

ECOLOGY AND BEHAVIOR OF THE
LONE STAR TICK

By

PAUL JOSEPH SEMTNER

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Bachelor of Science
Oklahoma State University
Stillwater, Oklahoma
1967

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1970

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ECOLOGY AND BEHAVIOR OF THE
LONE STAR TICK

Thesis Approved:

J. Alexander Han

Thesis Adviser

John R. Sauer

A. Howell

J. J. Cracraft

D. Durham

Dean of the Graduate College

PREFACE

The lone star tick [Amblyomma americanum (L.)] causes a severe problem in southeastern parts of the United States, and with tremendous populations of this pest occurring in localized areas throughout the Ozark region. This dissertation presents results of a series of four studies on various conditions which make it favorable for high numbers of the lone star tick to exist in eastern Oklahoma.

Caged adult ticks lived longest in habitats with less variable climatic conditions and it was shown that environmental conditions affected the tick's seasonal and diurnal behavior.

Molting time of engorged nymphs and their post-molt behavior was studied to obtain a more complete picture of the field biology of lone star ticks. Molting time decreased as the average daily temperatures increased.

The seasonal activity of lone star ticks, as indicated by drag and CO₂ samples, was studied in 17 different habitats. Sample sizes peaked at different times of the year in different habitats. Adult activity generally peaked during May and June. Nymphs had two activity peaks; one in either May, June or early July, and one in August or September. Larval populations reached peak numbers in August or September.

A great deal of indebtedness is owed to my major adviser, Dr. J. A. Hair, who spent many hours in the guidance and assistance in developing and completing this research.

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CHAPTER I

INTRODUCTION

The lone star tick, Amblyomma americanum (L.), is a very serious pest of man, wildlife and livestock throughout much of the south-central and southeastern United States. Very high populations occur in parts of Oklahoma, Texas, Arkansas and Louisiana. These high numbers are not a recent occurrence in Oklahoma, however, since early explorers recorded vivid descriptions of the high numbers of ticks attacking them in central Oklahoma (see Harlan, 1959). They also described the wide variety and great abundance of wild hosts such as buffalo, elk, deer and black bear.

In modern times, ticks continue to exist in great abundance, and up to 25 adult lone star ticks and several hundred nymphs are frequently found on single blades of grass in certain areas of eastern Oklahoma.

Much of eastern Oklahoma is rugged wooded terrain bisected by many valleys. It contains many man-made reservoirs and, therefore, has an abundance of water. Along the major streams extensive farming occurs, while ranching is the main source of income in the Ozark Plateau and parts of the Ouachita Mountains. In southeastern Oklahoma, forestry is important to the economy.

Outdoor recreation is one of the chief industries in this area with camping, water sports and hunting the most common outdoor activities. For the past several years our study area, Cherokee County, has

been second or third among Oklahoma's counties in the number of deer killed each year. It probably has the highest population of deer per unit area in the state. Two state game refuges occur in Cherokee County: the Cookson Hills State Game Refuge and Cherokee State Game Refuge. There are other hunting areas along Lake Tenkiller and Lake Fort Gibson.

Oklahoma State University entomologists have found that the lone star tick contributes heavily to fawn loss in their early stages of life. It is said to be the most serious tick pest of livestock in the southeastern United States (Hooker, et al., 1912).

This pest also contributes to human annoyance, and causes many tourists who are attacked never to return to this area. This tick has been incriminated in the transmission of several important human diseases, such as Rocky Mountain spotted fever, Tularemia, Q-fever and Bullis fever.

A method of control is needed to reduce the tick populations to lower levels without treating the entire infested area with an acaricide, since large scale treatment with an acaricide may also harm other arthropods, fish, wildlife and man. Cultural and mechanical control of ticks in certain areas is desirable and practical but is not applicable to the whole region.

It is important to know as much as possible about the biology and ecology of the lone star tick to develop more desirable control procedures. Important areas of study include its life cycle under normal conditions, tick movement in its natural environment, and determination of the location of each stage's inactive phase during the year.

Thus, the present study was conducted to elucidate the activity and behavior of adult lone star ticks in different plant associations; to study the seasonal activity cycle of each stage in different plant associations using two methods of sampling; and to study the effect of season on newly molted ticks.

CHAPTER II

ACTIVITY AND SURVIVAL OF CAGED TICKS IN DIFFERENT ECOLOGICAL HABITATS

An early report indicated that the lone star tick [Amblyomma americanum (L.)] was of greater importance as a pest of man than any other tick species in the eastern and southern states (Hooker, et al. 1912). Since the report by Hooker, et al., a voluminous amount of information has accumulated that suggests that this species is an important vector of several diseases, causes considerable losses to the livestock industry because of weight losses and/or control efforts, produces mortality in wildlife and is so annoying to man within certain areas of its range that it possibly suppresses the economic development of such areas. These numerous papers were reviewed by Hair and Howell (1970).

It has long been felt that various environmental factors played an important role in the distribution and abundance of this noxious pest (Bishopp and Trembley 1945; Lancaster 1957; Hair and Howell 1970; and Sonenshine, et al. 1966). Types of vegetation, and more specifically, the environmental conditions created by these different habitats have been of principal concern to several lone star tick researchers (Lancaster 1957; Sonenshine, et al. 1966; Semtner, et al. 1971a). Semtner, et al. (1971a) and Wilson, et al. (1972) presented conclusive proof that numbers of lone star ticks found within a particular area generally

depend on the physical makeup of existing vegetation. However, many of the factors responsible for the presence and survival of ticks, in these areas, have not been ascertained.

It was the purpose of this study to compare adult tick longevity in 4 different ecological habitats and to relate temperatures, relative humidities and sun exposure, in the different areas, to longevity and behavior. In addition, we wished to ascertain behavioral movements of ticks in these different habitats.

Data collected in the laboratory indicate the importance of relative humidity and temperature in the behavior and survival of various species of hard ticks (Lees 1946; Feldman-Muhsam 1947; Lancaster and MacMillan 1955; Lancaster 1957; Knulle 1965; Sweatman 1967; Snow and Arthur 1966; and Sauer and Hair 1971). As ecologists in the field, these data are useful to us only as guides since many other factors such as tick behavior and rapidly changing environmental conditions allow ticks to compensate for deficiencies that they are bound to under laboratory environments. We felt that a clearer picture of the role of relative humidity and temperature in the behavior and survival of lone star ticks could be obtained under field conditions by following procedures similar to those outlined in this paper.

Methods and Materials

In order to determine the relationship between habitat type, several physical parameters and tick survival and behavior, 4 types of habitats showing considerable differences in physical makeup were selected in the Cookson Hills Game Refuge, Cherokee County, Oklahoma, during 1970. These

habitats were classed as (1) meadow; (2) persimmon forest; (3) upland oak-hickory forest; and (4) bottomland oak-hickory forest.

The meadow contained mainly broomsedge [Andropogon virginicus (L.)]¹ and bermudagrass (Cynodon dactylon) which had a height range of 30-45 cm. The area was flat and subject to sun and wind exposure since very little soil surface protection was afforded by the existing vegetation.

The persimmon forest habitat consisted mainly of persimmon (Diospyros virginiana) and sassafras (Sassafras albidum) as overstory vegetation with Sericea lespedeza (Lespedeza cuneata), buckbrush (Symphoricarpos orbiculatus) and Virginia wildrye (Elymus virginicus) comprising the majority of the undergrowth. Undergrowth was abundant and ca. 75-90 cm in height. Considerable protection of this study area for sun exposure was given by the existing vegetation.

The upland oak-hickory habitat had mostly post oak (Quercus stellata), black oak (Q. velutina), blackjack oak (Q. marilandica) and black hickory (Carya texana) as overstory and the sparsely occurring undergrowth was mainly buckbrush and rock dropseed (Muhlenbergia sobolifera). Overstory vegetation allowed very little sunlight penetration to the dense leaf litter found in this habitat type.

White oak (Q. alba), black oak, bitternut hickory (Carya tomentosa) and scaly-bark hickory (C. ovata), comprised the overstory vegetation in the bottomland oak-hickory forest. Soil litter was very dense and deep in this woods whereas very little undergrowth existed.

In order to evaluate the influence of habitat condition on tick behavior and survival, two screenwire cages, each containing 100 lone

¹Botanical nomenclature will follow that of U. T. Waterfall, 1970. Keys to the Flora of Oklahoma. 243 pp. Okla. State Univ., Stillwater.

star ticks marked with Day Glo[®] fluorescent pigment, were placed at random in each of the 4 habitats mentioned above. These tick-proof cages were 30 cm in diameter, 90 cm high and fabricated of 14 x 18 mesh galvanized screening. Seams of the screen cage were sealed with liquid solder in order to insure against tick escape.

Two metal rims (one 29.5 cm in diameter x 15 cm high and the other 30.5 cm in diameter x 7.5 cm high) formed the cage base. The rim with the smallest diameter was driven into the soil to a depth of approximately 7.5 cm. The screen cage top was then placed over the portion of the rim protruding out of the soil and/or duff. The second, or largest rim in diameter, was slid over the top of the cage and brought to rest on the soil surface where it surrounded the inner rim and cage top. Window sash rope (ca. 0.5 cm in diameter) was cut to the proper length and forced between the outer rim and base of the screen cage. This arrangement prevented escape of confined adult ticks and afforded considerable stability to the cage.

Lone star ticks used in this study were field collected and of unknown age. Since it is not likely that they molted from nymphs that had engorged during the spring of 1970, we can assume that they overwintered as flat adults which had molted from nymphs the previous summer.

After marking with fluorescent pigments (Wilson, et al. 1972), ticks were divided into groups of 100 and placed in cages within their respective habitats on 1 June, 1970. In order for the ticks to become acclimated to their new environment, a period of 10 days was allowed before the first observations were made. Observations were made twice a week at 0600-0800 hrs, 1000-1200 hrs, 1500-1800 hrs, and 2100-2300 hrs.

Observations included the number of ticks on the ground (or duff), on the cage or on plants within the cage; the mobility of the caged ticks; and the position of aggregates of ticks within or on the cage. Observations at night on the fluorescent marked ticks was made possible through the use of a portable Honda[®] generator and an ultra-violet light. In addition, the physical parameters measured were temperature, relative humidity and percent sun exposure.

Temperature measurements were taken on the cage exterior at -3 cm (within soil), ground level, 15 cm, 30 cm, 45 cm, and 60 cm, with the use of a YSI Telethermometer[®] (Yellow Springs Instrument Company, Inc., Yellow Springs, Ohio). Earlier observations indicated a negligible difference ($<0.5^{\circ}\text{C}$) in temperatures within and outside of this cage type. Relative humidity was measured at ground level, 15 cm and 45 cm with an Atkins Psychrometer[®] (Cole Parmer Instrument Company, 7425 N. Oak Park Avenue, Chicago, Ill.). An estimate of sun exposure within the areas was obtained by recording the average percentage of each cage receiving direct sun rays during the observation periods.

Observations on the physical conditions and tick survival and behavior were begun on 25 June and continued until 19 September, or until no further tick activity was observed. Once all tick activity appeared to have subsided, cages were removed and leaf litter and vegetation were examined thoroughly for surviving ticks.

Results and Discussion

Figure 1 illustrates the desirability of the 4 areas under study as tick habitats. From the time of initial observations, field collected adults lived for an average of less than 22 days in the meadow

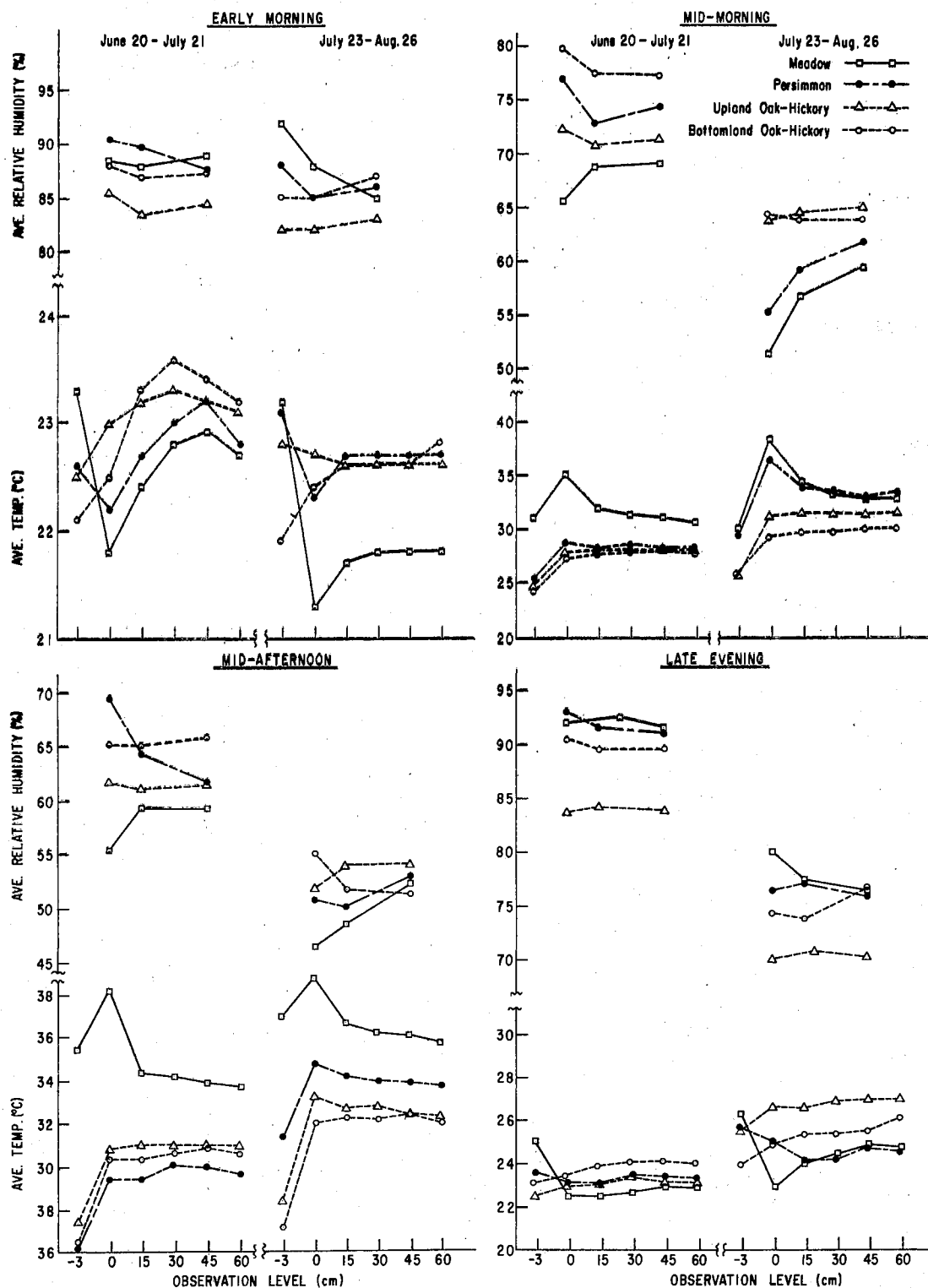


Figure 1. Survival of Adult Lone Star Ticks in Four Types of Habitats During 1970, Cherokee County, Oklahoma

habitat and the maximum longevity was less than 2 months. This type of habitat was noticeably more unfavorable than the other three. Although distinct differences in tick survival did not occur in the persimmon and upland oak-hickory forest, these habitats were obviously more favorable for survival than the meadow. Average tick longevity in the persimmon and upland oak-hickory woods was ca. 35 days. Average longevity of caged ticks in the bottomland oak-hickory was over 45 days. This suggested to us that there was a factor or factors in the bottomland woods that accounted for the greater suitability of this type of area as tick habitat.

Data on physical factors existing in the various habitats (Figure 2) indicate several trends that perhaps help explain the differences in tick longevity obtained in Figure 1. The curves in Figure 2 revealed that during the early summer (20 June - 21 July) daytime temperatures are much higher in the meadow habitat than either of the other three types of habitats. These curves also suggest that meadows have the lowest nighttime temperatures and that these frequently drop below those encountered in the wooded areas.

Average biweekly temperature curves for the 3 wooded areas under study during 20 June to 21 July showed many similarities. As the summer progressed (23 July to 26 August), more pronounced differences in daytime temperature curves within the woodlots occurred (Figure 2). For example, whereas temperatures in the persimmon and bottomland oak-hickory were quite similar during 20 June to 21 July, much higher daytime temperatures began to occur in the persimmon woods during the latter part of the summer (23 July to 26 August). As can be noted from Figure 2, average temperatures for the late summer period were ca. 5°C

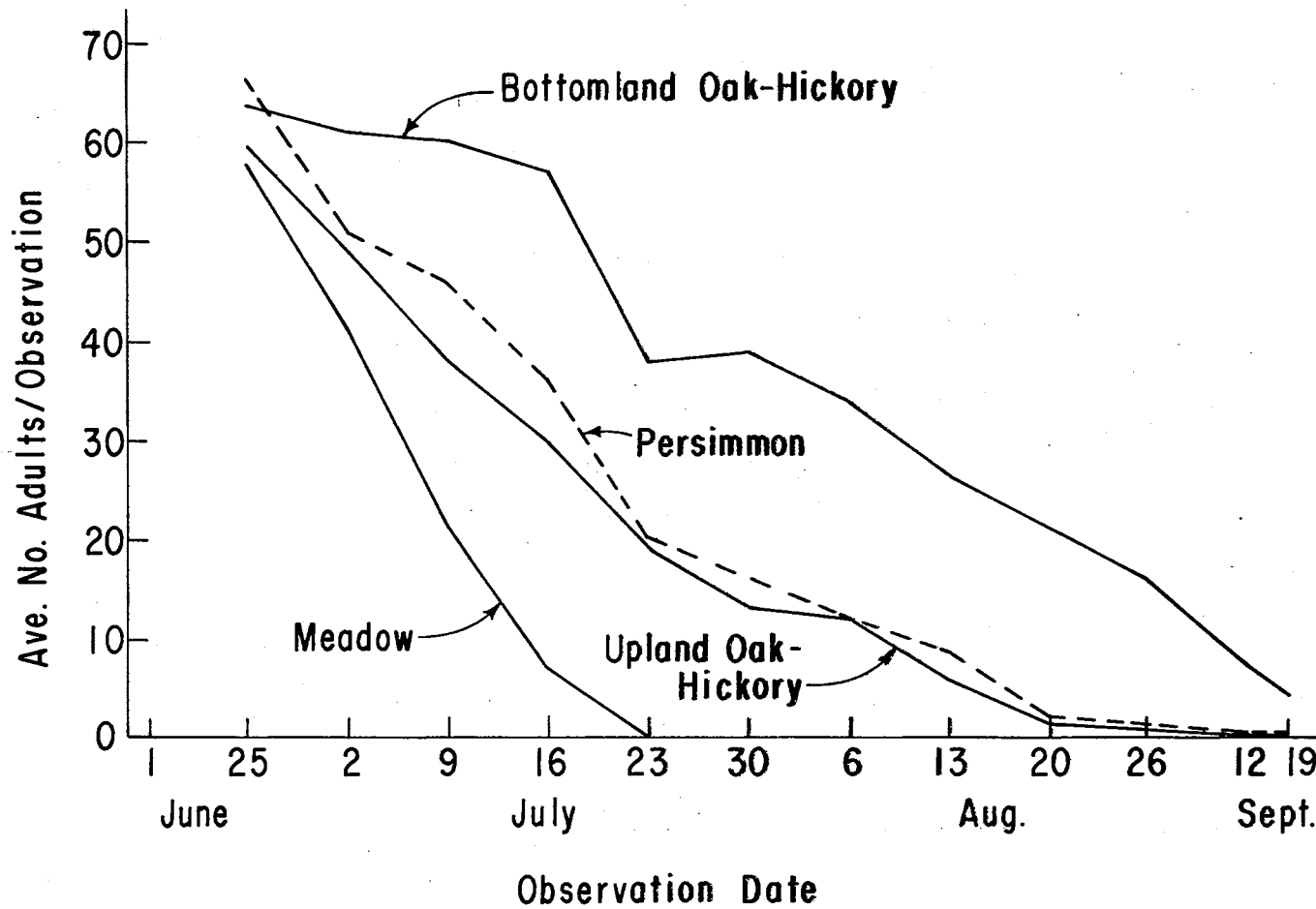


Figure 2. Temperature and Relative Humidity at Various Levels in Different Ecological Habitats During the Summer of 1970, Cherokee County, Oklahoma

higher in the persimmon woods than the other woody habitats. During the late summer, tick cages within the meadow continued to be exposed to higher daytime temperatures and lower nighttime temperatures than cages in other types of habitats.

The relative humidity curves plotted for each type of habitat were generally inversely related to the temperature curves. Meadows had high nighttime humidities and very low daytime humidities. Upland and bottomland oak-hickory forests generally had the highest daytime humidities but meadows and persimmon woods frequently had higher nighttime humidity readings.

In summarizing the data shown in Figure 2, we note that the meadow habitat is subject to drastic extremes in relative humidity and temperature on a daily and also a seasonal basis. On the other hand, the bottomland oak-hickory forest showed less fluctuation in daily temperatures and we will note in Figure 2 that late season temperature curves for this habitat show very little increase over the early season curves. Mid-afternoon curves taken between 23 July to 24 August for the persimmon and upland oak-hickory habitats showed marked increases in average temperature over the early season curves.

The data in Figure 2 suggest that all habitats have relative humidities too low during much of the day to prevent water loss by lone star adults since Sauer and Hair (1971) demonstrated that the C.E.H. (Critical Equilibrium Humidity) relative humidity for adults was approximately 85 percent. The C.E.H. is that humidity below which the arthropod gives up water to the environment. We must assume, therefore, that temperature was a very important factor in tick longevity in these

studies since Sauer and Hair further showed that rate of water loss, at specific humidities, was correlated with temperature and/or saturation deficit.

Data in Figure 1 also suggest that adult ticks confined in the meadow habitat lose more water during the day than they can reabsorb from the environment during the night.

Since temperatures were not extreme and humidities failed to get excessively low, the bottomland oak-hickory habitat probably allowed adult lone star ticks to compensate during the night for minor daytime water losses.

The most obvious changes in tick behavior within the different habitats occurred between 13 July and 28 July (Figures 3, 4). Figure 3 is a composite curve showing the vertical behavioral trend of caged ticks in all habitats under study and the top curve of this figure, which represents data from a flagging survey in the same areas, indicates that similar behavior occurred in non-caged ticks. When adults were introduced into the cages in each habitat, they were released on the ground. This could account for the larger number of ticks observed on the ground on 23 June. These data (Figures 3, and 4) show that a high percentage of the caged ticks occupied resting sites on the cage side and vegetation between 30 June and 13 July, but as the temperature in the various habitats increased sharply after this period (Figure 4), most adults sought refuge in the cover of the cage bottom. Figure 2 indicates that relative humidities in the study areas also changed drastically during this time.

Figure 4 shows that adult behavior changes in all habitats during the first half of July. It can also be noted that average ambient

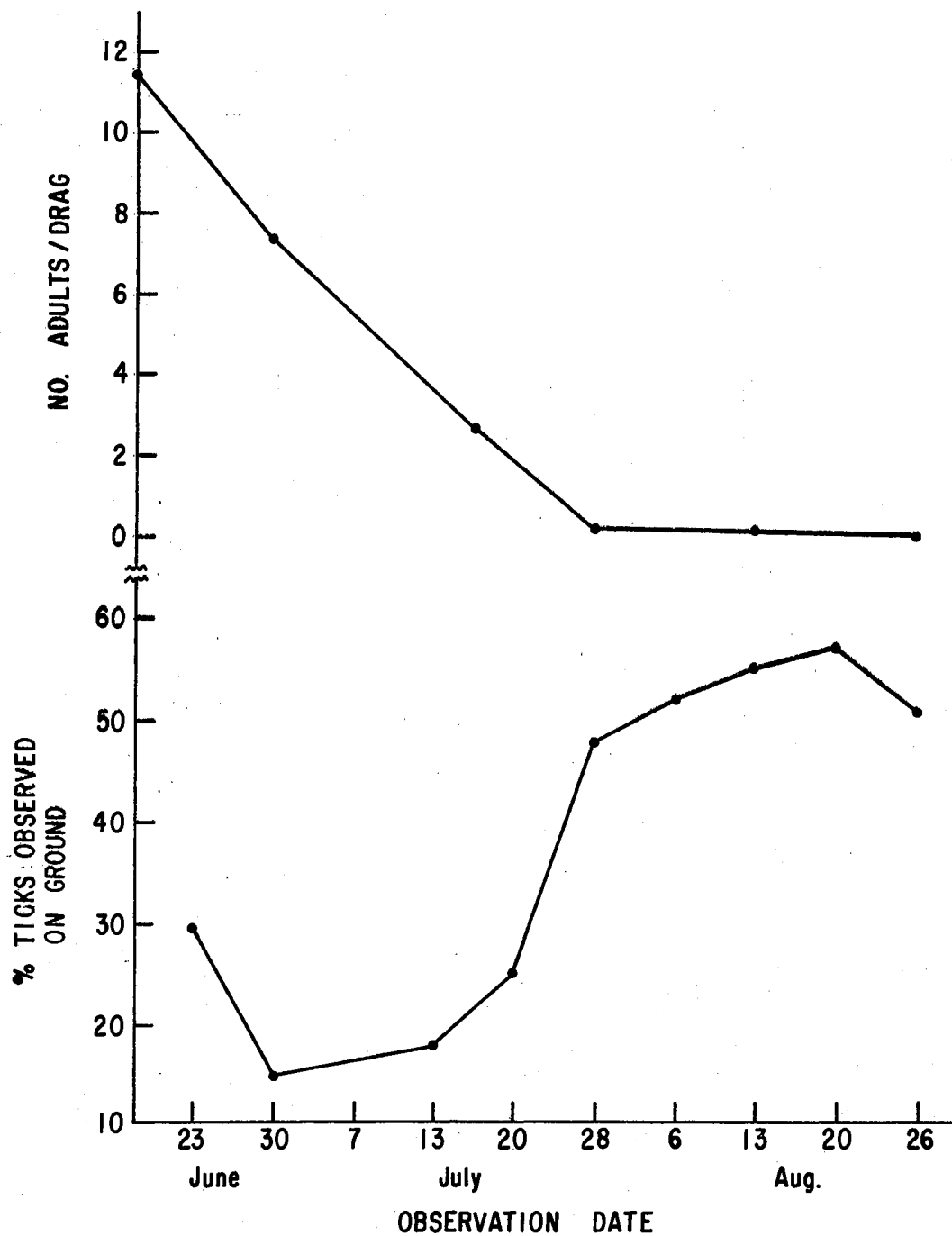


Figure 3. Average Percent of Caged Adult Ticks in Four Types of Habitats Observed on the Ground and the Average Number of Adult Ticks per Drag Collected From Vegetation in Similar Habitats During 1970

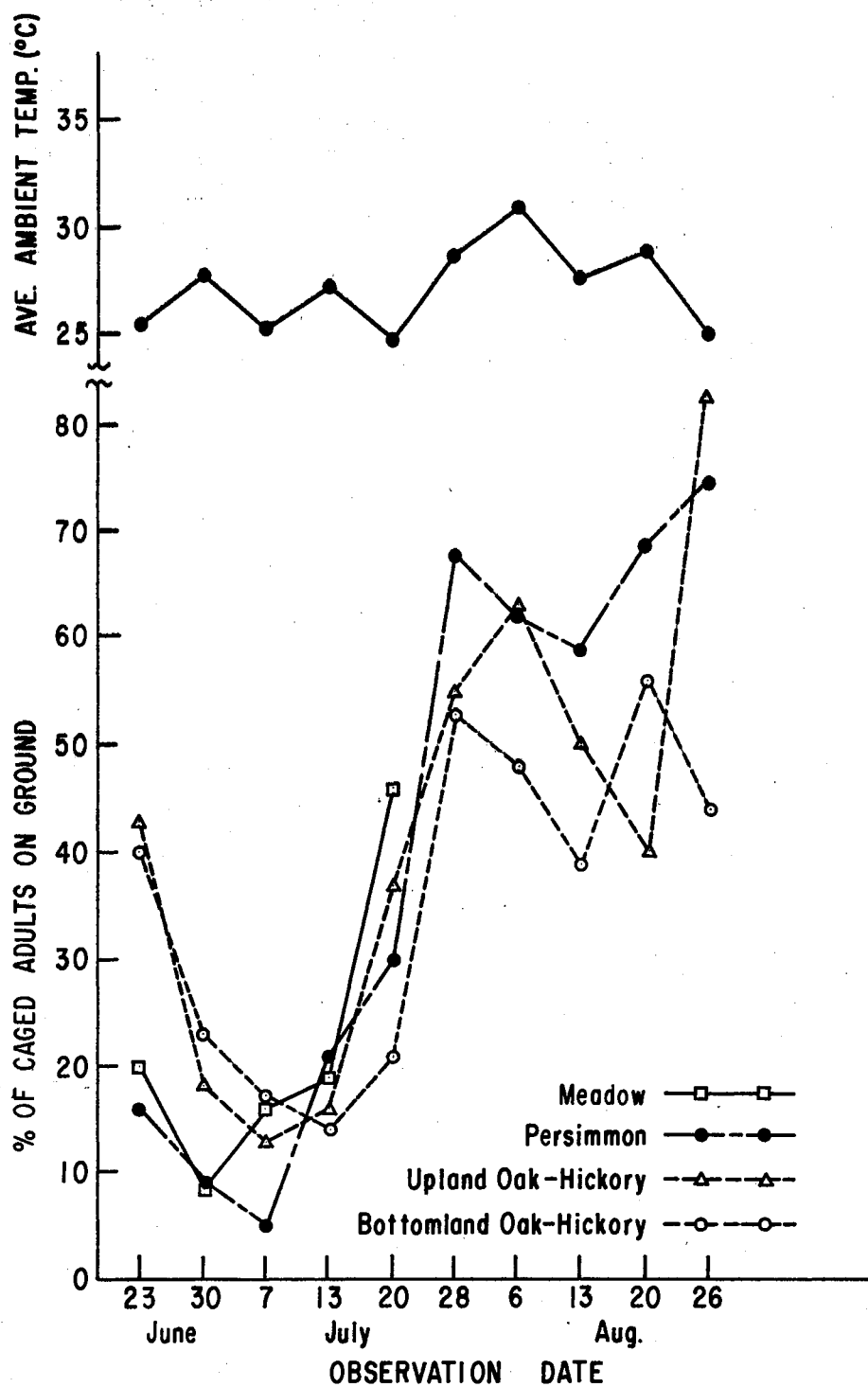


Figure 4. The Relationship Between Average Seasonal Temperature and the Percent of Adult Ticks Observed on the Ground in Four Diverse Habitats During 1970

temperatures in the study areas had a marked increase during July. Since relative humidity was shown to be inversely correlated to temperature, we can assume that all tick habitats also undergo a marked reduction in relative humidity during this time period.

The findings of this investigation indicate that specific types of habitats are more favorable as tick habitat than others. We might assume that high temperatures encountered in meadows are responsible for excessive losses of water in lone star ticks and that in most cases this loss is in excess of the amount that adults are able to reabsorb during periods when the relative humidity in these habitats is above the Critical Equilibrium Humidity of the tick.

We can conclude, therefore, that the bottomland oak-hickory habitat was the most favorable habitat in our studies due to lower daytime temperatures and less variable diurnal temperatures occurring in this area. It is possible that adults in this habitat were able to compensate for most daytime water losses by water absorption during the night. The data might suggest, however, that high temperatures during mid-July interfere with this capability of the tick since noticeable mortality occurs at this point and the slope of the survivorship curve (Figure 1) after this point is quite similar to that of the other 2 woodlot habitats.

Data in Figures 3 and 4 reveal behavioral traits of the lone star tick previously unreported and presents information that suggests that flagging techniques for sampling has yielded an erroneous picture of seasonal abundance of adults during past observations (Hair and Howell 1970). Figure 3 indicates that flagging procedures during 1970 showed a cessation in adult activity near the end of July. We believe that

most workers have interpreted this in the past to mean that most old adults (those that have survived the summer) had succumbed by this time. The lower portion of Figure 3 shows that a behavioral response is responsible for the small numbers of adults appearing on drags during the late summer (August) and that most survivors during this time retreat to the forest floor from vegetation within the habitat. It is of importance that high temperatures and increasing moisture deficits (Figure 4) appear to influence this downward migration (Figure 3).

CHAPTER III

SEASONAL BEHAVIOR OF ADULT AMBLYOMMA AMERICANUM

(L.) IN DIFFERENT HABITAT TYPES

Great numbers of lone star ticks occur in certain parts of the south central and southeastern United States (Brennan 1945; Bishopp and Trembley 1945; Cooley and Kohls 1944; and Hair and Howell 1970). In certain parts of its range such as eastern Oklahoma very high lone star tick populations cause extreme annoyance to man and animals.

The area used in this study has previously been described by Semtner (1971a, b) and had very high populations of lone star ticks during these investigations. Research was initiated to determine the effect of the environment on the activity and behavior of adult lone star ticks under field conditions.

MacLeod (1936) showed a significant correlation between tick activity and temperature. The extent of larval tick [Ixodes ricinus (Linnaeus)] response to gravity was also influenced by temperature (MacLeod, 1935) and ticks have also been shown to be negatively geotrophic between 14 and 24°C. They were positively geotrophic above and below that temperature range.

The vertical migration of I. ricinus (Lees and Milne, 1951) was attributed to the water content in the body of this tick. When there was little or no moisture deficit, ticks would move up on the vegetation, and when the moisture deficit reached a certain point, they moved

back down into the moist mat to replenish their lost body water. Lone star ticks, as well as I. ricinus, are able to reabsorb water from environments above their critical equilibrium humidities (Sauer and Hair 1971; Lees 1948).

The behavior and intensity of activity of lone star ticks appear to vary from one part of the country to another. Smith and King (1950) working with lone star ticks in South Carolina, observed that ticks were much more active there than in Texas and they attributed this to South Carolina's higher humidity.

MacLeod (1935) found that as the temperature increases, the effect of humidity in prolonging the survival period of ticks (I. ricinus) steadily diminishes.

Brennan (1945), in central Texas, observed that lone star ticks remain on the ground through much of the season due to the dry climate, and noted that ticks sought shelter under litter of oaks and junipers.

In northeastern Oklahoma, active adult lone star ticks occur mainly on the ground during February, March, and early April, ascending vegetation in great numbers in late April, May, and June (Hair and Howell, 1970). A peak in adult numbers is reached in late May or early June (Hair and Howell 1970; Clymer, et al. 1970a). After these dates there is a steady decrease in active adults and few are found after 1 August.

Lees and Milne (1951) found that I. ricinus adults began their host-seeking position on plants during the day or night, but most showed decreased activity at night. While studying the diurnal behavior of the desert tick, Hyalomma asiaticum, Schulze and Schlottko, Balashov (1960) found that it was inactive during the night, but spent much of the cooler part of the morning and late afternoon seeking hosts. During

the hot part of the day they would move down into the litter and crevices of gerbil holes to avoid the high temperatures on the sand surface.

The present studies were initiated to determine the survival and activity of adult lone star ticks in different habitats and compare it to the climatic conditions recorded for the period of study; to observe the seasonal and diurnal vertical migration of lone star adults and observe their relationship to temperature, relative humidity and changes in photoperiod changes.

Methods and Materials

Studies on the behavior of adult lone star ticks were set up by field collection of adults with CO₂ tick traps (Wilson, et al., 1972) during April and May. Ticks were marked with Day-Glo[®] fluorescent pigments (Wilson, et al., 1972) to make their detection in the field easier. They were then divided into 12 groups of 25 males and 25 females each. Groups were selected at random and introduced into the habitat types mentioned below.

Four different habitats were selected and used for comparative studies. These were a meadow, persimmon grove, upland oak-hickory forest and bottomwoods. The meadow contained several species of grasses including Johnson grass (Sorghum halepense), orchard grass (Dactylis glomeratus), fescue (Festuca spp.), broomsedge bluestem, brome (Bromus spp.) and sericea lespedeza. The persimmon habitat contained persimmon and a few sassafras, with a dense understory of buckbrush sericea lespedeza. Virginia wild rye was a common grass found in the persimmon habitat. Leaf litter coverage was moderate. The upland oak-hickory

forest consisted of post oak, blackjack oak, black oak, southern red oak (Quercus falcata) and hickory. The undergrowth was light and included buckbrush and saw greenbriar with moderate litter cover. The bottomwoods contained white oak, black oak, chinquapin oak (Q. muhlenbergia), American elm (Ulmus americana), and several species of hickory. Understory was light and included Bromus spp. and rock dropseed, with moderate leaf litter cover.

Unpublished data showed that those adult ticks which were field collected during April and May had overwintered from the previous summer. The age of the majority of the ticks used was probably between 7 and 11 mo, although some had probably overwintered two winters or more and were ca. 19-23 mo old, since the majority of engorged nymphs molt between June and October (Semtner, P.J., Unpublished data, 1972).

Ticks were confined to these habitats by 30 x 90 cm cylindrical screenwire cages which were anchored into the ground by sheet metal rims (Semtner, et al., 1971b).

Releases were made in each of the four different habitats in three different areas. Therefore, each area had three cages (replications) per habitat. The releases were made on 10 April - in area #2, 16 April - in areas #1 and 8 May - in area #3 in 1971. In area #2, a second release was made into the two cages in each habitat with the least number of ticks observed on 28 May due to the poor rate of survival by ticks initially placed in this area. Early season observations were made of adults that had been placed within cages during the summer of 1970 and had overwintered.

Observations were made at weekly intervals beginning a week after the initial release and continuing until ticks were no longer observed

in any of the cages (early October). Each cage was checked four times a day, once a week. After the last active tick was observed, the cage was taken up to examine the soil litter for living and dead ticks.

Observation during the study entailed: (1) the number of active ticks on the cage, on the vegetation, on the ground and the total number of ticks observed within the cages; (2) the orientation of the ticks in the cages; (3) temperature readings at -3, 0, 15, 30, 45 and 60 cm near the cage; and (4) relative humidity readings at 0, 15 and 45 cm.

The "expected activity" was determined for the ticks in each habitat from 1 June, 1971 until they were no longer active in the cages. This was done in the same form as life expectancy might be determined in a life table. In contrast to a life table, "expected activity" was used to account for ticks which became inactive at certain times, and which would probably overwinter, and also for those which died.

Temperature measurements were taken with a YSI Telethermometer[®] with a six channel probe system (Hoch, et al., 1971). One reading at the six levels was taken during each observation. The relative humidity at three levels was taken consistently from 3 June to 3 August, 1971 using an Atkins[®] Psychrometer (Hoch, et al., 1971). Means were determined for each area, habitat, date and time.

Results and Discussion

Activity

Considerable differences were observed in the activity of lone star ticks between the meadow habitat and the other three habitats (Figure 5). The mean number of active adults per cage in the bottomwoods was significantly higher than the upland oak-hickory, persimmon and

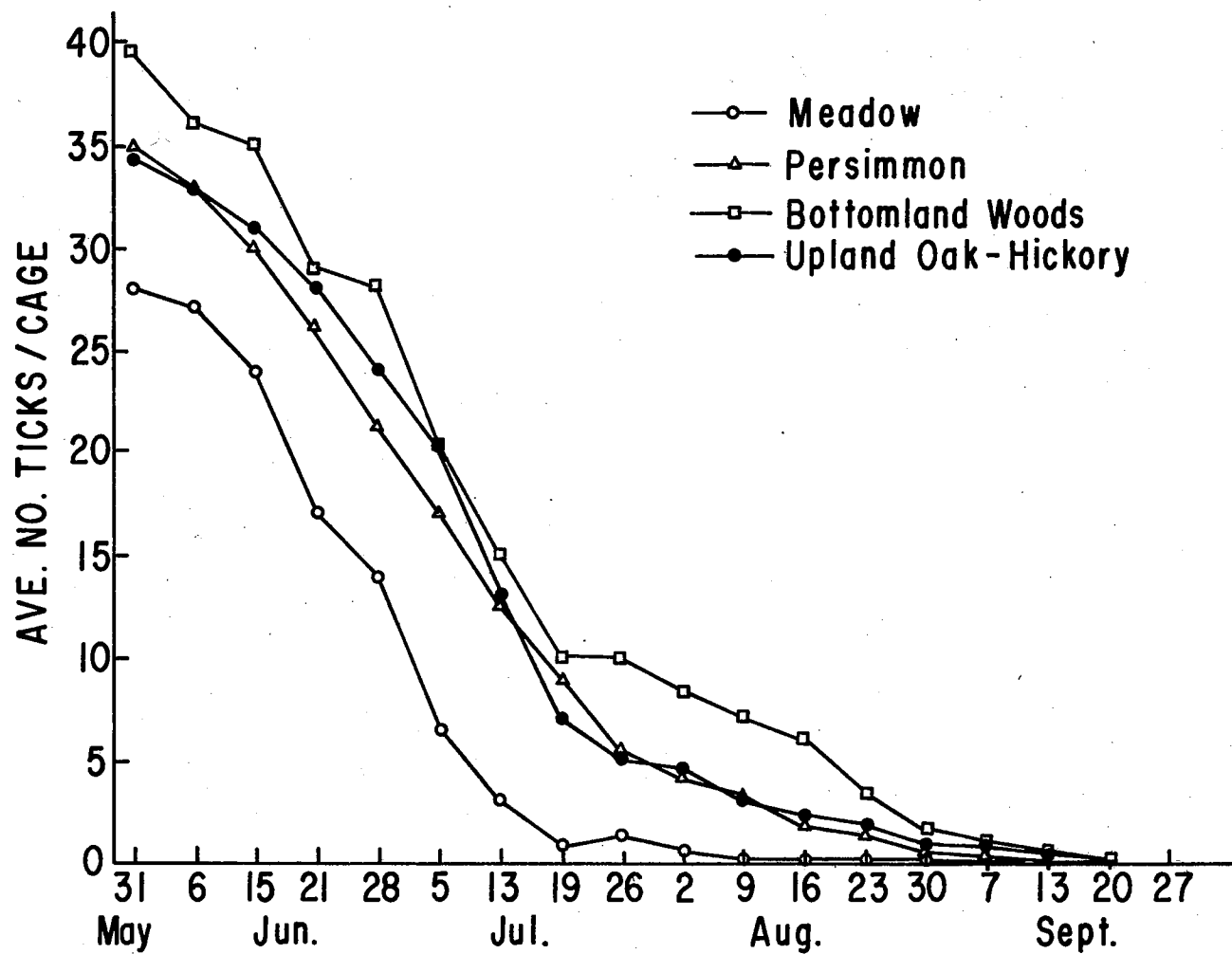


Figure 5. Seasonal Activity of Adult Lone Star Ticks in Four Different Habitats During 1971

meadow according to a Duncan's multiple range test (Table I). The mean number of adults in the meadow was significantly lower than was found in the other habitats, while mean active tick populations were not significantly different between the upland oak-hickory and persimmon habitats.

The ticks in the meadow had the lowest number of active ticks per cage during early June with 29 (Figure 5). It was followed in order by: upland oak-hickory, 34.5/cage; persimmon, 35/cage; and bottomwoods, 39.5/cage. A sharp drop in the active adult populations began in mid-June and continued until mid-July when there was a stabilization of activity. This was followed by a gradual decline in activity into late August and September.

Very few ticks were still active in the meadow (0.5/cage) during early August, while the upland oak-hickory and persimmon habitats had 4 - 5 ticks/cage, and the bottomwoods had an average of ca. 8/cage. During late August there was an average of less than one active tick per cage in all habitats, except the bottomwoods which had an average of ca. 1.5/cage. Semtner, et al. (1971b) noted more distinct differences in similar habitats during 1970. In 1970, active ticks were not found in the meadow after mid-July, while they were still active in moderate numbers in the other habitats. During late August approximately 15 ticks/cage were found in the bottomwoods habitat, with few being still active during late September. During October, when the cages were taken up, no ticks were active, although several living ticks (<1/cage) were recovered and would have probably survived the winter (Semtner, et al., 1971b). The behavior of these ticks was similar to those adults that had molted during the summer of 1970. They seemed to be negatively

TABLE I
 MEAN NUMBER OF ACTIVE ADULT TICKS PER CAGE BY
 HABITAT IN CHEROKEE COUNTY, OKLAHOMA
 FROM 24 MAY TO 3 AUGUST, 1971

Habitat	Ticks/cage Mean ^a
Bottomwoods	24.3A
Upland Oak-Hickory	21.4B
Persimmon	21.1B
Meadow	16.1C

^aMeans followed by the same letter are not significantly different at the 5 percent level according to Duncan's Multiple Range Test.

phototrophic when taken from their resting place under leaves and within the duff and upon being exposed to light the ticks would immediately crawl back under the leaves (Semtner, P.J., Unpublished data). Lancaster (1957) and Smith and Cole (1941) noted similar results in the lone star tick and the American dog tick, Dermacentor variabilis (Say).

The higher temperatures, higher light intensities and lower humidities in the meadow during the daytime apparently produced more unfavorable conditions for tick activity than occurred in the other habitats (Figure 6, Table II). The persimmon habitats, however, had the highest average daytime humidities and moderate temperatures during most of the day, but had a shorter period of activity than was observed in the bottomwoods (Figure 7).

Expected Activity

Of those ticks living within the cages during early June their average "expected activity" by habitat was as follows: meadow, 30.1 days; persimmon, 36.7 days; upland oak-hickory, 38.7 days; and bottomwoods, 41.2 days (Table III). In early July, the following days of expected activity was observed: meadow, 10.6 days; persimmon, 16.6 days; upland oak-hickory, 16.9 days; and bottomwoods, 25.5 days. The "expected activity" for ticks living to 1 August ranged from 10.0 days in the meadow to 20.6 days in the bottomwoods. Early September activity expectancies ranged from 3.5 days in the meadow to 12.2 days in the bottomwoods.

The "expected activity" depends upon both the tick's survival and when they become inactive after going into the leaf litter. Semtner, et al. (1971b) found that activity of ticks released during early June, 1970, ranged from less than 22 days in the meadow habitat to more than 45 days in the bottomwoods. They noted that the daytime (midmorning

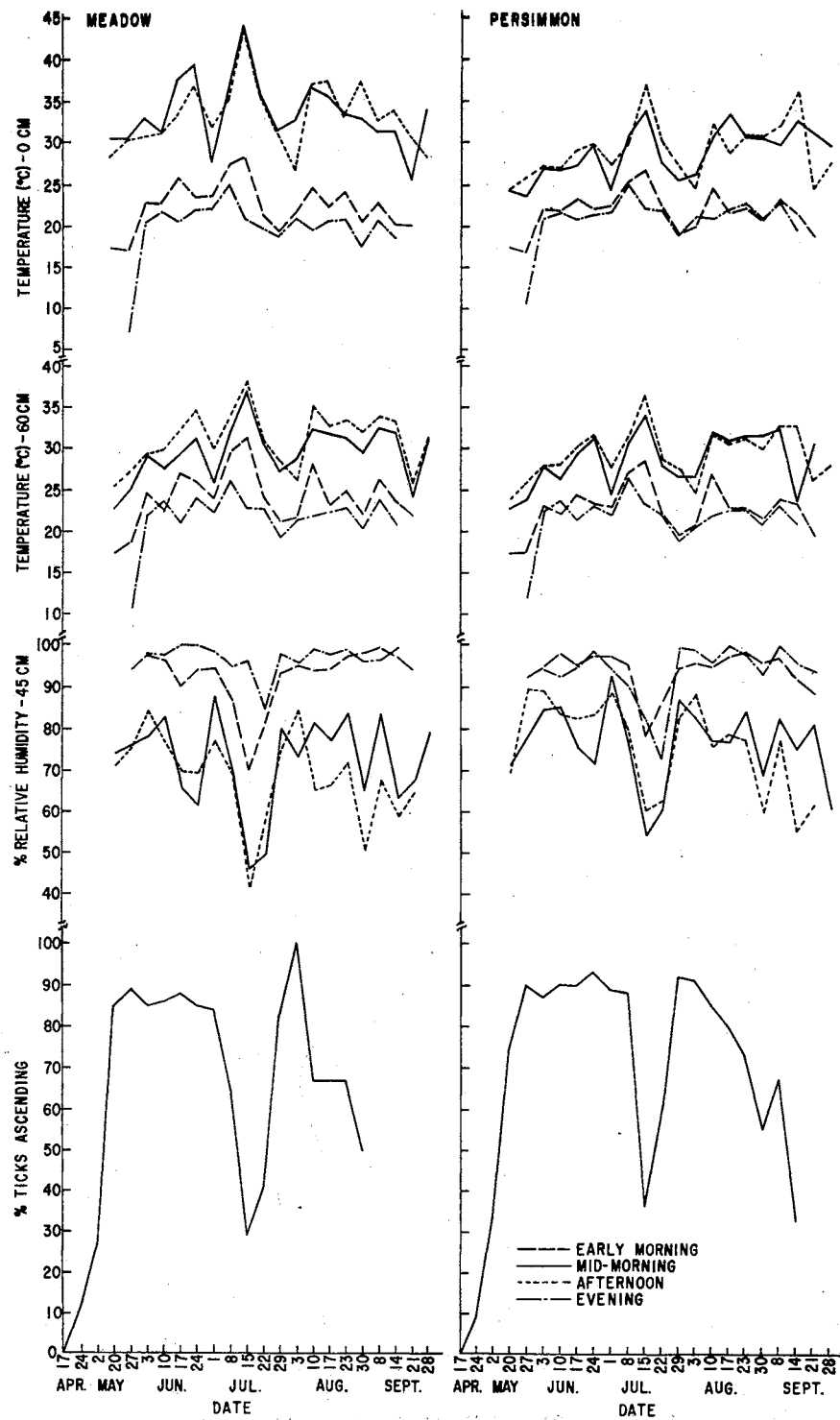


Figure 6. The Effect of Temperature and Humidity on Adult Lone Star Tick Migration During 1971 in the Persimmon and Meadow Habitats

TABLE II
 MEAN¹ TEMPERATURE AT TWO LEVELS AND AVERAGE RELATIVE
 HUMIDITY AT ONE LEVEL IN FOUR DIFFERENT
 TICK HABITATS, CHEROKEE COUNTY,
 OKLAHOMA, MAY TO AUGUST, 1971

Time	Bottomwoods	Upland Oak-Hickory	Persimmon	Meadow
Early Morning				
T ₂ ^a	20.7C	21.0C	21.6B	22.8A
T ₅ ^b	21.5C	21.7C	22.5B	23.8A
H ₁ ^c	90.6A	88.4B	90.5A	86.4C
Mid-Morning				
T ₂	26.2C	27.1B	27.0B	34.2A
T ₅	26.9C	27.1C	27.6B	29.2A
H ₁	71.4B	71.6B	77.2A	70.3B
Afternoon				
T ₂	27.4C	28.3B	28.1B	33.3A
T ₅	28.5C	28.6C	28.9B	30.5A
H ₁	72.5A	68.9B	74.6A	68.8B

^aAverage temperature in °C at ground level.

^bAverage temperature in °C at 45 cm.

^cAverage percent relative humidity at 45 cm.

¹Means followed by the same letter are not significantly different at the 5 percent level according to Duncan's multiple range test.

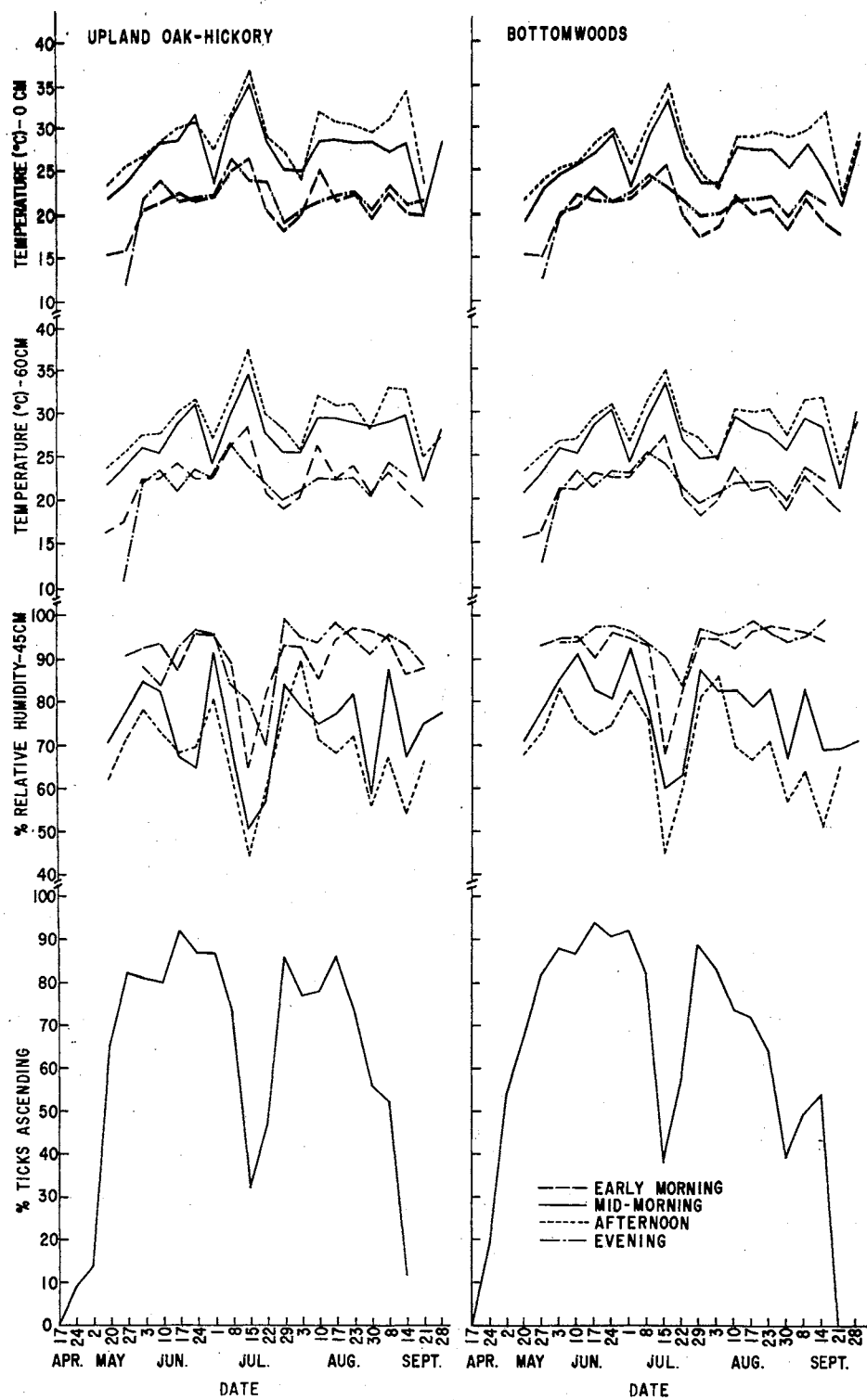


Figure 7. The Effect of Temperature and Relative Humidity on the Vertical Migration of Lone Star Ticks in Upland Oak-Hickory and Bottomwoods Habitats

TABLE III
 EXPECTED ACTIVITY^a TIME IN DAYS OF SECOND SEASON ADULT
 LONE STAR TICKS IN FOUR HABITATS AT WEEKLY
 INTERVALS DURING LATE SPRING AND SUMMER
 1971, IN EASTERN OKLAHOMA

Date	Habitat			
	Meadow	Persimmon	Upland Oak-Hickory	Bottomwoods
4 June	30	37	39	41
10	25	32	32	38
17	19	27	29	33
24	16	25	25	31
30	13	23	21	28
7 July	11	16	17	26
14	10	19	20	26
21	15	19	22	31
28	9	17	20	24
4 August	10	15	19	21
10	13	12	18	16
17	18	13	16	12
24	11	10	12	11
31	4	10	11	12
7 Sept.		5	12	9
14		2	7	9
21			4	6
28				4

^aExpected Activity = an estimate of the average number of days of activity remaining in those ticks at a given time

and afternoon) relative humidity was slightly higher and that the temperature was lower in the bottomwoods than in the other three habitats from mid-July to mid-August. A much more distinct survivorship curve was also noted. It should be pointed out that this bottomwoods habitat was more heavily shaded than the ones used during 1971. It was also located on a moist northern slope.

Seasonal Vertical Migration

Adult lone star tick activity was first observed during mid-February, but ticks remained in close association with the leaf litter and duff. During this period, they would respond to human breath, and crawl from the debris at the base of the cage and ascend the sides of the cage. As the temperature decreased during the evening, the ticks returned to the soil litter. Similar behavior was observed through March and into early April. Reports by Hair and Howell (1970) are in agreement with these observations. During late April, an upward migration began as the average daily high temperatures were over 25°C. The percent of ticks ascending the vegetation and cages increased from 0 percent in mid-April to ca. 90 percent during late May and early June.

Minor changes in the percent of ticks up on the cages were noted between 1 June and 1 July. During early July, a moderate movement of ticks back to the ground and into the leaf litter at the base of the cages was observed. A sharp movement to the ground and litter occurred during mid-July in all habitats (Figures 6, 7).

During late July those ticks still alive began moving back up the cages and vegetation, but the number was greatly reduced. Due to the reduced sample sizes, the second peak was much more variable in the percent of ticks ascending than the first peak. The second activity

peak began to decline by mid-August and by mid-September most active ticks were observed on the ground.

Observations made during 1970 were initiated on 25 June, when approximately 60 percent of the ticks had ascended (Figure 8). The percent of ticks ascending peaked in late June and remained fairly constant until mid-July. In late July a sharp decrease in the percent of ticks observed on the cage and vegetation was noted. From late July to late August the percent on the ground again remained fairly constant although the sample numbers were decreasing. The reduction in ticks ascending during late July corresponded to an increase in average ambient temperatures (Semtner, et al., 1971b). These observations were comparable to the present study which had a similar reduction correlated to low humidities and high temperatures.

The movement of adult ticks up the vegetation during April corresponds to drag samples taken during 1970 (Semtner, et al., 1971b). Activity of adults on drag samples increased from April to a peak in early June. A reduction in activity followed and by mid-August few adults were picked up. This was similar to observations by Clymer, et al. (1970a) and Hair and Howell (1970). In the present study activity in cages peaked at about the same time as peaks were observed on drag samples, but activity of caged ticks continued later into the season.

The vertical migration of adult ticks appeared to be regulated by a combination of factors, including relative humidity, temperature and possibly photoperiod. Increasing temperatures, in combination with increasing photoperiod, appears to initiate early season activity. A few ticks may also respond during the winter (November to February) if a host lies near their overwintering habitat. During late May, 1971,

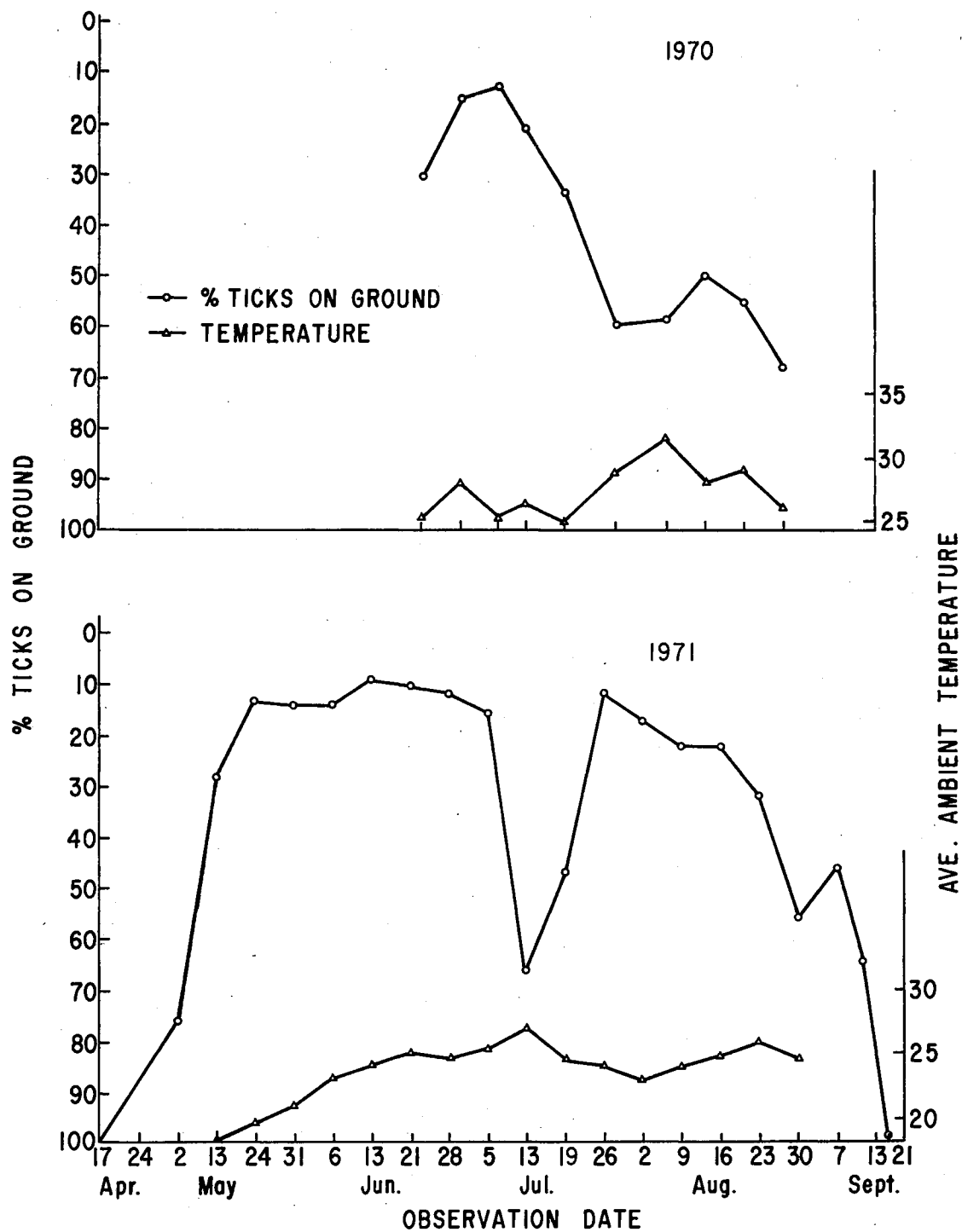


Figure 8. The Seasonal Vertical Migration of Adult Lone Star Ticks During 1970 and 1971 in Relation to the Weekly Mean Temperature

when 90 percent of the ticks had ascended vegetation, temperatures and relative humidities were generally favorable for lone star tick activity at the tips of vegetation. The daytime relative humidities, heavy morning dews and photoperiod began decreasing and temperatures increased during early July (Figures 6, 7 and Table I). These factors combined to cause a movement of ticks down the cages and vegetation into the leaf litter and duff by mid-July. During mid-July, only 25 to 40 percent of the ticks observed were on the cage and vegetation and the total number observed was much lower. The summer's highest temperatures and lowest relative humidities occurred at this time (Figure 6, 7 and Table IV).

A cool wet period began in late July and continued until mid- to late August (Table IV). At the beginning of this period an increase in the percent of ticks ascending corresponded to the cooler temperatures and higher relative humidities. During late August as temperatures increased and the relative humidities and photoperiods decreased, most ticks moved back to the ground.

This seasonal behavior is similar to observations recorded by MacLeod (1935) for Ixodes ricinus. He noted that larvae were negatively geotrophic from 14 to 24°C, but positively geotrophic above and below this range.

The photoperiod began decreasing during late June, yet the population had already started to decline early in June (possibly due to mortality). Gladney and Wright (1971) found that decreasing photoperiod caused a decrease in the attachment rate of adult lone star ticks. Newly molted adults tend to avoid light and crawl under leaves when disturbed during late summer and fall (Semtner, P.J., Unpublished data, 1972). Lancaster and MacMillan (1955) reported that adult ticks would

TABLE IV

WEEKLY MEAN HIGH AND LOW TEMPERATURES AND
MEAN PRECIPITATION IN EASTERN OKLAHOMA¹
DURING THE 1970 AND 1971 STUDY PERIODS

Date	1970			Date	1971		
	Temp. H	(C) L	Precip. mm		Temp. H	(C) L	Precip. mm
				April			
				4-10	19.6	3.8	9
				11-17	25.0	10.6	1
				17-23	24.5	11.7	43
				24-1 May	23.4	10.6	20
				May			
				2- 8	24.5	11.5	26
				9-15	23.4	10.4	33
				16-22	27.3	12.9	8
				23-29	26.0	14.1	68
				30-5 June	29.1	17.1	26
June				June			
1- 4	20.7	13.8	46	6-12	30.8	19.2	17
5-11	27.7	16.3	2	13-19	31.7	17.8	9
12-18	32.6	22.3	36	20-26	32.5	25.6	25
19-25	31.9	19.8	21	27-3 July	31.4	20.2	37
26- 2 Jul	34.0	20.1	0				
July				July			
3- 9	33.7	18.5	8	4-10	33.5	21.8	18
10-16	34.9	21.9	11	11-17	35.7	20.9	1
17-23	33.1	18.0	5	18-24	31.5	19.2	92
24-30	34.2	19.9	3	25-31	29.7	16.4	30
31- 6 Aug	38.7	23.0	4				
August				August			
7-13	36.2	21.0	5	1- 7	27.4	17.3	30
14-20	37.6	22.4	2	8-14	31.9	19.2	13
21-27	33.4	18.7	35	15-21	31.9	19.2	7
28-31	34.4	19.3	0	21-28	32.4	20.2	9
				29-4 Sept.	30.7	18.6	4
				September			
				5-11	32.9	20.5	45
				12-18	30.5	15.6	45
				19-25	21.8	12.2	23
				26-31			2

H = high; L = low

¹Means of climatological data for Sallisaw, Tenkiller Dam, Stillwell, and Tahlequah weather stations. U.S. Dept. of Commerce, 1970, 1971, Climatological Data, Oklahoma. 78:81-140; 80:49-156. Superintendent of Documents, Government Printing Office, Washington, D. C.

not attach during mid-August, but it is known that small numbers of adults are found on deer in eastern Oklahoma during deer season (late November) (Clymer, et al., 1970b).

Diurnal Behavior

During May and June ticks in the meadow and persimmon habitats tended to congregate behind the supporting stake and under the top rim of the cage out of the sun as was found by Semtner, et al. (1971b) in a similar study the previous year. Ticks in the woody habitats tended to congregate on the north and east sides of the cages (Figure 9). Tendencies of the ticks to congregate occurred in many cages and these congregations would often remain in about the same location for several weeks. Lees and Milne (1951) noted that wind direction had the main effect upon the orientation of larval I. ricinus, while the sun was of secondary importance. In our studies the wind direction and velocity were not recorded, but it was usually SW, S or SE, and may have been important in orientation.

Spot observations of diurnal movements during February, March and April indicated that most adult lone star ticks were in close association with the leaf litter and duff at this time of the year. Initial observations of the leaf litter, at this time of the year, showed few ticks crawling among the dead leaves. However, upon stimulation by human breath, ticks often responded vigorously. Since a few do occur on hosts during the winter months (February) and moderate numbers are observed on animals during March and April (Hair and Howell, 1970), ticks probably seek out their host in response to the host's body heat and CO₂ production. MacLeod (1938) observed that I. ricinus occurred in

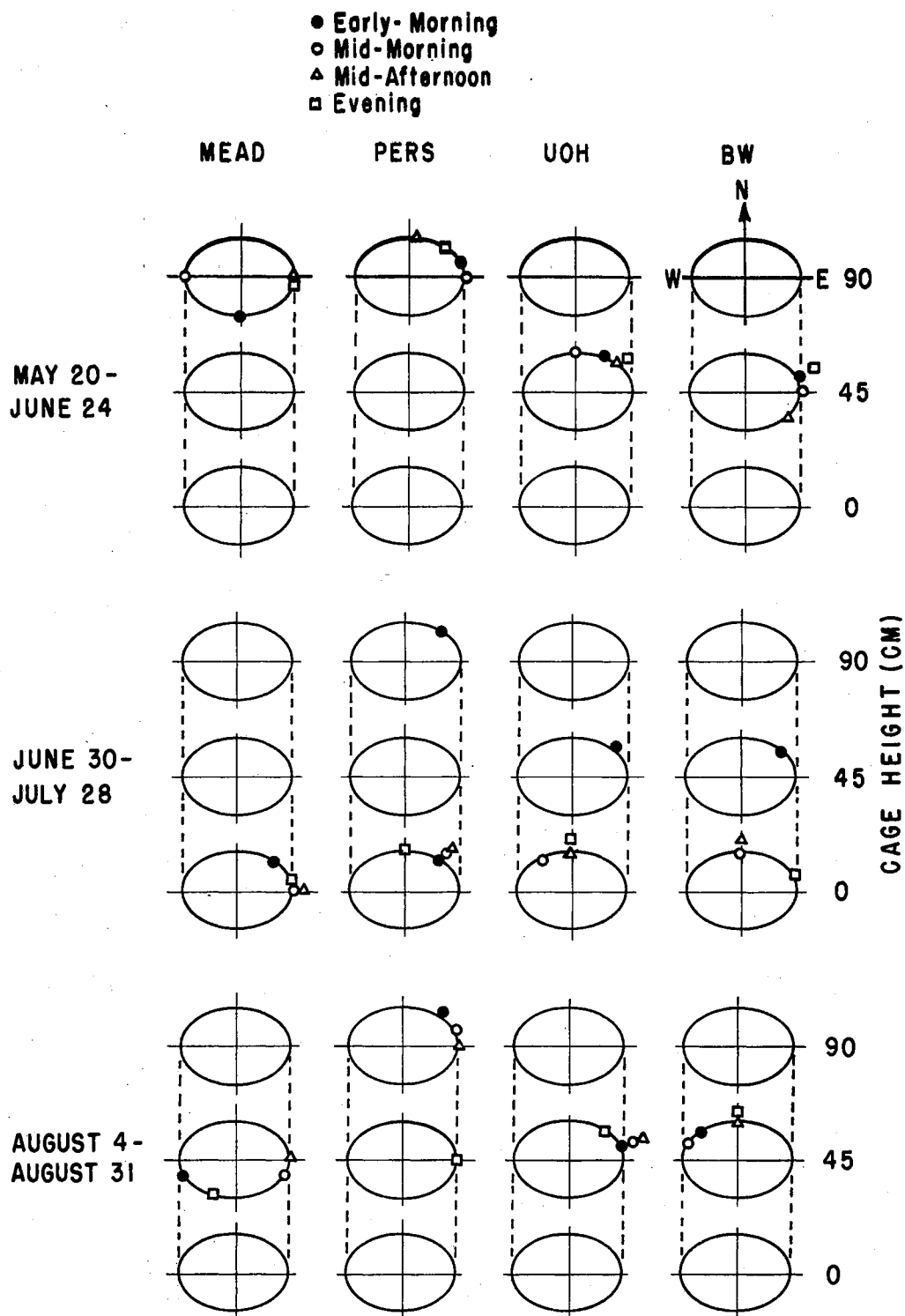


Figure 9. The Orientation of Lone Star Ticks Within Cages During 1971 in Eastern Oklahoma

very light numbers during the early spring and attributed those found on sheep and deer to early season activity in response to the host lying near the ticks' overwintering place and thus causing them to come out of their quiescence.

An upward migration of caged ticks occurred during late April and early May (Figures 6, 7). Decreasing numbers of ticks were found on the ground as the day progressed during late May (Figure 10) with the evening having the fewest and early morning the highest number on the ground. During June (Figure 10) little change in the percentage of ticks was observed at the different times of the day on the ground. Greater percentages of ticks ascending the vegetation were observed during the early morning and late evening between 7 July and 24 August (Figure 10) with a movement of ticks to the ground during the hotter parts of the day. This indicated that ticks moved up and down the vegetation during that time of the year in response to some stimulus or stimuli. A shortening day length could have also affected their diurnal behavior at this time. The attachment rate of lone star ticks reared under decreasing photoperiods has been found to be significantly lower than the attachment rate of lone star ticks reared at the same temperature and relative humidity, but with an increasing photoperiod (Gladney and Wright, 1971). Similar observations were made by Lancaster (1957) with the lone star tick and Smith and Cole (1941) in the American dog tick. It is believed, however, that the adult ticks in this study moved up and down the vegetation during this season in response to the high daytime temperatures and low humidities. Ticks were observed to crawl to cooler places beneath the duff and leaf litter to avoid the hotter part of the day.

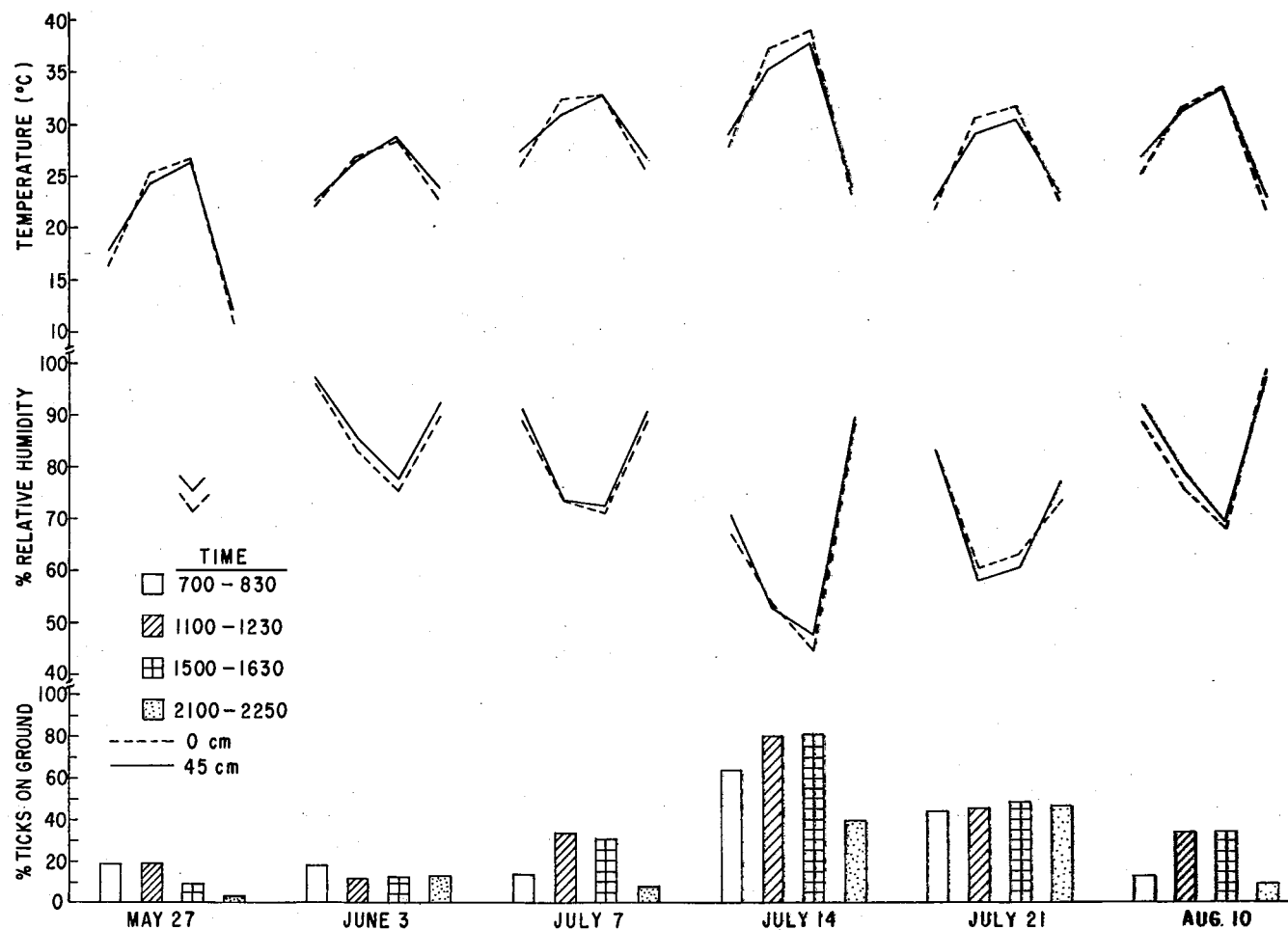


Figure 10. Diurnal Movement of Adult Lone Star Ticks at Four Different Times of the Day at Several Times During the Summer of 1971 in Relation to Temperature and Relative Humidity in Cherokee County, Oklahoma

The above-mentioned behavior is similar to observations made by Balashov (1960) who noted that after being inactive during the night, Hyalomma asiaticum moved out of the crevices and animal burrows during the morning hours and actively sought a host. As the temperature became too warm for their survival, during the late morning they became inactive, seeking shelter beneath the ground and in litter. When the temperature began cooling, the ticks continued their search for a host until evening.

From 14 to 21 July (Figure 10) very high percentages of adult ticks under observation were found on the ground. On 14 July, the diurnal behavior differed and the percentages of ticks on the ground increased during the day. The ticks descended at mid-morning and mid-afternoon and then re climbed the vegetation at night. On 21 July the percentage of ticks on the ground remained relatively constant throughout the four observation times. The reason for this change from 14 July is not known, but the temperatures dropped slightly, while the relative humidities increased somewhat from the 14th to the 21st. The decreasing photoperiod and an increase in precipitation may have stabilized their diurnal activity.

The temperature and humidity gradients are thought to have an affect on the early season behavior of adult lone star ticks. During the early part of the season the temperature may be warm enough for ticks to move around on the ground due to the warming of the litter by radiant heat from sunlight, but they may not be inclined to climb up vegetation since they will encounter lower temperatures. Lees (1948) noted that Ixodes ricinus reared in the laboratory under high temperatures sought the lower temperatures in a temperature gradient chamber.

Similar results were observed by Goldsmith (1966) working with Boophilus microplus (Canestrini). This phenomenon may also be a characteristic of lone star ticks.

Conclusion

The rate of tick activity was generally highest in the bottomwoods with the persimmon and upland oak-hickory habitats intermediate and lowest in the meadow. The "expected activity" time of adults was longest in the bottomwoods habitat and shortest in the meadow. Seasonal activity of adults began in February, when ticks sought hosts from the ground. Ticks began ascending vegetation and cages in mid- to late April. A peak in the percent of ticks ascending was reached in late May and in early June and remained fairly constant until early July when ticks began descending in response to lower humidities, greater moisture deficits and higher temperatures. After reaching the base of the descent curve in mid-July, a second ascent of the population was observed during late July, probably in response to increasing humidities and lower temperatures.

The diurnal behavior of lone star ticks varied from one time of the year to another. During the late winter and early spring, ticks were in close association with the leaf litter and soil. During May, the percent of ticks ascending seemed to increase from morning to evening. During June it remained relatively constant throughout the day, while during July there was an upward movement of ticks from mid-afternoon until evening and a downward movement between early morning and mid-morning. More ticks remained on the ground during the middle of the day and ascended the vegetation at night during July and August.

CHAPTER IV

SEASONAL ACTIVITY OF THE LONE STAR TICK AS INDICATED BY TWO SAMPLING METHODS USED IN DIFFERENT VEGETATIVE TYPES

The economic importance of the lone star tick, Amblyomma americanum (L), has been reviewed by Hair and Howell (1970) and Bolte, et al. (1970). Large numbers of this pest occur in certain habitats at specific times of the season (Semtner, et al., 1971a; and Brennan, 1945). The purpose of this study was to determine and compare seasonal differences in tick activity in different plant associations.

In eastern Oklahoma adult and nymphal lone star ticks begin their activity in late February, reaching peak activity on drags in late May and early June. Adult activity subsides near mid-August. Nymphal populations have a second peak of activity during late August or early September (Hair and Howell, 1970). Lone star tick larvae began to appear in numbers during late June or early July, but a few masses occurred earlier. Larval populations peaked during late July and early August (Hair and Howell, 1970). Researchers in other parts of the lone star tick's range noted similar peaks in lone star tick activity while using drags and/or animals for sampling (Drummond 1967; Lancaster 1957; Sonenshine, et al. 1966).

Lone star ticks are much more abundant in certain habitats than others. Very high concentrations have been reported in parts of Texas,

Arkansas and Oklahoma in brushy pastures, deep leaf litter, under single trees and beneath low trees (Brennan 1945; Cooley and Kohls 1944; Lancaster 1957; Semtner, et al. 1971a). Sonenshine, et al. (1966) and Sonenshine and Levy (1971) found that lone star ticks were distributed randomly within their Virginia study areas with the exception of non-wooded habitats. Extensive studies have been conducted on the vegetative associations of Ixodes ricinus and Dermacentor andersoni (Stiles), as well as several tick species in Asia and Africa (MacLeod 1962; Rich 1971; Wilkinson 1967; and Sonenshine, et al. 1966).

Several factors play an important role in determining tick distribution and include: (1) host utilization of a habitat type, especially during the season when large numbers of ticks are engorging and falling to the ground; (2) the favorability of the habitat for tick survival once ticks are introduced; (3) possible ability of ticks to migrate short distances to more favorable microclimatic conditions; and (4) any combination of factors 1 - 3 (Hair and Howell, 1970).

The white-tailed deer, Odocoileus virginianus, Zimmermann, one of the main hosts of lone star ticks in eastern Oklahoma (Clymer, et al., 1970b), shows seasonal changes in the habitats which they frequent. This causes concentrations of certain tick stages in certain habitat types due to seasonal utilization by this important host. Semtner, et al. (1971b) noted that adult ticks had a much higher rate of survival in a bottomwoods habitat, than in upland oak-hickory and persimmon habitats, but that fewer ticks were normally picked up in that area due to lower host usage.

Relative humidity and temperature surely play an important role in tick survival and distribution. Eggs of the lone star tick rarely

hatched at relative humidities below 60 percent (Sonenshine and Tigner 1969; Lancaster and MacMillan 1955; Sauer and Hair 1971) and adults lose a great deal of water when the relative humidity reaches a level below 70 percent, especially when the temperature is 35°C or higher (Sauer and Hair, 1971). It has been shown that during the active season of adult lone star ticks, brushy areas have much higher humidities during the daytime than occurs in meadows (Lancaster and MacMillan 1955; Sonenshine and Tigner 1969; and Semtner, et al. 1971b). Hoch, et al. (1971) showed that clearing of underbrush and thinning of trees resulted in a 50 to 75 percent reduction in lone star populations in recreational area plots. This reduction in tick numbers was related to increased temperatures and reduced relative humidities (Hoch, et al., 1971). It has been suggested that improved pastures keep tick populations much lower than unimproved pastures (Portman 1945; and Lancaster 1957).

Materials and Methods

The distribution and seasonal activity of the lone star ticks were studied in the western one-half of Cookson Hills Game Refuge in a series of plots throughout the refuge. During 1970, 25 plots in 3 areas with 16 habitats were sampled. During 1971, 7 areas containing .25 ha in area were studied. The plots were divided into 17 different groups (plant associations or habitat types) depending upon their plant species composition. Table V summarizes the different plant associations studied.

In each wooded plot the dominant trees were determined by sampling five different plant locations of the plot using the point quarter

TABLE V

COMMON TREES AND GROUND PLANTS OF THE DIFFERENT VEGETATIVE HABITAT
TYPES SAMPLED FOR LONE STAR TICKS DURING 1970 AND 1971

Habitat #	Common Name	Common Plants	
		Trees	Herbs and Grasses
01	Hay meadows		Johnson grass Bromegrass (<u>Bromus</u> spp.) Panicum (<u>Panicum</u> spp.) Broomsedge bluestem Foxtail (<u>Setaria</u> spp.) Korean Lespedeza (<u>Lespedeza</u> <u>stipulacea</u>)
02	Native prairie		Broomsedge bluestem Little bluestem (<u>Andropogon scoparius</u>)
03	Glade	Scattered - Hackberry (<u>Celtis</u> spp.) Winged elm (<u>Ulmus alata</u>) Ash (<u>Fraxinus</u> spp.) Persimmon	Little bluestem Big bluestem (<u>A. gerardi</u>) Broomsedge bluestem Hairy grama (<u>Bouteloua hirsuta</u>) Side oats grama (<u>Bouteloua</u> <u>curtipendula</u>)
04	Opening-in-woods	Surrounded by - Black oak Post oak American elm Persimmon Sassafras	Broomsedge bluestem (<u>Sericea</u> <u>lespedeza</u>)
05	Johnson grass	Scattered - Young persimmon	Johnson grass Broomsedge

TABLE V (CONTINUED)

Habitat #	Common Name	Common Plants	
		Trees	Herbs and Grasses
06	Southern red oak	Southern red oak Post oak Hickory Elm Ash	Buckbrush Broadleafed unolia (<u>Unolia latifolia</u>) Panicum (<u>Panicum boscii</u>) Rock dropseed
07	Black oak	Black oak Northern red oak (<u>Q. ruba</u>) Post oak White oak Hickory	Panicum Buckbrush
08	Post oak	Post oak Black oak Black hickory Southern red oak American elm	Buckbrush Saw greenbriar
09	White oak	White oak Black oak Northern red oak Hickory	Panicum Spicebush (<u>Lindera benzoin</u>)
10	Hickory	Bitternut Shagbark Mockernut hickory Southern red oak American elm Northern red oak	Spicebush Broadleafed unolia

TABLE V (CONTINUED)

Habitat #	Common Name	Common Plants	
		Trees	Herbs and Grasses
11	Sassafras	Mature sassafras Persimmon Black oak American elm Bitternut	Buckbrush Saw greenbriar Virginia wildrye
12	Persimmon	Persimmon Sassafras Hackberry Bitternut Black oak Post oak	Panicum (<u>Panicum anceps</u>) Blackberry (<u>Rubus</u> spp.) Saw greenbriar Virginia wildrye Tick clover (<u>Desmodium</u> spp.) Johnson grass
13	Winged elm	Winged elm Sassafras Persimmon	Saw greenbriar Virginia wildrye
14	Small sassafras	Low dense sassafras	Tick clover Panicum (<u>P. oligosanthos</u>) Blackberries Broomsedge
15	Pines	Shortleafed pine (<u>Pinus echinata</u>) Blackjack oak Chinquapin (<u>Castanea ozarkensis</u>) Post oak Southern red oak Black oak	Sparkleberry (<u>Vaccinium</u> spp.) Little bluestem Winged simac (<u>Rhus copallina</u>)

TABLE V (CONTINUED)

Habitat #	Common Name	Common Plants	
		Trees	Herbs and Grasses
16	Maple	Sugar maple (<u>Acer saccharum</u>) American elm Hickory Northern red oak Southern red oak Chinquapin oak	
17	American elm	American elm Slippery elm (<u>Ulmus rubra</u>) Ash Mockernut Bitternut Box elder (<u>Acer negundo</u>) Burr oak (<u>Q. macrocarpa</u>) Chinquapin oak Southern red oak	Spicebush Unolia Buckbrush Panicum Rock dropseed

sampling method (Phillips, 1959). Understory and prairie species composition was estimated by taking five 1 m^2 samples and recording the plants present in each.

Active tick populations were sampled during 1970 using the drag-sweep method (Clymer, et al., 1970a), while the CO_2 trap method was used during 1971 (Wilson, et al., 1972). The change in sampling technique was made because CO_2 traps, when compared to the drag-sweep sampling method, have been shown to be more desirable in sampling the number of ticks actively seeking a host (Wilson, et al., 1972). In 1970 studies, 4 drag samples were taken at biweekly intervals from early April to mid-October. Ticks taken by drag sampling were returned to the study plots after they were counted on the drag and sweep. In second year studies (1971), four CO_2 traps were run for one hour in each of the different plots at biweekly intervals. Trapping was initiated in late March and continued into early October. Ticks taken by CO_2 baited traps during 1971 were not returned to the study areas.

Four trap samples were taken at random in each plot unless the traps were placed too close together. To avoid excessive interaction of the operating traps, they were placed at least 20 m apart. After being baited with ca. 0.25 kg of dry ice and allowed to operate for one hour, traps were taken up and the trapping part of the tape was afixed to the trap to prevent other ticks from being trapped. A one hour trapping time was shown to give an accurate sample of the adult and nymphal populations, but not as accurate for larvae (Kinzer, unpublished data, 1972). After trapping, each tick stage and sex was counted on the tape of each trap.

From the data collected, the seasonal activity of ticks by habitat was estimated and the number of ticks collected in each plot was compared.

Results and Discussion

Seasonal Activity

Table VI indicates the seasonal distribution of lone star ticks on drags in 1970 and CO₂ tick traps during 1971 for several different study areas in Cookson Hills Refuge.

Peaks of adult activity occurred in late May, during both 1970 and 1971. Nymphal activity shown by drags during 1970 varied greatly from area to area (Figure 11). Populations in area #2 peaked during early July, while those in area #3 remained relatively constant from late May to late July and those in area #1 reached a high in early June. A second, reduced peak in nymphal activity occurred during September in area #1. During 1971 nymphal populations generally had two activity peaks: one during late May or early June and a second during early September (Figure 12 and Table VI). In area #2 the initial peak of nymphal activity was later than in the other areas studied.

Larval activity peaks usually occurred from mid-August to mid-September of 1970 and one of the areas had what appeared to be a second larval peak during mid-September (Figure 11). Observations during 1971 showed maximum larval activity occurring from 18 July to 23 September in the different areas (Figure 12).

Adult and nymphal stages were collected with CO₂ traps in each area throughout the sampling period.

TABLE VI

SEASONAL PEAKS OF ADULT, NYMPHAL, AND LARVAL LONE STAR
TICKS IN DIFFERENT STUDY AREAS OF CHEROKEE
COUNTY, OKLAHOMA DURING 1970 AND 1971

Area	Study Initiated	Adult	Peaks		Larval	Last Observed Adult	Initial Observed Larvae
			1st	2nd			
1970							
#1	4 April	22 May 6 June	6 June	27 Aug	12 Aug	12 Aug	16 July
#2	30 May	30 May	22 May	29 July	12 Aug	12 Aug	2 July
#3	4 April	22 May	10 July	--	19 Sept 21 Aug	12 Aug	30 May 26 June
1971							
#1	24 Mar	25 Apr 7 June	7 June		9 Aug 1 Sept	27 Sept	20 July
#2	23 Mar	25 May	23 June 17 July	1 Sept	18 July 19 Aug		
#3	29 Mar	17 May	17 May	8 Sept	24 Aug	8 Oct	26 July
#4	27 Mar	28 May	28 May 21 June	1 Sept	2 Aug 1 Sept	29 Sept	20 July
#5	27 May	27 May 11 June	31 May	7 Sept	16 Aug 23 Sept	8 Oct	
#6	31 May	31 May	11 June	15 Sept	26 July 20 Aug	7 Oct	2 July
#7	4 June	4 June	4 June	8 Sept	13 Aug	8 Oct	15 July

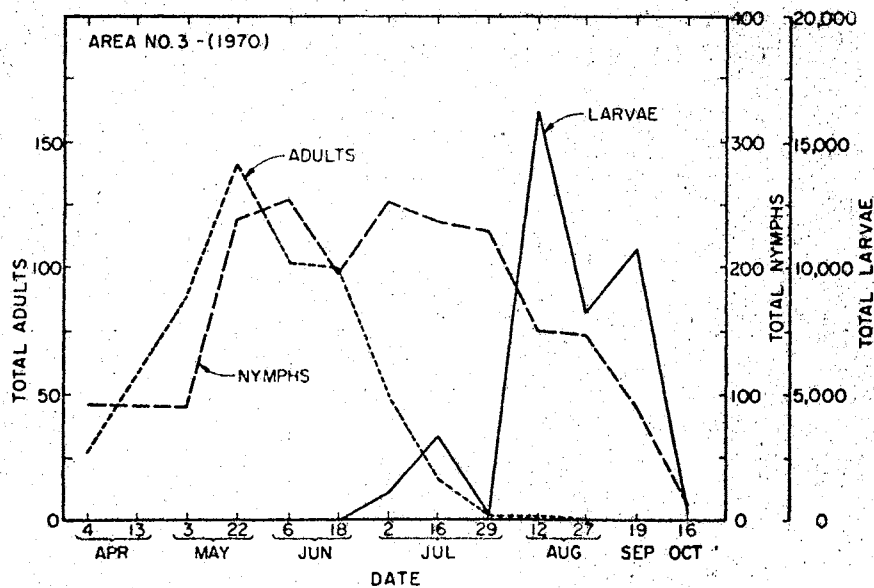
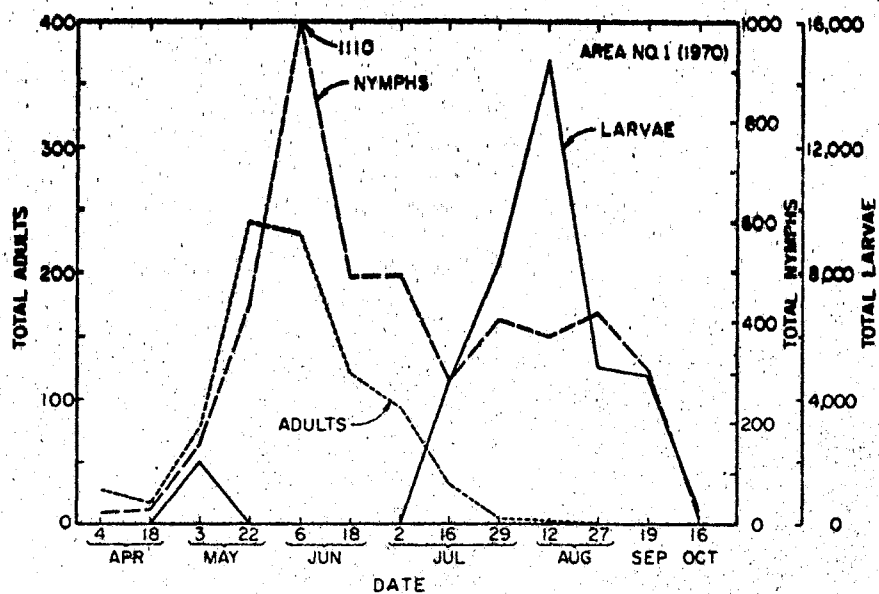


Figure 11. Seasonal Activity of Adult, Nymphal, and Larval Lone Star Ticks in Two Areas of Cherokee County, Oklahoma, During 1970

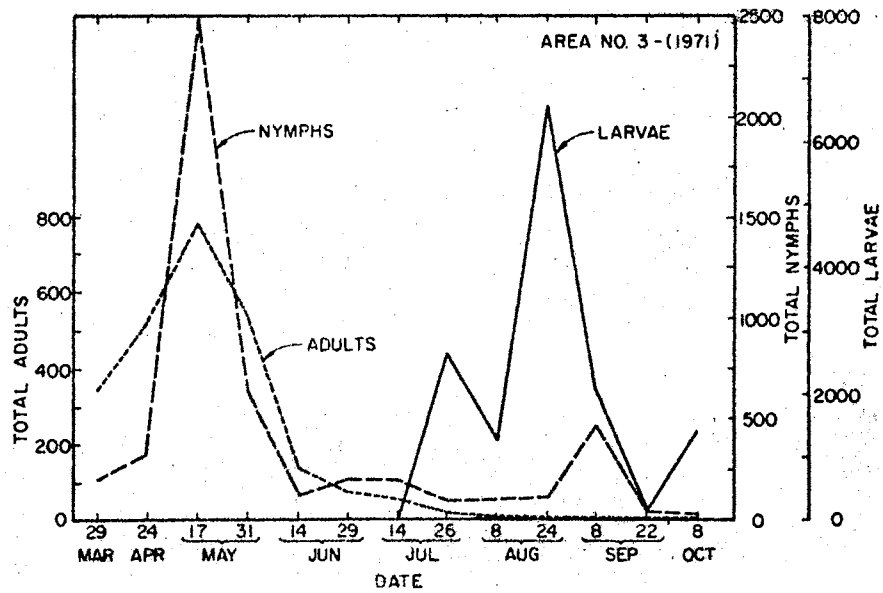
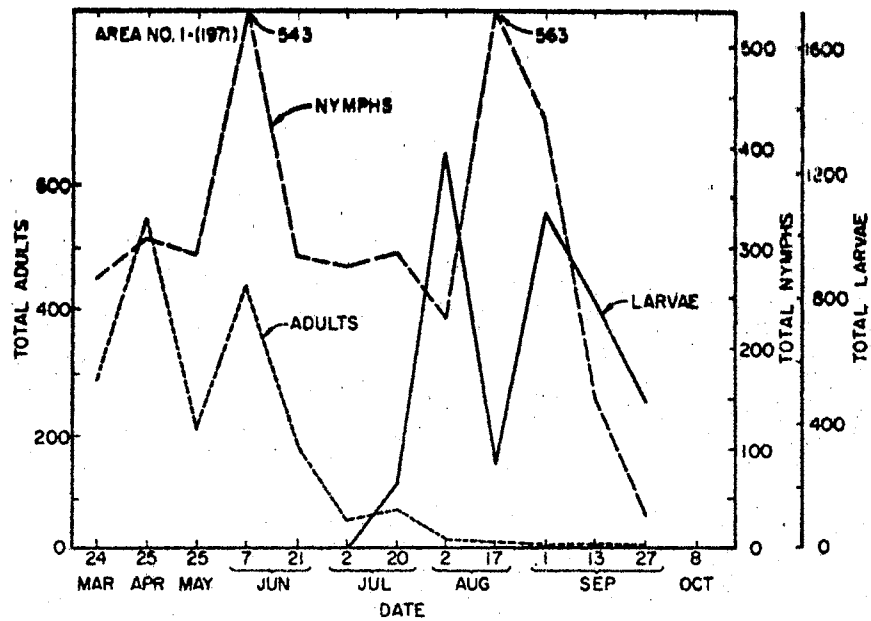


Figure 12. Seasonal Activity of Adult, Nymphal and Larval Lone Star Ticks in Two Areas of Cherokee County, Oklahoma, During 1971

Seasonal Activity of Lone Star Ticks in Different Habitats

Adults 1970. During 1970 the highest numbers of adults in the meadow (01) and pines (15) habitats were found during early May, with 6 of 16 habitats having activity peaks during late May (Figure 13 and Table VII). These late May peaks occurred in the open habitats (01, 02, and 03), and the persimmon (12), sassafras (11) and winged elm (13) habitats where high tick populations occurred (Figure 10). Highs in adult activity occurred in early June in the oak-hickory habitats (06, 07, 08, and 09) (Table VII).

Nymphs 1970. Nymphal activity during 1970 peaked earliest in the grassy habitats and latest in winged elm (13), pines (15), hickory (10) and maple (16) habitats (Figure 14 and Table VII). Of these, only the winged elm habitat had a second peak later in the year. Nymphal populations in most other plant associations peaked during early June with a second peak from early July to late August. Figure 14 shows nymphal activity peaks for three different habitats during 1970. Nymphal populations in the southern red oak habitat peaked when numbers in the other habitats were reaching lows in activity (16 July). The sassafras (11) habitat shows two distinct peaks in nymphal activity during 1970, one in June, and a second in late August. The first peak is due to the overwintering nymphs, while the second peak is probably due to recently molted nymphs from 1970's engorged larvae. These had probably fallen from their hosts two weeks to a month earlier in July and early August.

Larvae 1970. During 1970 larval activity in the meadow habitat began rising and reached a peak earlier than in the other habitat types and the numbers sampled remained fairly constant for two months

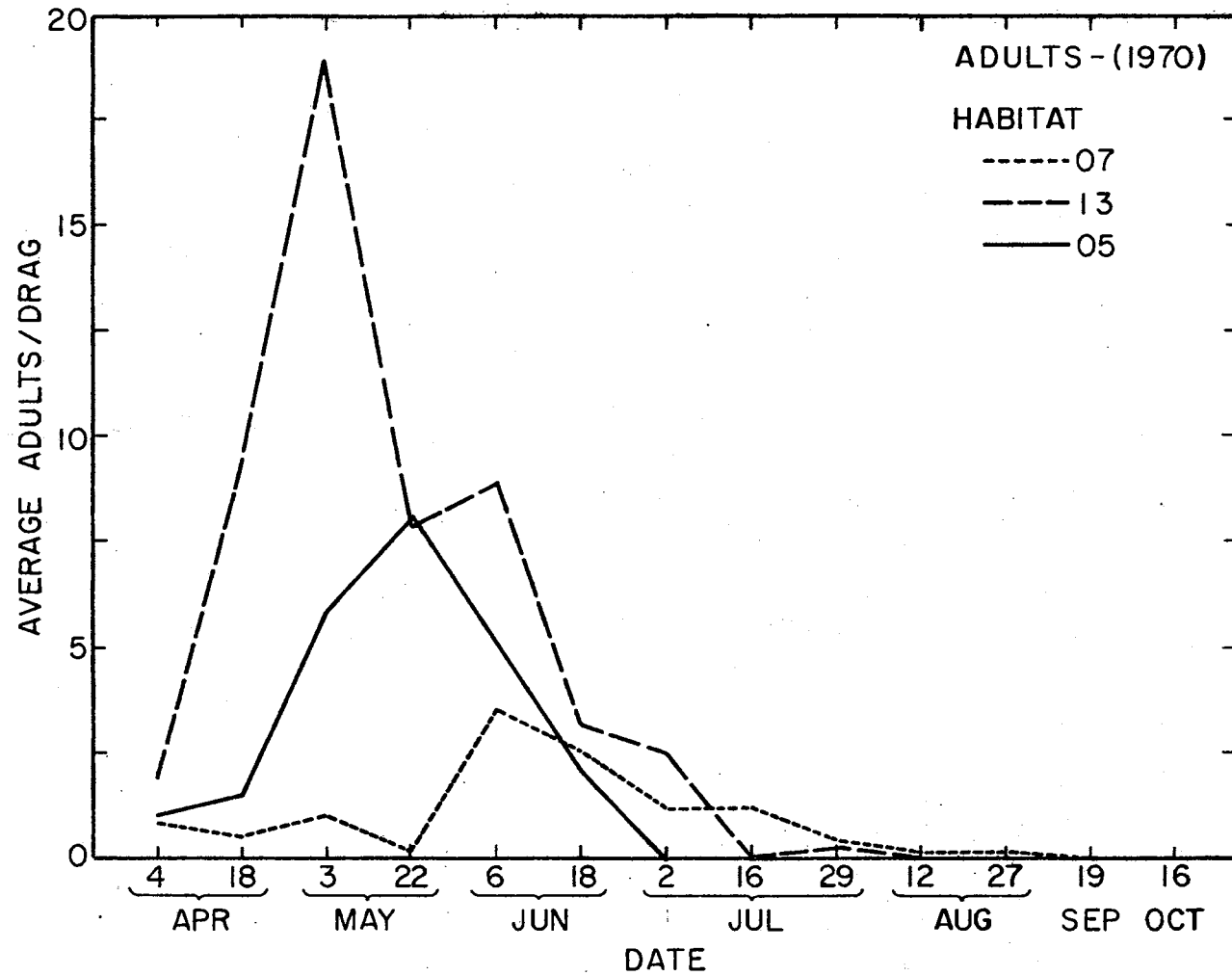


Figure 13. Seasonal Activity of Adult Lone Star Ticks in Different Habitats of Cherokee County, Oklahoma, During 1970

TABLE VII

DATES OF ACTIVITY PEAKS OF EACH ACTIVE STAGE OF
LONE STAR TICKS DURING 1970 AND 1971,
CHEROKEE COUNTY, OKLAHOMA

Date	Habitat ^a	Date	Habitat
<u>Adults</u>			
	1970		1971
3 May	01, 15, 16-constant	27 Mar	<u>03</u> ^b
	3 May to 2 July	25 Apr	<u>02</u> , 04, 06, 08, 09,
22 May	02, 03, 11, 12, 13,		15, 16, 17
	17	25 May	03, 05, 07, <u>08</u> , ^c 10,
6 June	<u>01</u> , 05, 06, 07, 08,		11, 12, 13, <u>14</u>
	09, <u>12</u> , <u>17</u>	6 June	01, <u>06</u> , <u>13</u>
		20 June	<u>03</u> , <u>02</u>
<u>Nymphs</u>		1970	
	First Peak		Second Peak
18 Apr	02	2 July	01, 17
3 May	03	16 July	07
22 May	01, 05, 07, 08, <u>11</u> ,	29 July	12
	12, 17	12 August	13
6 June	11	27 August	08, 11
18 June	13, 15, 16		
2 July	10, 06		
		1971	
	First Peak		Second Peak
25 Apr	15	17 Aug to	
7 June	01, 03, 04, 08,	1 Sept	16
	11, 16	17 Aug	09, 12, 17
21 June	02, 07, 09, 12, 17	13 Sept	01, 02, 03, 04, 07,
2 July	10		08, 10
<u>Larvae</u>			
	1970		1971
2 July	01	18 July	04
29 July	05	2 Aug	01, 02, 03, 10, <u>15</u>
12 Aug	02, 08, 13	16 Aug	08, 11, 16
27 Aug	03, 07, 11	1 Sept	06, <u>11</u> , 12, 13
19 Sept	10, 12, 16, 17	14 Sept	07, 10
		28 Sept	<u>08</u> , <u>12</u> , <u>15</u> , 17

^aFor habitat names see Table V.

^bIf both habitat peaks are underlined, the two peaks are equal in size.

^cWhen a habitat had two peaks, the smaller peak is underlined.

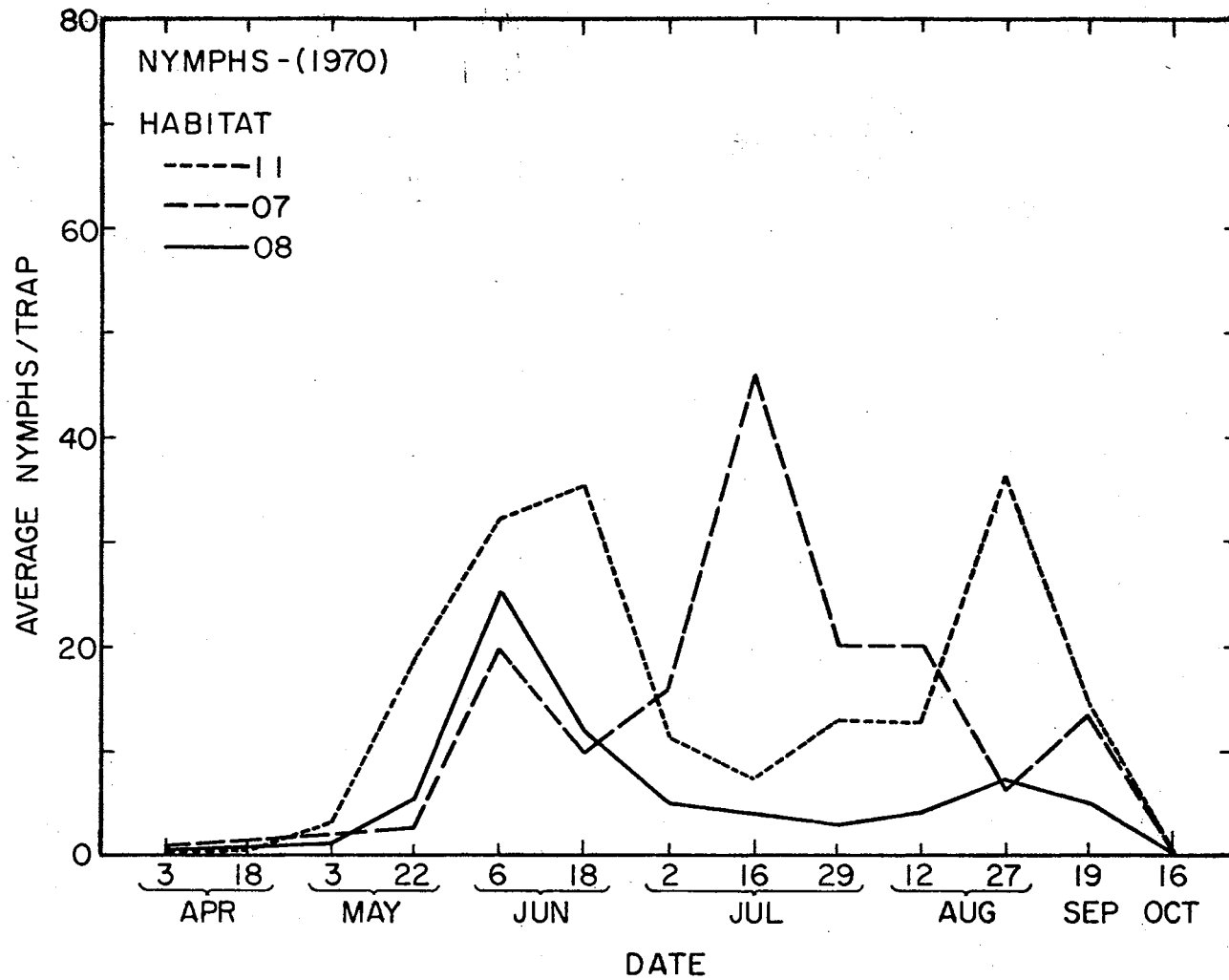


Figure 14. Seasonal Activity of Nymphal Lone Star Ticks in Different Habitats of Cherokee County, Oklahoma, During 1970

(Figure 15 and Table VII). Activity of larvae peaked in the post oak (08) habitat about five weeks earlier than in the persimmon habitat (12), which had an activity peak during mid-September (Figure 15). This indicates a wide range in larval activity between the different habitats during 1970.

Adults 1971. Peaks in adults which responded to CO₂ traps in different habitat types during 1971 occurred on four different sampling dates. Most peaks occurred between 25 April and 25 May, but several peaks were noted between 6 June and 20 June. Opening-in-woods (04) (Figure 16) showed a typical peak occurring in late April, followed by a sharp reduction in tick activity by late May. Table VII lists other habitats which had activity highs in late April. It includes three of the four oak-hickory types (06, 07, 08), pines (15), maple (16), and American elm (17). Plant associations having peaks in adult abundance during late May included hickory (10), sassafras (11), persimmon (12), winged elm (13), Johnson grass (05), and small sassafras (14) habitats which occurred in edge locations between the main forest and the meadows and prairies. Peaks in adult populations were not distinct in the meadows, prairies, and glades, but they seemed to be either early (late March) or delayed until early June. Failure to see distinct peaks in adult numbers was due to the low numbers of ticks collected in these prairie-like habitats on all sampling dates.

Nymphs 1971. During 1971 nymphal populations in all habitats reached highs during early June and a second peak usually occurred in late August or September (Figure 17). During this year bimodal peaks of activity were evident in the opening-in-woods and hickory habitats

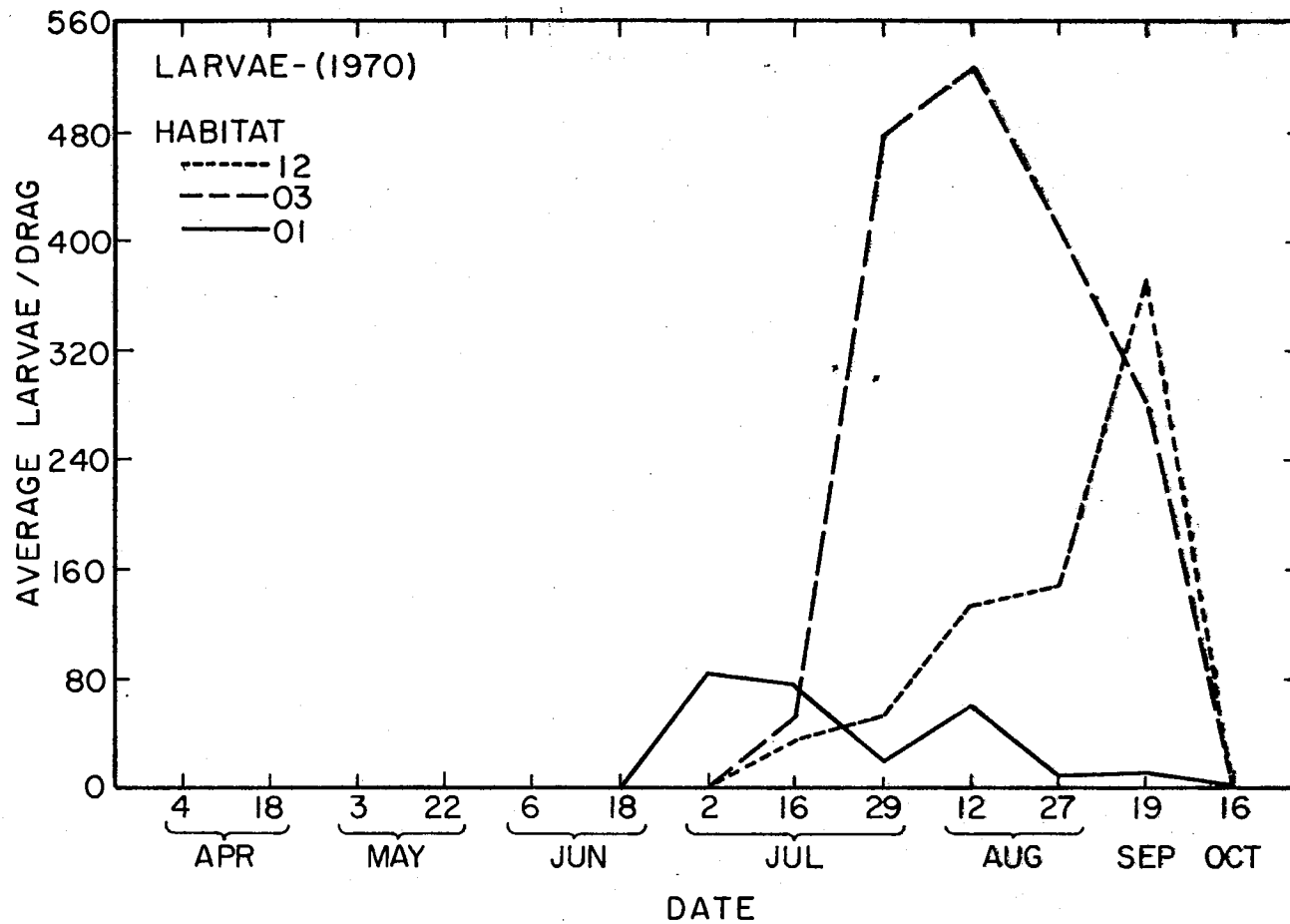


Figure 15. Seasonal Activity of Larval Lone Star Ticks in Different Habitats of Cherokee County, Oklahoma, During 1970

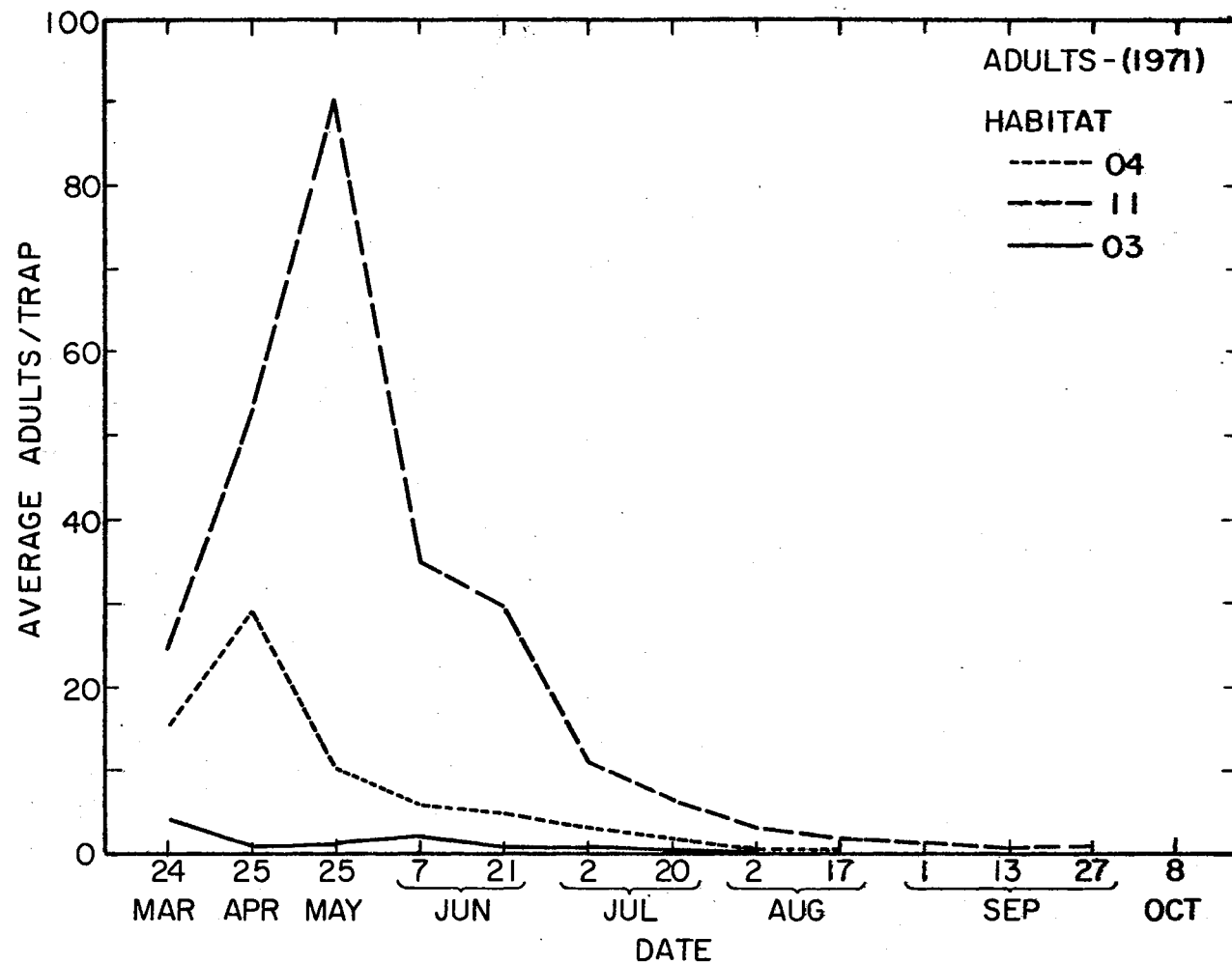


Figure 16. Seasonal Activity of Adult Lone Star Ticks in Different Habitats of Cherokee County, Oklahoma, During 1971

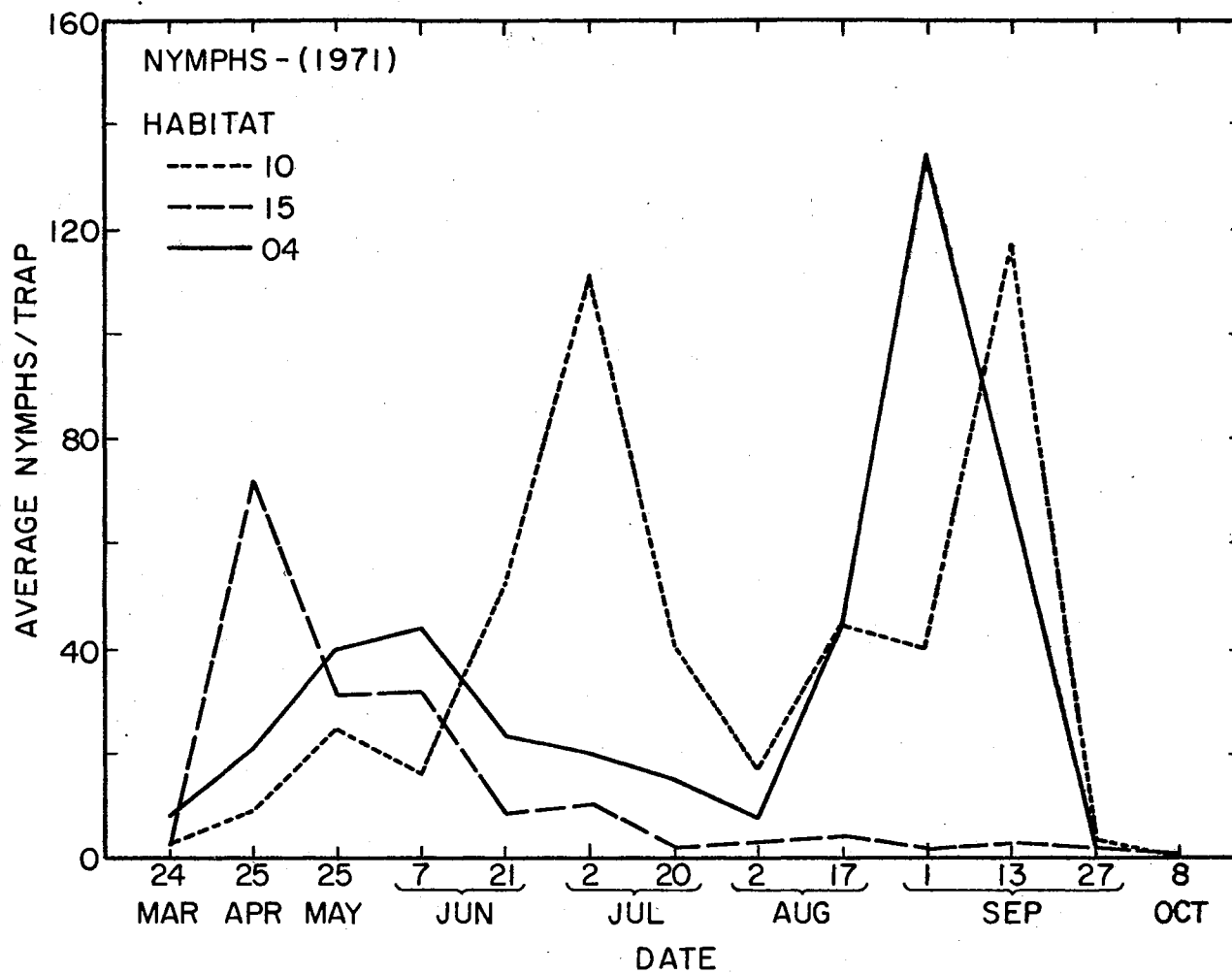


Figure 17. Seasonal Activity of Nymphal Lone Star Ticks in Different Habitats of Cherokee County, Oklahoma, During 1971

types (Figure 17). The initial peak of nymphal populations in the opening-in-woods habitat was about a month earlier than in the hickory habitat (10). The pine-oak plant association had an activity peak during late April, with no second peak being observed during 1971.

The lack of a second nymphal activity peak in the pines habitat probably indicated that few engorged larvae were dropped at an appropriate time to become active and seek a host during August and September. The second peaks in the hickory and the opening-in-woods probably indicated frequent use of these areas by hosts carrying large numbers of engorged seed ticks during July and early August. Seasonal peaks of nymphal activity may also depend upon microclimatic conditions of the general area.

Larvae 1971. In 1971 larval activity in opening-in-woods (04) peaked the earliest of the plant associations on 20 July (Figure 18), but most habitats had populations peaks similar to sassafras (11) which reached highs during mid-August (Figure 18). The native prairie (02) had a late increase of larval activity during 1971, while larvae in similar habitats peaked earlier in the season during 1970. There was a sharp contrast in the abundance of precipitation during 1970 and 1971 and the lower temperatures accompanying the wet summer may have allowed greater numbers of tick eggs to survive and hatch later in the season due to the longer incubation period at lower temperatures (Hooker, et al., 1912). The summer of 1970 was hot and dry and may have caused earlier hatching or mortality of eggs deposited late in the summer.

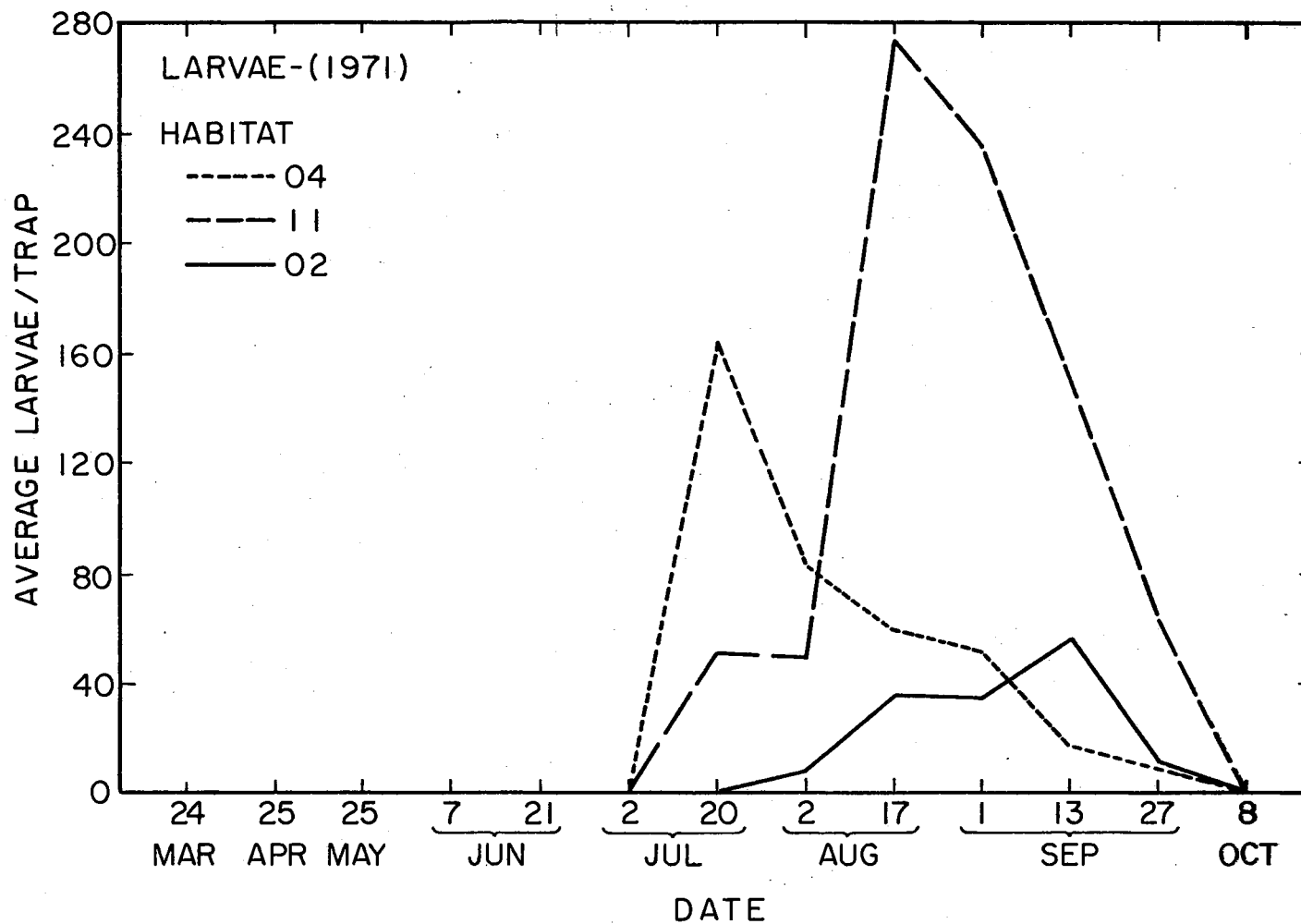


Figure 18. Seasonal Activity of Larval Lone Star Ticks in Different Habitats of Cherokee County, Oklahoma, During 1971

Area Variation in Tick Abundance

There seemed to be considerable variation between tick populations in different study areas (groups of plots) of the refuge even though they were relatively close together. Samples were taken at the same time under similar conditions in areas #1, #2, and #4. Yet differences in the average number of ticks per trap were very marked. Area #1 generally had lower numbers of each stage of lone star tick per sample than did areas #2 and #4 (Table VIII).

Areas #3, #5, #6, and #7 sampled at similar times also showed a great deal of difference in numbers of ticks present in them (Table VIII). The areas with low numbers of adults were generally more isolated from prairies and meadows than those with higher tick numbers. It is believed that this was due to lower host populations within these areas. Since earlier studies (Semtner, et al., 1971b) on caged ticks in areas similar to those mentioned in the present study with relatively low tick populations (white oak) survived a longer length of time than in habitats where ticks were more abundant (persimmon). Tick abundance depends upon host usage.

Distribution of Lone Star Ticks in Different Plant Associations

Adults 1970. During 1970 plant associations with the highest numbers of lone star ticks sampled included persimmon (12), sassafras (11), opening-in-woods (04), and winged elm (13), (Table IX). This corresponded with earlier findings by Semtner, et al. (1971a) who indicated that lone star adults were most prevalent in a combination of these habitat types.

TABLE VIII
MEAN^a NUMBER OF EACH TICK STAGE SAMPLED IN THE
DIFFERENT SAMPLE AREAS IN CHEROKEE COUNTY
OKLAHOMA DURING JUNE - SEPTEMBER, 1971

Area #	Adults	Nymphs	Larvae
1	2.8	10.0	15.0
2	7.5	74.0	35.5
3	3.4	8.0	46.0
4	4.8	75.0	51.0
5	11.7	17.5	42.6
6	3.2	21.0	25.0
7	2.5	8.0	13.0

^aMean number of ticks per one hour's trapping time
using CO₂ baited traps.

TABLE IX
 MEAN NUMBER¹ OF ADULT LONE STAR TICKS/Drag SAMPLE²
 DURING SPRING AND SUMMER, 1970, IN DIFFERENT
 HABITATS IN CHEROKEE COUNTY, OKLAHOMA

Area #1		Area #2		Area #3	
Hab	Mean	Hab	Mean	Hab	Mean
12	6.6A	04	6.4A	13	4.1A
11	3.5B	11	4.7A	03	3.4B
05	2.0C	10	2.6B	15	1.2C
16	1.2D	07	2.4B	10	1.1CD
08	1.2D	17	1.8B	01	.8DE
04	1.2D	01	1.0B	06	.8DEF
17	.9DE			02	.4EF
10	.7DE			07	.3F
01	.5E				
02	.4E				
09	.3E				

¹ Means within each area with similar letters are not significantly different.

² A drag sample is the actual number of ticks collected per 21.9 m² using a drag and sweep.

During 1970 low numbers of adults were found in the meadows (01), prairies (02), glades (03), white oak (09), post oak (08), southern red oak (06) and some hickories (10) (Table IX). These habitats, with the exception of the meadow and post oak, were more isolated and probably received less deer usage than the other habitats during the early nymphal season the year before (1969).

Nymphs 1970. A different pattern of abundance occurred in nymphs when they were compared to adult distribution. The greatest number of nymphs were taken from the southern red oak, American elm (17), sassafras, persimmon, winged elm, and white oak (Table X). Low nymphal populations were found in the meadow, native prairie, pines (15), and black oak (07). Large variations occurred within the same habitat from two different areas (i.e., the southern red oak in area #2 averaged ca. 29 nymphs/sample, while a similar habitat in area #3 had only 3.5 ticks/sample). The reason for this difference was not determined but was probably due to less intensive host usage in area #3 or to more unfavorable environmental conditions in that area. Area #3 plots had the second highest number of nymphal ticks during 1970 (Table X).

Larvae 1970. Larval activity was greatest in the hickory habitat (10) of area #2 and lowest in the hickory habitat in area #1 during 1970 (Table XI). This indicates that many engorged females dropped and laid eggs in the plot in area #2 during the spring and summer of 1970, while it appears that few were dropped in the same habitat type of area #1. It is believed that this variation is again due to differences in host animal usage. A great deal of deer movement occurred in area #2 as attested by several heavily used game trails in the area,

TABLE X
 MEAN NUMBER¹ OF NYMPHAL LONE STAR TICKS/DRAW SAMPLE
 DURING SPRING AND SUMMER, 1970, IN DIFFERENT
 HABITATS IN CHEROKEE COUNTY, OKLAHOMA

Area #1		Area #2		Area #3	
Hab	Mean	Hab	Mean	Hab	Mean
12	23.1A	07	29.4A	10	15.8A
17	19.8AB	17	28.8A	13	14.2A
09	19.6AB	11	16.8B	03	3.4B
11	17.3B	10	15.2B	06	3.0B
08	6.3C	04	9.3C	07	1.9B
16	6.0C	01	2.0D	15	1.6B
10	5.7C			02	1.2B
04	4.3C			01	.3B
05	3.3C				
02	1.5C				
01	1.2C				

¹ Means within each area with similar letters are not significantly different.

TABLE XI

MEAN NUMBER OF LARVAL LONE STAR TICKS/DRAW SAMPLE
DURING THE SPRING AND SUMMER, 1970, IN DIFFERENT
HABITATS, CHEROKEE COUNTY, OKLAHOMA

Area #1		Area #2		Area #3	
Hab	Mean ^a	Hab	Mean	Hab	Mean
08	298A	10	427A	13	415A
12	193A	17	200B	10	132B
11	134B	04	169BC	07	104BC
04	103BC	11	127CD	03	86C
01	83CD	07	115D	06	44D
05	54DE	01	30E	01	29DE
17	26EF			15	15DE
16	26EF			02	9E
02	13EF				
09	10EF				
10	5EF				

^a Means within each area followed by the same letters are not significantly different.

while the hickory plot in area #1 was isolated by a high bluff to the south and was a considerable distance from the closest meadow.

Other habitats with high numbers of larvae included: winged elm, sassafras, American elm, opening-in-woods, southern red oak, and persimmon (Table XI). Those with low populations sampled included: white oak, meadow, American elm, maple (16), and Johnson grass (05).

Adults 1971. The highest average number of adult lone star ticks by area and by plant association were as follows: area #1 - black oak; area #2 - American elm and hickory; area #3 - black oak and southern red oak; area #4 - persimmon; area #5 - winged elm; area #6 - post oak and American elm; and area #7 - black oak (Table XII).

Tick abundance was ascertained in the 56 different study plots. Of these the 20 plots with the highest number of adults/sample were determined. These 20 plots included the following plant associations and the number of each appearing in the top 20: southern red oak, 3; black oak, 3; sassafras, 3; post oak, hickory, persimmon, winged elm, and American elm each had 2; and pines had 1 in the top 20. Of the 56 plots studied, 4 were of each of the following: southern red oak, black oak, hickory, winged elm, and American elm; 3 plots of the following were sampled: post oak, sassafras, and pine. Only 2 plots of persimmon were sampled. Of the 56 sampled the 20 plots having the lowest number of adults were as follows: meadow, prairie, and glade, 4 each; maple, 3; opening-in-woods, 2; and small sassafras, pines and American elm, 1. All of the above plant associations had 4 plots each with the exception of the pine association which had 3 plots and the small sassafras which had 1 plot. These results indicate that high numbers of adult ticks occur beneath low dense trees such as sassafras,

TABLE XII

MEAN NUMBER OF ADULT LONE STAR TICKS SAMPLED IN THE
DIFFERENT HABITATS BY AREA USING CO₂ TRAPS
DURING THE SPRING AND SUMMER, 1971,
CHEROKEE COUNTY, OKLAHOMA

Area #1		Area #2		Area #3		Area #4		Area #5		Area #6		Area #7	
Hab	Mean ^a	Hab	Mean	Hab	Mean	Hab	Mean	Hab	Mean	Hab	Mean	Hab	Mean
06	15.7A	17	32.9A	07	21.0A	12	49.5A	13	118.9A	17	6.6A	06	8.0A
09	4.9B	10	21.5B	06	15.6AB	11	13.4B	11	15.4B	08	5.6AB	15	5.3B
17	3.4BC	11	14.6BC	10	12.2BC	08	10.2BC	10	12.1B	07	4.8ABC	09	2.0C
16	3.3BC	12	11.2BCD	15	5.9CD	04	6.2BC	08	4.8B	09	4.2ABC	07	1.9C
04	2.5BC	13	10.5CD	13	5.4CD	05	5.9BC	17	3.7B	13	2.1BCD	02	1.2C
10	2.3BC	04	8.7CD	03	2.1D	02	.7C	06	3.6B	16	1.5CD	16	.8C
03	2.0BC	07	7.3CD	02	1.3D			04	.7B	15	1.0CD	16	.7C
01	1.6BC	01	.3D	01	.6D			14	.6B	03	.1D	03	.2C
								02	.3B				
								01	.2B				

^aMeans within each area followed by the same letters are not significantly different according to Duncan's Multiple Range Test.

persimmon, and winged elm, as well as most oak-hickory and American elm habitats (Table XII). Few adults were found in the meadows, prairies, glades, opening-in-woods, maple, or white oak associations.

Nymphs 1971. The plant associations with the most nymphs per sample, in each area, were: area #1, American elm; area #2, American elm; area #3, black oak (Table XIII); area #4, persimmon; area #5, sassafras and winged elm; area #6, post oak; and area #7, black oak (Table XIII). The lowest numbers of nymphs in each area occurred in the meadows, prairies or glades (Table XIII). Of the 56 plots sampled in all the areas over the same period of time the 20 with the highest nymphal populations were determined. Those plant associations with plots occurring in the top 20 in nymphs/sample were as follows: opening-in-woods, sassafras, and winged elm, 3 times; black oak, post oak, hickory, persimmon, and American elm, 2 times; and southern red oak, 1 time. All of the above plant associations had 4 plots each except the sassafras and post oak, which had 3 each and the persimmon with 2.

The 20 study plots with the lowest active nymphal lone star tick populations during the study period included: meadow, prairie, and glade, 4 plots each; maple, 2 plots; and opening-in-woods, black oak, white oak, hickory, small sassafras (14), and pines 1 plot each. All of the above mentioned plant associations had 4 plots each except white oak and pines with 3 each and small sassafras, 1.

Larvae 1971. Of the 20 plots having the highest populations of larvae during 1971, 3 plots each were from the sassafras and winged elm associations; the glade, southern red oak, post oak, persimmon and

TABLE XIII

MEAN NUMBER OF NYMPHAL LONE STAR TICKS SAMPLED USING
CO₂ TRAPS DURING THE SPRING AND SUMMER, 1971,
IN DIFFERENT VEGETATIVE HABITATS,
CHEROKEE COUNTY, OKLAHOMA

Area #1		Area #2		Area #3		Area #4		Area #5		Area #6		Area #7	
Hab	Mean ^a	Hab	Mean	Hab	Mean	Hab	Mean	Hab	Mean	Hab	Mean	Hab	Mean
04	17.8A	17	134.0A	06	35.5A	12	217.4A	11	50.5A	08	71.8A	06	20.2A
17	16.4AB	10	112.2AB	07	33.5A	11	87.1B	13	47.2A	13	36.8AB	15	12.8AB
16	13.4ABC	12	95.8ABC	10	13.3AB	04	77.2B	10	42.3A	17	30.9AB	09	12.5AB
06	10.6ABCD	13	70.8BCD	15	9.0B	08	21.4C	06	16.3B	09	11.4B	16	6.2BC
09	6.8BCD	11	63.6CD	13	6.7B	05	12.6C	17	9.4B	07	8.6B	02	4.9BC
10	5.1CD	07	46.8D	03	1.8B	02	1.0C	08	7.0B	16	3.2B	07	4.2BC
03	4.2CD	04	43.8DE	01	.6B			14	5.6B	15	1.9B	16	2.6BC
01	2.1CD	01	1.7E	02	.5B			04	2.1B	03	1.1B	03	1.2C
								02	.8B				
								01	.5B				

^aMeans within each area followed by the same letters are not significantly different.

American elm associations had 2 plots each in the top 20; and opening-in-woods, Johnson grass, black oak and small sassafras had one each. All of the above mentioned plant associations had 4 plots sampled, except post oak and sassafras with 3 each, persimmon with 2, and Johnson grass and small sassafras with 1 each. Of the 56 plots sampled, the 20 with the lowest larval population came from the following plant associations and the number of plots from each: meadow, 4 plots; prairie, white oak, and maple, 3 each; and glade, opening-in-woods, southern red oak, black oak, hickory, pine, and American elm, 1 each. All the above mentioned plant associations had 4 plots each, with the exception of the white oak and pines associations which had 3 plots each. For plot by plot comparison of larval populations see Table XIV.

Results of the distribution study of each stage of lone star ticks indicate that there is considerable variation in tick populations from plots within the same plant associations, but high tick populations occur more frequently in certain associations than in others (Table XV). These findings agree with earlier studies by Lancaster (1957) and Semtner, et al. (1971a). These results are not in complete agreement with findings by Sonenshine and Levy (1971) and Sonenshine, et al. (1966) who found the distribution of lone star ticks in woody habitats was at random in their Virginia study areas.

TABLE XIV

MEAN NUMBER OF LARVAL LONE STAR TICKS SAMPLED USING
CO₂ TRAPS DURING THE SPRING AND SUMMER, 1971,
IN DIFFERENT VEGETATIVE HABITATS,
CHEROKEE COUNTY, OKLAHOMA

Area #1		Area #2		Area #3		Area #4		Area #5		Area #6		Area #7	
Hab	Mean ^a	Hab	Mean	Hab	Mean	Hab	Mean	Hab	Mean	Hab	Mean	Hab	Mean
03	38.5A	11	79.2A	13	122.1A	05	69.5A	04	105.1A	08	64.9A	16	24.0A
06	16.3AB	12	45.8AB	06	49.0B	11	57.9AB	11	79.6AB	13	50.2AB	03	16.8A
10	15.7AB	13	29.7B	03	36.5B	08	53.9AB	06	58.0BC	17	33.6ABC	07	16.7A
04	9.3B	17	27.1B	07	25.1B	12	28.1BC	14	29.8CD	07	17.8BC	09	11.6A
16	6.0B	04	22.9B	02	21.8B	04	15.9C	17	28.5CD	15	16.9BC	16	11.3A
17	5.6B	10	20.1B	15	10.5B	02	2.0C	08	25.0CD	03	7.1C	06	10.2A
01	4.4B	07	4.4B	10	9.5B			13	21.7CD	16	5.7C	02	8.1A
09	3.0B	01	3.2B	01	9.3B			10	17.2CD	09	3.1C	15	1.9A
								02	11.9D				
								01	6.9D				

^aMeans within each area followed by the same letters are not significantly different.

TABLE XV
 MEAN NUMBER OF ADULT, NYMPHAL AND LARVAL LONE STAR
 TICKS IN THE DIFFERENT PLANT ASSOCIATIONS IN
 CHEROKEE COUNTY, OKLAHOMA, DURING
 JUNE - SEPTEMBER, 1971

Habitat	Rep. ¹	Adults	Nymphs	Larvae
Hay meadow	4	.6	1.5	7.5
Native prairie	4	.6	2.0	14.0
Glade	4	.6	1.5	31.0
Opening-in-woods	4	1.9	39.0	44.0
Johnson grass	1	3.9	15.0	93.0
Southern red oak	4	6.9	15.0	38.0
Black oak	4	5.8	21.0	19.0
Post Oak	3	4.7	35.0	41.0
White oak	3	2.8	10.0	6.0
Hickory	4	7.2	38.0	19.0
Sassafras	3	7.1	56.0	87.0
Persimmon	2	15.0	172.0	48.0
Winged elm	4	24.6	45.0	66.0
Small sassafras	1	.4	5.0	33.0
Pines	3	2.9	7.0	11.0
Maple	4	1.2	6.0	12.0
American elm	4	6.9	47.0	27.0

¹ Within each habitat replication 36 samples were taken.

CHAPTER V

THE EFFECT OF SEASON ON MOLTING TIME OF ENGORGED NYMPHS AND POST-MOLT BEHAVIOR OF ADULTS

Although the lone star tick, Amblyomma americanum (L.), has long been recognized as a serious pest of man and other animals, little specific data on the life history, ecology and behavior have been available until recently. Studies by Lancaster (1955, 1957), Sonenshine, et al. (1966), Sonenshine and Levy (1971), Semtner, et al. (1971a, b), Hoch, et al. (1971), Wilson, et al. (1972), Drummond (1967) and Gladney and Drummond (1970), have contributed important knowledge to help us better understand the complex biology of this species.

The current study was one of a series initiated in 1967 to ascertain the bionomics of lone star ticks in the Ozark Mountains. Specific objectives of this study were to ascertain molting time of replete nymphs released under field conditions during the different times of the year and to observe post-molt behavior of adults during the first and second summer under different habitat conditions.

Materials and Methods

Nymphal Molting

Every two weeks from early May to October, 1971, nymphal lone star ticks were field collected around CO₂ tick traps (Wilson, et al. 1972) and allowed to engorge on rabbits that had not been used previously for

tick rearing. After engorgement in the field laboratory, ticks were divided into 6 groups of 50 nymphs each and were transported back to the field where they were released and confined in screenwire cages. The cages were placed at random throughout a 0.5 ha plot in an upland oak-hickory forest. The screenwire cages were similar to those described in an adult tick behavior study (Semtner, et al., 1971b), except that they were 30 cm high instead of 90 cm. Releases of replete nymphs were made at biweekly intervals from 15 May 1971 to 4 October 1971.

Observations were made at weekly intervals from 20 May to 13 November 1971 by taking up the cages and checking the number of ticks that had molted and the number that remained as replete nymphs. Before taking the cage up, the observer exhaled 10 times into the cage to determine the number of active ticks responding.

Adults Entering Second Summer

During mid-June, 1970, 100 engorged nymphs were released in each of a series of screenwire cages in four different habitat types: persimmon, prairie, upland oak-hickory, and bottomwoods. Three cages were placed in the prairie, upland oak-hickory and bottomwoods habitats and two were set up in the persimmon habitat. Observations on the ticks were made throughout the summer of 1970 until late September and resumed again in February 1971. Observations were completed in September 1971.

First year observations were made to determine if any of the newly molted adults would come to the surface of the leaf litter in response to human breath. During the second year observations consisted of the number of ticks on the cage, the number on the ground and the number on vegetation within the cage.

Results and Discussion

Molting Time

As can be seen from Figure 19, molting time for nymphs engorging and dropping in Cherokee County, Oklahoma, between 31 May and 20 August was approximately 33 days in an upland oak-hickory forest. Although data were not collected, it can be assumed that molting time would be longer in the cooler, bottomwoods described in other studies by our group. Conversely, assuming that adequate moisture is available, we would expect a shorter molting time in meadow habitats.

It is interesting to correlate the data in Figure 20 with activity data presented earlier (Hair and Howell 1970; Semtner, et al. 1971a, b). From the data presented herein we can assume that replete nymphs dropping prior to 12 May will require 51 or more days to molt and those repleting after 1 September require a minimum of 60 days, if they molt at all. Subsequent observations on 1 March 1972 on releases made after 4 October 1971 showed that no molting occurred and more than 90 percent mortality of overwintering engorged nymphs.

Since earlier reports (Hair and Howell, 1970) indicate the "normal" activity period of host-seeking nymphs to be between April and October, our data suggest that the bulk of replete nymphs are dropped at a time when molting requires 29-35 days. It is also apparent that replete nymphs dropping early in the summer or after the second nymphal peak is reached in August and September are hampered in their molting process by cooler, unfavorable temperatures. In an early paper, Hooker, et al. (1912) reported nymphal molting as soon as 16 days following engorgement and made mention of the lengthened molting period due to winter

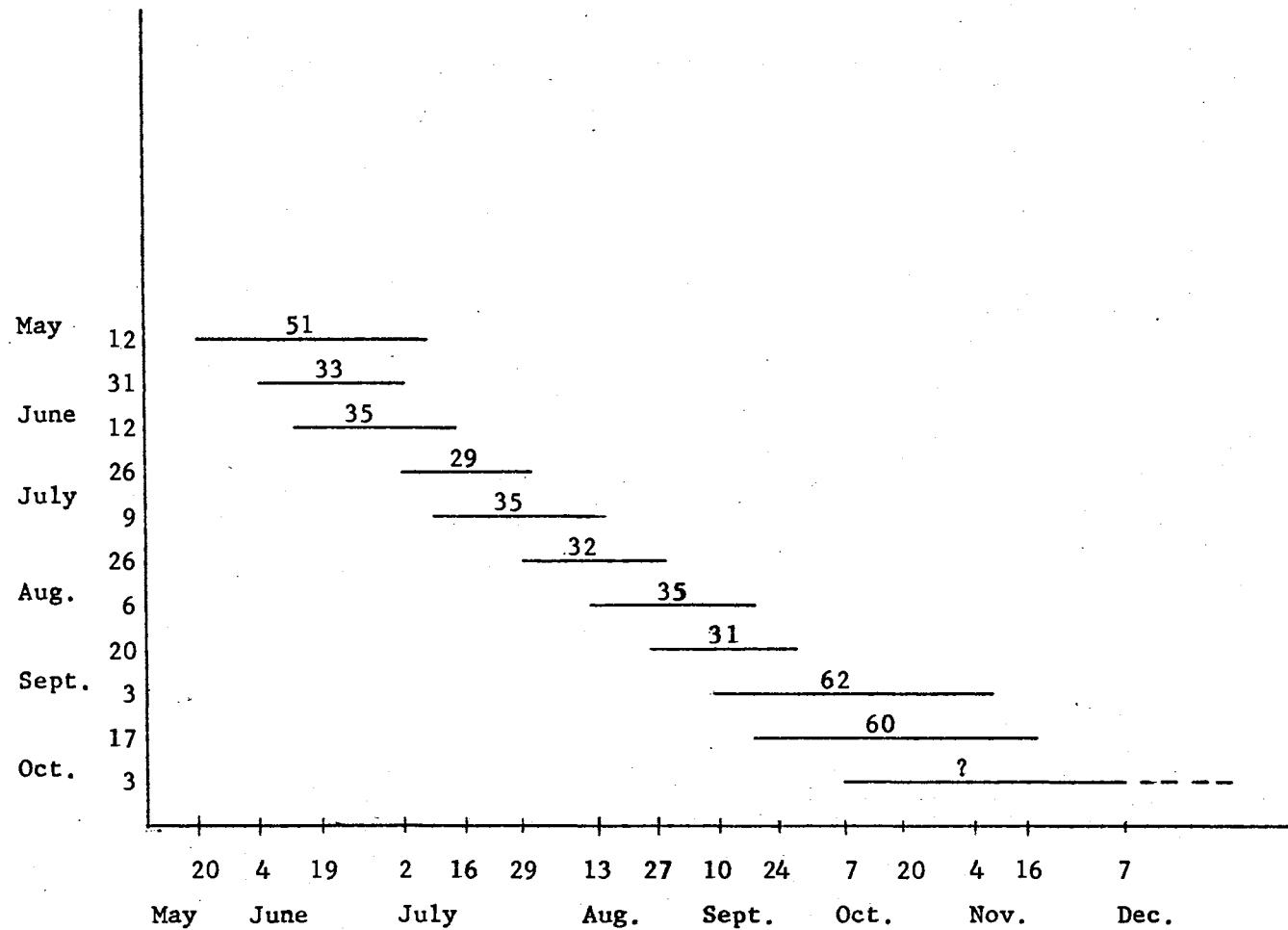


Figure 19. Average Molting Time in Days of Engorged Nymphs Released at Biweekly Intervals in a Cherokee County, Oklahoma, Woodlot, May to October, 1971.

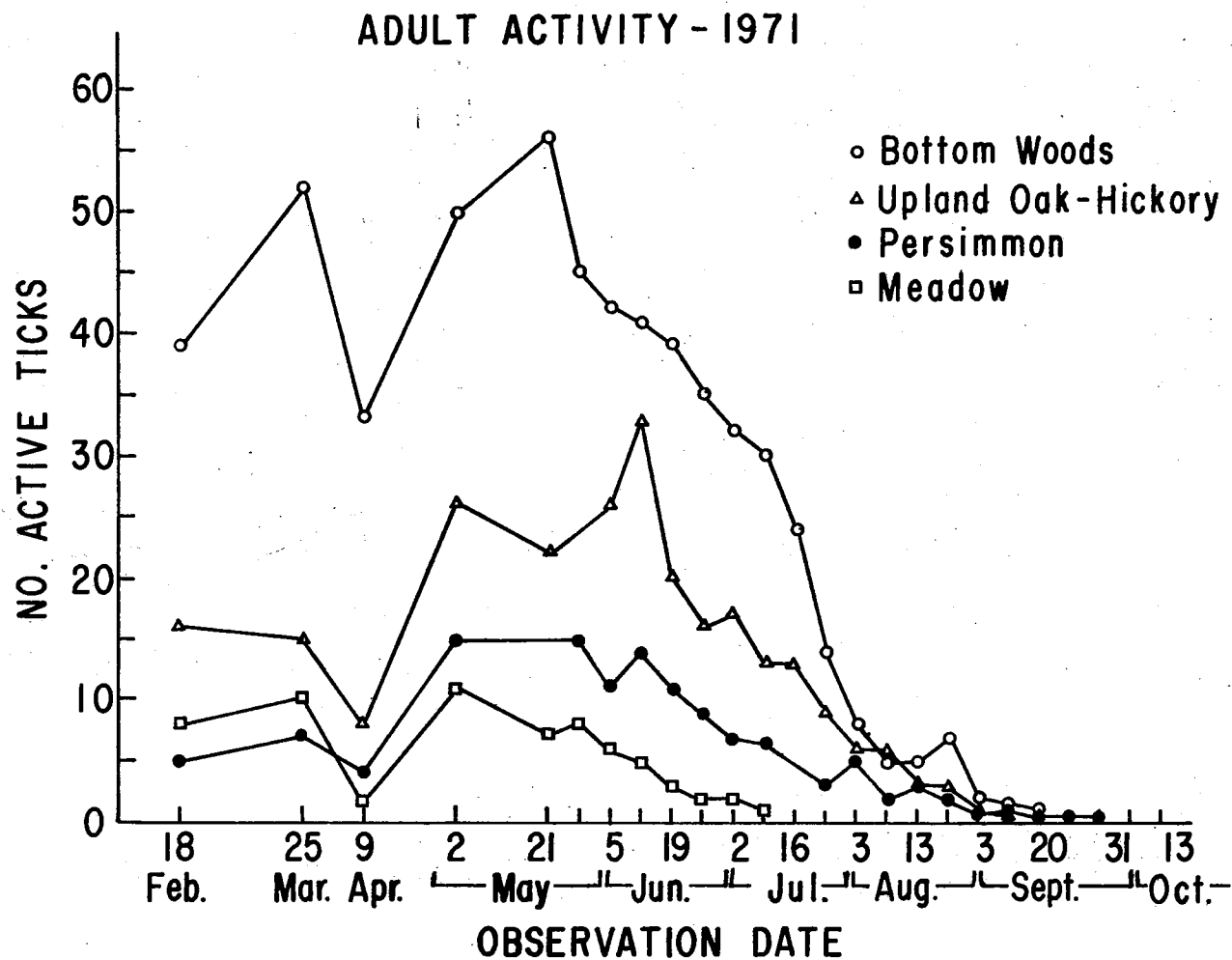


Figure 20. Average Number of Active Adult Lone Star Ticks Per Cage During 1971 of Ticks Released in Late June of 1970 in Four Different Habitats

temperatures. Data collected and presented from 1909 by these workers showed molting times more nearly what we found in the present study, but data presented for years 1907 and 1908 suggested a molting time of 2 to 3 wks shorter than we noted in the present study.

Behavior of Year 1 Adults

Table XVI indicates the probable behavioral pattern for adults during the first summer following the molt. These data are especially informative in that they indicate very limited or no activity of adults during the first summer after molting. It was observed that newly-molted adults responded to human breath to a limited extent (maximum 14 percent) immediately following heavy rains and/or a period of low temperatures. As can be seen in Table XVI, nymphs engorging between 12 May and 12 June produce adults which are mostly indifferent to human breath and only a small portion of the total number present respond for a limited time during July. Follow-up observations failed to show active ticks during the remainder of the summer. Also of special interest is the observation that nymphs repleting after 26 June produced adults by 24 July, but these failed to become active at any time during 1971.

First year adults generally remained relatively light in color and were negatively phototrophic. When compared to adults molting earlier, those molting in late September and October remained sluggish and light in color through the winter of 1971 and were less avid responders to CO₂ in March of 1972.

TABLE XVI

POST MOLT FIRST YEAR ACTIVITY^a OF NEWLY MOLTED ADULT LONE STAR TICKS TO HUMAN
BREATH DURING MAY TO DECEMBER, 1971, IN CHEROKEE COUNTY, OKLAHOMA

Engorgement Date	Observation Dates													
	May		June				July					Aug.		Dec. ^b
	20	28	4	12	19	26	2	9	16	24	29	6	13	17
12 May	0	0	0	0	0	0*	4**	14	37	2	2	0	0	0
31			0	0	0	0	3**	5	82	6	5	0	0	0
12 June					0	0	0	0*	15**	3	1	0	0	0
26							0	0	0	0	0	0	0	0
9 July									0	0	0	0	0	0
26											0	0	0	0
6 Aug													0	0
20														0
3 Sept														0
17														0
3 Oct														0
13														0
17														0

^aOf possible 300 adult lone star ticks

*First molting noted

**All nymphs molted

^bNo active ticks were observed between 13 August and 17 December.

Activity of Year 2 Adults

Observations during the early spring of 1970, 71 and 72 showed that 2 and 3 year adults became active and sought hosts very early in the season. Figure 20 shows typical activity curves for year 2 adults in 4 different habitat types during 1971. Adults molted during 1970 from adults released in mid-June. Semtner, et al. (1971b) has demonstrated that the bottomwoods habitats allow for the greatest longevity of caged adults. It is then of interest that more ticks became active and remained active in this habitat type than in any other habitat observed throughout the season.

Upland oak-hickory woods appear to be reasonably good lone star tick habitat (Semtner, et al., 1971) and the present study showed an average of 33 active 2-year-old ticks per cage in this habitat type on 12 June 1971. Original introductions of 100 replete nymphs per cage were made in mid-June, 1970. Observations on a cage of these ticks during February and March, 1972 showed up to 30 very active male and female ticks entering their third summer. At the time of this writing, observations on 2 and 3 year adults, during February and March, showed similar behavioral patterns. However, additional observations should be made on adults entering their third season.

Findings in these studies help substantiate earlier theories presented on certain aspects of the lone star tick life cycle and also present some departures from inferred occurrences. For example, Lancaster (1957) states, "The time required for the overwintered, engorged nymphs to transform . . .", and therefore leads the reader to believe that nymphs might commonly overwinter as repletes. Based on our findings in these studies, we are inclined to believe that success in

maintaining the cycle is dependent on the engorged nymphs molting into adults prior to inactivation by cool October temperatures. Should the nymph fail to molt, then chances of overwintering in Oklahoma appear to be decreased substantially.

Our findings in this study do support a recent, and previously unreported, finding by Sonenshine and Levy (1971). These workers propose that adults remain inactive during the first summer following the molt. Our observations tend to support this, in general, but suggest that adults molting early in the summer (before mid-June) may seek hosts, whereas those molting from mid-June to mid-October fail to respond to CO₂ and heat and therefore show no signs of host-seeking.

Semtner, et al. (1971b) have already emphasized the greater suitability of bottomwoods over certain other areas as tick habitat. Not only do ticks survive and stay active longer in this habitat type, but findings presented in Figure 20 suggest much better overwintering in bottomwoods than in three other habitat types observed.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The average longevity of caged adult lone star ticks, Amblyomma americanum, released into four habitats during early June, was less than 22 days in the meadow habitats, approximately 35 days in the per-simmon and upland oak-hickory habitats, and more than 45 days in the bottomland oak-hickory habitat. Temperature and relative humidity measurements indicated very high daytime temperatures and low humidities in the meadow with a considerable cooling of temperature and rise in relative humidity during the nighttime. In response to rising temperatures during mid- and late July, adults migrated down the vegetation to the soil and/or leaf litter. They perhaps extend their longevity by this close association with the soil.

During 1971 the average number of active adults was lowest in the meadow and highest in the bottomwoods habitat. Seasonal activity began in February when adults sought hosts from the ground. Ticks began ascending the vegetation and cages in mid- to late April, and a peak in the percent ascending was reached in late May and early June. The percent of ticks on the cage and vegetation remained relatively constant until early June, when the ticks began descending. After reaching a low in the percent of ticks on the cages and vegetation during mid-July, a second ascent of the population was observed in late July. The data suggest that vertical movements may be a response to changing relative

humidities and temperatures. Climatic factors appear to correspond closely to patterns of behavior of adults in the field.

The diurnal behavior varied from one time of the year to another. During the late winter and early spring ticks were in close association with the leaf litter and soil. The percent of ascending ticks increased from morning until evening during May. It remained relatively constant throughout the day during June. In July and August more ticks remained on the ground during the hot part of the day and ascended the vegetation at night.

There were several weeks' difference in the activity peaks measured by the numbers of ticks sampled of each tick stage from one habitat to another. The general adult peak occurred in late May and early June. Nymphs had two peaks during 1971, one in early June and one in August and September. Larval activity peaks ranged from late July to mid-September depending on the habitat.

In study plots of different habitats throughout the game refuge the highest number of adult lone star ticks were collected beneath low trees including winged elm, persimmon, sassafras, opening-in-woods, American elm, hickory, and black oak. Low adult numbers occurred in the meadows, prairies, glades, opening-in-woods, maple and white oak habitats. High nymphal populations were found in the sassafras, winged elm, persimmon, opening-in-woods, oak-hickory, and American elm. Low populations were found in the glades, prairies, meadows and sugar maples. High larval populations occurred beneath the low trees and were also abundant in the upland oak-hickory habitats. Low numbers were found in the meadows, prairies, maple, and white oak habitats. Areas of the

refuge where white-tailed deer populations were low supported fewer ticks than those with high deer populations.

Molting time of those engorged nymphal ticks released during May averaged ca. 50 days, while those released from June to September averaged ca. 33 days and those released during late September and October averaged 60 or more days. The overwintering survival rate of engorged nymphs released during September and October was greatly reduced. Adult lone star ticks were found to overwinter at least two winters.

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VITA

Paul Joseph Semtner

Candidate for the Degree of

Doctor of Philosophy

Thesis: ECOLOGY AND BEHAVIOR OF THE LONE STAR TICK

Major Field: Entomology

Biographical:

Personal Data: Born in Seminole, Oklahoma, May 9, 1945, the son of Mr. and Mrs. Joe Semtner.

Education: Graduated from Konawa High School, Konawa, Oklahoma, in May, 1963; received the Associate of Science degree from Eastern Oklahoma A & M Junior College, Wilburton, Oklahoma, with a major in Entomology in May, 1965; received the Bachelor of Science degree from Oklahoma State University with a major in Entomology in August, 1967; received the Master of Science degree from Oklahoma State University in May, 1970, with a major in Entomology; received the Doctor of Philosophy degree from Oklahoma State University in May, 1972, with a major in Entomology.

Professional Experience: Lab Assistant, Entomology Department, Oklahoma State University, Spring and Summer, 1967; Graduate Teaching Assistant, Entomology Department, Oklahoma State University, Fall, 1967-1969; Graduate Research Assistant, Oklahoma State University, Spring, 1968 to present.

Organizations: Sanborn Entomology Club, Sigma Xi, Entomological Society of America.