# ENVIRONMENTAL MODIFICATION THROUGH MECHANICAL AND CHEMICAL TREATMENT AS A MEANS OF TICK CONTROL

By

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ENVIRONMENTAL MODIFICATION THROUGH
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## PREFACE

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# CHAPTER I

## INTRODUCTION

Ticks have caused large economic losses throughout the years to both the livestock and recreational industries. Chemicals have been developed for tick control but these serve as only temporary measures and have to be reapplied often. There has been an increased interest in some type of integrated control program which would reduce tick populations to tolerable levels without frequent expensive treatment.

Eastern Oklahoma has had a serious tick problem for many years and has been considered as a "hot spot" for several tick-borne diseases. Ticks have also greatly reduced the profits made in the livestock industry. A new industry is emerging in this part of the state, and once again ticks are beginning to reduce the economic gain. Outdoor recreation is becoming an important part in the economic structure of eastern Oklahoma and this "unlimited" resource cannot be fully realized until suitable tick control procedures are put into use.

A need for an integrated tick control program was evident and as an aid to this program it was necessary to establish objectives. These objectives were: (1) to determine effectiveness of habitat modification through mechanical and chemical treatment as a means of tick control; (2) to determine means of tick dispersal in the study areas; and (3) to determine seasonal and ecological distribution of the prevalent tick species.

It was hoped that a control program could be developed that would improve the recreational potential of eastern Oklahoma and at the same time decrease the tremendous economic losses to the livestock industry which are caused by ticks. The results of this study are included in this dissertation.

CHAPTER II

# REVIEW OF THE LITERATURE

Ticks have plagued man for centuries, and he has long sought ways to avoid them. Pagenatecher (1861) cited extracts from classical literature relating to the earliest mention of ticks. Among these were: Aristotle (384-322 B.C.), who referred to ticks as "disgusting parasites which came out of the grass"; Cato (234-149 B.C.) referred to ticks as being troublesome in sheep production; and Pliny (23-77 A.D.) referred to an animal (tick) that lives on blood, with its head always fixed and whose body swells until it bursts.

Their importance as a disease vector was first realized when Smith and Kilbourne (1893) discovered that the cattle tick, Boophilus annulatus (Say), was the necessary intermediate host for the causal agent of Texas fever. This discovery led to further studies which demonstrated that ticks were capable of transmitting many diseases caused by different organisms (Pratt and Littig, 1962) and also can produce forms of toxicosis (Neitz, 1962) and a toxic paralysis (Brunetti, 1965; Wilkinson, 1965; Grégson, 1966a). Through the course of time ticks have become the most versatile vector of animal disease agents (Philip, 1963).

In recent years there has been much work done on the identification, biology, host range, and life cycle of ticks in the United States (Hooker, Bishopp, and Wood, 1912; Bishopp and Trembley, 1945; Howell, 1953; and others). Ticks generally have a specific range, and according to Eddy (1940), Oklahoma's ticks were represented by two families, seven genera and 15 species and the Ixodidae or hard ticks composed five genera and 12 species of this group. Amblyomma americanum (L.) or the lone star tick was found to be the most prevalent.

According to Cooley and Kohls (1944) the lone star tick has been incriminated as a vector of Rocky Mountain Spotted fever, Tularemia, American Q fever, Bullis fever, and Spotted fever. They also listed Oklahoma as being in the preferred range for this tick. Prior to this, Parker, Kohls and Steinhaus (1943) had demonstrated the rickettsia of Rocky Mountain Spotted fever from A. americanum (L.) ticks which had been collected from east central Oklahoma. Calhoun (1954) found that the lone star tick was a common vector of Tularemia in Arkansas and other similar ecological areas. Tritschler (1965), in Missouri, found that the lone star tick was responsible for a severe allergy and nerve condition in horses.

Amblyomma americanum (L.) is a three-host tick and readily attacks man in all active stages (Bishopp and Trembley, 1945; Sacktor, Hutchinson and Granett, 1948; and Lancaster, 1955). This tick has a wide host range and commonly attacks birds and most mammals (Cooley and Kohls, 1944). Lancaster (1955) found that it composes over 95% of the tick population in Arkansas.

The need for tick control was very critical during the Texas cattle fever outbreak, and a successful eradication program was carried out (Mohler, 1905) against the Texas cattle fever tick. This tick was found in Oklahoma in much of the same area as the Amblyomma americanum. However, the host specific, one-host Texas cattle fever tick was more easily controlled than the three-host, nonspecific lone star tick.

Howell (1953) felt that it was seldom economically feasible to control ticks over wide areas, but by personal prophylaxis, limited area treatment, and the control of tick hosts, tick bites and tick-borne diseases could be largely avoided. Acaricides have been used in the past with fair results, but the resulting environmental contamination may be serious unless extensive safeguards are followed.

Area tick control has become very important with the increase in the tourism industry and some states have considered legislation to work out satisfactory control programs (Arkansas Legislature, 1967). Biological and chemical control have been employed with varying amounts of success.

Howard (1907, 1908) found that there were two hymenopteran parasites that attack ticks in the field and additional records have been accumulated in many parts of the world (Pervomaisky, 1947; Goldsmith, 1965). This method of control has not been developed and more research is needed. Birds seem to play a role in limited areas as a means of tick control by picking ticks from livestock and also in grooming themselves (Petrishcheva and Zhmayeva, 1949). However, ground inhabiting birds have been a major host for immature stages of the lone star tick (Cooley and Kohls, 1944).

Knipling (1964) and others discussed the characteristics which were necessary to control certain arthropod species by the sterility method and the requirements for its practical application. Several problems have been foreseen in the adaptation of this control procedure for ticks and the sterility method does not appear to be promising for use in area control. However, Drummond, Medley, and Graham (1966) successfully used the radiation principle to control the lone star tick through male sterilization.

Pasture rotation and dipping of livestock were successfully utilized in the eradication program in the United States (Mohler, 1905) against the Texas fever tick and Wilkinson (1964) found this method effective in Australia. Mutch (1966) found that by cleaning up pastures and using rotational grazing the tick problem could be reduced. In 1945 Portman applied pasture rotation as a means of control for the lone star tick in Missouri and found that by keeping cattle out of a pasture from June 15 until after the first heavy frost he could reduce the tick burden.

According to Howell (unpublished data) losses due to ticks have ranged as high as 20% in the Oklahoma livestock industry. With this in mind, Howell was able to average a 76% reduction in ticks over a 12-year period through a pasture rotation program and he found that by excluding all animals from an area he obtained a 98% reduction. He also reported that tick populations increase relative to the amount of brush in a pasture. Harley and Wilkinson (1964) had similar results in a planned dipping and pasture rotation program in Australia.

Some work has been done on the effects of clearing with herbicides on small rodent populations. By altering the habitat and lowering animal populations, tick populations would also be lowered. Johnson and Hansen (1969) found that treatment of forb and shrub-grass range with 2,4-D usually produced an increase in grass cover and a decrease in most forbs and shrubs. Gopher and chipmunk populations were reduced by this habitat change. Goertz (1962), in Oklahoma, found that cotton rats were limited to those areas within their total range where density and height of grass cover and associated forbs and low-growing woody species provided dense cover. If deprived of this necessary habitat, cotton rat populations rapidly declined.

In 1965, Martin conducted a study to determine the effects of a herbicide on wildlife populations and found that songbirds exhibited a preference for the treated areas in the spring and summer months but were more numerous in the control during the fall and winter. Reduced numbers of bobwhite quail were observed in the treated plots, with the fox squirrel showing the most drastic emigration from the treated areas.

Theiler (1965) reported that ticks are greatly affected by temperature and relative humidity and this was in agreement with Odùm's (1959) concept of an ecological niche. Lancaster and MacMillan (1955) reported that oviposition did not occur in the lone star tick below a relative humidity of 73% and replete larvae did not molt at a relative humidity below 69%.

According to their (Lancaster and MacMillan, 1955) findings, lack of moisture and a low relative humidity greatly reduce lone star tick populations. Knülle (1966) found that the longevity of some tick larvae was abruptly shortened at humidities below 80% and that the ticks' ability to go for long periods without feeding depends on the humidity.

Most of the tick control work that has been done in the past has been based on the use of acaricides applied by various methods. Chemical tick control gained importance in the widespread eradication program (Mohler, 1905) of the Texas fever tick. With the advent of chlorinated hydrocarbon insecticides, many tests were carried out. However, man soon found that acaricides must be used with caution.

With this in mind, various screening procedures were established and attempts were made to determine the most effective materials to use and in what amount. Drummond (1958) outlined a standard screening procedure for certain groups of insecticides and the USDA has been screening large numbers of insecticides for several years. Drummond, Moore, and Wrich (1960) conducted field testing to determine the effectiveness of certain chemicals for lone star tick control by comparing them with toxaphene which had become a standard. They found that none of the materials tested on cattle were effective after two weeks. In later work Drummond and Medley (1965) found that 16 of 20 insecticides tested gave 80% or better control, but none were highly effective after a two-week period.

Various methods have been explored to determine the most effective types of control. Drummond, Whetstone, and Ernest (1966) found that if livestock were sprayed it was very important that they be thoroughly wet and that all parts of their bodies come in contact with the acaricide. Lancaster (1958) commented that dipping vats were effective but expensive to construct and costly to charge. He found that by carrying out a thorough spray program on a 21-day spray interval it was possible to break the life cycle of the lone star tick; however, part of the population was maintained by other hosts.

The lone star tick has a wide host range and this has greatly complicated its control. Tugwell and Lancaster (1962) reported that the lone star tick occurred on 18 species of birds and mammals and that the host's size and habits governed its attack. For environmental alteration to be possible as a means of tick control, specific host survey studies were necessary.

Lancaster (1958) found that the number of lone star ticks present was directly dependent on the habitat. He found that brushy areas yielded over 70% of the ticks sampled and that tall sedge along well-used trails yielded an additional 18%. Humidity also played an important role in the location of the ticks and Theiler (1965) found that areas with a low rainfall seldom were suitable for lone star ticks. He also reported that ticks were not only dependent on their immediate environment but also on the presence and relative abundance of their hosts, which are as essential for their maintenance as for their dispersal.

Standard methods for making estimations of tick populations do not exist and tick sampling has long presented a challenge to the field researcher. Tick populations are composed of both active specimens in search of hosts and inactive specimens, and tick activity appears to depend on many things, such as temperature, humidity, length of day, and the season. Ticks normally migrate only short distances, but Smittle, Hill and Phillips (1967) found they moved over 75 feet in search of shade and a host.

The drag flag has been used for many years, but Horen (1954), in an attempt to get greater accuracy, designed a drag flag which was attached to a 3-foot equilateral triangle with a 6-inch handle at its apex that allowed the drag flag to be used in a variety of ways. Lancaster (1958) made tick counts by attaching a flannel cloth (24 x 36 inches) to a dowel and pulling it for 100 feet at each location. This was done twice monthly during the tick season.

In 1961, Wilkinson compared several sampling techniques and found that a wheeled device was most efficient but was difficult to handle and he also found that legging counts were most effective in rough areas.

Garcia (1962) used $CO_2$ for collecting ticks under field conditions. A carbon dioxide bait trap was found by Miles (1968) to be effective in collecting ticks from animal burrows, and Tugwell and Lancaster (1962) outlined a method for obtaining ticks from various hosts.

# CHAPTER III

# METHODS AND MATERIALS

## Location

Eastern Oklahoma was selected as the site for this study for several reasons. This region has one of the highest tick populations in Oklahoma and is located in an area where preliminary work has been conducted. Tourism is an increasingly important source of income and cattle and wildlife are abundant. Federal and state controlled lands were made available for research and the personnel of the agencies involved were very cooperative and intensely interested in this program.

The detailed study area selected is in the Cherokee Wildlife Refuge in northeastern Muskogee and southwestern Cherokee counties. This area is in close proximity to several lakes which teem with outdoor activity and wildlife. Also a rotational grazing and spray program (Carlile and Howell, unpublished data) had been in operation in this area since 1964.

Three demonstration areas were established on July 15, 1967, with six 1-acre plots in each block. The three blocks were located within a 1-mile radius in Cherokee county but differed slightly as to terrain and tick reinfestation pressure. Block No. 1 (Corral No. 2; NE¼ SW¼ S9 R21E T14N) was open woodland. Block No. 2 (Mackey crossing; SW¼ SW¼ S8 R21E T14N) was creek bottom subject to overflow. Block No. 3 (Mary Ballard field; NW¼ NE¼ S16 R21E T14N) was woodland open to less than 15% sunlight.

The cattle grazing and spray program based on monthly spraying and rotation was continued in much the same manner as before and some of the applicable data were included in this study. There were eight pastures, each containing approximately 4,000 acres, located in the Cherokee Wildlife Refuge.

The host survey was conducted in the vicinity of the test blocks and included samples taken from several square miles. The survey of ticks on deer was conducted throughout eastern Oklahoma with emphasis on the Cherokee Wildlife Refuge.

Environmental Alteration

Each of the three test blocks was divided into six 1-acre plots treated respectively as follows: (1) mechanical clearing of all undergrowth and enough of the larger vegetation to allow penetration of 70-80% sunlight, (2) mechanical clearing with the addition of an acaricide, (3) mechanical clearing with the addition of a herbicide, (4) application of an acaricide to existing vegetation, (5) application of a herbicide to existing vegetation, and (6) no treatment (Figure 1).

Clearing was accomplished by hand equipment and chain saws. All of the underbrush and enough of the larger vegetation were removed in clearing the plots to allow penetration of 70-80% sunlight. The brush was removed from the cleared plots to simulate recreational areas. No vegetation was removed from the uncleared plots.

The acaricide-treated plots were sprayed with Shell Chemical Company's Gardona® (Raybon®, SD-8447)[a] 75% wettable powder at the rate

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[a]Phosphoric acid, 2-chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl ester.

Figure 1. A comparison of a cleared and uncleared plot, showing the amount of vegetation removed.

of 1 pound of actual toxicant per acre. Gardona® was selected for use after being screened in the laboratory for several years (Figure 2).

The acaricide was applied after pretreatment counts were made. Reapplications were made when tick populations demonstrated an increase in the acaricide-treated plots.

In the preliminary work of 1967 the plots were sprayed with 2-gallon compressed-air hand sprayers. Control was satisfactory but this technique was considered too slow and uneconomical. Power equipment was employed during 1968 to speed the application of the acaricide and it was also used in treatment of established recreational areas. Applications were made with a pickup-mounted high pressure power sprayer which was operated at a pressure of 300 psi.

The herbicide plots were treated with 2,4,5-T,OS[a] at the recommended rate of 1 gallon in 24 gallons of diesel oil applied with 2-gallon compressed air sprayers. In the mechanically cleared plots the herbicide was applied as a stump treatment as the area was cleared. The uncleared plots received the herbicide as a basal bark spray which was applied to the point of runoff. The amount of herbicide applied was dependent on the vegetative cover present.

Herbicide applications were made during a period of hot, dry weather in the summer of 1967 and unsatisfactory results were obtained. The herbicide treatments were reapplied in early 1968 with satisfactory results.

The plots that received clearing and acaricide and clearing only were maintained by cutting back all regrowth at six-week intervals

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[a]2,4,5-trichlorophenoxyacetic acid.

Figure 2. Acaricides were applied to existing recreational areas with the aid of a pickup-mounted sprayer.

during the growing season. After the initial treatment of herbicide and the retreatment in 1968, no further herbicide applications were made.

## Sampling Procedure

A sweep net, 15 inches in diameter, and a drag flag consisting of heavy weight muslin 36 x 72 inches attached to a 3-foot dowel were used in estimating the tick populations. The sweep net was employed in the usual sweeping method while the drag flag was pulled behind the person taking the sample by a heavy cord attached to the shoulders (Figure 3).

Each sample consisted of an area 25 yards long and 1 yard wide. Four samples were selected at random in each plot and the average or mean number of ticks was determined.

At the end of each 25-yard sample the adult and nymphal ticks present on the drag and sweep net were counted and an estimate was made of the number of larval ticks present. A whisk broom was then used to remove the ticks from the drag and sweep while remaining in the sampled plot.

Samples were conducted at 10- to 14-day intervals except when climatic conditions prohibited sampling. During periods of low tick activity periodic samples were made to record their activity.

## Tick Host Survey

Surveys of ticks on animals were extremely important in furnishing biological data pertinent in tick control efforts. Seasonal distribution, species composition, abundance, and geographical distribution were part of the data obtained from these studies.

In June 1967 an animal collecting program was initiated and many species of animals were collected. A scientific collector's permit was

Figure 3. Tick populations were estimated in a treated plot by sweep net and drag flag techniques.

obtained from the Oklahoma Department of Wildlife Conservation to make possible the collection and sampling of various types of animals during the year.

Animals were collected for sampling in the following manner: live animal traps, jaw traps, .22 caliber rifle, road kills, tranquilizer gun, and checking game kills by hunters.

Small rodents were attracted and trapped in live animal traps by using a bait consisting of peanut butter, oatmeal, and bacon grease. The bait was mixed and placed in small packets made from newspaper. The packets were then placed in a plastic bag in a refrigerator to keep them fresh. This method enabled traps to be set much more rapidly in the field and also reduced the time necessary for cleaning them.

The rodents were removed from the traps (Figure 4) and placed in a wide-mouth plastic jar containing cotton which had been saturated with chloroform. As soon as the animal succumbed it was removed and placed in a plastic freezer bag which was labeled and sealed for later sampling. The bags were then placed in an ice chest and allowed to cool for several hours (Tugwell and Lancaster, 1962).

After cooling, the dead rodent was removed from the bag and placed in 50% ethanol and agitated vigorously. Close inspection was made of the plastic bag to remove ticks that might be present. The rodent was then removed from the ethanol and carefully inspected for ticks that were still attached. The alcohol was filtered through paper toweling and the ticks collected were placed in a labeled vial containing 70% ethanol for later identification.

Animals that were shot and were small enough were processed in this manner. Larger animals that were collected were visually examined and

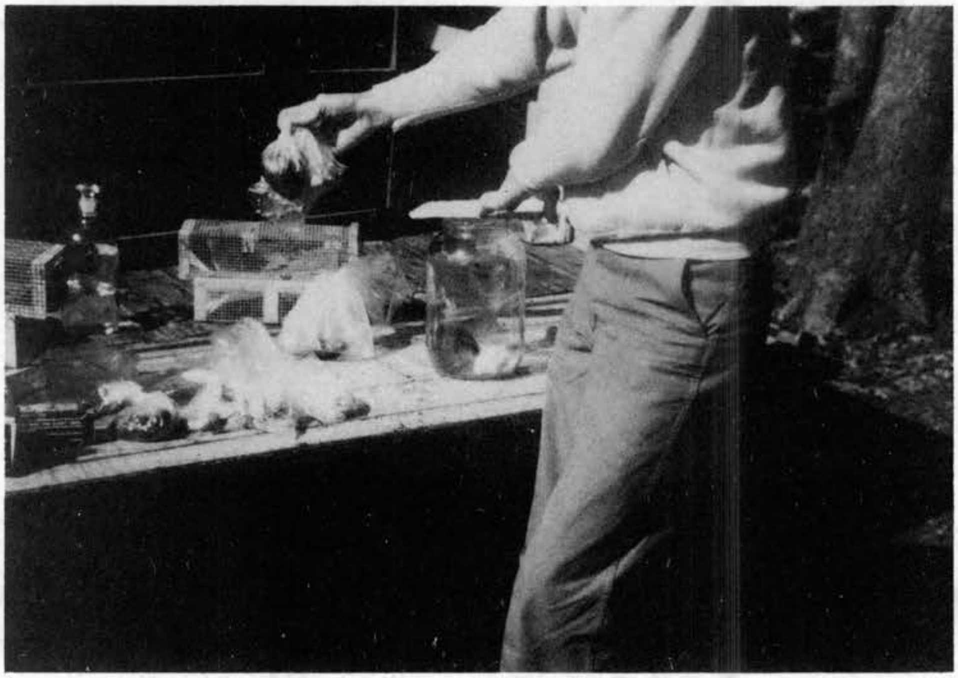

Figure 4. Small rodents were stored in plastic bags until examination for tick infestations was possible.

disposed of without taking them into the laboratory. Many animals, such as raccoons, were anesthetized with chloroform and released after a close visual inspection had been made.

This was accomplished by removing the animal from a live trap with a holder consisting of a 5-foot piece of conduit pipe with a 0.125-inch cable looped through it. The animal was restrained by the holder and a plastic container containing chloroform-soaked cotton was placed over its mouth and nostrils. This was kept in place until the animal became limp and then it was removed. If the animal showed signs of awakening, it was replaced as needed.

After the check of the animal was completed it was ear notched for later identification and released. If the animal showed signs of not recovering, artificial respiration was applied to the rib cage until normal breathing was restored.

During deer hunting season, which is normally held in October and November, personnel were maintained at the various deer check stations throughout Oklahoma and all deer brought to the stations were examined for ticks (Figure 5). An estimate of total populations was made and specimens were collected for later identification. From these specimens the life stages and relative numbers were determined.

Tick host preference data were also obtained from cattle which were used in a combination grazing and tick control study. These cattle were present in the area from April through September.

Specimens from all mammals and birds were placed in 70% ethanol and labeled for later identification.

Animal activity was monitored in the test blocks by daily observations made while working in the area, as described by Sanderson in 1966.

Figure 5. Freshly killed deer were examined during a survey to determine tick distribution and prevalence.

Observation towers were constructed and used throughout the year. Signs of grazing and animal droppings were also noted. Daily and seasonal trends of animal activity were observed in this manner and this information was correlated with the data obtained on tick populations in the test blocks.

Pasture Rotation and Cattle Dipping

On April 1 of each year 300 cows and calves were placed in each of four of the eight paired pastures. During 1966 and 1967 three groups of the cattle were sprayed with a high pressure sprayer and rotated to a companion pasture on the first of each month of the grazing period. Dipping vats were constructed and used in 1968 (Figure 6). All of the cattle were treated prior to their entrance into the pastures. The fourth group of cattle was rotated each month but did not receive any acaricide treatment. The cattle were removed from the pastures on October 1.

Six animals were selected at random from each pasture and tick counts were made (Figure 7). Six-square-inch areas in the axillary, around udder or scrotum, and around the tailhead or anus were examined. The number of ticks was recorded but no attempt was made to record the various stages found.

Thirty-four check sites were selected in the eight pastures and these sites were sampled once each month during the grazing period. A drag flag was used to make the counts but the sweep net was not incorporated into this phase of the study. The sample areas were marked by stakes and were 25 yards long.

Figure 6. Cattle dipping was utilized as a means of tick control.

Figure 7. Animals were checked regularly to determine the effectiveness of the cattle dipping and pasture rotation program.

Recreational Areas

The research was also extended to include treatment and maintenance of some existing recreational areas and camp sites. Tick populations were low in many of these areas at the beginning of the treatment.

Existing camping areas were sprayed once each month with Gardona® at the rate of 0.5 pounds of toxicant per acre. Some clearing and herbicide work was done in the recreational areas.

Due to the low populations of ticks present in some recreational areas, no attempt was made to keep accurate records on tick populations. The recreational areas involved included approximately 800 acres, much of which was along the shores of Lake Tenkiller.

# CHAPTER IV

## RESULTS AND DISCUSSION

### Environmental Alteration

The 1967 work began on July 15 and covered the larval season. These data provided excellent information for further tests.

The replicated plots receiving "clearing plus an acaricide" or "acaricide only" demonstrated the highest percent control over a four-week period. Table I shows the perliminary data on larval control.

TABLE I

CHANGE IN TICK POPULATIONS FOUND IN EXPERIMENTAL PLOTS DURING 1967 EXPRESSED AS PERCENT[a]

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| Weeks Post-Treatment | Cleared and Acaricide | Cleared and Herbicide | Cleared Only | Acaricide Only | Herbicide Only | No Treatment |
| 1 | -100 | -70 | -60 | -100 | -80 | +1 |
| 2 | -97 | -87 | -45 | -99 | -35 | -88 |
| 3 | -79 | -92 | -60 | -98 | -4 | -5 |
| 4 | -100 | -21 | -93 | -92 | -63 | -79 |

[a]Based on number of ticks per 225 ft.$^2$ of surface area.

It was known that clearing of the test plots would affect animal activity but no attempt was made during the course of this study to prevent this normal activity. The activity in the uncleared plots appeared to be little affected by the acaricide applications but the uncleared plots receiving herbicide appeared to have less activity.

In the "cleared only" and "cleared plus acaricide" plots, deer activity was slightly increased when second growth vegetation began to appear. The "cleared plus herbicide" plots demonstrated a slight increase in large animal activity. Many animals tended to follow the path of least resistance and would often cross the cleared plots. Small animal activity was greatly reduced by the removal of the ground cover in the plots which were cleared. This agreed with previous work done by Goertz (1962) in Oklahoma.

Animal exclusion has been shown to be important in preventing tick reinfestation in treated areas but this exclusion would not be desirable for many outdoor "nature" areas. The clearing was designed to change the microhabitat (Odum, 1959) of the tick and therefore make it less favorable for its survival.

Lone star tick activity declines rapidly in the fall, but some overwintering forms can be found throughout the year. It was found through sampling of untreated areas that the larvae reach a peak population between July 15 and August 15. The nymphs peak May 15 through June 15 and the adults appear to reach their highest populations in May. The seasonal distribution of the lone star ticks found on vegetation has been shown in Figure 8.

The plots received the same treatment each time. When tick populations were observed to be increasing in any of the acaricide-treated

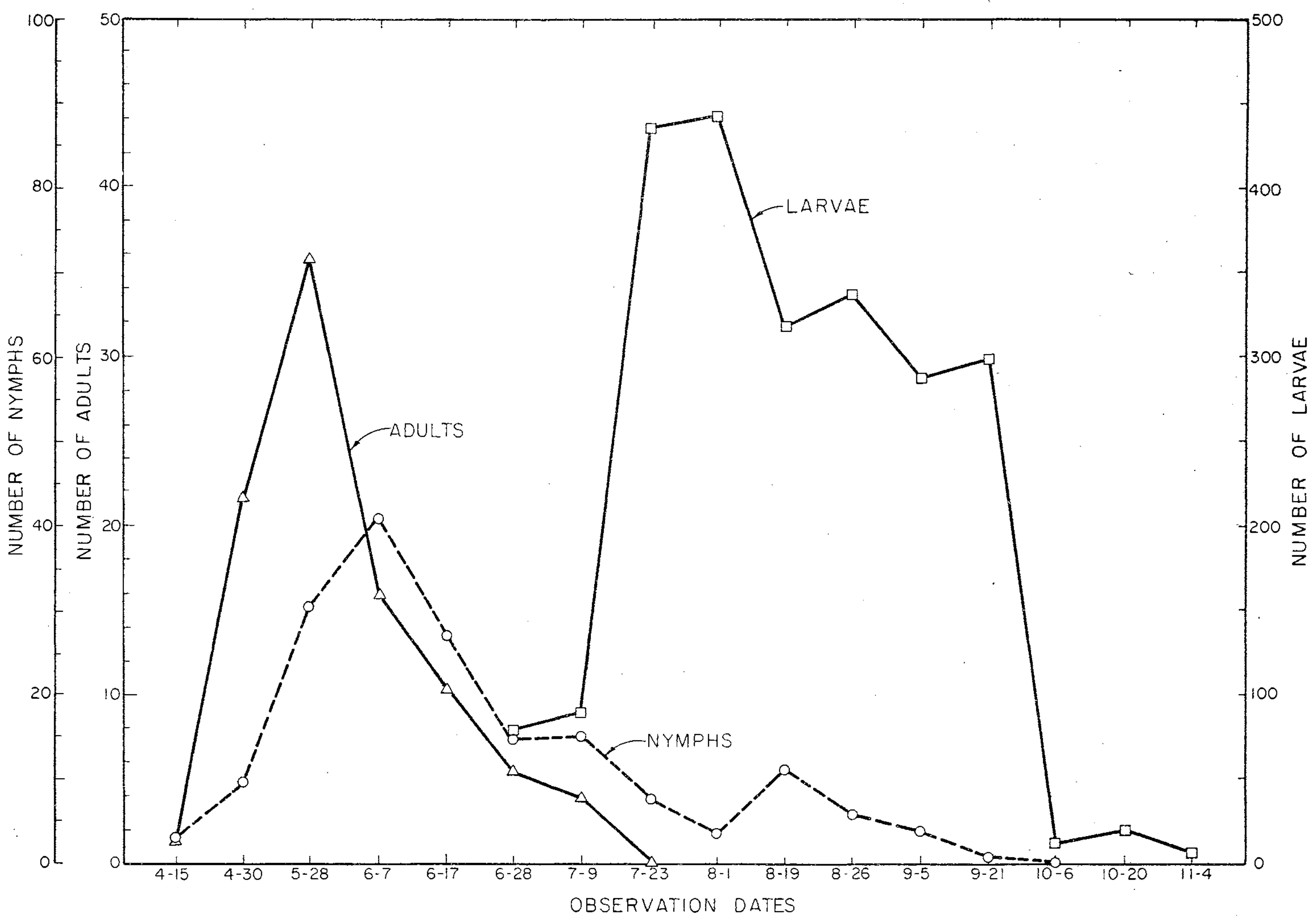


Figure 8. Seasonal distribution of various stages of the lone star tick (Amblyomma americanum) in Cherokee County, Oklahoma, during 1968.

plots, they all were treated. This was done to keep the three replicated blocks as nearly alike as possible. Spraying was generally completed in 1.5 days.

There were five acaricide treatments applied during 1968 - on April 16, June 13, July 10, July 25, and August 30. The second July application was necessary due to high isolated populations of larval lone star ticks.

The same pattern was followed each time the plots were sprayed to assure a uniform application. Weather conditions had some effect on the coverage. Wind was seldom a factor but during the hotter part of the summer there was some volatilization. When possible, spraying was not done during the extreme heat of the day. Muddy conditions forced the June 13 application to be applied three days later than desired.

Some control was obtained in all of the plots which were mechanically cleared (Figures 9 and 10). The plots receiving "clearing plus an acaricide" demonstrated the most effective control of all the exposed life stages of the lone star tick. Correct timing of the applications was very important. If they were applied when the ticks were seeking a host, excellent control was obtained. Time of application was determined by carefully monitoring tick activity in the check plots.

The plots receiving "clearing plus herbicide" were ranked second of those which were cleared. It should be pointed out that often heavy concentrations of ticks in a small area and the difficulty of obtaining a uniform sample will cause certain data to appear negative. This was the case of the September 5, 1968, data where the nymphal activity (Figure 10) appeared to be higher than it actually was. By monitoring animal activity in the plots, it was observed that the area containing

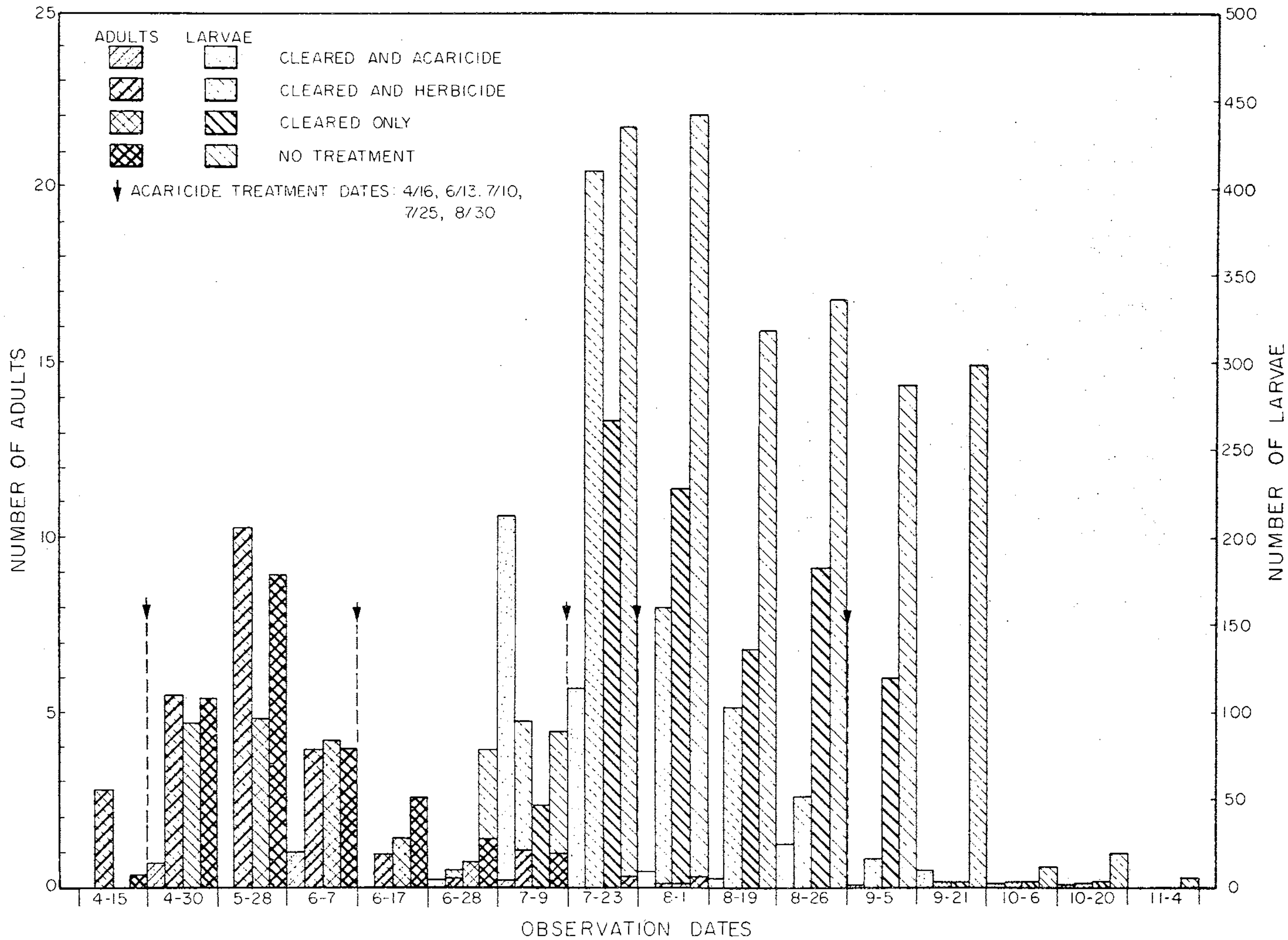


Figure 9. Average numbers* of adult and larval ticks occurring in woodland areas receiving either clearing and acaricide, clearing and herbicide, clearing only, or no treatment during 1968.

*Estimates represent average numbers of ticks occurring in twelve 75 x 3 ft. areas.*

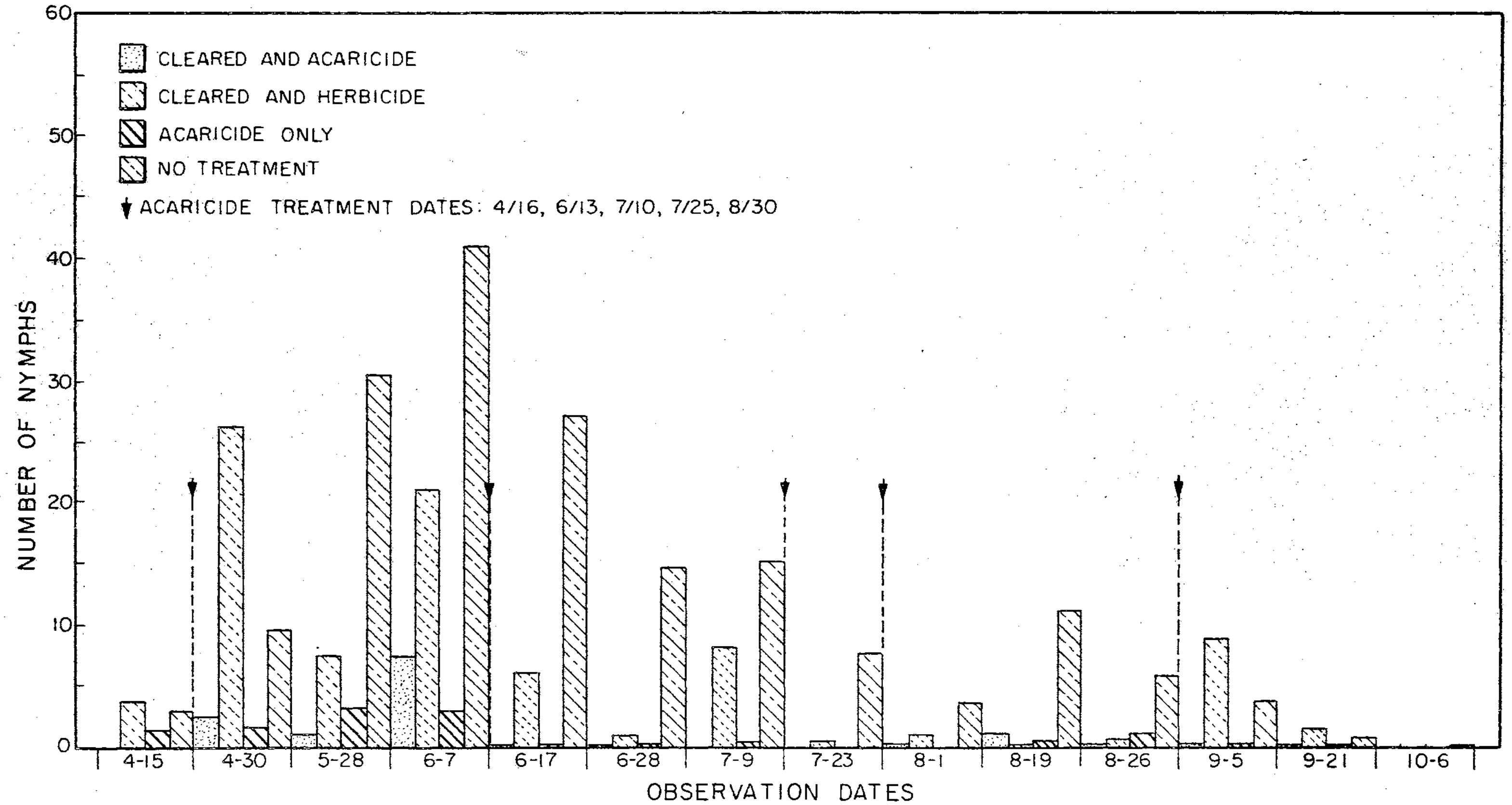


Figure 10. Average number* of nymphal ticks occurring in woodland areas receiving clearing and acaricide, clearing and herbicide, acaricide only and no treatment during 1968.

*Estimates represent average numbers of nymphal ticks occurring in twelve 75 x 3 ft. areas the high nymphal population had been used extensively as a bedding area for deer. These nymphs had been larvae which dropped off and molted in the test plots.

"Clearing only" yielded 40 to 50% control of all the prevalent life stages. This was significant in that by clearing the tick burdens were reduced and it made the area more desirable for recreation and increased the productive capacity of the pastures. A major problem with "clearing only" was the rapid regrowth that usually occurred. If this regrowth were allowed to remain it could make conditions more favorable for tick activity than before any clearing had been done. It was also observed that wildlife activity tended to increase as the regrowth began to appear. The deer liked to browse on the tender second growth and spent quite a bit of time in the cleared plots that did not receive a herbicide. Small animal activity, especially that of the cotton rat, increased as more cover became available.

The application of acaricides to unaltered vegetation provided more effective control than the herbicides applied in the same manner. However, the herbicide has the added feature of "cleaning up" the area and increasing its productive use. Figure 11 shows the comparison of the acaricide and herbicide only plots.

When considering all of the treatments, the "clearing plus an acaricide" gave the best control. The "acaricide only" was next, followed by "clearing plus a herbicide," "herbicide only," and "clearing only" (Table II). Table III gives the mean numbers of ticks found in the various plots by vegetation sampling during the 1968 phase of this study.

An integrated program consisting of the application of a herbicide

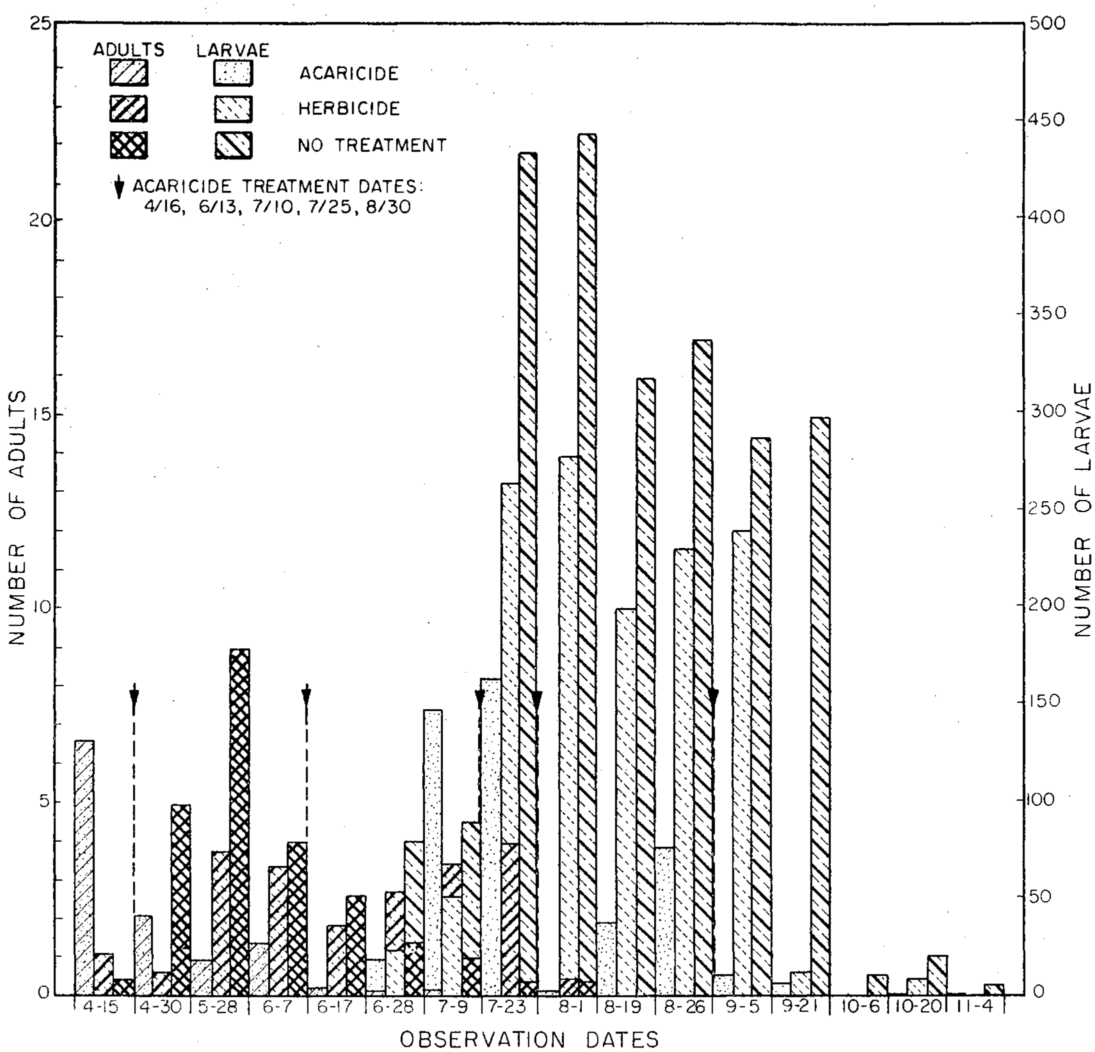


Figure 11. Average number* of adult and larval ticks occurring in woodland areas receiving an acaricide, a herbicide or no treatment during 1968.

**Estimates represent average numbers of ticks occurring in twelve 75 x 3 ft areas*

TABLE II

PERCENT CONTROL[a] OF LONE STAR TICKS OBTAINED IN PLOTS RECEIVING MECHANICAL, CHEMICAL, OR MECHANICAL-CHEMICAL CONTROL METHODS

| Date | | Cleared and Acaricide | Cleared and Herbicide | Cleared Only | Acaricide Only | Herbicide Only |
|---|---|---|---|---|---|---|
| 4-15 | L[b] | 0 | 0 | 0 | 0 | 0 |
| | N[b] | 100 | *[c] | 100 | 50 | 0 |
| | A[b] | 100 | * | 100 | * | * |
| | T[b] | 100 | * | 100 | * | 17 |
| 4-30 | L | * | * | 0 | 0 | 0 |
| | N | 74 | * | * | 82 | 0 |
| | A | 87 | 0 | 16 | 64 | 89 |
| | T | 78 | * | * | 75 | * |
| 5-28 | L | 0 | 0 | 0 | 0 | 0 |
| | N | 96 | 75 | 21 | 89 | 63 |
| | A | 100 | * | 84 | 90 | 57 |
| | T | 97 | 54 | 26 | 90 | 62 |
| 6-7 | L | 0 | 0 | 0 | 0 | 0 |
| | N | 81 | 48 | 49 | 93 | 37 |
| | A | 74 | 3 | * | 67 | 15 |
| | T | 81 | 44 | 44 | 91 | 35 |
| 6-17 | L | 0 | 0 | 0 | 0 | 0 |
| | N | 99 | 77 | 29 | 99 | 71 |
| | A | 100 | 64 | 48 | 92 | 28 |
| | T | 99 | 76 | 31 | 99 | 67 |
| 6-28 | L | 97 | 88 | 100 | 75 | 71 |
| | N | 99 | 93 | * | 99 | * |
| | A | 100 | 77 | 46 | 85 | * |
| | T | 97 | 89 | 16 | 79 | * |
| 7-9 | L | * | * | 47 | * | 55 |
| | N | 100 | 47 | 55 | 97 | * |
| | A | 78 | * | 100 | 89 | * |
| | T | * | 2 | 48 | * | * |
| 7-23 | L | 74 | 6 | 38 | 62 | 39 |
| | N | 100 | 91 | * | 100 | * |
| | A | 100 | 100 | 100 | 100 | * |
| | T | 75 | 7 | 37 | 63 | 34 |
| 8-1 | L | 98 | 64 | 48 | 100 | 37 |
| | N | 97 | 78 | 50 | 100 | * |
| | A | 100 | 68 | 68 | 100 | 0 |

TABLE II (Continued)

| Date | | Cleared and Acaricide | Cleared and Herbicide | Cleared Only | Acaricide Only | Herbicide Only |
|---|---|---|---|---|---|---|
| | T | 98 | 64 | 48 | 100 | 31 |
| 8-19 | L | 99 | 68 | 57 | 88 | 38 |
| | N | 90 | 98 | 70 | 95 | 97 |
| | A | 0 | 0 | 0 | 0 | 0 |
| | T | 99 | 69 | 57 | 89 | 40 |
| 8-26 | L | 93 | 85 | 46 | 78 | 32 |
| | N | 95 | 88 | 90 | 78 | 87 |
| | A | * | 0 | 0 | 0 | 0 |
| | T | 93 | 85 | 47 | 78 | 33 |
| 9-5 | L | 99 | 94 | 58 | 96 | 17 |
| | N | 95 | * | 95 | 92 | 53 |
| | A | 0 | 0 | 0 | 0 | 0 |
| | T | 99 | 91 | 59 | 96 | 18 |
| 9-21 | L | 97 | 99 | 99 | 98 | 95 |
| | N | 88 | * | 100 | 88 | 25 |
| | A | 0 | 0 | 0 | 0 | 0 |
| | T | 97 | 99 | 99 | 98 | 95 |
| 10-6 | L | 98 | 80 | 80 | 100 | 100 |
| | N | 100 | 100 | 100 | 100 | 100 |
| | A | 0 | 0 | 0 | 0 | 0 |
| | T | 98 | 80 | 80 | 100 | 100 |
| 10-20 | L | 96 | 86 | 78 | 100 | 61 |
| | N | 0 | 0 | 0 | 0 | 0 |
| | A | 0 | 0 | 0 | 0 | 0 |
| | T | 96 | 86 | 78 | 100 | 61 |
| 11-4 | L | 100 | 100 | 100 | 98 | 100 |
| | N | 100 | 100 | 100 | 100 | 100 |
| | A | 0 | 0 | 0 | 0 | 0 |
| | T | 100 | 100 | 100 | 99 | 100 |

[a]Percent net control calculated by a modification of Abbott's formula: $\frac{\text{No. in control - No. in treated plot}}{\text{No. in control}} \times 100$

[b]Larvae, nymphs, adults, combined total.

[c](*) Represents higher populations in treatment than control.

TABLE III

AVERAGE NUMBERS[a] OF LONE STAR TICKS FOUND IN WOODLAND AREAS AFTER CHEMICAL-MECHANICAL CONTROL MEASURES HAD BEEN APPLIED DURING 1968

| Date | | Treatments[b] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Cleared and Acaricide | Cleared and Herbicide | Cleared Only | Acaricide Only | Herbicide Only | No Treatment |
| 4-15 | L[c] | 0 | 0 | 0 | 0 | 0 | 0 |
| | N[c] | 0 | 3.8 | 0 | 1.5 | 3.0 | 3.0 |
| | A[c] | 0 | 2.8 | 0 | 6.5 | 1.0 | 0.4 |
| | T[c] | 0 | 6.6 | 0 | 8.0 | 4.0 | 3.4 |
| 4-30 | L | 0.1 | 2.5 | 0 | 0 | 0 | 0 |
| | N | 2.6 | 26.1 | 23.1 | 1.8 | 19.8 | 9.9 |
| | A | 0.7 | 5.5 | 4.6 | 2.0 | 0.6 | 5.5 |
| | T | 3.4 | 34.1 | 27.7 | 3.8 | 20.4 | 15.3 |
| 5-28 | L | 0 | 0 | 0 | 0 | 0 | 0 |
| | N | 1.1 | 7.6 | 24.1 | 3.3 | 11.1 | 30.4 |
| | A | 0 | 10.3 | 4.8 | 0.9 | 3.8 | 8.9 |
| | T | 1.1 | 17.9 | 27.9 | 4.2 | 14.9 | 39.3 |
| 6-7 | L | 0 | 0 | 0 | 0 | 0 | 0 |
| | N | 7.5 | 20.8 | 20.7 | 2.8 | 25.4 | 40.3 |
| | A | 1.0 | 3.8 | 4.2 | 1.3 | 3.3 | 3.9 |
| | T | 8.5 | 24.6 | 24.9 | 4.1 | 28.7 | 44.2 |
| 6-17 | L | 0 | 0 | 0 | 0 | 0 | 0 |
| | N | 0.3 | 6.1 | 18.8 | 0.3 | 7.8 | 26.6 |
| | A | 0 | 0.9 | 1.3 | 0.2 | 1.8 | 2.5 |
| | T | 0.3 | 7.0 | 20.2 | 0.5 | 9.6 | 29.1 |

TABLE III (Continued)

| Date | | Treatments[b] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Cleared and Acaricide | Cleared and Herbicide | Cleared Only | Acaricide Only | Herbicide Only | No Treatment |
| 6-28 | L | 2.2 | 9.5 | 0 | 19.6 | 22.9 | 79.2 |
| | N | 0.1 | 1.1 | 79.1 | 0.1 | 441.3 | 14.7 |
| | A | 0 | 0.3 | 0.7 | 0.2 | 2.7 | 1.3 |
| | T | 2.3 | 10.9 | 79.8 | 19.9 | 466.8 | 95.2 |
| 7-9 | L | 211.7 | 94.4 | 47.9 | 147.1 | 50.0 | 89.6 |
| | N | 0 | 8.0 | 6.8 | 0.5 | 189.6 | 15.2 |
| | A | 0.2 | 1.0 | 0 | 0.1 | 3.4 | 0.9 |
| | T | 211.9 | 103.4 | 54.7 | 147.7 | 243.0 | 105.7 |
| 7-23 | L | 112.1 | 409.2 | 268.3 | 162.5 | 262.8 | 433.2 |
| | N | 0 | 0.7 | 9.4 | 0 | 25.1 | 8.0 |
| | A | 0 | 0 | 0 | 0 | 3.8 | 0.3 |
| | T | 112.1 | 409.9 | 277.7 | 162.5 | 291.7 | 441.5 |
| 8-1 | L | 8.3 | 159.7 | 228.3 | 1.3 | 276.7 | 441.4 |
| | N | 0.1 | 0.8 | 1.8 | 0 | 29.7 | 3.6 |
| | A | 0 | 0.1 | 0.1 | 0 | 0.3 | 0.3 |
| | T | 8.4 | 160.6 | 230.2 | 1.3 | 306.7 | 445.3 |
| 8-19 | L | 3.8 | 101.3 | 136.7 | 37.1 | 198.3 | 318.3 |
| | N | 1.1 | 0.2 | 3.3 | 0.6 | 0.3 | 11.1 |
| | A | 0 | 0 | 0 | 0 | 0 | 0 |
| | T | 4.9 | 101.5 | 139.0 | 37.7 | 198.6 | 329.4 |

TABLE III (Continued)

| Date | | Treatments[b] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Cleared and Acaricide | Cleared and Herbicide | Cleared Only | Acaricide Only | Herbicide Only | No Treatment |
| 8-26 | L | 24.6 | 50.9 | 182.4 | 75.0 | 230.4 | 337.1 |
| | N | 0.3 | 0.7 | 0.6 | 1.3 | 0.8 | 6.0 |
| | A | 0.8 | 0 | 0 | 0 | 0 | 0 |
| | T | 25.7 | 51.6 | 183.0 | 76.3 | 231.2 | 343.1 |
| 9-5 | L | 1.7 | 16.0 | 120.8 | 10.4 | 238.3 | 287.9 |
| | N | 0.2 | 9.0 | 0.2 | 0.3 | 1.8 | 3.8 |
| | A | 0 | 0 | 0 | 0 | 0 | 0 |
| | T | 1.9 | 25.0 | 121.0 | 10.7 | 240.1 | 291.7 |

[a]Numbers represent estimates of ticks occurring in twelve 75 x 3 ft. areas which were selected at random from the various test plots.

[b]Herbicide applied: 6/9; Acaricide applied: 4/16, 6/13, 7/10, 7/25 and 8/30.

[c]Larvae, nymphs, adults, and total of all three stages.

and followed by three to four acaricide applications at three- to four-week intervals should provide good seasonal tick control. This would also improve forage production and recreational potential by opening up the area.

## Tick Host Survey

The tick host survey was initiated in June 1967 and continued through 1968. Over 500 animals belonging to 24 different species were checked. The numbers listed in Table IV were not necessarily the total numbers of ticks found on the animals but should give some indication as to the host preference. Also it should be pointed out that the number of ticks present on the animals was influenced by the time of year.

During the spring and summer months the lone star tick (*Amblyomma americanum* L.) made up about 92% of the ticks removed from the various hosts and the American dog tick (*Dermacentor variabilis* Say) and the rabbit tick (*Haemaphysalis leporispalustris* Packard) composed the remaining 8%.

In the late fall and winter months the predominant ticks were the black-legged tick (*Ixodes scapularis* Say) and the winter tick (*Dermacentor albipictus* Packard). From 4 to 12% of the ticks recovered during the winter were *Amblyomma americanum* (L.).

Deer surveys were conducted during the 1965, 1966, 1967, and 1968 deer seasons. These surveys were conducted on an area-wide basis but only those deer killed in the vicinity of the test blocks were considered. Table V shows the results of the deer surveys.

The lone star tick was found on nearly every species of animal sampled and also appeared throughout the year. This agreed with earlier work done by Cooley and Kohls (1944). The environmental conditions

TABLE IV

TICKS[a] ON ANIMALS EXAMINED IN CHEROKEE COUNTY, OKLAHOMA, 1967 AND 1968

| Host | No. of Hosts | Ticks Present | Larvae | Nymphs | ♀ | ♂ |
|---|---|---|---|---|---|---|
| Whippoorwill | 2 | _A. americanum_ | 170 | 0 | 0 | 0 |
| Chaparral cock | 7 | _A. americanum_ | 320 | 10 | 0 | 0 |
| | | _H. leporispalustris_ | 33 | 4 | 0 | 0 |
| Cattle | 180 | _A. americanum_ | 23,540 | 2,420 | 180[b] | 60[b] |
| White-tailed deer | 30 | _A. americanum_ | 1,870 | 1,309 | 12[b] | 11[b] |
| | | _D. albipictus_ | 0 | 9 | 0 | 0 |
| | | _I. scapularis_ | 0 | 0 | 1 | 0 |
| Squirrel | 9 | _A. americanum_ | 509 | 62 | 0 | 0 |
| | | _D. variabilis_ | 1 | 0 | 0 | 0 |
| Raccoon | 43 | _A. americanum_ | 960 | 381 | 5 | 6 |
| | | _D. variabilis_ | 0 | 3 | 25 | 27 |
| | | _I. scapularis_ | 24 | 25 | 26 | 4 |
| | | _D. albipictus_ | 0 | 0 | 1 | 2 |
| Woodchuck | 3 | _A. americanum_ | 75 | 125 | 1 | 3 |
| | | _D. variabilis_ | 0 | 0 | 2 | 0 |
| Quail | 7 | _A. americanum_ | 78 | 46 | 0 | 0 |
| | | _H. leporispalustris_ | 220 | 20 | 0 | 0 |
| Skunk | 1 | _A. americanum_ | 12 | 8 | 0 | 0 |

TABLE IV (Continued)

| Host | No. of Hosts | Ticks Present | Larvae | Nymphs | ♀ | ♂ |
|---|---|---|---|---|---|---|
| Cottontail rabbit | 26 | *H. leporispalustris* | 299 | 123 | 51 | 59 |
| | | *A. americanum* | 871 | 215 | 0 | 0 |
| | | *D. variabilis* | 27 | 1 | 0 | 0 |
| | | *I. scapularis* | 0 | 1 | 0 | 2 |
| Horse | 5 | *I. scapularis* | 10 | 20 | 70 | 20 |
| | | *D. albipictus* | 0 | 2 | 3 | 0 |
| | | *A. americanum* | 15 | 7 | 2 | 3 |
| Cotton rat | 164 | *A. americanum* | 28 | 4 | 0 | 0 |
| Wood rat | | *I. scapularis* | 1 | 4 | 0 | 0 |
| | | *H. leporispalustris* | 1 | 0 | 0 | 0 |
| | | *D. variabilis* | 15 | 6 | 0 | 0 |
| White-footed mice | 70 | *A. americanum* | 4 | 3 | 0 | 0 |
| | | *I. scapularis* | 1 | 2 | 0 | 0 |
| | | *D. variabilis* | 25 | 0 | 0 | 0 |
| Grey fox | 2 | *A. americanum* | 0 | 1 | 0 | 0 |
| | | *I. scapularis* | 40 | 15 | 17 | 17 |
| Coyote | 1 | *I. scapularis* | 1 | 0 | 13 | 5 |
| Chipmunk | 2 | *A. americanum* | 1 | 0 | 0 | 0 |
| Opossum | 6 | *I. scapularis* | 0 | 0 | 1 | 0 |
| | | *D. albipictus* | 1 | 0 | 1 | 0 |
| Lizard | 4 | *I. scapularis* | 4 | 19 | 0 | 0 |

TABLE IV (Continued)

| Host | No. of Hosts | Ticks Present | Larvae | Nymphs | ♀ | ♂ |
|---|---|---|---|---|---|---|
| Red-tailed hawk | 2 | None | 0 | 0 | 0 | 0 |

[a]Not necessarily total ticks present on animal.

[b]These animals were examined during the late summer months when adult activity was minimal. In May, cattle and deer may have several thousand adults.

played an important role in the tick's activity. Little host specificity was demonstrated and the extent of parasitism depended on the size of the host and its habitat. The data agrees with that of Mohr and Stumpf (1964) and Worth (1951) which showed that larger animals were more heavily parasitized than smaller ones and those animals traveling further were also more heavily parasitized by ticks.

TABLE V

TICK POPULATIONS FOUND ON WHITE-TAILED DEER KILLED IN THE CHEROKEE WILDLIFE REFUGE DURING THE FALL HUNTING SEASON

| Year | No. Deer Sampled | Percent of Population | | |
|---|---|---|---|---|
| | | *I. scapularis* | *D. albipictus* | *A. americanum* |
| 1965 | 19 | 89 | 4 | 7 |
| 1966 | 27 | 85 | 13 | 2 |
| 1967 | 32 | 67 | 24 | 9 |
| 1968 | 27 | 70 | 22 | 8 |

The immature stages of the lone star tick parasitized all sizes of animals and birds, while the adults were found predominantly on medium- and large-sized animals. This was probably due to the location of the adults. Larvae were normally observed awaiting a host only a few inches from the soil surface, while nymphs and adults were often found several feet from the soil surface.

Ticks were apparently attracted to the animals by heat, $CO_2$ or some other stimulus. This positive attraction could be observed by watching ticks on plants as an animal or man approached. Large populations of ticks were often found in or near the bedding areas of animals. However, Balashov (1954) and Kheisin and Lavrenenko (1956) found, in Russia, that animal activity or movement stimulated the detachment of replete ticks from their hosts. This accounts for the high populations of larvae often found along animal trails and also demonstrates why large numbers of ticks can be found on animals which travel these paths.

## Pasture Rotation and Cattle Dipping

A pasture rotation and cattle dipping program has been utilized by the Oklahoma Department of Wildlife Conservation and the Oklahoma State University Department of Entomology since 1964 in an effort to determine more effective means of tick control (Table VI). The preliminary work of 1964 and 1965 was used to create a more efficient program.

TABLE VI

TICK NUMBERS ON CALVES AND PERCENT CONTROL DURING A THREE-YEAR STUDY PERIOD

| Year | Treated | | Untreated | | Percent Control |
|---|---|---|---|---|---|
| | Number | Av./Calf | Number | Av./Calf | |
| 1966 | 847[a] | 28.2 | 495[b] | 49.5 | 57 |
| 1967 | 897[a] | 29.8 | 456[b] | 45.6 | 65 |
| 1968 | 2530[c] | 27.1 | 1423[a] | 47.3 | 58 |

[a]Six animals examined on each of five observation periods.
[b]Two animals examined on each of five observation periods.
[c]Eighteen animals examined on each of five observation periods.

Uniform drag flag sampling procedures were not strictly adhered to during the 1968 season and that information was not included. However, the grazing program has real merit and should be continued.

The 1968 data on the calves examined demonstrated a 6% decrease in overall tick populations and a 4% increase on the untreated animals. This was attributed to more effective coverage of the animals with an acaricide through dipping and a slight decrease in the ticks found in the pastures.

Through this type of program better than 55% tick control has been maintained over a three-year period. Additional benefit has also been gained from such side benefits as fly control. With an intensified dipping program in the spring and early summer plus brush removal the amount of tick reduction should be greatly increased. If the cattle were treated on a 10- to 14-day interval the life cycle of the lone star tick would be greatly interrupted and much better control obtained.

## Recreational Areas

One of the major purposes of the research conducted was to determine efficient and effective means of tick control in recreational areas. In the well-kept camping areas of eastern Oklahoma tick populations were usually too low to measure adequately. However, one tick was capable of causing extreme discomfort to an unsuspecting individual. Table VII shows an indication of the people visiting part of the improved areas on Lake Tenkiller, which were near the test area and included in the acaricide treatments.

After the recreational area treatment was initiated no further complaints of tick or chigger bites were received. The spraying kept the ticks down for three to five weeks. The additional clearing and

TABLE VII

NUMBER OF PEOPLE VISITING SIX RECREATIONAL AREAS INCLUDED IN TICK CONTROL DEMONSTRATION PROJECTS AT TENKILLER FERRY RESERVOIR[a]

| Date | Elk Creek | Cookson Bend | Sixshooter | Chicken Creek | Snake Creek | Strayhorn |
|---|---|---|---|---|---|---|
| Sept. 1967 | 4,300 | 5,900 | 3,300 | 5,300 | 4,300 | 9,900 |
| Oct. 1967 | 2,500 | 5,700 | 2,500 | 3,200 | 4,000 | 4,200 |
| Nov. 1967 | 2,500 | 3,200 | 3,000 | 3,000 | 2,700 | 2,200 |
| Dec. 1967 | 2,000 | 2,000 | 1,500 | 3,000 | 2,000 | 1,700 |
| Jan. 1968 | 2,700 | 1,700 | 1,000 | 2,000 | 2,200 | 1,700 |
| Feb. 1968 | 4,500 | 2,000 | 1,200 | 2,000 | 2,500 | 2,500 |
| Mar. 1968 | 3,500 | 3,700 | 1,700 | 2,700 | 3,700 | 3,700 |
| Apr. 1968 | 6,000 | 5,700 | 2,500 | 3,000 | 5,700 | 8,000 |
| May 1968 | 8,000 | 6,500 | 3,200 | 6,500 | 8,000 | 7,700 |
| June 1968 | 18,500 | 15,500 | 6,000 | 11,200 | 14,000 | 13,000 |
| July 1968 | 13,500 | 15,700 | 6,000 | 12,000 | 21,700 | 20,700 |
| Aug. 1968 | 9,700 | 19,000 | 1,700 | 11,700 | 15,500 | 29,700 |
| Total | 77,700 | 86,600 | 33,600 | 65,600 | 86,300 | 105,000 |

[a]Data courtesy of U. S. Army Corps of Engineers.

use of herbicides made the areas less favorable for tick reinfestation.

Deer parasitized by ticks were often observed in the park areas but the reduced vegetation did not afford enough cover for the ticks to become reestablished. The removal of brush which made the ecological habitat less desirable for ticks and more desirable for recreational purposes indicates the importance of adequate clearing for tick control (Figure 12).

Figure 12. Infrequently used camping areas such as this require more intensive tick control efforts than well-maintained areas.

# CHAPTER V

## SUMMARY AND CONCLUSIONS

Simulated recreational areas were established in the Cherokee Wildlife Refuge in eastern Oklahoma. Six 1-acre plots were replicated three times and received one of the following treatments: (1) mechanical clearing of all undergrowth and enough of the larger vegetation to allow 70-80% sunlight penetration, (2) mechanical clearing with the addition of an acaricide, (3) mechanical clearing with the addition of a herbicide, (4) application of an acaricide to existing vegetation, (5) application of a herbicide to existing vegetation, or (6) no treatment.

Gardona® 75% wettable powder was used as the acaricide and applied at 1 pound toxicant per acre in the test plots and 0.5 pound per acre in the recreational areas. The herbicide used was 2,4,5-T,OS applied at the recommended rate.

Sampling was done with a sweep net and drag flag. Four random samples were taken in each plot at 10- to 14-day intervals with each sample consisting of an area 1 x 25 yards. This procedure provided a close estimate of the populations of active ticks present at the time of sampling.

The order of effectiveness was: mechanical clearing plus an acaricide, acaricide only, mechanical clearing plus a herbicide, herbicide only, and clearing only. The acaricide plots were most effective but the herbicide-treated plots had the added feature of decreasing animal utilization and thereby reducing the number of possible hosts present in the area.

Tick host surveys were conducted from June 1967 through 1968 and gave some indication as to the means of tick dispersal in the study areas. Over 500 animals belonging to 24 species were collected and the lone star tick (Amblyomma americanum L.) was recovered from 23 species.

The immature stages of the lone star tick exhibited little host specificity while the adults were primarily found on the larger animals. Through area sampling and host surveys, it was found that the larvae reached an active peak population between July 15 and August 15 and nymphs peaked May 15 through June 15. The adults appeared to reach their highest populations in May. Small populations of active adult and nymphal ticks were found throughout the year.

A cattle grazing and spray program has been utilized on eight pastures consisting of 4,000 acres each, with better than 55% control over a three-year period. Pasture rotation and cattle treatment has been an effective means of tick control in many areas.

Recreational areas were treated with 0.5 pound of Gardona® per acre applied at four-week intervals. After the initiation of this phase of the program tick and chigger infestations on campers in the treated areas were eliminated. Recreational areas can be maintained with little effort by keeping underbrush growth to a minimum and making regular applications of an acaricide.

An integrated program consisting of environmental alteration by means of mechanical and chemical treatment appears to be effective in area tick control. This type of control program is applicable to many of our recreational areas and will show an economic benefit if used.

This same program can be altered somewhat and applied to area control in pastures and other large outdoor areas.

Much work is yet to be done but it is hoped that the data presented in this dissertation will bring us a step closer in our efforts of tick control.

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