AN ABSTRACT OF THE THESIS OF

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Title: Distribution, Seasonal Occurrence, Abundance, and Hosts of Five Kansas Ticks (Acari: Ixodidae)

Abstract approved: Thomas A. Eddy

Ticks are vectors of many important human and animal diseases. Deficiencies exist in our recognition of the distribution, seasonal occurrence, abundance, and hosts of these widespread parasites. By examining tick hosts over a 17 month period, this study sought to extend our knowledge of the ecology of these serious pests. Thirty-one species of hosts representing three classes of vertebrates from seven Kansas counties were inspected for tick infestation. Twelve species of hosts yielded 2,585 ticks. Five species of ixodids were collected from birds and mammals: Amblyomma americanum, Amblyomma maculatum, Dermacentor albipictus, Dermacentor variabilis, and Haemaphysalis leporispalustris. No ticks were found on nine species of reptiles examined. Dermacentor variabilis was the most common tick occurring on large mammals, followed by A. americanum and A. maculatum. Dermacentor albipictus were collected in November and

December solely from white-tailed deer, Odocoileus virginianus, of which 100 percent were infested. Haemaphysalis leporispalustris was found exclusively on cottontail rabbits, Sylvilagus floridanus, and the degree of infestation was highly variable. Abundance peaks for A. maculatum and D. variabilis occurred in July of 1993 and 1994, while peaks for A. americanum varied. The collection of 65 A. maculatum from two adjoining counties suggests the establishment of this tick in southeast Kansas. Preferred feeding sites on mammals serve to increase tick survival, and generally coincide with those regions of the host's body that are difficult to groom. Feeding sites varied depending on the tick species, life stage, and host involved.

DISTRIBUTION, SEASONAL OCCURRENCE, ABUNDANCE, AND HOSTS OF FIVE KANSAS TICKS (ACARI: IXODIDAE)

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by

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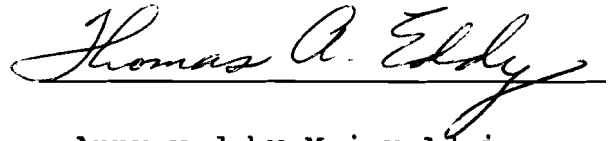

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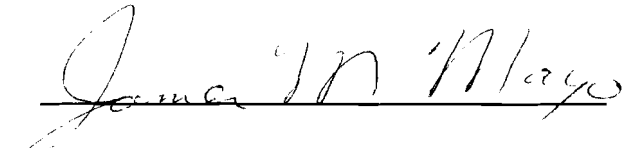

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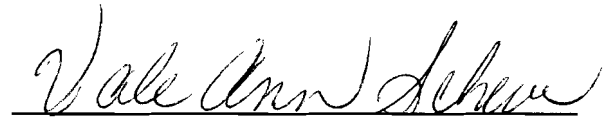

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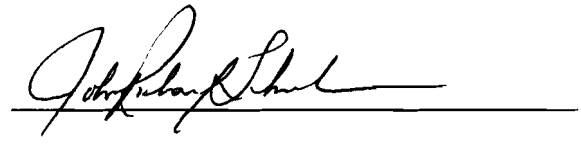

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INTRODUCTION

Ticks are vectors of many important human and animal diseases[1]. Tick transmitted Lyme disease caused by the spirochete Borrelia burgdorferi has reached epidemic status in the United States, including 52 reported cases in Kansas (Mock, Brillhart, and Upton 1992). In Oklahoma, ticks are suspected vectors of the recently identified human ehrlichiosis organism Ehrlichia chaffeensis (Sonenshine 1993). Ticks infest every class of terrestrial vertebrate and are responsible for annual world-wide economic losses estimated to be in the billions of dollars (Sonenshine 1991). Ticks also reduce the recreational value of infested lands. The magnitude of detrimental effects attributed to ticks emphasizes the significance of fully understanding their ecology. Knowledge of the animals serving as hosts for larval, nymphal, and adult ticks in Kansas is incomplete, and the seasonal occurrence of life stages is only partially known. Mapping of the distribution of ticks continues to be an ongoing process (Brillhart, Fox, and Upton 1994) as the recent discovery of a new state record illustrates (Mock, Brillhart, Fox, and Upton 1991).

The objective of this study was to add to existing knowledge of ixodid ecology by examining hosts,

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[1] For a complete listing see Sonenshine, D. E. 1993. Biology of Ticks Vol. 2, Part V. Oxford Univ. Press, New York. pp. 107-330.

distribution, seasonal occurrence, abundance of species, preferred feeding sites, and extent of infestations. Findings should contribute to our understanding of ticks, aid in the timing of defensive measures, and be of value to researchers and public health personnel who have interest in these species.

Thirty-one species of potential hosts from seven Kansas counties were examined for tick infestation. Animals from diverse habitats were caught by hand, live-trapped, shot, or found road-killed. Ticks were collected and stored in 95 percent ethanol for subsequent identification. Over a 17 month period 2,585 ixodids were recovered from 12 host species. Five species of hard ticks representing three genera were found. They included Amblyomma americanum, Amblyomma maculatum, Dermacentor albipictus, Dermacentor variabilis, and Haemaphysalis leporispalustris. Ticks were collected from birds and mammals, but no ticks were found on nine species of reptiles examined. Sixty-five A. maculatum taken from hosts in Coffey and Greenwood counties suggest the establishment of this species in southeast Kansas. Dermacentor variabilis was the most common species parasitizing large mammals, followed by A. americanum and A. maculatum. Abundance peaks for A. maculatum and D. variabilis occurred in July, while peaks for A. americanum varied from June in 1993 to May and September of 1994. Dermacentor albipictus were collected in November and

December solely from white-tailed deer, Odocoileus virginianus. Haemaphysalis leporispalustris were found only on cottontail rabbits, Sylvilagus floridanus, and the degree of infestation was highly variable. Preferred feeding sites on mammals usually were those regions of the host's body that could not be groomed. Feeding sites varied depending on the tick species, life stage, and host involved.

MATERIALS AND METHODS

Three classes of vertebrate hosts (Reptilia, Aves, and Mammalia) were examined for tick infestation. Tick collecting commenced on 8 May 1993, and continued through the winter to 18 September 1994. Kansas counties included in the study were Coffey, Greenwood, Johnson, Lyon, McPherson, Saline, and Wilson. Potential hosts were obtained from a variety of habitats including domiciles, outbuildings, mowed lawns, croplands, grasslands, brushy areas, and woodlands. Reptiles were caught by hand whereas wild birds and mammals were trapped, shot, or found road-killed along county roads and highways. Domestic dogs were directed through infested terrain for the purpose of acquiring ticks which were later recovered. Humans were another source of ticks. Mammal trapping devices included Sherman traps, wire mesh live-traps measuring 13 X 13 X 26 cm, and larger live-traps sized 18 X 18 X 105 cm. Live-traps were baited with dry dog food or fish, or were strategically placed rather than baited. Trapping as a

means of procuring mammalian hosts was used only in Greenwood County. To subdue mice and rats for inspection they were shot with a BB rifle. Intermediate-sized wild hosts that could be safely handled were live-trapped, examined, and released. For reasons of personnel safety, diseased animals were not searched. Thirty bobwhite quail were trapped by Kansas Department of Wildlife and Parks personnel during the summer months of 1993. All gamebirds and mammals were obtained by legal methods during established seasons.

Ticks on hosts were located visually or by feel, and were removed with fingers or forceps depending on the size of the tick. Unless stated otherwise, an attempt was made to collect all ticks from individual hosts. The information recorded included the date, county of collection, location in county, host, and location and number of ticks on host. Specimens were stored in 95 percent ethanol. A binocular dissecting microscope (7X-45X) was used to identify adults and many nymphs. Higher magnification (100X) was necessary to identify some nymphs and all larvae. Adults were sexed when they were identified. Pictorial and descriptive keys used included: Arthur 1962; Belding 1952; Chandler and Read 1966; Cooley 1946; Cooley and Kohls 1944; Cooley and Kohls 1945; Keirans and Clifford 1978; Keirans and Litwak 1989; and Strickland, Gerrish, Hourrigan, and Schubert 1976.

RESULTS

Tick species and counties of collection

Five species of hard ticks (Ixodidae) were encountered in this study: Lone Star tick, Amblyomma americanum; Gulf Coast tick, Amblyomma maculatum; winter tick, Dermacentor albipictus; American dog tick, Dermacentor variabilis; and rabbit tick, Haemaphysalis leporispalustris. Counties from which those species were taken and the numbers collected are listed in Table 1. The higher numbers of ticks recorded from Greenwood County was due to increased collecting time in that county.

Table 1. Distribution, species, and number of collected ixodids

	* County					
Species	CF	GWD	JO	LY	MP	WL
A. americanum	1	269		38	1	
A. maculatum	1	64				
D. albipictus		16	9	12		
D. variabilis	90	1,424		2	2	1
H. leporispalustris		655				

* County abbreviations: CF, Coffey; GWD, Greenwood; JO, Johnson; LY, Lyon; MP, McPherson; WL, Wilson.

Twelve ring-necked pheasants, Phasianus colchicus, and nine greater prairie chickens, Tympanuchus cupido, were examined in Saline County late in the season (Nov-Dec) and found not to be infested. Therefore, Saline County was excluded from the table.

Hosts examined and incidence of infestation

Nine species of reptiles, eight species of birds, and 14 species of mammals were examined for tick infestation. Ixodids were found on 12 of 31 species of animals inspected. Those 12 host species yielded 2,585 ticks from 223 productive examinations. Many non-productive examinations were performed as well.

No ticks were found on 99 reptiles examined. Reptilian species inspected and the number of each were: eastern box turtle, Terrapene carolina, 55; western box turtle, Terrapene ornata, 30; great plains skink, Eumeces obsoletus, one; six-lined racerunner, Cnemidophorus sexlineatus, two; collared lizard, Crotaphytus collaris, two; plains garter snake, Thamnophis radix, two; western racer, Coluber mormon, one; rat snake, Elaphe obsoleta, five; and bullsnake, Pituophis melanoleucus, one.

Ticks were found on two of eight avian species examined. Four birds of 205 inspected were found to harbor ticks. Bobwhite quail, Colinus virginianus, and wild turkey, Meleagris gallopavo, were parasitized by A. americanum nymphs. Birds examined from which ticks were not obtained included: canada goose, Branta canadensis, six; greater prairie chicken, Tympanuchus cupido, ten; ring-necked pheasant, Phasianus colchicus, 12; mourning dove, Zenaidura macroura, 158; common nighthawk, Chordeiles minor, one; and Bewick's wren, Thryomanes bewickii, one.

Ticks occurred on ten of 14 species of mammals inspected. Three humans, Homo sapiens, and two dogs, Canis familiaris, were the only mammals that were examined more than once. Those individuals contributed ticks on multiple occasions. Dogs, white-tailed deer, Odocoileus virginianus, and man were hosts of A. americanum adults. Nymphs of that species were collected from opossum, Didelphis virginiana, hispid cotton rat, Sigmodon hispidus, dog, white-tailed deer, and man. Larvae were found only on the dog. Dogs and man were the only hosts from which A. maculatum adults were collected. No nymphs or larvae of that species were found. White-tailed deer were hosts of D. albipictus adults and nymphs. No larvae were collected. Dermacentor variabilis adults were found on opossum, raccoon, Procyon lotor, dog, and man. Nymphs of that species were found on cottontail rabbit, Sylvilagus floridanus, deer mouse, Peromyscus maniculatus, and eastern wood rat, Neotoma floridana. Larvae of D. variabilis were collected from fox squirrel, Sciurus niger, deer mouse, and hispid cotton rat. Haemaphysalis leporispalustris adults, nymphs, and larvae were found exclusively on cottontail rabbits. Hosts from which ticks were collected, number examined, number infested, and total number of ticks recovered from each host species are shown in Table 2.

Table 2. Hosts harboring ticks and incidence of infestation

Host	no. examined	no. infested	no. ticks
Meleagris gallopavo (Wild turkey)	6	3	22
Colinus virginianus (Bobwhite quail)	42	1	1
Didelphis virginiana (Opossum)	8	2	10
Sylvilagus floridanus (Cottontail rabbit)	7	7	697
Sciurus niger (Fox squirrel)	5	1	1
Peromyscus maniculatus (Deer mouse)	13	6	31
Sigmodon hispidus (Hispid cotton rat)	12	4	10
Neotoma floridana (Eastern wood rat)	33	1	1
Canis familiaris (Dog)	* 3	3	1,710
Procyon lotor (Raccoon)	4	1	12
Odocoileus virginianus (White-tailed deer)	7	7	63
Homo sapiens (Man)	* 6	6	49

* Three dogs were examined one, four, and 256 times respectively. Three humans were examined once, two were examined four times each, and one (author) received 300 examinations.

Mammals examined from which ticks were not collected included: eastern mole, Scalopus aquaticus, two; house mouse, Mus musculus, six; coyote, Canis latrans, one; and bobcat, Lynx rufus, four.

Extent of infestations

One A. americanum nymph was found on a bobwhite quail, and up to 17 Lone Star nymphs were taken from one wild

turkey. Small rodents were not found to be heavily infested, and only nymphs and larvae were found to parasitize the mice, rats, and squirrels examined. The greatest number of ticks found on a small rodent was 23 D. variabilis nymphs and larvae taken from one deer mouse. Infestation of cottontail rabbits by H. leporispalustris was highly variable. Two cottontail rabbits inspected in August hosted six and 324 H. leporispalustris with 94 being the average for seven rabbits examined. In only one instance was a cottontail rabbit found to host a different species of tick, one D. variabilis nymph. Most opossums inspected were not found to be heavily parasitized by ticks. A maximum of eight D. variabilis adults plus one A. americanum nymph were collected from a single opossum. However, in Montgomery County one ill or injured opossum examined visually was observed to be severely infested (estimated 200+ ticks). Raccoons examined were found to harbor few ticks. Twelve D. variabilis adults were the greatest number of ticks collected from that host species. Dogs were often heavily beset with ticks. During the apex of tick abundance it was not unusual to find 25 to 45 ticks on a dog exposed to infested habitat for two to three hours. The maximum number collected from a dog initially free of ticks was 173 adults and nymphs (seven hours exposure). No attempt was made to collect all ticks from individual white-tailed deer, in most

instances tick samples were obtained from capes[2]. Indications were that deer hosted large numbers of D. albipictus. Twenty-six A. americanum adults and nymphs were collected from one white-tailed deer in June. However, that number was merely a representative sampling of the many ticks present.

Preferred feeding sites

Amblyomma americanum nymphs recovered from birds were located most often on the fleshy ventral surface of the wings where feathers were absent or sparse. Nymphs were also collected from the legs and sides of the bodies of wild turkeys. Dermacentor variabilis nymphs and larvae, and A. americanum nymphs parasitizing rodents were found exclusively on the ears and ear bases of those hosts. Haemaphysalis leporispalustris were taken from the ears, head, neck, and bodies of cottontail rabbits. The head was the favored feeding site and tick numbers decreased toward the posterior. On opossums and raccoons, D. variabilis adults and A. americanum nymphs were collected from the ears and head. Ticks were removed from virtually all regions of the bodies of dogs, although given sufficient time[3], D.

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[2] As used in taxidermy, "cape" refers to the skin from the shoulders forward removed for later mounting on a head form.

[3] It was observed that when infested dogs became inactive clinging ticks emerged from hiding to seek preferred feeding sites, see discussion.

variabilis, A. americanum, and A. maculatum adults preferred the head, ears, and backs of dogs as feeding sites. On large mammals larvae were found most often on thin-skinned regions such as ears, ear bases, face, and abdomen. Amblyomma americanum adults and nymphs were taken from the ears and antler velvet of white-tailed deer. Dermacentor albipictus adults and nymphs obtained from white-tailed deer were located most often on the dewlap and neck, and to a lesser extent on the ear bases, head, and shoulders. On human hosts embedded D. variabilis, A. americanum, and A. maculatum were found on legs, torso, neck, and head.

Seasonal occurrence and abundance peaks

Through the 17 month study period ticks were found on hosts each month except January and February. Seasonal occurrence of active life stages are shown in Table 3.

Table 3. Seasonal occurrence of tick life stages

Month	* Avg. daily temp. C	D. vari.	D. albi.	A. amer.	A. macu.	H. lepo.
Mar	7.44	A,N,L	-	A	-	-
Apr	14.44	A	-	A,N	A	-
May	19.33	A	-	A,N	A	-
Jun	23.50	A,N	-	A,N	A	A,N
Jul	26.83	A	-	A,N	A	A
Aug	26.05	A,N	-	N,L	A	A,N,L
Sep	21.22	A	-	N,L	-	-
Oct	15.38	+A,L	-	+A	-	-
Nov	7.55	-	A	-	-	-
Dec	1.94	-	A,N	-	-	-

* Recorded in the period 1954-76 at Eureka, Ks.
A = adult, N = nymph, L = larva
+ One A. americanum male taken from dog on 3 Oct. and one D. variabilis male found on dog 8 Oct. added post study.

Abundance peaks for D. variabilis, A. americanum, and A. maculatum were determined from collections spanning two warm seasons. Dermacentor variabilis numbers peaked in July of 1993 and 1994 with 304 and 355 collected in those months respectively (Fig. 1). All D. variabilis taken in July of both years were adults.

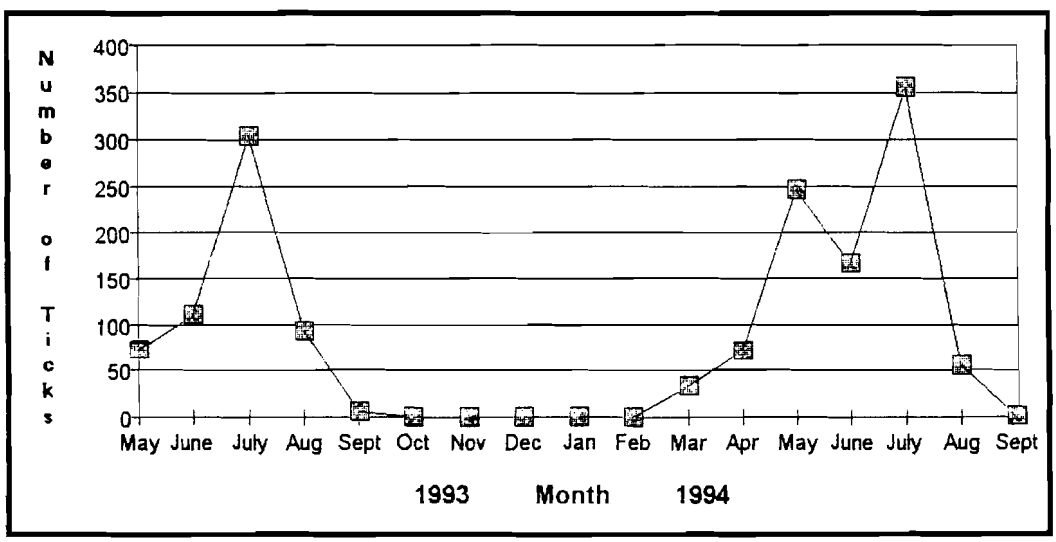

Fig. 1. Seasonal occurrence of Dermacentor variabilis.

In June 1993, 36 nymphs and 32 adult A. americanum were collected. Those 68 Lone Star ticks constituted the high in numbers for that year. In 1994 two peaks were noted, the first in May with 16 nymphs and 33 adults taken, and the second in September with 13 larvae and 45 nymphs collected (Fig. 2).

The greatest number of A. maculatum were found in July of 1993 and 1994. During those months 19 and 10 adults were collected respectively (Fig. 3).

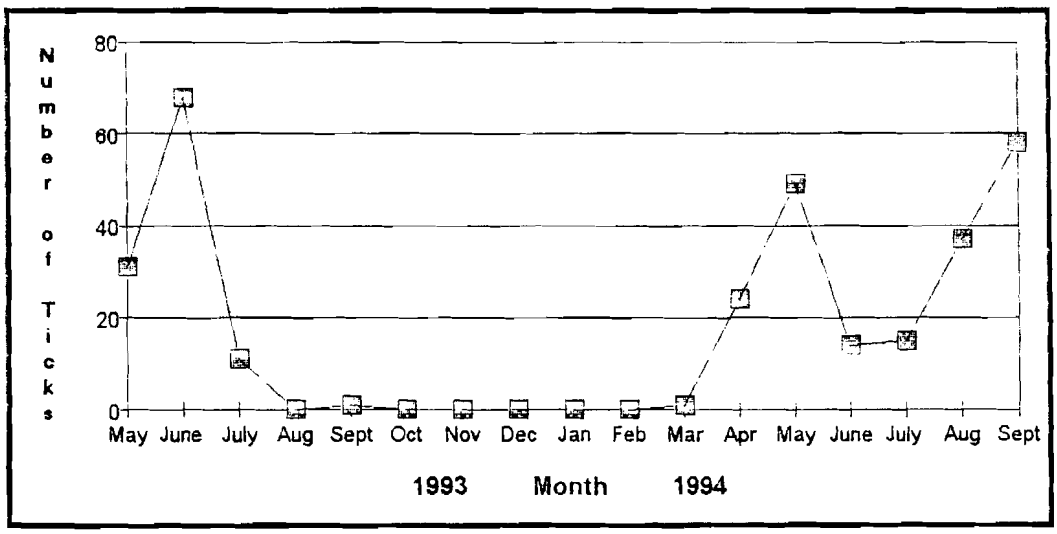

Fig. 2. Seasonal occurrence of Amblyomma americanum.

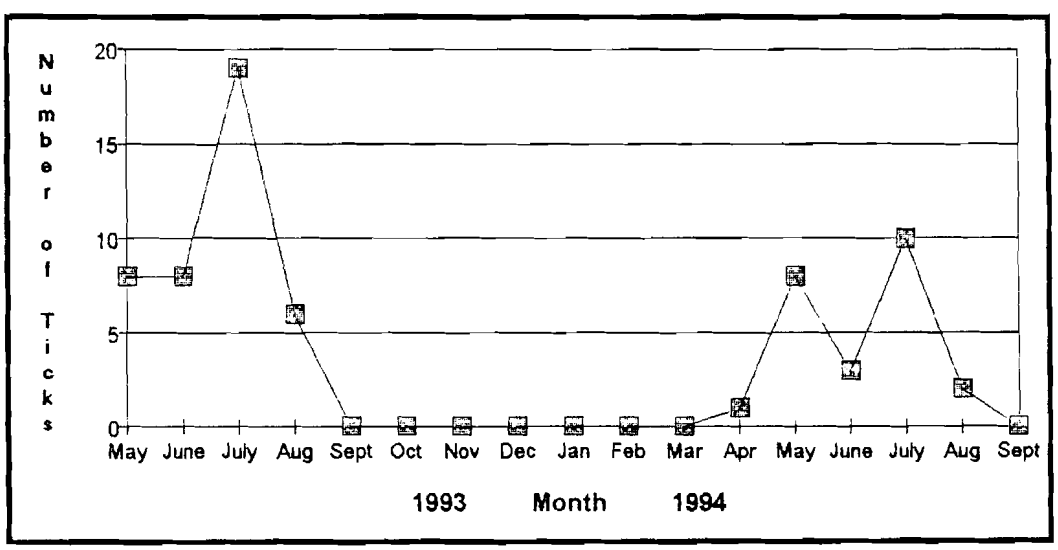

Fig. 3. Seasonal occurrence of Amblyomma maculatum.

Dermacentor albipictus and H. leporispalustris were not collected often enough for peaks of abundance to be determined. Absence of collecting the last two weeks of June 1994 had some influence on results.

Prevalence of species, life stages, and sex

Dermacentor variabilis was the most commonly encountered tick. This species comprised 59 percent of the total number of ticks taken from all hosts (Fig. 4).

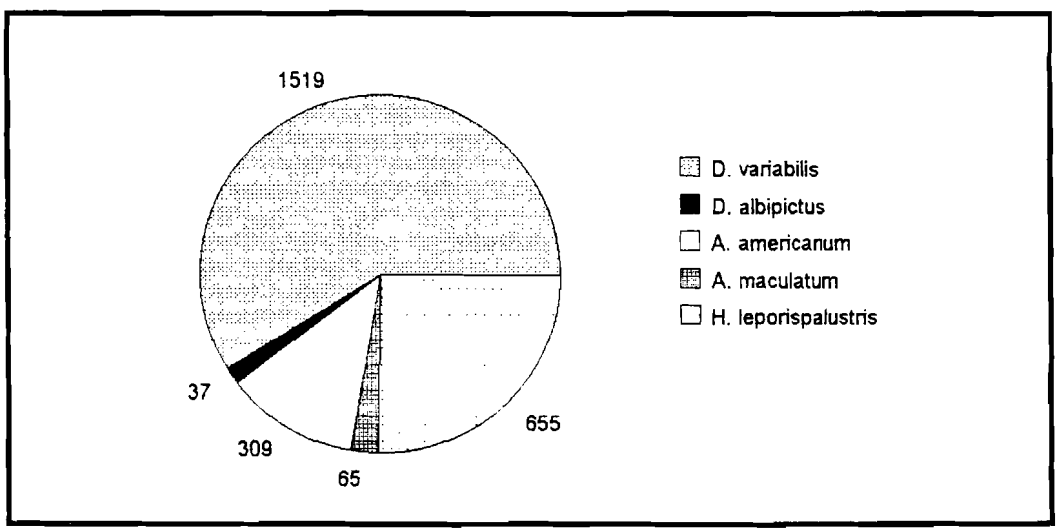

Fig. 4. Number and species of ticks collected from all hosts.

In addition, D. variabilis constituted 83 percent of the three species of ticks collected from dogs, one of which was examined almost daily through the warm months (Fig. 5). Of 1,519 D. variabilis collected, 32 were larvae, three were nymphs, and 1,484 were adults. There was a six percent difference in number between the sexes (765 males and 719 females).

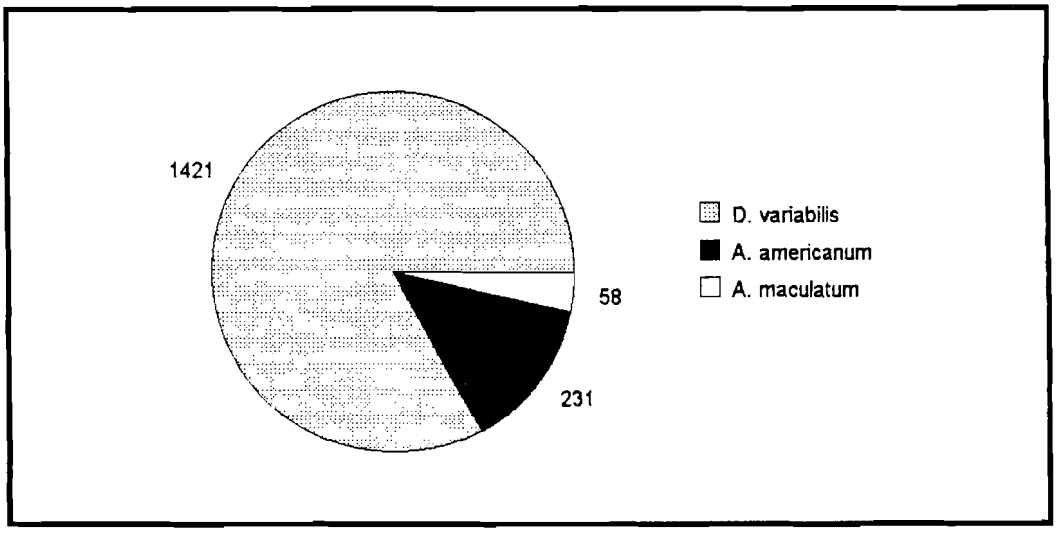

Fig. 5. Number and species of ticks collected from dogs, Canis familiaris.

Dermacentor albipictus made up one percent of the ticks collected. Of 37 found, three were nymphs and 34 were adults. This species exhibited the largest variation between sexes at 38 percent (13 males and 21 females); however, sample size was small. Amblyomma americanum comprised 12 percent of the ticks collected from all hosts. This tick was the second most common species taken from the dog (14 percent) and man (34 percent). The total number of A. americanum collected from all hosts was 309, of which larvae totaled 40, nymphs numbered 153, and 116 were adults. There was a 10 percent difference in number between males (61) and females (55). Amblyomma maculatum made up three percent of the ticks taken from all hosts, and ticks taken from one dog. Sixty-five adults were collected with a difference between sexes of 14 percent (30 males and 35 females). Haemaphysalis leporispalustris accounted for 25

percent of the total number of ticks collected. The number removed from seven cottontail rabbits was 655. Larvae totaled 281, nymphs numbered 244, and 130 were adults. A six percent difference between sexes was found (63 males and 67 females).

DISCUSSION

In Kansas, the range of A. americanum includes the eastern one-third of the state, although it may be encountered further west (Mock et al. 1992). The single female found on a dog in McPherson County is regarded as unusual because the species had been previously reported three counties south (Sumner) and two counties northeast (Geary) (Brillhart unpub. MS thesis 1992). The possibility exists the collection may have been a carry-in from the east. It was observed that A. americanum increased in abundance in woodland habitats. In south Greenwood County where grasslands give way to post oak, Quercus stellata, and blackjack oak, Quercus marilandica, this tick was predominant. Those results were similar to studies done in Oklahoma in which oak forests were found to support higher numbers of A. americanum than meadow habitats (Sonenshine 1993). Amblyomma americanum is known to use a wide range of hosts (Cooley and Kohls 1944). With the exception of bobwhite quail and opossum, all hosts reported were previously chronicled by Cooley and Kohls (1944) or Brillhart et al. (1994). Strickland et al. (1976) indicate

birds are common hosts of larvae and nymphs. Sonenshine (1993) refers to Zimmerman who found that A. americanum rarely used small mammals as hosts. Those reports support the results of this study as A. americanum larvae were collected only from dogs and only one nymph of 153 collected was recovered from a small mammal (hispid cotton rat). Previous studies found nymphs on animals up to the size of cows (Cooley and Kohls 1944). Perhaps the lengthy hypostome of the Lone Star tick allows early life stages to penetrate the thick skin of larger hosts. Of the ixodids found parasitizing large mammals, this species was second in abundance. Peaks of abundance for A. americanum adults and nymphs occurred in May and June. In September of 1994, nymphs and larvae of this species became abundant. Previous work in Kansas indicated the Lone Star tick was most plentiful in April-May (Brillhart et al. 1994). Variations in the degree of coloration of ornate markings on males was observed, as were differences in size among adults of the same sex.

Amblyomma maculatum is known to occur in geographic locations of high rainfall, temperature, and humidity, such as the Gulf Coast (hence the name Gulf Coast tick). Strickland et al. (1976) reported its establishment in Oklahoma. Published distribution records indicate the established range of A. maculatum extends further south than Kansas (Cooley and Kohls 1944; Keirans and Litwak 1989).

Previous work in Kansas recorded this species from Bourbon, Butler, Coffey, and Greenwood Counties (pers. comm. Upton). The collection of 65 adults, 64 of which were collected from 81 contiguous hectares (200 acres) in northeast Greenwood County suggests the establishment of A. maculatum in southeast Kansas, and an extension northward of its generally accepted range. Amblyomma maculatum adults were collected from May through August in 1993, and from April through August in 1994. Reported hosts of adults include livestock, dogs, deer, and man (Strickland et al. 1976). This tick was the third most common species occurring on man (seven), and dogs (58). Larvae and nymphs parasitize small mammals and birds, of which bobwhites and meadowlarks are important hosts (Cooley and Kohls 1944). Although early life stages were not found in this study, there is little doubt future investigations in northeast Greenwood County will yield larvae and nymphs. The greatest number of Gulf Coast ticks were obtained in July. This was the largest unfed tick collected. The Gulf Coast tick is capable of producing tick paralysis in man and dogs, and spotted fever rickettsia have been identified in this species (Sonenshine 1993).

Dermacentor albipictus differs from the other ticks encountered in that it occurs on its hosts from late fall through early spring (Bishopp and Wood 1913). In November and December, this species was collected from Greenwood,

Lyon, and Johnson Counties. All of those counties were previously recorded by Brillhart (unpub. MS thesis 1993) who suspects statewide distribution as evidenced by mail-ins from deer hunters. Strickland et al. (1976) lists common hosts as horses, cattle, deer, elk, and moose. This study recovered the species only from white-tailed deer, of which all seven were infested. Brillhart (unpub. MS thesis 1993) also found D. albipictus solely on white-tailed deer. Prior to and during this study the author's involvement in taxidermy provided the opportunity to inspect 30 white-tailed deer capes from eastern Kansas, 100 percent of which were infested with D. albipictus. If those experiences are used as an indicator, it is probable that most (if not all) white-tailed deer in eastern Kansas are infested with the winter tick through the winter months. If that host was available to the author in January and February it is presumed active life stages of hard ticks would have been collected in Kansas every month of the year.

Dermacentor variabilis was the most common species encountered (59 percent), which coincided with previous investigations in Kansas (Brillhart et al. 1994; Mock et al. 1991; Waddington 1975). This tick was the most frequently collected species on man (53 percent) and dog (83 percent). All hosts identified in this study had been formerly reported (Arthur 1962). Dermacentor variabilis is not host specific, and it is recognized that early life stages prefer

smaller hosts (Brillhart et al. 1994), and adults select larger hosts (Sonenshine 1993). Results of this study conform to those findings as D. variabilis larvae were collected from the deer mouse, hispid cotton rat, and fox squirrel. Nymphs were collected from the deer mouse, eastern wood rat, and cottontail rabbit, and adults were collected from opossum, raccoon, dog, and man. The peak in abundance of D. variabilis adults was found to occur in July of both 1993 and 1994. That was slightly later than a two year Virginia study in which D. variabilis adult numbers peaked at the end of June (Sonenshine 1993). The American dog tick is distributed statewide (Brillhart et al. 1994). Much size variation was observed among D. variabilis adults of the same sex. Also noted were dissimilarities in the ornate markings on the scutum of males, and differences in the degree of light pigmentation on the dorsal surfaces of femurs.

Haemaphysalis leporispalustris was collected only in Greenwood County, however, that was the only location where lagomorphs were examined. Brillhart et al. (1994) reported this tick from Butler, Jefferson, and Pottawatomie counties. Cooley and Kohls (1946) indicate its distribution includes all of North America. The principle host of H. leporispalustris adults is lagomorphs (Keirans and Litwak 1989) and it may be found on other small mammals as well (Arthur 1961; Chandler and Read 1961; Cheng 1973). However,

Sonenshine (1993) states adults may be found only on lagomorphs. Nymphs and larvae of this species may also feed on ground-inhabiting birds (Cooley 1946; Strickland et al. 1976), of which about 60 have been recorded (Arthur 1962). This study recovered H. leporispalustris only from cottontail rabbits. Due to the very small size of early life stages this tick could be overlooked. It was found that H. leporispalustris commenced to vacate expired cottontail rabbits within a few minutes at ambient temperatures of 30-36 C, which proved to be a great aid in collecting this tiny species. The total H. leporispalustris taken from individual cottontail rabbits was highly variable (six, 13, 13, 14, 22, 264, and 324). Although the last two figures seem extreme, the size of this tick is such that high numbers may be tolerated. The rabbit tick is said to normally occur in great numbers on its hosts and all stages occur on hosts at all times of the year (Arthur 1962).

Abundance peaks for D. variabilis and A. maculatum occurred in July of both years while peaks for A. americanum varied from June in 1993 to May and September in 1994. It is recognized that photoperiod, incident solar energy, ambient temperature, and other environmental factors alter tick behavior (Sonenshine 1993). In late May and June of 1994, northeast Greenwood County experienced six weeks of hot, dry weather which may have reduced the questing activity of this desiccation-sensitive species. The year-

to-year discrepancy in abundance peaks for A. americanum may also have been influenced by sampling irregularities.

Ixodid males usually remain on the host feeding repeatedly and mating with additional females, which exit the host after one large meal (Sonenshine 1991). Because males may fertilize several females, it was expected females would outnumber males, but results did not bear that out. Counting only ticks removed from humans and dogs (ticks did not remain on those hosts long enough to feed to repletion), it was found males outnumbered females by six percent among the American dog tick and by 14 percent among the Lone Star tick. Gulf Coast tick females outnumbered males by 14 percent, although in comparison the sample size was much smaller. Statistical analysis by Compare Proportions tests applied to each tick species indicated there were no significant differences between numbers of males and females.

Reptiles were examined in search of unidentified hosts of larval A. americanum and Ixodes scapularis. Reported hosts of the larvae include lizards (Strickland et al. 1976). No larvae of either species were found on reptiles. However, it was felt sample sizes were small except for box turtles (85). Results suggest reptiles are not preferred hosts. The importance of the Lone Star tick and black-legged tick was demonstrated by Piesman and Sinsky (1988) who found I. scapularis capable of acquiring and maintaining

B. burgdorferi transstadially at 83 percent efficiency in laboratory experiments. While spirochetes were identified in A. americanum three days after feeding (at 13 percent efficiency), none were found after ten days.

Of 223 productive examinations, single tick species occurred on hosts 144 times, concurrently with one other species 61 times, and with two other species 18 times. The average number of ticks per infestation was: larvae 35, nymphs seven, and adults nine. Brillhart et al. (1994) found infestations to average 30 for larvae and nymphs (combined), and three to four for adults. The only infestations that were judged to be severe occurred on the dog, and on one ill or injured opossum (visual inspection). The author suspects severe infestations may be more common than is indicated here, for prior to this study examples involving a wide range of hosts (wild turkeys, raccoons, coyotes, dogs, deer, cattle, and man) were observed. The absence of ticks found on the coyote and bobcats examined was probably a result of lateness of season because the occurrence of ticks on those animals is well recognized (Brillhart et al. 1994; Schwartz and Schwartz 1981). The low number of ticks found on raccoons was likely due to examinations performed late in the season, and it is presumed the majority of ticks had vacated the road-killed animals inspected during the warm months. Previous studies in Kansas found all of 136 raccoons to be infested (Mock et

al. 1991). The lack of ticks found on eastern wood rats (one tick from 33 examined) is noteworthy because 21 were trapped during months of peak tick activity. Brillhart et al. (1994) found none of eight wood rats to be infested. Follow-up inquiries with mammalogists and students who have handled numerous eastern wood rats indicated the species normally hosts few ticks. Those indications raise additional questions. It is felt the low number of birds infested (four of 205 examined) was due to most examinations being performed late in the season owing to restrictive legal harvest dates. Also a large number of the birds checked during warm months were other than ground-inhabiting species. The preferred method of inspecting birds was to dry pluck the carcass thus exposing the skin. Appreciation is expressed to Kansas Department of Wildlife and Parks for their examination of 30 bobwhite quail; personnel were tagging birds requiring release in good condition. Because circumstances dictated fully feathered, live birds be examined quickly, it is probable ticks were overlooked.

Different species and life stages of ticks are known to prefer certain feeding sites on the bodies of their hosts (Strickland et al. 1976). By observing tick-host interactions on dogs, it was noted that tick survival often depended on the selection of feeding sites where scratching or biting was restricted. The course of events leading to a

blood meal are fraught with danger, and not all ticks that made initial contact succeeded in feeding to repletion. Questing ticks grasped the first opportunity to cling to a dog, no matter what part of the body was seized. At or near the site of first contact ticks buried themselves in the coat to prevent being brushed off by vegetation. Ticks held fast at that location all day if necessary until the dog became immobile. Individuals that had initially hidden at an unfavorable location then emerged to seek a safe position for feeding where the likelihood of removal by the host would be reduced or impossible. As ticks crawled about on the resting dog some were felt or seen and bitten, resulting in injury or death. Those that chose to feed where the dog was capable of biting or scratching were oftentimes dislodged, injured, or killed. Similar tick-host behavior likely occurs regardless of host species. Observations suggest preferred feeding sites serve to increase tick survival.

Many people associate ticks with woodlands and that habitat is favored by certain species. However, the majority of D. variabilis adults collected from man and dog were acquired in uplands dominated by native tall grasses. The most productive tick collecting area had been managed for nine years so each tract was burned every second year, with the exception of draws and shrub plantings that have not been burned for nine years. In Virginia, Sonenshine

(1993) found D. variabilis to be abundant in old field meadow habitat if sufficient shade, humidity, and animal hosts were present. Field roads and fire lanes provided the easiest walking and were natural routes for man and dog to follow. For that reason, roads and lanes were the chosen paths of medium and large mammals, evidenced by tracks and visual sightings. The high numbers of ticks encountered on those routes indicates tick abundance is dependant on suitable habitat, and distribution and abundance of hosts. Arthur (1962) refers to the Russian investigators Kheisin and Lavrenenko, and Balashov, whose observations of cows demonstrated that drop-off of ticks occurred when the host animals had become active following periods of inactivity. Sonenshine (1993) also states that drop-off is synchronized with host behavior patterns that may vary depending on the species of tick involved and the habits of their hosts. Arthur (1962) cites Nuttall who suggested the timing of drop-offs accounted for the abundance of ticks along animal trails and he reasoned that larval stages would be well situated to acquire new hosts. Although those reports account for the abundance of ticks found along animal trails and other high use areas, additional factors are involved. Sonenshine (1993) cites Smart and Caccamise who demonstrated that adult tick numbers are influenced most by the abundance of small mammals that serve as hosts to larvae and nymphs. Therefore, the flourishing population of D. variabilis

adults within the study area referred to was the result of many factors including suitable vegetation that provided adequate shading, humidity and protection from extreme temperatures, plentiful small mammals serving as hosts for larvae and nymphs, ample medium and large hosts for adults, and sufficient cover allowing engorged females to successfully hide and lay eggs.

CONCLUSIONS

Collections suggest the range of A. maculatum extends northward into southeast Kansas. Future work should focus on obtaining early life stages that would confirm the establishment of this species beyond any doubt.

Three of the five tick species collected are known to parasitize man. Dermacentor variabilis was found to be the most common species attacking humans, followed by A. americanum and A. maculatum. The first two species were shown to become active in Kansas beginning in March. The danger of being bitten by ticks extends into October. People frequenting the out-of-doors should time precautionary measures accordingly.

Of the three classes of vertebrates inspected for tick infestation mammals were most frequently parasitized. Indications were that reptiles are not preferred hosts.

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