# A STUDY OF THE IXODID TICKS OF NORTHERN FLORIDA, INCLUDING THE BIOLOGY AND LIFE HISTORY OF *IXODES SCAPULARIS* SAY (IXODIDAE: ACARINA)

by
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# INTRODUCTION

## Historical

According to Hooker et al. (1912), the first paper on the biology of a tick was published by Doctor Cooper Curtice in 1891 (Curtice, 1891). Doctor Curtice's work was concerned with the cattle fever tick, Boophilus annulatus (Say), which was at that time a very prevalent and important tick in the southern United States.

Since the time of Curtice's pioneer work, many accounts have been published on this species and other important ticks, both in the United States and in other countries. In the United States, biological investigations on important species have been rather extensive in all of the major geographical areas except the Southeast.

Since many aspects of the biology of ticks are influenced considerably by climate, as well as other environmental factors, the various species should be carefully studied under conditions prevailing in the southeastern United States, even though they may have been studied in the more northern limits of their distribution. The work of Hixson (1940) on Amblyomma maculatum Koch in southern Georgia seems to be the only published report of an intensive study of a species, other than the cattle fever tick, in this area. Previous reports pertaining especially to the ticks of Florida have been concerned primarily with host relationships and

distribution within the State. There are no published papers of a detailed biological study of any tick under Florida conditions.

Banks (1904) appears to be the first worker who published a list of the ticks of Florida. Banks' list included only four species. Other early papers, dealing primarily with host relationships and intrastate distribution, were Hunter and Hooker (1907) and Hooker (1908, 1909a, 1909b).

Boardman (1929) studied the ticks in the area of Gainesville, Florida but contributed very little to the biology of the various species. Bequaert (1932) reported on Amblyomma dissimile Koch in Florida. Hixson (1939) published on ticks affecting dogs in Florida but mostly gave information of a general nature. The same author (Hixson, 1941) reported in a brief note on the host relationships of the immature stages of Ixodes scapularis Say in the State. Travis (1941) examined wild animals in southern Florida in a study pertaining to the tropical cattle tick, Boophilus microplus (Can.).

Taylor et al. (1948) studied Dermacentor variabilis (Say) and Amblyomma americanum (L.) in relation to Rocky Mountain spotted fever in Florida. Taylor (1951) gave the distribution of ticks within the State by counties, based on information from the literature and on a study covering the period 1947 through 1949.

Since several species of ticks are discussed in this

report, a more detailed review of previous work pertaining to each species is included under the headings of the various species.

## Objectives

The principal objectives of the research reported herein were (1) to make a general survey of the ixodid ticks of northern Florida, giving special attention to the host relationships, seasonal activities, and habitat distributions of the most important species, and (2) to make as many observations as possible on species of minor importance. This type of information is needed for the purpose of making intelligent and effective recommendations for controlling important ticks in northern Florida.

The research covered the period from late 1949 to early 1953, except for the Spring of 1951. A few records of tick collections in 1948 are also included.

## Species of Ixodidae Present in Florida

According to Taylor the ticks of the family Ixodidae that have been previously reported from Florida are Amblyomma americanum (L.), Amblyomma cajennense (Fabr.), Amblyomma dissimile Koch, Amblyomma maculatum Koch, Amblyomma tuberculatum Marx, Boophilus annulatus (Say), Boophilus microplus (Can.), Dermacentor nigrolineatus Pack., Dermacentor variabilis (Say), Haemaphysalis chordeilis (Pack.), Haemaphysalis leporis-palustris (Pack.), Ixodes

cookei Pack., Ixodes scapularis Say, Ixodes texanus Banks, and Rhipicephalus sanguineus (Latr.).

Of the 15 species listed above, 12 are well established in the State. Ten are present in northern Florida. Boophilus annulatus has apparently been eradicated. Amblyomma cajennense has not been reported since the record by Banks (1908). Bishopp and Trembley (1945) reported Dermacentor nigrolineatus from northern Florida. This species was not found during the present study. Boophilus microplus is confined to a few counties in the southern part of the State. Amblyomma dissimile has not been reported north of Palm Beach County in Florida. However, Carpenter et al. (1946) reported this species from Georgia. During this study, three species were found that have not been previously reported from Florida. These were Ixodes affinis Neumann, Ixodes bishoppi Smith and Gouck, and Ixodes brunneus Koch. Of the 13 species now known to occur in northern Florida, only five are known to be of considerable importance. These are Amblyomma americanum, Amblyomma maculatum, Dermacentor variabilis, Ixodes scapularis, and Rhipicephalus sanguineus.

In this study, details of life history were included only for Ixodes scapularis. This species has not previously received much attention in any part of its range. Amblyomma americanum and Dermacentor variabilis also received

considerable attention in this study since neither has been studied extensively in the Southeast. Rhipicephalus sanguineus is confined to domestic environments in northern Florida and was rarely encountered. Although some of the other species discussed below, especially Haemaphysalis leporis-palustris, may play an important role in the epidemiology of tick-borne diseases in other areas, all of them were treated as species of minor importance in this study.

# METHODS

## Host Relationships

Data on host relationships were obtained by regular examinations of domestic animals and by shooting, trapping, and capturing wild animals.

Larger wild animals such as deer, bear, bobcats, and raccoons were hunted with dogs. Animals that had been killed by automobiles on the highways were examined if found soon after death.

Small mammals such as rats and mice were trapped with a special live trap designed by Doctor H. B. Sherman of the Biology Department, University of Florida. Snap traps were not used since many ticks will leave a dead host within a few hours after the animal dies.

Birds were shot, placed in a paper bag, and examined later in the laboratory. Some snakes and lizards were captured alive and examined in the field or in the laboratory. All poisonous snakes, such as the diamond-back rattlesnake and the coral snake, were shot.

## Seasonal Activity

Seasonal activity of the different stages of the various species was studied in two ways. Those stages attacking domestic animals were collected at regular intervals from cattle and dogs. These data gave the desired information

for the adult stage of all of the important species. The immature stages of these species all normally utilize small animals as hosts; therefore, the data from wild animals were more valuable in showing the seasonal activity of the larvae and the nymphs.

Another method used in studying seasonal activity was that of taking samples in the natural habitats by dragging a cloth over the low-growing vegetation. The drags were made of white cotton flannel. The cloth was three feet wide and each piece was cut six feet long and then hemmed at each end. A small rope was attached to the center of a stick in the front hem. The rope was marked at a distance of about eight feet from the drag and was always held in one hand at this mark while pulling the cloth over vegetation. A stick was also inserted in the back hem. In some of the habitats in Florida, the drag with rigid sticks or rods at the ends is very difficult to use because the rods do not allow the drag to pass between trees and brush in densely wooded areas. In order to overcome this, the two end sticks were cut about one foot in length and pieces of an old garden hose were slipped onto each end. This made it possible to drag the cloth between trees that were growing fairly close together.

The cloth drag is a useful apparatus for collecting ticks from vegetation, but has several disadvantages which should be well known to the worker using it. Some species of ticks remain close to the ground at all times, especially the immature stages, and are not taken in representative

numbers by a cloth drag. This is especially true where such ticks are in areas having tall grass or shrubby vegetation. The drag seldom reaches the lower levels in those areas; therefore, the ticks do not come in contact with the cloth. Another disadvantage is that many ticks are brushed off the drag by the vegetation while the cloth is being pulled along. In all of the drag samples taken in this study the ticks were collected from the cloth at intervals of 25 paces. Even with such frequent examinations many ticks that were seen on the drag were often brushed off before the 25 paces were completed.

## Habitat Distribution

In order to determine the habitat distribution of the various species of ticks, regular collections from hosts and with the drag were made in certain areas of each major habitat studied. The three habitats studied are described below.

In the hammock habitat a quadrat of approximately 80 acres was sampled at two-week intervals for more than a year with a cloth drag. A different part of the quadrat was sampled each time. Domestic and wild animals were also examined at frequent intervals in this habitat.

Several quadrats of approximately 20 acres each in the sandhills habitat were selected and sampled at regular intervals with the cloth drag. The reason for establishing several quadrats in this habitat was that most samples were

negative. Not many host records were obtained in this habitat. The sandhills are sparsely settled due to poor soil conditions, and few opportunities were available for examining domestic animals.

The major part of this research was conducted in the flatwoods habitat. For this reason, no special quadrat was utilized in sampling this habitat. Drag samples were made in the flatwoods throughout the year in connection with other phases of the research, and more animals were examined in the flatwoods than in either of the other two habitats studied. These data gave the desired information relative to the species of ticks present in this habitat.

## Habitat Burning Studies

For generations it has been the custom in Florida to burn the woods each winter in order to provide tender grass for cattle on the open range. The custom of annual burning is still widely practiced, both in fenced and open ranges. Of the three habitats studied in this research, the sandhills and the flatwoods are most frequently burned. The hammocks support very little grass and are usually quite damp; therefore, they seldom burn.

The effect of woods fires on the population of Ixodes scapularis was studied in the flatwoods northeast of Gainesville, Florida. Several large blocks of land in the same general area were selected for sampling based upon their

history of forest fires. The range was from one to more than ten years from the date of their last burning to sampling. The blocks were divided into plots and the plots were then sampled in a random fashion to determine the relative tick population of each block. All samples were taken with the cloth drag in a similar manner in each plot. The sample size was 500 paces. This experiment was repeated over three seasons. A more detailed account of the experimental design will be given under the discussion of Ixodes scapularis.

## Life History Studies

The life history of Ixodes scapularis was determined by observations in a screened insectary and in cages under field conditions on the campus of the University of Florida. Other species were also brought into the laboratory at times for observations on certain aspects of their biology.

Engorged ticks collected from hosts in the field were placed in paper pill boxes on moist sand in a screened insectary in a manner similar to that described by Hooker et al. Instead of covering the tops of the boxes with gauze, as described by those authors, the solid disc was removed from the top and a piece of cellophane was used to cover the opening by pressing the rim of the top back into its original position over the cellophane. The cellophane maintained a high moisture content in the pill box and also facilitated examination of the specimens without removing the top. This

method was used to obtain data on preoviposition, oviposition, molting periods, and longevity of ticks in the insectary.

Data on engorgement of adult ticks were obtained by placing ticks on dogs and observing them daily until they dropped. The ticks were marked with paints and were often recovered from the dogs' sleeping quarters. This method made possible the study of engorging ticks without enclosing them in a cage on the host.

Field cages were maintained on the grounds near the insectary in order to study the various aspects of the life history as well as the behavior of ticks under more natural conditions. Several types of field cages were used. One was a pint-size, wide-mouth fruit jar with bottom removed and the solid disc top replaced with screen wire. These cages were used in studying preoviposition, egg incubation periods, and larval longevity. Another type cage used was a wooden frame 12 inches square made of one by four inch pine boards with the bottom of each board beveled for easy insertion into the soil. These cages were used primarily for observing the behavior of ticks. A third type cage was used in studying molting and longevity of nymphs and adult ticks in the field. This was a tin can with both the top and bottom removed. The cans were mostly number two size. The cylinder was inserted into the soil so that only three to

four inches of the top remained above ground. The trash, leaves, and about one half inch of the top soil were removed from the inside of the can. The soil level in the can was then restored with white builder's sand. The ticks were placed on the white sand and covered with several layers of leaves to maintain the proper moisture conditions. Examination of ticks was made with a hand lens after removing the leaves. The white sand was used in the cages in order to produce a contrasting background for observing the ticks. This worked especially well with the nymphs since they are small and very difficult to find on dark soil.

Petroleum jelly was smeared along the upper edge of all three types of cages in order to reduce the escape of the ticks. This worked well with the immature stages but did not prevent the escape of the adults of Ixodes scapularis.

In a few instances, one other type of cage was utilized in studying molting periods and longevity in the field. This was a paper pill box from which the solid bottom and top were removed and replaced by cheesecloth. These boxes, containing engorged larvae or nymphs, were placed on top of the soil and covered with leaf mold. The pill boxes were often damaged by termites and decay; therefore, they were not used extensively.

Natural hosts of the immature stages of the various ticks were captured and utilized in the insectary for

studying engorgement of the larvae and nymphs. These animals were infested with ticks and kept in hardware-cloth cages over large funnels. As the engorged ticks dropped from the hosts they were caught in beakers containing water. In certain instances animals captured in nature that were already infested with ticks were placed in these cages until the ticks dropped from them.

All dates utilized in calculating preoviposition, oviposition, incubation of eggs, engorgement, molting, and longevity of ticks are inclusive. For example, in calculating the incubation periods of eggs, the date the first egg was laid and the date the first larva hatched were both included in the calculation.

## Temperature Records

A hygrothermograph was operated near the rearing pans in the insectary at all times. Temperature records used in this study were recorded in this manner unless otherwise specified. All temperature data are in degrees Fahrenheit.

In all places in this report where the average daily temperature for October 1951 was used, the figure was based on the dates October 24 to October 31 inclusive; the average temperature for March 1952 was based on 30 days; and the average temperature for September 1952 was based on 28 days. All other average monthly temperatures were based on the total number of days in the month.

## Names of Plants and Animals

In describing the various habitats and in referring to host animals for the ticks, common names were used for both plants and animals throughout the manuscript. A list of the common names used, together with their Latin equivalents, are appended at the end of the report. Hamilton (1943) was the source for the names of mammals; Carr (1940) was followed in naming reptiles; and West and Arnold (1946) were the authorities followed in naming plants. Names of birds were kindly supplied by Doctor Pierce Brodkorb of the University of Florida.

## HABITATS

According to Cooke (1939) the State of Florida is divided into five natural topographic divisions. These are (1) the Western Highlands, (2) the Marianna Lowlands, (3) the Tallahassee Hills, (4) the Central Highlands, and (5) the Coastal Lowlands. The research reported in this paper was conducted in the northern part of the Florida Peninsula which includes only two of Cooke's topographical divisions, the Coastal Lowlands and the Central Highlands. The other three divisions are completely within the non-peninsula area of the State, commonly known as West Florida.

No attempt has been made to describe northern Florida in exact details relative to geological, pedological, and botanical characteristics. The principal objective was to distinguish between the three major habitats that are most important to the tick fauna of the area.

According to Henderson (1939) the character of the vegetation in Florida is largely determined by the soil types. For the purpose of this study, the faunal habitats were divided into three general types. These are the flatwoods, the hammocks, and the sandhills. To natives of northern Florida the mere mention of one of these terms brings to mind certain characteristic types of vegetation.

## The Flatwoods

The name flatwoods is applied to those extensive areas of Florida where the ground is low and practically level and the characteristic vegetation is either longleaf or slash pine, or mixtures of the two, saw-palmetto, wire grass, and gallberry (Plate 1). Carr (1940) divided the flatwoods of Florida into several types. For the purpose of this study the term flatwoods is synonomous with Carr's Palmetto Flatwoods.

Henderson stated that this habitat is composed of only two soil series, the Leon and the St. Johns. The soil types are all sands or fine sands and are poorly drained. The flat topography is not conducive to surface drainage, and percolation is usually poor due to an almost impervious organic layer that is found at a depth of approximately one and one-half feet below the top soil. Due to the impervious nature of this organic hardpan the top soil in the flatwoods may be very dry in dry seasons and in the rainy season surface water often remains for long periods.

The monotony of the characteristic pine-palmetto association in the great flatwoods areas of northern Florida is interrupted by the presence of small ponds. Most of these ponds are shallow and may be entirely grown over with cypress trees or black gum. Also interspersed among the extensive pine-palmetto association are strips of hardwoods that form the characteristic vegetation which borders the streams

in the flatwoods. These strips of hardwoods are usually quite narrow, especially inland from the coastal areas. In some parts of the flatwoods, especially where limestone sinks are prevalent, the hardwoods occur in isolated stands that may be completely surrounded by the pine-palmetto association. The hardwood growths are termed hammocks. In addition to the cypress or black gum ponds and small hammocks, there also occur in some parts of the flatwoods isolated spots of sandhills varying in size from less than one acre to several hundreds of acres. Thus, the flatwoods, which form the most extensive habitat type in northern Florida, are interspersed with less extensive areas representative of both the other major habitat types considered in this study.

Since the soils of the flatwoods are very sandy and poorly drained, they are not cultivated extensively. These lands are utilized primarily for growing timber for the production of lumber and turpentine, and for grazing livestock. In fact, the flatwoods constitute the most extensive grazing areas throughout the State of Florida. The Coastal Lowlands, except for the Everglades, are composed principally of flatwoods. Large areas of flatwoods are also found in the Central Highlands.

The flatwoods are burned extensively every fall and winter, primarily for the purpose of providing a tender growth of wire grass for cattle during the winter and early spring. The effects of burning in this habitat on the population of Ixodes scapularis will be discussed later.

According to Carr the characteristic reptile of the flatwoods is the large diamond-back rattlesnake. Among the birds that appear to be most important as hosts for ticks, the meadow lark and the bobwhite quail are plentiful. Mammalian hosts for ticks that appear to be characteristic of the flatwoods fauna are the northern cotton rat, the Florida raccoon, the Florida opossum, the Florida bobcat, and the southern fox squirrel. The cotton mouse is also abundant in the ponds and in the limited hardwood growth in this habitat. This mouse is rarely encountered in the pine-palmetto association. Cattle and hogs range throughout the flatwoods.

## Hammocks

The term hammock is applied to any evergreen hardwood forest in Florida. In describing the hammock habitats, Carr's classification and descriptions were followed in part.

Low Hammock. The term low hammock refers to a growth, composed mostly of hardwoods, occurring in low or wet situations somewhat intermediate between cypress swamp lands and mesophytic hammock lands. The cabbage palm-redbay association along coastal areas of the peninsula may be classified as low hammock. The gum swamps of northern Florida, as well as certain mixed associations such as the sweetgum-red maple association are also classified as low hammocks. No extensive studies were made in low hammock as a separate

habitat from mesophytic hammock.

Mesophytic Hammock. This is considered to be the climax growth of northern Florida (Plate 2). One of the most typical types of mesophytic hammock is the magnolia-holly-blue beech-ironwood association. However, there is much variation both as to soil type and vegetational complexes involved in the term mesophytic hammock. From the standpoint of this study, the mesophytic hammock has slightly higher and better drained soils than low hammock but the soils are quite moist. The tree growth is dense and there is very little undergrowth. There is usually a layer of leaf mold several inches thick on the forest floor. The large hardwood forest known as Gulf Hammock, bordering the Gulf of Mexico in Levy County, Florida is a mixture of both low hammock and mesophytic hammock. This hammock covers several thousands of acres and was the principal hammock area studied.

Henderson stated that the soils of Gulf Hammock are the Parkwood series. This series is underlaid by marl at depths of usually less than four feet.

Reptile hosts for ticks most characteristic of mesophytic hammock are the ground skink and the broad-headed skink. The cotton mouse is the most abundant mammalian tick host. Other characteristic small mammalian hosts are the gray squirrel, the southern golden mouse, and the Florida wood rat. Among the larger wild mammals the Virginia deer, the

Florida raccoon, and the Florida opossum are usually plentiful. Range cattle and hogs are also abundant. Very few collections of birds were made in this habitat, but it was noted that cardinals were numerous.

Upland Hammock. As the name implies, upland hammocks are evergreen hardwood forests growing on rather high, well drained soils. The live oak, the red oak, and the hickory are typical trees of the upland hammocks. Only a limited number of observations were made in the upland hammocks during this study.

The ground skink is one of the common reptiles. The broad-headed skink is rare or absent in the upland hammock. The cotton mouse was not found in this study to be abundant in upland hammocks. All of the other hosts listed under mesophytic hammock occur in the upland hammocks. However, the utilization of much of the upland hammock land for agricultural purposes has had a pronounced effect on the fauna. Civilization has, for example, forced the Virginia deer out of much of this habitat.

## Sandhills

What has been termed the sandhills in this study is, in part, Carr's high-pine and Henderson's rolling sandy pine land. The name sandhills was used because this is the term most descriptive of this habitat in its present state, and also because this is the name most often used in northern Florida when referring to this habitat. Laessle (1942)

also used the term sandhills to describe this habitat.

The sandhills were once covered and dominated by the stately longleaf pine. Due to severe lumbering operations these once attractive rolling pine lands are now, in many areas, barren wastes of sand dominated by the very unattractive turkey oak (Plate 3). Annual burning does not improve the appearance of these sandhills. The longleaf pine is easily killed by fire when small, and even where an occasional tall pine is still growing very little natural reseeding has occurred.

The typical association is the longleaf pine-turkey oak association. In the lower elevations wire grass and saw-palmetto are common. The bluejack oak is also prevalent in the lower elevations.

The soil in the sandhills studied in this research are characterized by what Laessle termed the Deep Phase of Norfolk Fine Sand. The top six inches are yellow-gray fine sand. Beneath the top layer is a layer of fine yellow sand that varies in depth from six to eight feet, or more.

The large land turtle, commonly known as the gopher or gopher-tortoise, is probably the most typical reptile that occurs in the sandhills. Pocket gophers are the best known mammals of the sandhills. These pocket gophers are usually referred to locally as salamanders. The Florida deer mouse is also reported to be typical of this habitat in the central and southern parts of Florida (Hamilton, 1943). The

northern cotton rat was collected in areas of the sandhills having a heavy growth of wire grasses. Typical ground-feeding birds are the bobwhite quail and the meadow lark.

The sandhills are by far the driest of the habitats studied. Rogers (1933) showed that the evaporation rate in this habitat was much higher than in mesophytic hammock or flatwoods. Laessle indicated that the sandhills are even more xeric than the sand scrubs of Florida.

# THE GENUS AMBLYOMMA KOCH, 1884

## AMBLYOMMA AMERICANUM (LINNAEUS, 1758)

Morgan (1899) was the first worker to contribute to our knowledge of the life history of Amblyomma americanum. His research was conducted in Louisiana. Other early workers who contributed to the biology of this tick were Hunter and Hooker, Hooker (1908, 1909a.), and Hooker et al. Recent papers on distribution and host relationships of this tick are Cooley and Kohls (1944) and Bishopp and Trembley. Brennan (1945a., 1945b.) studied the field biology of Amblyomma americanum in Texas and included an extensive list of hosts, especially among birds. Morlan (1952) reported this tick from 12 species of small mammals in southern Georgia. Griffith (1951) recently published on the life cycle of Amblyomma americanum in Texas.

### Economic Importance

Because of its adaptability to a wide range of hosts and its habit of attacking the larger mammals in all of its parasitic stages, Amblyomma americanum has long been recognized as one of the most important ticks in the United States. In recent years this tick has acquired new significance for its role in the transmission of Rocky Mountain spotted fever and American Q fever. Bullis fever and tularemia are other diseases of which this species is strongly suspected as a vector. Brennan (1945b.) reviewed

the literature on the medical importance of Amblyomma americanum up to 1945. Taylor et al. suspected this species to be one of the vectors involved in one of four cases of Rocky Mountain spotted fever reported in Florida during 1947. While this tick may be very abundant locally, it is limited in its importance by its habitat distribution in northern Florida.

## Distribution

Bishopp and Trembley showed Amblyomma americanum to be distributed in the United States from east-central Texas northeastward to southern Iowa and then almost due eastward to New Jersey. They indicated that its sporadic occurrence in the more northern states is due to accidental introduction. The southern range was given by these authors as Guatemala, Guiana, and Brazil. Cooley and Kohls (1944) indicated that it is common in Mexico. Taylor cited two previous records of this species in Florida, one from the northern and one from the southern extremities of the State. Taylor's collections were taken from Hillsborough County to the Florida-Georgia boundary.

## Host Relationships

From the standpoint of host relationships Amblyomma americanum is the best adapted of all Florida ticks. This is due both to a wide range of suitable hosts and to the fact that all parasitic stages readily attack such common

larger mammals as cows, dogs, deer, and many others, including man. The immature stages also extend their host relationships to many kinds of birds. No record of Amblyomma americanum from reptiles was found in the literature.

The Larva. Host records in this study for the larva of Amblyomma americanum are shown in Table I. Future studies will undoubtedly extend this Florida host list, especially among the birds. Most of the birds examined were taken in the flatwoods habitat where the research was concentrated. It was shown in this study that Amblyomma americanum is rarely encountered in the flatwoods habitat of northern Florida.

All records of ticks from man, wherever used in this report, refer only to instances in which the ticks were attached. The records of the larva of Amblyomma americanum from man are shown in Table I. Actually, man is an excellent host for all stages of this tick and many thousands of larvae were brushed from the writer's clothing during this study in order to prevent their attaching. Brennan (1945a.) stated that this tick is an important factor in lowering the morale of troops on bivouac at Camp Bullis, Texas. He cited an instance where 294 nymphs and adults were detached from one soldier.

The Nymph. Host records for the nymph of Amblyomma americanum are shown in Table II. In general, the same remarks made above in connection with the larva also apply

TABLE I

HOST RELATIONSHIPS OF THE LARVA OF *AMBLYOMMA AMERICANUM* (L.) IN NORTHERN FLORIDA

| Host | Lots | Total number of larvae collected | Average number of larvae per host |
|---|---|---|---|
| Cardinal | 3 | 40 | 13.3 |
| Cow | 16 | 116 | 7.2 |
| Florida bobcat | 1 | 17 | 17.0 |
| Gray squirrel | 2 | 27 | 13.5 |
| Man | 2 | 8 | 4.0 |
| Virginia deer | 1 | 11 | 11.0 |

TABLE II

HOST RELATIONSHIPS OF THE NYMPH OF *AMBLYOMMA AMERICANUM* (L.) IN NORTHERN FLORIDA

| Host | Lots | Total number of nymphs collected | Average number of nymphs per host |
|---|---|---|---|
| Bobwhite quail | 1 | 1 | 1.0 |
| Cardinal | 3 | 5 | 1.7 |
| Cow | 43 | 135 | 3.1 |
| Dog | 11 | 11 | 1.0 |
| Florida raccoon | 1 | 1 | 1.0 |
| Gray squirrel | 4 | 7 | 1.7 |
| Hog | 1 | 8* | --- |
| Man | 5 | 12 | 2.4 |
| Rabbit | 1 | 4 | 4.0 |
| Virginia deer | 2 | 26 | 13.0 |
| Wild turkey | 1 | 2 | 2.0 |

*All ticks not collected.

to the nymph.

Table IV shows data from 58 examinations of cows in a favorite habitat of Amblyomma americanum. The numbers of larvae and nymphs shown do not leave the impression that the cow is a favorite host for the immature stages in northern Florida.

Conspicuously absent from the hosts lists for both the larva and the nymph are small mammals of the rat and mouse groups. The cotton mouse probably reaches its peak of abundance in northern Florida in the favorite habitat of Amblyomma americanum. Of 113 of these mice examined none was infested with this tick. Morlan examined 249 of these mice in southwestern Georgia and reported none infested with this tick. Brennan (1945b.) also concluded that small rodents were not important hosts in Texas.

The gray squirrel is the smallest mammal that was found to be a good host for the immature stages in this study. This squirrel is found in large numbers in the hammocks of northern Florida and undoubtedly plays an important role in the biology of Amblyomma americanum.

The Adult. The adult of Amblyomma americanum apparently confines its attack to mammals but has a wide range of suitable hosts among this group. Adult host records obtained in this study are shown in Table III. The records of Bishopp and Trembley, and Brennan (1945b.) indicate that the Virginia deer is probably the most important natural host for the

TABLE III

HOST RELATIONSHIPS OF THE ADULT OF *AMBLYOMMA AMERICANUM* (L.) IN NORTHERN FLORIDA

| Host | Lots | Total number of adults collected | Average number of adults per host |
|---|---|---|---|
| Cow | 61 | 451 | 7.4 |
| Dog | -- | 59 | --- |
| Florida gray fox | 1 | 3 | 3.0 |
| Hog | 3 | 29 | 9.7 |
| Man | 1 | 3 | 3.0 |
| Virginia deer | 2 | 7 | 3.5 |

adult, and probably for the larva and nymph of this tick. Records from the deer in this study also indicate the importance of this host, especially for the larva and the nymph.

Another domestic animal that appeared to be of considerable importance as a host in northern Florida, and probably throughout the deep South, was the hog. For many generations it has been the custom in this area to allow semi-wild hogs to range the woodlands. They range in considerable numbers over all terrestrial habitats in northern Florida and are especially abundant where acorns and similar foods are plentiful. Only a few opportunities were found for examining these hogs because of their semi-wild nature. However, on one occasion during this study one of these animals was examined rather hurriedly in a favorite habitat of the Amblyomma americanum. Circumstances did not permit a complete collection of ticks, but it was estimated that more than 200 ticks were attached to this animal. All ticks collected proved to be adults and nymphs of Amblyomma americanum. The larva has also been reported from the hog (Bishopp and Trembley) but published records, and data obtained in this study, do not indicate that this animal is an important host for the larva.

## Seasonal Activity

Morgan found that Amblyomma americanum reached a peak of abundance in Louisiana in March and April. He also noted that no engorged adult ticks were found on cows in the

interval between August and March.

Bishopp and Trembley reported that this species has been taken in all stages from hosts throughout the year in the southern states but stated that it is less abundant during midwinter.

Brennan (1945b.) studied the incidence of this tick on hosts at Camp Bullis, Texas. Brennan's paper contains the only published data found in the literature that is sufficient to show activity trends of all stages throughout the year in the deep South. That worker found little or no tick activity in Texas between October and January.

The Larva. The data on nymphs and adults shown in Tables IV and V are in accord with the statement by Bishopp and Trembley that this tick is active throughout the year in the South. The data on larvae in these tables do not show that this stage was active every month. However, if more host animals had been examined, larvae might have been found during all months. This is indicated by the record shown in Table V of 21 larvae collected from cows in February. It seems very unlikely that a tick which is normally most active during the warmer months would also be active in February but not during the other winter months. The data in Tables IV and V show that the larva was at its lowest point of activity from December to May. Also, it seems reasonable to assume that the larval activity might be different during different seasons.

In this study larvae were not encountered by any method

TABLE IV

COLLECTIONS OF AMBLYOMMA AMERICANUM (L.)
FROM COWS IN GULF HAMMOCK, FLORIDA,
SEPTEMBER 1951 THROUGH SEPTEMBER 1952

| Month and year | Number of cows examined | Total number of ticks collected and average number per cow | | | | | |
|---|---|---|---|---|---|---|---|
| | | Larvae | | Nymphs | | Adults | |
| | | Number | Average | Number | Average | Number | Average |
| 1951 | | | | | | | |
| September | 4 | 0 | 0.0 | 2 | 0.5 | 3 | 0.7 |
| October | 5 | 1 | 0.2 | 8 | 1.6 | 2 | 0.4 |
| November | 3 | 0 | 0.0 | 0 | 0.0 | 2 | 0.7 |
| December | 4 | 0 | 0.0 | 2 | 0.5 | 7 | 1.7 |
| 1952 | | | | | | | |
| January | 6 | 0 | 0.0 | 30 | 5.0 | 52 | 8.7 |
| February | 6 | 21 | 3.5 | 26 | 4.3 | 60 | 10.0 |
| March | 5 | 0 | 0.0 | 8 | 1.6 | 109 | 21.8 |
| April | 4 | 0 | 0.0 | 1 | 0.2 | 49 | 12.2 |
| May | 8 | 4 | 0.5 | 10 | 1.2 | 76 | 9.5 |
| June | 4 | 21 | 5.2 | 2 | 0.5 | 35 | 8.7 |
| July | 3 | 33 | 11.0 | 23 | 7.7 | 43 | 14.3 |
| August | 4 | 36 | 9.0 | 21 | 5.2 | 9 | 2.2 |
| September | 2 | 0 | 0.0 | 18 | 9.0 | 0 | 0.0 |
| Totals | 58 | 116 | 2.0 | 151 | 2.6 | 447 | 7.7 |

TABLE V

COLLECTIONS OF AMBLYOMMA AMERICANUM (L.) WITH A DRAG IN GULF HAMMOCK, FLORIDA, AUGUST 1951 THROUGH NOVEMBER 1952

| Month and year | Number of drag samples | Total number of ticks collected and average number per sample | | | | | |
|---|---|---|---|---|---|---|---|
| | | Larvae | | Nymphs | | Adults | |
| | | Number | Average | Number | Average | Number | Average |
| 1951 | | | | | | | |
| August | 2 | Many | --- | 43 | 21.5 | 1 | 0.5 |
| September | 2 | Many | --- | 23 | 11.5 | 0 | 0.0 |
| October | 2 | Few | --- | 26 | 13.0 | 0 | 0.0 |
| November | 1 | Few | --- | 0 | 0.0 | 0 | 0.0 |
| December | 3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1952 | | | | | | | |
| January | 2 | 0 | 0.0 | 7 | 3.5 | 2 | 1.0 |
| February | 1 | 0 | 0.0 | 6 | 6.0 | 1 | 1.0 |
| March | 2 | 0 | 0.0 | 111 | 55.5 | 13 | 6.5 |
| April | 2 | 0 | 0.0 | 166 | 83.0 | 15 | 7.5 |
| May | 3 | 1* | 0.3 | 214 | 71.3 | 20 | 10.0 |
| June | 2 | 16 | 8.0 | 12 | 6.0 | 5 | 2.5 |
| July | 2 | 35 | 17.5 | 114 | 17.5 | 10 | 5.0 |
| August | 2 | 32 | 16.0 | 156 | 78.0 | 11 | 5.5 |
| September | 1 | 7 | 7.0 | 77 | 77.0 | 0 | 0.0 |
| October | 1 | 6 | 6.0 | 18 | 6.0 | 0 | 0.0 |
| November | 1 | 3 | 3.0 | 0 | 3.0 | 0 | 0.0 |

*The numbers in this column from May through November 1952 indicate clumps of larvae.

of collecting during the months of March and April of 1952. During that year the first larvae were collected May 31, both from hosts and with the cloth drag. Larvae were also found on the writer's clothes on that date and none had been collected in this manner for several months preceding that date.

Laboratory studies with this tick showed that engorged adults collected from cows in Gulf Hammock in February 1952 started laying eggs in March and that these eggs started hatching the last week in May. Therefore, it seems reasonable to state that larval activity began the latter part of May 1952 as a result of the hatching of eggs laid in March of that year.

Brennan (1945b.) found unfed larvae to be plentiful on June 8, 1943, when his work was started at Camp Bullis, Texas. However, during 1944 that worker obtained his first record of an unfed larva on June 9. A larval peak was noted in early June during 1943 and another in late August. During 1944 he recorded a larval peak in late June which leveled off in July. No larval peak was noted in August 1944.

Data in Table IV show that the larval activity increased rapidly in June 1952 in northern Florida and reached a peak in July and August. There was a rapid decline in larval activity beginning in September. Data for September 1951, shown in Table V, agree with that for September 1952.

Data for the larva in Table IV agree in general with that in Table V. However, some explanation of the methods

used in recording larval collections with the cloth drag is in order. The larvae of Amblyomma americanum climb to the tops of small shrubs and other low-growing vegetation and accumulate in great numbers on terminal branches. There they await the passing of a host. During the peak of their activity it is not uncommon to find thousands of larvae on a cloth drag which has been pulled a short distance over low shrubs. Counting them cannot even be considered in a study of this kind. Therefore, when sampling with a drag was begun in August 1951, the larvae were estimated as being numerous or few. This is the usual method followed by most workers in indicating larval populations by collections with a cloth drag.

Beginning in May 1952 it was decided that counting the clumps of larvae that appeared on the drag might show the relative abundance of the larvae. In order not to count the same clumps when the drag was examined at intervals of 25 paces, the larvae were brushed from the drag with a whisk broom after each count. This method seems to be of value in indicating relative abundance of larvae since there seems to be a close correlation between the data for larvae in Tables IV and V during 1952.

The Nymph. Nymphs were collected every month except November. On cows they were least numerous from September through December during 1951. There was a peak of activity during January and February 1952, then a decline that began

in March and extended through June 1952. Another peak was attained during July, August, and September of 1952. However, the data in Table V do not agree with these findings throughout that period. The data from cows were quite variable. Therefore, the data in Table V are probably more reliable for showing the seasonal activity of the nymph. These data show that the nymphs were quite active during all periods except November through February, and in June. The period of minimum activity during November to March was probably due to low temperatures.

Brennan (1945b.) stated that nymphal activity began at Camp Bullis, Texas in February. Data in Table V show that activity began as early as December during 1951 in northern Florida. Nymphs were collected both from cows and with a drag in January 1952.

The Adult. Adults were found on cows every month in the year in this study (Table IV). The data are shown graphically in Figure 1. The period of greatest activity began in January and reached a peak in March. Activity dropped during April, May, and June, then increased again in July. A rapid decline in activity began in August and continued at a low point until January.

Brennan (1945b.) found that adults became active in Texas in February and reached a peak in late May or early June. As stated earlier, that worker found little or no activity in Texas from October through January.

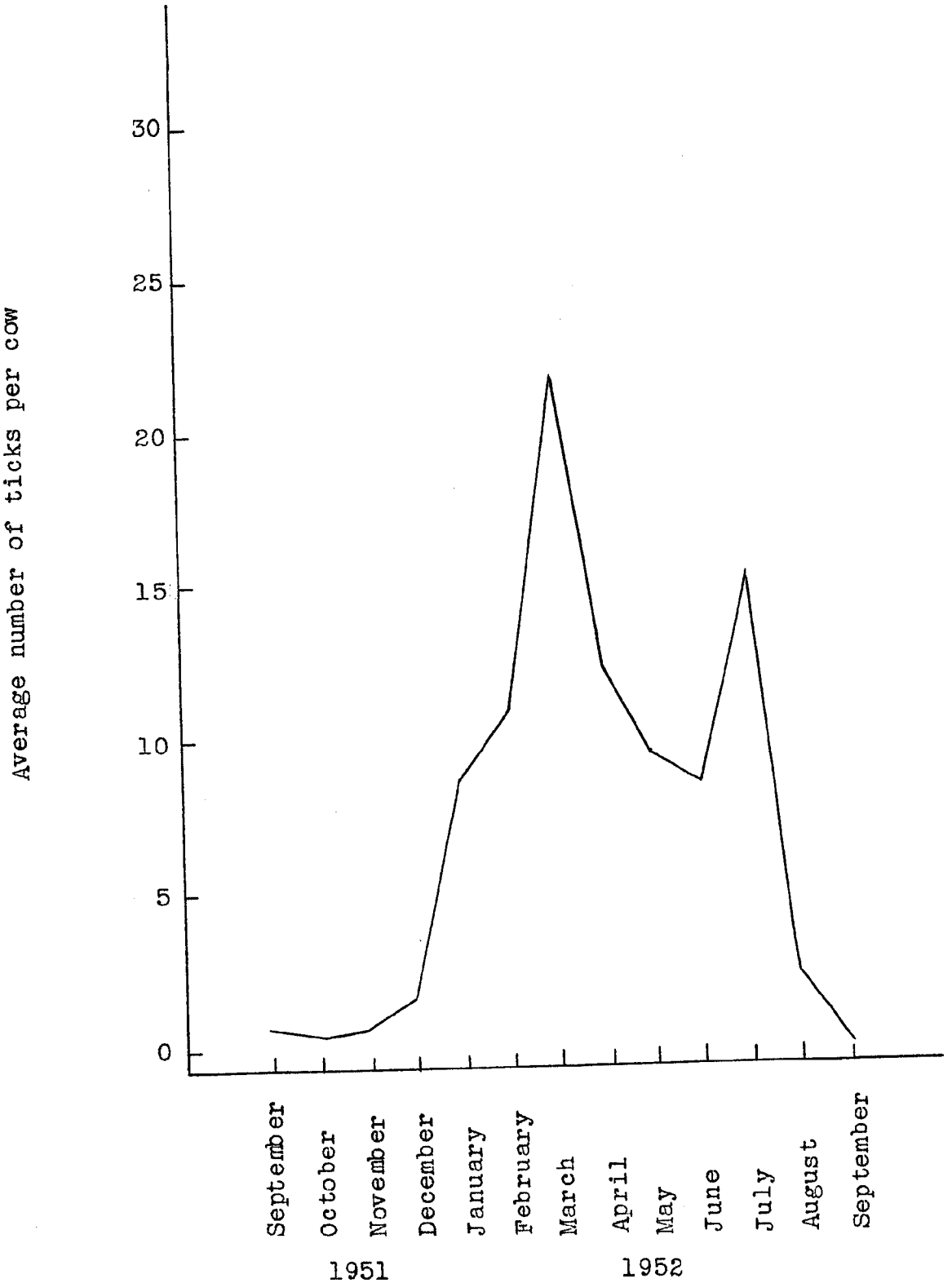


Figure 1. Seasonal activity of the adult of Amblyomma americanum (L.). Ticks collected from same cows at bimonthly intervals, September 1951 through September 1952.

## Habitat Distribution

Hooker et al. in writing about the habitat distribution of the various species of Amblyomma in the United States said that they are very hardy but require some protection, such as timber or underbrush. Amblyomma maculatum, however, was said to live on the prairie. Bishopp and Trembley stated that there is much local variation in the abundance of Amblyomma americanum and that it is found most abundantly in wooded areas having dense underbrush. River bottoms in prairie areas and the canebrakes of Louisiana and Mississippi were cited as suitable habitats for this tick.

Brennan (1945a.) described in more detail the preferred habitat of this tick at Camp Bullis, Texas. His observations on the tick's environmental requirements agree in general with those made in the present study. That is, Amblyomma americanum appeared to be restricted to areas characterized by dense shade and a rather high moisture content at the soil level. Brennan did not find this tick in semi-barren nor grassland areas.

In northern Florida this species is restricted to hardwood forests, or what is termed the hammock habitat in this study. This species apparently does not complete its life cycle in the pine-palmetto association in the flatwoods. Only one collection of this tick, a single male specimen, was obtained in the sandhills. This collection was made with a cloth drag on a sandhill that was adjacent to a large

hammock. It is possible that this specimen dropped from an animal that wandered from the hammock. Extensive sampling with a cloth drag (Table IX) in sandhills farther removed from hammocks failed to show the presence of this tick. The same was true for numerous samples with a cloth drag in the flatwoods.

The statement relative to this tick not being able to breed in the flatwoods habitat needs further explanation in view of the data shown in Table VI. As described earlier, the extensive flatwoods areas of northern Florida are interspersed with hammocks and sandhills of varying size and physical characteristics. Also, the streams which pass through the flatwoods characteristically have a strip of hardwoods bordering each side. Amblyomma americanum maintains itself in these more or less isolated hammock areas, even when completely surrounded by typical flatwoods, provided that the hammock areas are fairly extensive.

Cattle and other animals that roam the flatwoods utilize these hammock spots both for feeding and resting. Even though their principal range is in the flatwoods, these animals are bound to acquire some ticks from the small hammocks. These conditions and circumstances probably account for the few ticks taken from animals in the flatwoods during this study. Complete records of this tick from host animals in the flatwoods, covering almost four years of study, are shown in Table VI.

TABLE VI

TOTAL COLLECTIONS OF *AMBLYOMMA AMERICANUM* (L.)
IN THE FLATWOODS OF NORTHERN FLORIDA,
OCTOBER 1949 THROUGH JANUARY 1953

| Date of collection | | Host | Number of ticks | | | Location |
|---|---|---|---|---|---|---|
| | | | Larva | Nymph | Adult | |
| 1950 | | | | | | |
| February | 24 | Bobwhite quail | 0 | 1 | 0 | Levy County, near Gulf Hammock |
| April | 23 | Dog | 0 | 0 | 1 | Alachua County |
| May | 9 | Dog | 0 | 0 | 1 | Alachua County |
| July | 10 | Cow | 0 | 0 | 1 | Alachua County |
| October | 1 | Florida bobcat | 17 | 0 | 0 | Levy County, near Gulf Hammock |
| 1952 | | | | | | |
| April | 11 | Dog | 0 | 0 | 1 | Alachua County |
| September | 16 | Cow | 0 | 1 | 0 | Alachua County |
| Totals | | | 17 | 2 | 4 | |

The record of 17 larvae collected from a Florida bobcat shown in Table VI should also be mentioned here. These large cats feed over a range of several miles. The one from which these larvae were collected was killed in the flatwoods only a few miles from Gulf Hammock, Florida. Also within feeding range of this bobcat were many smaller hammocks which could easily have been the habitat in which the ticks attached to this animal.

Further proof of the habitat distribution of Amblyomma americanum may be seen by comparing the data in Tables IV and VI. From September 1951 through September 1952 a total of 714 specimens, all stages included, of this tick were collected from 58 cows in Gulf Hammock, Florida. During that same period 440 cows in the flatwoods of Alachua County yielded only one nymph of Amblyomma americanum. This record, September 16, 1952, is included in Table VI.

In addition to these host data, Table V shows that 29 drag samples taken in Gulf Hammock during the period August 1951 through November 1952 yielded a total of 1,050 nymphs and adults of Amblyomma americanum and uncounted thousands of larvae. During that same period 87 drag samples in flatwoods habitats were completely negative for this tick.

Amblyomma americanum was found in all of the three types of hammocks studied. Most of the hammock studies were conducted in the large area surrounding the town of Gulf Hammock, Florida. The tick was very abundant in that area,

which is a mixture of low hammock and mesophytic hammock. This tick did not appear to be so abundant in the upland hammock studied. However, since studies in the upland hammock were infrequent, a fair comparison of tick densities in various types of hammocks cannot be made.

The broad scope of the present research did not allow a detailed study of this interesting problem. However, certain considerations can be noted from the information at hand. Since Amblyomma americanum readily attacks a wide range of hosts that are common to all habitats studied, the possibility of host relationships being a factor in this unusual distribution pattern can definitely be ruled out. The various physical features of the environment appear to be the most likely controlling factor, or factors. Of these, moisture, both humidity and soil moisture, seems the most likely answer to the problem. This is the same general conclusion drawn by Brennan (1945b.) from his observations on this tick in Texas. However, in both instances the conclusions are theoretical and will have to be proved or disproved by further research.

## AMBLYOMMA MACULATUM KOCH, 1844

As stated in the introduction to this paper, Hixson worked out the field biology of Amblyomma maculatum in southern Georgia. Therefore, detailed and prolonged observations on this species were not made in this study. Hixson

also reviewed the literature pertaining to this tick up to 1940.

Since one of the desired results of this research was to provide fundamental information as a guide to recommendations for controlling ticks in northern Florida, a brief discussion of the seasonal activity of this tick on cattle and its habitat distribution appears to be in order.

## Seasonal Activity

No special effort was made to study the seasonal activity of the larva and nymph of Amblyomma maculatum, but observations were made on the infestations of cows by the adult. The adult tick is especially important since it is frequently a predisposing factor in screwworm infestations in its hosts.

Opportunities were available for making rather frequent examinations for this tick on range cattle in the flatwoods. The tick was easily recognized in the adult stage because of its habit of attaching in large patches on the ears and also because of its characteristic color markings. Therefore, only samples of the ticks observed were collected, and the evaluation of the degree of infestation was based upon the number of cows infested.

Table VII shows the seasonal incidence of this tick on cows in northern Florida during 1950. These data indicate that infestation of cows by this tick in northern Florida

TABLE VII

SEASONAL INCIDENCE OF AMBLYOMMA MACULATUM KOCH ON RANGE CATTLE IN THE FLATWOODS OF NORTHERN FLORIDA, JUNE THROUGH DECEMBER 1950

| Date | | Number of cows examined | Per cent infested |
|---|---|---|---|
| June | 19 | 22 | 4.0 |
| June | 23 | 18 | 11.1 |
| June | 27 | 68 | 22.0 |
| July | 3 | 16 | 12.5 |
| July | 10 | 45 | 13.3 |
| August | 1 | 43 | 81.4 |
| August | 22 | 43 | 27.9 |
| September | 27 | 28 | 14.2 |
| October | 6 | 20 | 5.0 |
| November | 4 | 24 | 8.3 |
| December | 2 | 43 | 2.3 |

was similar to the incidence that Hixson found on sheep in southern Georgia. June through September is the important period from the standpoint of control of this species in northern Florida.

### Habitat Distribution

Hixson listed the preferred habitat of Amblyomma maculatum in southern Georgia as open grasslands. This undoubtedly included the flatwoods as described in the present study. The flatwoods of northern Florida and southern Georgia form one continuous habitat at many points along the boundary.

Flatwoods were found to be by far the most important habitat of Amblyomma maculatum in this study. However, a small number of adults were taken from cows that ranged only in a large hammock. There can be no doubt that these ticks attached to their hosts in that habitat. Amblyomma maculatum was never found to be abundant on cows in hammocks.

On September 1, 1951, 53 larvae of this tick were collected from a cloth drag on a sandhill adjacent to Gulf Hammock in Levy County, Florida. This is the only record of Amblyomma maculatum from the sandhill habitat obtained in this study.

## AMBLYOMMA TUBERCULATUM MARX, 1894

Amblyomma tuberculatum is the only tick discussed in this paper which has Florida as its type locality. Marx (in

Hubbard, 1894) described this species, which is the largest North American tick, from a specimen collected by Hubbard at Crescent City, Putnam County, Florida.

Hooker (1909a.) published on the host relationships of the larva, and Hooker et al. published on the life cycle of this species. Except for occasional host and distribution records, nothing has been published on the field biology of Amblyomma tuberculatum since that time.

## Economic Importance

Bishopp and Trembley reported that the larva of Amblyomma tuberculatum has, in a few instances, been known to infest domestic chickens in considerable numbers. The present study showed that the larva will attach to man in nature. In view of this, Amblyomma tuberculatum must be regarded as being of potential medical importance.

## Distribution

Bishopp and Trembley reported Amblyomma tuberculatum only from Florida, Georgia, South Carolina, Alabama and Mississippi. Cooley and Kohls (1944) stated that one specimen was reported from Cuba by Neumann in 1899, but indicated that this specimen was probably collected from a gopher-tortoise that was brought to Cuba from the United States. There are no other records of this tick having been collected outside the southeastern United States. Practically all published references on the distribution of this tick state that it is present only where the large gopher-tortoise is

found.

## Host Relationships

Amblyomma tuberculatum has been reported in the adult stage only from the large land turtle in the southeastern United States.

The most complete host lists for this species are those published by Cooley and Kohl (1944) and Bishopp and Trembley.

The Larva. The larva of Amblyomma tuberculatum is known to attack mammals and birds. The larva has not been previously reported from cold-blooded hosts.

Host records for the larva obtained in this study are shown in Table VIII. Man is the only new host record among the mammals listed. The bobwhite quail and the robin are new host records from birds.

The finding of the larva on the fence lizard is a new record both for the lizard and for reptiles (Plate 4). The first specimens from this host observed in this study were taken from lizards collected by Mr. John Crenshaw, a student at the University of Florida. The ticks were obtained through the cooperative efforts of Doctor Benjamin Leavitt, Biology Department, University of Florida. Subsequent to that time larvae were collected from fence lizards on several occasions during this study. The fence lizard is found abundantly in the favorite habitat of the tick and probably serves as an important host.

Also of special interest among the hosts shown in Table VIII is the Florida gray fox. The only published record of

TABLE VIII

COLLECTIONS OF LARVAE OF AMBLYOMMA TUBERCULATUM MARX, NOVEMBER 1949 TO JANUARY 1953

| Host | Lots | Larvae | |
|---|---|---|---|
| | | Number collected | Average number per host |
| Mammalia | | | |
| Cottontail rabbit | 2 | 5 | 2.5 |
| Cow | 1 | 4 | 4.0 |
| Dog | 4 | 29 | 7.2 |
| Florida gray fox | 3 | 243 | 81.0 |
| Fox squirrel | 2 | 35 | 16.5 |
| Man | 2 | 5 | 2.5 |
| Aves | | | |
| Meadow lark | 3 | 11 | 3.7 |
| Quail | 3 | 6 | 2.0 |
| Robin | 1 | 1 | 1.0 |
| Reptilia | | | |
| Fence lizard | 9 | 12 | 1.3 |

the larva from this host is that of Morlan. That worker examined 14 foxes in southwestern Georgia and recorded a total of four larvae of Amblyomma tuberculatum from them.

Table VIII shows that 243 larvae were collected from three foxes in this study. The apparent difference between Morlan's data and that in Table VIII from this host could be due to several factors. The habitat in which the foxes were collected is one factor, and the season during which they were collected could also be important. Also, the tick is probably much more abundant in northern Florida than in southwestern Georgia. This is due to the greater abundance of the gopher-tortoise in Florida than in other areas.

The Florida gray fox and the southern fox squirrel are both common in the principal habitat of the tick. Although not many of these animals were examined, the high rate of infestation, together with their prevalence in the habitat of the tick, are strong indications that these mammals are among the most important hosts for the larva in northern Florida.

The Nymph. The nymph, like the adult, appears to be restricted to cold-blooded animals as natural hosts. Cooley and Kohls (1944) recorded five nymphs of Amblyomma tuberculatum from the fence lizard. The locality of this record was given as Silver Springs, Marion County, Florida. There are no other published records of the nymph from any host other than the gopher-tortoise.

No special attention was given to collecting nymphs and adults in this study, though a few ticks of both stages were occasionally received from students and other friends. All of these were from gopher-tortoise.

## Seasonal Activity

The adults of Amblyomma tuberculatum have been taken from the gopher-tortoise throughout the year, as shown by Bishopp and Trembley. Those authors also stated that their records indicate that the larva is probably present on hosts the year round. They added, however, that most of their collections were made during the winter months, especially in December.

During this study larvae were collected from November throughout the winter and spring months through March. No larvae were collected from May through October in the spring and summer seasons. Since many suitable hosts were examined during the late spring and summer during almost four years of study, it is concluded that the larva is not active during that period.

Since no special efforts were made to collect nymphs and adults, no significant data were obtained on the seasonal activity of these stages.

## Habitat Distribution

The principal habitat of Amblyomma tuberculatum in northern Florida is probably the sandhills. As stated above, the gopher-tortoise is the only known host for the adult of

Amblyomma tuberculatum. Due to this restriction on hosts for the adult, the habitat of the turtle is probably the principal habitat of the tick.

According to Carr the gopher-tortoise is one of the characteristic animals in the sandhills (Carr's high-pine) of Florida. The burrows of this turtle are not found in areas having a high water table such as the pine-palmetto association of the flatwoods. However, the flatwoods are interspersed with sandhills and it is not at all uncommon to find these turtles crawling in the flatwoods.

Engorged ticks undoubtedly drop from the turtles as they progress slowly through the flatwoods. Thus, one would expect to find the tick in that habitat. In fact, the majority of the host records of the larva in this study were from the flatwoods habitat. This, however, was probably due to the fact that more animals were examined in the flatwoods habitat than in any other habitat studied.

It seems significant that not a single record of this tick in any stage was obtained in the hammock habitat. Likewise, the gopher-tortoise was never observed in a hammock during this study.

Table IX shows complete records of sampling in the sandhills habitat with a cloth drag where the sandhills were far removed from hammocks. The larva of Amblyomma tuberculatum was the only stage of any tick recorded from these samples.

TABLE IX

COMPLETE RECORD OF SAMPLING WITH A CLOTH DRAG IN THE SANDHILLS QUADRATS

| Date | Size of sample (steps) | Ticks collected | | |
|---|---|---|---|---|
| | | Species | Stage | Number |
| 1951 | | | | |
| September 29 | 500 | --- | --- | 0.0 |
| October 13 | 750 | --- | --- | 0.0 |
| 30 | 730 | --- | --- | 0.0 |
| November 12 | 500 | --- | --- | 0.0 |
| December 1 | 750 | --- | --- | 0.0 |
| 30 | 750 | Amblyomma tuberculatum | Larva | 6.0 |
| 1952 | | | | |
| January 12 | 500 | Amblyomma tuberculatum | Larva | 6.0 |
| 26 | 500 | Amblyomma tuberculatum | Larva | 23.0 |
| 27 | 2,000 | Amblyomma tuberculatum | Larva | 8.0 |
| February 9 | 500 | Amblyomma tuberculatum | Larva | 9.0 |
| March 15 | 500 | --- | --- | 0.0 |
| 22 | 750 | --- | --- | 0.0 |
| April 5 | 500 | --- | --- | 0.0 |
| May 17 | 750 | --- | --- | 0.0 |
| 31 | 500 | --- | --- | 0.0 |
| June 14 | 750 | --- | --- | 0.0 |
| July 26 | 500 | --- | --- | 0.0 |
| August 29 | 500 | --- | --- | 0.0 |
| September 14 | 500 | --- | --- | 0.0 |
| October 18 | 500 | --- | --- | 0.0 |
| November 29 | 500 | --- | --- | 0.0 |

However, all stages of this tick undoubtedly occur in the sandhills. No explanation can be offered as to why the nymph and adult were not taken in this extensive sampling. The answer may become apparent when future studies reveal more information on the habits of the various stages of the tick.

The only published reference to the habits of this tick are those of Hooker et al. Those workers noted that the engorged nymph, under laboratory conditions, burrowed one to two inches in sand before molting. They suggested that the larva may do the same, but this was not observed. The burrowing habit of the nymph of Amblyomma tuberculatum is especially interesting in view of the dry nature of the sandhills habitat. Future studies might show that this burrowing habit is the principal factor making possible the propagation of this species in the sandhills.

The entire records of sampling in the sandhills are included in Table IX in order to be able to refer to this table when discussing the habitat distributions of other ticks.

# THE GENUS DERMACENTOR KOCH, 1844

## DERMACENTOR VARIABILIS (SAY), 1821

The American dog tick, Dermacentor variabilis, is one of the best known and most often studied ticks in the United States.

Morgan was the first worker to publish on the biology of this important tick. Other early papers dealing with the biology of this tick that appeared soon after Morgan's pioneer work were those of Hunter and Hooker, Hooker (1908), and Hooker et al.

From 1912 to the present time the literature dealing with various aspects of the biology, economic importance, and control of Dermacentor variabilis has become rather extensive. However, as pointed out in the introduction to this paper, no extensive studies have been conducted on this tick in the southeastern United States. The most comprehensive report of the biology of Dermacentor variabilis is that by Smith et al. (1946). This paper described the biology of this tick in the vicinity of Martha's Vineyard, Massachusetts. Those authors also reviewed the literature on Dermacentor variabilis up to 1946.

### Economic Importance

Dermacentor variabilis is well known as the principal vector of Rocky Mountain spotted fever in the eastern United

States. Parker et al. (1937) summarized the importance of this tick, along with others, in the transmission of human diseases. Although the incidence of Rocky Mountain spotted fever in man is much higher in the northeastern states than in the South, Brigham and Watt (1940) isolated highly virulent strains of this disease from Dermacentor variabilis in Georgia. This disease is rare in Florida, but Taylor et al. found Dermacentor variabilis in all areas from which four cases of the disease were reported in the State in 1947. However, only circumstantial evidence was obtained in linking this tick to the disease in Florida.

Other than its importance as a vector of human diseases, Dermacentor variabilis is well known as an important parasite of the dog.

## Distribution

The distribution of Dermacentor variabilis was thoroughly reported by Bishopp and Trembley, and by Smith et al. Those authors showed that it is present throughout the eastern half of the United States, extending north into Canada and south into Mexico. It is also known from Oregon and California on the West Coast but is not known to occur in the Rocky Mountain region. This tick, according to the authors cited above, reaches its peak of abundance along the East Coast of the United States. Bishopp and Trembley also stated that the tick is common in the Gulf Coast States, especially in Florida and Texas.

## Host Relationships

Small mammals, especially small rodents, have been shown by many workers to be the most important hosts for the larva and the nymph of Dermacentor variabilis (Larrouse et al., 1928), (Bishopp and Smith, 1938), (Smith et al.). All published reports on the subject of host relationships seem to agree that the dog is the most important host of the adult throughout the range of the tick. However, it is conceivable that in sparsely settled regions certain species of wild animals could very well play a more important role than the dog as a host for the adult.

The Larva and the Nymph. The larva and the nymph of this tick are discussed together because the same animals were found to serve as the important hosts for both stages in northern Florida. It was shown by Smith et al. that the meadow mouse and the white-footed mouse are the two most important hosts for the larva and the nymph of Dermacentor variabilis in Massachusetts, the meadow mouse being the more important of these two hosts. Those authors also listed several other less important hosts for the larva and the nymph in that area. Eddy and Joyce (1944) reported the northern white-footed mouse to be the most important host for the larva and the nymph in Iowa. Those workers also found the Mearns cottontail to be an important host of the immature stages in Iowa.

The cotton mouse and the northern cotton rat were the

most important hosts for the larva and nymph of Dermacentor variabilis found in this study. The meadow mouse and the northern white-footed mouse do not occur in Florida. All hosts records for the larva and the nymph obtained in this study are shown in Table X.

The cotton mouse is one of the most abundant mammals in northern Florida. It is found in the hammocks and in the cypress ponds of the flatwoods. It rarely frequents the pine-palmetto association of the flatwoods, nor does it exist in the sandhills habitat. The habitat distribution of the northern cotton rat in Florida is almost the opposite of that of the cotton mouse.

The cotton rat is abundant in the sandhills and in the pine-palmetto association of the flatwoods where these habitats are protected from fire. Although the cotton rat can exist in very dry areas, it requires considerable ground cover in order to be abundant in such areas. The cotton rat is seldom encountered in hammocks except at the margins where the hammocks merge into flatwoods or sandhills.

Between the cotton mouse and the cotton rat these two hosts for the larva and nymph of Dermacentor variabilis cover all the principal terrestrial habitats in northern Florida. Considering this distribution pattern, and the fact that both were found to be good hosts for the tick, it is probable that these two rodents are the most important hosts for the larva and the nymph of Dermacentor variabilis in this area.

TABLE X

HOST RELATIONSHIPS OF THE LARVA AND THE NYMPH OF *DERMACENTOR VARIABILIS* (SAY) IN NORTHERN FLORIDA

| Host | Total number examined | Total number of larvae collected | Average number of larvae per host | Total number of nymphs collected | Average number of nymphs per host |
|---|---|---|---|---|---|
| Mammalia | | | | | |
| Cotton mouse | 113 | 456 | 4.0 | 45 | 0.4 |
| Eastern cottontail rabbit | 22 | 2 | 0.1 | 7 | 0.3 |
| Florida bobcat | 9 | 0 | 0.0 | 1 | 0.1 |
| Florida deer mouse | 1 | 2 | 2.0 | 0 | 0.0 |
| Florida wood rat | 4 | 9 | 2.5 | 2 | 0.5 |
| Northern cotton rat | 67 | 245 | 3.6 | 37 | 0.5 |
| Southern golden mouse | 18 | 5 | 0.3 | 24 | 1.3 |
| Aves | | | | | |
| Bobwhite quail | 56 | 2 | 0.04 | 0 | 0.0 |

Taylor showed a high infestation rate of the larva and nymph on the rice rat in southern Florida, and Morlan published similar data from southwestern Georgia. However, because of the restricted habitat of this rat in southern Florida, it is probably not so important a host as the cotton mouse and the cotton rat. The rice rat frequents very wet marshy areas in northern Florida. The Florida wood rat is restricted to the hammocks and is not abundant. The Florida deer mouse is found only in the drier habitats such as the sandhills and is probably not of great importance as a host for Dermacentor variabilis. In this study, the southern golden mouse appeared to be a good host for the nymph but not for the larva.

Travis, without giving stages of the tick, reported a high infestation rate of Dermacentor variabilis on both the Florida cotton mouse and the Florida cotton rat in southern Florida. Presumably the ticks were all larvae and nymphs since the adult is not known to attack mammals as small as these.

Only two larvae and seven nymphs were collected from the 18 cottontail rabbits examined in this study. Morlan also found that the cottontail was not an important host in southwestern Georgia.

The record of the larva from the bobwhite quail shown in Table X is of interest because this tick has rarely, if ever, been reported from birds. The two larvae shown

represent two separate collections from that host. However, it should be pointed out that neither of the larvae taken from the quail were engorged, and it is possible that they were just temporarily on that host. It is conceivable that if a tick will cling to a cloth drag it might cling to most any other object that happened to make contact with it. Birds have certainly never been shown to be important hosts for this tick in any stage.

The Adult. The data in Table XI, as expected, bear out the importance of the dog as a host for the adult of Dermacentor variabilis. Although the number of Florida bobcats examined is not comparable to the number of dogs examined, this host showed a slightly larger average number of ticks per host. This large cat is plentiful throughout most of northern Florida and ranges over practically all of the principal terrestrial habitats. It is especially abundant in the flatwoods. Mr. Carl Jones of Gulf Hammock, Florida killed approximately 90 of these animals in the flatwoods of Levy County in about four seasons of hunting. Considering the abundance of this animal and its high rate of infestation by Dermacentor variabilis, it is probably a more important host of this tick than the dog over much of northern Florida.

Twenty-one of the 24 ticks collected from hogs came from one of the semi-wild hogs. However, the data obtained on these animals is not extensive enough to justify a strong

TABLE XI

HOST RELATIONSHIPS OF THE ADULT OF
DERMACENTOR VARIABILIS (SAY)

| Host | Total number examined | Total number of ticks collected | Average number of ticks per host |
|---|---|---|---|
| Cow | 525 | 13 | 0.02 |
| Dog | 288 | 2,107 | 7.30 |
| Florida bobcat | 9 | 74 | 8.20 |
| Florida opossum | 10 | 8 | 0.80 |
| Florida raccoon | 31 | 62 | 2.00 |
| Hog | 5 | 24 | 4.80 |
| House cat | 2 | 1 | 0.50 |
| Southern fox squirrel | 5 | 1 | 0.20 |

statement relative to their importance as a host for this tick.

The Florida opossum and the Florida raccoon are both abundant in northern Florida. A large percentage of these animals collected was infested with adults of Dermacentor variabilis, but the average rate of infestation per animal was relatively low. Morlan showed a slightly higher infestation rate for the raccoon in southwest Georgia. His data on the opossums are in agreement with that shown in Table XI.

Over most of the range of Dermacentor variabilis the cow is not considered an important host. However, Bishopp and Smith stated that in Iowa as many as 64 adults were shown to attach to a single cow in nature in one day. This is approximately five times the number collected from 525 cows during this study.

When data such as these are compared, the need for research on ticks in all of the principal areas covered by their distribution becomes more and more apparent. There were a few additional records of Dermacentor variabilis from the cow in this study that were not included in the data. These collections were made through the kindness of friends who owned host animals. The vials containing the ticks were not always labeled with the name of the host, and since dogs were also involved in all such instances

these additional records from the cow were omitted entirely. However, if all these records had been included, the total number of ticks collected from cows would not have exceeded 64.

## Seasonal Activity

Most published reports dealing with the subject indicate that temperature is the controlling factor in determining the seasonal activity of Dermacentor variabilis. However, Smith and Cole (1941) concluded that the length of day is an important factor in controlling the seasonal activity of the larva and the nymph. These authors found that long periods of daylight were more favorable for larval and nymphal activity than short ones. Their results did not show this to be true for the adult.

Bishopp and Smith studied the seasonal activity of this tick in the vicinity of Washington, D. C.; Eddy and Joyce made studies of a similar nature in Iowa; Collins et al. (1949) reported on seasonal activity on Long Island; and Smith et al. gave the seasonal cycles at Martha's Vineyard, Massachusetts. Only Morlan has published data on seasonal activities of this tick in the southeastern United States that show the actual months the various stages were collected.

The Larva. Bishopp and Smith found the larvae and nymphs of Dermacentor variabilis on hosts throughout the

winter months in the area around the District of Columbia. Eddy and Joyce working in Iowa found no larvae on hosts during December, January and February. Smith et al. found that the larvae became active in March or April, reached a peak in March, April, or May, and ceased activity in September or October at Martha's Vineyard, Massachusetts. A second peak of activity was sometimes noted by these workers in August or September.

Bishopp and Trembley stated that in the southern states ticks are found in all stages on hosts throughout the year, but that they are usually more prevalent in the spring in this area.

Table XII shows collections of the larvae and nymphs of Dermacentor variabilis on the cotton mouse, the southern golden mouse, and the northern cotton rat during this study. Larvae were collected every month in the year except June. Examination of a larger number of hosts during June might have shown the larva to be active during that month. However, Morlan found no stage of this tick on 25 cotton rats collected in southwestern Georgia during June, and he found only nymphs during March, April, and May. Morlan examined a total of 966 cotton rats. He did not break this number down by months, but he stated that nine or more cotton rats were taken each month from January 1947 to May 1948.

Additional studies are needed to show the seasonal

TABLE XII

COLLECTIONS OF THE LARVAE AND NYMPHS OF *DERMACENTOR VARIABILIS* (SAY) FROM COTTON MICE, GOLDEN MICE, AND COTTON RATS BY MONTHS, OCTOBER 1949 THROUGH SEPTEMBER 1952

| Month | Number of host examined | Number of larvae | Number of nymphs | Average number of larvae per host | Average number of nymphs per host |
|---|---|---|---|---|---|
| January | 37 | 112 | 31 | 3.0 | 0.8 |
| February | 22 | 85 | 19 | 3.9 | 0.8 |
| March | 12 | 10 | 17 | 0.8 | 1.4 |
| April | 14 | 5 | 9 | 0.3 | 0.6 |
| May | 19 | 9 | 10 | 0.5 | 0.5 |
| June | 7 | 0 | 0 | 0.0 | 0.0 |
| July | 16 | 23 | 1 | 1.4 | 0.06 |
| August | 7 | 144 | 2 | 20.6 | 0.3 |
| September | 14 | 25 | 2 | 1.8 | 0.1 |
| October | 34 | 230 | 11 | 6.8 | 0.3 |
| November | 7 | 31 | 0 | 4.4 | 0.0 |
| December | 9 | 28 | 5 | 3.1 | 0.5 |

peaks of larval activity, but the data in Table XII show trends. Based on the average number of larvae per host, the data indicate that the larvae were at a peak in October and in August. However, it should be pointed out that 130 of the 144 larvae collected in August came from a single cotton rat. Therefore, the average of 20.6 larvae per host shown for August could be abnormally high. The over-all trend indicates that the larvae were abundant on hosts during the fall and winter months, followed by a rapid decline during spring and early summer, and a low period of activity in June.

The Nymph. Table XII shows that nymphs were collected during every month in the year except June and November. Only a small number of hosts were examined during each of these months. The number of nymphs collected does not justify much discussion relative to peaks. However, the highest rate of infestation shown was in March. The larvae showed a sudden drop in activity in March. It appears that the nymphs were less active during the summer and early fall than in winter. Morlan took the nymphs from hosts in southwestern Georgia every month except June.

Except for the larval peak that possibly occurs in Florida in August, the seasonal activity for both the larva and the nymph in this area appears to be almost the exact opposite of that shown for the same stages in Massachusetts by Smith et al. and in Iowa by Eddy and Joyce.

The Adult. Table XIII shows the seasonal activity of the adult of Dermacentor variabilis in northern Florida. The data are shown graphically in Figure 2.

The data show that the adult was found on hosts throughout the year, but the season of greatest activity was not greatly different from the period of highest activity in the northern range of this tick.

Bishopp and Smith, working in Maryland and adjacent states, found that adults began activity from the middle of March to the middle of April and reached a peak in late May or early June. Eddy and Joyce found the activity of the adult to extend from April to October in Iowa, with a peak in May. Smith et al. found that activity began in April in Massachusetts, reached a peak in June or July, and ceased in August or September.

Figure 2 shows that in northern Florida the season of greatest activity began in March, rose rapidly in April to a peak in May, dropped gradually during June and July and then more abruptly in August. From September on through the winter the decline was very gradual and almost levelled off during November, December, January, and February. Although the tick was present both on dogs and wild mammals during the winter months, they certainly were not numerous enough to be considered important as pests during that season. During the time of minimum activity the ticks appeared to become active only on warm days. This was noted while

TABLE XIII

COLLECTIONS OF ADULTS OF DERMACENTOR VARIABILIS (SAY) FROM DOGS IN NORTHERN FLORIDA, OCTOBER 1949 THROUGH DECEMBER 1952

| Month | Number of dogs examined | Number of ticks collected | Average number of ticks per dog |
|---|---|---|---|
| January | 9 | 1 | 0.1 |
| February | 7 | 3 | 0.4 |
| March | 30 | 32 | 1.1 |
| April | 25 | 362 | 14.5 |
| May | 29 | 642 | 22.1 |
| June | 16 | 346 | 21.6 |
| July | 20 | 344 | 17.2 |
| August | 28 | 230 | 8.2 |
| September | 42 | 76 | 1.8 |
| October | 34 | 49 | 1.4 |
| November | 24 | 12 | 0.5 |
| December | 23 | 10 | 0.4 |

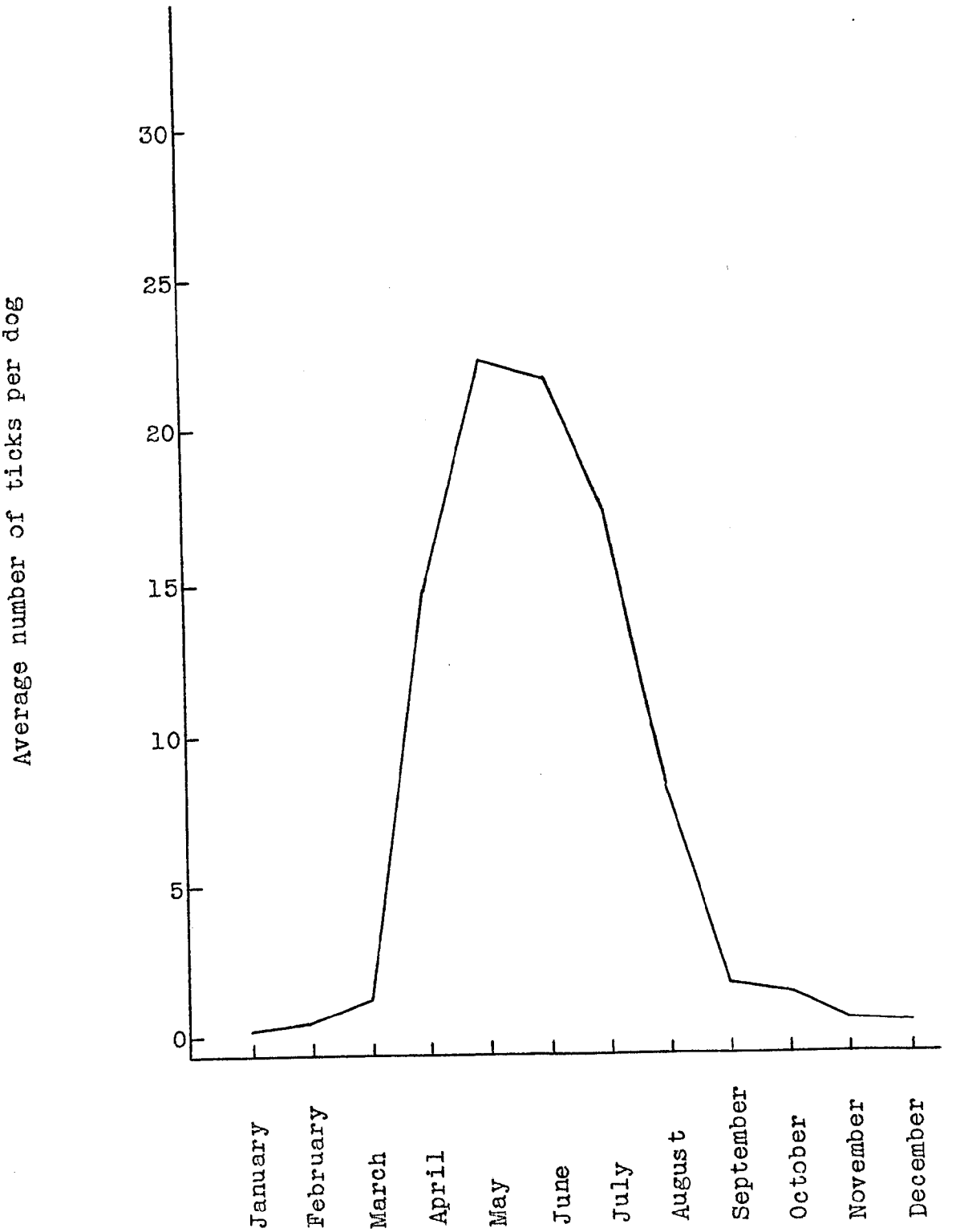


Figure 2. Seasonal activity of the adult of Dermacentor variabilis (Say). Ticks collected from dogs at regular intervals from October 1949 through December 1952.

taking samples with a cloth drag and also by collections from the writer's clothes.

Thus, it appears that the most important difference in the seasonal activity of Dermacentor variabilis in northern Florida and in the northern states is to be found in the activities of the larva and the nymph, but not the adult. This emphasizes the work by Smith and Cole on the length of day as it affects the activities of the larva and nymph.

Although very little rearing of Dermacentor variabilis was undertaken during this study, a few observations should be of interest in relation to the seasonal activity of the tick. An engorged female was collected from a dog on September 25, 1952, and placed in a field cage. The first eggs were laid October 3, and the first egg hatched November 24. All eggs had hatched by December 15, and the larvae were all in one large clump on the bottom side of a leaf lying on the ground in the cage on that date. When the cage was examined December 24 some larvae had formed a clump on the underside of the top leaf in the cage. The larvae became very active when disturbed. They swarmed over the leaves and appeared to be seeking a host. The larvae were noted to act in a similar manner on January 2, 1953, at 65 degrees and again on January 3 at 52 degrees. On January 11, at 50 degrees, the larvae were active but were very sluggish in their movements. The next examination of the cage was made on January 17 and no larvae were in the cage. There had been

several warm days just prior to that date and it is assumed that the larvae became active and escaped from the cage. No petroleum jelly had been smeared along the top rim of the cage. These observations seem to be in agreement with the high rate of larval infestations on hosts during the winter months.

## Habitat Distribution

Dermacentor variabilis was found to be prevalent both in the flatwoods and in the hammocks during this study. Almost all of the collections from dogs shown in Table XIII were made in the flatwoods. All of the records of the larvae and the nymphs from the cotton mouse, southern golden mouse, and Florida wood rat shown in Tables X and XII were from the hammock habitat. The records from the northern cotton rat shown in these tables were taken mostly in the flatwoods, with a few records coming from marginal areas.

Throughout this study not a single record of this tick in any stage was made from the sandhills habitat. Although no species of tick, other than Amblyomma tuberculatum, was found in the sandhills far removed from hammocks and flatwoods, this habitat needs more study before a positive statement can be made that no other tick can exist there. Fewer hosts were examined in the sandhills than in the other habitats and the sandhills are severely burned almost annually.

## THE GENUS HAEMAPHYSALIS KOCH, 1844

### HAEMAPHYSALIS CHORDEILIS (PACKARD), 1869

Hooker et al. published on the life cycle and host relationships of Haemaphysalis chordeilis. Except for collections from hosts, mostly birds, there appears to have been very little, if any, work conducted on the field biology of this species since that time.

The distribution given by Bishopp and Trembley include the southern and eastern parts of the United States and eastern Canada.

Although this species is usually referred to as the bird tick because birds are its preferred hosts, Bishopp and Trembley recorded it from several mammals, including man. Those authors stated that this tick is at times reported to be a serious pest of poultry in the northeastern states. To the writer's knowledge, this species has not been shown to be of any economic importance in the South.

The meadow lark is most often reported to be the principal host of Haemaphysalis chordeilis. All of the specimens taken in this study were from that host. The complete records are shown in Table XIV.

### HAEMAPHYSALIS LEPORIS-PALUSTRIS (PACKARD), 1869

The life cycle and host relationships of the rabbit tick,

TABLE XIV

COLLECTIONS OF HAEMAPHYSALIS CHORDEILIS (PACKARD) IN NORTHERN FLORIDA

| Date | | Location | Number of ticks collected | | |
|---|---|---|---|---|---|
| | | | Larvae | Nymphs | Males |
| 1951 | | | | | |
| January | 1 | Alachua County | | | 2 |
| | 26 | Alachua County | | | 1 |
| 1952 | | | | | |
| February | 29 | Alachua County | | | 1 |
| March | 14 | Alachua County | 6 | 1 | |
| | 21 | Alachua County | | 2 | |
| | 21 | Alachua County | 1 | 2 | |
| | 28 | Alachua County | 39 | 1 | |
| | 28 | Alachua County | | 2 | |
| Totals | | | 46 | 8 | 4 |

Haemaphysalis leporis-palustris, were studied by Hooker et al. Green et al. (1943) reported on a ten-year study of the rabbit tick in Minnesota; Joyce and Eddy (1942) studied this tick in Iowa; and Portman (1944) reported on it in Missouri. Morlan published on the seasonal activity in southwestern Georgia.

Although this species does not attack man, it is well known as a vector of such important diseases as Rocky Mountain spotted fever and tularemia among its hosts in nature.

According to Bishopp and Trembley, Haemaphysalis leporis-palustris is the most common and widely distributed tick in North America. Cooley (1946) stated that this species was recorded from Argentina as Haemaphysalis leporis by Aragao (1938).

The principal hosts, as the common name implies, are lagomorphs. Bishopp and Trembley listed a number of other small mammalian hosts and stated that the young stages are often found on birds in considerable numbers. Those authors listed many birds among the hosts.

Host relationships of Haemaphysalis leporis-palustris resulting from the present study are shown in Table XV. The data tend to show the importance of ground-feeding birds as hosts for the larvae and nymphs in northern Florida. This was by far the most common tick found on birds in this study.

A sufficient number of preferred hosts were not collected

TABLE XV

HOST RELATIONSHIPS OF HAEMAPHYSALIS LEPORIS-PALUSTRIS (PACKARD) IN NORTHERN FLORIDA

| Host | Number examined | Number of ticks collected | | | Average number of ticks per host | | |
|---|---|---|---|---|---|---|---|
| | | Larva | Nymph | Adult | Larva | Nymph | Adult |
| Mammalia | | | | | | | |
| Eastern cottontail rabbit | 18 | 216 | 144 | 113 | 12.0 | 8.0 | 6.3 |
| Marsh rabbit | 5 | 8 | 5 | 16 | 1.6 | 1.0 | 3.2 |
| Aves | | | | | | | |
| Bobwhite quail | 56 | 263 | 37 | 0 | 4.2 | 0.7 | 0.0 |
| Brown thrasher | 2 | 6 | 4 | 0 | 3.0 | 2.0 | 0.0 |
| Butcher bird | 2 | 6 | 1 | 0 | 3.0 | 0.5 | 0.0 |
| Cardinal | 4 | 2 | 0 | 0 | 0.5 | 0.0 | 0.0 |
| Meadow lark | 15 | 20 | 11 | 0 | 1.3 | 7.3 | 0.0 |
| Owl | 1 | 1 | 0 | 0 | 1.0 | 0.0 | 0.0 |
| Pine warbler | 8 | 2 | 0 | 0 | 0.2 | 0.0 | 0.0 |
| Robin | 5 | 3 | 3 | 0 | 0.6 | 0.6 | 0.0 |
| Towhee | 18 | 158 | 27 | 0 | 8.8 | 1.5 | 0.0 |

during each month in the year to determine whether all stages were active the year round. However, Morlan found the adults on cottontail rabbits during each month of the year for two years in southwestern Georgia, and Bishopp and Trembley reported that all stages are present on hosts throughout the year in the southern states. Portman gave the same information for southern Missouri, but not for the northern part of that State.

## THE GENUS IXODES LATREILLE, 1795

### IXODES AFFINIS NEUMANN, 1899

Ixodes affinis has not been previously reported from the United States. However, Doctor Glen M. Kohls recently stated in a personal communication that he has one specimen from Florida and has been hoping that others would be submitted to him for identification before publishing a note on its occurrence in the State.

Cooley and Kohls (1945) discussed the synonomy of this species which was apparently confused with Ixodes scapularis Say by early workers (Banks, 1908) (Nuttall et al., 1911). All published records are from Central and South America.

Two female specimens of Ixodes affinis were collected during the present study. One was collected from a dog July 14, 1951, at Gulf Hammock, Florida; the other specimen was collected from a Florida bobcat in the same locality October 28, 1951. Both specimens were sent to Doctor Glen M. Kohls for examination and he confirmed the identification. These two records and the one mentioned above by Kohls are the only ones from the United States. Although this tick is obviously established in northern Florida, it must be considered rare in light of the few specimens collected in the present study. The collection from a dog listed above is a new host record and also the first record

from a domestic animal.

## IXODES BISHOPPI SMITH AND GOUCK, 1947

Smith and Gouck (1947) described a new ixodid tick, Ixodes bishoppi, taken in numbers from birds and mammals in the vicinity of Savannah, Georgia. The description of this new species was published in 1947, just two years before this study was begun. The tick was found on 40 of 56 cotton rats examined, one of the most widespread and abundant mammals in the southeastern United States. Other hosts listed by Smith and Gouck were house wren, towhee, house mouse, and cottontail rabbit.

The finding of this underscribed tick in numbers on such a common mammal as the cotton rat in recent times, serves to emphasize further the statement that there is a great need for intensive research on ticks in the Southeast. Even more recently Morlan (1952) reported this tick from southwestern Georgia for the first time. Morlan also added the spotted skunk as a host for the larva and nymph. In a recent conversation with Doctor Carroll N. Smith in Orlando, Florida, it was learned that he and Mr. Gouck have in the past few years found this tick to be rather common in central Florida. Their records from Florida have not been published. Collections of Ixodes bishoppi in this study are shown in Table XVI. The cotton mouse is a new host record for this species.

TABLE XVI

COLLECTIONS OF *IXODES BISHOPPI* SMITH AND GOUCK

| Date | Host | Location | Habitat | Number of ticks collected | | | |
|---|---|---|---|---|---|---|---|
| | | | | Larvae | Nymphs | Males | Females |
| December 21, 1948 | Cotton rat | Palm Beach County | Ocean front | | 1 | | |
| October 29, 1949 | Cotton rat | Levy County | Meso-phytic hammock | 1 | | | |
| February 26, 1950 | Cotton mouse | Levy County | Meso-phytic hammock | | 1 | | |
| May 6, 1950 | Cotton mouse | Levy County | Meso-phytic hammock | | 1 | | |
| July 8, 1950 | Cotton rat | Levy County | ------ | | | | 3 |
| July 10, 1950 | Cotton rat | Levy County | ------ | | | 1 | 2 |
| May 3, 1952 | Cotton mouse | Levy County | Meso-phytic hammock | | 1 | | |
| September 14, 1952 | Cotton rat | Levy County | Flat-woods | 1 | | | |
| Totals | | | | 2 | 4 | 1 | 5 |

## IXODES BRUNNEUS KOCH, 1884

Ixodes brunneus has not been previously reported from Florida. However, it is not surprising that it was found during this study since it was reported from southern Georgia by Bishopp and Trembley and from Atlanta, Georgia by Cooley and Kohls (1945). Nuttall et al. reported that this species occurs in Europe, Africa, and North America, but Cooley and Kohls (1945) did not recognize records of Ixodes brunneus originating outside North America.

Ixodes brunneus is known to attack only birds. Bishopp and Trembley stated that the tick often has an adverse effect on its host. They mentioned several instances where birds were found unable to fly, or were dead, with only one adult tick attached to the head or neck. No record was found in the literature that showed data on the biology and life history of this species.

In this study, two larvae were taken from a towhee January 26, 1949, and one engorged adult was taken from a towhee January 26, 1950. Both collections were made in Austin Cary Forest, flatwoods habitat, Alachua County, Florida.

## IXODES COOKEI PACKARD, 1869

Ixodes cookei is widely distributed in the United States (Bishopp and Trembley) and has been reported from Canada by Cooley and Kohls (1945). However, published

reports indicate that it is collected more frequently in the eastern United States than in other areas. According to the above authors, this species has been found almost exclusively on wild mammals but Bishopp and Trembley also showed records from man, dog, and cow, and Cooley and Kohls recorded it from man and dog. Bishopp and Trembley's distribution records include Florida, and Taylor also collected it from a dog in Marion County, Florida.

Collections of Ixodes cookei in the present study are shown in Table XVII. In addition to these records, 30 Ixodes larvae that possibly belong to this species, were collected from a Florida raccoon, but these larvae have not been positively identified. There are no keys to the larvae of North American ticks and no known larvae of this species were available for comparison.

In view of the relatively large number of known hosts for Ixodes cookei examined in this study, it is concluded that this species is rare in northern Florida.

## IXODES TEXANUS BANKS, 1909

Ixodes texanus apparently confines its attack almost entirely to wild mammals. Cooley and Kohls (1945) and Bishopp and Trembley recorded this species from scattered locations generally throughout the United States. The latter authors also showed three collections from Florida, and Taylor recorded this tick from a raccoon in Citrus County, Florida.

TABLE XVII

COLLECTIONS OF *IXODES COOKEI* PACKARD IN NORTHERN FLORIDA

| Date | Host | Location | Habitat | Number of ticks collected | |
|---|---|---|---|---|---|
| | | | | Nymphs | Females |
| November 23, 1950 | Florida raccoon | Jefferson County | Mesophytic hammock | 1 | |
| November 25, 1950 | Florida raccoon | Taylor County | Mesophytic hammock | 1 | |
| January 17, 1952 | Florida raccoon | Alachua County | Flatwoods | | 2 |
| Totals | | | | 2 | 2 |

Ixodes texanus is apparently not abundant any place within its range. Collections made in this study are shown in Table XVIII.

## IXODES SCAPULARIS SAY, 1821

Morgan was the first worker to attempt a study of the biology of Ixodes scapularis. He called the tick Ixodes ricinus L. but it is now known that the species he studied was Ixodes scapularis. His attempts to rear this tick under laboratory conditions were not successful. However, Professor Morgan did contribute to the host list of this species. Hunter and Hooker added to the host list and mentioned that it is abundant on dogs in Florida, where some of their collections were made. Hooker (1908) also attempted to rear this species but was not successful. The same author (Hooker, 1909) gave the distribution of Ixodes scapularis as it was known in 1909.

Hooker et al. were the first workers to rear Ixodes scapularis in the laboratory. The life history information reported on this species was obtained under laboratory conditions in Texas. It is interesting to note that two of the engorged females used in their laboratory studies were collected at Hawthorne, Florida. Their paper contains the only published data on details of the life history of Ixodes scapularis.

Since 1912 brief notes on this species, referring

TABLE XVIII

COLLECTIONS OF IXODES TEXANUS BANKS IN NORTHERN FLORIDA

| Date | Host | Location | Habitat | Number of ticks collected | |
|---|---|---|---|---|---|
| | | | | Nymphs | Females |
| December 5, 1949 | Florida raccoon | Alachua County | Flatwoods | | 1 |
| December 26, 1949 | Southern fox squirrel | Taylor County | Flatwoods | 24 | |
| January 28, 1950 | Florida raccoon | Alachua County | Flatwoods | | 1 |
| September 12, 1950 | Florida raccoon | Alachua County | Flatwoods | | 1 |
| January 17, 1952 | Florida raccoon | Alachua County | Flatwoods | | 4 |
| Totals | | | | 24 | 7 |

primarily to host relationships and distribution, have been published by a number of authors. The more important of these references are Larrousse et al., Hixson (1941), Travis (1941), Bishopp and Trembley, Cooley and Kohls (1945), Brennan (1945a.), Eads (1949), and Morlan. Taylor studied the host relationships, mostly of the adult stage, and the distribution of Ixodes scapularis in Florida (unpublished thesis).

## Economic Importance

Ixodes scapularis is one of the most prevalent and most important ticks in northern Florida. Although it is not known to be a vector of any disease in nature, its abundance and wide range of hosts among the larger mammals, including man, makes this species a very important pest.

## Distribution

Taylor showed Ixodes scapularis to be present throughout Florida. Cooley and Kohls (1945) and Bishopp and Trembley gave the distribution in other areas. The latter authors reported this species from Canada to Florida, as far west as Texas, and south into Mexico. It has not been reported from the West Coast of the United States nor from the north central states. A survey of publications on ticks in various South American countries did not reveal the presence of Ixodes scapularis (Aragao 1936, 1938).

The various reports on its distribution point to the conclusion that it is not very abundant except in the extreme southern United States, and especially in Florida. This is probably the principal reason that Ixodes scapularis has not received a great deal of attention from other workers.

## Life Cycle

Seasonal Activity of the Adult. Bishopp and Trembley reported that the adult of Ixodes scapularis had been taken from hosts every month of the year in the South by workers of the United States Department of Agriculture. During four years of intensive collecting in the present study, no records of the adult were obtained in July and August, and only one in June. In view of these findings, it seems likely that records for June, July, and August are probably a result of unusual circumstances, rather than normal host-seeking activity of the tick.

In one experiment a male and a female that had been reared in the laboratory were placed on a dog in July. The female attached and engorged, but the male refused to mate with the female and repeatedly fell from the host. As will be discussed later, studies on the behavior of this species indicate that the adult does not seek a host during the hot summer months.

In order to determine the seasonal cycle of the adult,

collections were made at weekly intervals on a herd of dairy cattle near Gainesville, Florida from July 26, 1951, through July 25, 1952, and from September 16, 1952, through January 31, 1953. The data are shown in Table XIX. All ticks were collected from each animal at every collecting period. Months during which no Ixodes scapularis were found on the cows were omitted from the table. The negative months were July and August 1951 and April, May, June, and July 1952. No collections were made during August 1952.

The data show that during both seasons the first tick was found in the latter part of September. At least one animal in the herd was infested with this tick each week beginning September 21, 1951, through March 21, 1952, and from September 25, 1952, through January 31, 1953, when the studies were terminated. Thus, the season of host seeking activity of the adult began the latter part of September during both seasons.

As shown in Table XIX, the activity increased rapidly in October and reached a peak about the middle of November. The decrease in activity was also rather sharply marked in December, then more gradual during January, February, and March. The data are shown graphically in Figure 3.

The data in Table XIX do not show the complete seasonal cycle of the adult. A considerable number of collections were made from other hosts during April and May; therefore, the activity season is considered to be from September 15 to

TABLE XIX

WEEKLY COLLECTIONS OF ADULTS OF IXODES SCAPULARIS SAY FROM A HERD OF DAIRY COWS

| Date of collection | Number of cows examined | Total number of ticks | | | Average number of ticks per cow by months |
|---|---|---|---|---|---|
| | | Males | Females | Both sexes | |
| 1951 | | | | | |
| September 21 | 9 | 0 | 1 | 1 | September |
| 28 | 9 | 0 | 1 | 1 | .1 |
| October 6 | 10 | 0 | 7 | 7 | October |
| 12 | 12 | 3 | 17 | 20 | |
| 17 | 9 | 9 | 33 | 42 | 4.6 |
| 24 | 10 | 14 | 51 | 65 | |
| 31 | 9 | 18 | 76 | 94 | |
| November 7 | 10 | 31 | 115 | 146 | November |
| 14 | 9 | 76 | 258 | 334 | |
| 21 | 9 | 44 | 142 | 186 | 20.9 |
| 28 | 9 | 20 | 88 | 108 | |
| December 5 | 9 | 19 | 57 | 76 | December |
| 12 | 8 | 3 | 17 | 20 | |
| 19 | 9 | 8 | 41 | 49 | 5.4 |
| 26 | 7 | 7 | 29 | 36 | |
| 1952 | | | | | |
| January 2 | 8 | 8 | 22 | 30 | January |
| 9 | 10 | 11 | 24 | 35 | |
| 16 | 10 | 13 | 16 | 29 | 2.5 |
| 22 | 10 | 2 | 10 | 12 | |
| 30 | 10 | 3 | 12 | 15 | |
| February 6 | 9 | 7 | 23 | 30 | February |
| 14 | 9 | 3 | 13 | 16 | |
| 22 | 9 | 0 | 8 | 8 | 1.5 |
| 29 | 9 | 0 | 2 | 2 | |
| March 7 | 9 | 0 | 1 | 1 | March |
| 14 | 4 | 1 | 0 | 1 | .2 |
| 21 | 9 | 0 | 2 | 2 | |
| September 25 | 10 | 0 | 1 | 1 | September .1 |
| October 15 | 9 | 9 | 65 | 74 | October |
| 31 | 6 | 70 | 271 | 341 | 27.7 |
| November 8 | 7 | 106 | 150 | 256 | November |
| 15 | 7 | 95 | 226 | 321 | |
| 22 | 6 | 36 | 79 | 115 | 32.8 |
| 28 | 8 | 81 | 147 | 228 | |
| December 6 | 7 | 25 | 72 | 97 | December |
| 13 | 6 | 12 | 34 | 46 | 9.7 |
| 20 | 8 | 18 | 42 | 60 | |
| 1953 | | | | | |
| January 2 | 6 | 15 | 40 | 53 | January |

TABLE XIX (continued)

WEEKLY COLLECTIONS OF ADULTS OF IXODES SCAPULARIS SAY FROM A HERD OF DAIRY COWS

| Date of collection | | Number of cows examined | Total number of ticks | | | Average number of ticks per cow by months |
|---|---|---|---|---|---|---|
| | | | Males | Females | Both sexes | |
| 1953 | | | | | | |
| January | 10 | 7 | 4 | 21 | 25 | January |
| | 17 | 4 | 1 | 6 | 7 | 4.4 |
| | 31 | 3 | 0 | 1 | 1 | |

May 30 in northern Florida.

Portman (1949) reported that adults of Ixodes scapularis become active in Missouri when fall temperatures drop to around 45 degrees and continue activity until spring. This tick begins activity at much higher temperatures in northern Florida. In September 1951, the minimum temperature was 69 degrees and the average for the month was 78.6 degrees. The first reading below 50 degrees after the ticks became active occurred November 3. In September 1952, the minimum temperature recorded was 68 degrees and the average was 76.8 degrees for 28 days. Two days were not recorded because of a failure of the hygrothermograph. The first reading below 50 degrees after the ticks became active occurred October 21. Collins et al. (1949) found the adults of Ixodes scapularis to reach a peak of abundance in April on Long Island, New York.

Engorgement of the Adult. The dog was utilized as a host

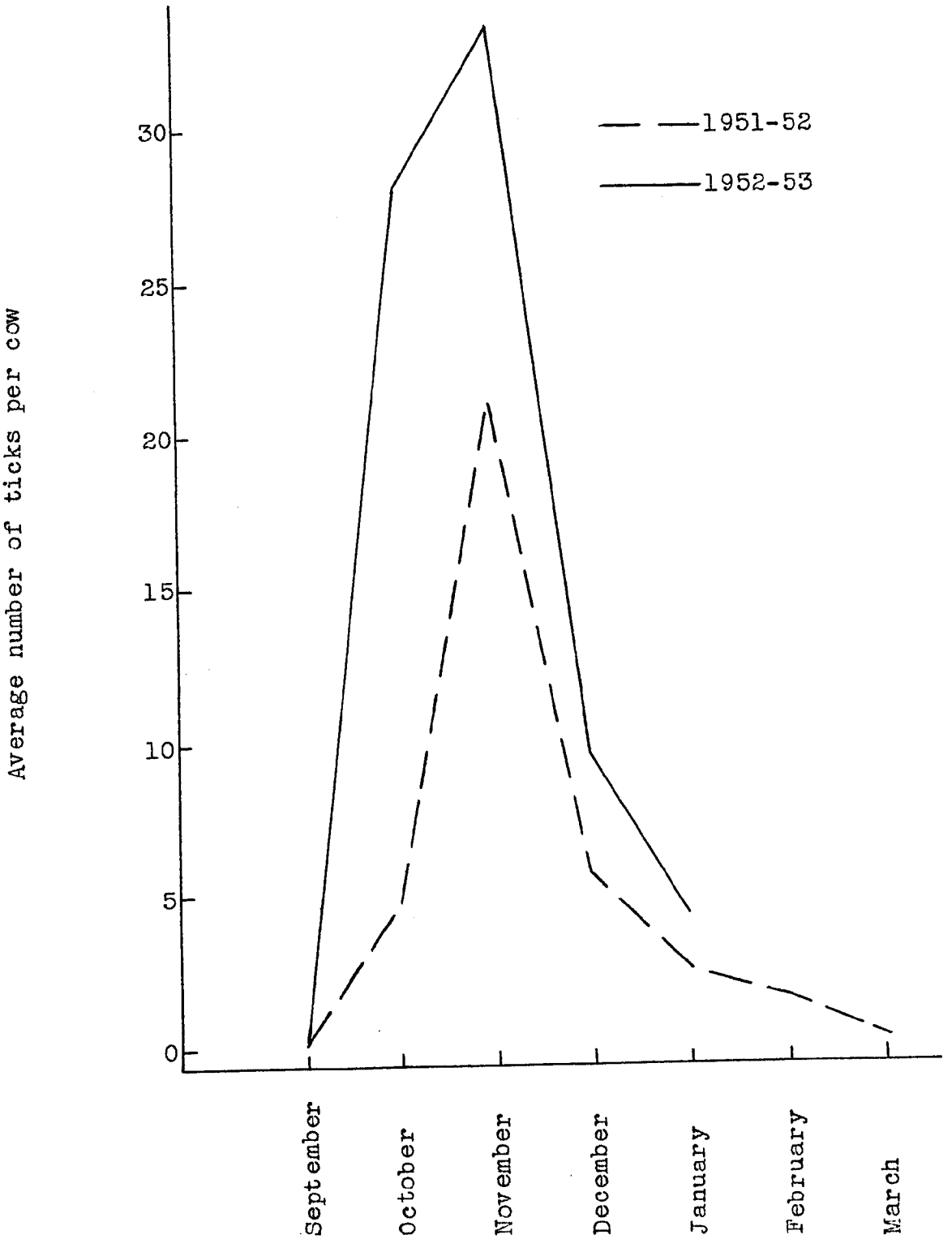


Figure 3. Seasonal activity of the adult of Ixodes scapularis Say. Ticks collected at weekly intervals from September through March, 1951-52 and from September through January, 1952-53 from the same herd of dairy cows.

in all tests conducted on engorgement of the adults of Ixodes scapularis. The minimum engorgement period was found to be six days and the maximum was 20 days. The data are shown in Table XX.

Hooker et al. studied engorgement of this species on the cow. The results obtained by these workers indicated that mating did not shorten the engorgement period. They cited two examples in which two females, both of which mated while on the host, remained attached 21 and 26 days respectively without becoming fully engorged. One of these ticks was rubbed off by the host and the other was sloughed off. The minimum period of engorgement recorded by those workers was eight days.

Results in this study show that mating did influence the duration of the engorgement period. The data in Table V show that in all tests where a tick had been attached for at least six days before mating, engorgement was completed in from one to three days after mating took place. Ticks that were mated the day they attached all engorged within the narrow range of six to ten days. Three ticks that never mated required 16 to 17, 20, and 21 days respectively for engorgement. Two ticks that had been attached for two days prior to mating both dropped engorged six days later, requiring a total of eight days between attaching and dropping.

Preoviposition. In preparation for egg laying the engorged tick may wedge itself into the space between grass

TABLE XX

ENGORGEMENT OF THE ADULT OF IXODES SCAPULARIS SAY ON DOGS

| Date tick put on host | Date first coupled with male | Date dropped | Engorgement period (days) | Days between mating and dropping |
|---|---|---|---|---|
| 1952 | | | | |
| March 20 | March 31 | April 1 | 13 | 1 |
| 20 | Never | April 4 or 5 | 16-17 | -- |
| 24 | March 24 | March 30 | 9 | 9 |
| April 6 | April 8 | April 13 | 8 | 6 |
| 6 | Never | 26 | 21 | -- |
| July 5 | Never | July 24 | 20 | -- |
| November 8 | November 8 | November 13 | 6* | 6 |
| December 6 | December 14 | December 15 | 10 | 1 |
| 6 | 8 | 13 | 8 | 6 |
| 1953 | | | | |
| January 2 | January 10 | January 12 | 11 | 3 |
| 2 | 12 | 13 | 12 | 1 |
| 26 | 26 | 31 | 6 | 6 |
| 26 | 26 | 31 | 6 | 6 |
| 26 | 26 | February 4 | 10 | 10 |

*This tick was fully engorged and dropped without being touched when the dog's skin was rolled slightly during examination.

stems at the ground level or it may crawl beneath leaves or other litter and come to rest on the top of the soil. Under the latter conditions, a small form is made in loose soils by the female and a depression is excavated beneath the anterior part of the body. In making the form, a small mound of soil is piled along each side of the body.

The preoviposition period of three specimens was reported by Hooker et al. to be 15, 16, and 17 days respectively. In northern Florida, the preoviposition period was found in this study to vary from eight to 19 days under field conditions. The data on 38 specimens collected from natural hosts between October 24, 1951, and March 7, 1952, and placed in field cages, are shown in Table XXI. The average preoviposition period was 14.7 days. The minimum period of eight days occurred in October and the maximum of 19 days occurred both in November and January.

Temperature probably has an influence on the preoviposition period but the data do not show this conclusively. Ticks collected on the same date did not all start ovipositing the same date, even when placed in adjacent field cages. This indicates that other factors must have had an influence on preoviposition.

Preoviposition data on 35 ticks kept in pill boxes on moist sand in a screened insectary agreed in general with the data from field cages. Under these conditions, the preoviposition period ranged from ten days to 33 days, and the

TABLE XXI

PREOVIPOSITION OF IXODES SCAPULARIS SAY
IN FIELD CAGES

| Date ticks collected | | Number of ticks | Average preovi-position period (days) | Average daily temperature by months | Average preovi-position period by months (days) | Range (days) |
|---|---|---|---|---|---|---|
| 1951 | | | | | | |
| October | 24 | 3 | 8.6 | 74.9 | 10.8 | 8-14 |
| | 31 | 2 | 14.0 | | | |
| November | 14 | 4 | 16.7 | 59.3 | 14.7 | 12-19 |
| | 21 | 6 | 15.3 | | | |
| | 28 | 8 | 13.3 | | | |
| December | 5 | 3 | 15.0 | 61.4 | 14.7 | 11-17 |
| | 19 | 2 | 14.0 | | | |
| | 30 | 3 | 15.0 | | | |
| 1952 | | | | | | |
| January | 2 | 3 | 18.6 | 59.6 | 18.0 | 16-19 |
| | 9 | 1 | 16.0 | | | |
| February | 6 | 1 | 17.0 | 57.8 | 17.0 | 17 |
| | 14 | 1 | 17.0 | | | |
| March | 7 | 1 | 16.0 | 64.4 | 16.0 | 16 |
| Totals | | 38 | 14.7 | | | 8-19 |

NOTE: The standard error of the mean was .44.

average was 18.7 days. Some differences are to be expected because of the differences between the two environments.

Period of Oviposition. Studies on the seasonal activity of the adult of Ixodes scapularis showed that engorged ticks were first found on hosts about October 15, both in 1951 and in 1952. The first eggs from these ticks were deposited in field cages about the third week in October of both years.

Ticks in field cages were usually not disturbed during oviposition. However, one observation showed that a tick that began oviposition November 12, 1952, deposited its last egg between February 12 and 15, 1953. This was an oviposition period of three months. Detailed observations on oviposition were made in the insectary. These data will be discussed under a separate heading.

Since the peak of activity of the adult occurred about November 15, the peak of oviposition probably occurred between December 1 and December 15. This is calculated on the basis of the average preoviposition period of approximately two weeks shown in the preceding section. Oviposition probably continues into June, and possibly early July, since a few ticks engorge and drop in May.

Incubation of Eggs. Hooker et al. reported that eggs deposited January 6, in Texas, started hatching March 17. This was a total of 72 days. The average daily temperature during that period was 62 degrees Fahrenheit.

Table XXII shows data on the incubation period of eggs in field cages from 31 ticks collected between October 31, 1951, and March 22, 1952, in northern Florida. The average incubation period was 81.2 days, with a range of 62 to 89 days. Eggs deposited during December had the longest incubation period, and those deposited in March had the shortest period.

Data on the incubation of 30 egg masses in the insectary was very similar to that in field cages for the same period. These data are included (Table XXIII) in order to show the apparent effect of higher temperatures in reducing the incubation period. Five egg masses deposited in the insectary during March 1952 had an average incubation period of 57 days, with a range of 49 to 61 days. Two egg masses deposited in April had an average incubation period of 41 days, with a range of 37 to 45 days. The average daily temperature for May 1952 was 77.3 degrees and the average for June 1952 was 81.3 degrees. These data show that the eggs deposited in April, on an average, hatched in less than half the time required by eggs deposited in November and December.

Seasonal Activity of the Larva. Engorged ticks began dropping from their hosts between October 1 and October 15. The earliest hatching of eggs recorded in this study occurred December 28, 1951.

Sufficient data were not obtained to allow a positive statement as to the time that these larvae began host-seeking

TABLE XXII

INCUBATION OF EGGS OF IXODES SCAPULARIS SAY IN FIELD CAGES

| Date oviposition began | | Number of ticks | Average incubation period (days) | Average daily temperature by months | Average incubation period by months (days) | Range (days) |
|---|---|---|---|---|---|---|
| 1951 | | | | | | |
| October | 31 | 1 | 83 | 74.9 | 83.0 | 83 |
| November | 1 | 2 | 82 | | | |
| | 13 | 2 | 79.5 | 59.3 | 80.2 | 77-82 |
| | 27 | 1 | 78 | | | |
| December | 2 | 2 | 78 | | | |
| | 3 | 1 | 83 | | | |
| | 4 | 4 | 86 | | | |
| | 10 | 3 | 87.7 | 61.4 | 85.0 | 78-89 |
| | 11 | 4 | 86.5 | | | |
| | 21 | 2 | 84 | | | |
| 1952 | | | | | | |
| January | 1 | 1 | 79 | | | |
| | 13 | 3 | 72.7 | | | |
| | 19 | 1 | 78 | 59.6 | 76.5 | 72-83 |
| | 20 | 2 | 77 | | | |
| | 24 | 1 | 83 | | | |
| March | 22 | 1 | 62 | 64.4 | 62.0 | 62 |
| Totals | | 31 | 81.2 | | | 62-89 |

NOTE: The standard error of the mean was 1.07.

TABLE XXIII

INCUBATION OF EGGS OF IXODES SCAPULARIS SAY IN A SCREENED INSECTARY

| Date oviposition began | | Number of ticks | Average incubation period (days) | Average daily temperature by months | Average incubation period by months (days) | Range (days) |
|---|---|---|---|---|---|---|
| 1951 | | | | | | |
| October | 26 | 1 | 71.0 | 74.9 | 71.0 | 71 |
| November | 1 | 1 | 68.0 | | | |
| | 10 | 1 | 77.0 | | | |
| | 14 | 1 | 83.0 | | | |
| | 15 | 1 | 85.0 | 59.3 | 82.6 | 68-94 |
| | 16 | 1 | 89.0 | | | |
| | 28 | 1 | 94.0 | | | |
| December | 1 | 1 | 83.0 | | | |
| | 2 | 4 | 85.0 | | | |
| | 3 | 2 | 89.5 | | | |
| | 18 | 1 | 87.0 | 61.4 | 86.5 | 83-92 |
| | 21 | 1 | 90.0 | | | |
| | 24 | 1 | 86.0 | | | |
| 1952 | | | | | | |
| January | 7 | 1 | 84.0 | | | |
| | 8 | 1 | 82.0 | | | |
| | 10 | 1 | 81.0 | | | |
| | 12 | 1 | 80.0 | 59.6 | 79.1 | 74-84 |
| | 21 | 1 | 74.0 | | | |
| | 26 | 1 | 74.0 | | | |
| March | 5 | 2 | 59.5 | | | |
| | 11 | 1 | 59.0 | | | |
| | 12 | 1 | 58.0 | 64.4 | 57.0 | 49-61 |
| | 30 | 1 | 49.0 | | | |
| April | 10 | 1 | 45.0 | | | |
| | 28 | 1 | 37.0 | 66.6 | 41.0 | 37-45 |
| Totals | | 30 | 75.8 | | | 37-94 |

activity. This was due primarily to the fact that the only host known at the time was in hibernation when the larvae hatched. This host was the broad-headed skink, which will be discussed later. However, observations were made on the activities of the larvae in the field cages. Eggs were hatching well by January 3, 1952. The larvae became very active on January 6, when disturbed. The temperature at that time was 64 degrees. Between January 15 and February 5, larvae were observed to be active both in field cages and in the insectary with the temperature ranging from 50 degrees to 72 degrees.

The first laboratory infestation trial was made on January 15, 1952, using a cotton mouse as a test animal. This trial and two additional trials with this host, on January 21 and February 5 respectively, were failures. The failure of the ticks to attach was probably due to the fact that the cotton mouse is not a preferred host of the larva of this tick. Two successful laboratory infestations were obtained on February 12 using the southern golden mouse as a host.

These observations on larval activity and successful laboratory infestations do not prove that the larvae were actively seeking hosts in nature at that time, but they suggest that the larvae would probably have attached to a host in January and February if the opportunity had occurred.

The earliest record of the larva from a host was March

10, 1950. This collection was made in Lake County, which is in central Florida. The earliest record in northern Florida was April 22, 1950. Table XXIV shows collections of the larvae from two of their principal hosts during 1952. The last larva was collected on August 29. Larval activity probably extends into September.

Now that some of the principal hosts of the larva are known, future studies will show the seasonal cycle more accurately. Tentatively, the seasonal cycle of the larva is considered to be from January through September.

Engorgement of the Larva. Table XXV shows the engorgement period of 736 larvae of Ixodes scapularis on various hosts. Hooker et al. engorged larvae of this species on a cow and reported an engorgement period of three to nine days.

The data in Table XXV indicate that the engorgement period might vary with different hosts. However, the number of ticks shown for some of the hosts is not sufficient to justify definite conclusions at this time. The minimum period of four days occurred on the golden mouse and the maximum of 16 days occurred on both the Carolina anole and the broad-headed skink.

Molting of the Larva. At an average temperature of 77.19 degrees Fahrenheit during May, Hooker et al. found the molting period of the larva to be from 23 to 31 days. Table XXVI shows data on molting periods of 198 larvae in

TABLE XXIV

COLLECTION OF LARVAE AND NYMPHS OF IXODES SCAPULARIS SAY ON GROUND SKINKS AND BROAD-HEADED SKINKS, 1952

| Month | Number of skinks examined | Total number of larvae collected | Average number of larvae per skink | Total number of nymphs collected | Average number of nymphs per skink |
|---|---|---|---|---|---|
| February | 1 | 0 | 0.0 | 0 | 0.0 |
| March | 5 | 0 | 0.0 | 0 | 0.0 |
| April | 0 | 0 | 0.0 | 0 | 0.0 |
| May | 20 | 149 | 7.4 | 3 | 0.1 |
| June | 14 | 28 | 2.0 | 12 | 0.8 |
| July | 6 | 7 | 1.2 | 5 | 0.8 |
| August | 23 | 3 | 0.1 | 6 | 0.3 |
| September | 6 | 0 | 0.0 | 1 | 0.2 |
| October | 6 | 0 | 0.0 | 0 | 0.0 |
| November | 4 | 0 | 0.0 | 0 | 0.0 |
| Totals | 85 | 187 | 2.2 | 27 | .3 |

TABLE XXV

ENGORGEMENT OF LARVAE OF IXODES SCAPULARIS SAY, 1952

| Date host infested | Host | Total | Average engorgement period by hosts (days) | Range (days) |
|---|---|---|---|---|
| February | Golden mouse | 3 | | |
| March | Golden mouse | 6 | 5.9 | 4-9 |
| March | Carolina anole | 13 | | |
| April | Carolina anole | 4 | 14.2 | 13-16 |
| June | Ground skink | 1 | 6.0 | 6 |
| July | Broad-headed skink | 709 | 8.8 | 6-16 |

TABLE XXVI

MOLTING OF LARVAE OF IXODES SCAPULARIS SAY IN FIELD CAGES, 1952

| Month ticks dropped engorged | Number of larvae dropped | Average molting period (days) | Range (days) |
|---|---|---|---|
| July | 149 | 21.6 | 20-27 |
| August | 49 | 21.2 | 20-26 |
| Totals | 198 | 21.5 | 20-27 |

NOTE: The standard error of the mean was .08.

field cages in northern Florida during the summer of 1952. The ticks dropped during July and August when the average daily temperature was 80.8 degrees and 79.6 degrees respectively. The minimum molting period was 20 days and the maximum was 27 days. The average for all larvae was 21.5 days.

Data in Table XXVII show molting periods in the insectary for larvae dropped during the period February 16, through August 5, 1952. These data are included to show the apparent effect of temperature on molting of the larvae. One larva that dropped in February required 52 days to molt. Seven larvae that dropped in March required an average of 60.6 days to molt, with a range of 49 to 66 days. The data for July and August in Table XXVII are very similar to that for the corresponding months in the field cages.

Seasonal Activity of the Nymph. The earliest record of a nymph of Ixodes scapularis taken in nature during this study was April 5, 1952. This specimen was taken on a cloth drag. The date is in agreement with the time of molting of the first larva in rearing test; this date was April 17, 1952. This is also additional evidence that at least some larvae attach to hosts in January or February. Nymphs that had not fed did not live through the winter in survival tests. Thus nymphs that were collected in the spring developed from larvae which dropped engorged that spring. Longevity of the larva and the nymph will be discussed more fully under a separate heading.

TABLE XXVII

MOLTING OF LARVAE OF IXODES SCAPULARIS SAY
IN A SCREENED INSECTARY, 1952

| Month ticks dropped engorged | Number of larvae dropped by months | Average daily temperature | Average molting period by months (days) | Range (days) |
|---|---|---|---|---|
| February | 1 | 57.8 | 52.0 | 52 |
| March | 7 | 64.4 | 60.6 | 49-66 |
| May | 68 | 77.3 | 27.7 | 23-40 |
| June | 3 | 81.3 | 26.7 | 24-29 |
| July | 107 | 80.8 | 23.0 | 20-31 |
| August | 23 | 79.6 | 25.0 | 22-29 |
| Totals | 209 | | 26.2 | 20-66 |

NOTE: The larvae represented in this table were engorged on the following hosts: golden mouse, ground skink, carolina anole, broad-headed skink. The average daily temperature for April 1952, not shown in the table, was 66.6 degrees.

During 1952 nymphs were taken in nature every month from April through November. Collections from skinks during 1952 (see Table XXIV) indicate that nymphs are most active during June, July, and August. However, as in the case of the larval cycle, more data are needed to show the nymphal cycle accurately.

Engorgement of the Nymph. All tests on engorgement of nymphs were conducted with the broad-headed skink. This is one of the preferred natural hosts. The data are shown in Table XXVIII.

There is an indication that temperature might affect the engorgement period; however, more data at low temperatures are needed to show this conclusively. The minimum engorgement period of seven days occurred in both July and August and the maximum of 20 days occurred in November. The range in November was 17 to 20 days. The average engorgement period for July and August was nine and nine-tenths days and in November the average was 18.4 days.

Hooker et al. reported a range of three to eight days for engorgement of nymphs on the cow.

Molting of the Nymph. Data on the molting, in field cages, of 83 nymphs that dropped engorged from June through September 1952 are shown in Table XXIX. The molting of males and females is shown separately.

Hooker et al. observed the molting of 14 nymphs. These

TABLE XXVIII

ENGORGEMENT OF NYMPHS OF IXODES SCAPULARIS SAY, 1952

| Months | Number of ticks engorged | Average daily temperature | Average engorgement period (days) | Range (days) |
|---|---|---|---|---|
| July | 26 | 80.8 | 8.9 | 7-11 |
| August | 76 | 79.6 | 10.2 | 7-19 |
| November | 5 | 61.3 | 18.4 | 17-20 |
| Totals | 107 | | 10.2 | 7-20 |

TABLE XXIX

MOLTING OF NYMPHS OF IXODES SCAPULARIS SAY IN FIELD CAGES, 1952

| Month tick dropped engorged | Totals by months Male | Female | Average daily temperature | Average molting period by months (days) Male | Female | Both sexes | Range (days) Male | Female |
|---|---|---|---|---|---|---|---|---|
| June | 3 | 0 | 81.3 | 32.3 | ---- | ---- | 30-34 | ----- |
| July | 10 | 8 | 80.8 | 31.3 | 32.4 | 31.8 | 29-33 | 32-33 |
| August | 19 | 23 | 79.6 | 30.9 | 33.3 | 32.2 | 30-32 | 30-36 |
| September | 4 | 16 | 76.8 | 28.2 | 32.9 | 31.9 | 28-29 | 29-46 |
| Totals | 36 | 47 | | 30.8 | 32.9 | 32.0 | 28-34 | 29-46 |

NOTE: The standard error of the mean for males was .23, for females 1.02, and for both sexes .23.

workers found a range of 25 to 56 days at an average daily temperature of 82.74 degrees. At slightly lower average temperatures, a minimum molting period of 28 days and a maximum of 46 days were observed in this study.

On November 9, 1952, a broad-headed skink was infested with 16 nymphs, five of which attached to the host. Two of these dropped November 25 while still only partly engorged. The other three nymphs completed engorgement; two dropped November 27 and one November 28. Two of the fully engorged nymphs were placed in a field cage and the other three nymphs were kept on moist sand in the laboratory. At the time of writing, approximately four months after the ticks dropped, these ticks appear to be in good condition and none of them has molted. Although the number of ticks in this test was small, there is a strong indication that the prolonged period without molting was due to low temperatures. It is expected that additional data will be obtained on this interesting aspect of the molting of the nymph in future studies. The possible significance of this observation in the life cycle of Ixodes scapularis will be discussed under a separate heading.

In their observations on the molting of the nymph, Hooker et al. did not find a difference in the molting period of the two sexes. The data in Table XXIX show that there was an average difference of approximately two days between the molting periods of the two sexes from July through

September. The three ticks that molted in June were males. Although the ranges overlapped, the minimum molting period for a male tick was 28 days and the minimum for a female was 29 days; the maximum for a male was 34 days, and for a female the maximum was 46 days.

## Discussion of Life Cycle

The life cycle of most three-host ticks, such as Ixodes scapularis, is a rather complicated process. This is due primarily to the fact that the parasitic stages must depend almost entirely on chance in finding a suitable host. Physical factors in the environment, especially temperature, also exert a considerable influence on the basic developmental processes. Therefore, the life cycle of individual ticks may vary in duration by several weeks, or even a year.

Considering the life cycle as covering the period from the time eggs are deposited until progeny from those eggs will begin oviposition, the minimum life cycle for Ixodes scapularis in northern Florida was found to be one year. This period was from October to October.

In determining the maximum duration of the life cycle, two factors must be considered. First, some individuals that hatch from eggs deposited in October do not find a host and deposit eggs before May of the second year. Thus, the life cycle of these individuals is extended to 19 months. Secondly, nymphs that engorge as late as November

probably do not molt until the following spring or summer. If the adults which molt from these nymphs do not deposit eggs until October of the second year, the life cycle of these individuals is extended to two years, or longer. Further studies will show whether the two-year life cycle actually occurs in northern Florida.

## Behavior

The behavior of all the parasitic stages was studied in field cages. A knowledge of the habits of ticks is essential to understanding their relationships to their hosts and to other factors of their environment.

The Larva. It is well known that the larvae of many ticks, soon after hatching, climb up on grass or shrubs and accumulate in clumps. There they await the passing of a suitable host to which they can attach. Other species remain close to the soil or ground litter at all times.

The larvae of Ixodes scapularis were found in this study to remain close to the soil. After becoming active, they crawled about among the litter near where they hatched and came to rest on the undersides of leaves or other debris. Here they remained, usually quiescent, until disturbed. When disturbed, the larvae quickly emerged from the undersides and crawled rapidly onto the top surfaces of the leaves with their forelegs extended as in the usual manner when seeking a host. If a host was not found, they returned to the undersides of the leaves within a few hours.

In tests to determine whether the larvae would climb, small sticks were stuck into the soil in the field cages in a vertical position. When the larvae were disturbed, a few individuals sometimes climbed to a height of a few inches above the top rim of the can. After several hours, these larvae returned to the undersides of leaves in the cages.

Evidence that this type of behavior prevails in the natural environment is shown by the results of collections with a cloth drag in various habitats of this tick. Although many drag samples were taken in the flatwoods habitat in connection with other phases of this study, not a single larva of Ixodes scapularis was taken in a drag sample in this habitat. The ground is characteristically covered with tall grasses in the flatwoods. Larvae were taken frequently on drag samples in the hammock habitat where leaf mold is the characteristic ground cover. The larvae were always scattered individually over the surface of the drag, never being found in clumps. This supports the observations made on behavior in field cages.

The probable cause of this behavior is that the larvae apparently have poor ability to withstand dessication. However, the only proof of this at the present is the observation that larvae died in the insectary within a few hours when kept in glass jars not containing moist sand.

The habit of remaining close to the soil is in accord

with the habits of the larva's principal hosts. This will be discussed more fully under host relationships.

The Nymph. The same general observations discussed above relative to larval behavior also apply to the nymph. However, tests have not been conducted to date to determine whether nymphs will climb vertical objects or how well they can survive atmospheric conditions above ground level. In drag samples nymphs were taken only in the hammock habitat.

The Adult. The earliest record of an adult tick molting from the nymph in this study was June 14. This was a nymph that dropped engorged from a host collected May 3. Since the nymphal activity begins in April, a few adults probably start appearing in late May or early June.

Rather extensive observations were made on the behavior of adults in field cages during 1952. Like the larvae and nymphs, the adults remained close to the soil, either under leaves on top of the soil or clinging to the undersides of leaves, throughout the summer months. They remained quiescent, usually with their legs drawn close to the body, even when disturbed. The ticks were examined by picking up the leaves with forceps and examining them with a hand lens.

It is well known by those who have come in contact with this tick during its active season that the adults are good climbers. Hooker et al. reported that Mr. E. A. Schwartz collected adults from hanging vines in Mexico. Adults were often collected from tall shrubs during this study. Since

the adults utilize only large animals as hosts the climbing habit is in accord with their host relationships.

With this information in hand, it was anticipated that during late September or early October the quiescent ticks would begin climing to seek a host. One of the open wooden frame cages, one foot square in size, was placed so that a shrub about one foot high was growing in the center of the cage. Leaves and a few sprigs of grass covered the soil in the cage. During August about 25 quiescent adult ticks were placed in this cage. The shrub and the grass were observed almost daily for tick activity. Small sticks were inserted into the soil in a vertical position in several smaller field cages in which there were quiescent ticks.

The flurry of activity to climb these various objects in the field cages did not occur as expected. The first observation of a tick climbing occurred October 6. This tick became active and climbed one of the sticks in a small field cage when the leaves in the cage were disturbed. Further observations showed that all ticks did not become active at the same time, even when disturbed. It was not until around the middle of November that most of the ticks in all cages became active. This corresponds with the time that the peak of abundance of the tick was found on cattle in this study (see Table XIX).

In most cases it seemed that the necessary stimulus for

activity was the presence of a host. In one instance, while examining the ticks in a cage, three females in a cage several feet away from the cage being examined were observed on the top rim of a cage nearby. They were actively waving their front legs as in the usual manner when seeking a host. On that same date, November 14, activity was observed in the wooden field cage containing the shrub. The ticks were stimulated by breathing close to the surface of the leaves on that date. Similar trials, almost daily up to that time, had not caused the ticks to become active. Subsequent to that time ticks were easily activated in the wooden cage, and several managed to find the trunk of the shrub and climbed to the top of it.

Observations were made on the length of time that adult ticks remained on vertical objects which they climbed. In most cases the ticks returned to the leaves in one or two days. In one instance several ticks were observed to remain up on sticks from December 1 to December 6. This was the longest period that any tick remained above the ground level in field cages during these studies.

The threshold of activity for the adult must be very low. At 35 degrees on December 17, 1952, ticks in the insectary became active when disturbed.

## Longevity

It is well known that most ticks have the ability to live

without food for long periods. This characteristic seems reasonable, and even necessary, since in nature finding a suitable host is left almost entirely to chance.

The Larva. The usual method of determining the longevity of larval ticks is to treat all the larvae that hatch from a single egg mass as a unit. The longevity is determined as the time from hatching of the first egg to the date the last larva dies. This plan was followed in the present study.

Survival was studied both in field cages and in the insectary. In the field cages the minimum survival period was 14.5 weeks and the maximum was 24 weeks. This indicates that some larvae can survive for at least five to six months under field conditions. The data are shown in Table XXX. Survival was considerably longer in the insectary where the ticks were kept in pill boxes on moist sand. The minimum survival period recorded under these conditions was 30.5 weeks and the maximum was 39.5 weeks. The date are shown in Table XXXI.

In addition to the data given above, other observations were made on a large number of larvae. On June 22, 1952, egg masses from 31 ticks, in field cages, that had their first hatch between January 21, 1952, and March 10, 1952, were checked for larval survival. Only one live larva was found. This appears to substantiate the data obtained on

TABLE XXX

LONGEVITY OF LARVAE OF IXODES SCAPULARIS SAY IN FIELD CAGES, 1951-52

| Tick code number | Date first eggs hatched | Period in which last larvae died | Approximate number of weeks survived | Range (weeks) |
|---|---|---|---|---|
| 1 | December 28, 1951 | April 29, 1952 - May 23, 1952 | 17.5-21 | |
| 34 | March 17, 1952* | June 22, 1952 - July 2, 1952 | 14.5-16 | |
| 35 | March 16, 1952 | June 22, 1952 - July 2, 1952 | 14.5-16 | 14.5-24 |
| 36 | March 19, 1952 | July 14, 1952 - July 28, 1952 | 17-19 | |
| 38 | March 19, 1952 | August 20, 1952 - September 1, 1952 | 22-24 | |

*Estimated

TABLE XXXI

LONGEVITY OF LARVAE OF IXODES SCAPULARIS SAY ON MOIST SAND IN A SCREENED INSECTARY, 1952

| Tick code number | Date first eggs hatched | Period in which last larvae died | Approximate number of weeks survived | Range (weeks) |
|---|---|---|---|---|
| 21 | February 16 | September 17-September 28 | 30.5-32 | |
| 24 | February 12 | September 28-October 10 | 32.5-34.5 | |
| 33 | February 23 | September 28-October 10 | 32.5-33 | 30.5-39.5 |
| 34 | March 13 | December 9-December 14 | 39-39.5 | |
| 38 | March 22 | December 9-December 11 | 38 | |
| 43 | March 29 | September 16-September 28 | 24-26 | |

the egg masses that were examined at regular intervals in field cages.

The Nymph. Twelve nymphs that molted August 19, 1952, and ten that molted August 21, 1952, were observed in field cages for survival.

Of those that molted August 19, four were found dead October 26 and eight were found alive. The last nymph in this group died between November 29 and December 8, 1952. Of the 12 nymphs that hatched August 21, 1952, two were found dead October 5. The last date a live nymph was observed in this cage was on October 26, 1952. Although none was found alive when the cage was checked on November 9, all of the ticks were not accounted for on this date. It is not known whether some escaped or whether they were just lost among the debris.

To summarize the results of the observations discussed above, the first nymphs were observed to die within five and one half weeks and the maximum positive record of survival was between 16 and 17 weeks.

Records of the survival of 38 nymphs in pill boxes on moist sand in the insectary are shown in Table XXXII. The minimum survival time under these conditions was 11 weeks and the maximum was 20.5 weeks.

The Adult. An unfortunate experience was met with in studying survival of adults of Ixodes scapularis in the

TABLE XXXII

LONGEVITY OF NYMPHS OF IXODES SCAPULARIS SAY ON MOIST SAND IN A SCREENED INSECTARY, 1952-53

| Date or period molted | Number of ticks | Date or period first nymph died | Date or period last nymph died | Approximate number of weeks survived | |
|---|---|---|---|---|---|
| | | | | Minimum | Maximum |
| June 8, 1952 | 1 | | September 1-16, 1952 | | 12-14 |
| June 4-8, 1952 | 3 | Before September 1, 1952 | September 16-28, 1952 | 12 | 14-16 |
| June 7, 1952 | 1 | | September 25-October 10, 1952 | | 16-18 |
| June 10, 1952 | 1 | | September 1-16, 1952 | | 12-14 |
| August 17, 1952 | 16 | Before November 10, 1952 | December 9-17, 1952 | 12 | 16-17.5 |
| August 19, 1952 | 6 | November 21-27, 1952 | January 5-10, 1953 | 14-15 | 20-20.5 |
| August 20, 1952 | 4 | Before November 10, 1952 | December 26, 1952-January 5, 1953 | 12 | 18.5-20 |
| August 22, 1952 | 6 | Before November 10, 1952 | November 21-27, 1952 | 11 | 13-14 |
| Totals | 38 | | | 11 | 20.5 |

field. It was planned to keep survival records on all adults that molted in the field cages. The unfortunate experience was that most of the adults escaped from the cages when the ticks became active in the fall. It had been assumed, wrongly, that the ring of petroleum jelly on the top rim of the cages would prevent their escape. Data were obtained on a small number of ticks and are shown in Table XXXIII. The minimum survival period observed was eight and one-half weeks and the maximum was 17 weeks.

Most of the engorged nymphs were placed in field cages to molt; therefore, only a few adult ticks were kept under insectary conditions. Survival data on these ticks are shown in Table XXXIV. A male that molted September 3, 1952, was still alive March 18, 1953, a minimum survival period of 28 weeks.

The data in Table XXXIII show a maximum survival of 17 weeks in field cages as compared to a maximum of 30 weeks on moist sand in the insectary.

Although the data do not represent a large number of ticks, the results indicate that the adults of Ixodes scapularis probably do not survive from one season of activity to the next in northern Florida. However, additional data are needed before this conclusion can be accepted without reservation. There are no published data on the longevity of adults of Ixodes scapularis.

TABLE XXXIII

LONGEVITY OF ADULTS OF IXODES SCAPULARIS SAY IN FIELD CAGES WITHOUT FOOD, 1952-53

| Date or period molted | Number of ticks | Date or period first tick died | Date or period last tick died | Approximate number of weeks survived | |
|---|---|---|---|---|---|
| | | | | Minimum | Maximum |
| September 14, 1952 | 1 | | December 26, 1952-January 3, 1953 | | 15 |
| September 29-October 1, 1952 | 2 | | December 9-17, 1952 | | 10-11.5 |
| September 29-October 4, 1952 | 3 | December 9-17, 1952 | December 26, January 3, 1953 | 10-11.5 | 12.5-14 |
| October 1-4, 1952 | 3 | Before December 1, 1952 | December 9-17, 1952 | 8.5 | 10-11 |
| October 2-5, 1952 | 4 | December 9-17, 1952 | January 26, 1953 | 10-11 | 17 |
| Totals | 13 | | | 8.5 | 17 |

TABLE XXXIV

LONGEVITY OF THE ADULT OF IXODES SCAPULARIS SAY ON MOIST SAND IN A SCREENED INSECTARY

| Date | Sex | Date or period tick died | Approximate number of weeks survived | |
|---|---|---|---|---|
| | | | Minimum | Maximum |
| June 27, 1952 | Male | Before November 10, 1952 | ---- | 19.5 |
| July 4, 1952 | Female | Before November 10, 1952 | ---- | 18.5 |
| July 9, 1952 | Female | February 1- February 5, 1953 | 29.5 | 30.0 |
| July 10, 1952 | Male | January 13- January 19, 1953 | 27.0 | 28.0 |
| August 29, 1952 | Female | March 16- March 18, 1953 | 24.0 | 24.5 |

## Host Relationships

The immature stages of Ixodes scapularis have been reported as attacking reptiles, birds, and mammals. The adult has been recorded from almost all of the larger mammals within its range of distribution. The most important references on host relationships are listed on page 85.

Most of the publications cited have only brief notes on the hosts for the immature stages, representing miscellaneous collections, and do not indicate the preferred hosts of the larvae and nymphs. The only previous collections extensive enough to determine the usual hosts of the immature stages were conducted in the area of Naushon Island, Massachusetts. Larrousse et al. first reported that the white-footed mouse was the normal host for the immature stages of Ixodes scapularis in that area. Following this lead, it was expected that the cotton mouse would be an important host in Florida. The data given below will show that this assumption was wrong.

The Larva. The most important host for the larva of Ixodes scapularis found in this study was the ground skink. As shown in Table XXXV, 66.1 per cent of these skinks examined between January and September were infested. Brennan (1945a.) first reported this skink to be a host of the larva and nymph. Brennan's record was from Camp Bullis, Texas.

The ground skink is one of the most abundant lizards in northern Florida. Its preferred habitat appears to be

TABLE XXXV

HOST RELATIONSHIPS OF THE LARVA OF IXODES SCAPULARIS SAY IN NORTHERN FLORIDA

| Host | Total number examined | Number infested | Per cent infested | Total number of larvae collected | Average number of larvae per animal |
|---|---|---|---|---|---|
| Mammalia | | | | | |
| Florida deer mouse | 1 | 1 | 100.0 | 1 | 1.0 |
| Southern golden mouse | 17 | 2 | 11.8 | 2 | 0.1 |
| Cotton rat | 40 | 1 | 2.5 | 1 | 0.02 |
| Aves | | | | | |
| Brown thrasher | 2 | 1 | 50.0 | 1 | 0.5 |
| Reptilia | | | | | |
| Broad-headed skink | 13 | 5 | 38.5 | 117 | 9.0 |
| Ground skink | 56 | 37 | 66.1 | 70 | 1.2 |
| Glass snake | 1 | 1 | 100.0 | 32 | 32.0 |
| Carolina anole | 15 | 2 | 13.3 | 4 | 0.2 |

NOTE: The figures in column two are the numbers of each host examined during the season of activity of the larva, January through September. The records cover the period from October 1949 through December 1952.

hammocks with a good quantity of leaf mold on the forest floor; however, it has been found in all habitats studied where there was a good quantity of ground litter present. Unlike most lizards, these little skinks remain at the ground level and apparently never climb. They live in the ground litter and during their most active season they may be seen by the dozens crawling rather rapidly among the leaves. When disturbed they disappear rapidly in the leaf mold, where it is almost impossible to find them again.

Apparently not much is known about the natural history of this lizard in Florida, so the following observations seem to be worth noting. The lizard was found to be very active in early spring and summer. About the middle of June 1952, the activity was rather suddenly decreased and it became difficult to find the skinks. This was true in the same areas where the skinks had been very active only a few weeks before the decrease in activity was noted. They continued to be relatively inactive until about September. After this time they were more active, especially the immature forms, than during the summer, but the adults were not nearly so active as in the spring. The last regular collection of these skinks during 1952 was November 29. Observations on their activities were continued throughout the winter months on the campus of the University of Florida. A small number of individuals were observed to be active on warm days throughout this period. The period of greatest

activity of the adults coincides with the period of greatest activity of the larva of Ixodes scapularis.

The reasons for stating that this skink is the most important host of the larva of Ixodes scapularis in northern Florida are (1) it was the most abundant lizard encountered; (2) its habit of living in the ground litter keeps it in constant contact with the environment of the larvae; (3) a high percentage of the lizards collected were infested; and (4) it is active to some extent every month in the year, and especially during the spring when the larval ticks are most active.

On the ground skink most of the ticks were found attached along the tail, but they occasionally were found on the anterior parts of the body.

Hixson (1941) was the first to report the broad-headed skink as a host of the larva and nymph of Ixodes scapularis in Florida. Hixson called this host the blue-tailed skink, but Carr stated that he had not seen this skink in Florida and indicated that it was doubtful that specimens previously reported from the State were really that species. Since the broad-headed skink is common in the area where Hixson's collections were made, it was probably this skink from which he collected the larvae and nymphs of this tick.

As shown by the data in Table XXXV, the broad-headed skink is an excellent host for the larva of Ixodes scapularis. It is much larger than the ground skink and had a

much higher infestation rate per individual. However, there are several reasons why it is not considered so important a host as the ground skink.

This large skink is limited in its local distribution to the hammock habitat and to marginal areas at the peripheries of the hammocks. Not a single specimen was found in the flatwoods or in the sandhills in this study. This is in agreement with Carr on the habitat distribution of this skink. Although the broad-headed skink is common in its habitat, it does not begin to compare in abundance with the ground skink in the hammocks. Where the ground skink lives in the ground litter, in close contact with the ticks, the broad-headed skinks are tree dwellers. According to Carr these lizards rarely leave their tree homes except during the mating season, which is in April and May. During the mating season the males fight on sight and are often seen chasing one another over the leaves on the ground. This period of activity on the ground coincides with the period of activity of the larval ticks. Larvae were collected from this skink from May through July, but not in large numbers during June and July. This, however, may have been due as much to the decrease in larval activity as to the habits of the host. Goin and Goin (1951) recently published on the natural history of this skink. These authors found that the skinks go into hibernation in September or

October and begin emerging from hibernation in March and April in the area of Gainesville, Florida.

Engorged larvae and nymphs on this host are shown in Plate 5. The ticks may attach on any part of the body, but the preferred spots are along the sides behind the legs, especially the front legs.

Another skink from which the larva of Ixodes scapularis was collected in this study was the glass-snake. Eads published a record of one nymph of this tick from the glass-snake in Texas. The collection of the larva in the present study is the first record of this stage of the tick on this host.

This large, legless skink, according to Carr, is fairly abundant in dry flatwoods, sandhills (Carr's high-pine), and upland hammocks. He did not list this species as occurring in mesophytic hammocks where the ground skink and broad-headed skink are common.

Although several of these interesting skinks were observed during this study, only one was collected. These lizards are very adept at escaping and take flight quickly when disturbed. The green color of the dorsal scales makes them difficult to see in grass, and one is usually not aware of their presence until they run.

The specimen collected was taken in the flatwoods during May 1952 and was infested with 32 larvae and three nymphs of Ixodes scapularis. All of the ticks were attached in the

longitudinal folds along the sides of the body and in the ears. The remainder of the body surface is covered with highly polished and closely overlapping scales. It seems very improbable that ticks could penetrate between these scales. This probably explains the distribution of the ticks on the skink's body.

Although only one specimen was examined, the large number of ticks with which it was infested, and the fact that this skink is common in the flatwoods suggests that it is one of the most important hosts in that habitat.

Collections of the larva of Ixodes scapularis from the Carolina anole also represents a new host record. This lizard, while found in all habitats of the tick, seemed to be of minor importance as a host.

Of the mammals listed in Table XXXV, only the southern golden mouse and the cotton rat were examined in sufficient numbers to justify an opinion of their importance. Neither of these rodents appeared to be of very much importance as a host for the larva. The southern golden mouse is restricted to the hammocks and the cotton rat is abundant in flatwoods and sandhills which are not frequently burned. Both of these mammals represent new host records for the larva.

The Florida deer mouse is found characteristically in the sandhills and scrubby marginal areas in northern Florida.

This would seem to limit its importance as a host based on the present knowledge of the habitat distribution of the tick. The collection of the larva from the Florida deer mouse is also a new host record.

The larva has been found on the cotton mouse by other workers(Bishopp and Trembley), but no records from this host were obtained in this study. Several attempts to infest the cotton mouse with larvae in the insectary were all failures. Although this mouse is very abundant in the hammocks of northern Florida, it is probably of little importance as a host for the larva of Ixodes scapularis.

Hooker et al. reported the immature stages of Ixodes scapularis from the quail, the blue jay, and the thrush. Bishopp and Trembley added the towhee to the known avian hosts.

None of the previous records from birds represent large numbers of positive collections or large numbers of ticks. A considerable number of birds, including all of the principal ground birds, were examined during this study and the record of one larva from a brown thrasher, shown in Table XXXV, is the only one obtained. Eads stated that he had taken no larvae and only a few nymphs of this tick from mammals and birds in Texas. Also, Brennan (1945a.) made extensive collections of ticks from many species of mammals and birds in Texas but reported the immature stages of Ixodes scapularis as occurring only on reptiles. Thus, it

is concluded that reptiles, and especially the skinks, are the principal hosts for the immature stages of Ixodes scapularis in northern Florida, and probably throughout the deep South.

The Nymph. The data in Tables XXXV and XXXVI show a close similarity between the hosts for the larva and for the nymph of Ixodes scapularis. The principal difference seems to be that the nymph is more frequently found on mammals, especially larger mammals, than is the larva. This is more evident in host records published by Bishopp and Trembley than in the data in Table XXXVI. Among the larger mammals, these authors reported records of the nymphs from the dog, white-tailed deer, and man. Taylor occasionally found the nymph on dogs in Florida. However, these records of the nymph from larger mammals do not indicate frequent or extensive collections from these hosts.

The collections of the nymph from the Florida bobcat and the cotton rat (Table XXXVI) are new mammalian host records for the nymph of Ixodes scapularis.

In addition to the records of the immature stages from birds discussed under host relationships of the larva, Bishopp and Trembley showed that the nymph has been taken on one occasion from a cardinal. Their record of 11 nymphs from two towhees is also interesting. The locality of these records was not given. A total of 18 towhees were examined during the present study and all were negative for Ixodes

TABLE XXXVI

HOST RELATIONSHIPS OF THE NYMPH OF IXODES SCAPULARIS SAY IN NORTHERN FLORIDA

| Host | Total number examined | Number infested | Per cent infested | Total number of nymphs collected | Average number of nymphs per animal |
|---|---|---|---|---|---|
| Mammalia | | | | | |
| Cotton mouse | 69 | 2 | 3.0 | 2 | 0.03 |
| Cotton rat | 40 | 3 | 7.0 | 3 | 0.07 |
| Florida bobcat | 7 | 1 | 14.3 | 1 | 0.10 |
| Reptilia | | | | | |
| Broad-headed skink | 13 | 10 | 77.0 | 28 | 2.10 |
| Ground skink | 56 | 2 | 3.6 | 2 | 0.03 |
| Glass snake | 1 | 1 | 100.0 | 3 | 3.00 |

NOTE: The figures in column two are the numbers of each host examined during the season of activity of the nymph, April through November. The records cover the period from October 1949 through December 1952.

scapularis.

The diverse nature of the host records of the immature stages of Ixodes scapularis discussed above tend to bear out the statement made in the introduction of this paper relative to the need for intensive studies of ticks in all parts of their ranges. There seems to be little doubt that small mammals serve as the principal hosts of the larva and nymph of Ixodes scapularis in Massachusetts. There also appears to be little doubt that reptiles are the principal hosts in northern Florida, and possibly throughout the southern range of this tick.

The Adult. As indicated earlier, the host relationships of the adult seems to be the one phase of the biology of Ixodes scapularis which is well known. This wide knowledge of the hosts of the adult ticks has resulted from contributions by many workers who have made both extensive and infrequent collections of ticks from the larger mammals, which serve as the principal hosts of the adult of this tick. The only record of the adult of Ixodes scapularis from a host other than mammals seems to be one reported by Cooley and Kohls (1945). This is a record of three females from the eastern blue jay taken at North Little Rock Arkansas.

Hunter and Hooker were the first workers to call attention to the abundance of the adult of Ixodes scapularis in Florida, and to the fact that this tick is a serious pest

of dogs in the State. Banks (1908) also discussed its abundance in Florida, southern Texas, and other parts of the South.

Table XXXVII shows host records of the adult in the present study. The cow seems to be a better host than the dog. There are no published data comparable to these that show a comparison of the importance of this tick on various domestic animals.

The data from wild animals, while not as extensive as that from the cow and the dog, are also of considerable interest. The Florida bobcat seemed to stand out among the hosts in this group. The opossum and the raccoon are among the most abundant larger mammals in all the habitats of this tick in northern Florida, yet they appeared to be very poor hosts.

Another interesting thing about the data in Table XXXVII is the more than two to one ratio of female ticks to male ticks collected from hosts. The same holds true for the data in Table XIX, where all ticks were collected at regular weekly intervals from dairy cows for a period of almost two years.

The female of Ixodes scapularis characteristically attaches on certain parts of the body of its host, and the favorite points of attachment seem to vary with the host. This tick has been called by various common names, one of which is the shoulder tick. This name undoubtedly arose

TABLE XXXVII

HOST RELATIONSHIPS OF THE ADULT OF
*IXODES SCAPULARIS* SAY IN NORTHERN FLORIDA,
OCTOBER 1949 THROUGH DECEMBER 1952

| Host | Total number examined | Total number ticks collected | | | Average number ticks per animal | | |
|---|---|---|---|---|---|---|---|
| | | Males | Females | Both sexes | Males | Females | Both sexes |
| Cow | 448 | 834 | 2476 | 3310 | 1.7 | 5.5 | 7.4 |
| Deer | 6 | 22 | 49 | | --- | --- | --- |
| Dog | 200 | 207 | 573 | 780 | 1.0 | 2.9 | 3.9 |
| Florida black bear | 4 | 3 | 14 | 17 | --- | --- | --- |
| Florida bobcat | 8 | 93 | 126 | 219 | 11.6 | 15.7 | 27.4 |
| Florida gray fox | 4 | 4 | 9 | 13 | 1.0 | 2.2 | 3.2 |
| Florida opossum | 9 | 1 | 5 | 6 | 0.1 | 0.5 | 0.7 |
| Hog | 5 | 0 | 1 | 1 | --- | --- | --- |
| Horse | 3 | 13 | 22 | 35 | 4.3 | 7.3 | 11.7 |
| House cat | 1 | 0 | 1 | 1 | 0.0 | 1.0 | 1.0 |
| Man | --- | 0 | 3 | 3 | 0.0 | --- | --- |
| Raccoon | 20 | 0 | 1 | 1 | 0.0 | 0.05 | 0.05 |
| Totals | | 1177 | 3280 | 4457 | | | |

NOTE: The figures in column two are the numbers of each host examined during the season of activity of the adult, September 15 through May 30. The records cover the period from October 1949 through December 1952. Averages were omitted where all ticks present on a host were not collected.

from an observation that the tick occasionally attaches at the top of the withers on the cow. However, attachment at that point is the exception rather than the rule. In this study, the favorite places of attachment on the cow were found to be under the lower jaw, the dewlap, the sides of the neck, and in the axillaries of all legs. Attachment in the axillaries seems to be a poor adaptation on the part of the tick. Many engorged ticks were found to be crushed as a result of the legs rubbing against the body of the cow.

On the dog the ticks were found to attach along the back from a short distance behind the shoulders to the head, all around the neck, on the ears, the sides of the head, and occasionally on the underside of the body. Attachment on the Florida bobcat appeared to be similar to that on dogs.

Circumstances did not permit collection of all the ticks present on the four Florida black bears examined, but the infestation seemed to be more general over the body than on other hosts.

The male of Ixodes scapularis does not attach to the host, in the usual meaning of the term, and is of no importance as a parasite. This observation has not been recorded in published reports on this tick. Nuttall et al. (1911) noted that the male of Ixodes ricinus L. in England had been observed to attach to a host, but that it had not been demonstrated that the male actually sucked blood.

Hixson (1934) found in a study of Ixodes sculptus

Neumann that the male of that species was not parasitic. Smith (1945) found the same to be true of the male of Ixodes dentatus Marx. These observations raise the question as to whether the male of any Ixodes tick is of any importance as a parasite. This seems to be a likely possibility when one considers the mating habits of these ticks, which will be discussed below.

After observing that the males never seemed to be attached when collected from a host, special attention was given to activities of the male during many months of collecting. Throughout this time there was only one instance in which a male was observed in what appeared to be a feeding position. This tick was on a cow, and during the time that it was being observed with a hand lens the tick moved away from the spot where it seemed to have its mouth parts inserted. On one other occasion, during the engorgement tests on dogs, a male tick was placed on the host near where a female tick was attached. The male went directly to the skin of the host and inserted its hypostome. This was observed with a hand lens. The tick remained in this position for a period of not more than three or four minutes, then it withdrew its hypostome from the host and went directly to the female and began mating. It seems unlikely that the tick could have taken much blood, if any, during this short interval. In all other instances where males were placed on a host near female ticks the males either started

crawling among the hairs of the host or went directly to the females and started mating.

## Mating

According to Nuttall et al. the mating process of Ixodes ticks was first described by Degeer in 1778. Although the process of the male pushing the spermatophore deeply into the oviduct of the female with its hypostome seems to be the usual method of mating among ticks, the unusual thing about this in the genus Ixodes is that the male may remain in the mating position with its hypostome inserted into the genital pore of the female for several days.

Another unusual habit of some species of Ixodes is that the ticks seem to mate any place where the sexes are brought together. With most other ticks, mating seems to occur only after the ticks are on a host and one sex, or both, have started sucking blood.

In this study, Ixodes scapularis was observed mating in field cages on two occasions during life history studies, and once an unattached female with a male in the mating position was collected from a cow. The ticks almost always coupled after being placed together in containers in the field.

Since feeding is not a prerequisite to mating, and since the male remains attached to the female for long periods of time while mating, it seems reasonable to assume that the

male need not be parasitic in order to perform its principal function in the reproductive process.

## Process of Oviposition

Nuttall et al. and Lees and Beament (1948) described the process of oviposition in Ixodes ricinus L. This process was found to be very similar in Ixodes scapularis but some differences were noted. Therefore, it seems worthwhile to describe the process as it was noted in this study.

With the hypostome in a ventral position, the ovipositor starts to protrude; the palpi begin to spread laterally when the extruding ovipositor reaches the end of the hypostome; Gene's organ does not reach maximum size until the palpi begin to spread; the horns of Gene's organ receive the egg at about the middle of the second palpal article; with the egg being held on top of the hypostome by Gene's organ, the ovipositor starts to recede and the palpi begin to close; the egg is drawn backward toward the base of the hypostome while the hypostome is still in the ventral position, and the egg appears to be rotated slightly between the horns of Gene's organ; when the palpi are completely closed the hypostome is suddenly brought back to its horizontal position and the egg is pushed into the egg mass above the scutum; the hypostome immediately starts to return to the ventral position; when the hypostome is again in the ventral position the ovipositor starts to protrude and the

whole process is repeated.

Lees and Beament observed that Gene's organ retracted completely within the body of Ixodes ricinus before the hypostome was raised with the egg on its dorsal surface. In Ixodes scapularis, Gene's organ is in contact with the egg from the time it is received from the ovipositor until it is pushed into the egg mass. This organ is not fully retracted into the body when the tick is continually laying eggs. According to Lees and Beament, the principal function of Gene's organ is to cover the eggs with wax as a protection against dessication.

## Number of Eggs Laid

There are no published data on the number of eggs deposited by Ixodes scapularis. Hooker et al. estimated that one engorged tick laid 3,000 eggs but the eggs were not counted.

Table XXXVIII shows the oviposition records of nine engorged ticks on moist sand in the insectary. The maximum number of eggs laid by an individual tick was 2,807 eggs and the minimum number was 1,108 eggs. The average number for the nine ticks was 2,052.7 eggs.

Table XXXIX shows a typical daily oviposition record of Ixodes scapularis. Almost all of the ticks for which daily oviposition records were kept lived for several weeks after the last egg was laid.

TABLE XXXVIII

OVIPOSITION RECORDS OF IXODES SCAPULARIS SAY

| Date tick collected or dropped | Size of tick | Date first egg laid | Date last egg laid | Oviposition period (days) | Total number of eggs laid |
|---|---|---|---|---|---|
| March 14, 1952 | 9x7x5 | March 30, 1952 | May 15, 1952 | 47 | 2,778 |
| March 28, 1952 | 9x6x5 | April 10, 1952 | May 22, 1952 | 43 | 2,115 |
| March 30, 1952 | 8x6x3 | -------- | May 20, 1952 | -- | 1,108 |
| April 1, 1952 | 7x6x5 | -------- | May 22, 1952 | -- | 1,334 |
| April 13, 1952 | 6.5x5x3.2 | April 28, 1952 | May 31, 1952 | 34 | 1,550 |
| November 13, 1952 | 9x6.5x5 | December 1, 1952 | February 20, 1953 | 82 | 2,018 |
| November 28, 1952 | 9.5x7.5x5.5 | December 21, 1952 | March 14, 1953 | 84 | 2,506 |
| November 28, 1952 | 9x6.5x5.5 | December 21, 1952 | February 22, 1953 | 64 | 2,258 |
| December 6, 1952 | 10x7x5.5 | January 7, 1953 | March 13, 1953 | 66 | 2,807 |

NOTE: The size of ticks is in millimeters. Reading from left to right in column two the figures represent length, width, and thickness. The hypostome was not included in the length measurement.

TABLE XXXIX

DAILY OVIPOSITION RECORD OF A FEMALE OF *IXODES SCAPULARIS* SAY COLLECTED NOVEMBER 28, 1952

| Day | Number of eggs | Day | Number of eggs | Day | Number of eggs |
|---|---|---|---|---|---|
| 1 | 56 | 29 | 136 | 57 | 14 |
| 2 | 12 | 30 | 101 | 58 | 0 |
| 3 | 26 | 31 | 59 | 59 | 1 |
| 4 | 16 | 32 | 73 | 60 | 3 |
| 5 | 67 | 33 | 28 | 61 | 4 |
| 6 | 60 | 34 | 49 | 62 | 3 |
| 7 | 52 | 35 | 47 | 63 | 2 |
| 8 | 62 | 36 | 0 | 64 | 4 |
| 9 | 33 | 37 | 6 | 65 | 0 |
| 10 | 78 | 38 | 30 | 66 | 0 |
| 11 | 188 | 39 | 14 | 67 | 0 |
| 12 | 3 | 40 | 29 | 68 | 0 |
| 13 | 0 | 41 | 14 | 69 | 0 |
| 14 | 33 | 42 | 29 | 70 | 0 |
| 15 | 0 | 43 | 25 | 71 | 0 |
| 16 | 1 | 44 | 27 | 72 | 0 |
| 17 | 12 | 45 | 7 | 73 | 0 |
| 18 | 128 | 46 | 11 | 74 | 0 |
| 19 | 1 | 47 | 14 | 75 | 0 |
| 20 | 100 | 48 | 18 | 76 | 0 |
| 21 | 83 | 49 | 27 | 77 | 0 |
| 22 | 16 | 50 | 12 | 78 | 0 |
| 23 | 11 | 51 | 6 | 79 | 0 |
| 24 | 6 | 52 | 7 | 80 | 0 |
| 25 | 73 | 53 | 19 | 81 | 0 |
| 26 | 66 | 54 | 9 | 82 | Tick died |
| 27 | 108 | 55 | 11 | | |
| 28 | 125 | 56 | 1 | | |

NOTE: The numbering of the days starts on the date oviposition began. For this tick the first date of oviposition was December 21, 1952. The total number of eggs laid was 2,258. Oviposition was in a screened insectary.

## Effect of Temperature on Oviposition

Table XL shows the average number of eggs laid per day by four specimens of Ixodes scapularis and the corresponding average temperatures. The threshold for oviposition appeared to be approximately 50 degrees. The data in Table XL are typical of all data recorded with reference to the influence of temperature on oviposition.

At 72 degrees the rate of oviposition was observed on two different occasions to be one egg every six minutes. At that rate a tick would lay 240 eggs in 24 hours. The largest number recorded for an individual tick was 241 eggs in 25.5 hours. The average temperature during that period was 68.7 degrees.

Data in Table XXXVIII also indicate the effect of temperature on the rate of oviposition. Ticks that began laying eggs in late March and in April completed oviposition in a shorter time than those that began oviposition in December and in January.

## Habitat Distribution

Ixodes scapularis was found to be prevalent in the flatwoods and in the hammocks of northern Florida. This species was not collected in any stage in the sandhills far removed from hammocks or flatwoods, as shown by the data in Table IX. This is a strong indication that Ixodes scapularis does not successfully propagate itself in the sandhills. However, since it was shown in this study that habitat burning

TABLE XL

AVERAGE NUMBER OF EGGS LAID PER DAY
BY FOUR SPECIMENS OF IXODES SCAPULARIS SAY
FROM JANUARY 1, 1952, THROUGH JANUARY 27, 1952

| Date | Average temperature | Average number of eggs laid |
|---|---|---|
| January 1 | 50.5 | 5.7 |
| 2 | 56.9 | 12.5 |
| 3 | 47.0 | 3.2 |
| 4 | 43.8 | 2.2 |
| 5 | 50.2 | 3.2 |
| 6 | 55.9 | 59.5 |
| 7 | 63.4 | 80.2 |
| 8 | 64.5 | 115.2 |
| 9 | 60.2 | 60.7 |
| 10 | 49.9 | 12.7 |
| 11 | 45.2 | 9.0 |
| 12 | 43.4 | 9.2 |
| 13 | 54.2 | 96.7 |
| 14 | 62.1 | 87.5 |
| 15 | 65.8 | 89.5 |
| 16 | 66.9 | 91.0 |
| 17 | 68.7 | 144.2 |
| 18 | 68.4 | 111.7 |
| 19 | 68.6 | 80.0 |
| 20 | 63.2 | 91.5 |
| 21 | 62.3 | 17.2 |
| 22 | 66.5 | 68.7 |
| 23 | 56.2 | 41.5 |
| 24 | 49.1 | 0.0 |
| 25 | 51.3 | 5.0 |
| 26 | 59.8 | 28.2 |
| 27 | 63.2 | 34.5 |

affects the population of this species, and since the sandhills are usually severely burned annually, more collections, especially from hosts, are needed in order to justify this conclusion.

## Effect of Habitat Burning on Population Numbers

Several investigators throughout the world have studied the effects of fire on tick populations. Fricks (1915) reported that burning the grass was one method used in efforts to control the Rocky Mountain wood tick in the northwestern United States during early investigations on this tick. de Jesus (1935) recommended burning pastures as a control for the cattle tick in the Philippine Islands. Buck (1935) recommended brush burning as a means of tick control in Madagascar. Bishopp (1932) found that neither burning nor plowing pastures destroyed all specimens of the cattle tick. Smith et al. (1946) noted that wild fires greatly reduced the abundance of adults of Dermacentor variabilis in Massachusetts.

The studies reported here relative to the effects of habitat burning on populations of Ixodes scapularis were undertaken for the specific purpose of determining whether this species is more abundant in non-burned areas than in burned areas of the flatwoods of northern Florida. Annual burning of open range lands has been practiced in this State for many generations (see Plate 6). Therefore, it

became obvious early in this study that habitat burning might prove to be an important factor in the ecology and biology of ticks in this area. The studies were devoted to Ixodes scapularis primarily because it is the most active species during the winter months, which is also the season when most of the burning occurs. All samples were taken during the season of activity of the adult of this species.

The areas selected for sampling, henceforth referred to as blocks, were located in a typical pine-palmetto flatwoods section about eight miles northeast of Gainesville, Florida. Blocks of approximately one square mile in size were selected for sampling based upon their history of forest fires. Block I was burned the year before sampling and had a history of frequent burning; block II was burned two years before sampling and had a history of frequent burning; block III was burned three years before sampling and had a history of frequent burning; block IV had not been burned for at least 14 years before sampling. Block IV was considered non-burned in this experiment and was used as the control block for comparison of results.

Blocks were not necessarily continuous tracts of land except in the case of block IV. This block was in a single tract except that a small portion was divided from the main body by a highway. It so happened that block I was, for the most part, adjacent to the control block. It had been the custom for many years to control-burn the lands annually that

are adjacent to block IV in order to protect it from wild fires. Block IV was the Austin Cary Forest which is owned and managed by the University of Florida School of Forestry.

Blocks were divided into plots approximately 200 feet in width and 1,500 feet in length. Since the recently burned blocks were not always in a single tract, the plots within a block were sometimes in groups separated by distances varying from approximately one quarter mile to one mile. Blocks I and IV were each represented on both sides of a main highway. This resulted in some plots in each of these blocks, which represent the extremes in this experiment, being adjacent to one another and often separated only by a wire fence. Random samples were drawn from the combined plots within each block before sampling was begun.

The plots usually fronted on a road and the sample was taken in a similar manner in each plot. The sampling procedure was to begin dragging a short distance from the road near the center of the plot and proceed away from the road and toward one side of the plot until one half the sample distance had been completed, then the drag was turned toward the center and opposite side of the plot and back to the starting point. This procedure reduced the walking time by one half, which was an important factor since as many as eight samples of 500 steps each were sometimes taken in a single day.

Since the object was to be able to make a general

statement relative to the effects of burning on the tick population, the blocks were, where possible, extended over large areas in order that a broader inference might be obtained from the results. Although the flatwoods appear to be a very homogenious habitat, it was felt that this procedure would reduce possible variation due to block differences.

The results of several years study of Ixodes scapularis in northern Florida have shown that large numbers of these ticks are not collected by sampling with a cloth drag. This is probably due to two factors. First, it was learned by studying the behavior of the tick that adults will climb vertical vegetation when seeking a host but apparently do not remain above the ground level for long periods. Secondly, it was observed that the adults are easily dislodged from the cloth drag by the vegetation.

The number of ticks taken by drag samples are in no way comparable to the number taken from host animals in the same area. Therefore, it was felt that several replications, over a period of years, would be needed in order to obtain conclusive results.

Due to a complete lack of knowledge of what to expect from the sampling before the experiment was undertaken, too many blocks were selected during the first year. This resulted in fewer samples per block. However, some data were

obtained which are comparable with other years. The study was begun in the fall of 1950 and repeated in 1951 and 1952. The data for all years are shown in Table XLI.

Results. In order to eliminate some negative samples and a few missing plot samples, the samples were grouped in pairs and the average number of ticks of the combined samples was used as the basis for the analysis.

An analysis of the results for the year 1951 showed no significant differences between treatments within that year. This was probably due to the variability within samples and the small total number of ticks collected. However, a logical analysis of these data is to combine comparable blocks over a period of time and use years as replications. Blocks I, II, and IV are comparable for all three years. Combining these data and using years as replications there was a highly significant difference in treatment response over the three year period. The analysis was as follows:

| Years | Block I | Block II | Block IV | Totals |
|---|---|---|---|---|
| 1950 | 0.00 | 0.50 | 3.50 | 4.00 |
| 1951 | 0.25 | 0.88 | 2.86 | 3.99 |
| 1952 | 0.30 | 2.40 | 4.20 | 6.90 |
| Totals | 1.55 | 3.78 | 10.56 | 14.89 |
| $\bar{x}$ | 0.18 | 1.26 | 3.52 | |

| Source of variation | Degree of freedom | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Total | 8 | 20.3697 | | |
| Years | 2 | 1.8732 | .9366 | |
| Blocks | 2 | 17.3980 | 8.6990 | 31.68** |
| Error | 4 | 1.0985 | .2746 | |

TABLE XLI

COLLECTIONS OF ADULTS OF IXODES SCAPULARIS SAY IN RELATION TO HABITAT BURNING STUDIES DURING 1950, 1951, 1952

| Year | Sample number | Number of ticks collected per sample | | | |
|---|---|---|---|---|---|
| | | Block I | Block II | Block III | Block IV |
| 1950 | 1 | 0.0 | 0.0 | --- | 3.0 |
| | 2 | 0.0 | 1.0 | --- | 8.0 |
| | 3 | 0.0 | 1.0 | --- | 0.0 |
| | 4 | 0.0 | 0.0 | --- | 3.0 |
| 1951 | 1 | 0.0 | 0.0 | 1.0 | 0.0 |
| | 2 | 0.0 | 0.0 | 1.0 | 7.0 |
| | 3 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 4 | 0.0 | 3.0 | 0.0 | 0.0 |
| | 5 | 2.0 | 0.0 | 0.0 | 4.0 |
| | 6 | 0.0 | --- | 2.0 | 6.0 |
| | 7 | 0.0 | --- | 1.0 | 3.0 |
| | 8 | 0.0 | 2.0 | 3.0 | 3.0 |
| 1952 | 1 | 1.0 | 6.0 | 0.0 | 3.0 |
| | 2 | 0.0 | 1.0 | 1.0 | 3.0 |
| | 3 | 0.0 | 0.0 | 1.0 | 9.0 |
| | 4 | 0.0 | 6.0 | 3.0 | 0.0 |
| | 5 | 1.0 | 1.0 | 1.0 | 2.0 |
| | 6 | 0.0 | 4.0 | 2.0 | 3.0 |
| | 7 | 0.0 | 0.0 | 1.0 | 3.0 |
| | 8 | 1.0 | 2.0 | 1.0 | 10.0 |
| | 9 | 0.0 | 3.0 | 0.0 | 6.0 |
| | 10 | 0.0 | 1.0 | 3.0 | 3.0 |
| Totals | | 5.0 | 31.0 | 21.0 | 79.0 |

The l.s.d. at the .05 probability was 1.20 and 1.98 at the .01 probability.

Further analysis of these data showed that when collections from blocks I and II were combined and then compared with collections from the control block, the difference was still highly significant. Also, the following analysis shows that there was no significant difference in the number of ticks collected in blocks I and II:

| Source of variation | Degree of freedom | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Total | 8 | 20.3697 | | |
| Years | 2 | 1.8732 | .9366 | |
| Blocks | 2 | 17.3980 | 8.6990 | 31.68** |
| I, II vs. IV | 1 | 15.6392 | 15.6392 | 56.95** |
| I vs. II | 1 | 1.7588 | 1.7588 | 6.40 |
| Error | 4 | 1.0985 | .2746 | |

The data in Table XLI show that data are comparable for all blocks during the years 1951 and 1952. The results showed a significant difference in treatment response. Using years as replications the analysis was as follows:

| Years | Block I | Block II | Block III | Block IV | Totals |
|---|---|---|---|---|---|
| 1951 | .25 | .88 | 1.00 | 2.86 | 4.99 |
| 1952 | .30 | 2.40 | 1.30 | 4.20 | 8.20 |
| Totals | .55 | 3.28 | 2.30 | 7.06 | 13.19 |
| $\bar{x}$ | .28 | 1.64 | 1.15 | 3.52 | |

| Source of variation | Degree of freedom | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Total | 7 | 13.4495 | | |
| Years | 1 | 1.2880 | 1.2880 | |
| Blocks | 3 | 11.3502 | 3.7834 | 13.99* |
| Error | 3 | .8113 | .2704 | |

The l.s.d. at the .05 probability was 1.65 and 3.04 at the .01 probability.

The following analysis shows a highly significant difference between the number of ticks collected in the control block and the combined collections from all burned blocks. There was no significant difference between tick collections in burned blocks.

| Source of variation | Degree of freedom | Sum of squares | Mean square | F |
|---|---|---|---|---|
| Total | 7 | 13.4495 | | |
| Years | 1 | 1.2880 | 1.2880 | |
| Blocks | 3 | 11.3502 | 3.7834 | 13.99* |
| I, II, III vs. IV | 1 | 9.4376 | 9.4376 | 34.90** |
| I vs. II vs. III | 2 | 1.9126 | .9563 | 3.54 |
| Error | 3 | .8113 | .2704 | |

The results of these studies show that there was a larger population of adult Ixodes scapularis in non-burned areas of the flatwoods of northern Florida than in areas recently burned and with a history of frequent burning. It can also be stated that three or more years without fire in frequently burned areas is required for tick populations to build up to a point equal to populations in areas which have been free of fire for twelve years or longer

Since the objective of this study was only to establish whether populations of this tick are higher in non-burned than in burned areas, no special effort was made to determine the causes for the results obtained.

The most obvious reason why ticks are not as plentiful

in burned areas would appear to be that the fire destroys the ticks. While this is very probably an important factor, it is probably not the only cause. In fact, ticks were collected on a drag sample in one instance within a few days after a tract of land had been control-burned in Austin Cary Forest. The ticks had apparently climbed the vegetation after it had been charred by the fire. This shows, at least in that instance, that all ticks were not destroyed by the fire. This fire occurred in the control block where there was a heavy layer of ground litter over most of the area. It was observed that much of this ground litter was only seared over by the fire and was by no means destroyed. It seems reasonable to assume that some of the ticks that were in or under the ground litter when this fire occurred might have escaped being killed.

Pre-burn samples were taken during 1951 in four plots in Austin Cary Forest a few days before a tract was control-burned. An average of four and five-tenths ticks per plot was collected. The same plots were sampled again the following year and an average of three and seventy-five one hundreths ticks per plot was collected. These observations indicate that more than one burning is required to reduce the population of Ixodes scapularis in a flatwoods area that has not been burned in 14 years or longer.

Another possible factor is the effect of fire on the

vegetation and ground cover. Areas of the flatwoods that are frequently burned have little or no ground litter. Plant life is stunted and not as dense in frequently burned areas as in areas protected from fire. This is shown in Plates 1 and 7. These differences in the nature of the vegetation and the ground cover in protected and burned areas probably influence humidity and temperatures near the ground level where most ticks are found. However, no data were obtained to support this observation.

It also seems reasonable to assume that more host animals for ticks would be found in areas protected from fire because of more protective cover in those areas. The only positive observation made to support this theory, as it concerns Ixodes scapularis, was that the little ground skink was frequently observed in Austin Cary Forest where the ground litter was deep, but was not observed in severely burned areas of the flatwoods. This skink is considered the most important host for the larva of Ixodes scapularis found in this study. More observations are needed, however, before it could be stated definitely that this skink does not occur in the frequently burned areas.

## THE GENUS RHIPICEPHALUS KOCH, 1844

### RHIPICEPHALUS SANGUINEUS (LATREILLE), 1806

The brown dog tick, Rhipicephalus sanguineus, was reported by Bishopp and Trembley and Cooley (1946) to be world wide in distribution. Those authors also discussed the habits, hosts, and importance of this species. In addition to being a severe pest of the dog, this tick is known to transmit piroplasmosis of dogs. Cooley (1946) also indicated that the brown dog tick might be of some importance as a vector of Rocky Mountain spotted fever. Many hosts of this tick besides the dog have been reported in various parts of the world.

The habit of living close to the dog often causes heavy infestations in kennels and in human dwellings. The transporting of dogs and tick-infested household furnishings has undoubtedly been responsible for the wide dissemination of this species throughout the world.

The authors cited above indicated that Rhipicephalus sanguineus is of tropical or subtropical origin. Bishopp and Trembley reported that the tick can maintain itself only in heated buildings in the colder regions.

Although no special effort was made to collect this tick during the present study, many animals were examined, including 288 dogs, and collections of this tick were rare.

These collections, all from the dog, are shown in Table XLII. These data do not indicate the severity with which this tick often attacks dogs in Florida. Gross infestations of the brown dog tick on dogs have been observed in Gainesville, Florida, where the number of ticks would appear to defy enumeration. These observed heavy infestations were all in urban areas where dogs were confined for long periods in close quarters.

Three of the records in Table XLII represent collections from dogs in rural areas where the dogs were rarely, if ever, confined. Under such conditions dogs may rest or sleep in a different location each night, often with no more protection than is offered by the branches of a tree. Such habits by the host, it seems, would not prevent the tick from building up large populations if it could withstand out-of-doors conditions here. Also, it seems reasonable to assume that hunting dogs would be heavily infested if the tick is present in any great numbers out-of-doors. The opposite condition was found in this study.

Since the brown dog tick was not taken under sylvatic conditions in almost four years of collecting, and since it was only occasionally collected in small numbers from dogs in rural areas during this study, it appears that the tick is confined largely to domestic, and especially urban, habitats in northern Florida.

TABLE XLII

COLLECTIONS OF RHIPICEPHALUS SANGUINEUS (LATREILLE) IN NORTHERN FLORIDA

| Date | Host | Location | Number of ticks collected | |
|---|---|---|---|---|
| | | | Males | Females |
| May 9, 1950 | Dog | Alachua County | | 2 |
| October 13, 1950 | Dog | Alachua County | 1 | |
| March 22, 1952 | Dog | Levy County | | 1 |
| February 15, 1953 | Dog | Gilchrist County | | 1 |
| Totals | | | 1 | 4 |

SUMMARY

An intensive study of ixodid ticks was conducted in northern Florida during the period from late 1949 through January 1953. Thirteen species, representing five genera, were collected.

Special attention was given to the host relationships, seasonal activities, and habitat distributions of Amblyomma americanum (L.), Dermacentor variabilis (Say), and Ixodes scapularis Say. Biology and life history studies were conducted on Ixodes scapularis.

The habitats studied were (1) flatwoods, characterized by the pine-palmetto association; (2) hammocks, characterized by evergreen hardwoods of various associations; and (3) sandhills, characterized by the longleaf pine-turkey oak association.

The adult of Amblyomma americanum was collected from hosts during every month in the year but was most active from January to August. Adults were collected only from larger mammals. The larvae were collected during every month in the year except March and April. The season of greatest activity was from June through August. The larvae were collected from mammals and birds. Nymphs were collected during every month except November. This stage was quite active throughout the year except during the period from

November through February and in June. Nymphs were collected from Mammals and birds. Neither the larvae nor the nymphs were collected from mammals smaller than the gray squirrel. Amblyomma americanum was found to be abundant only in the hammocks. No stage of this species was found in the sandhills that were far removed from hammocks. This species was collected only rarely in flatwoods. It apparently breeds in the small hammocks interspersed among the pine-palmetto associations in the flatwoods.

Amblyomma maculatum Koch was not studied extensively since this species has been studied in southern Georgia. The adults were most prevalent on cows from June through September. The favorite habitat for this tick in northern Florida was found to be the flatwoods. Specimens were collected in small numbers from cattle that ranged only in hammocks. Larvae were collected in one instance on a cloth drag in the sandhills near flatwoods and a hammock.

Amblyomma tuberculatum Marx was recorded in the larval stage from mammals, birds, and one reptile. New host records obtained for the larva are man, bobwhite quail, robin, and fence lizard. The record from the fence lizard is also the first record of the larva from reptiles. The larvae were found to be active only from November through March. Nymphs and adults were found only on the gopher-tortoise. No seasonal activity data were obtained for the nymphs and

the adults. This species was collected in the flatwoods and in the sandhills, but no records were obtained from hammocks.

The adult of Dermacentor variabilis (Say) was collected from dogs during every month in the year. The period of greatest activity began in March, reached a peak in May, dropped gradually during June and July and then more abruptly in August. Only an occasional specimen was found during November, December, January, and February. The tick is of no importance as a pest of dogs during the winter months. The Florida bobcat was found to be an excellent host for the adult and probably is of more importance than the dog as a host for Dermacentor variabilis in the rural areas of northern Florida. This tick was rarely found on cows. The larvae of Dermacentor variabilis were collected from hosts during every month except June. The period of greatest activity for the larvae was from October through February and in August. The nymphs were collected during every month except June and November. Nymphs were more abundant on hosts during the period from December through May. The most important hosts for the larva and the nymph were the cotton mouse and the northern cotton rat. An unengorged larva was taken from the bobwhite quail in two separate instances. This species does not normally infest birds. Dermacentor variabilis was prevalent in the flatwoods and in the hammocks. No records of this species were obtained in

the sandhills habitat.

Haemaphysalis chordeilis (Packard) was collected infrequently in the flatwoods habitat. All records were from the meadow lark.

Haemaphysalis leporis-palustris (Packard) was found to be abundant on lagomorphs, and the immature stages were found more frequently than any other tick on birds.

Two female specimens of Ixodes affinis Neumann were collected, one from a dog July 14, 1951, and one from a Florida bobcat October 28, 1951. Both collections were made at Gulf Hammock, Levy County, Florida. The record from the dog is a new host record for this species. There are no previous reports of this species from the United States. However, Doctor Glen M. Kohls, of the U. S. Public Health Service, has an unpublished record of a single female collected in this same locality in Florida during 1948.

All stages of Ixodes bishoppi Smith and Gouck were collected from the northern cotton rat, and the nymphs were collected from the cotton mouse. The record from the cotton mouse is a new host record for this species. Ixodes bishoppi has not been previously reported from Florida, but Doctor Carroll N. Smith has unpublished records of this tick from central Florida.

Two records of Ixodes brunneus Koch were obtained. Two larvae were collected from a towhee January 26, 1949, and

one engorged female was collected from a towhee January 26, 1950. Both collections were made in the flatwoods in Alachua County, Florida. This is the first report of Ixodes brunneus from Florida.

Ixodes cookei Packard was collected in three instances from the Florida raccoon; one nymph November 23, 1950, Jefferson County; one nymph November 25, 1950, Taylor County; and two females January 17, 1952, Alachua County, Florida.

Twenty four nymphs of Ixodes texanus Banks were collected from a southern fox squirrel in Taylor County, Florida December 26, 1949. All other collections of this species were females taken from Florida raccoons in the flatwoods in Alachua County. The records are as follows: one December 5, 1949, one January 28, 1950; one September 12, 1950; and four January 17, 1952.

Adults of Ixodes scapularis Say were found to be abundant on cows and dogs. The Florida bobcat appeared to be one of the most important hosts among wild mammals. The immature stages of Ixodes scapularis were found to utilize lizards, especially the skinks, as their principal hosts. The ground skink was found to be the most important host for the larvae. The broad-headed skink and the glass snake appeared to be the most important hosts for the nymphs. New host records for the larvae are the glass snake, Carolina anole, southern

golden mouse, northern cotton rat, and Florida deer mouse. New host records for the nymphs are the Florida bobcat and the northern cotton rat.

Adults of Ixodes scapularis were found on hosts only from late September to May. The peak of abundance occurred near the middle of November during 1951 and 1952. Females outnumbered males on hosts at a ratio of approximately two to one. Engorged ticks started dropping in October. The average preoviposition period in field cages was 14.7 days during the period from October through March, with a range of eight to 19 days. Incubation during that period required an average of 81.2 days, with a range of 62 to 89 days.

Larvae were active from January through September with the peak of abundance in early spring, probably April or May. Engorgement of the larvae required from four to 16 days. The time required for engorgement appeared to vary with different hosts. Molting of the larvae in field cages required an average of 21.5 days during July and August, with a range of 20 to 27 days. A small number of larvae that dropped during February and March required from 49 to 66 days to molt.

Nymphs were active from April through November. The peak of activity appeared to be during June, July, and August. Engorgement of the nymph on the broad-headed skink required an average of 10.2 days, with a range of seven to

20 days. During the period June through September 1952 male nymphs required an average of 30.8 days to molt, and female nymphs required an average of 32.9 days to molt. A few nymphs that dropped in November 1952 had not molted four months later. This indicated that nymphs that drop as late as November probably do not molt until the following spring.

The minimum life cycle for Ixodes scapularis in northern Florida was found to be one year. This period was from October to October. There was a strong indication that the life cycle may be extended to two years for ticks that do not drop engorged as nymphs before November.

The larva and the nymph of Ixodes scapularis were found to remain on the soil or in the ground litter at all times. The adult remained quiescent beneath ground litter from June until its season of activity began in the fall. At that time, the adults climbed shrubs and grasses when stimulated by the presence of a host. If a host was not found, the ticks returned to the ground within a few days.

Larvae lived in field cages without food from 14.5 to 24 weeks. The longevity of unfed nymphs in field cages was observed to be from five and one-half weeks to 17 weeks. The longevity of unfed adults in field cages was from eight and one-half to 17 weeks. The longevity of all stages was considerably longer on moist sand in an insectary than in field cages.

Ixodes scapularis mated wherever the two sexes were

brought together, on or off a host. The duration of oviposition ranged from approximately six weeks to three months. Low temperatures retarded the rate of oviposition. Fifty degrees Fahrenheit appeared to be near the threshold for egg laying. The maximum number of eggs laid by a fully engorged tick was 2,807; the minimum number recorded was 1,108; and the average number for nine specimens was 2,052.

The male of Ixodes scapularis was never observed attached to a host. Only on one occasion was a male observed to insert its hypostome into the skin of a host. In that instance the hypostome was withdrawn in less than five minutes, and the male coupled with a female near by. It was concluded that the male is of no importance as a parasite.

Comparisons of populations of the adult of Ixodes scapularis in burned and non-burned areas of the flatwoods habitat showed conclusively that this species was more abundant in an area that had not been burned in 14 years than in areas having a range of from one to three years from the date of the last burning to time of sampling, and with a history of frequent burning. It was further shown that there was no significant difference in populations of this tick in the three classes of burned areas studied. The conclusion was that more than three years without fire are required in an area with a history of frequent burning in order for populations of this tick to reach a level comparable to populations that obtain in areas not having been

burned in 14 years.

Ixodes scapularis was found to be prevalent in the flatwoods and hammock habitats, but no record of this tick was obtained in sandhills that were far removed from other habitats.

Rhipicephalus sanguineus (Latreille) was collected only from dogs and only in domestic environments.

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# APPENDIX

## NAMES OF HOST ANIMALS AND PLANTS

### Aves

Bobwhite quail.....*Colinus virginianus* (L.)

Brown thrasher.....*Toxostoma rufum* (L.)

Butcher bird.....*Lanius ludovicianus* L.

Cardinal.....*Richmondena cardinalis* (L.)

Eastern blue jay.....*Cyanocitta cristata* (L.)

House wren.....*Troglodytes aëdon* Vieillot

Meadow lark.....*Sturnella magna* (L.)

Owl.....Strigiformes

Pine warbler.....*Dendroica pinus* (Wilson)

Robin.....*Turdus migrotorius* L.

### Mammalia

Eastern cottontail.....*Sylvilagus floridanus* (Allen) (rabbit)

Florida black bear.....*Eurctos floridanus* Merriam

Florida bobcat.....*Lynx rufus floridanus* (Rafinesque)

Florida cotton mouse.....*Peromyscus gossypinus palmarius* Bangs

Florida cotton rat.....*Sigmodon hispidus littoralis* (Chapman)

Florida deer mouse.....*Peromyscus floridanus* (Chapman)

Florida gray fox.....*Urocyon cinercoargenteus floridanus* Rhoads

Florida opossum.....*Didelphis virginiana pigra* Bangs

Florida raccoon (raccoon).....*Procyon lotor elucus* Bangs

Florida wood rat.....*Neotoma floridana* (Ord)

Gray squirrel.....*Sciurus carolinensis* Gmelin

House mouse.....*Mus musculus musculus* Linnaeus

Marsh rabbit.....*Sylvilagus palustris paludicola* (Miller and Bangs)

Meadow mouse.....*Microtus pennsylvanicus pennsylvanicus* (Ord)

Mearns cottontail.....*Sylvilagus floridanus mearnsi* (Allen)

Northern cotton rat (cotton rat).....*Sigmodon hispidus hispidus* Say and Ord

Northern white-footed mouse.....*Peromyscus leucopus noveboracensis* (Fischer)

Pocket gopher (Salamander).....*Geomys floridanus* (Audubon and Bachman)

Rice rat.....*Oryzomys palustris* (Harlan)

Southern fox squirrel.....*Sciurus niger niger* Linnaeus

Southern golden mouse.....*Peromyscus nuttalli aureolus* (Audubon and Bachman)

Spotted skunk.....*Spilogale ambarvalis* Bangs

Virginia deer (deer).....*Odocoileus virginianus virginianus* (Boddaert)

White-footed mouse.....*Peromyscus leucopus* (Rafinesque)

## Reptilia

Blue-tailed skink.....*Eumeces fasciatus* (Linnaeus)

Broad-headed skink.....*Eumeces laticeps* Schneider

Carolina anole.....*Anolis carolinenis* Voight

Coral snake.....*Micrurus fulvius fulvius* (Linnaeus)

Diamond-back rattlesnake..*Crotalus adamanteus* Beauvois

Fence lizard (Eastern pine lizard).....*Sceloporus undulatus undulatus* (Latreille)

Glass snake.....*Ophisaurus ventralis* (Linnaeus)

Gopher-tortoise (gopher)..*Gopherus polyphemus* (Daudin)

Ground skink.....*Leiolopisma unicolor* (Harlan)

Plants

Black gum.....*Nyssa sylvatica biflora* (Walt.) Sarg.

Blue beech.....*Carpinus caroliniana* Walt.

Bluejack oak.....*Quercus cinerea* Michx.

Cabbage palm (Palmetto)...*Sabal palmetto* (Walt.) Lodd.

Cypress (pond-cypress)....*Taxodium ascendens* Brongn.

Gallberry.....*Ilex glabra* (L.) A. Gray

Hickory.....*Carya tomentosa* (Lam.) Nutt.

Holly.....*Ilex opaca* Ait.

Ironwood (hop-hornbean)...*Ostrya virginiana* (Mill.) K. Koch

Live oak.....*Quercus virginiana* Mill.

Longleaf pine.....*Pinus palustris* Mill.

Magnolia.....*Magnolia grandiflora* L.

Redbay.....*Persea borbonia* (L.) Spreng.

Red maple.....*Acer rubrum* L.

Red oak.....*Quercus falcata* Michx.

Saw-palmetto.....*Serenoa repens* (Bartr.) Small

Scrub oak.....*Quercus laevis* Walt.

Slash pine.....*Pinus elliotti* Engelm.

Sweetgum.....*Liquidambar styraciflua* L.

Plate 1.

A scene in the flatwoods of northern Florida showing the typical pine-palmetto association. This photograph was taken in Austin Cary Forest in an area that was last burned about 1936. The photograph was made in the spring of 1953.

Plate 2.

A scene in a mesophytic hammock of northern Florida.

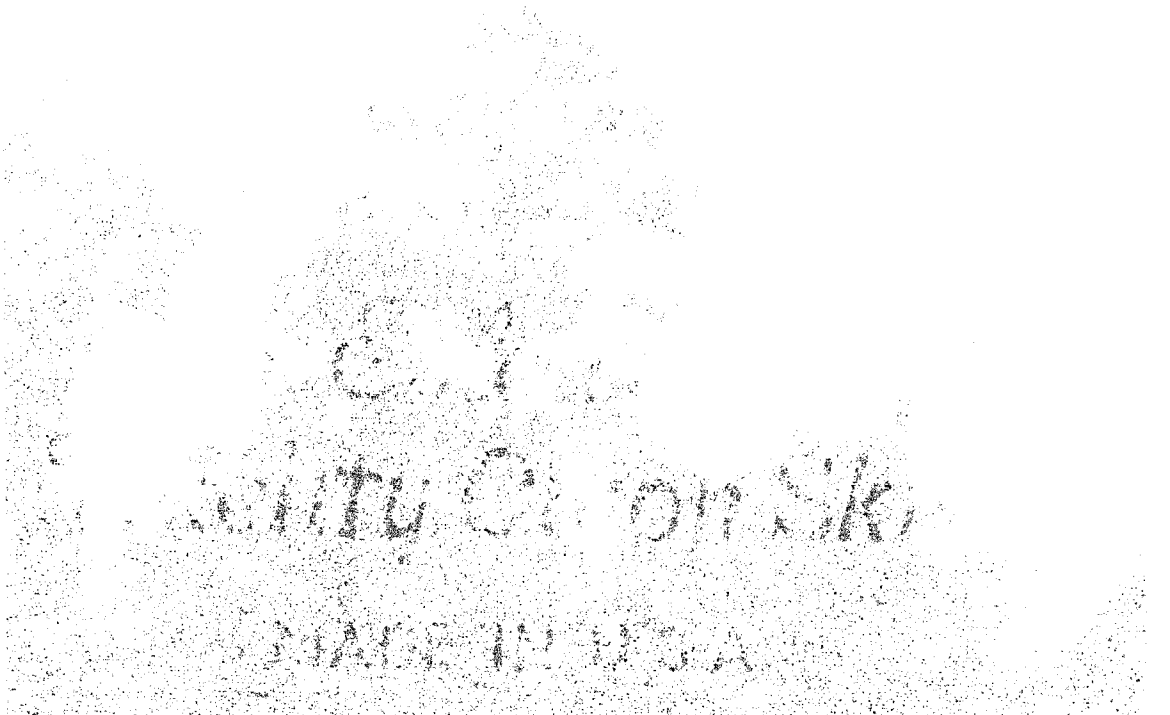
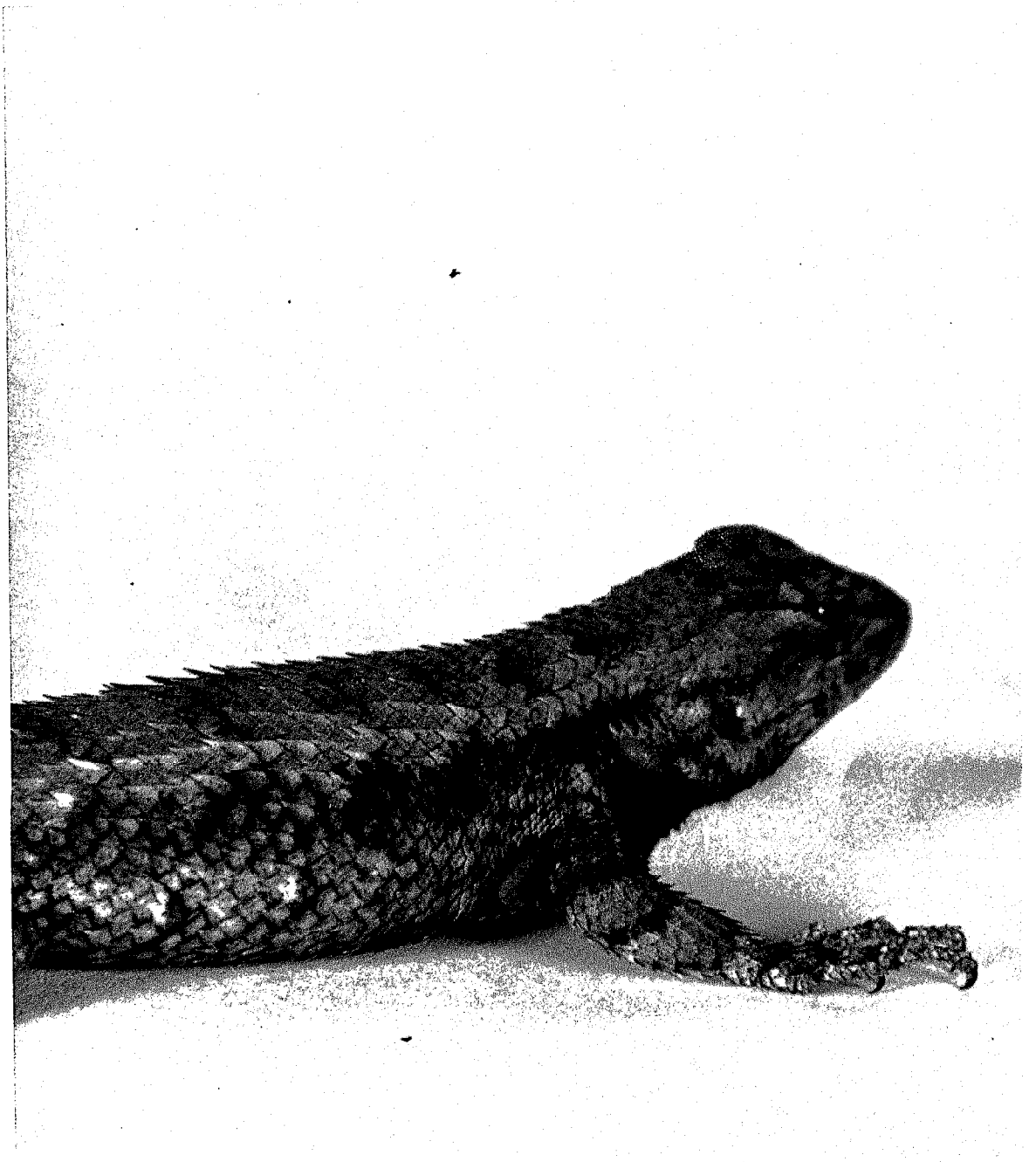


Plate 3.

The longleaf pine-turkey oak association typical of the sandhills of northern Florida.

Plate 4.

Larvae of *Amblyomma tuberculatum* Marx on the fence lizard.



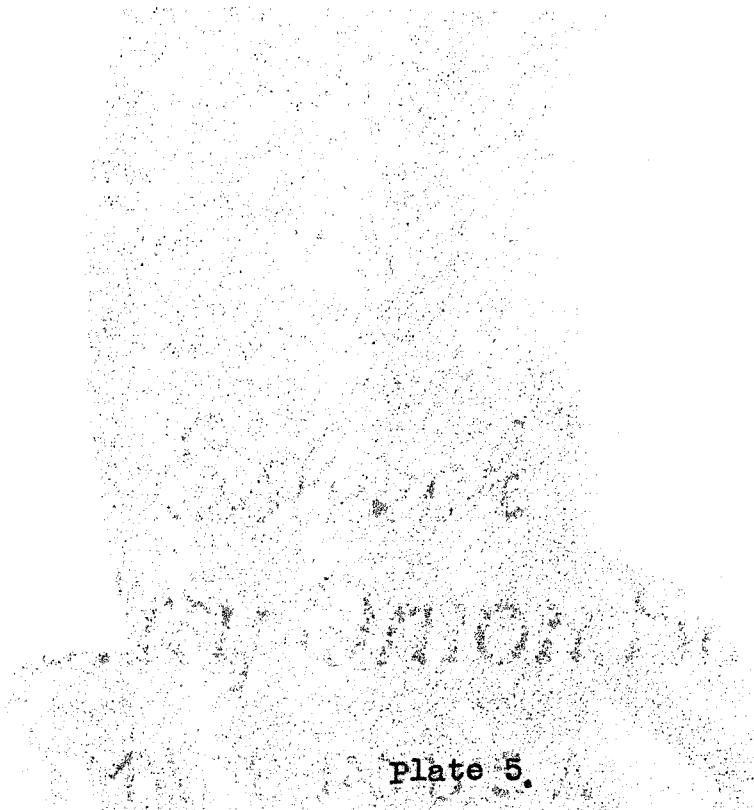


Plate 5.

Larvae and nymphs of Ixodes scapularis Say on the broad-headed skink.

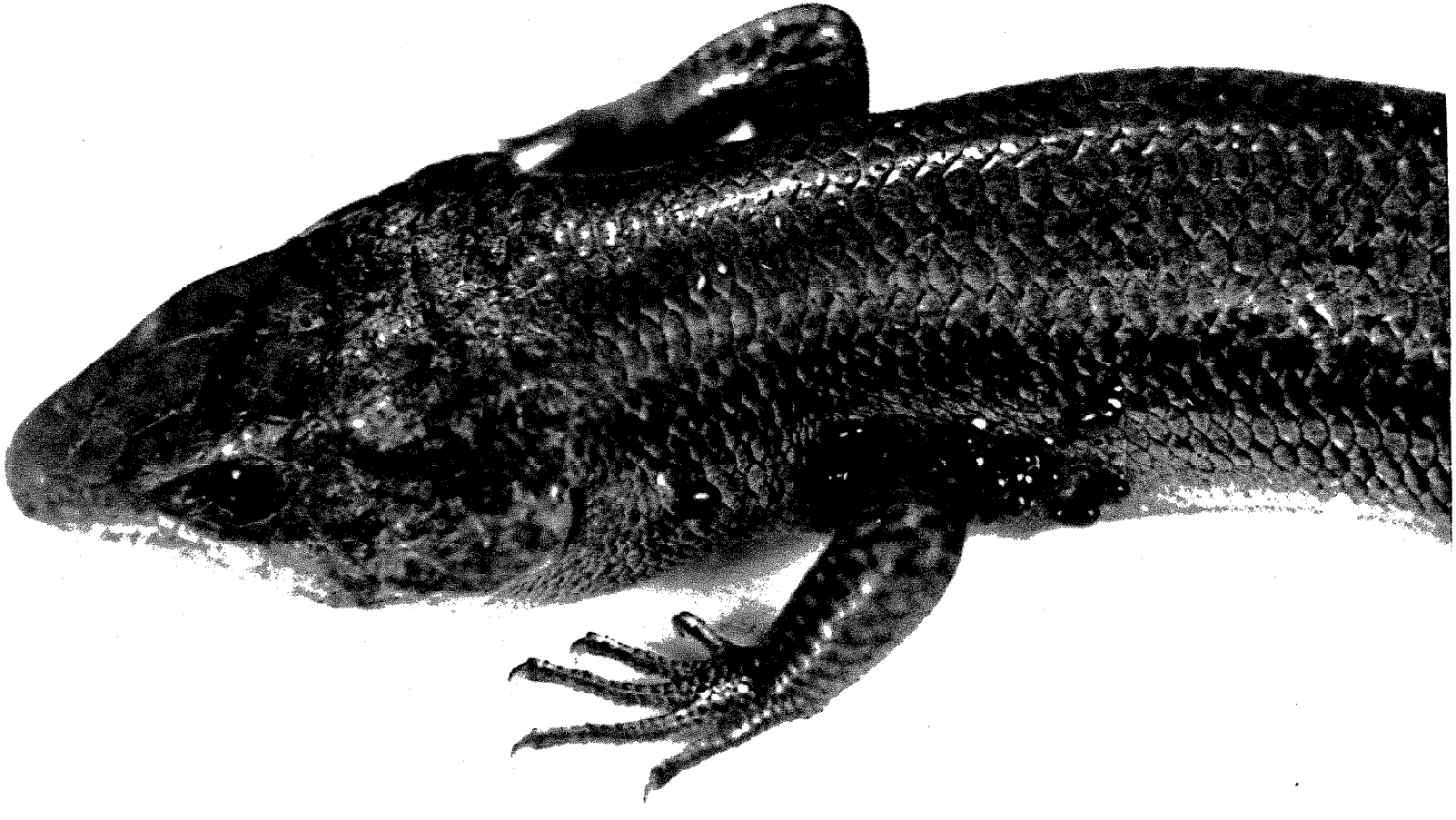


Plate 6.

A scene in a frequently burned area of the flatwoods in northern Florida. This area was burned in the winter of 1952, and the photograph was made in the spring of 1953.

Plate 7.

A recently burned area of the flatwoods in northern Florida.