The Journal of Agriculture of the University of Puerto Rico

In continuation of The Journal of the Department of Agriculture of Puerto Rico
Published by THE AGRICULTURAL EXPERIMENT STATION, Rio Piedras, P. R.

Published Quarterly: January, April, July and October of each year.

VOL. XXV January 1941 No. 1

THE BIOLOGY OF THE TROPICAL CATTLE TICK AND OTHER SPECIES OF TICK IN PUERTO RICO, WITH NOTES ON THE EFFECTS ON TICKS OF ARSENICAL DIPS[1]

By H. DOUGLAS TATE
Formerly Associate Entomologist, Division of Insects Affecting Man and Animals, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture

INTRODUCTION

For many years the presence of the tropical cattle tick, *Boophilus annulatus microplus* (Can.) (*australis* Fuller), in Puerto Rico has been a serious impediment to the development of the cattle industry in that island. In addition to heavy losses occasioned by tick infestation alone, the rôle of these ectoparasites in the transmission of tick fever of cattle has resulted in enormous losses and has presented an obstacle to the introduction of the better breeds of non-immune stock from tick-free areas.

This tick is a variety of the common cattle tick, *Boophilus annulatus* Say, which occurred throughout the southern portions of the United States prior to the initiation of eradication work.

Both these varieties are single-host ticks; *i.e.*, they remain on the same animal for their entire period of development from larvae, or seed ticks, to engorged females, after which they drop to the ground, seek protection, and soon begin to deposit eggs. The host relationships, habits, developmental periods, and longevity of this tropical variety in the United States have been shown by Hooker, Bishopp, and Wood (2) to be similar to those of the cattle tick, *Boophilus annulatus*.

1 Headquarters for these studies were located at the Puerto Rico Agricultural Experiment Station, Mayaguez, P. R., from the beginning of the studies through November 1937; and at the School of Tropical Medicine, San Juan, P. R., from December 1937 until the termination of the work in the summer of 1938. At each of these institutions various facilities, including office and laboratory space, were furnished. The writer acknowledges his indebtedness to Wilbur McPherson and S. H. Still of the Bureau of Animal Industry, United States Department of Agriculture, who were in charge of cattle tick eradication in Puerto Rico, for their assistance in obtaining materials and equipment and for their cooperation in various other ways.

The facts that both these varieties prefer cattle as the host and do not commonly attack the various species of wild animals, and that *Boophilus annulatus* has been largely eradicated from the United States, indicated the feasibility of eradicating the tropical variety from Puerto Rico. During the year 1936 plans were made by the Bureau of Animal Industry, United States Department of Agriculture, in cooperation with the Puerto Rico Reconstruction Administration and the Insular Department of Agriculture, to conduct an eradication campaign in Puerto Rico. Since successful eradication obviously must be based on an accurate knowledge of the biology of the tick concerned, and under the conditions involved, it was decided that a study should be made of the biology of the tick in Puerto Rico.

The investigations which form the basis of this report were begun during the latter part of 1936 and completed during the summer of 1938. The technical phases of the problem were under the general supervision of F. C. Bishopp, In Charge of the Division of Insects Affecting Man and Animals, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in cooperation with the Federal Experiment Station, Mayaguez, P. R. These investigations were first carried on with funds available to the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture for studies on insects of Puerto Rico. From December 1937 to the termination of the work the project was carried on with funds allotted to the Bureau of Animal Industry by the Puerto Rico Reconstruction Administration.

ECONOMIC IMPORTANCE

The tropical cattle tick will attach itself to practically any part of the body of its host, but it usually occurs in greatest abundance about the head and ears, flanks, and escutcheon. At the points of heavy concentration there is considerable irritation, frequently resulting in cracking and sloughing of the skin. Heavily infested animals lose condition and become listless and emaciated, a condition frequently referred to as tick anemia, which predisposes them to other more acute diseases. Among dairy animals there is a marked decrease in milk production. Occasionally cattle, especially young animals, die as a result of gross tick infestation.

Of perhaps greater importance than the tick infestation itself is the fact that these ectoparasites are the natural agents of dissemination of splenetic or tick fever of cattle. Not only has this disease caused heavy losses through the death of many animals and through loss of condition and lowered vitality of many others, but it has also greatly retarded the

improvement of native stock, particularly dairy animals, because of the reluctance to import purebred stock from tick-free areas. The eradication of the tick, with the resulting elimination of tick fever and an increased production of milk and butter, undoubtedly would contribute greatly toward a more extended use of dairy products by the poorer classes of Puerto Rico, who now can afford only a little of such food.

GEOGRAPHICAL DISTRIBUTION

The tropical cattle tick is widely distributed throughout the West Indies and over practically the entire area of South and Central America. In some parts of Mexico it is recorded as a serious pest. In the United States it was well established in several counties in Florida and over a smaller area in Texas previous to the tick-eradication work of the United States Department of Agriculture, which has reduced the infested area to the extreme southern portions of Texas and Florida. From these records it is apparent that this variety is distributed throughout the tropical and sub-tropical parts of the Western Hemisphere. It has become established also in Borneo, Sumatra and the Philippine Islands.

NON-PARASITIC DEVELOPMENT

Method of Study

The method followed in determining the preoviposition period, incubation period of the eggs, and possible larval life was essentially that described by Hooker, Bishopp, and Wood (2). For confining the ticks, bottomless glass tubes 1½ inches in diameter and 8 inches in length were used. About 2 inches of sand and clay was packed in one end of the tubes, and they were then set in sandy, well-drained soil with the soil level in the tube even with the ground surface. The top of each tube was then covered over with a piece of muslin held in position by a strong cord. To prevent any disturbance of the tubes they were surrounded by a fence of one-half-inch mesh, and the top of the enclosure was covered over with burlap as a protection against downpours of rain. In this way the ticks were partially exposed to the rain but largely protected from the direct rays of the sun. This prevented the condensation of moisture within the tubes, except during the most humid weather in areas of comparatively high rainfall. Observations could be made readily through the glass tubes without disturbing the ticks.

The circumstances under which these tests were conducted are considered to represent closely optimum natural conditions for development

TABLE 1. PREOVIPOSITION, INCUBATION, AND LARVAL LONGEVITY OF *BOOPHILUS ANNULATUS MICROPLUS* IN OUTDOOR CAGE AT MAYAGUEZ, PUERTO RICO

CAGE A—THE SOIL SURROUNDING TUBES MOISTENED BY RAIN ONLY

Date females collected from host	Preoviposition period	Minimum incubation period	Larval longevity
	Days	*Days*	*Days*
1936			
December 17	4	34	115
December 26	6	39	106
1937			
January 14	6	40	105
January 30	4	39	120
February 13	5	32	120
March 1	3	31	116
March 15	4	30	113
March 30	3	30	113
April 14	3	27	115
April 29	4	25	122
May 14	3	28	103
June 1	2	27	129
June 16	4	25	111
July 14	3	28	109
July 29	3	28	107
August 12	2	28	119
September 16	2	29	130
October 5	3	28	141
October 15	3	26	133
November 3	2	30	145
November 16	2	33	138

CAGE B—THE SOIL SURROUNDING TUBES KEPT MOIST BY ADDITION OF WATER

Date females collected from host	Preoviposition period	Minimum incubation period	Larval longevity
	Days	*Days*	*Days*
1937			
January 14	6	40	112
January 30	4	38	121
February 13	5	34	128
March 1	3	33	118
March 15	3	33	112
March 30	4	31	120
April 14	3	31	113
April 29	4	27	113
May 14	3	30	103
June 1	2	29	109
June 16	4	30	115
July 14	3	28	109
July 29	3	28	130
August 12	2	28	125
September 4	2	27	144
September 16	2	29	144
October 5	3	28	133
October 15	3	26	138
November 3	2	30	142
November 16	2	33	140
December 11	2	33	154
1938			
January 12	2	38	145

and longevity of the non-parasitic stages (eggs and larval) when the ticks are not on hosts.

All records of the non-parasitic stages herein reported were obtained under outdoor conditions. Tests were conducted in three climatically

different areas, Maricao, Santa Rita, and Mayaguez. Maricao is fairly typical of the mountainous regions which, generally speaking, include the central portion of the island; Santa Rita is representative of a comparatively small but rather definite area along the dry southern coastal region; and along the remainder of the coastal region climatic conditions more nearly approach those at Mayaguez.

In the series of tests at Mayaguez, two cages were used to hold the tubes, one of which was moistened by rain only and a second to which water was added whenever necessary to maintain it in a continuously moist condition. In this second cage water was needed infrequently, except for brief intervals during the dry season, hence there was little variation in the results obtained in the two cages. In the Santa Rita area the greater portion of the rainfall occurred during the last 6 months of the year and this, as a rule, was in the form of infrequent but heavy downpours. As a result, the soil surrounding the tubes was dry most of the time even during the rainy season.

In each series of longevity tests, each series being represented by a line of data in tables 1-3, 15 engorged females were used, one being placed in each of 5 tubes and 5 females in each of 2 other tubes. The tubes at Mayaguez were examined from 4 to 5 times each week. At Maricao and Santa Rita examinations usually were made at weekly intervals, but more frequently if a previous observation indicated that a marked change, such as hatching, might take place within a period of less

TABLE 2. PREOVIPOSITION, INCUBATION, AND LARVAL LONGEVITY OF *BOOPHILUS ANNULATUS MICROPLUS* IN OUTDOOR CAGE AT SANTA RITA, PUERTO RICO

Date females collected from host	Preoviposition period [1]	Minimum incubation period	Larval longevity
	Days	*Days*	*Days*
1936			
December 17	6	32	75
December 28	4	36	72
1937			
January 14	6	33	90
February 13	5	27	87
March 15	4	21	71
April 14	3	23	72
May 14	3	22	88
June 16	4	18	74
July 14	3	22	66
August 12	2	22	78
September 16	2	22	65
October 15	3	19	78
November 16	2	23	73
December 11	2	26	90
1938			
January 12	2	33	85
February 14	4	28	78

[1] These ticks were kept at Mayaguez until oviposition began, hence these preoviposition records do not apply to Santa Rita.

than 1 week. These observations were continued from the time the female were placed in the tubes until the last larva had died. To reduce to a minimum the time and expense involved in traveling, all engorged females used in the tests at Maricao and Santa Rita were first confined in tubes at Mayaguez until oviposition began and then transferred immediately to these other locations.

TABLE 3. PREOVIPOSITION, INCUBATION, AND LARVAL LONGEVITY OF *BOOPHILUS ANNULATUS MICROPLUS* IN OUTDOOR CAGE AT MARICAO, PUERTO RICO

Date females collected from host	Preoviposition period [1]	Minimum incubation period	Larval longevity
	Days	*Days*	*Days*
1936			
December 28	4	76	149
1937			
January 14	6	67	161
February 13	5	71	144
March 15	4	63	184
April 14	3	57	180
May 14	3	52	159
June 16	4	46	173
July 14	3	49	163
August 12	2	47	148
September 16	2	58	179
October 15	3	54	175
November 16	2	66	165
December 11	2	75	158

[1] These ticks were kept at Mayaguez until oviposition began, hence these preoviposition records do not apply to Maricao.

Preoviposition Period

The preoviposition period, which represents the interval between detachment of the female and the beginning of oviposition, ranged from 2 to 6 days (tables 1-4). There was no appreciable difference in the duration of the preoviposition period of partially engorged females and replete females. A smaller number of eggs, however, was deposited by the partially engorged individuals.

Oviposition Period

The oviposition period of individual ticks was not determined because of the unimportance of such records and the time that would have been required to obtain them. Data were obtained, however, on a group of 33 females in the insectary at Mayaguez. Among these the range was from 11 to 18 days. The duration of this period depends on temperature and to some extent on humidity as well as on a number of other factors, such as state of engorgement. Maximum daily egg production was attained a few days after oviposition began, and there was a marked

decline in the rate of deposition during the last week or 10 days. The females died within 5 to 10 days after the total oviposition was completed.

The eggs deposited by each of 10 females that dropped from cattle under natural conditions were counted and the average was found to be 2,257, with a maximum of 3,518 and a minimum of 1,395.

Incubation Period

The duration of the incubation period is dependent largely on temperature, and to some extent on humidity, warm, moist weather being most conducive to speedy hatching. Abnormally dry, hot weather resulted in a partial dehydration of the eggs, after which they did not hatch normally, and prolonged exposure to direct sunlight destroyed their viability.

At Mayaguez the minimum incubation period in individual egg clusters ranged from 25 to 40 days (table 1); at Santa Rita, from 18 to 36 days (table 2); and at Maricao, from 46 to 76 days (table 3). The minimum incubation period was considered as extending from the time the first eggs were deposited until the eggs in the series began to hatch. Although the hatching period ranged from 5 to 8 days, the majority of the eggs hatched within the first 4 or 5 days.

No appreciable variation in the incubation period could be detected among samples of eggs segregated at the beginning of oviposition, near the middle, or toward the termination of this period.

Length of Larval Life

The longevity of the larvae was considered from the standpoint of larvae that did not succeed in attaching to any host and extended from the time at which hatching began until the last larva had died of starvation. The actual time during which the larvae would have been capable of successfully attaching to a host probably would be slightly less than this period.

The length of the possible larval period depends largely on temperature and humidity. During protracted periods of high temperatures and low humidity, the larvae emerge from the eggs in a weakened condition, and also, under such conditions, life is shortened through an accelerated loss of body moisture by evaporation. A high relative humidity prolongs life, apparently by conserving the body fluids and decreasing the activity of the tick.

As shown in table 4, the larval life at Mayaguez ranged from 103 to 154 days, at Santa Rita from 65 to 90 days, and at Maricao from 144 to 184 days.

TABLE 4. SUMMARY OF DATA OBTAINED ON PREOVIPOSITION PERIOD, INCUBATION PERIOD OF EGGS, AND LARVAL LONGEVITY OF *BOOPHILUS ANNULATUS MICROPLUS* AT MAYAGUEZ, MARICAO, AND SANTA RITA, PUERTO RICO

Station	Preoviposition period[1]	Minimum incubation period	Larval longevity	Mean average temperature	Average[2] rainfall	Total[3] rainfall
	Days	*Days*	*Days*	*° F.*	*Inches*	*Inches*
Mayaguez (Cage A)..	2-6	25-40	103-145	76.31	6.46	135.66
Mayaguez (Cage B)..	2-6	26-40	103-154			
Santa Rita...	2-6	18-36	65-90	78.34	1.78	37.40
Maricao	2-6	46-76	144-184	72.53[4]	8.17	171.56

[1] All preoviposition periods were determined at Mayaguez.
[2] Average monthly rainfall for 21 months during which longevity tests were conducted.
[3] Total rainfall for 21-month period.
[4] For May-November 1937 only.

Duration of the Non-parasitic Period

The total possible non-parasitic period is of particular significance in determining the time it is necessary to continue dipping operations to accomplish tick eradication. Although there was little variation in this period from season to season under Puerto Rican conditions, there was a marked variation at different locations on the island, as is shown in tables 1, 2, and 3. At Santa Rita the period from dropping of female to the death of the last larva ranged from 89 to 129 days, or a maximum of approximately 4⅓ months; at Maricao the range was from 197 to 251 days, or a maximum of approximately 8⅓ months; and Mayaguez represented an intermediate zone, the range being from 134 to 189 days, or a maximum of approximately 6¼ months.

Temperature and rainfall records for the three different localities are shown in table 4. Since temperature records for the Maricao area are not available except for the months of May to November 1937, inclusive, the mean average of 72.53° F. is presented merely as an approximation for the entire period.

DEVELOPMENT OF PARASITIC STAGES

Method of Study

For studying the parasitic stages, the experimental animals were placed in stalls, the floors of which were made of concrete. Each stall, or cage, was surrounded by a moat which was kept filled with water to prevent escape of the ticks as well as to prevent their movement from one animal to another. Before each test was begun the stalls were thoroughly washed and then disinfected. To insure that the experimental animals were tick free previous to the beginning of an experiment, they were

dipped in a standard arsenical solution. Immediately afterwards they were placed in the tick-free stalls and kept under observation from 10 days to 2 weeks before being used. Throughout the course of the experiment each type of animal was completely isolated to preclude any possibility of accidental infestation.

A series of infestation experiments were conducted on cattle, horses, goats, sheep, dogs, and hogs. Particular emphasis was placed on observations relative to the time elapsing between larval attachment and dropping of the engorged female. The duration of parasitic development is of great practical importance in tick eradication, since the interval between dippings is based on this period. All the animals of each type were infested simultaneously with from 2,000 to 2,500 larval ticks each. All larvae used in the tests were of vigorous stock, insofar as could be determined, and with a known history and of about the same age. The infested animals were examined daily, and records were made as to the state of development of the ticks and any abnormal host reaction.

Development on Cattle

Five different series of infestation experiments were conducted with cattle. In the first experiment one of the animals used was a young bull of native stock, and the other a young heifer having about one-quarter Zebu (Brahma) blood. Since in the first experiment no ticks completed development on the animal with Zebu blood, a cross between native stock and Guernsey was substituted for succeeding tests, since such animals are more susceptible to tick infestations.

Of the approximately 2,000 larval ticks applied to each animal, only a small proportion successfully attached themselves and developed to the adult stage. The actual numbers of engorged females that dropped from the animals in the five series of tests were 32, 139, 45, 660, and 47, respectively, and the infestation having 139 females is considered as typical and the detailed records are presented in table 5.

Larval stage. When the larvae were placed on an animal they immediately scattered and crawled about excitedly over the host. Within a short time, however, most of them began making attempts to attach themselves. In many cases several attempts were made before a satisfactory location was found. Apparently there was a marked preference on the part of the larvae for certain portions of the body of the host, usually points where the hair coat and skin were thinnest. Soon after the larvae were applied the hosts became considerably irritated and scratched and licked themselves. Undoubtedly a considerable number of

TABLE 5. PARASITIC PERIOD OF *BOOPHILUS ANNULATUS MICROPLUS* ON CATTLE AS FOUND ON TWO INFESTED HOSTS. THE INFESTATION INCLUDED 139 FEMALES. MALES WERE OBSERVED UP TO LAST DAY THAT FEMALES WERE PRESENT

Date (1937)	Remarks
April 26	Larvae placed on cattle.
April 27— 1st day	All remaining larvae attached.
May 5— 9th day	First nymphs observed.
May 7—11th day	All larvae molted.
May 10—14th day	First adult observed.
May 15—19th day	All nymphs molted.
May 16—20th day	11 engorged females dropped.
May 17—21st day	16 engorged females dropped.
May 18—22nd day	43 engorged females dropped.
May 19—23rd day	34 engorged females dropped.
May 20—24th day	14 engorged females dropped.
May 21—25th day	18 engorged females dropped.
May 22—26th day	1 engorged female dropped.
May 23—27th day	2 engorged females dropped.

the larvae were thus removed. In the five series of tests conducted, the larval stage ranged in length from 7 to 12 days.

Nymphal stage. A noticeable circular swelling, ranging from one-third to three-fourths of an inch in diameter, developed around the point of attachment of the nymphs, a condition previously observed by other workers. This reaction disappeared upon completion of the nymphal stage and was not observed to be associated with either the larval or adult stage.

The nymphal stage ranged in length from 5 to 17 days, but most of the nymphs molted by the eighth or ninth day.

Adult stage. The period of parasitization by the adult ranged from 5 to 23 days. A majority of the femals, however, engorged and dropped from the host by about the tenth day. In most cases the males were observed to remain on the host for about the same length of time as the females.

The time elapsing between attachment of the larvae and the dropping of the engorged females ranged from 18 to 37 days, but the greater number of specimens had completed engorgement and dropped by the twenty-fifth day. The length of the entire life cycle may range between 41 and 300 days.

Infestation Experiments on Goats

In the first experiment with goats two mature males were used; in the three succeeding tests two kids, one male and one female, respectively; and in the fifth or last experiment, a male kid.

The larvae attached themselves almost exclusively to the head, neck, and back, except that in the case of male goats they attached in comparatively large numbers to the scrotum. In infestations Nos. 3 and 4 large numbers attached along the back in the long, thin hair where de-

velopment was markedly more rapid than on other parts of the body, with the exception of the scrotum. Those that attached to the ears developed slowly, and the majority of them became detached before development was completed.

In some cases the observations could not be made complete enough to determine accurately the duration of certain stages. The total time of development, however, could be determined with little difficulty. In general, the minimum developmental period of the parasitic stages did not vary markedly from that on cattle. On the other hand, the average maximum was considerably longer.

The numbers of females that completed engorgement and dropped from the host in the 5 series of tests were 18, 2, 49, 55, and 17, respectively. One infestation has been selected as representative and the results are presented in detail in table 6. In the entire series the larval stage ranged from 7 to 18 days, the nymphal stage from 7 to 27 days, the adult stage from 6 to 20 days, and the period from attachment of larvae to dropping of engorged females from 20 to 38 days.

TABLE 6. PARASITIC DEVELOPMENT OF *BOOPHILUS ANNULATUS MICROPLUS* ON GOATS. THE DATA ARE FROM THE INFESTATIONS ON ONE MALE AND ONE FEMALE KID

Date (1937)	Remarks
August 6	Larvae placed on goats.
August 14—8th day	First larvae molted.
August 18—12th day	Last larvae molted.
August 21—15th day	First nymph molted.
August 28—22nd day	8 engorged females dropped.
August 30—24th day	18 engorged females dropped.
August 31—25th day	5 engorged females dropped.
September 1—26th day	10 engorged females dropped.
September 2—27th day	2 engorged females dropped.
September 6—31st day	1 engorged female dropped.
September 7—32nd day	1 engorged female dropped.
September 8—33rd day	3 engorged females dropped.
September 13—38th day	1 engorged female dropped.

Infestation Experiments on Sheep

The animals used in the first three tests on sheep consisted of one well-matured male and one young female, each of which was a cross between the wool and the sparsely woolly types of sheep. For the fourth and fifth experiments young wool-type rams were used. With few exceptions the larvae attached to the ears, head, neck, or inguinal region, and, in the case of males, to the scrotum, which was an extremely favorable site for development. In general, attachment occurred in places where there was little or no wool.

In some cases the exact limits of the larval and nymphal stages could not be determined accurately, mainly because of the difficulty of locating the ticks in the long hair. A considerable number of individuals that

attached, particularly in the ears, and developed to the nymphal stage, and in some cases even molted to the adult stage, failed to complete development. In infestation No. 1, 28 replete females dropped from the host. None completed development in infestations Nos. 2 and 5. The reason for this failure was not determined. In the fourth infestation, 480 engorged females developed, 90 percent or more of which were attached to the scrotum. Infestation No. 1 is selected as fairly typical of development on sheep and the detailed records are presented in table 7. In those instances where accurate determinations could be made, the range of the larval stage was found to be from 7 to 12 days, the nymphal stage from 7 to 13 days, and the adult stage from 4 to 24 days. The total parasitic period, concerning which complete records were obtained, ranged from 20 to 37 days.

TABLE 7. PARASITIC DEVELOPMENT OF *BOOPHILUS ANNULATUS MICROPLUS* ON SHEEP. (ONE MALE AND ONE FEMALE HOST ANIMAL)

Date (1937)	Remarks
February 15	Larvae placed on sheep.
February 28—13th day	Partly engorged to engorged nymphs observed.
March 1—14th day	First adults observed.
March 9—22nd day	3 engorged females dropped. Nymphs present.
March 11—24th day	6 engorged females dropped. Nymphs present.
March 12—25th day	6 engorged females dropped. All nymphs molted.
March 13—26th day	2 engorged females dropped.
March 14—27th day	1 engorged female dropped.
March 15—28th day	3 engorged females dropped.
March 17—30th day	2 engorged females dropped.
March 18—31st day	1 engorged female dropped.
March 19—32nd day	2 engorged females dropped.
March 22—35th day	1 engorged female dropped.
March 24—37th day	1 engorged female dropped.

Infestation Experiments on Horses

In each of the five tests with horses, native animals of the pony type were used; in the first three, a mare and a young colt; in the fourth, an old stallion; and in the fifth, a fairly mature mare. In all cases from 2,000 to 2,500 larvae were placed on each animal, but, with the exception of infestation No. 5, no ticks were found following application of the larvae. The colt used in the first three tests had a light infestation of *Boophilus annulatus microplus,* including all stages, at the time it was purchased; but apparently its susceptibility had been lost, at least temporarily, when the experiments were conducted.

The animal used in infestation No. 5 had a moderately heavy infestation of both *Boophilus annulatus microplus* and *Dermacentor nitens* when procured, but only a few ticks developed as far as the nymphal stage in the experimental infestation with *B. a. microplus* a few weeks later. On the fifth day following the application, large numbers of partly engorged to engorged larvae were observed; on the seventh day,

a few recently molted larvae were noted, and by the tenth day only nymphs were present. Following this there was a rapid decrease in the number of nymphs and none could be found after the fourteenth day. The horse developed a severe case of sarcoptic mange soon after the experiment was begun, which probably influenced the tick infestation.

Infestation Experiments on Dogs

Four series of experiments were conducted with dogs. In the first three, two well-matured animals were used; and in the fourth, one was a mature male and the other a small male puppy. At the points of attachment of the ticks, which did not appear to be confined to any particular region of the body, considerable bleeding occurred, usually terminating in a mildly ulcerating sore. The presence of the ticks evidently caused severe irritation, since the animal reacted by violent scratching and rubbing of the body, which frequently either crushed or detached the parasites.

Although none of the females became completely engorged in the first experiment with dogs, 35 of them became sufficiently engorged to deposit viable eggs. In infestations Nos. 2 and 3 only a small number developed to the nymphal stage, and a still smaller number became adults. Twenty-nine adult females, all of which were on the small male puppy, completed development in infestation No. 4.

The larval and nymphal stages were both found to range in length from 8 to 16 days, the adult stage from 14 to 20 days, and the period following larval attachment to dropping of the engorged females from 22 to 29 days. The 29-day record, however, is not considered as representing the maximum, since the majority of the ticks became detached before engorgement was completed. The records obtained in infestation No. 1 are presented in detail in table 8 as an example of tick development on dogs.

TABLE 8. PARASITIC DEVELOPMENT OF *BOOPHILUS ANNULATUS MICROPLUS* ON TWO DOGS

Date (1937)	Remarks
February 15	Larvae placed on dogs.
February 27—12th day	Engorged nymphs observed.
March 4—17th day	Unengorged adult observed.
March 9—22nd day	Nymphs still present.
March 11—24th day	4 females, 3/3 to 3/2 engorged, dropped. No nymphs observed.
March 12—25th day	10 females, 3/4 to 3/3 engorged, dropped.
March 13—26th day	9 females, 3/4 to 3/3 engorged, dropped.
March 14—27th day	5 females, 3/3 to 3/2 engorged, dropped.
March 15—28th day	3 slightly engorged females, dropped.
March 16—29th day	4 females, 3/4 to 3/2 engorged, dropped.

Infestation Experiments on Hogs

The animals used in the four series of experiments with hogs were as follows: In the first and second tests, two young pigs weighing about 20 pounds each; in the third, two pigs weighing about 50 pounds each; and in the fourth, a single animal weighing about 60 pounds. Although a considerable number of larvae attached themselves, usually on or near the base of the ears, and developed for a short time, they began to disappear during the late larval or early nymphal stages. Only a very small proportion developed to the adult stage, and, with the exception of one female, none of these became sufficiently engorged to oviposit. The hogs rubbed themselves against the sides of the pen or other objects and this tended to destroy any ticks on exposed parts of the body, particularly engorged individuals.

The results of one infestation experiment are presented in table 9 as a typical example of development on hogs.

TABLE 9. PARASITIC DEVELOPMENT OF *BOOPHILUS ANNULATUS MICROPLUS* ON A HOG

Date (1937)	Remarks
October 13.....	Larvae placed on hog.
October 19—6th day.....	About 2 dozen larvae attached near base of ear.
October 20—7th day.....	Small proportion of above larvae observed in same position.
October 21 to November 9...	No ticks observed.
November 9—27th day.....	1 female, about three-fourths engorged, attached to shoulder.
November 10—28th day.....	This female tick crushed.

Miscellaneous Infestation Experiments

In February 1938 approximately 1,000 larval ticks were placed on a white rabbit. Although daily observations were made, no attached ticks were found for the first 12 days following the application. On the thirteenth day one partly engorged nymph was observed on the rabbit's ear. Ten days later the nymph molted but became detached on the fourteenth day following without having completed development.

In conjunction with the above test, about 1,000 larval ticks were placed on each of two chickens (mature hens, native stock). On the following day a small number of unattached larvae were present but none could be located on succeeding days.

HOST RELATIONSHIPS

Cattle are the favorite host of *Boophilus annulatus microplus* but horses, goats, sheep, and other animals are commonly attacked.

To establish the host range of the tropical cattle tick under Puerto Rican conditions, and at the same time to determine the relative impor-

tance of its hosts, various types of animals, both domestic and wild, were carefully examined under natural conditions. Incidentally, the wild mammal fauna in Puerto Rico is confined entirely to the rat, mongoose, and bats. Records were made regarding the stages of ticks present, the presence of females sufficiently engorged to deposit eggs being especially noted. The results of these studies are presented in the following paragraphs and in table 10.

TABLE 10. SUMMARY OF RECORDS OF HOSTS OF *BOOPHILUS ANNULATUS MICROPLUS* EXAMINED IN NATURE

Type of animal	Animals examined	Animals infested	
	Number	*Number*	*Percent*
Goats	375	58	15.5
Sheep	360	82	22.8
Horses	131	16	12.2
Hogs	383	0	0
Dogs	180	2	1.1
Mongooses	15	1*	0
Bats	27	0	0
Rats	5	0	0

* Unengorged and unattached.

Goats

A total of 375 goats of various ages were examined and of these approximately 15 percent were infested with *Boophilus annulatus microplus*. Usually only larvae, nymphs, or unengorged adults were found and in quite a number of instances only a few specimens (5 to 10) were observed. In a small percentage of cases, however, several hundred ticks were taken from a single animal, among which were a considerable number of engorged females.

The sites of attachment were most commonly the head and ears, along the back, between the toes, and in the case of males, the scrotum. Occasionally several hundred larvae, nymphs, and unengorged adults were found attached to the inner folds of the external ear.

Among goats, a higher degree and frequency of infestation was evident on young animals, particularly those only a few weeks old, but in one instance well-engorged ticks were taken from practically all parts of the body of a well-matured female, and in a number of other cases mature animals were found to be quite heavily infested. Occasionally when young animals were found to be heavily infested with ticks of all stages, including well-engorged females, they were kept under observation for several weeks to determine the period of time over which the infestation was maintained. In spite of the fact that some of these animals were kept under such conditions as to offer an excellent opportunity for reinfestation, invariably they became tick free after a few weeks. Two such

animals were purchased for experimental purposes in connection with host tests. In the first test, which was begun soon after the purchase of the animals, only a small proportion of the larval ticks applied attached themselves, and a still smaller proportion completed development. In two succeeding tests, however, these same animals proved to be excellent tick hosts.

There are a considerable number of goats in Puerto Rico, both in the country and in villages, some of which are used for milk production and others for slaughter. The majority of these animals are owned by laborers, who, as a rule, have from one to three or four animals which usually are tied out each day by means of a leash along roadsides, fence rows, ditch-banks, or in other idle areas. Since these animals ordinarily are not allowed to range in pastures with cattle they are not consistently exposed to ticks. The animals live in close association with their owner, as a result of which any large parasites, such as engorged female ticks of *Boophilus annulatus microplus,* are likely to be removed by hand.

A few comparatively large herds of goats, consisting of 15 to 30 animals representing various ages, were located and carefully examined. The frequency of tick infestation among individuals in these herds was found to be much greater than among isolated animals.

Apparently isolated goats, or those occurring in comparatively small groups, do not maintain a tick population for more than a few months, unless cattle are present to furnish a continuous source of reinfestation. On the other hand, it appears quite likely that herds of goats of a dozen individuls or more, in which animals of various ages are present, may maintain a tick population over a period of several months, if not indefinitely.

Sheep

The sheep population in Puerto Rico, as compared to goats, is small, but a majority of them occur in relatively large herds. Of 360 animals examined, 82, or 22.8 percent, were found to be infested with *Boophilus annulatus microplus.* As compared to goats, a somewhat greater proportion were harboring engorged female ticks.

Attachment was almost invariably to those parts of the body free from wool or long hair, such as the ears, head, parts of the neck, and the inguinal region. A considerable portion of the sheep in Puerto Rico are the sparsely wooled type and a mixture of this type with the wool breeds, and the density of wool on sheep in Puerto Rico is considerably less than that which normally occurs on similar breeds in the United States. On such animals the degree and frequency of infestation was much less than

on the wool-type breeds of North America. At Aguirre Central, a herd of 94 wool-type sheep was examined, 64 or 68 percent of which were tick-infested, whereas out of a herd of 55, consisting of the wool and sparsely wooled types mixed, examined on the following day on the property of Guanica Central, only 2 animals, or 3.6 percent, were infested with ticks. Both herds were ranging in pastures with tick-infested cattle under conditions that appeared to be equally favorable for picking up an infestation.

Sheep should be considered an important factor in Puerto Rico in maintaining a population of *Boophilus annulatus microplus*.

Horses

Occasionally single horses were found to be heavily infested with the tropical cattle tick, whereas others equally exposed were tick free. In some instances a single horse among a number of others, all of which were ranging together in a pasture, was found to be heavily infested, whereas no ticks were present on the other animals. The susceptibility of an individual animal, however, appeared to vary markedly from time to time.

Attachment was usually on the breast and neck region, but in cases of heavy infestation ticks were found on various parts of the body, particularly in the mane and tail. Young animals coated with long hair appeared to be especially favorable hosts. On such animals a relatively greater number of engorged females were encountered than on mature animals.

Of 131 horses examined, 16, or 12.2 percent, were found to be infested with *Boophilus annulatus microplus,* and it is concluded that horses, as well as goats and sheep, should be regarded as a potential source of danger in Puerto Rico and should be taken into consideration in a program for eradicating the cattle tick. This is particularly important in the movement of animals from tick-infested areas to tick-free areas.

Other Animals

A total of 383 native hogs, including all ages and from various sections of the island, were examined under natural conditions. In no case were ticks found.

Of 180 dogs examined, *Boophilus annulatus microplus* was found on only 2 animals; in one case a single female tick about one-third engorged and in the other an unengorged nymph. It is evident that under natural conditions in Puerto Rico the occurrence of this tick on dogs is extremely rare and of an accidental or temporary nature. Eighty, 44.4 percent,

of the 180 dogs examined were infested with the brown dog tick (*Rhipicephalus sanguineus* (Latr.)).

No ticks were found on 27 bats, including 2 species, *Artibeus jamaicensis jamaicensis* Leach and *Tadarida numina* (Gray), which were collected from 3 different localities on the island.

The mongoose, which originally was introduced into Puerto Rico as a beneficial predator, is common and widespread. Fifteen of these animals were carefully examined, but no ticks were found, with the exception of one unengorged larva of *Boophilus annulatus microplus*.

A number of mature brown rats collected under somewhat similar circumstances were found to be tick-free.

RESISTANCE TO TICK INFESTATION

It was frequently observed that certain individuals among cattle manifested a marked resistance to infestation by the tropical cattle tick. Among Zebu animals, both pure-bred and crosses, a marked degree of resistance to tick infestation was evident. A variation in susceptibility unquestionably exists in other breeds of cattle. This condition was apparent even to a greater extent among less favorable host species such as horses, goats, sheep, and dogs.

Observations indicated that young animals, particularly among horses, goats, and sheep, were more susceptible to tick attack than older animals. Specific cases were noted in which young animals carrying a heavy tick infestation gradually became tick-free even though conditions were extremely favorable for a continuous reinfestation. It would seem that in some cases repeated attacks of ticks tended to produce immunity or increased resistance.

Somewhat similar host reactions were observed in connection with dogs infested with *Rhipicephalus sanguineus*.

OTHER TICKS OCCURRING IN PUERTO RICO

In Puerto Rico three species of ticks commonly occur, namely, the tropical cattle tick (*Boophilus annulatus micriplus*), the tropical horse tick (*Dermacentor nitens*), and the brown dog tick (*Rhipicephalus sanguineus*). To the writer's knowledge, two other species have been collected on the island, but apparently neither has become well established up to the present time. The iguana tick (*Amblyomma dissimile* Koch) was taken from toads (*Bufo marinus L.*) in Puerto Rico in 1935 by Francisco Sein of the Insular Experiment Station. During a conversation with the writer, Mr. Sein stated that the ticks were taken from toads

that had been imported to the island a short time previously. Although a considerable number of toads were examined in Puerto Rico during the course of the present work, no ticks were found. The writer collected a species of tick, *Amblyomma cruciferum Neumann,* from an iguana lizard (*Cyclura stegnegeri* Barbour and Noble) which recently had been introduced from Mona Island.

The Tropical Horse Tick

Of 131 horses from various parts of the island, which were examined, 75, or 57.2 percent, were infested with *Dermacentor nitens*. This tick was found in greatest abundance on horses in the mountainous regions where rainfall is comparatively heavy. In such areas the majority of the horses are small animals, and, as a rule, they are in rather poor physical condition. Heavy infestations of *D. nitens* rarely were encountered on well-kept horses.

In cases of light or moderate infestations attachment was confined largely to the ears, the anal region, and the inguinal region, but in heavy infestations the ticks often were attached to practically any part of the body. On one occasion a laborer was observed scraping ticks from a horse with a machete.

The tropical horse tick occurs on goats and sheep to about the same extent as does the tropical cattle tick on these animals. It is more commonly found, however, within the ears. *Dermacentor nitens* was not taken on cattle by the writer.

Notes on life cycle of Dermacentor nitens. *Dermacentor nitens* is a one-host tick; that is, it spends its entire parasitic life on the same animal. Although the writer conducted no life-history studies, he noted that at Mayaguez the preoviposition period covered from 3 to 5 days and the incubation period from 21 to 28 days.

Dunn (1), who made some observations on the life history of *Dermacentor nitens* in Panama, presented records concerning the longevity of the non-parasitic stages as follows: Preoviposition period from 5 to 7 days, and incubation period from 25 to 27 days. During the course of these observations the temperature range was from approximately 71° to 94° F., which corresponds rather closely with the temperature range in Puerto Rico.

Hooker, Bishopp, and Wood (2) summarized the development of the parasitic stages, which were studied at Dallas, Tex., as follows: "The larvae are short lived, living only 71 days in summer under the most favorable conditions; they engorge and molt on the host as soon as 8 days after attachment. Nymphs may molt as soon as the seventeenth day

after attachment or 7 days after the larvae molt. Adults may engorge and drop as soon as 9 days after the nymphal molt or 26 days after attachment as larvae."

From the foregoing notes it is evident that the life cycle of *Dermacentor nitens* is similar to that of *Boophilus annulatus microplus*.

The Brown Dog Tick

A considerable proportion of the dogs in Puerto Rico are more or less continuously infested with the brown dog tick (*Rhipicephalus sanguineus*). The severity of an infestation of a given animal varies considerably from time to time, largely depending on prevailing climatic conditions, particularly rainfall. At Mayaguez the population of the brown dog tick was comparatively low during the dry season, the specimens encountered more commonly being unengorged adults. At times there was found to be as much as 90 percent parasitization of the tick by the hymenopterous parasite *Hunterellus hookeri* How., which undoubtedly plays an important part in the control of this tick.

Rhipicephalus sanguineus is a particularly serious pest among well-kept dogs, or animals having a restricted range; whereas among stray dogs, which were numerous in Puerto Rico, this pest occurs much less frequently. The writer did not take *R. sanguineus* from any animals in Puerto Rico other than the dog, with the exception of a small number of immature stages observed on young domesticated rabbits which were being kept in close contact with tick-infested dogs. In cases where infested dogs are allowed to remain to some extent in dwelling houses, ticks often may be observed crawling about over the floors, walls, and furniture, and on rare occasions they attach themselves to man.

PARASITES OF TICKS

During the study of tick incidence on various hosts, engorged nymphs of *Boophilus annulatus microplus* and *Rhipicephalus sanguineus* were collected for the purpose of determining if parasites of these were present. The nymphs were collected from animals on various parts of the island, placed on moist sand in the insectary at Mayaguez, and kept under observation for approximately 1 month. An attempt was made to collect nymphs of *B. a. microplus* in the vicinity of areas where parasites of *R. sanguineus* were known to occur.

Of 23 collections, including 1,000 specimens of engorged nymphs of *Boophilus annulatus microplus*, none were found to be parasitized. Among 15 collections of *Rhipicephalus sanguineus*, the percentage of

parasitization ranged from 0 to 94.1. Of a total of 574 engorged nymphs collected, 232, or 40.4 percent, were parasitized. Samples of the parasites were submitted to the Bureau of Entomology and Plant Quarantine for identification and all were found to be *Hunterellus hookeri.*

The number of parasites emerging from an engorged nymph ranged from 4 to 10, the usual number being, however, from 7 to 10. As a rule emergence of the parasites occurred from 2 to 3 weeks after collection of the engorged nymphs.

No parasites emerged from any of several collections of *Dermacentor nitens* made in the vicinity of Mayaguez.

EFFICACY OF THE STANDARD ARSENICAL DIP IN THE DESTRUCTION OF BOOPHILUS ANNULATUS MICROPLUS IN PUERTO RICO

The experimental animals were dipped in a standard arsenical dip[2] diluted to a strength of 0.18 to 0.19 percent arsenious oxide. The criterion for determining the efficacy of the dip was to collect engorged female ticks from cattle at intervals after dipping and place them under conditions favorable for oviposition and incubation of the eggs. The females were kept under observation until they died and, in case oviposition occurred, the eggs were kept until the viability was determined.

As a rule engorged females removed from animals within a short time after a dipping either failed to oviposit or, if they did so, only a small proportion, if any, of the eggs hatched. In some instances, particularly in the case of heavily infested animals, ticks, including engorged females, were still present after the animal had been dipped the second time. With rare exceptions, however, the animals were free of ticks following the third dipping.

In one experiment female ticks that had been removed from animals 8 days after a dipping produced approximately a normal number of viable eggs, whereas females removed previous to this time produced few if any eggs, practically none of which hatched. In another case four females removed at the end of 72 hours after a dipping deposited about a normal number of eggs, the majority of which were viable. The reason for this apparent discrepancy was not determined, but quite probably these particular individuals had not come in full contact with the dip solution.

Athough in one series of tests a few females which were removed from the host up to the fifty-second hour after a dipping oviposited, none

[2] The arsenical dip solution used was a commercial one which met the specifications of the Bureau of Animal Industry of the United States Department of Agriculture.

of the eggs hatched. After this no engorged females were present, but live unengorged ticks were observed on the animal on the third and fourth days.

It is generally supposed that nymphs that are in the process of molting at the time of dipping are protected from the solution to some extent by the presence of the old skin. Although this is merely an assumption, it has been offered by other workers as a possible explanation for the presence of live ticks after a dipping.

In practically all cases ticks that were discovered maturing on animals after a dipping were in locations comparatively well protected by a long coat of hair. This observation is in accord with that of Legg (3) in Australia.

EFFICACY OF ARSENICAL DIP IN THE DESTRUCTION OF DERMACENTOR NITENS

Since horses are a potential source of breeding of *Boophilus annulatus microplus,* it was considered advisable to dip them at 14-day intervals along with cattle. As previously stated, a considerable proportion of the horses in Puerto Rico are infested with the tropical horse tick (*Dermacentor nitens*). In view of the fact that *D. nitens* has a life cycle somewhat similar to that of *B. a. microplus,* it seemed logical to suppose that perhaps it could be eradicated in the regular dipping procedure as prescribed for the cattle tick. An attempt was therefore made to determine the effectiveness of the standard arsenical dip in the destruction of this tick.

In certain areas where horses were heavily infested with *Dermacentor nitens,* a number of them were kept under observation over a period of several weeks during the early stages of the systematic dipping operations, and records were made as to the presence of ticks after the treatments. All records and observations indicated that the toxicity of standard arsenical dips for *D. nitens,* when specimens of that species were thoroughly wet with arsenical solution, was practically the same as for *Boophilus annulatus microplus.*

Fifteen engorged females taken from horses within a few minutes after a dipping in a solution testing 0.18 percent arsenious oxide and placed in pill boxes on moist sand died without having oviposited. The same number of females taken from horses under similar circumstances at a later date deposited a small number of eggs, none of which hatched.

Dermacentor nitens normally attaches within the ears, under the tail, and between the hind legs where they have considerable protection from

the solution. The long hair and waxy or oily secretion in the ears of horses often prevented thorough wetting of the inner surface of the external ear. Horses, also, frequently succeeded in holding their heads above water when going through the dipping vats. Occasionally ticks in protected places on other parts of the body failed to come in contact with the dip solution. Because of these circumstances, it was obvious that in order to eradicate *D. nitens* during the course of the regular procedure for the tropical cattle tick it would be necessary to exercise special precautionary measures to insure that the dip solution comes in contact with all ticks in protected places.

SUMMARY

The tropical cattle tick (*Boophilus annulatus microplus* Can.) is of importance not only because of the irritation caused and debilitating effect on the host animal but because it is a natural agent of dissemination of splenetic or tick fever of cattle. It is widely distributed throughout South America, Central America, and Mexico, as well as in the islands of the West Indies and in Borneo, Sumatra, and the Philippine Islands. In the United States, although formerly occurring in several counties in Florida and over a smaller area in Texas it has now been eradicated from all except the extreme southern portions of these two States.

The facts that this variety and the cattle tick (*Boophilus annulatus* Say) do not commonly attack wild animals and that the cattle tick has been largely eradicated from the United States indicated the feasibility of eradicating the tropical variety from Puerto Rico. The biology under Puerto Rican conditions was therefore investigated as a basis for eradication work, and the results of studies in 1936, 1937, and 1938 are given in this paper.

Ticks in their non-parasitic periods were studied in bottomless glass tubes set in the soil, and those in their parasitic periods, as attached to host animals confined in isolated stalls.

The preoviposition period ranged from 2 to 6 days, the oviposition period from 11 to 18 days, and the minimum incubation period, under different climatic conditions, from 18 to 76 days.

There was no marked seasonal variation in larval longevity of *Boophilus annulatus microplus* in Puerto Rico. Larval longevity in the dry southern coastal region and in the higher altitudes of the interior, where there is a comparatively high rainfall, however, ranged from 65 to 184 days; and the total non-parasitic period, or the period from the dropping of the engorged female to the death of the last larva, ranged from 89 to 251 days.

The larvae began to molt from the seventh to the twelfth day after their application to a bovine host. Nymphs completed engorgement 12 to 26 days after attachment, or 5 to 17 days after the larval molt. The period from the nymphal molt to the dropping of the engorged female, or the adult stage, ranged from 5 to 23 days. The minimum period from attachment of the larva to the dropping of the engorged female was 18 days, and the maximum period was 37 days.

The life cycle, including both parasitic and non-parasitic development, may be completed in Puerto Rico on cattle within a minimum period of approximately 41 days; the maximum may extend over a period of approximately 300 days. The minimum parasitic period of *Boophilus annulatus microplus* on goats, sheep, and dogs was found to be practically the same as that on cattle.

The tropical cattle tick was taken from goats, sheep, and horses in considerable numbers under natural conditions. Host records definitely indicate that these animals should be taken into account in a cattle tick eradication campaign in Puerto Rico. In Puerto Rico, dogs, hogs, and mammals other than the above apparently are of little or no importance as natural hosts of the cattle tick.

In addition to *Boophilus annulatus microplus* two other species of ticks commonly occur in Puerto Rico and are of widespread economic importance, *viz.*, the tropical horse tick (*Dermacentor nitens*) and the brown dog tick (*Rhipicephalus sanguineus*).

No parasites of the tropical cattle tick were found. However, a high degree of parasitization by the hymenopterous parasite *Hunterellus hookeri* was encountered among nymphs of the brown dog tick.

Standard arsenical dips, such as are used in the continental United States, proved to be effective in destroying the tropical cattle tick in Puerto Rico, practically all the animals being free of engorged female ticks after the second or third dipping. The arsenical dip was also effective against the tropical horse tick but considerably greater care was necessary in dipping horses to insure that the solution came in contact with all the ticks on the animal.

LITERATURE CITED

1. **Dunn, L. H.** Observations on the Preoviposition, Oviposition and Incubation of *Dermacentor nitens* in Panama (Arach., Acar.) Ent. News **26**: 214-219. 1915.
2. **Hooker, W. A., F. C. Bishopp, and H. P. Wood.** The Life History and Bionomics of Some North American Ticks. U. S. Dept. Agri., Bur. Ent. Bull. **106**: 239, illus. 1912.
3. **Legg, John.** Some Observations on the Life History of the Cattle Tick (*Boophilus australis*). Queensland Roy. Soc. Proc. **61**: 121-132. 1929.