavity of the preceding segment. A minute sensory structure, Haller's organ, occurs on the tarsi of the first pair of legs. Hard ticks have a scutum on the dorsal surface in all stages. Soft bodied ticks (Argasidae) lack a scutum.

There are 3 active life stages: larva, nymph and adult. Larvae and sometimes the nymphs are called "seed ticks" in eastern Virginia. Larvae have only 3 pairs of walking legs. Nymphs resemble adults, but lack external sex characters. Species of Argasidae have 2 or more nymphal stages which cannot be distinguished; species of Ixodidae have only a single nymphal stage. Sexual dimorphism is apparent in the adult stage. In hard ticks, the scutum covers the entire dorsal surface in the male, but only the anterior dorsal surface in the female. Ixodid females have a pair of porous areas on the dorsal surface of the basis capituli which are lacking in the males.

Selected characters have been used to identify ticks in this work. More detailed descriptions are given by Cooley (1938, 1946) and Cooley and Kohls (1944a, 1944b, 1945) for the adults and nymphs, and Clifford et al. (1961) for the larvae. Terminology of setae on the larval body is that of Clifford et al. (1961), except in the case of the larva of *Ornithodoros kelleyi*. Definitions of some terms used in this work are given below.

Illustrations used in this work are photomicrographs and line drawings. To conserve space, only ventral views of the female, nymph, and larva of most species are figured. Figures 1 and 2a illustrate selected characters used in identifying the females, figure 2b is on male; figure 3 illustrates the nymph, while figures 4 and 5 illustrate characters used in identifying the larva.

DEFINITION OF TERMS AND ABBREVIATIONS USED
(Abbreviations appear in parentheses)

Anal groove: A groove in the cuticle associated with the anal aperture. Its position and shape may be used for taxonomic purposes (see also under median post-anal groove) (Fig. 2b).

Anal plate: A sclerite (area of very hard cuticle) on the ventral surface of the male (Fig. 2b).

Auriculae (aur.): Paired extensions on the ventrolateral surfaces of the basis capituli (Fig. 28).

Basis capituli (B.C.): The basal part of the capitulum, from which the hypostome and palps arise (Fig. 1).

Capitulum: Includes basis capituli, hypostome, chelicerae, and palps (not figured).

Carinae: Ridgelike structures found near the lateral edges of the scutum in adults and nymphs of some ticks (not figured).

Cervical grooves: Elongated, paired depressions in the scutum in all stages (Fig. 2a).

Cornua: Hornlike posterior projections on the dorsal surface of the basis capituli (Fig. 22, 23). Rarely, they occur on the ventral surface (not figured).

Coxa 1: First segment of a leg (Fig. 1).

Coxal fold (coxal f.): Cuticular fold medial to the coxal on the ventral surface in some argasid ticks (not figured).

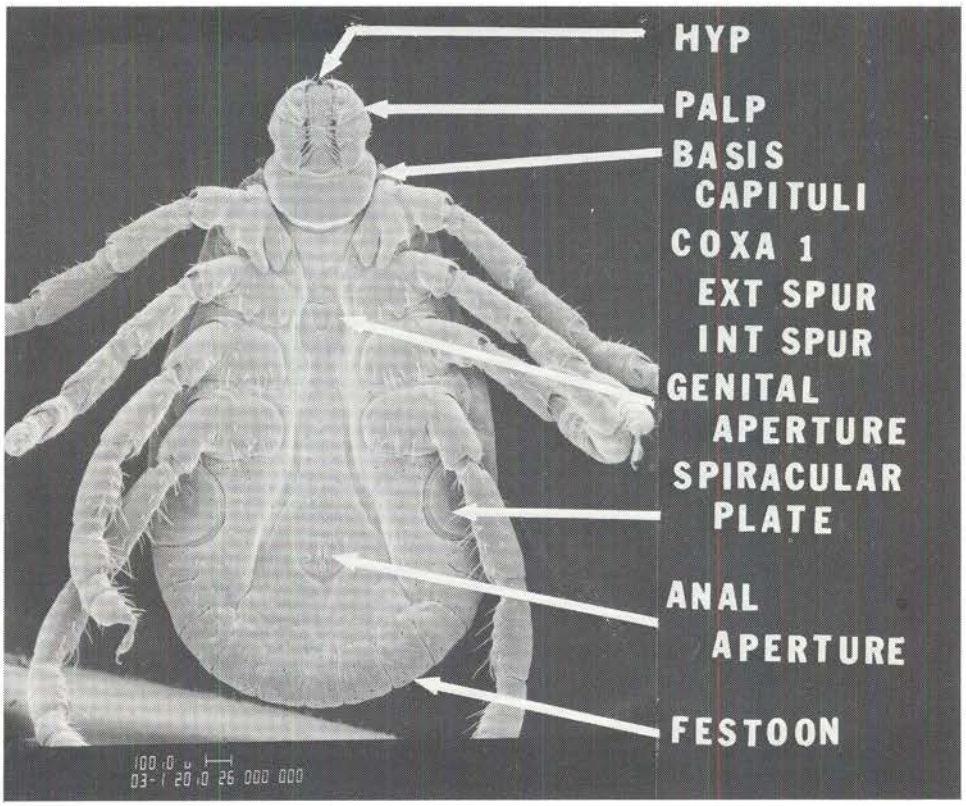


Fig. 1. *Dermacentor variabilis* female, venter

Coxal gland aperture (coxal G1. A): Porelike opening of the ducts of the coxal glands (not figured).

Crenulations: Faint, toothlike protuberances on the hypostome, usually in males (not figured).

Dentition: The arrangement of the denticles on the hypostome; e.g., 2/2 indicates 4 files of denticles, 2 on each side of the midline (see also files, hypostome, Fig. 1).

Dorsal plate: Sclerite on the dorsum of the larva in some argasid ticks (not figured).

Festoon: Indentations on the posterior edge of the body, resembling cell-like divisions (Fig. 1).

Files: The arrangement of the hypostome denticles in longitudinal rows (see also hypostome, Fig. 1).

Genital orifice (G.O.): The opening of the vulva on the ventral surface of the female (Fig. 2b).

Goblets: The cell-like divisions on the surface of the spiracular plate (Fig. 3).

Hypostome (HYP): The ventral, protuberant holdfast projecting anteriorly from the basis capituli, between the palps (see also files, Fig. 1).

Lateral carinae: See carinae.

Mammillated: Having small, hemispherical elevations (on the cuticle of many argasids).

Median plate: Sclerite (area of very hard cuticle) on the ventral surface of the male (Fig. 2b).

Median post-anal groove (Med. P.A.G.): Groove posterior to the anus in the midline on the ventral surface (Fig. 6).

Palp: One of the paired appendages. The palps form part of the capitulum, and bear sensory structures on their apices (Fig. 1).

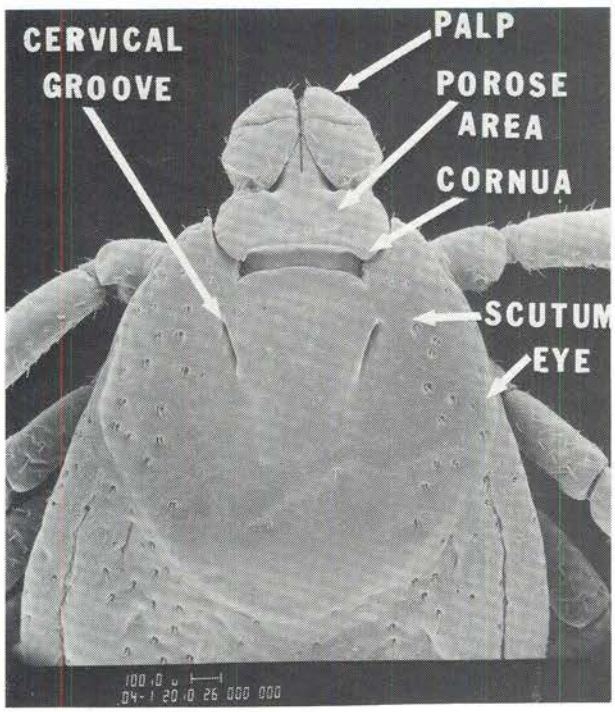
Palpal articles: The 4 divisions (segments) of each palp, numbered consecutively I-IV from the basal to the distal end (Fig. 1).

Preanal groove (Pr. Gr.): Groove anterior to the anus in the midline on the ventral surface (Fig. 6).

Scutum: Anterior sclerite or plate, covering the anterior part of the basis capituli, behind the hypostome (Fig. 5).

Sensilla auriformia (S.A.): Minute, ear-shaped sensory structures on the body, especially of the larvae (Fig. 8).

Sensilla sagittiformia (SS): Subcircular structures on the marginal body surface, posterior to the scutum, in the larvae of some ticks (absent in species of *Ixodes* and *O. kelleyi*). Structures' presence or absence and position, relative to the



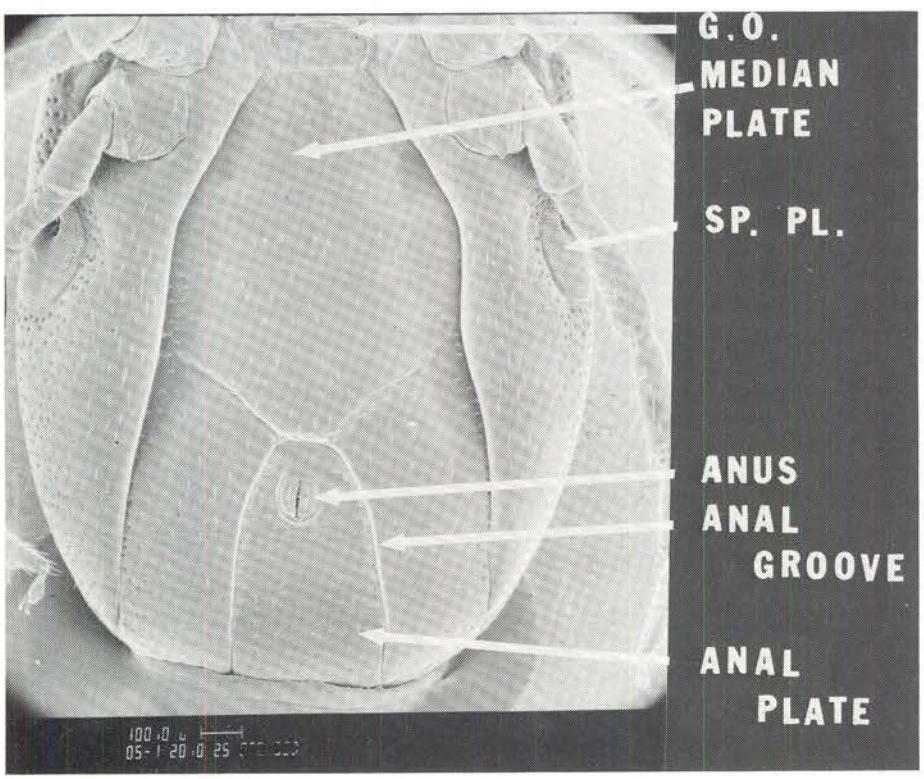


Fig. 2. a) *Dermacentor variabilis* female, capitulum and scutum dorsal view b) *Ixodes cookei* male, ventral plates

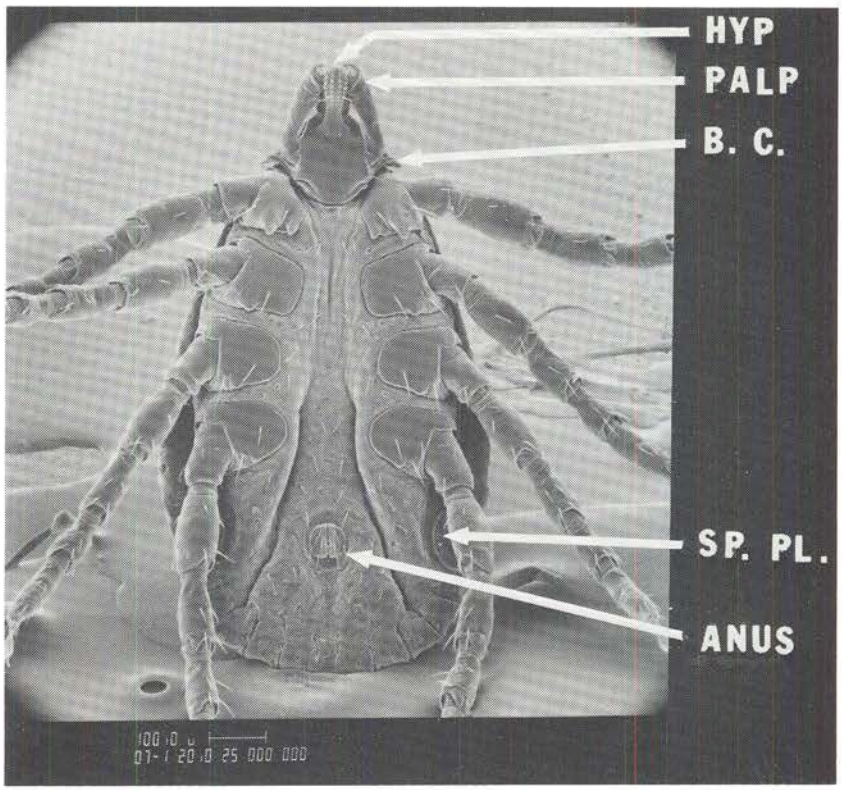


Fig. 3. *Dermacentor variabilis* nymph, venter

marginal dorsal setae, is especially useful for diagnostic purposes (Fig. 5).

Spiracular plate (SP. PL.): Prominent sclerite (area of very hard cuticle) on the ventral surface posterior to Coxa IV, surrounding the spiracle. The surface is usually characterized by goblets of varying size and shape. (Fig. 1, 3).

Spur: Broad, subtriangular prominence on the legs and, occasionally, palps.

Supra coxal fold (S. Coxal F.): Cuticular fold lateral to the coxae on the ventral surface in some argasid ticks. (Fig. 6).

Ventral cornua: See cornua.

ABBREVIATIONS USED FOR SETAE IN FIGURES OF THE LARVAE

All body setae figured are paired unless noted otherwise. The numeral after the abbreviation represents the position of the seta in an anterior to posterior series (in some cases, only 1 member of the series is present; e.g., Ph_1); others in the series may not be identified to avoid confusion.

Ixodidae (Figs. 4 and 27)

$cd^{1,2}$: Central dorsal 1, 2
$md^{1,7}$: Marginal dorsal 1, 7
$mv^{1,5}$: Marginal ventral 1, 5
pa^{1}: Preanal 1
ph^{1}: Post-hypostomal 1
$pm^{1,4}$: Premarginal 1, 4
Pp^{1}: Post-palpal 1
$sC^{1,2,3}$: Scutal 1-3
sT^{1}: Sternal 1

Argasidae (Fig. 8)

A.S.: Anal seta
Med.P.A.S.: Median post-anal seta (unpaired)
P.A.S. 1-3: Perianal setae 1-3
P. Coxal S.: Post-coxal seta
P. Hyp. $S^{1,2}$: Post-hypostomal seta 1, 2
St.S.: Sternal seta

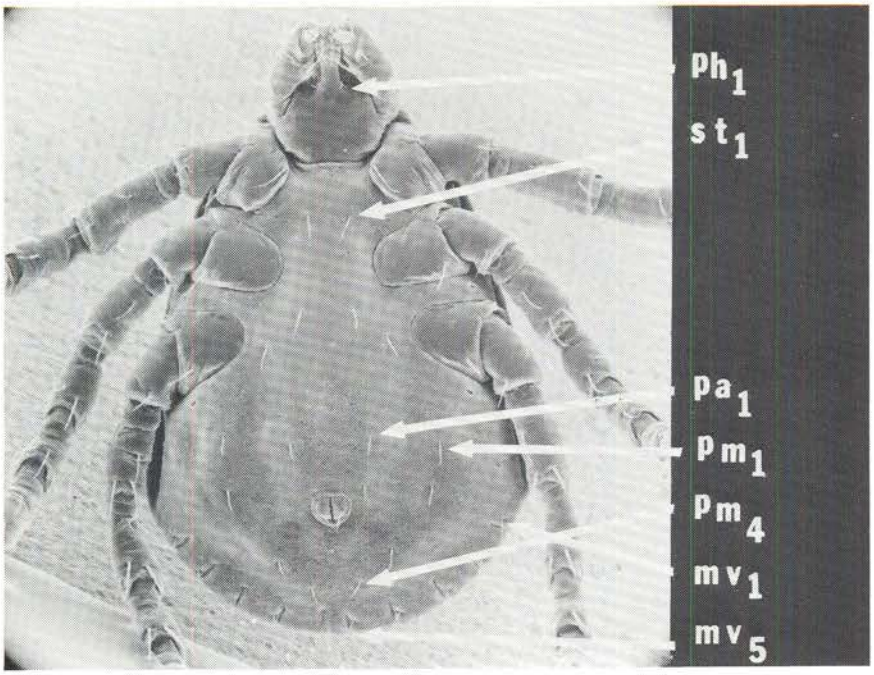


Fig. 4. *Dermacentor variabilis* larva, venter

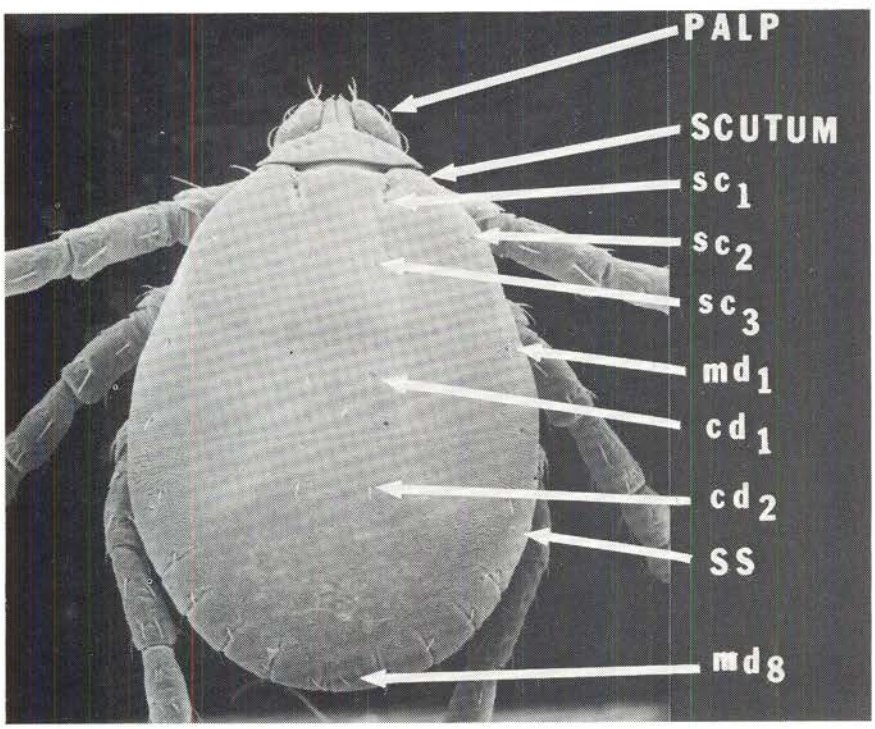


Fig. 5. *Dermacentor variabilis larva,* dorsum

KEYS TO THE TICKS OF VIRGINIA

Key to Families

1. Body cuticle of adults and nymphs leathery, mammillated, scutum absent; capitulum ventral, not visible from above. Larvae with a dorsal plate located centrally; palpal article IV prominent ..... **Argasidae** (with 1 species ***Ornithodoros kelleyi***),* p. 12

   Body cuticle of all stages folded or striate, never leathery or mammillated; scutum present, anterior or covering entire dorsum; capitulum anterior, visible from above. Larvae without a dorsal plate, palpal article IV reduced, may or may not be recessed in a cavity of article III ..... **Ixodidae**

Key to the Genera and Species of Ixodidae

Key to Females

1. Anal groove curved in front of anus; eyes and festoons absent; scutum of adults inornate 2

   Anal groove absent or curved behind anus; eyes and festoons present or absent; scutum of adults ornate or inornate 8

2. Hypostome with main denticles arranged 4/4 or 6/6 3

   Hypostome with main denticles arranged 3/3 4

3. Hypostome dentition 6/6; auriculae retrograde, pointed; coxa I with a long, pointed internal spur; parasites of birds (immatures only) or rabbits (all stages) . ***Ixodes dentatus,*** p. 32

   Hypostome dentition 4/4; auriculae large, truncated; basis capituli appears constricted behind the auriculae, expanded posteriorly; parasites of birds, never found on rabbits ..... ***Ixodes brunneus,*** p. 28

4 (2). Internal spur on coxa I long and pointed 5

   Internal spur on coxa I short or absent 6

5. Lateral carinae on scutum distinct; hosts usually carnivores and other medium-sized mammals ..... ***Ixodes cookei,*** p. 29

   Lateral carinae absent; hosts varied ..... ***Ixodes scapularis,*** p. 35

6 (4). Scutum and dorsal surface of capitulum rugose; basis capituli with a prominent hump on either side of the hypostome ..... ***Ixodes texanus,*** p. 37

   Scutum not as above, hump absent or indistinct 7

7. Hypostome dentition 3/3 throughout entire length; auriculae absent; coxae with spurs; hosts varied ..... ***Ixodes angustus,*** p. 25

   Hypostome dentition 3/3 only in distal half; auriculae present (small); coxal spurs absent; hosts usually squirrels ..... ***Ixodes marxi,*** p. 34

8 (11). Palpal article II expanded laterally and extending beyond margin of basis capituli 9

   Palpal article II not as above 10

9. Ventral cornua present; hosts birds and rabbits .... ***Haemaphysalis leporispalustris,*** p. 24

   Ventral cornua absent; hosts usually birds ..... ***Haemaphysalis chordeilis,**** p. 22

10 (8). Palps long and narrow; article II about twice as long as article III ..... ***Amblyomma,*** 11

   Palps short and broad; article II and III about equal in length 12

11. Scutum with an iridescent white spot at the posterior edge ..... ***Amblyomma americanum,*** p. 13

   Scutum with iridescent white or pale markings in an extensive pattern (rare in Virginia) ..... ***Amblyomma maculatum,*** p. 16

12 (10). Basis capituli hexagonal, lateral margins acute; scutum inornate; hosts usually dogs ..... ***Rhipicephalus sanguineus,*** p. 38

   Basis capituli rectangular, lateral margins straight; scutum ornate or inornate; hosts varied 13

13. Scutum ornamented; spiracular plate with numerous small goblets; hosts varied, usually medium or large mammals ..... ***Dermacentor variabilis,*** p. 20

   Scutum usually unornamented (Virginia specimens);** spiracular plate with a few large goblets; hosts usually deer ..... ***Dermacentor albipictus,*** p. 19

*Not known from Virginia.

**This species may exist in either an ornamented or unornamented form; Virginia specimens have all been unornamented.

Key to Males

1. Anal groove encircles anus anteriorly; eyes and festoons absent; ventral body surface completely covered by plates 2
   Anal groove absent or behind anus; eyes and festoons present or absent; ventral body surface without plates, or plates not completely covering surface 8

2. Lateral denticles of hypostome large, protruding, pointed ..... ***Ixodes scapularis,*** p. 35
   Most hypostomal denticles small or reduced to crenulations 3

3. Internal spur on coxa I long 4
   Internal spur on coxa I short 5

4. Median and anal plates about equal in length ..... ***Ixodes cookei,*** p. 29
   Median plate about twice as long as anal plate ..... ***Ixodes dentatus,*** p. 32

5 (3). Hypostome with crenulations only on anterior half ..... ***Ixodes angustus,*** p. 25

6. Internal spurs on coxae I-III; anal plate weakly sclerotized ..... ***Ixodes brunneus,*** p. 28
   Internal spur only on coxa I; anal plate well sclerotized 7

7. Spiracular plate large with many goblets; dorsal surface of capitulum rugose ..... ***Ixodes texanus,*** p. 37
   Spriacular plate small, goblets few; capitulum not rugose ..... ***Ixodes marxi,*** p. 34

8 (2). Palpal article II expanded laterally and extended beyond margin of basis capituli 9
   Palpal article II not as above 10

9. Ventral cornua present ..... ***Haemaphysalis leporispalustris,*** p. 24
   Ventral cornua absent ..... ***Haemaphysalis chordeilis,**** p. 22

10 (8). Palps long and narrow (about 3 times as long as wide); article II about twice as long as article III 11
   Palps short and broad (about twice as long as wide); articles II and III about equal in length 12

11. Scutum with iridescent white or pale markings in a few isolated spots ..... ***Amblyomma americanum,*** p. 13
   Scutum with iridescent white or pale markings in an extensive interconnected pattern (rare in Virginia) ..... ***Amblyomma maculatum,*** p. 16

12 (10). Basis capituli hexagonal; lateral margins acute; scutum inornate; hosts usually dogs ..... ***Rhipicephalus sanguineus,*** p. 38

13. Scutum ornamented; spiracular plate with numerous small goblets, hosts varied, usually medium or large mammals (e.g., dogs, deer, etc.) ..... ***Dermacentor variabilis,*** p. 20
   Scutum usually unornamented (Virginia specimens);** spiracular plate with a few large goblets; hosts usually deer ..... ***Dermacentor albipictus,*** p. 19

Key to Nymphs

1. Anal groove encircles anus anteriorly, eyes and festoons absent 2
   Anal groove indistinct or curved behind anus; eyes and festoons present or absent 8

2. Palps long and thin, length:width ratio greater than 3.5:1; auriculae present 3
   Palps relatively short and thick; length:width ratio less than 3.5:1; auriculae present or absent 5

3. Hypostome dentition 4/4; hosts birds or rabbits ..... ***Ixodes dentatus,*** p. 32
   Hypostome dentition 3/3; hosts varied 4

4. Auriculae large, retrograde spines; with small, sharp spines anterior to auriculae; hosts are birds ..... ***Ixodes brunneus,*** p. 28
   Auriculae rudimentary, just behind palps; secondary spines absent; hosts varied ..... ***Ixodes scapularis,*** p. 35

5 (2). Palpal article I with spurs 6
   Palpal article I without spurs 7

6. Palpal article I with prominent anterior and posterior spurs; hosts usually small mammals ..... ***Ixodes angustus,*** p. 25
   Palpal article I with a prominent posterior spur; anterior spur indistinct or absent; hosts usually medium sized mammals ..... ***Ixodes cookei,*** p. 29

7 (5). Auriculae present; scutum smooth; hosts usually squirrels ..... ***Ixodes marxi,*** p. 34
   Auriculae absent, but with lateral edges of the basis capituli flared (ventral view); scutum rugose; hosts usually raccoons ..... ***Ixodes texanus,*** p. 37

8 (2). Palpal article II expanded laterally and extending beyond margin of basis capituli 9
   Palpal article II not as above 10

9. Basis capituli without sharp lateral margins, sides parallel; hosts usually birds and rabbits ..... ***Haemaphysalis leporispalustris,*** p. 24
Basis capituli with sharp lateral margins (dorsal view), sides not parallel; hosts usually birds ..... ***Haemaphysalis chordeilis,*** p. 22

10 (8). Palps long and narrow; article II about twice as long as article III 13
Palps short and broad; articles II and III about equal in length 12

11. Basis capituli without sharp lateral margins ..... ***Amblyomma americanum,*** p. 13
Basis capituli with sharp lateral margins (rare in Virginia) ***Amblyomma maculatum,*** p. 16

12 (10). Basis capituli hexagonal; hosts usually dogs ..... ***Rhipicephalus sanguineus,*** p. 38
Basis capituli subtriangular or rectangular; hosts varied 13

13. Basis capituli subtriangular in dorsal view; spiracular plate with numerous goblets; coxa IV without spurs; hosts usually small mammals ..... ***Dermacentor variabilis,*** p. 20
Basis capituli rectangular in dorsal view; spiracular plate with few goblets; external spur on coxa IV; hosts usually deer ..... ***Dermacentor albipictus,*** p. 19

Key to Larvae

1. Anal groove present, curved in front of anus; sensilla sagittiformia absent; with 1 pair of post hypostomal setae and 1 pair of post-palpal setae 2
Anal groove absent; sensilla sagittiformia present; with 1 pair of posthypostomal setae ... 8

2. Palps long and thin, length:width ratio greater than 3:1; article II conspicuously narrowed at junction with article I; hypostome dentition 3/3 anteriorly; body with 7 pairs of marginal dorsal setae and 1 pair of supplementary setae 3
Palps short and broad, length:width ratio less than 3:1; article II not conspicuously narrowed at junction with article I; hypostome dentition 2/2; body with 8 or 9 pairs of marginal dorsal setae, supplementary setae absent 5

3. Body with 5 pairs of central dorsal setae; hosts birds ..... ***Ixodes brunneus,*** p. 28
Body with 3 pairs of central dorsal setae; hosts varied 4

4. Auriculae indistinct or absent; hosts birds or rabbits ..... ***Ixodes dentatus,*** p. 32
Auriculae present, distinct; hosts varied ..... ***Ixodes scapularis,*** p. 35

5 (2). Palpal article I with prominent anterior and posterior spurs ..... ***Ixodes angustus,*** p. 25
Palpal article I without spurs, or with only a small knoblike posterior spur 6

6. Body with 8 pairs of marginal dorsal setae and 4 pairs of marginal ventral setae; coxa I with a large triangular spur, coxae II and III with large ridgelike spurs .. ***Ixodes cookei,*** p. 29
Body with 9 pairs of marginal dorsal setae and 3 pairs of marginal ventral setae; coxa I with a small spur, coxae II and III without spurs 7

7. Basis capituli with auriculae; hosts mostly squirrels ..... ***Ixodes marxi,*** p. 34
Basis capituli without auriculae; hosts mostly medium sized mammals ..... ***Ixodes texanus,*** p. 37

8. Palpal article II expanded laterally and extended beyond margin of basis capituli 9
Palpal article II not as above 10

9. Basis capituli with rounded lateral margins; hosts mostly birds or rabbits ..... ***Haemaphysalis leporispalustris,*** p. 24
Basis capituli with sharp lateral margins; hosts mostly birds ..... ***Haemaphysalis chordeilis,*** p. 22

10. Body with 2 marginal dorsal setae anterior to sensillum sagittiforme on each side; palps rather long and narrow, about 3 times as long as wide; with 11 festoons 11
Body with 3 or 4 marginal dorsal setae anterior to sensillum sagittiforme on each side; palps shorter, broader, usually about twice as long as wide; with 9 festoons 12

11. Basis capituli more or less subtriangular in dorsal view, lateral margins sharp; coxa I with 1 spur ..... ***Amblyomma americanum,*** p. 13
Basis capituli more or less rectangular in dorsal view, lateral margins rounded; coxa I with 2 spurs (rare in Virginia) ..... ***Amblyomma maculatum,*** p. 16

12 (10). Body with 4 marginal dorsal setae anterior to the sensillum sagittiforme on each side; palpal article I indistinct, fused with article II; hosts mostly dogs ..... ***Rhipicephalus sanguineus,*** p. 38
Body with 3 marginal dorsal setae anterior to the sensillum sagittiforme on each side; palpal article I distinct, not fused with article II; hosts varied 13

13. Lateral margins of basis capituli sharp basis capituli appears triangular in dorsal view; hosts mostly small mammals (e.g., mice and voles) ..... ***Dermacentor variabilis,*** p. 20
Lateral margins of basis capituli rounded, almost straight; basis capituli appears rectangular in dorsal view; hosts usually deer ..... ***Dermacentor albipictus,*** p. 19

Family Argasidae
Soft-Bodied Ticks

Genus *Ornithodoros* Koch, 1844

All stages lack a scutum; the cuticle is mammillated in adults and nymphs. The larva usually has a dorsal plate more or less central in position. Palpal article IV is prominent, not recessed in a cavity of article III. Typically, nest or burrow parasites.

Ornithodoros kelleyi Cooley and Kohls, 1944
Bat Tick
(Figs. 6, 7, 8)

DIAGNOSIS.—Adults and nymphs are distinguished from other Virginia ticks by the warty, mammillated cuticle and the position of the capitulum, which is recessed in a camerostomal fold beneath an anterior projection (hood) of the body. The dorsal surface contains numerous discs in a characteristic pattern. The spiracles are located between coxae II and IV, and the small spiracular plate lacks goblets. There is no dorsal plate. Males are distinguished from females by the shape of the genital aperture. Nymphs (not figured) resemble the adults but are smaller and lack a genital aperture (a tiny pore is present in the late-stage nymphs in the location where the genital aperture will appear). Larvae are distinguished from larvae of ixodid ticks by the dorsal plate which is central in position instead of the anterior scutum found in ixodid larvae. Larvae of *Argas persicus* (Oken) may be distinguished from those of *O. kelleyi* by the much greater number of dorsal body setae, approximately 28 pairs, as compared to only 15-17 pairs in *O. kelleyi.* Although a record purported to be of *A. persicus* exists (a record in the VPI&SU collection of J. M. Amos and W. J. Brown) it is unverified, and no specimens were obtained for identification. Consequently, this species cannot be considered to exist in the state at this time.

DISTRIBUTION, HOSTS AND SEASONAL ACTIVITY.—Widely scattered records of this tick have been reported from 21 states in the United States, from 1 province in Canada, and from Cuba (Wilson and Baker, 1971). In the states near Virginia, it has been collected from Maryland and Georgia. Anastos and Clifford (1956) described a colony of this tick in a bat roost in a church attic in St. Mary's County on the eastern shore of Maryland. Hence, its occurrence in Virginia is likely. Its only known hosts are bats. The ticks are found in bat roosts, frequently in secluded areas of human habitations. They are active when the bats are present during the warmer months of the year, and survive during the winter until the bats return from hibernation in distant caves. The ticks are able to feed at all times of the year. However, the pattern of oviposition and hatching in this soft tick suggests

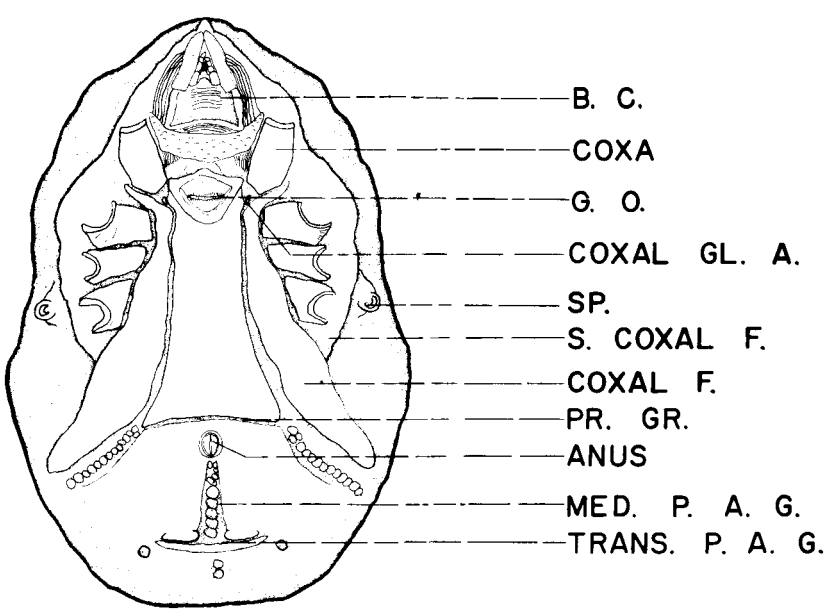


Fig. 6. *Ornithodoros kelleyi* female, venter

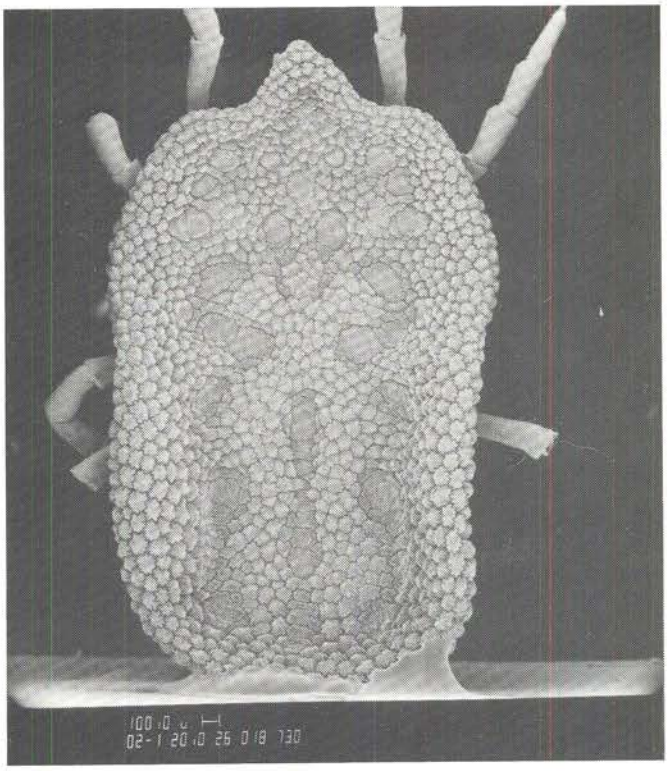


Fig. 7. *Ornithodoros kelleyi* female, dorsum

an adaptation to the interrupted seasonal presence of the bat hosts. Females which fed in the spring on bats returning from winter hibernation, oviposited in 10 to 19 days ($\bar{x}$ = 13.3 days, n = 8), and 83.3% of the eggs hatched. In contrast, females which fed on bats in the fall or winter laid infertile eggs (3 females), or delayed oviposition to the following spring. Oviposition time for this group was 41 to 197 days ($\bar{x}$ = 98.4 days, n = 13), and 92.2% of the eggs hatched. These differences were noted even though both groups of ticks were held in a dark incubator under identical conditions (Sonenshine and Anastos, 1960).

VIRGINIA RECORDS.—None.

REMARKS.—This species is not known to be a vector of disease nor a pest of man or domestic animals.

Family Ixodidae
Hard-Bodied Ticks

Genus *Amblyomma* Koch, 1844

DIAGNOSIS—(Virginia Species).—Palps long and narrow; in adults and nymphs, article II about twice as long as article III. Adults are ornate. Eyes and festoons present. The anal groove is behind the anus. Larvae with only 2 marginal dorsal setae anterior to the sensillum sagittiforme on either side and only 1 pair of posthypostomal setae; dorsally, there are 3 pairs of scutal setae, 2 pairs of central dorsal setae, and 8 pairs of marginal dorsal setae.

Amblyomma americanum (Linnaeus, 1758)
Lone Star Tick
(Figs. 9, 10, 11)

DIAGNOSIS.—The palps of adults and nymphs long and thin, article II about twice as long as article III. The palps of other Virginia ixodid ticks (except *A. maculatum*) are shorter and relatively broader in relation to their length. **Females** can be distinguished from *A. maculatum* by the presence of a conspicuous white spot at the apex of the scutum in *A. americanum*. **Males** are recognized by the 2 pairs of semicircular white lines, 1 pair on the antero-lateral area of the scutum, the other on the postero-lateral area, in contrast to the extensive ornate pattern of the scutum of *A. maculatum*. **Nymphs** are inornate, the coxae have external spurs, and the lateral edges of the basis capituli are parallel. **Larvae** are distinguished from those of *A. maculatum* by the parallel or slightly rounded margins of the basis capituli and the 2 spurs on coxa I. Larvae are distinguished from those of other

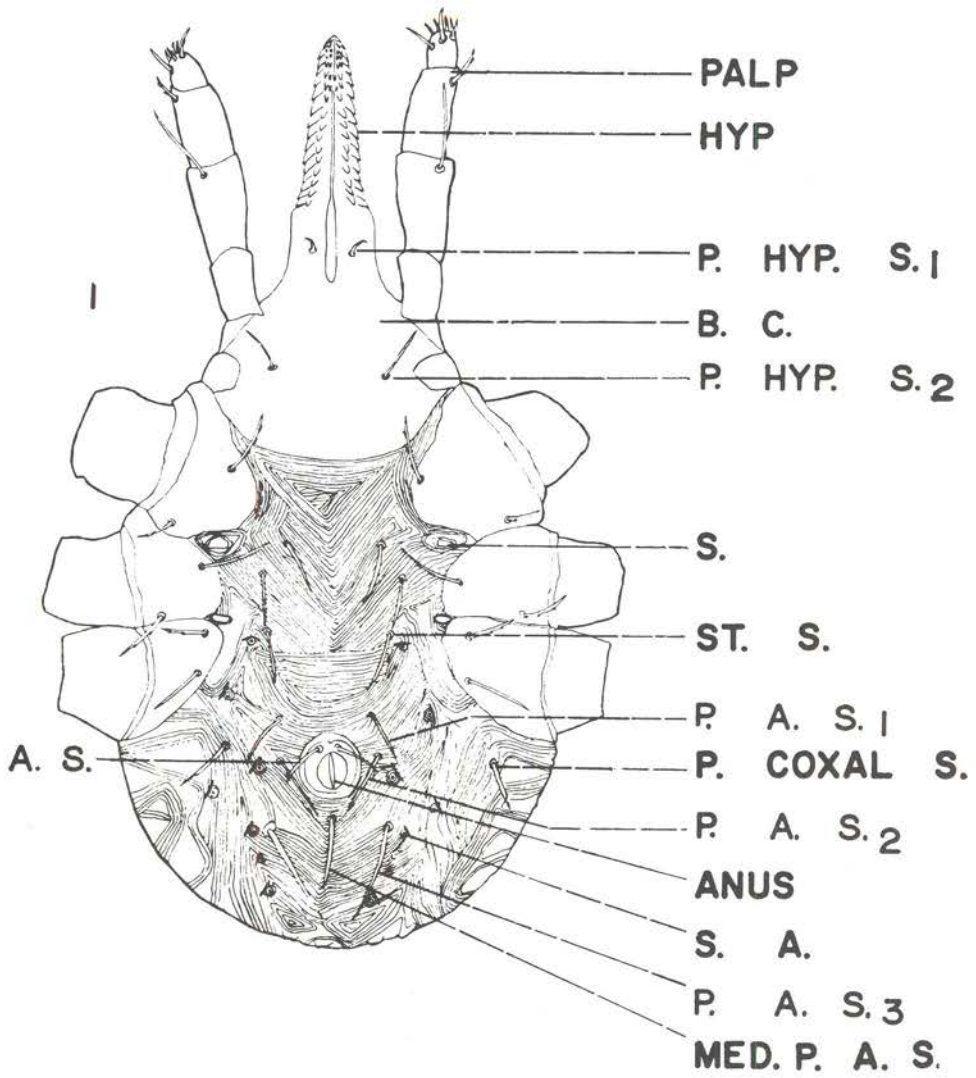


Fig. 8. *Ornithodoros kelleyi* larva, venter

ixodid genera by the 2 pairs of marginal dorsal setae anterior to the sensillum sagittiforme on each side of the relatively long, straight palps (not extending lateral beyond the margins of the basis capituli), and the body with 11 festoons.

DISTRIBUTION, HOSTS, and SEASONAL ACTIVITY.—This 3-host tick ranges from the Middle Atlantic states throughout the southeastern and most of the central United States. According to Bishop and Trembley (1945), it is especially plentiful along the South Atlantic States, Gulf Coast States, and Arkansas, Missouri and Oklahoma. Bequaert (1946) states that the northern limit of its breeding range in the Eastern United States is in southern New Jersey and Pennsylvania.

The host range of this tick is very broad and numerous species of mammals and birds are parasitized. Adults are found more frequently on medium- or large-sized mammals, including man, dogs and other domestic animals, and deer. Immatures frequently infest the same hosts, but they are also common on birds. According to Bishop and Trembley (1945), rabbits are rarely infested. Sonenshine et al. (1965) reported only 1 larva from almost 50 rabbits examined during a 3-year period at Montpelier in Hanover County, Virginia. However, Jacobson et al. (1978) reported several collections of this tick from rabbits taken in Nottoway and Montgomery counties in Virginia. Small mammals are rarely infested.

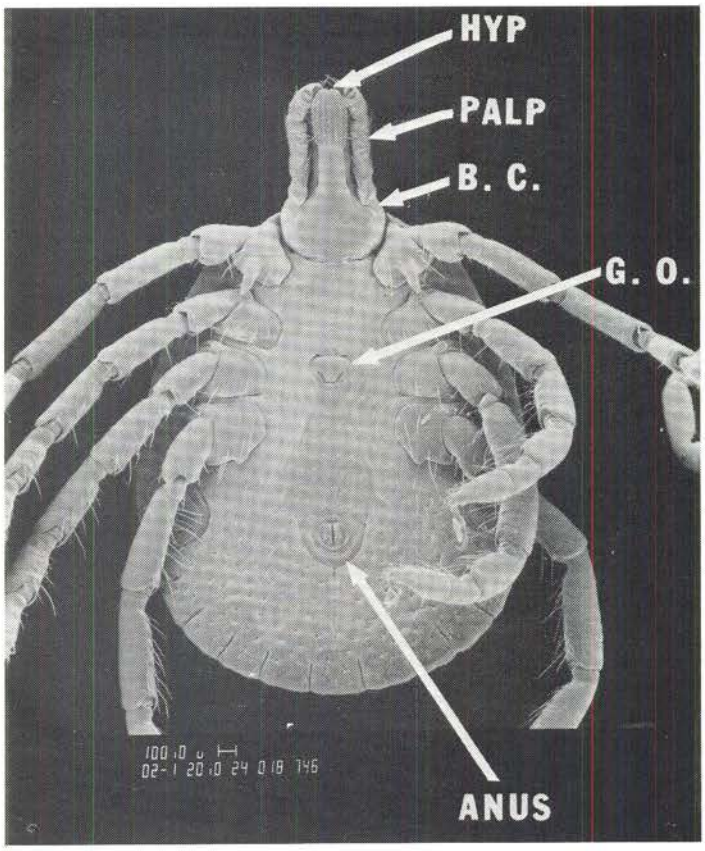


Fig. 9. *Amblyomma americanum* female, venter

Seasonal activity is confined to the spring, summer, and early fall. Peak adult activity may be expected in May or June, peak nymphal activity in June, and peak larval activity in August or September. Adult abundance at the time of peak activity was estimated at 421 to 1,029 ticks/ha at Montpelier, Hanover County, Virginia; the 5-year average was 657/ha (Sonenshine et al., 1966; Sonenshine and Levy, 1971). In contrast, adult abundance at peak activity in the Newport News City Park, Newport News, Virginia, ranged from 1334 to 4212/ha; the 2-year average was 2773 ticks/ha (Sonenshine and Levy, 1971). Nymphal abundance at the time of peak activity at these 2 localities was 218 to 2283 ticks/ha at Montpelier, with a 5-year average of 949 ticks/ha, and 2145 to 3857/ha at Newport News City Park, with a 2-year average of 3,001/ha. The abundance of Lone Star Tick larvae was estimated at Newport News City Park in only 1 year to be at 16,958 larvae/ha. These workers (Sonenshine and Levey, 1971) noted that ticks were found much less frequently in exposed habitats such as old fields or pasture than in dense woodlands. Significant differences in tick distribution were also found among 7 different forest types. The relatively undisturbed, subclimax forest of the Newport News City Park was regarded as being the more nearly optimal habitat for this species with up to 5.5 times more Lone Star Ticks than the mixed old woodlot communities characteristic of the area in Hanover County. Habitats which support large herds of white tailed deer (such as does Newport News City Park) are likely to develop tremendous Lone Star Tick populations (Bolte et al., 1970).

VIRGINIA RECORDS (Fig. 12).—*A. americanum* has been reported from 33 counties from the Atlantic Coast to Montgomery County, as well as from the cities of Charlottesville, Hampton, Lynchburg, Newport News, Norfolk, Petersburg, Richmond, and Virginia Beach. Evidently, it is well established throughout the Coastal Plain and the Piedmont, Blue Ridge, and Valley and Ridge physiographic provinces; only 2 of the counties, Montgomery and Botetourt, of Valley and Ridge-Middle Section and

none in the Alleghany Plateau province yielded collections of this tick.

REMARKS.—*A. americanum* is a vector of Rocky Mountain spotted fever, and it is probably responsible for some of the human cases of this disease reported each year. Burgdorfer (1975), however, cited evidence of a virulent rickettsiae from 41.9% of ticks collected in Arkansas. *A. americanum* is also implicated in the etiology of tick paralysis (Arthur, 1961), Q. fever (a Rickettsia infection) and tularemia (Pratt and Littig, 1974).

A. americanum is a serious pest of man and his domestic animals disregarding disease associations. Impressive evidence of the destructive capacity of this tick was presented by Bolte, et al. (1970) who demonstrated that it caused severe injury and even death among white tailed deer fawns in eastern Oklahoma; 17% of fawns less than 6 weeks old were blinded by gross tissue damage around the head and ears from tick bites. In another sample, the death of 4 young fawns was traced directly to tissue destruction and secondary infection from massive Lone Star Tick infestations.

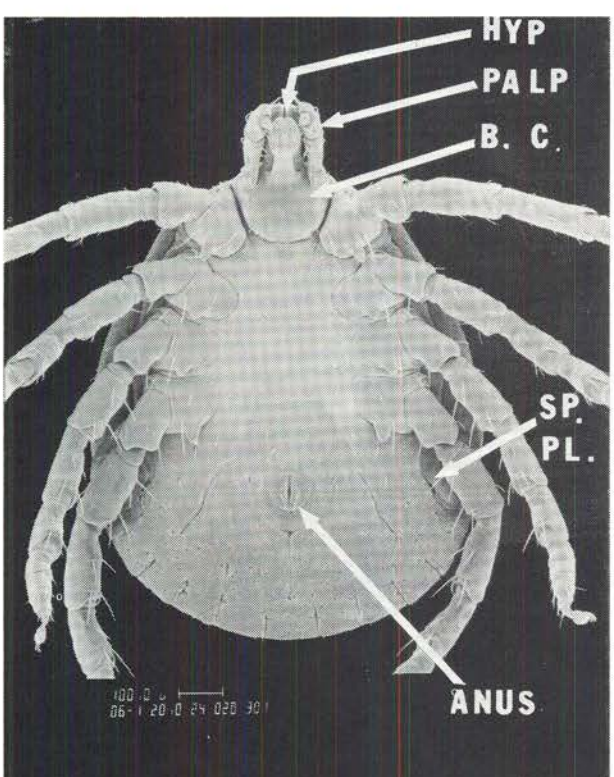


Fig. 10. *Amblyomma americanum* nymph, venter

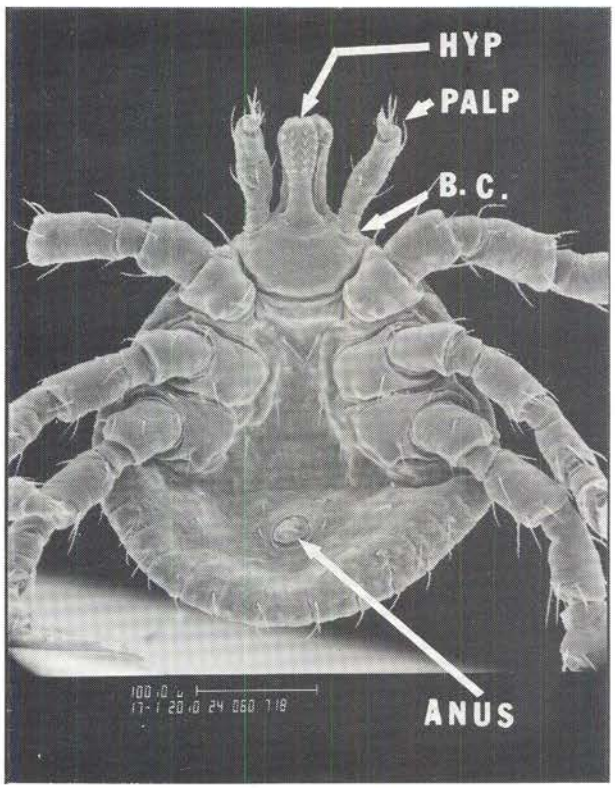


Fig. 11. *Amblyomma americanum* larva, venter

Amblyomma maculatum **Koch, 1844**
Gulf Coast Tick
(Figs. 13, 14, 15)

DIAGNOSIS.—The palps of the adults and nymphs are long and thin, article II is about twice as long as article III. The palps of other Virginia ixodid ticks (except *A. americanum*) are shorter and relatively broader in relation to their length. **Females** can be distinguished from *A. americanum* by the ornate pattern of the scutum with white lines contrasting with a dark background. The **males** are recognized by a similar ornamentation over the entire scutum. The **nymphs** are differentiated from *A. americanum* by the sharply pointed lateral edges of the basis capituli and an external spur only on coxa II. The **larvae** are distinguished from those of *A. americanum* by the subtriangular appearance of the basis capituli, with sharp lateral edges, and the single spur on coxa I. Larvae are distinguished from those of other ixodid genera by the 2 pairs of marginal dorsal setae anterior to the sensillum sagittiforme and the elongated palps (not extending

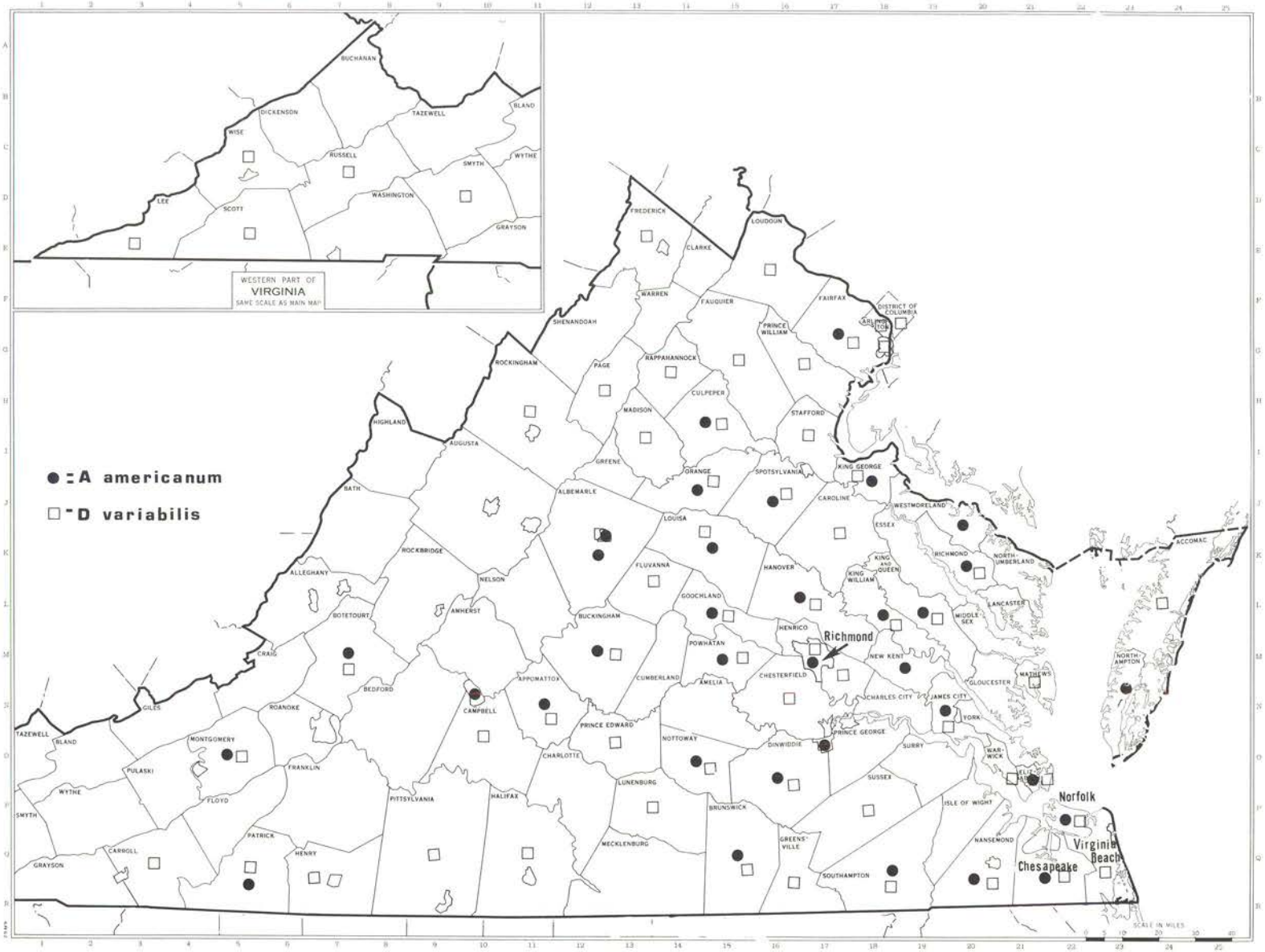


Fig. 12. Map of distribution of certain Virginia ticks

beyond the lateral margins of the basis capituli) and the body with 11 festoons.

DISTRIBUTION, HOSTS, AND SEASONAL ACTIVITY.—This 3-host tick is common throughout the southeastern states (those bordering the Gulf of Mexico, Oklahoma, Arkansas, and the South Atlantic States to South Carolina (Cooley and Kohls, 1944b; Wilson and Baker, 1972; Bishop and Trembley, 1945)). It also occurs in Mexico, Central America, and South America. Host diversity is very large, but common hosts are domestic animals, especially cattle, horses, and other large animals. Immatures frequently infest ground feeding birds. Knowledge of seasonal activity is meager. According to Bishop and Trembley (1945), ticks are most abundant in the United States in late summer and early fall, though immature stages may occur on birds throughout the year.

VIRGINIA RECORDS.-Five collections of this tick were reported by Sonenshine et al. (1965) from Lunenburg and Hanover counties, the City of Chesapeake, Norfolk, and Richmond. Cooley and Kohls (1944b) cite a record from Virginia, but without locality data. No other state records of *A. maculatum* are known. Wilson and Baker (1972) reported 5 collections from Georgia. It is unlikely that this tick is established in Virginia, and the few instances of its recovery in the state may reflect its transport by migratory birds. However, the possibility of its establishment in the less extreme climatic conditions of the southeastern coastal areas cannot be discounted.

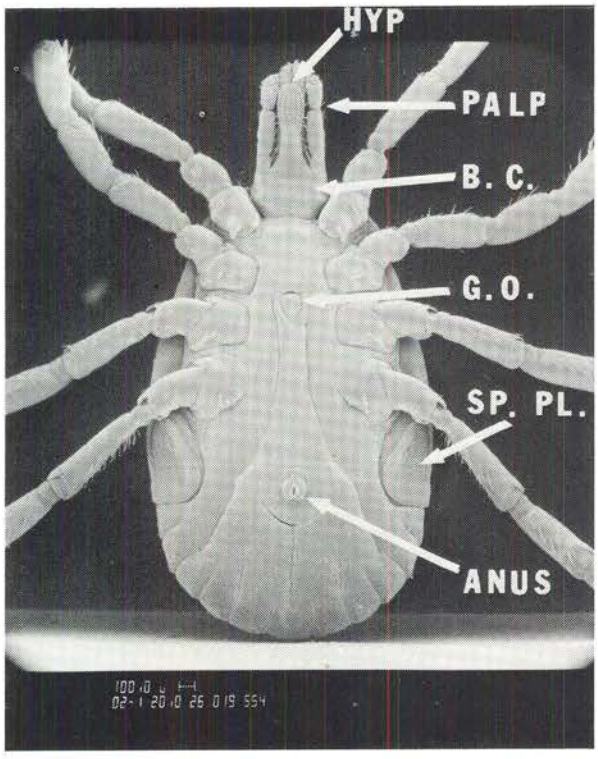


Fig. 13. *Amblyomma maculatum* female, venter

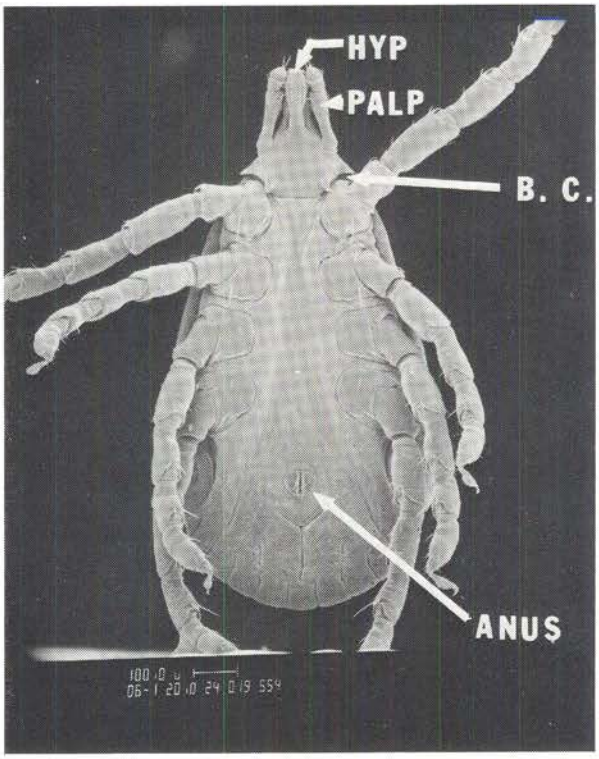


Fig. 14. *Amblyomma maculatum* nymph, venter

REMARKS.—This tick is one of the most important tick pests of cattle in the Gulf Coast States and the South Atlantic States. The bites of the tick cause extensive tissue destruction which may attract screw worm flies or other myiasis producing insects.

Genus *Dermacentor* Koch, 1844

DIAGNOSIS (Virginia species only).—The palps are short and relatively broad, eyes are present on the scutum, the body has 11 festoons, and the anal groove is posterior to the anus. In adults, the basis capituli is rectangular. Larvae have 3 marginal dorsal setae anterior to the sensillum sagittiforme on either side and only 1 pair of posthypostomal setae; dorsally, there are 3 pairs of scutal setae, 3 pairs of central setae, and 8 pairs of marginal dorsal setae.

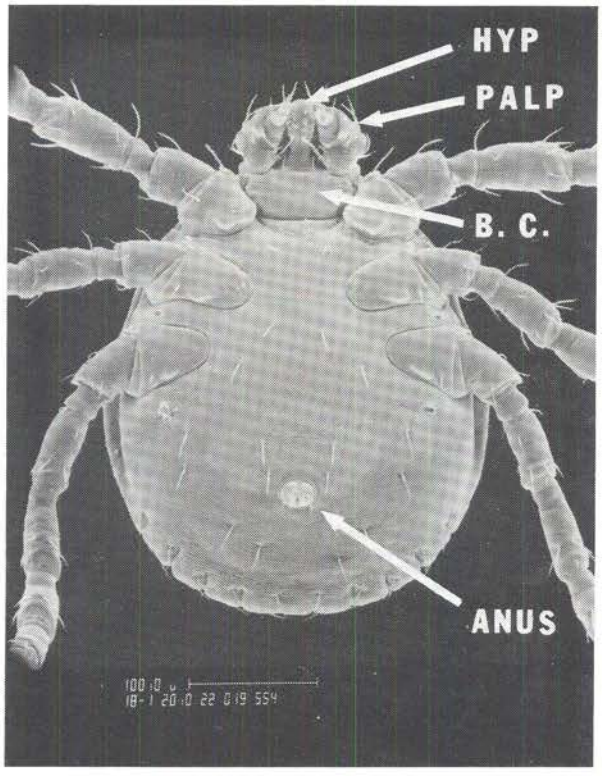


Fig. 15. *Amblyomma maculatum* larva, venter

Dermacentor albipictus **(Packard, 1869)**
Winter Tick
(Figs. 16, 17, 18)

DIAGNOSIS.—All stages are distinguished from other genera of ixodid ticks of Virginia by the rectangular shape of the basis capituli, the posterior position of the anal groove, palps relatively short, not extending beyond the lateral margins of the basis capituli, eyes on the scutum, and 11 body festoons. **Adults** (both sexes) are distinguished from *D. variabilis* by the relatively few large goblets in the spiracular plate. Many populations in various parts of the United States, including Virginia, lack scutal ornamentation in contrast to the irridescent silvery or white lines on the scutum of *D. variabilis* (rarely, dwarfs without ornamentation occur in *D. variabilis*, according to Homsher and Sonenshine, 1973). **Nymphs** are distinguished from *D. variabilis* by the rectangular shape of the basis capituli, with the lateral edges rounded or almost straight, the small number of goblets in the spiracular plate, and the absence of an external spur on coxa IV. **Larvae** are distinguished from *D. variabilis* by the rectangular shape of the basis capituli, with the lateral edges convex or almost parallel. Larvae are distinguished from those of other genera of Virginia Ixodidae by the 3 marginal dorsal setae anterior to the sensillum sagittiforme on each side as well as the other differences noted above.

DISTRIBUTION, HOSTS AND SEASONAL ACTIVITY.—This 1-host tick is widely distributed throughout the United States; it also occurs in northern Mexico and southern Canada (Cooley 1938; Bishop and Trembley, 1945; Gregson, 1956). According to Bishop and Trembley, it is most abundant in the southern part of the United States, especially the arid areas of Texas and New Mexico.

The Winter Tick is especially common to white tailed deer, but it also infests horses, cattle, and other large herbivores. Seasonal activity is well defined. Larvae commence activity in the early fall, attach themselves to hosts, and develop on the same animals to nymphs and adults during the succeeding months. Engorged females drop and oviposit on the ground (Howell, 1940). Larvae that emerge in the spring diapause until fall. Photoperiodic regulation of larval activity has been postulated as the mechanism controlling host seeking activity (Wright, 1969).

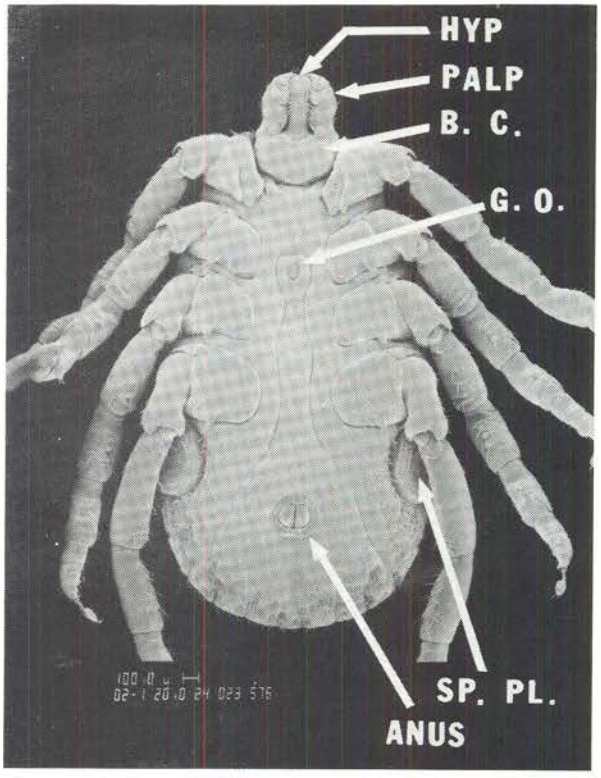


Fig. 16. *Dermacentor albipictus* female, venter

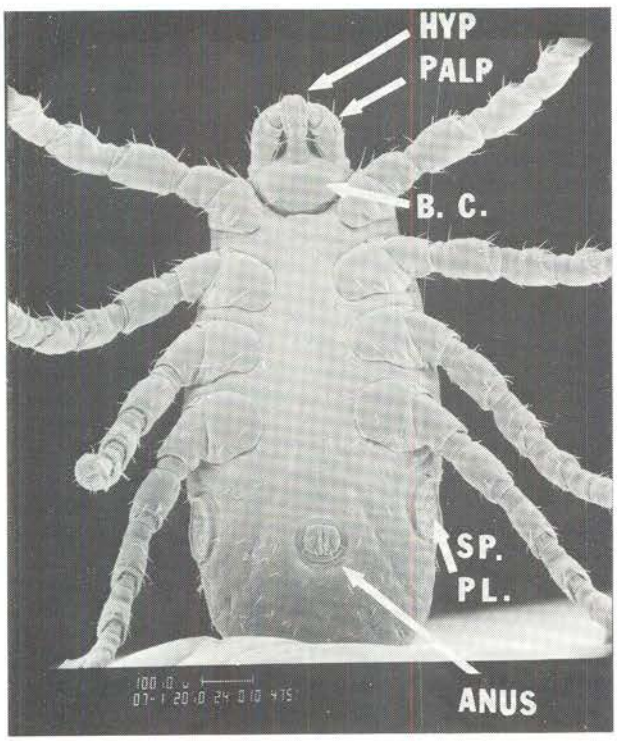


Fig. 17. *Dermacentor albipictus* nymph, venter

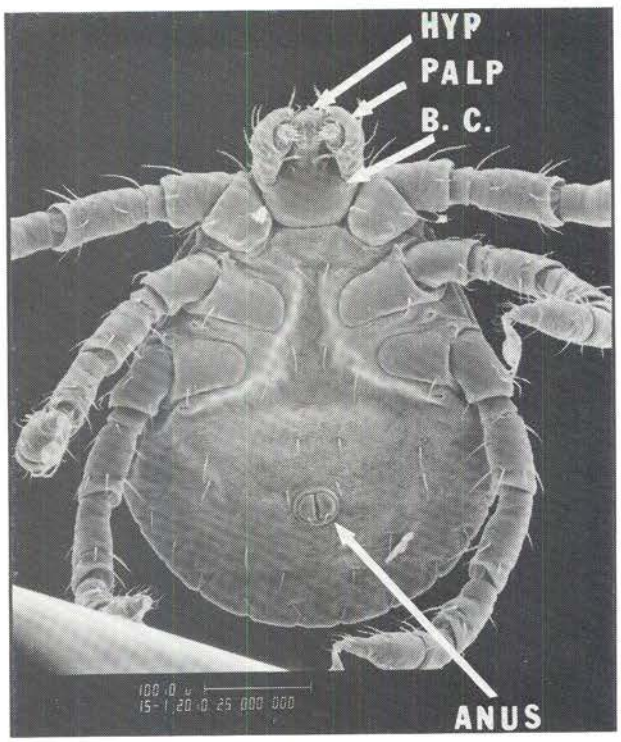


Fig. 18. *Dermacentor albipictus* larva, venter

D. albipictus exhibits 2 contrasting forms: an ornamented and an unornamented form. Apparently, only the unornamented strain occurs in Virginia, because all of the collections from different parts of the state were of this type (Sonenshine et al., 1965). Tick density on deer was found to be greater in the southern than in the north Piedmont counties.

VIRGINIA RECORDS.—Augusta, Brunswick, Caroline, Dinwiddie, Nottoway, and Spotsylvania counties, all from white tailed deer (Sonenshine et al., 1965).

REMARKS.—This tick has been reported to be the vector of "moose disease," caused by a bacterium, *Klebsiella paralytica* (Bequaert, 1946). It is a serious pest, and deer and moose are said to die as a result of blood loss resulting from heavy infestations of the Winter Tick (Pratt and Littig, 1974).

Dermacentor variabilis (Say, 1821)
American Dog Tick
(Figs. 1, 2a, 3, 4, 5)

DIAGNOSIS.—**Adults** are distinguished by the relatively numerous, crowded goblets in the spiracular plate and by the ornamented scutum with irregular silvery streaks contrasting with a dark background (rarely, unornamented dwarf ticks occur). The **nymphs** and **larvae** are recognized by the more or less triangular appearance of the basis capituli (dorsal view) with sharply pointed lateral edges.

DISTRIBUTION, HOSTS AND SEASONAL ACTIVITY.—The range of this tick is from the Atlantic Coast throughout the eastern and central United States to the foothills of the Rocky Mountains, as well as southeastern and south central Canada. Isolated, but apparently established, breeding populations occur in California, Oregon, and Washington. Recent evidence of range extension to the north was presented by Dodds et al. (1969). Hosts for the immatures are small mammals, especially mice and voles. Host associations for the immature ticks in Virginia are summarized in Table 1 from Sonenshine (1973). In other areas of its range, various small mammals may assume a different order of importance. Adults parasitize medium- and large-sized mammals, including man and dogs. Raccoons are among the most important medium-sized mammal hosts. Wild host associations of the adult stages in Virginia are summarized in Table 2.

Seasonal activity is well defined. In Virginia, Sonenshine et al. (1966) demonstrated that tick

Table 1. Frequency of occurrence of *Dermacentor variabilis* larvae and nymphs on small mammals captured in the Montpelier (Hanover County) study area, 1963-1970.[1]

Host Species	Animal Examinations		Tick Infestations			
			Larvae		Nymphs	
	Total Animal Examinations	% of all Hosts	Total No.	% of Total	Total No.	% of Total
White-footed mouse	2,060	57.2	5,758	74.4	309	52.8
Flying squirrel	138	4.5	17	0.2	1	0.2
Ground squirrel	51	1.7	6	0.1	4	0.7
Pine vole	68	2.2	108	1.4	27	4.6
Jumping mouse	13	0.4	1	0.0	0	0.0
Meadow vole	372	12.1	1,654	21.4	238	40.7
Harvest mouse	207	6.7	97	1.3	2	0.3
House mouse	47	1.5	18	0.2	1	0.2
Rice rat	8	0.3	60	0.8	3	0.5
Cottontail rabbit	41	1.3	16	0.2	0	0.0
Shrews (3 spp.)	103	3.4	0	0.0	0	0.0
Totals	3,108	---	7,735	---	585	---

[1]From Sonenshine (1973)

Table 2. Relative ranking of medium sized wild mammals as hosts for adult *Dermacentor variabilis* and their contribution to support of the tick population at the Montpelier (Hanover County) study area during the 5 month tick activity period, April 1 through August 31 (17 feeding periods), 1963-1969.[1]

Host Animal	Avg Ticks/ Animal	Avg. No. Animals on Study Area	Estimated No. Fed Ticks			Percent of all Ticks
			Total	Females Only	Females/ ha	
Raccoon	31.93	3.0	1,628	580	32.9	4.5
Striped skunk	8.72	2.9	430	153	8.7	1.2
Opossum	9.78	5.8	964	344	19.5	2.6
Red fox	10.23	0.4	70	25	1.5	0.2
Gray fox	5.83	0.1	10	4	0.3	0.0
Gray squirrel	0.86	41.0	599	213	12.1	1.6
Woodchuck	1.89	1.0	32	11	0.7	0.1
Cottontail rabbit	0.05	38.7	2	1	0.1	0.0
Totals			3,733	1,330	75.8	10.2

[1]Based on estimates of the total unfed adult population at peak abundance, by Sonenshine et al. (1966) and Sonenshine (1972).

activity begins in March, following the emergence of the unfed larvae from their winter diapause. Peak larval activity occurs in April in most years. Nymphs become most abundant in May or early June. Adult activity in Virginia commences in April (rarely, in March) and continues through August. The adult population comprises 2 groups: 1) the overwintering survivors that emerge in early spring, and 2) young adults that emerge later following molting of the engorged nymphs. The former group is responsible for the early surge of tick activity in the spring. The latter group, however, comprises the great bulk of the summer tick population, at least in Virginia. At the time of peak activity in late June or early July, the estimated adult tick population in an area of Hanover County, during a 5-year study period, ranged from 1215 to 5496 ticks/ha. Daily host-seeking activity was found to fluctuate greatly with changes in response to incident solar radiation intensity, mostly due to cloud cover (Atwood and Sonenshine, 1967).

American Dog Ticks tend to be especially abundant along trails, roadsides, and the forest boundaries surrounding old fields or other clearings. Such habitats abound in rural areas where there are numerous small farms interspersed with small woodlots. Sonenshine et al. (1966) and Sonenshine and Levy (1972) demonstrated that *D. variabilis* adults were at least twice as abundant in the old field-forest edge as in the adjacent clearings. Ticks are also abundant in adjacent forested areas dominated by early successional stages of forest growth. However, tick survival is extremely restricted in large clearings (e.g., greater than 25 acres) exposed to long periods of severe desicacation. Ticks are also virtually absent in large tracts of mature, sub-climax forest such as the 7,500-acre Newport News City Park. In the Great Dismal Swamp Wildlife Refuge, Garrett and Sonenshine (1977) demonstrated that *D. variabilis* has become established alongside the man-made roads and ditches, but has failed to colonize the forested interior habitat.

VIRGINIA RECORDS.—According to Sonenshine et al. (1965), the American Dog Tick was reported from 50 counties and 13 cities, ranging from the Atlantic coast to Lee County in the western-most mountains. Additional records in the VPI&SU collection are from Carroll, Frederick, Southhampton, Holland and Smyth counties. It may be assumed that this tick is established through the entire state at lower elevations (Map, Fig. 12).

REMARKS.—The American Dog Tick is the most important vector of Rocky Mountain spotted fever in the United States. In most years, Virginia ranked first or second (after North Carolina) in the number of cases of this disease reported for any state. In addition, *D. variabilis* transmits tularemia, or rabbit fever; of the 129 cases reported in the United States in 1976 (Anonymous, 1976) 8 occurred in Virginia. The tick is also responsible for tick paralysis, which has been reported from the Eastern United States (Gregson, 1973). *D. variabilis* is also implicated as a possible vector of human babesiosis (McEnroe, 1977).

Genus *Haemaphysalis* Koch, 1844

DIAGNOSIS (Virginia specimens).—All stages are recognized by the expanded lateral extensions of palpal article II, which extend beyond the margins of the basis capituli. Eyes are absent. The anal groove is posterior to the anus. The **males** lack ventral plates or shields. The **larvae** have only 2 marginal dorsal setae anterior to the sensillum sagittiforme on either side, and only 1 pair of posthypostomal setae. Dorsally, there are 3 pairs of scutal setae, 2 pairs of central setae, and 8 pairs of marginal dorsal setae.

Haemaphysalis chordeilis (Packard, 1869)
(Figs. 19, 20, 21)

DIAGNOSIS.—**Adults** are distinguished from *H. leporispalustris* by the lack of ventral cornua on the

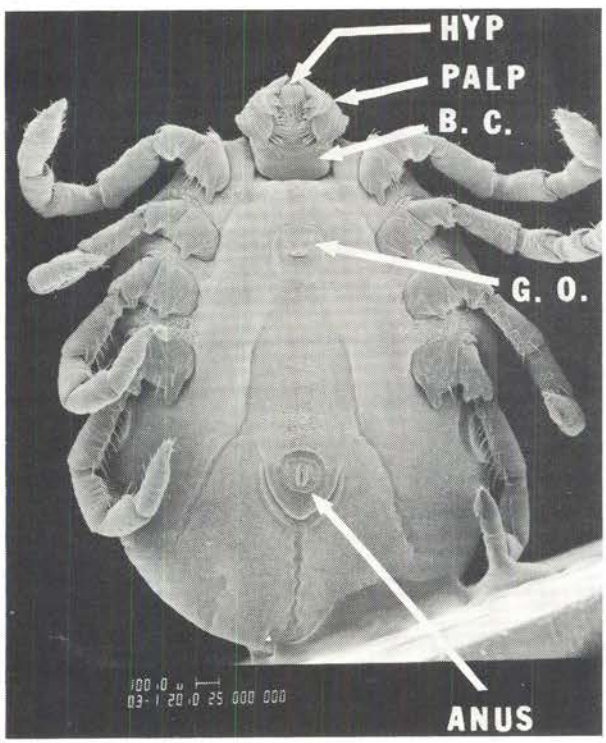


Fig. 19. *Haemaphysalis chordeilis* female, venter

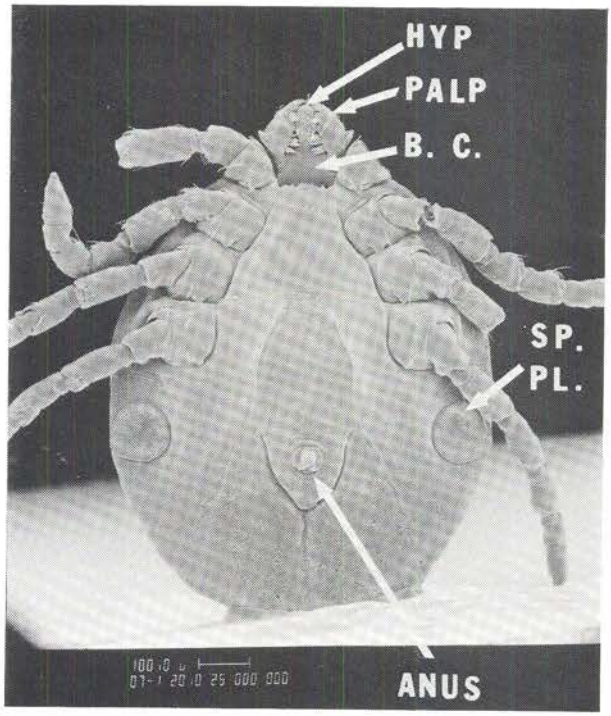


Fig. 20. *Haemaphysalis chordeilis* nymph, venter

basis capituli; **nymphs** and **larvae** are separated from *H. leporispalustris* by the parallel sides of the basis capituli (lateral edges sharp in *H. leporispalustris*).

DISTRIBUTION, HOSTS, and SEASONAL ACTIVITY. This tick is believed to be widely distributed throughout the Eastern United States and Eastern Canada. Although not recorded from Virginia, its occurrence in states nearby (e.g., Pennsylvania and South Carolina) suggests that Virginia may be included in its range (Clifford et al., 1961). Common hosts are ground feeding birds. Records from mammals, including man and domestic animals also exist, though there may be some doubt as to their validity. Little information is available on seasonal activity.

VIRGINIA RECORDS.—None.

REMARKS.—Cooley (1946) states that *H. chordeilis* "has been reported as killing turkeys in various places in the United States," but he does not elaborate nor cite any references. No other information on disease or injurious effects relating to this tick are known.

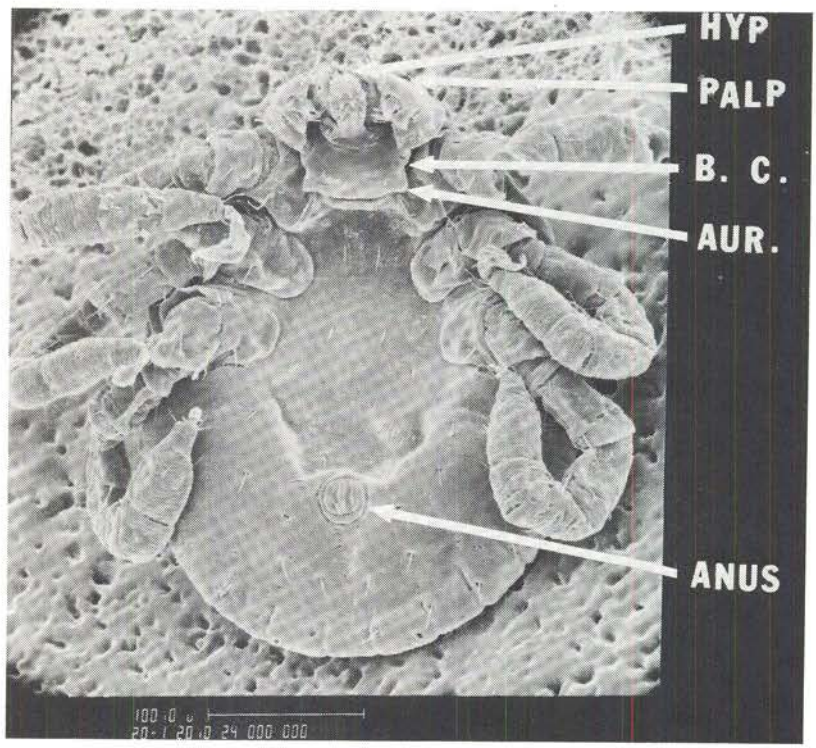


Fig. 21. *Haemaphysalis chordeilis* larva, venter

Haemaphysalis leporispalustris **(Packard, 1869)**
Rabbit Tick
(Figs. 22, 23, 24)

DIAGNOSIS.—**Adults** are distinguished from *H. chordeilis* by the ventral cornua on the basis capituli. **Nymphs** and **larvae** are distinguished by the shape of the basis capituli, which has parallel lateral edges (dorsal view) in *H. leporispalustris* but is pointed at the side in *H. chordeilis.*

DISTRIBUTION, HOSTS, and SEASONAL ACTIVITY .—This 3-host tick has been recorded from virtually all of North America, as well as parts of Central and South America (Cooley, 1946). Lagomorphs are the preferred hosts, and adult ticks are rarely found on any other animal. This tick does not bite man. Larvae and nymphs, however, will attach to a wide variety of ground feeding birds. Sonenshine and Stout (1970) reported 40 species of birds as hosts for the immature stages at their Montpelier (Hanover County, Virginia) study site. The bobwhite quail was the most important bird host, but the white throated sparrow, song sparrow, and other fringillids, were also important. The white throated sparrow was the most important host in a similar study of bird-tick relationships near Chapel Hill, North Carolina. However, in coastal areas between Cape Charles, Virginia, and Long Island, New York, the Swainson's thrush and the veery

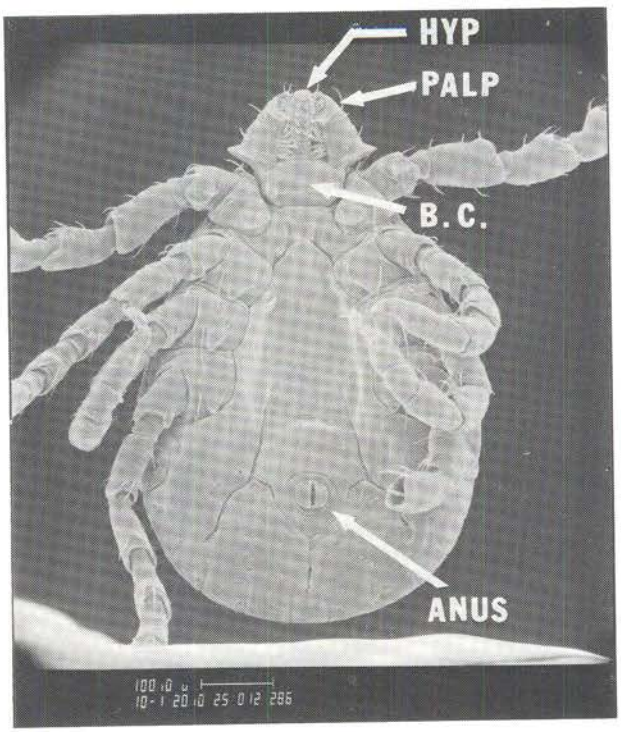


Fig. 23. *Haemaphysalis leporispalustris* nymph, venter

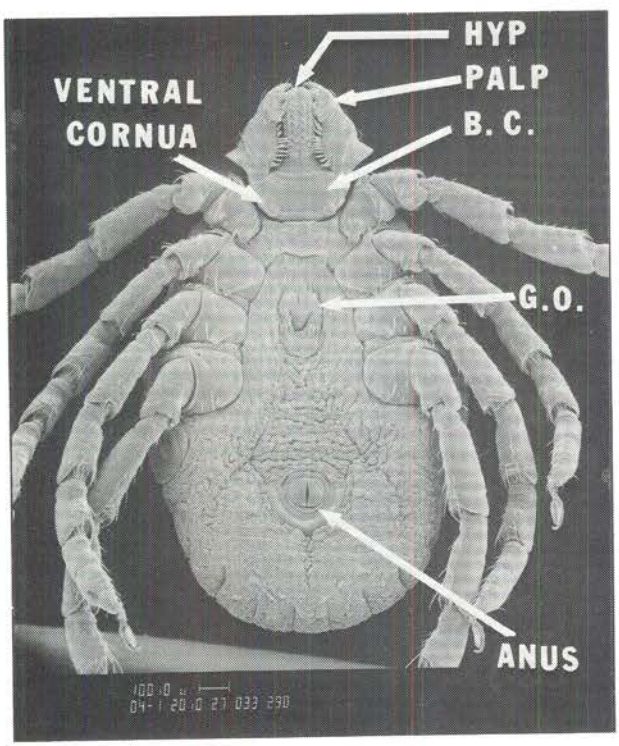


Fig. 22. *Haemaphysalis leporispalustris* female, venter

were reported to be the most important bird hosts in the fall (Sonenshine and Clifford, 1973). Comparing the coastal and Piedmont area localities, the same authors concluded that birds of the families Turdidae and Fringillidae were the major hosts for the immatures in the coastal localities, while Fringillidae, Parulidae, Troglotyditidae and Thraupidae were most important in the Piedmont area (Table 3).

The Rabbit Tick is active throughout the year in the milder, southern parts of its range, but activity apparently ceases during the winter in the colder, northern climates (Sonenshine and Stout, 1970). Immature tick activity on birds in the Atlantic coastal areas was compared with that on birds and rabbits in the Piedmont areas noted above . A summary is given in Table 4. In the coastal area, larval activity was greatest during the period July through December; nymphal activity, during August and September. Few immatures were found at other times of the year. In Piedmont areas, larval activity was bimodal , with peaks in February and October. Nymphal activity was also bimodal, with peaks in April and November. Adults were observed on rabbits at Montpelier in all months; peak abundance was in May. Jacobson et al. (1978) found Rabbit Ticks on rabbits examined at Camp Pickett (Nottoway County) in all months of the year, but in Montgomery County during winter, ticks were

Table 3. Summary of tick infestations of wild birds: host relationships between Piedmont and Coastal Area of the Eastern United States bird banding locations, 1965-1968.[1]

Family	Coastal Area Locations						Piedmont Area Locations					
	Total Birds Examined	% All Birds	Total *H. leporis-palustris*	% All Ticks	Total *I. dentatus*	% All Ticks	Total Birds Examined	% All Birds	Total *H. leporis-palustris*	% All Ticks	Total *I. dentatus*	% All Ticks
Turdidae	811	12.3	1,317	42.9	518	23.8	261	2.3	267	1.0	21	4.1
Fringillidae	1,033	15.7	358	11.7	870	39.9	6,341	54.8	1,032	39.6	383	73.9
Emberizidae	88	1.3	136	4.4	170	7.8	44	0.4	25	1.0	4	0.8
Parulidae	2,218	33.7	660	21.5	86	3.9	2,677	23.1	337	12.9	5	1.0
Mimidae	375	5.7	314	10.2	206	9.4	182	1.6	162	6.21	22	4.2
Troglodytidae	53	0.8	54	1.8	107	4.9	110	1.0	550	21.1	521	10.0
Corvidae	239	3.6	26	0.8	94	4.3	88	0.8	15	0.6	0	0.0
Icteridae	152	2.3	112	3.7	4	0.2	100	0.9	88	0.3	0	0.0
Thraupidae	242	3.7	51	1.6	85	3.9	847	7.3	133	5.1	31	6.0
Other infested birds[2]	765	11.6	43	1.4	41	1.9	87	0.7	320	12.3	0	0.0
Uninfested birds[3]	614	9.3	0	---	0	---	834	7.2	0	---	0	---
Totals	6,590	---	3,071	---	2,181	---	11,571	---	2,608	---	518	---

[1]From Sonenshine and Clifford (1973)
[2]Sturnidae, Certhiidae, Vireonidae, Phasianidae, Paridae, Sylviidae, Picidae, Sittidae and Alcedinidae.
[3]Bombycillidae, Caprimulgidae, Strigeidae, Cucilidae, Trochilidae, Accipitridae, Anatidae, Columbidae and Scolopacidae.

virtually absent from rabbits. Records of Jacobson et al. (1978) for mountainous Montgomery County (summarized in Table 5) suggest that the behavior of the Rabbit Tick in that area resembles its behavior in the northern range. In contrast, the findings for the Piedmont and coastal areas resemble the year-round activity pattern, with well-defined seasonal peaks for each life stage, characteristic of the southern part of the species range.

VIRGINIA RECORDS.—The Rabbit Tick has been reported from 25 counties and 8 cities from the Atlantic coast to Wise County in the western-most mountains: Accomack, Amelia, Augusta, Bedford, Caroline, Chesterfield, Dinwiddie, Fairfax, Giles, Goochland, Hanover, James City, King and Queen, King William, Middlesex, Montgomery, Northumberland, Nottoway, Pittsylvania, Prince Edward, Prince George, Spotsylvania, Southampton, Sussex, and Wise, and from the cities of Arlington, City of Chesapeake, Lynchburg, Nansemond, Norfolk, Petersburg, Richmond, and City of Virginia Beach. Presumably, the Rabbit Tick is established throughout the state.

REMARKS.—This species is implicated in the transmission of Rocky Mountain spotted fever among wildlife. It may be important to the extent that man-biting ticks share the same hosts as the

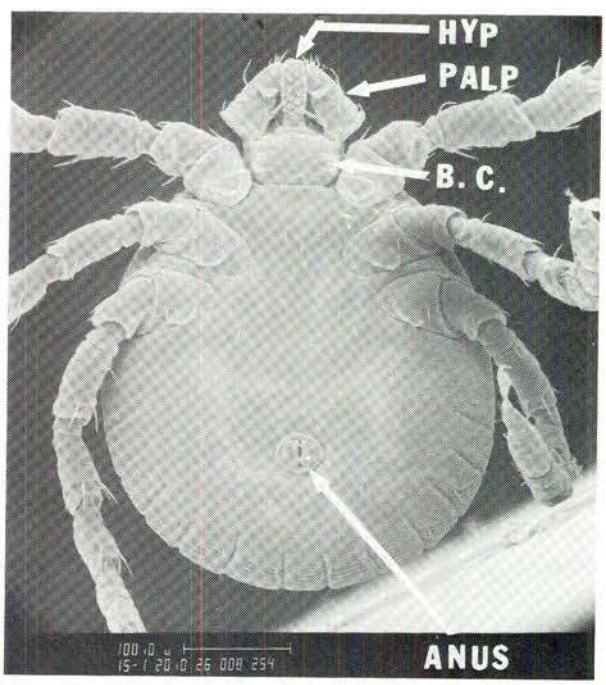


Fig. 24. *Haemaphysalis leporispalustris* larva, venter

Table 4. Seasonal occurrence of immature Rabbit Ticks, *Haemaphysalis leporispalustris* on birds at eastern United States Coastal and Piedmont localities.[1,2]

Season/ Month	Coastal Habitats					Piedmont Habitats				
	No. Birds Examined	No. Larvae	Avg./ Bird	No. Nymphs	Avg./ Bird	No. Birds Examined	No. Larvae	Avg./ Bird	No. Nymphs	Avg./ Bird
A. Spring-Summer										
March	52	2	0.04	2	0.04	3,024	149	0.05	150	0.05
April	209	16	0.08	2	0.01	896	60	0.07	93	0.10
May	127	4	0.03	3	0.03	820	10	0.01	24	0.03
June	177	0	0.00	4	0.03	159	0	0.00	0	0.00
July	22	7	0.32	0	0.00	17	0	0.00	0	0.00
Totals & Avg.	587	29	0.05	11	0.02	2,041	219	0.11	267	0.13
B. Summer-Fall										
August	312	124	0.40	35	0.11	69	178	2.56	1	0.02
September	3,380	1,590	0.47	272	0.08	250	343	1.37	52	0.21
October	1,415	646	0.46	32	0.02	409	301	0.74	26	0.05
November	710	315	0.44	1	0.00	1,534	627	0.41	16	0.01
December	196	16	0.08	0	0.00	758	87	0.12	3	0.00
Totals & Avg.	6,013	2,691	0.45	340	0.06	3,020	1,536	0.51	98	0.03

[1]From Sonenshine and Stout (1970) with permission of the journal.
[2]From Sonenshine and Clifford (1973) with permission of the journal.

Table 5. Seasonal occurrence of Rabbit Ticks, *Haemaphysalis leporispalustris* on Cottontail Rabbits *(Sylvilagus floridanus)* in 2 localities in Virginia.[1]

Season	Radford Arsenal Montgomery County		Camp Pickett Nottoway County	
	Ticks/Male	Ticks/Female	Ticks/Male	Ticks/Female
Spring	14.3	11.4	39.6	26.0
Summer	3.3	5.8	24.6	19.5
Fall	40.0	6.8	31.5	83.1
Winter	0.7	0.8	16.6	14.3

[1]From Jacobson et al. (1978) with permission of the journal.

infected Rabbit Ticks. Infected Rabbit Ticks transported by wide ranging migratory birds may be responsible for establishing new foci of disease in wildlife, though conclusive evidence of this was not demonstrated. The Rabbit Tick is probably the major tick vector of tularemia among rabbits. In addition to disease transmission, tick infestations may be so severe as to injure the host. Green et al. (1943) reported an average of 5,000 ticks/hare in Minnesota; quail and meadowlarks were observed to be so heavily infested that they were severely emaciated, and some were believed to have been killed by the ticks.

Genus *Ixodes* Latreille, 1795

DIAGNOSIS (Virginia specimens).—All stages are recognized by the shape of the anal groove, which encircles the anus anteriorly. The ticks are always inornate, without eyes or festoons. **Males** have the ventral surface covered by 7 non-salient contiguous ventral plates. **Larvae** lack sensilla sagittiformia, but have 2 pairs of posthypostomal setae. The scutum has 5 pairs of scutal setae; the number of remaining dorsal body setae varies among the different species.

Ixodes angustus Newmann, 1899
(Figs. 25, 26, 27)

DIAGNOSIS.—The **female** is recognized by the long pointed hypostome with large denticles arranged 3/3 throughout its entire length. The **nymph** is distinguished from other Virginia *Ixodes* by the large anterior and posterior spurs on palpal article I (*I. cookei* nymphs lack a distinct anterior spur). The **larva** has 15 pairs of dorsal body setae (8 MD, 5 SC, 2 CD) and 9 pairs of postero ventral setae (4 PM, 2 PA, and 3 MV). The larva is distinguished from that of *I. cookei* by the anterior palpal spur, which is missing in *I. cookei*, and the small internal spur on coxa I, which is much larger in *I. cookei*.

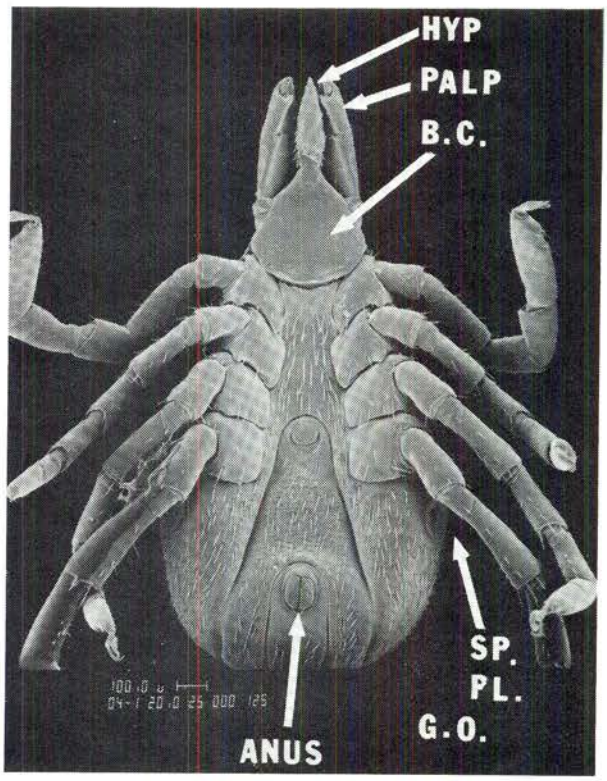


Fig. 25. *Ixodes angustus* female, venter

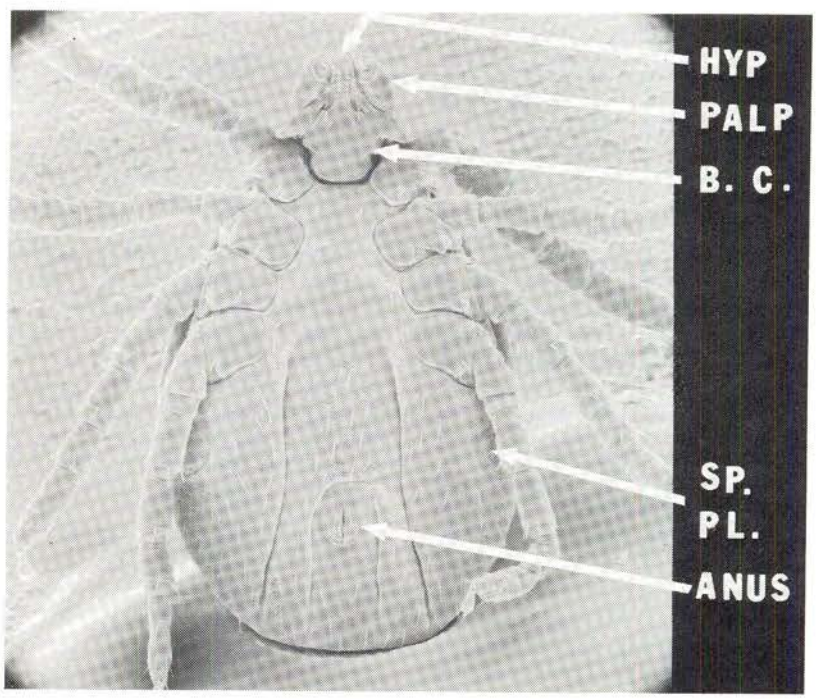


Fig. 26. *Ixodes angustus* nymph, venter

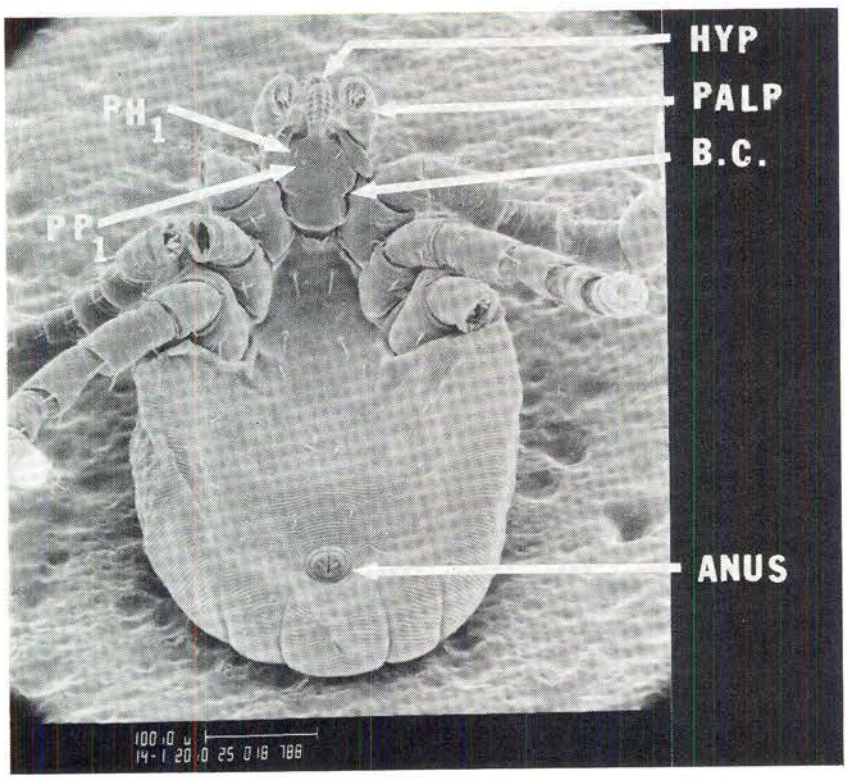


Fig. 27. *Ixodes angustus* larva, venter

DISTRIBUTION, HOSTS and SEASONAL ACTIVITY.—This tick is found throughout virtually all of North America. In the Western United States and Western Canada, larvae are virtually indistinguishable from those of *Ixodes ochotonae* Gregson. Typical hosts are small mammals. Bishop and Trembley (1945) reported finding adults on hosts or in the hosts' nests throughout the year in Washington and Oregon; immatures, however, were found only after October. In Utah, Allred et al. (1960) reported larvae during May, nymphs from May through September, and adults in May, June, and August.

VIRGINIA RECORDS.—The only known Virginia records are 3 females from the white footed mouse *P. leucopus* in Giles County and 1 female from the same host in Rockingham County (Sonenshine et al., 1965).

REMARKS.—This tick is subject to considerable variation. Larval material from areas of the Western United States and Western Canada shows marked differences from the form described by Clifford et al. (1961) from Rhode Island.

Ixodes brunneus **Koch, 1844**
(Figs. 28, 29, 30)

DIAGNOSIS.—The **female** is recognized by the long, pointed hypostome with denticles arranged 4/4 anteriorly and by the shape of the basis capituli in ventral view, which is narrow and tapering anteriorly but broadened posteriorly. The auriculae are broad and truncated. In the **male**, the scutum is relatively smooth with few punctations or setae, the marginal grooves terminating in deep anterior depressions. The **nymph** resembles the female, with large cornua and auriculae. The **larva** has 19 pairs of dorsal body setae (8 MD, 5 SC, 5 CD, and 1 S); and the 10 pairs of central dorsal setae will distinguish this larva from those of other *Ixodes* parasitizing birds in this state.

DISTRIBUTION, HOSTS, and SEASONAL ACTIVITY.—This tick is found in the Eastern and Central United States; it is also known from central South America (Wilson and Baker, 1972). Hosts are birds, mostly Passeriformes. Sonenshine and Stout (1970) found the slate colored junco to be the most important host. Host-seeking activity is confined to the colder months of the year.

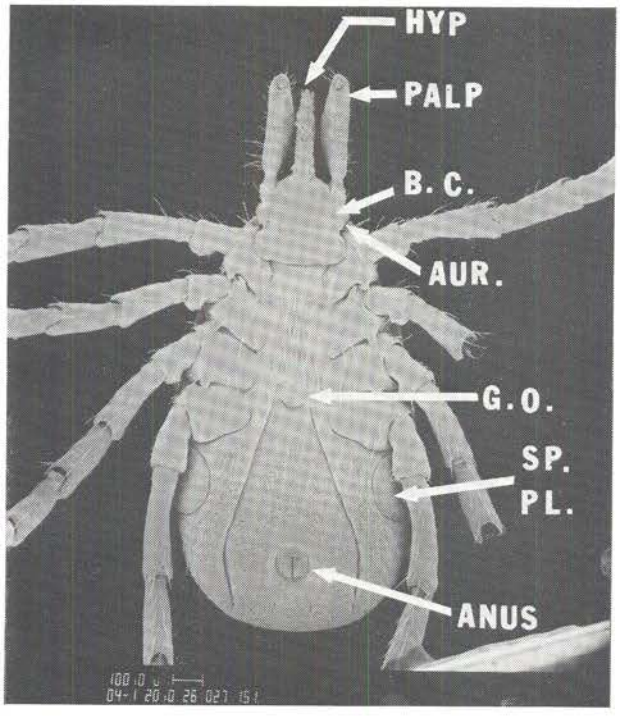


Fig. 28. *Ixodes brunneus* female, venter

VIRGINIA RECORDS.—Amelia and Fairfax counties (Cooley and Kohls, 1945); Amelia, Fairfax, Goochland, and Loudon counties (Sonenshine et al., 1965); Hanover County (Sonenshine and Stout, 1970).

REMARKS.—Clifford et al. (1969) reported evidence of *R. rickettsii* in one pool of *I. brunneus* from migratory birds.

Ixodes cookei **Packard, 1869**
(Figs. 31, 32, 33)

DIAGNOSIS.—**Females** are distinguished from other *Ixodes* parasitizing mammals in Virginia by the rounded hypostome with denticles arranged 3/3 anteriorly, the lack of auriculae, and a long pointed spur on coxa I. The prominent lateral carinae on the scutum will distinguish it from *I. scapularis*. In the **males** coxa I has a long internal spur. The **nymph** resembles the female, but palpal article I has a long, pointed internal spur. The **larva** has 15 pairs of dorsal body setae (8MD, 5 SC, 2 CD) and 10 pairs of postero-ventral body setae (4 PM, 2 PA, and 4 MV). The larva is distinguished from *I. angustus* by the absence of an anterior palpal spur (present in *I. angustus*) and the internal spur on coxa I, which is larger than in *I. angustus*.

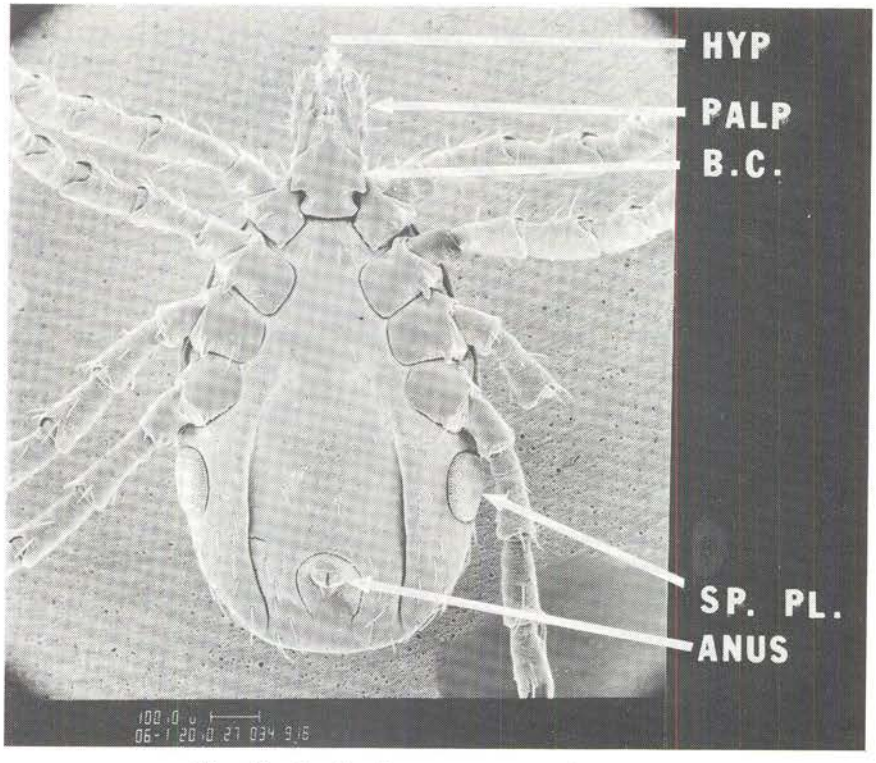


Fig. 29. *Ixodes brunneus* nymph, venter

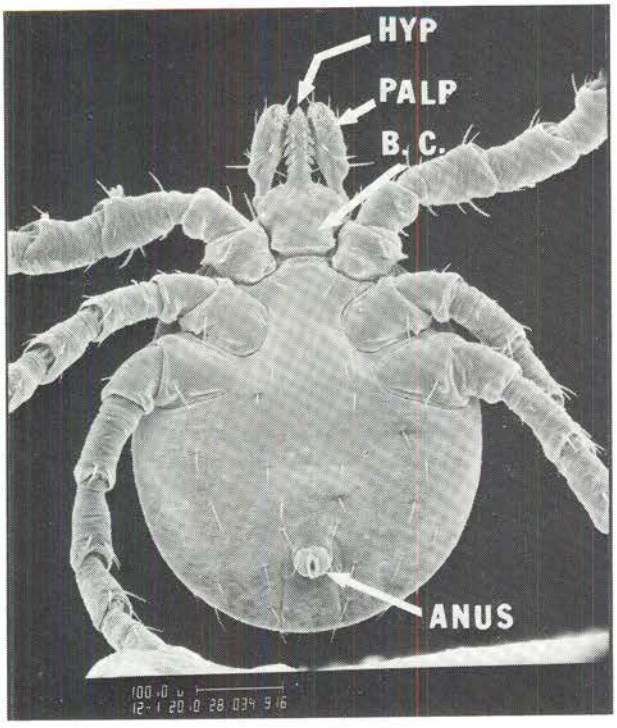


Fig. 30. *Ixodes brunneus* larva, venter

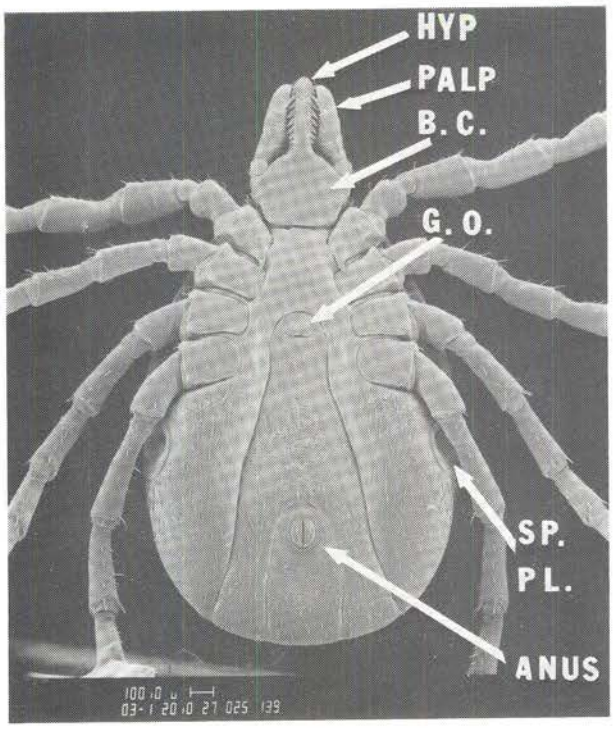


Fig. 31. *Ixodes cookei* female, venter

DISTRIBUTION, HOSTS, and SEASONAL ACTIVITY.—This species is widely distributed throughout the Eastern and Central United States and parts of eastern Canada. Typical hosts are wild carnivores, but numerous other mammals, including man and dogs have been infested (Bishop and Trembley, 1945). In Virginia, this species was found frequently on 4 of 7 medium-sized wild mammal species examined during a 6-year study period (Sonenshine and Stout, 1971). The most important host for the adults was the striped skunk, *Mephitis mephitis*, but raccoons, skunks, and foxes were important as hosts for the immature stages. Only 2 ticks were found on numerous opossums, and none were found on numerous gray squirrels examined by these workers. Detailed host data are summarized in Table 6. Seasonal data from Virginia, from this same source, show that peak adult activity can be expected in February. Larvae and nymphs are most abundant on hosts during the winter months (Table 7). In Canada however, the ticks were found to be most abundant in July and August (Cooley and Kohls, 1945).

VIRGINIA RECORDS.—Caroline, Fairfax, King and Queen, Nottoway, Prince Edward, Prince George, Richmond, Spotsylvania, and Washington counties (Sonenshine et al., 1965); Hanover County, Sonenshine and Stout (1971). Additional records in the VPI&SU collection are from Culpeper and

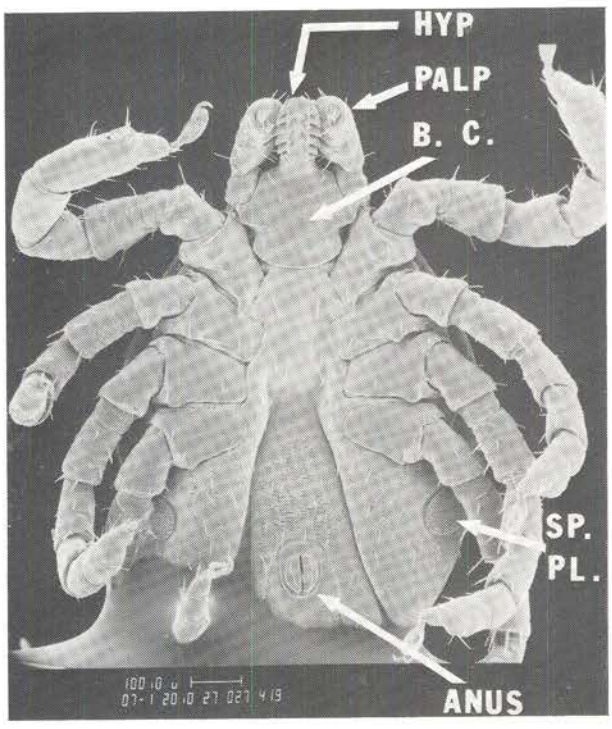


Fig. 32. *Ixodes cookei* nymph, venter

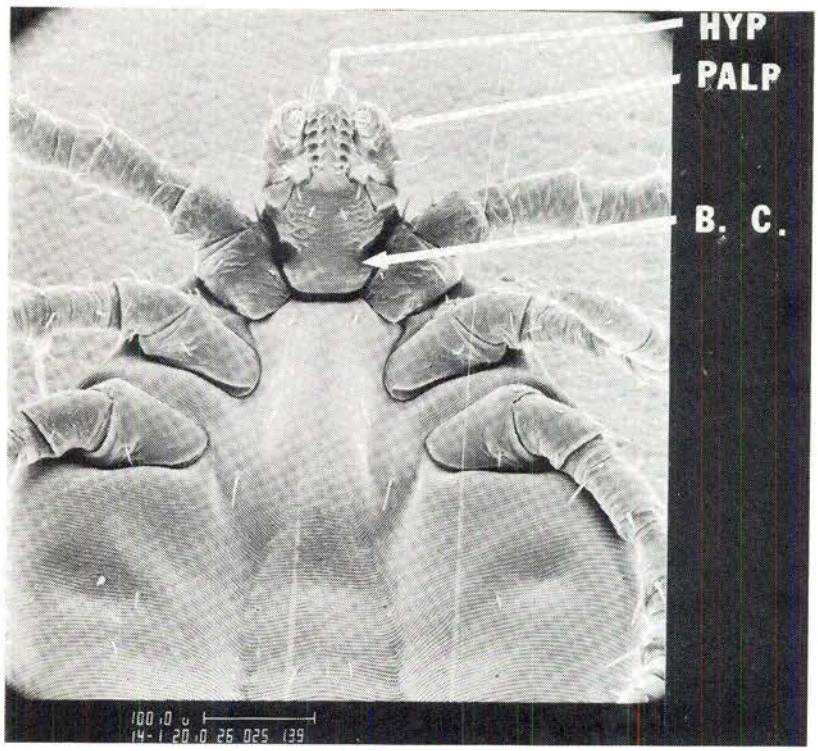


Fig. 33. *Ixodes cookei* larva, venter

Fluvanna counties. The tick is apparently widely distributed in the Piedmont; its occurrence in other areas of the state is not documented as well.

REMARKS.—According to Yunker (1970), *I. cookei* is implicated in the transmission of Powassan virus, especially in Ontario, Canada, where it is the vector in a natural cycle of virus transmission involving ground hogs and ticks. Strains of Powassan virus were recovered from *I. cookei* and its ground hog hosts in New York (Whitney and Jamnback, 1965).

Table 6. Host associations of *Ixodes cookei* in Hanover County, Virginia (1963-1969).[1]

Mammal Species	No. Hosts Examined	Adults		Nymphs		Larvae	
		Total Ticks	Avg./ Animal	Total Ticks	Avg./ Animal	Total Ticks	Avg./ Animal
Raccoon	117	11	0.09	61	0.52	330	2.82
Striped skunk	72	138	1.92	208	2.89	50	0.70
Opossum	168	1	0.00	1	0.00	0	0.00
Red fox	56	18	0.32	107	1.92	64	1.14
Gray fox	23	2	0.09	17	0.74	83	3.60
Gray squirrel	115	0	0.00	0	0.00	0	0.00
Woodchuck	12	0	0.00	3	0.25	0	0.00
Totals	563	170	0.30	397	0.71	527	0.94

[1]From Sonenshine and Stout (1971).

Table 7. Seasonal occurrence of *Ixodes cookei* on medium sized wild mammals in Hanover County, Virginia (1963-1969).[1]

Month	No. Animals Examined	Total Adults	Avg./ Animal	Total Nymphs	Avg./ Animal	Total Larvae	Avg./ Animal
January	26	2	0.08	11	0.42	7	0.27
February	33	57	1.73	58	1.76	20	0.61
March	43	25	0.58	54	1.26	0	0.00
April	60	3	0.05	10	0.17	0	0.00
May	37	8	0.22	13	0.35	35	0.95
June	49	9	0.18	11	0.23	0	0.00
July	43	6	0.50	63	1.47	8	0.19
August	59	10	0.17	10	0.17	1	0.02
September	60	9	0.15	41	0.68	40	0.67
October	55	15	0.27	36	0.66	21	0.38
November	60	24	0.40	60	1.00	44	0.73
December	38	2	0.53	30	0.79	351	9.24

[1]From Sonenshine and Stout (1971)

Ixodes dentatus **Marx, 1899**
(Figs. 34, 35, 36)

DIAGNOSIS.—**Adults** are small, about 2.0 mm long. **Females** are distinguished by the long hypostome with denticles arranged 6/6, the elongated retrograde auriculae and the long internal spur on coxa I. In the **male** the median plate is about twice as long as the anal plate and the internal spur on coxa I is long. **Nymphs** resemble the females, except that the hypostome dentition is reduced to 4/4 and the auriculae are rounded. The **larva** has 16 pairs of dorsal body setae (7 MD, 5 SC, 3 CD, and 1 S) and 10 postero-ventral body setae (4 PM, 2 PA, and 4 MV). Coxa I also has a long internal spur. The absence of auriculae will distinguish these larvae from those of *I. scapularis*.

DISTRIBUTION, HOSTS and SEASONAL ACTIVITY.—This tick occurs in Eastern and North Central United States. The typical hosts for all life stages are cottontail rabbits. Birds serve as host for the larvae and nymphs, but not for adults. Ground-feeding birds, especially white throated sparrows and other sparrows, rufous sided towhee, hermit thrush and brown thrasher were found to be among the most important bird hosts in Hanover County, Virginia, for the immatures (Sonenshine and Stout, 1970). Similar bird hosts were important for this tick in the North Carolina Piedmont near Chapel Hill; the Carolina wren and slate colored junco were also found to be important hosts. In coastal areas between New York and Virginia, thrushes (Family Turdidae) and sparrows (Family Fringillidae) were the most important bird hosts for the immatures (Sonenshine and Clifford, 1973) (Table 8).

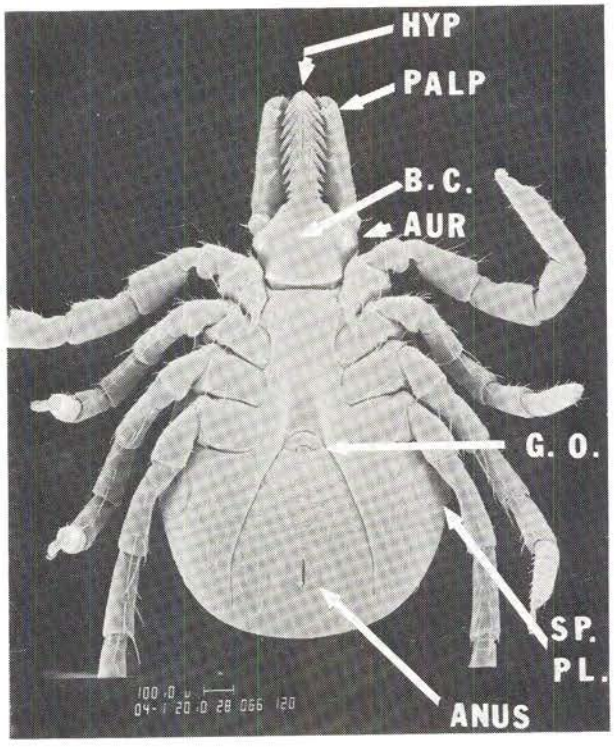


Fig. 34. *Ixodes dentatus* female, venter

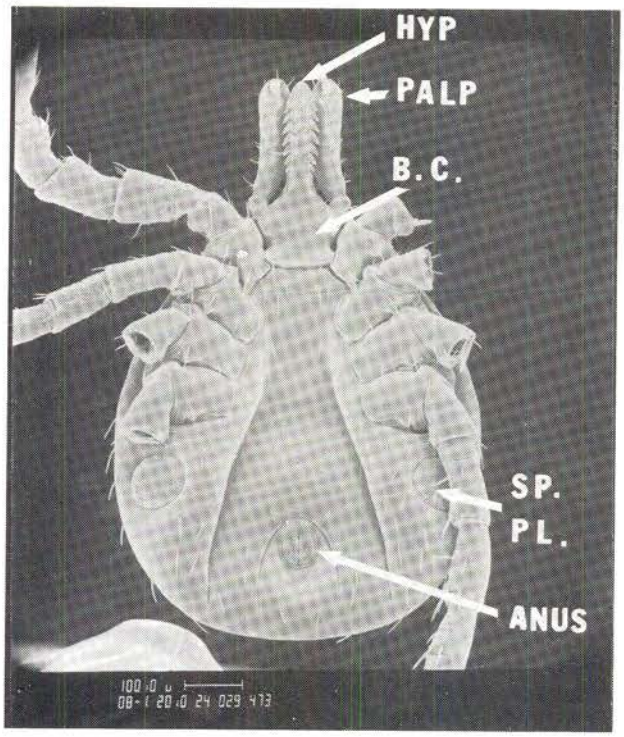


Fig. 35. *Ixodes dentatus* nymph, venter

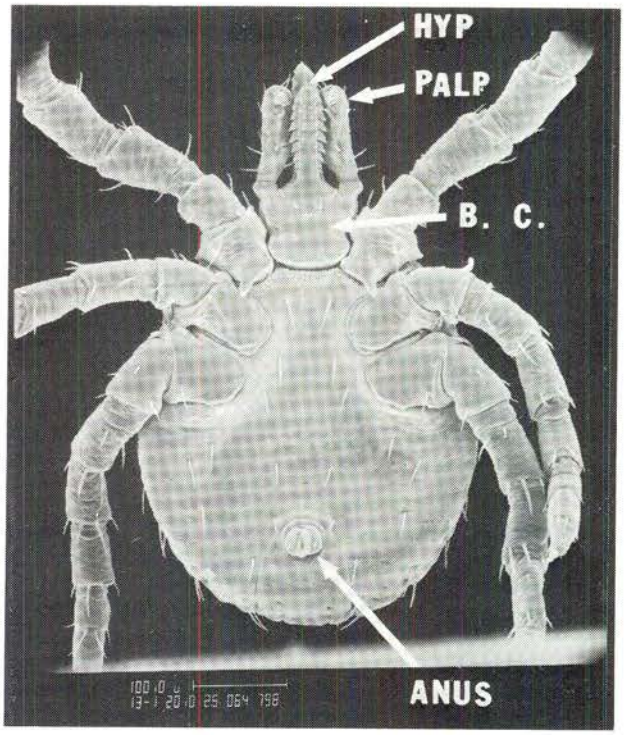


Fig. 36. *Ixodes dentatus* larva, venter

Table 8. Seasonal occurrence of *Ixodes dentatus* immatures on wild bird hosts in the Piedmont and Coastal areas of the Eastern United States.[1,2]

Month	Coastal Areas					Piedmont				
	No. Birds Examined	No. Larvae	Avg./ Bird	No. Nymphs	Avg./ Bird	No. Birds Examined	No. Larvae	Avg./ Bird	No. Nymphs	Avg./ Bird
January	---	---	---	---	---	1160	12	0.01	0	0.00
February	---	---	---	---	---	1693	5	0.00	0	0.00
March	52	8	0.15	0	0.00	3024	52	0.02	8	0.00
April	209	42	0.20	2	0.01	896	25	0.03	7	0.01
May	127	3	0.02	2	0.02	820	2	0.00	4	0.01
June	177	5	0.03	0	0.00	159	0	0.00	0	0.00
July	22	0	0.00	0	0.00	17	0	0.00	0	0.00
August	312	2	0.10	0	0.00	69	0	0.00	0	0.00
September	3380	484	0.14	10	0.01	250	3	0.01	1	0.00
October	1415	1006	0.71	9	0.01	409	56	0.14	0	0.00
November	710	524	0.74	3	0.01	1534	256	0.29	0	0.00
December	196	81	0.41	0	0.00	738	71	0.12	0	0.00

[1]Data from Sonenshine and Clifford (1973) with permission of the journal.
[2]Data from Sonenshine and Stout (1970) with permission of the journal.

Table 9. Seasonal occurrence of tick, *Ixodes dentatus*, on cottontail rabbits (*Sylvilagus floridanus*) in 2 localities in Virginia.[1]

Season	Radford Arsenal Montgomery County		Fort Pickett Nottoway County	
	Ticks/ Male	Ticks/ Female	Ticks/ Male	Ticks/ Female
Spring	173.8	127.7	8.2	4.4
Summer	12.9	9.4	1.8	3.5
Fall	279.0	338.8	0.2	1.3
Winter	135.8	13.4	7.6	21.6

[1]From Jacobson et al. (1978) with permission of the journal.

Seasonal activity of this tick, especially of larvae, appears to be well defined. Table 8, from Sonenshine and Stout (1970) and Sonenshine and Clifford (1973) for the North Carolina Piedmont suggests a bimodal activity pattern for larvae, with peak occurrence in November; in coastal areas, the peak months also occurred in the fall. Nymphal activity was less well defined, though also mostly in the fall and winter months. Collections of this tick from rabbits showed adults to be most numerous in April and May (Sonenshine and Stout, 1970). Jacobson et al. (1978) found the greatest abundance of *I. dentatus* on rabbits at Radford Arsenal, Montgomery County, Virginia, to occur in the fall. These records are not directly comparable with the preceding studies, since the life stages of the tick were not identified. At Camp Pickett, in Nottoway County, Virginia, peak *I. dentatus* activity was observed in the winter months. The mean number of *I. dentatus* per rabbit at peak density in Montgomery County was 305.6, in contrast to 14.1 ticks/rabbit in Nottoway County. Records of Jacobson et al. (1978) for Rabbit-Tick infestations in these areas are summarized in Table 9.

VIRGINIA RECORDS.—Accomack, Amelia, Augusta, Bland, Chesterfield, Fairfax, Giles, King and Queen, Lancaster, Louisa, Nansemond, Nottoway, Pittsylvania, Prince George, Spotsylvania counties and the City of Chesapeake and the cities of Norfolk and Petersburg (Sonenshine et al., 1965). Sonenshine and Clifford (1973) added Accomack and Hanover counties. Jacobson et al. (1978) added Montgomery County. Evidently, the tick occurs throughout the state.

REMARKS.—Infection of this tick with the rickettsia of Rocky Mountain spotted fever, *R. rickettsii*, was found in 5 of 49 pools of immature ticks from migratory birds and 2 mixed species pools containing immature *I. dentatus* and *H. leporispalustris* (Clifford et al., 1969).

Ixodes marxi **Banks, 1908**
Squirrel Tick
(Figs. 37, 38, 39)

DIAGNOSIS.—**Females** are recognized by the long hypostome with the dentition 3/3, the elongated scutum, and the absence of distinct spurs on the palps or coxae. In the **male,** the internal spur on coxa I is short, coxae II and III lack internal spurs, and the small spiracular plate has few

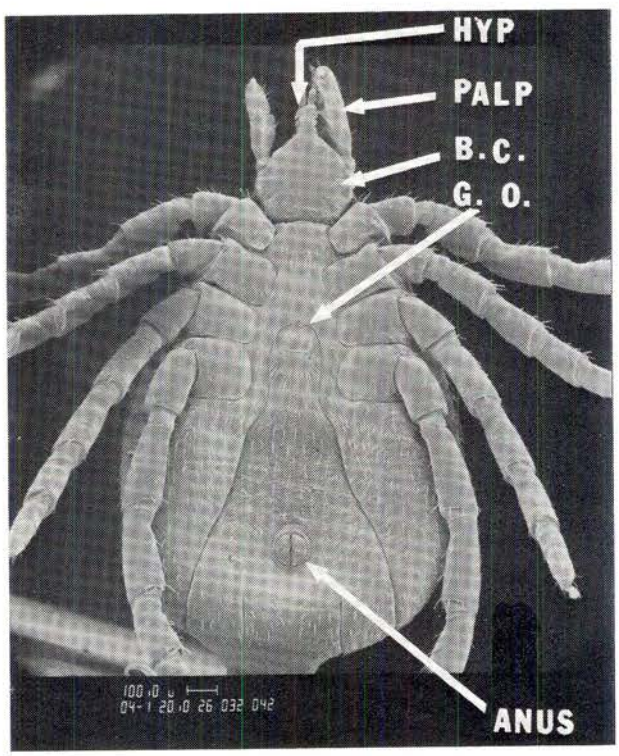


Fig. 37. *Ixodes marxi* female, venter

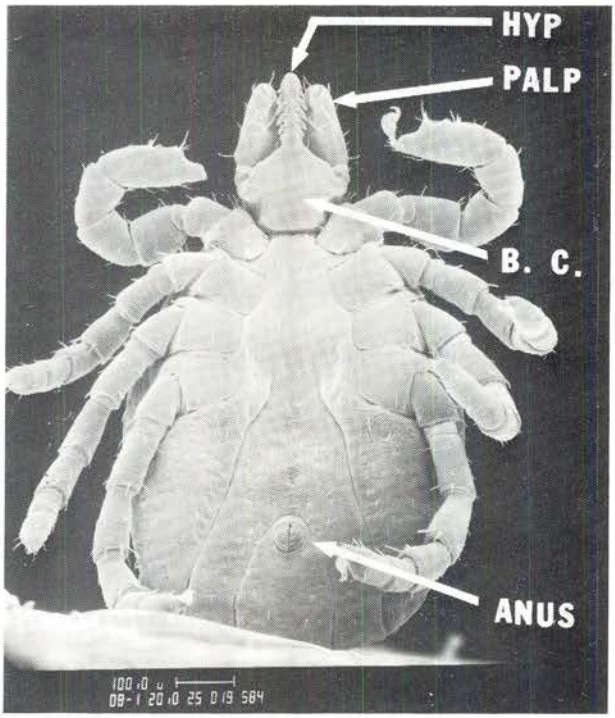


Fig. 38. *Ixodes marxi* nymph, venter

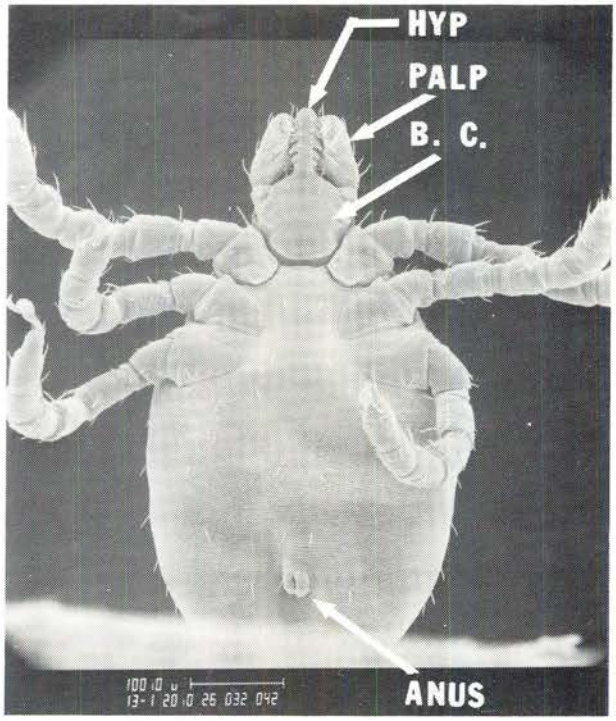


Fig. 39. *Ixodes marxi* larva, venter

goblets. **Nymphs** have a rounded hypostome, salient auriculae, and a small internal spur on coxa I. **Larvae** have 16 pairs of dorsal body setae (9 MD, 5 SC, and 2 CD; supplementary setae are absent) and 9 pairs of postero-ventral body setae (4 PM, 2 PA, and 3 MV). The absence of palpal spurs distinguishes the larva from that of *I. angustus,* while the presence of auriculae separates it from the larva of *I. texanus.*

DISTRIBUTION, HOSTS and SEASONAL ACTIVITY.—This species occurs in Canada and much of the Eastern and Central United States. Known hosts consist almost entirely of squirrels, especially the gray squirrel, red squirrel, and flying squirrel. Virtually nothing is known of the species activity.

VIRGINIA RECORDS.—Sonenshine et al. (1965) reported *I. marxi* from a gray squirrel in Montgomery County. More recently (August 15, 1972), I found it in nests of the flying squirrel, *Glaucomys volans,* near Ashland in Hanover County.

Ixodes scapularis **Say, 1821**
Black Legged Tick
(Figs. 40, 41, 42)

DIAGNOSIS.—The **female** is distinguished by its pointed hypostome, rounded scutum, black legs, and by the crowded appearance of the numerous goblets in the spiracular plate. The lack of lateral carinae on the scutum will distinguish it from *I. cookei.* The long internal spur on coxa I and the absence of palpal spurs also help to distinguish the female from other Virginia *Ixodes.* The **male** is recognized readily by the unusually large protruding lateral denticles on the hypostome. The **nymph** resembles the female, but the internal spur of coxa I is reduced. The **larva** has 16 pairs of dorsal body setae (7 MD, 5 SC, 3 CD, and 1 S) and 10 pairs of postero-ventral setae (4 PM, 2 PA, and 4 MV). These larvae are distinguished from those of *I. dentatus* by the small internal spur on coxa I and the presence (*I. scapularis*) of auriculae.

DISTRIBUTION, HOSTS, and SEASONAL ACTIVITY.—This species has been found in eastern Canada and most of the Southeastern and Central United States and parts of Mexico. However, according to Bequaert (1946), its breeding range does not extend north of Cape Cod, Massachusetts. Its extensive hosts range includes numerous mammals, birds, and even lizards. Deer are

especially important wild hosts for this tick. Adults are found most frequently on medium or large-sized mammals, including man and dogs; immatures may infest these same hosts as well as a wide range of birds and lizards. *I. scapularis* is one of the few species of *Ixodes* that can be collected on a tick drag. According to Bishop and Trembley (1945), it is most abundant in the Southern United States during fall and spring.

VIRGINIA RECORDS.—Augusta, James City, and Richmond counties and the city of Norfolk (Sonenshine et al., 1965); 3 *I. scapularis* adults (sex not stated) were reported by Garrett and Sonenshine (1977) from the Dismal Swamp (Washington Ditch Road), Nansemond County, in August 1972.

REMARKS.—This species has been implicated in the transmission of babesiosis to man (McEnroe, 1977). Two cases of human infestation reported on Nantucket Island, Massachusetts, are thought to have been due to *Babesia microti*. Recent work by Spielman and Piesman (1978) demonstrated growth and development of *B. microti* in *Ixodes sp.* near *scapularis*.

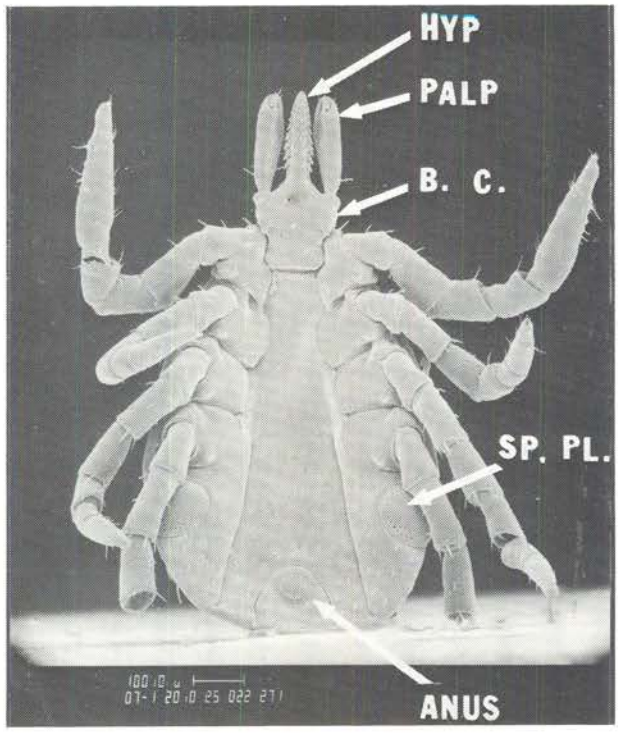


Fig. 41. *Ixodes scapularis* nymph, venter

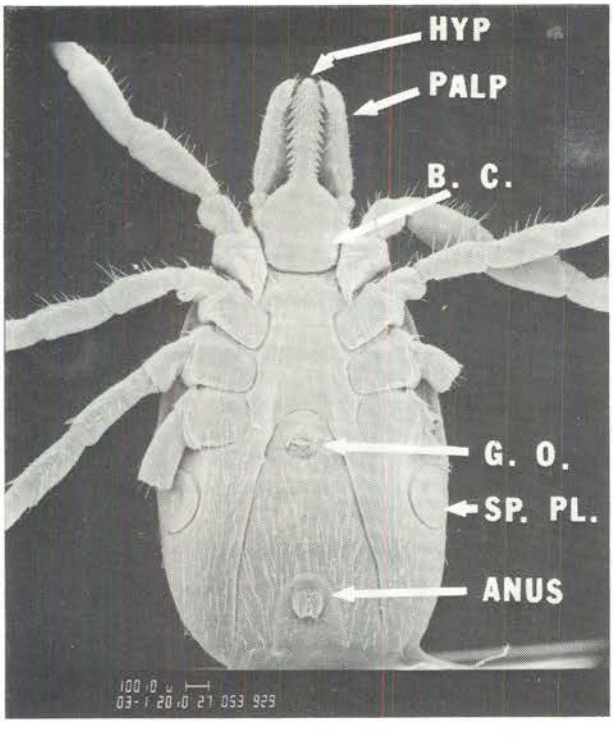


Fig. 40. *Ixodes scapularis* female, venter

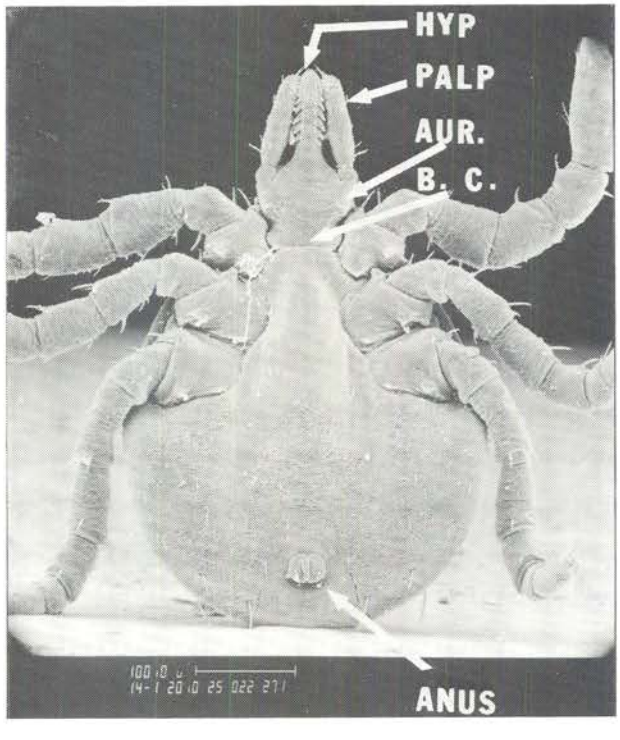


Fig. 42. *Ixodes scapularis* larva, venter

Ixodes texanus **Banks, 1908**
(Figs. 43, 44, 45)

DIAGNOSIS.—The **adults** are recognized by the rugose surface of the capitulum (dorsal) and scutum. In the **female,** the small protruding lateral humps on the basis capituli on either side of the hypostome help to separate it from other Virginia *Ixodes*. The **nymph** resembles the female, with a rugose scutum and a small internal spur on coxa I. The **larva** has 16 pairs of dorsal body setae (9 KMD, 5 SC, and 3 CD) and 9 pairs of postero-ventral body setae (4 PM, 2 PA, 3 MV). Larvae may resemble those of *I. marxi,* but *I. texanus* larvae lack auriculae.

DISTRIBUTION, HOSTS and SEASONAL ACTIVITY.—*I. texanus* ranges throughout most of the United States (Cooley and Kohls, 1945; Bequaert, 1946). It has also been collected in southern Canada. Common hosts are wild carnivores and various squirrels, but it has also been taken from a dog. In studies at Montpelier, in Hanover County, and Newport News City Park, *I. texanus* was found only on raccoons, even though hundreds of wild mammals of 6 other species were examined. Data on seasonal activity are summarized in Table 10. Peak adult and nymphal activity at Montpelier was found in April; larvae, however, were most abundant in October. At Newport News City Park (not shown in the table), adults were most numerous in May; larvae, in November.

VIRGINIA RECORDS.—Caroline, Fairfax, King and Queen, and Nottoway counties and the City of Virginia Beach (Sonenshine et al., 1965). Sonenshine and Stout (1970) report collections from Hanover County and the city of Newport News. One collection was from a gray fox; all others, from raccoons.

REMARKS.—None.

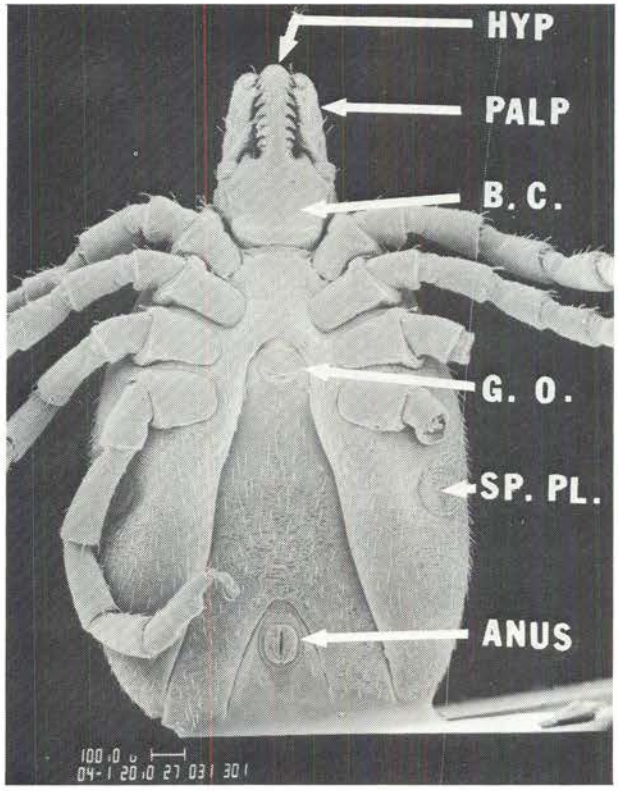


Fig. 43. *Ixodes texanus* female, venter

Table 10. Seasonal occurrence of *Ixodes texanus* on Raccoons in Hanover County, Virginia (1963-1969).[1]

Month	No. Raccoons Examined	Total Adults	Avg./ Animal	Total Nymphs	Avg./ Animal	Total Larvae	Avg./ Animal
January	5	2	0.40	23	4.60	15	3.00
February	3	3	1.00	12	4.00	0	0.00
March	11	31	2.82	85	7.73	12	1.09
April	13	80	6.15	155	11.92	37	3.25
May	5	4	0.80	3	0.60	0	0.00
June	13	0	0.00	1	0.08	0	0.00
July	8	12	1.50	0	0.00	0	0.00
August	19	0	0.00	1	0.05	0	0.00
September	11	0	0.00	15	1.33	20	1.82
October	15	2	0.13	8	0.53	502	33.47
November	8	7	0.88	13	1.63	0	0.00
December	6	2	0.33	0	0.00	0	0.00

[1]From Sonenshine and Stout (1971).

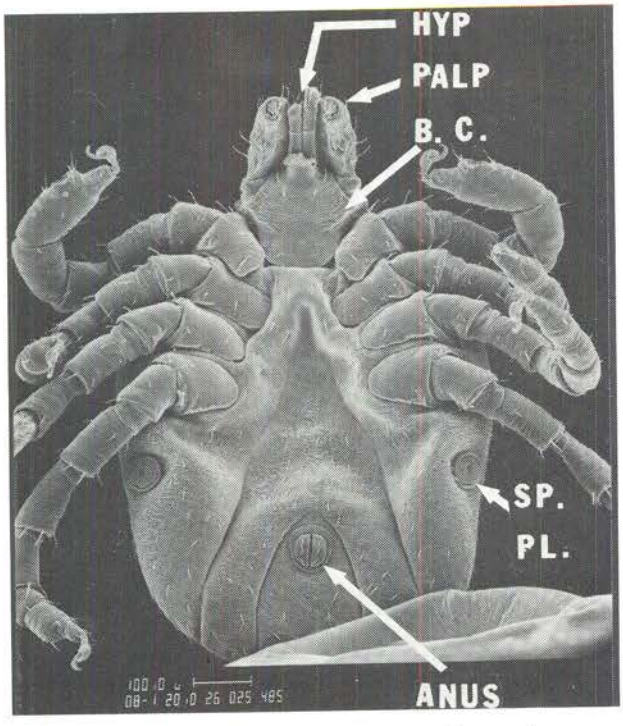


Fig. 44. *Ixodes texanus* nymph, venter

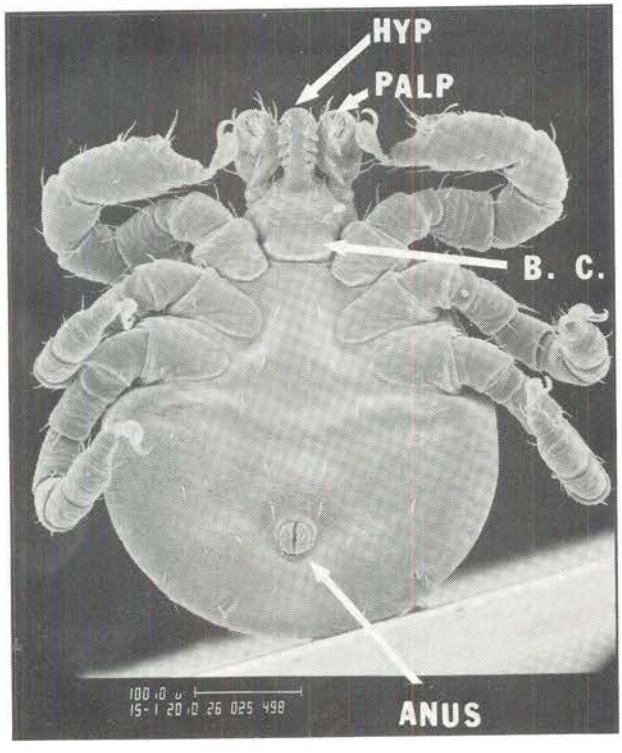


Fig. 45. *Ixodes texanus* larva, venter

Genus *Rhipicephalus* Koch, 1844

DIAGNOSIS (Virginia species only).—All stages with the basis capituli hexagonal. Eyes present. Body with 9 festoons. Inornate. **Larvae** with 4 marginal dorsal setae anterior to the sensillum sagittiforme on either side and only 1 pair of posthypostomal setae; dorsally, there are 3 pairs of scutal setae, 2 pairs of central setae, and 8 pairs of marginal dorsal setae.

Rhipicephalus sanguineus (Latreille, 1806)
Brown Dog Tick
(Figs. 46, 47, 48)

DIAGNOSIS.—All stages can be differentiated from other Virginia ticks by the hexagonal shape of the basis capituli in dorsal view and the presence of 9 festoons. **Adults** are unornamented. The **larvae** have 4 marginal dorsal body setae anterior to the sensillum sagittiforme on each side.

DISTRIBUTION, HOSTS and SEASONAL ACTIVITY.—This 3-host tick is known from virtually all of the United States and parts of Mexico and Canada (Cooley, 1946; Gregson, 1956). The principal host is the domestic dog, though

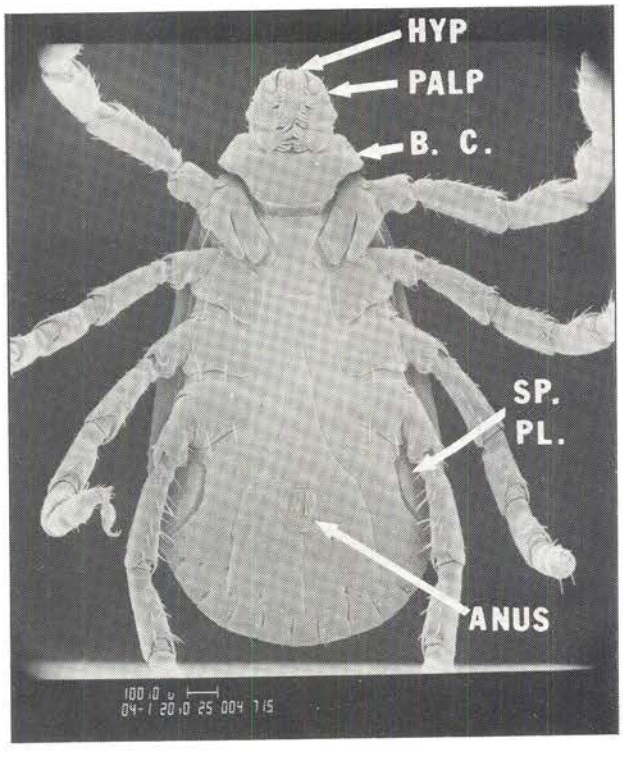


Fig. 46. *Rhipicephalus sanguineus* female, venter

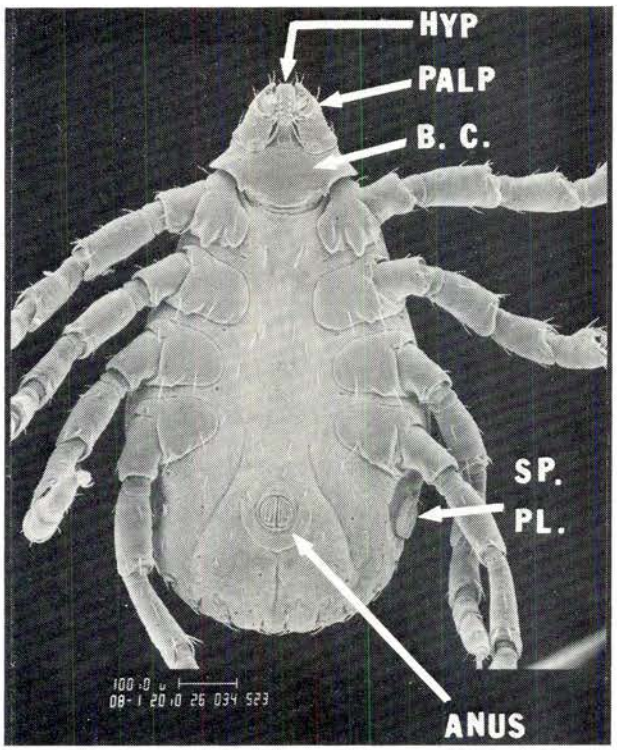


Fig. 47. *Rhipicephalus sanguineus* nymph, venter

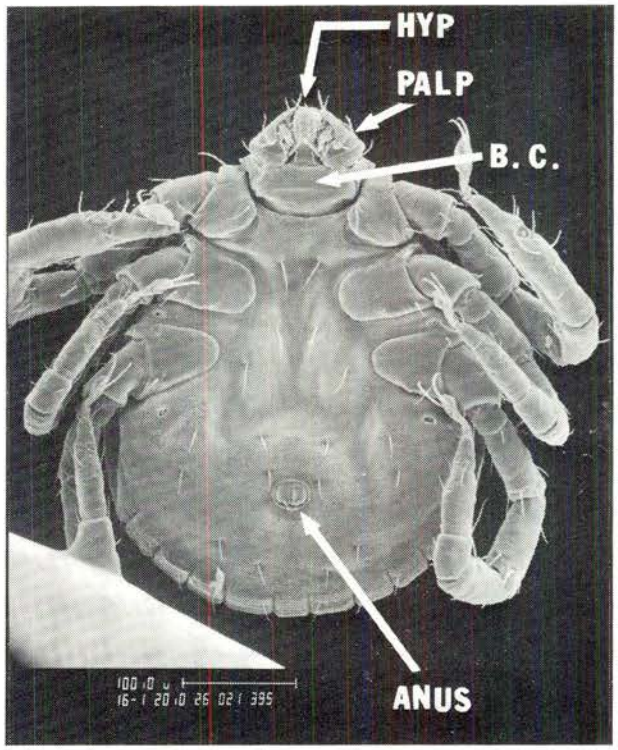


Fig. 48. *Rhipicephalus sanguineus* larva, venter

numerous records of other hosts, including man, are known. In the United States and Canada, the tick is found mostly in habitations where dogs are kept, such as homes and kennels. The tick is active throughout the year, though extent of activity is dependent on temperature. According to Enigk and Grittner (1953), the Brown Dog Tick does not survive exposure to temperatures below 5°C. Thus, it is doubtful whether it survives the winters in the northern parts of the Unites States except in heated buildings.

VIRGINIA RECORDS.—Sonenshine et al. (1965) reported this tick from the cities of Norfolk, Newport News, Richmond and from Arlington, Surry, and York counties. Additional records in the VPI&SU collection are from Alleghany, Campbell, Chesterfield, Clarke, Culpeper, Fairfax, Henrico, Henry (Martinsville), Isle of Wight (Smithfield), Loudoun, Mathews, Nansemond, Page, Prince William, Spotsylvania (Fredericksburg), and Warren counties. It is expected that the tick occurs more or less indiscriminately throughout the state.

REMARKS.—The Brown Dog Tick is the most common tick pest on dogs. Consequently, the tick may become a serious pest in households, where dogs are kept indoors. Enormous infestations may develop, with all stages crawling on furniture, walls and floors.

Burgdorfer (1975) described the discovery of a rickettsia of the spotted fever group, similar to but distinct from *R. rickettsii*, in Brown Dog Ticks from dogs in Mississippi. Isolates from these ticks were non-pathogenic for male guinea pigs. The virulence of the new agent for man in unknown.

In the Old World, *R. sanguineus* is an important vector of boutenneuse fever (caused by *Rickettsia conorii*), but the disease does not appear to have been imported into the United States.

LITERATURE CITED

Allred, D., D. Eldenbeck, and L. D. White. 1960. Ticks of the genus *Ixodes* in Utah. Brigham Young Univ. Sci. Bull. Biol. Series 1(4):1-42.

Anastos, G. and C. M. Clifford. 1956. The occurrence of an *Ornithodoros* tick in Maryland. J. Parasitol. 41:146.

Anonymous. 1976. Morbidity and Mortality Reports. Center for Disease Control, Atlanta, Georgia. 62 pp.

Arthur, D. R. 1961. Ticks and Disease. Row, Peterson and Co., Evanston, Illinois. 445 pp.

Atwood, E. L., J. T. Lamb, Jr., and D. E. Sonenshine. 1965. A contribution to the epidemiology of Rocky Mountain spotted fever in the eastern United States. Amer. J. Trop. Med. Hyg. 14:331-337.

Atwood, E. L. and D. E. Sonenshine. 1967. Activity of the American Dog Tick *Dermacentor variabilis* (Acarina: Ixodidae) in relation to solar energy changes. Ann. Entomol. Soc. Amer. 60(2):354-362.

Bequaert, J. C. 1946. The ticks, or Ixodoidea, of the Northeastern United States and Eastern Canada. Entomol. Amer. n.s. 25:73-232.

Bishop, F. C. and H. L. Trembley. 1945. Distribution and hosts of certain North American ticks. J. Parasitol. 31:1-54.

Bolte, J. R., J. A. Hair and J. Fletcher. 1970. White tailed deer mortality following tissue destruction induced by Lone Star Ticks. J. Wildl. Mgmt. 34:546-552.

Burgdorfer, W. 1975. A review of Rocky Mountain spotted fever (Tick-borne Typhus), its agent and its tick vectors in the United States. J. Med. Entomol. 12(3): 269-278.

Clifford, C. M., G. Anastos, and A. Elbl. 1961. The larval ixodid ticks of the eastern United States (Acarina: Ixodidae). Misc. Publ. Entomol. Soc. Amer. 2:213-237.

Clifford, C. M., D. E. Sonenshine, E. L. Atwood, C. S. Robbins and L. E. Hughes. 1969. Tests of ticks from wild birds collected in the Eastern United States for rickettsiae and viruses. Amer. J. Trop. Med. Hyg. 18(6): 1056-1061.

Clymer, B. C., D. E. Howell, and J. A. Hair. 1970. Environmental alteration in recreation areas by mechanical and chemical treatment as a means of Lone Star Tick control. J. Econ. Entomol. 63:504-509.

Cooley, R. A. 1938. The genera *Dermacentor* and *Otocentor* (Ixodidae) in the United States, with studies in variation. Natl. Inst. Hlth. Bull. 171. 89 pp.

——— 1946. The genera *Boophilus, Rhipicephalus* and *Haemaphysalis* (Ixodidae) of the new world. Natl. Inst. Hlth. Bull. 187. 54 pp.

Cooley, R. A. and G. M. Kohls. 1944a. The Argasidae of North America, Central America, and Cuba. Amer. Midl. Nat. Monogr. 1. 152 pp.

——— 1944b. The genus *Amblyomma* (Ixodidae) in the United States. J. Parasitol. 30: 77-111.

——— 1945. The genus *Ixodes* in North America. U. S. Public Health Service. Natl. Inst. Hlth. Bull. 184. 246 pp.

Dodds, D. G., A. M. Martell and R. E. Yescott. 1969. Ecology of the American Dog Tick, *Dermacentor variabilis* (Say) in Nova Scotia. Can. J. Zool. 47:171-181.

Enigk, K. and I. Grittner. 1953. Zur Zucht und Biologie der Zecken. Z. Parasitenk. 16(1):56-83.

Garrett, M. K. and D. E. Sonenshine. 1977. The ecology of the two dominant tick species in relation to the Dismal Swamp Wildlife Refuge in Virginia. Univ. Press of Virginia. In press.

Green, R. G., C. A. Evans, and C. L. Larson. 1943. A ten year population study of the rabbit tick, *Haemaphysalis leporispalustris*. Amer. J. Hyg. 38:360-381.

Gregson, J. D. 1956. The Ixodidae of Canada. Canada Dept. Agric. Publ. 930. 92 pp.

——— 1973. Tick paralysis. An appraisal of natural and experimental data. Canada Dept. of Agric. Monograph 9. 109 pp.

Hair, J. A. and D. E. Howell. 1970. Lone Star Ticks, their biology and control in Ozark recreational areas. Oklahoma State Univ. Agric. Exper. Station Bull. B-679. 47 pp.

Hattwick, M. A., W. R. O'Brien, and B. F. Hanson. 1976. Rocky Mountain spotted fever: epidemiology of an increasing problem. Ann. Intern. Med. 84(6):732-739.

Homsher, P. J. and D. E. Sonenshine. 1973. The occurrence of the unornamented dwarf trait in the American Dog Tick, *Dermacentor variabilis* (Say): Is it genetically controlled? Ann. Entomol. Soc. Amer. 66(3):689.

Howell, D. E. 1940. The ecology of *Dermacentor albipictus* (Packard). Proc. 6th Pacific Sci. Congr. (Berkeley). Stanford and San Francisco. July 24-August 12, 1939. 4:439-458.

Jacobson, H. A., R. L. Kirkpatrick and B. S. McGinnes. 1978. Disease and physiologic characteristics of two cottontail populations in Virginia. Wildlife Monog. 60:1-53.

Krantz, G. W. 1970. A manual of Acarology. O.S.U. Book Stores, Inc., Corvallis, Oregon. 335 pp.

Larson, R. W. and M. B. Bryan. 1959. Virginia's Timber. U. S. Dept. Agric. (Forest Service) Forest Survey Release 54. 56 pp.

McEnroe, W. D. 1977. Human babesiosis. Science 195:506-507.

McKiel, J. A., E. J. Bell, and D. B. Lackman. 1967. *Rickettsia canada:* A new member of the typhus group of rickettsiae isolated from *Haemaphysali leporispalustris* ticks in Canada. Canada J. Microbiol. 13:503-510.

Pratt, H. D. and K. S. Littig. 1974. Ticks of public health importance and their control. U. S. Public Health Service, DHEW Publ. No. (CDC) 75-8242. 37 pp. + keys.

Price, W. H. 1954. The epidemiology of Rocky Mountain spotted fever. II. Studies on the biological survival mechanism of *Rickettsia rickettsii.* Amer. J. Hyg. 60:292-319.

Sonenshine, D. E. 1972. Ecology of the American Dog Tick, *Dermacentor variabilis,* in a study area in Virginia. I. Studies on population dynamics using radioecological methods. Ann. Entomol. Soc. Amer. 65:1164-1175.

——— 1973. Influence of host-parasite interactions on the population dynamics of ticks. Misc. Publ. Entomol. Soc. Amer. 9(5):243-249.

Sonenshine, D. E. and G. Anastos. 1960. Observations on the life history of the bat tick *Ornithodoros kelleyi* (Acarina: Argasidae). J. Parasitol. 46(4):449-454.

Sonenshine, D. E., E. L. Atwood, and J. T. Lamb, Jr. 1966. The ecology of ticks transmitting Rocky Mountain spotted fever in a study area in Virginia. Ann. Entomol. Soc. Amer. 59:1234-1262.

Sonenshine, D. E. and C. M. Clifford. 1973. Contrasting incidence of Rocky Mountain spotted fever in ticks infesting wild birds in eastern U. S. Piedmont and coastal areas, with notes on the ecology of these ticks. J. Med. Entomol. 10(5):497-502.

Sonenshine, D. E., J. T. Lamb, Jr. and G. Anastos. 1965. The distribution, hosts and seasonal activity of Virginia ticks. Va. J. Sci. 16(1):26-91.

Sonenshine, D. E. and G. F. Levy. 1971. The ecology of the Lone Star Tick *Amblyomma americanum* (L.) in 2 contrasting habitats in Virginia (Acarina: Ixodidae). J. Med. Entomol. 8(6): 623-635.

——— 1972. The ecology of the American dog tick, *Dermacentor variabilis* in a study area in Virginia. 2. Distribution in relation to vegetative types. Ann. Entomol. Soc. Amer. 65(5):1175-1182.

Sonenshine, D. E. and I. J. Stout. 1970. A contribution to the ecology of ticks infesting wild birds and rabbits in the Virginia-North Carolina Piedmont (Acarina: Ixodidae). J. Med. Entomol. 7:645-654.

——— 1971. Ticks infesting medium sized wild mammals in two forest localities in Virginia (Acarina: Ixodidae). J. Med. Entomol. 8(3):217-227.

Spielman, A. and J. Piesman. 1978. Transmission of human babesiosis on Nantucket. Proc. 5th Internatl. Congr. Acarology, E. Lansing, Michigan. August.

Whitney, E., and H. Jamnback. 1965. The first isolation of Powassan virus in New York State. Proc. Soc. Exp. Biol. Med. 119:432-435.

Wilson, N. and W. W. Baker. 1972. Ticks of Georgia (Acarina: Metastigmata). Tall Timbers Res. Station, Tallahassee, Fla. 29 pp.

Wright, J. E. 1969. Photoperiodic induction of diapause in larvae of the winter tick, *Dermacentor albipictus.* Ann. Entomol. Soc. Amer. 62(2): 285-287.

Yunker, C. E. 1970. Worldwide research on human and animal diseases caused by tick borne viruses. Misc. Publ. Entomol. Soc. Amer. 6(7): 330-338.