A COMPARISON OF SAMPLING METHODS FOR THE LONE STAR TICK [AMBLYOMMA AMERICANUM (LINNAEUS)]

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PREFACE

Ticks are a serious pest because they harm livestock and because of their potential to transmit disease to man and animals. The lone star tick [Amblyomma americanum (Linnaeus)] is detrimental to the tourist business in eastern Oklahoma (Hair and Howell 1970).

The potential for harm from ticks makes it desirable to have a method that can validly estimate numbers of ticks at any time in any type of vegetation. Heretofore, no survey technique has had this capability. The purpose of this study was to design and construct a trap that could hold dry ice and dispense a known tick attractant (carbon dioxide) slowly at ground level. This trap was tested as a survey method against the method currently used. The potential for using CO_2 in future control methods was evaluated.

I wish to express my appreciation for the valuable advice and guidance given by Dr. J. A. Hair, Committee Chairman, during this study. Special appreciation is extended to Dr. J. R. Sauer, Dr. N. N. Durham, and Dr. R. R. Walton.

Appreciation is extended to Joe Fletcher for advice and aid in construction of some of the materials used in this study.

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CHAPTER I

INTRODUCTION

The lone star tick, *Amblyomma americanum*, is a serious pest of man, domestic animals, and wildlife in many parts of the United States. The economic damage to the cattle industry is great in several states of the Ozark region (Hair and Howell 1970; Lancaster 1957). Eastern Oklahoma is particularly plagued by large numbers, and development of hunting and recreation areas has suffered.

Many acaricides are effective in controlling ticks (Mount et al. 1968, 1970; Hoch et al. 1971a), but the concern over the detrimental effects of many of our best chemicals provided the impetus for placement of restrictions on their use.

Because the detrimental effects of many of our pesticides are not fully understood, it is wise for scientists to seek nonchemical control measures when possible. During the past fifty years a substantial number of entomological research projects have been devoted to nonchemical means of control for destructive arthropods, i.e., mechanical or biological, and use of repellents and attractants.

Results of studies involving CO_2 for tick attraction make limited area control with attractants seem feasible. Smittle et al. (1967) observed random movement of ticks 75 ft. in 72 hr, while Smith et al. (1946) noted *Dermacentor variabilis* (Say) movement toward a road 400 ft. away. Garcia (1963) observed *Ornithodoros coriaceus* Koch migration to

CO_2 under favorable temperature conditions and Wilson et al. (1972) observed lone star adult movement of 21.3 meters to a CO_2 source.

The harm caused by ticks makes it desirable to have a survey method that will give valid estimates of the numbers in a habitat. The flagging method used and described by Clymer et al. (1970a) has been used widely to survey for the presence of ticks. This technique depends on physical attachment of the ticks on a canvas net or drag cloth. Semtner and Hair (1973a) found that lone star ticks spend much of their life on vegetation waiting for hosts and that vertical migrations on vegetation are responses to temperature and humidity. It seems obvious, then, that differences in vegetation and terrain will cause differences in tick activity. Large areas having heavy overstory (forested areas) have little or no ground vegetation (understory) for host-seeking ticks to ascend. The large variation in results from flagging done in this area by Clymer et al. (1970a) and Semtner et al. (1971b) can be more easily understood when these factors are considered.

One of the goals of this study, therefore, was to determine the feasibility of using an attractant, CO_2, as a survey tool. Traps were designed and constructed to capture ticks as well as attract them. The overall effectiveness of CO_2 traps was compared with flagging, the standard survey technique. This study also involved determination of the effects of differing amounts of overstory, understory, and leaf litter on each technique and on the response of the different life stages to each sampling technique. Criteria for comparison of the methods were: 1) average number of ticks collected/sample; 2) variation among samples; 3) seasonal distribution; and 4) differences in the response of the various stages.

The shortest effective trap operating time under field conditions was determined. During the late 1971 tick season a new trap was designed (type B) and was compared to the previous trap (type A) as to efficacy. Another major aspect of this research was to evaluate the potential of CO_2 to be used for controlling ticks in large as well as limited areas.

Because insecticide treatment of large areas of nonfarm land is neither economically nor ecologically sound, future control efforts might utilize some form of attractant in conjunction with limited amounts of acaricides.

CHAPTER II

LITERATURE REVIEW

The Role of Carbon Dioxide in Hematophagous Arthropod Attraction

It is now well established that carbon dioxide is one of the main factors in attracting hematophagous arthropods to their hosts. This gas is a nonspecific factor but is limited in range by the level of carbon dioxide normally present in the atmosphere and also by the physiology of the receptors involved in its detection.

The response threshold seems to vary with species. Gillies and Wilkes (1969) determined experimentally that *Anopheles gambiae* Giles would respond to as little as 0.1 percent carbon dioxide. The CO_2 concentration in breath, although essential, seems to be only one of several factors in attraction of *Aedes aegypti* (Linnaeus) (Kahn and Maibach 1972). Garcia and Laing (1970) observed that CO_2, breath, and human handling were all factors stimulating *A. aegypti* adult females to land and feed. The complete role of CO_2 in attraction is still uncertain and may vary with species. Several species of mosquitoes were attracted solely to CO_2 at distances of 20 to 40 yards (Gillies and Wilkes 1969). The malaria vector, *A. melas*, orients to host olfactory cues at 40 to 60 yards. Gillies and Wilkes (1974) found *A. melas* Theobald orientation to natural hosts at 7 meters and to CO_2 at 3 meters.

Carbon dioxide has been used as an attractant in sampling blood-sucking insects for many years. Both dry ice and CO_2 from compressed gas cylinders have been successfully used. Reeves and Hammon (1942) utilized CO_2 for live trapping mosquitoes in a disease monitoring study. Since this early effort, many researchers have used CO_2 as an attractant to collect a diversity of mosquito species (Reeves 1951; Bellamy and Reeves 1952; Reeves 1953; Dow et al. 1957; Newhouse et al. 1966). Several of the standard mosquito sampling techniques (New Jersey light trap, Malaise trap, CDC light trap) have been compared with and without CO_2 bait added. The number of mosquito species collected with CO_2 baited light traps was significantly greater than in unbaited light traps (Newhouse et al. 1966; Carestia and Savage 1967; Parsons et al. 1974). Defoliart and Morris (1967) developed a CO_2 baited trap that was efficient for collecting mosquitoes and tabanids. They later compared the mosquito catches from this trap with those of the CDC miniature light trap (Morris and Defoliart 1969). These results were species specific with neither trap giving better results for all species. Harden et al. (1970), using CO_2 to supplement mosquito collections on human beings, also found a great species variation in attraction. Neither light nor L(+) lactic acid increased the sampling ability of CO_2 (Stryker and Young 1970).

Several researchers have successfully utilized CO_2 traps to reduce numbers of tabanids on cattle (Wilson et al. 1966; Everett and Lancaster 1968; Wilson 1968). Wilson and Richardson (1970) found that Chrysops species were less attracted to CO_2 than were several Tabanus species. Roberts (1970, 1971) also utilized CO_2 in Malaise traps for trapping tabanids. Blume et al. (1972) increased the numbers of tabanids captured by adding CO_2 to a modified Malaise trap.

Anderson and Hoy (1972) found that a CO_2 insect flight trap would quantitatively substitute for a natural host with respect to the daily attack rate of *Symphoromyia sakeni* and *S. pachyceras*.

Nelson (1965), Whitsel and Shoeppner (1965), and Shoeppner and Whitsel (1967) found CO_2 attractive to Ceratopogonid sp. Other hematophagous arthropods that have responded to CO_2 include: Triatomididae (Wiesinger 1956); Muscidae (Defoliart and Morris 1967); Simulidae (Fallis and Smith 1964; Snoddy and Hays 1966; Bradbury and Bennett 1974).

Certain species of fleas and mites were stimulated by CO_2, but it was not believed to be involved in attraction (Sasa et al. 1957; Sasa and Wakasugi 1957; Sasa 1957). Miles (1968) collected fleas from rat burrows with CO_2-baited traps.

History of Carbon Dioxide in Tick Attraction

Several species of ticks have been collected utilizing CO_2 attraction, indicating that a substantial number of species of this pest may be vulnerable to this technique. Garcia (1962, 1963, 1965, 1969) has demonstrated the presence of CO_2 receptors in five species of ticks including *Dermacentor occidentalis* Marx, *D. albipictus* (Packard), *D. andersoni* (Stiles), *Ornithodoros coriaceus* Koch, and *Ixodes pacificus* Cooley and Kohls. Two other members of the *Ornithodoros* genus, *O. parkeri* Cooley and *O. savignyi* (Audouin), have been collected with the aid of CO_2 (Miles 1968; Nevill 1964). Howell (1975) observed klinokenetic movement of previously quiescent *O. cooleyi* Kohls and Hoogstraal when experimentally exposed to 4.8% carbon dioxide. Prior to initiation of the present investigation, the literature indicated that only one worker had attempted to utilize CO_2-baited traps for the purpose of collecting ticks (Miles 1968). Nevill (1964) used open bowls to dispense CO_2 and collect O. savignyi and predicted that it would save time and labor in sampling this sand burrowing species.

Garcia (1962) found the response of adult D. andersoni to CO_2 much greater than the larval response. All stages of the lone star tick respond readily to CO_2 stimulation (Wilson et al. 1972). Lone star larvae, however, do not readily leave vegetative protection to migrate to hosts.

Carbon Dioxide Traps and Flagging in Tick Survey

In the past, tick populations have been estimated by flagging, the standard survey technique (Clymer et al. 1970a). The accuracy of this method is debatable, since discrepancies have been found in data collected using this method (Clymer et al. 1970a; Hair and Howell 1970).

Semtner et al. (1971b) used the flagging method in a study of tick abundance in different vegetative habitats. Large population differences were found in the different habitats with brush and low trees supporting the highest population of adults and nymphs. Using this technique, Semtner found the highest nymph populations in areas of thin underbrush (0-25%), which conflicts with results of Hoch et al. (1971b), in which clearing vegetation and allowing more penetration of sunlight reduced thick populations. Semtner found largest adult numbers in areas of higher ground brush (75% or more). Sonenshine et al. (1966), using flagging, demonstrated that Amblyomma americanum populations were fairly evenly distributed in four different woody vegetative types in Virginia. Sonenshine and Levy (1971) found no consistent relationship between tick distribution and any of the several dominant forest types studied. These relations of adult and nymph abundance conflict with laboratory findings by J. R. Sauer (personal communication) that lone star nymphs succumb more readily than adults to low humidity. These discrepancies could be due to the inability of the flagging technique to accurately sample different vegetative types. Semtner et al. (1971b) also indicated a decrease in tick numbers per drag with increase in height of woody vegetation, probably due to increasingly uneven vegetation as height increased and thus, less consistent sampling.

The importance of environmental factors on the abundance and distribution of lone star ticks has been extensively researched (Bishopp and Trembly 1945; Lancaster 1957; Hair and Howell 1970; Sonenshine et al. 1966; Semtner et al. 1971b; Semtner and Hair 1973b). Temperature and relative humidity were major factors of tick longevity and fecundity (Feldman-Muhsam 1947; Knülle 1965; Lees 1946; McLeod 1935; Lancaster and MacMillan 1955; Semtner et al. 1971a; Semtner and Hair 1973a; Semtner et al. 1973). Relative humidity of ca. 85% is necessary to keep lone star adults from desiccating (Sauer and Hair 1971).

In the field environmental differences are created by varying amounts of vegetation. Ticks have critical limits of temperature and relative humidity necessary for survival. They must find the microhabitat they need on vegetation or in ground leaf litter or perish. Semtner et al. (1971a) found average longevity of caged adults to vary from 22 days in meadow habitat to more than 65 days in bottomland oak-hickory forest. Much of the terrain in eastern Oklahoma is heavily forested, having deep leaf litter and little or no ground vegetation for vertical, host-seeking tick movement. The effect of shading in forested areas made substantial differences in the temperature of the ground vegetation and leaf litter where host-seeking activity occurs (Semtner et al. 1971b). This could mean that presence or absence of ground vegetation may be a major factor in flagging accuracy. Ticks need ground vegetation for vertical migration when seeking a blood meal as well as for environmental protection. Semtner et al. (1971a) studied several vegetative types and found daytime temperatures in all of them were above lone star tolerances for vertical migration during mid-summer, but suitable earlier and later in the season. Semtner and Hair (1973a) also correlated up and down migration of lone star adults on vegetation with temperature and relative humidity and concluded that ticks may be in a host-seeking state physiologically, but will be prohibited from ascending vegetation by either low early season temperatures (February-March) or high mid-season temperature and low humidity (July). Flagging seems to sample only those ticks that have ascended vegetation and are actively seeking a blood meal; thus, it is as much a measure of optimum conditions for host-seeking as of tick abundance. It seems that flagging would need to be done when conditions of temperature and relative humidity were suitable for vertical migration of ticks on vegetation to obtain a representative sample of the tick population. Since optimum conditions exist only for several months of the year, there seems to be evident need for a more sensitive survey device.

Carbon dioxide baited tick traps, in contrast, are not dependent on ground vegetation for accurately sampling ticks. The stimulus, CO_2, is more similar to a natural host cue. Carbon dioxide disperses along the surface of the gound and penetrates the leaf litter to some degree. Ticks can migrate to the trap while staying in or on the leaf litter and not have to leave the protective microhabitat necessary for their survival. Ticks may be able to migrate to carbon dioxide traps under environmental conditions that would be unfavorable for vertical migration on vegetation.

Strother et al. (1974) indicated that lone star ticks were active from mid-winter to early fall. Clymer et al. (1970b) found small numbers of lone star ticks on deer in cold weather. Several workers have postulated that ticks found on hosts in winter and early spring were aroused from quiescence by CO_2 or body heat from a host lying near their overwintering habitat (McLeod 1938; Semtner 1972).

The potential of attractants for future use in control efforts of lone star ticks will be evaluated based on the results of this study.

CHAPTER III

METHODS AND MATERIALS

Trap Design and Construction

Construction of a trapping device for the efficient dispersal of carbon dioxide under field conditions was the first requirement in this study. Effective field operation required this trap to be compact, portable, and simple to assemble and operate. Low operation cost was also sought, since good results in these studies could lead to development of a device to be marketed commercially for small area tick control, e.g., back yards or recreation areas. Dry ice was the carbon dioxide source. Traps were constructed so they would not be cold and thus repellent to the ticks.

Trap Type A

This trap was constructed basically of a fiberglass hull filled with polyurethane for insulation (Figure 1,B). The hull was a layer of fiberglass 1/8-1/4 in. thick (Figure 1,A). The trap consisted of a base portion (Figure 1,C) ca. 15 in.^{2} to which masking tape (the trapping device) was attached (Figure 1,F). A dry ice reservoir (Figure 1,D) ca. 6 in.^{2} by 7 in. high was set in the middle of the base. A lid for the reservoir was constructed by placing a 1 in. thick preformed piece of polyurethane on a 6 x 6 in. piece of fiberglass (Figure 1,E).

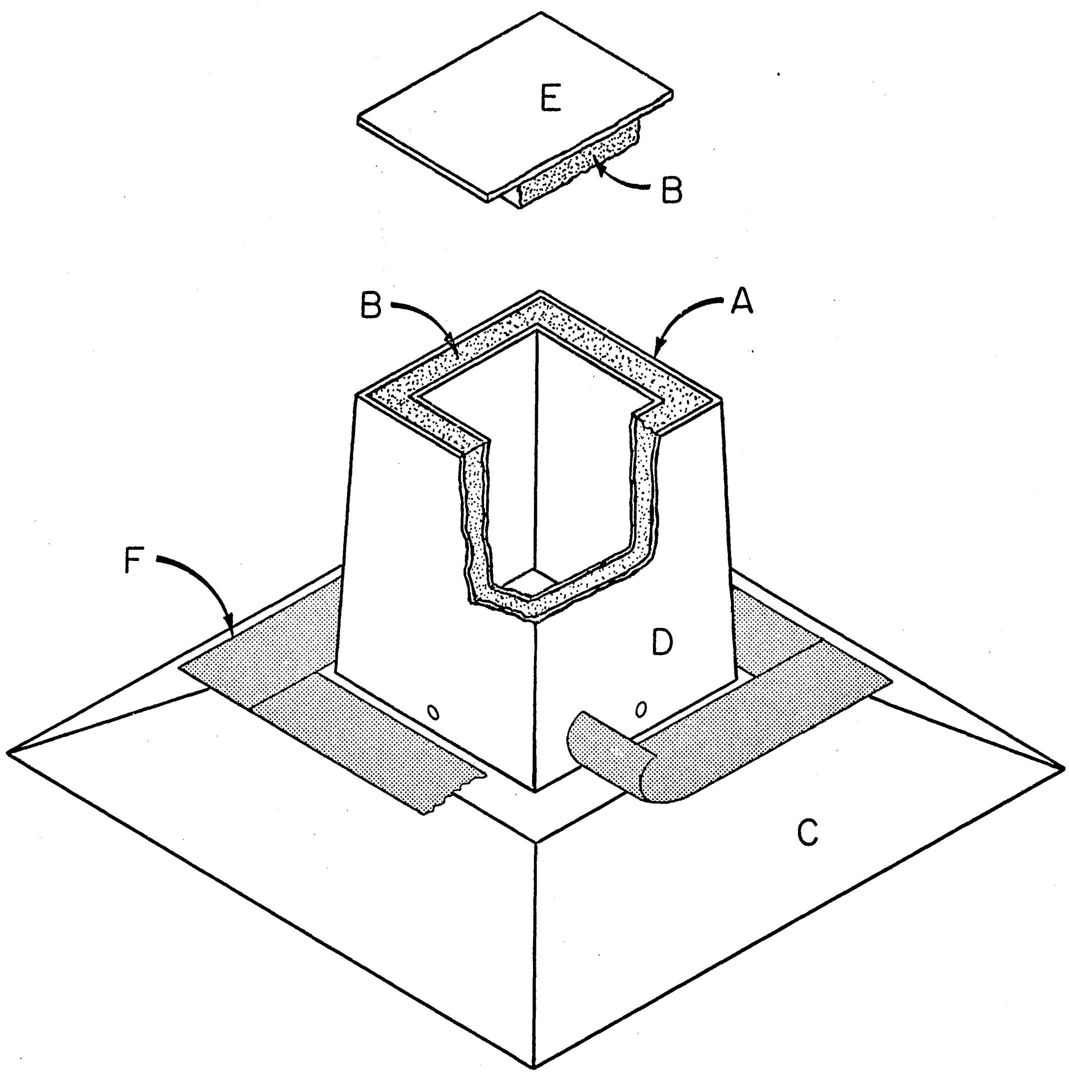

Figure 1. Diagram of Trap Type A: A. Outer fiberglass shell. B. Polyurethane insulation on lid and inside trap. C. Base portion of trap showing sloping sides. D. Reservoir for holding dry ice. E. Trap lid. F. Masking tape overhanging base

Initial construction involved fashioning a wooden easy-release form which had dimensions 1/4 in. smaller than the outer shell of the trap. A second form for the inner lining of the reservoir was a solid wood piece 5 x 5 x 6 in. (Figure 2). Waxed paper was secured over these forms to insure their easy release from the formed shells. Fiberglass mats to adequately cover the forms were cut and placed over the waxed paper prior to application of the catalyzed resin. Excess fiberglass mat was trimmed from the forms while the resin was hardening within the mat. A second coat of resin was applied to the outer shell at a later time to give a smooth outer surface. Both resin coats were applied with a paint brush.

The reservoir lining was attached inside the outer trap shell by a small bridge of resin between shell top and reservoir top. Both forms were inverted for application of this resin bridge. The bridge also provided a flat surface around the trap top for lid support. The trap bottom was attached by placing the hardened shell on a precut piece of mat slightly larger than the trap bottom while resin on it was hardening. Four 2-in. holes were precut into the bottom piece for later addition of the foam.

The lid was formed from the union of a 1 x 4 x 4 in. piece of polyurethane with a piece of fiberglass mat 5 $in.^2$. The polyurethane was trimmed to obtain a snug fitting lid for the trap.

Adding polyurethane for the insulation was the last construction step. Polyurethane was poured into the trap through precut bottom holes with the traps in inverted position. Foam filled all the void and the extruding excess was trimmed from the bottom holes when dry.

The masking tape was placed on the traps so that ca. 70 percent of

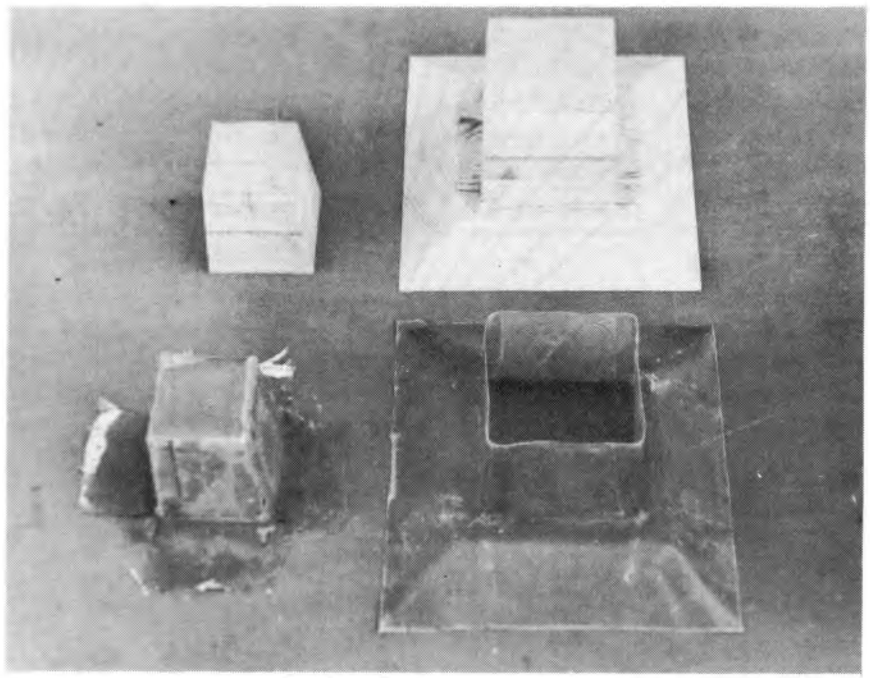

Figure 2. Outer shell and reservoir lining (below) of trap A and wooden easy release forms (above) used in their construction

its width overhung the sloping portion of the base. Traps were placed in the field with all edges of base in contact with either soil or vegetation, thus assuring that attracted ticks could climb upon the trap and become entangled in the masking tape. A 1/4 in. hole was drilled in each side of the reservoir at its base for carbon dioxide emission. The polyurethane served to insulate the trapping portion of the trap from the dry ice.

Trap Type B

This trap (type B) was constructed of the same material as the fiberglass polyurethane trap (type A), but it had several modifications in design. The tall dry ice reservoir made type A difficult to stack and cumbersome for field transport. One worker could not effectively carry more than two traps, thus necessitating extra trips to plots inaccessible by vehicle. Type B was designed for easy stacking and transport. Carriers were designed to carry four traps, since four samples were taken per plot in these tests.

The design change for type B entailed lowering the reservoir into the base of the trap, thus reducing the total height including the lid to four inches. The capacity of the reservoir was reduced to less than half that of type A and height of the base portion was increased. A depression was designed into the bottom of the trap to fit over the lid of other traps for secure stacking during storage and transport.

Two easy release wooden forms were constructed (Figure 3). The cup-shaped form molded the shell for the whole trap, except the bottom. The solid wooden block in the bottom of this form molded the reservoir into the outer shell. The raised center of the second form molded the

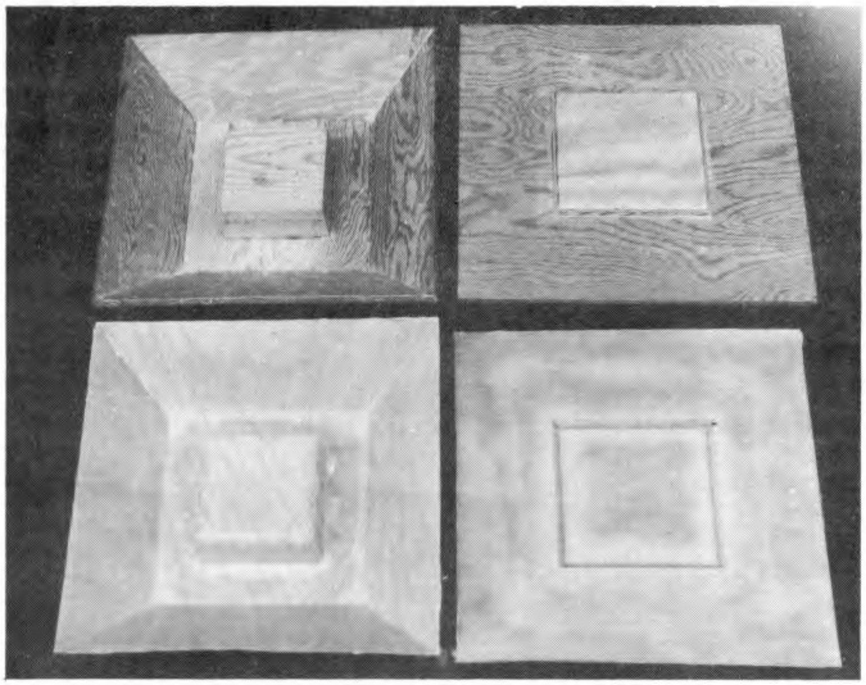

Figure 3. Outer shell and bottom (below) of trap type B and wooden easy release forms (above) used in their construction

depression into the trap bottom. Fiberglass and resin were applied to these forms and removed when hardened. Addition of polyurethane foam (Figure 4) and sealing the edges of the bottom and shell together with resin completed construction. The lid was made from two pieces of plyboard 6 3/8 and 4 15/16 in. sq., respectively. The smaller piece fit snugly inside the reservoir with the overhanging edges of the large piece supported by the trap top. Carbon dioxide from the reservoir had to seep out under the edges of the top piece. The lid was coated with resin for weather resistance.

Trap B dimensions were 15 in.^{2} on bottom and 9 in.^{2} on top with a 5 x 5 x 2 in. reservoir in the center of the top. The depression in the trap bottom was 3/4 in. deep and angled inward from 7 to 6.5 in.^{2}. The lid extended 0.5 in. above the trap, and fitted into the bottom depression of any other trap for stacking. Figure 5 shows trap lid, masking tape in position, and three traps in stacked position.

The masking tape for trapping ticks was positioned on the top of the trap with ca. 70% of its width overhanging the 45^o angled sides.

A carrier with a capacity for four traps was constructed of lightweight aluminum. It was 15 in.^{2} by 16 in. high. Pieces of angled aluminum fitted each trap corner vertically and these were connected at the tip and the base by horizontal stripes along the sides. An X brace was fastened across the bottom and a handle for carrying was put on top.

Trap A and B Comparison

Tests were conducted to compare trap type B with type A for field efficacy. Eight traps (4 type A and 4 type B) were placed in an alternating pattern in test plots. Tick counts were made from the tape

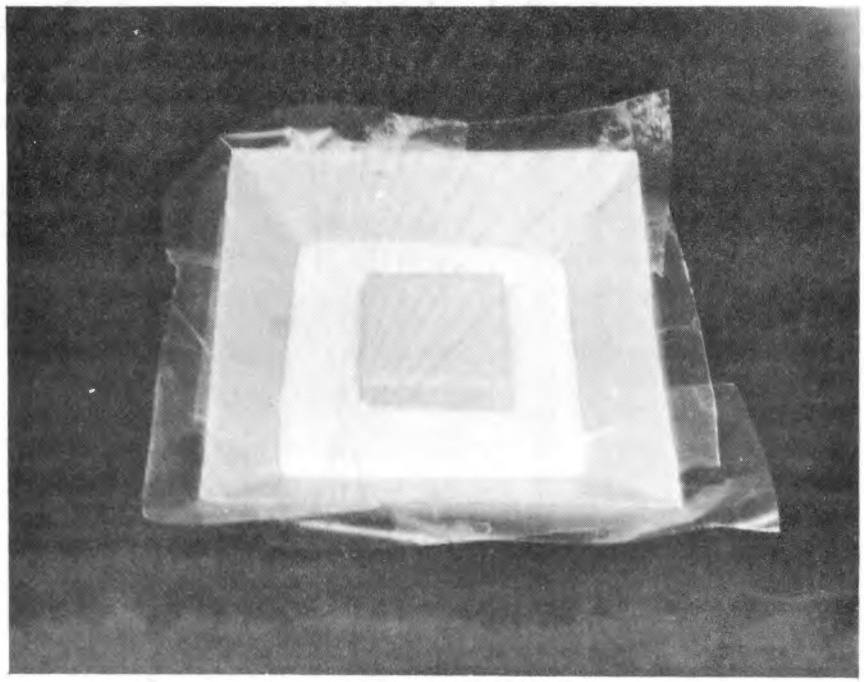

Figure 4. Trap type B inverted and being filled with polyurethane foam

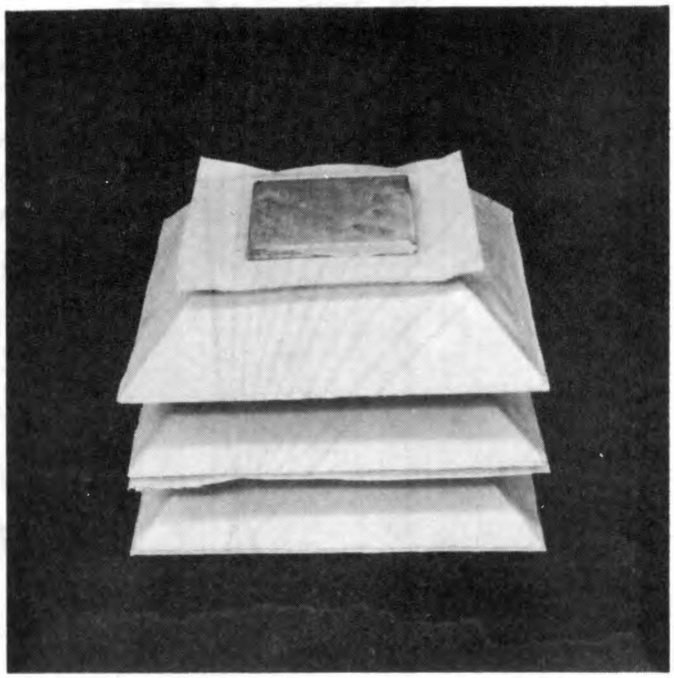

Figure 5. Three type B traps, stacked, showing lid and masking tape on trap

after one hour of operation. The means of the ticks collected from the two trap types were compared. These tests were conducted in the morning and afternoon on four days.

Comparison of Flagging and Carbon Dioxide Traps

All field tests in this study were conducted within or close to the periphery of the Cookson Hills State Game Refuge located near Cookson, Oklahoma, ca. 20 miles south of Tahlequah in Cherokee County, Oklahoma.

These tests with CO_2 traps and flagging were not a comparison of equal sized sampling area but a test of efficiency for simplicity of technique and accuracy in monitoring tick activity. Wilson et al. (1972) found the effective sampling area of a CO_2 trap to be ca. 450 m^2, while the flagging method samples were ca. 100 m^2. Flagging was done with a sweep net and drag cloth. The net was swung through the ground vegetation once per step and a cloth ca. 1 x 2 meters was pulled over the ground vegetation. Tick counts were taken from the sweep net and drag cloth after 25 steps and totaled for one sample. Four flagging samples were taken in each test plot as described by Clymer et al. (1970). For valid comparison with this procedure, four carbon dioxide trap samples were taken from each plot. Each plot sampled was first flagged, then immediately trapped with four traps, each operating for six hours. All tick stages captured by the two methods were counted except for larvae exposed by flagging, and these were estimated.

The flagging samples were taken at random in the plot. Traps were placed with at least 100 ft. between them to minimize trap interaction. Each plot was ca. 0.4 hectare in size. Test plots were new or previously undisturbed plots chosen at random each test day within the

Game Refuge. Each trap was loaded at time of setting with ca. two kg dry ice and masking tape was put on to ensnare the attracted ticks.

The procedures described above were conducted regularly in the five most prevalent types of vegetative habitat in the Cookson Hills State Game Refuge in Cherokee County, Oklahoma, between May 15 and October 10, 1971, and between March 9 and May 20, 1973. The five vegetative habitats were sampled in one day and replicated twice each week during the summer. During the spring each vegetative type was sampled twice per week and during the fall each type was sampled once per week. New test plots were chosen each sampling day from within the game refuge.

Habitat Classification

These tests were conducted in the five most prevalent vegetative types within the game refuge as perceived by the author.

Each habitat was classified by the amount of overstory, understory, and leaf litter present. The rating criteria were the amount or percent of ground surface: 1) shaded by overstory; 2) covered by ground vegetation; 3) covered by leaf litter. A rating scale of low (0 to 25%), medium (25-75%), high (75-100%) was used. Overstory, understory, and leaf litter were rated in each of the habitats as follows: low (L), medium (M), or high (H).

The three letter combinations for each habitat will be used throughout this text to refer to specific habitats, as shown below.

Habitat Type	Parameter		
	Overstory	Understory	Leaf Litter
LML	L	M	L
LHL	L	H	L
MMM	M	M	M
HLH	H	L	H
HMH	H	M	H

Ratings in each plot were value judgments on the part of the researcher.

Effective Sampling Time Interval

Optimum sampling time was determined by recording numbers of ticks collected on a stationary trap at different time intervals. The number collected in a time period was converted to a percent of the total collected in twelve hours.

Ten traps were placed 100 ft. apart in a uniform area. At the end of one, two, three, six, and twelve hours the tape on each trap was marked, removed, and stored for later counting. It was important for the worker to spend a minimum of time in the area of the operating trap to minimize the effect of outside tick stimulation. A technique of alternating traps was implemented to accomplish this. An extra trap was used to replace trap No. 1, trap No. 1 was used to replace trap No. 2, etc. When each trap was picked up, the tape was removed, labeled, and stored. The trap was cleaned of ticks, retaped, and more dry ice was added to approximate the original amount.

Results were expressed as percentage of ticks picked up during each time interval and as the cumulative percent as the test progressed.

CHAPTER IV

RESULTS AND DISCUSSION

Trap A and B Comparison

The type A trap caught large numbers of each stage of the lone star tick (Figure 6). Tests were conducted in late season 1971 to compare trap type B with type A for overall efficacy.

The results from comparison tests of trap types A and B are presented in Table I. The results of the morning tests indicate type B averages are only slightly higher for each stage. The afternoon sampling data shows type A averages slightly higher for adults but lower for nymphs and larvae. These differences were probably due to population variance in the test plots and not to any major attraction differences in the trap types. This indicates that results obtained from future tests with type B can be validly compared with data already collected with type A.

Weekly Means and Seasonal Distribution

The weekly means of all stages of the lone star tick are presented in Tables II-V for each of the vegetative types. Stage population differences between habitats are easily discernible.

Adults

Biologically significant differences in the number of adults/sample

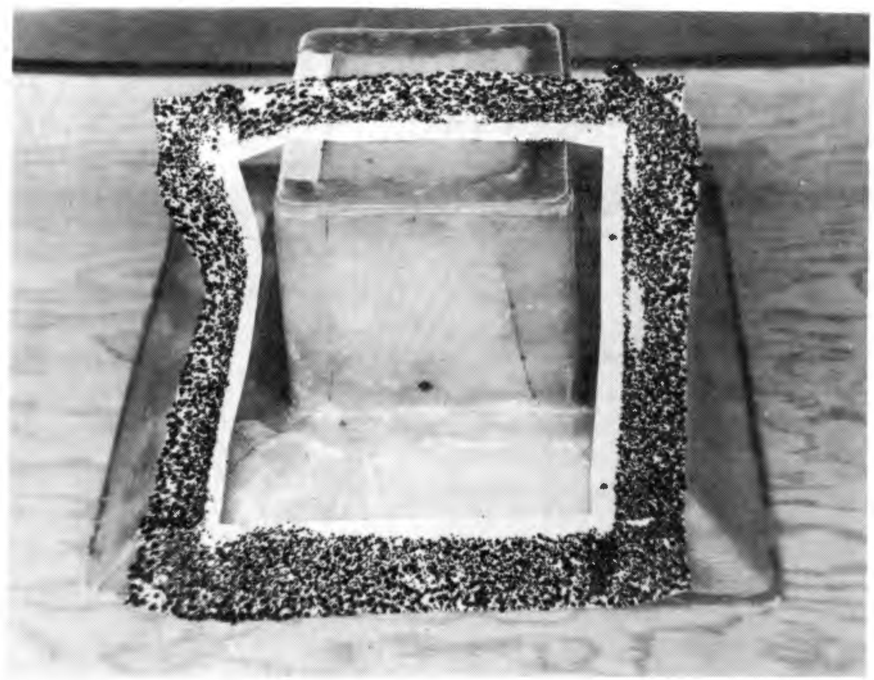

Figure 6. Trap type A with tape removed and inverted to show lone star adults, nymphs, and larvae stuck to the tape

TABLE I

MEAN[a] NO. OF LONE STAR TICKS COLLECTED WITH TRAP TYPES A AND B DURING AUGUST, 1971, CHEROKEE COUNTY, OKLAHOMA

Tick Stage	Type A	Type B
	Morning	
Male	.5	.9
Female	1.6	2.8
Nymph	46.8	97.3
Larvae	303.1	322.4
	Afternoon	
Male	.6	.5
Female	.7	1.1
Nymph	93.2	41.1
Larvae	272.3	77.2

[a]Average of 4 samples

TABLE II

WEEKLY MEANS OF LONE STAR MALES, FEMALES, NYMPHS, AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING IN FIVE VEGETATIVELY DIFFERENT HABITATS IN CHEROKEE COUNTY, OKLAHOMA, MARCH AND APRIL, 1973

Hab. Type+	Method	March WK 1	March WK 2	March WK 3	March WK 4	April WK 1	April WK 2	April WK 3	April WK 4
		Males							
LML[a]	F*	0.10	0.10	0.50	0.10	0.00	1.00	0.41	1.58
	CO_2**	24.60	12.10	12.00	36.30	50.92	34.25	24.25	120.08
LHL[b]	F	0.25	0.75	0.25	0.13	0.08	0.13	0.08	2.00
	CO_2	20.37	38.33	6.50	46.25	7.25	7.87	38.33	41.25
MMM[c]	F	0.00	0.17	0.00	0.25	0.25	1.13	1.08	0.50
	CO_2	23.88	23.08	6.63	57.75	26.50	24.75	57.42	47.33
HLH[d]	F	0.13	0.08	0.13	0.00	0.00	0.13	0.08	0.58
	CO_2	31.88	19.42	12.63	122.50	17.08	106.25	108.83	95.42
HMH[e]	F	0.25	0.08	0.00	0.13	0.33	0.13	1.00	1.00
	CO_2	14.63	29.00	11.25	52.25	19.42	14.13	71.58	66.92
		Females							
LML	F	0.00	0.00	0.10	0.00	0.00	1.38	0.33	0.61
	CO_2	21.80	13.00	11.60	40.50	54.58	43.87	28.92	119.08
LHL	F	0.00	0.83	0.00	0.00	0.17	0.50	0.17	1.08
	CO_2	20.63	35.92	4.87	6.00	7.92	11.25	40.25	49.25

TABLE II (CONTINUED)

Hab. Type+	Method	March WK 1	March WK 2	March WK 3	March WK 4	April WK 1	April WK 2	April WK 3	April WK 4
MMM	F	0.00	0.00	0.13	0.13	0.17	0.62	1.42	0.33
	CO_2	23.50	24.92	8.38	59.13	30.25	31.38	71.75	53.75
HLH	F	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00
	CO_2	41.00	21.83	17.00	115.00	17.83	111.63	122.92	105.00
HMH	F	0.00	0.00	0.00	0.00	0.17	0.00	0.25	0.00
	CO_2	17.00	31.08	14.88	61.75	24.00	15.63	78.00	73.67
		Nymphs							
LML	F	0.00	0.00	0.00	0.10	0.83	4.63	0.33	3.25
	CO_2	7.40	8.70	1.80	63.30	33.75	51.25	208.67	296.92
LHL	F	0.00	0.75	0.00	0.00	0.17	0.25	0.00	9.92
	CO_2	0.00	0.00	6.00	77.88	17.41	13.75	216.92	77.42
MMM	F	0.00	0.00	0.00	0.00	0.08	2.00	0.83	0.83
	CO_2	6.63	40.08	44.75	440.39	20.33	12.00	377.75	88.67
HLH	F	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.08
	CO_2	33.63	24.08	3.25	592.63	50.67	84.13	165.75	240.08
HMH	F	0.00	0.00	0.00	0.00	0.08	0.00	0.83	1.00
	CO_2	8.50	8.67	4.13	176.50	15.25	14.00	493.17	136.17

TABLE II (CONTINUED)

Hab. Type	Method	March WK 1	March WK 2	March WK 3	March WK 4	April WK 1	April WK 2	April WK 3	April WK 4
		Larvae							
LML	F	0.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LHL	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MMM	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HLH	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HMH	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a]Low overstory, medium ground vegetation, low leaf litter

[b]Low overstory, high ground vegetation, low leaf litter

[c]Medium overstory, medium ground vegetation, medium leaf litter

[d]High overstory, low ground vegetation, high leaf litter

[e]High overstory, medium ground vegetation, high leaf litter

+Habitat

*Flagging

**Carbon dioxide baited tick traps

TABLE III

WEEKLY MEANS OF LONE STAR MALES, FEMALES, NYMPHS, AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING IN FIVE VEGETATIVELY DIFFERENT HABITATS IN CHEROKEE COUNTY, OKLAHOMA, MAY, 1973, AND JUNE, 1971

Hab. Type+	Method	May WK 1	May WK 2	May WK 3	May WK 4	June WK 1	June WK 2	June WK 3	June WK 4	June WK 5
		Males								
LML[a]	F*	2.08	3.85	2.67	2.00	1.33	4.17	1.25	0.42	0.17
	CO_2**	40.83	48.00	26.75	23.58	11.17	28.67	7.58	2.25	0.67
LHL[b]	F	2.58	0.25	5.17	3.92	4.67	3.17	2.33	0.92	0.00
	CO_2	30.83	13.63	18.03	39.50	23.75	24.08	11.25	1.25	1.91
MMM[c]	F	2.67	1.25	2.00	1.42	3.50	3.33	1.50	1.58	1.00
	CO_2	72.08	26.38	63.17	37.08	50.83	16.33	13.91	14.00	18.08
HLM[d]	F	0.67	1.38	1.33	1.75	1.83	1.50	1.75	0.75	0.08
	CO_2	58.83	143.50	106.08	57.50	36.75	182.58	38.42	11.25	16.00
HLH[e]	F	3.58	2.13	2.67	2.17	4.08	3.16	2.00	2.08	1.25
	CO_2	25.83	101.00	34.08	46.92	34.75	45.08	22.41	54.75	20.33
		Females								
LML	F	1.42	2.37	2.33	1.25	1.08	4.25	1.42	0.42	0.08
	CO_2	42.67	47.38	39.08	33.33	12.33	33.50	13.92	1.75	1.00
LHL	F	2.00	0.50	5.08	5.08	3.83	4.75	3.17	1.00	0.17
	CO_2	30.42	12.25	28.17	50.50	30.33	34.08	23.58	1.50	3.42

TABLE III (CONTINUED)

Hab. Type+	Method	May WK 1	May WK 2	May WK 3	May WK 4	June WK 1	June WK 2	June WK 3	June WK 4	June WK 5
MMM	F	1.58	1.13	0.67	1.50	2.67	4.33	2.58	1.42	1.08
	CO_2	72.33	31.13	86.83	56.50	67.58	28.50	19.42	26.75	29.50
HLH	F	0.08	0.75	0.75	1.42	1.33	2.50	0.83	0.83	0.25
	CO_2	66.42	152.25	162.75	75.75	60.67	209.67	48.50	16.58	14.42
HMH	F	2.00	2.00	3.83	2.75	3.58	3.41	2.42	2.33	1.00
	CO_2	30.25	104.13	56.08	71.08	56.08	70.83	30.67	67.92	21.67
		Nymphs								
LML	F	6.33	6.50	5.25	3.83	7.75	3.91	11.00	1.66	1.00
	CO_2	185.00	203.75	103.08	72.33	31.08	48.08	51.75	8.42	2.42
LHL	F	4.58	3.00	3.42	12.17	30.42	24.16	9.50	11.25	2.33
	CO_2	52.17	10.75	19.33	149.17	145.67	341.50	41.42	10.83	48.50
MMM	F	1.92	3.50	1.92	3.67	7.25	5.08	13.33	3.08	3.58
	CO_2	360.91	136.50	177.42	159.50	66.83	91.67	124.33	160.58	222.67
HLH	F	0.33	10.50	5.08	11.50	13.67	23.58	28.42	3.58	6.41
	CO_2	120.58	197.88	211.67	429.17	205.92	1448.67	527.42	45.33	55.00
HMH	F	4.08	5.75	29.67	8.50	14.33	20.33	15.75	15.75	5.75
	CO_2	31.67	175.13	112.58	202.42	102.50	378.33	165.75	486.25	113.00

TABLE III (CONTINUED)

Hab. Type+	Method	May				June				
		WK 1	WK 2	WK 3	WK 4	WK 1	WK 2	WK 3	WK 4	WK 5
		Larvae								
LML	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.50	0.00
	CO_2	0.00	0.00	0.83	0.00	0.00	0.00	0.00	4.67	105.50
LHL	F	0.00	0.00	0.00	8.33	0.00	0.00	0.00	0.00	53.33
	CO_2	0.00	0.00	0.00	0.00	0.50	0.17	0.00	19.00	513.75
MMM	F	0.00	0.00	0.00	0.00	0.00	0.25	0.00	1.25	0.00
	CO_2	0.00	0.00	2.08	2.17	0.00	0.00	0.00	1.58	5.67
HLH	F	0.00	0.00	35.42	0.83	39.58	0.00	0.00	0.00	0.00
	CO_2	0.00	0.00	2.50	1.33	0.08	0.67	0.00	1.00	0.25
HMH	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	0.00	0.00	9.33	0.00	0.25	0.00	0.00	0.00	3.58

[a]Low overstory, medium ground vegetation, low leaf litter

[b]Low overstory, high ground vegetation, low leaf litter

[c]Medium overstory, medium ground vegetation, medium leaf litter

[d]High overstory, low ground vegetation, high leaf litter

[e]High overstory, medium ground vegetation, high leaf litter

[+]Habitat

[*]Flagging

[**]Carbon dioxide baited tick traps

TABLE IV

WEEKLY MEANS OF LONE STAR MALES, FEMALES, NYMPHS, AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING IN FIVE VEGETATIVELY DIFFERENT HABITATS IN CHEROKEE COUNTY, OKLAHOMA, JULY AND AUGUST, 1971

Hab. Type+	Method	July WK 1	WK 2	WK 3	WK 4	August WK 1	WK 2	WK 3	WK 4
		Males							
LHL[a]	F*	0.17	0.25	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2**	6.08	1.17	4.13	0.42	1.41	0.00	0.00	0.83
LML[b]	F	0.25	0.00	0.00	0.00	0.08	0.00	0.00	0.00
	CO_2	1.17	2.17	0.38	0.08	0.50	0.00	0.08	0.00
MMM[c]	F	2.00	0.33	0.25	0.17	0.00	0.00	0.08	0.08
	CO_2	14.83	9.17	4.63	6.17	1.08	1.83	0.67	0.25
HLH[d]	F	0.50	0.17	0.00	0.08	0.00	0.00	0.00	0.00
	CO_2	13.08	5.92	3.75	2.83	3.25	1.17	1.08	0.58
HMH[e]	F	0.33	0.33	0.00	0.50	0.08	0.00	0.08	0.00
	CO_2	12.08	38.58	6.00	8.92	3.33	1.75	1.00	0.42
		Females							
LHL	F	0.25	0.00	0.00	0.83	0.17	0.00	0.00	0.00
	CO_2	8.00	1.58	7.63	0.75	4.92	0.00	0.00	0.08
LML	F	0.17	0.33	0.00	0.08	0.08	0.00	0.00	0.00
	CO_2	1.58	2.42	0.63	0.17	0.92	0.00	0.58	0.00

TABLE IV (CONTINUED)

Hab. Type+	Method	July WK 1	July WK 2	July WK 3	July WK 4	August WK 1	August WK 2	August WK 3	August WK 4
MMM	F	2.42	0.50	0.50	0.08	0.08	0.00	0.17	0.00
	CO_2	26.92	17.00	7.25	10.50	2.50	2.92	1.58	1.42
HLH	F	1.00	0.17	0.13	0.08	0.25	0.00	0.08	0.00
	CO_2	20.67	10.17	7.75	5.33	8.75	4.75	1.83	2.00
HMH	F	0.42	0.58	0.25	0.08	0.25	0.00	0.08	0.00
	CO_2	18.08	54.25	12.38	16.58	8.75	4.75	1.83	2.00
		Nymphs							
LHL	F	3.17	0.67	0.00	0.50	3.00	0.08	2.58	1.75
	CO_2	58.75	7.92	6.50	2.67	159.25	6.42	12.50	65.58
LML	F	0.42	1.00	0.00	0.25	1.58	0.83	2.25	6.92
	CO_2	16.92	12.25	1.87	1.00	70.83	4.17	34.83	15.83
MMM	F	16.75	2.25	0.25	10.75	1.08	3.67	9.58	8.25
	CO_2	267.25	179.67	115.75	355.00	61.50	200.00	87.08	338.75
HLH	F	8.50	1.17	0.00	1.50	2.17	1.33	17.75	13.00
	CO_2	209.42	9.08	21.13	55.58	83.08	48.92	142.50	210.42
HMH	F	6.00	11.25	1.00	7.83	7.83	8.42	6.00	13.25
	CO_2	56.66	366.58	84.75	227.00	243.75	210.92	228.25	236.17

TABLE IV (CONTINUED)

Hab. Type+	Method	July WK 1	July WK 2	July WK 3	July WK 4	August WK 1	August WK 2	August WK 3	August WK 4
		Larvae							
LHL	F	27.92	160.00	450.00	64.17	356.25	200.42	6.67	231.67
	CO_2	285.25	74.92	937.00	815.58	1075.50	658.00	67.50	365.08
LML	F	102.50	14.17	510.00	77.50	616.67	247.50	387.50	191.67
	CO_2	175.67	12.25	614.88	136.75	1729.17	467.25	2011.67	866.25
MMM	F	38.33	68.33	275.00	295.83	979.17	495.83	46.25	270.83
	CO_2	216.50	336.25	246.13	1483.42	1632.67	1112.42	331.67	1765.00
HLH	F	8.33	0.00	26.25	89.17	345.83	181.25	212.08	605.42
	CO_2	0.33	0.58	254.13	80.42	835.83	1286.25	357.83	1367.92
HMH	F	0.00	12.50	187.50	226.67	483.33	275.00	438.33	816.67
	CO_2	142.75	297.25	1688.88	2850.83	607.50	588.33	655.67	1605.00

[a]Low overstory, high ground vegetation, low leaf litter

[b]Low overstory, medium ground vegetation, low leaf litter

[c]Medium overstory, medium ground vegetation, medium leaf litter

[d]High overstory, low ground vegetation, high leaf litter

[e]High overstory, medium ground vegetation, high leaf litter

[+]Habitat

[*]Flagging

[**]Carbon dioxide baited tick traps

TABLE V

WEEKLY MEANS OF LONE STAR MALES, FEMALES, NYMPHS, AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING IN FIVE VEGETATIVELY DIFFERENT HABITATS, CHEROKEE COUNTY, OKLAHOMA, SEPTEMBER AND OCTOBER, 1971

Hab. Type+	Method	September WK 1	WK 2	WK 3	WK 4	October WK 1
				Males		
LHL[a]	F*	0.00	0.00	0.00	0.00	0.00
	CO_2**	0.13	0.00	0.00	0.00	0.00
LML[b]	F	0.00	0.00	0.00	0.00	0.00
	CO_2	0.00	0.00	0.00	0.00	0.00
MMM[c]	F	0.00	0.00	0.00	0.00	0.00
	CO_2	0.25	0.00	0.00	0.50	0.25
HLH[d]	F	0.00	0.00	0.00	0.00	0.00
	CO_2	0.75	0.63	0.00	0.50	0.00
HMH[e]	F	0.00	0.00	0.00	0.00	0.00
	CO_2	0.13	0.13	0.75	0.50	0.00
				Females		
LHL	F	0.00	0.00	0.00	0.00	0.00
	CO_2	0.50	0.00	0.50	0.00	0.00
LML	F	0.00	0.00	0.00	0.00	0.00
	CO_2	0.00	0.00	0.00	0.00	0.00
MMM	F	0.00	0.00	0.00	0.00	0.00
	CO_2	0.00	0.13	0.25	0.00	0.00
HLH	F	0.00	0.00	0.00	0.00	0.00
	CO_2	1.00	0.88	0.25	0.25	0.00
HMH	F	0.00	0.00	0.00	0.00	0.00
	CO_2	0.75	0.50	0.00	0.00	0.25
				Nymphs		
LHL	F	0.38	1.13	2.00	0.50	0.00
	CO_2	5.13	33.75	10.50	2.00	0.00
LML	F	0.75	0.75	0.00	0.50	0.00
	CO_2	79.63	315.25	2.50	1.25	0.00

TABLE V (CONTINUED)

Hab. Type	Method	September WK 1	September WK 2	September WK 3	September WK 4	October WK 1
MMM	F	0.75	2.63	1.25	1.50	0.00
	CO_2	461.25	338.50	224.50	32.50	1.75
HLH	F	2.50	3.13	3.25	1.00	0.00
	CO_2	623.88	286.63	82.50	19.50	1.00
HMH	F	3.87	4.25	18.50	0.50	0.25
	CO_2	214.00	168.00	36.75	7.25	1.50
				Larvae		
LHL	F	15.00	221.25	2.50	12.50	0.75
	CO_2	147.88	527.63	54.75	8.75	3.00
LML	F	31.25	40.00	0.00	15.00	27.50
	CO_2	46.63	104.38	6.00	11.50	35.50
MMM	F	807.50	67.50	16.25	45.00	1.25
	CO_2	2756.25	213.25	79.00	46.25	396.50
HLH	F	288.75	975.00	195.00	162.50	112.50
	CO_2	952.50	1996.25	279.00	221.50	9.75
HMH	F	318.75	425.00	80.00	562.50	32.50
	CO_2	660.38	1456.25	255.00	760.50	18.75

[a]Low overstory, high ground vegetation, low leaf litter

[b]Low overstory, medium ground vegetation, low leaf litter

[c]Medium overstory, medium ground vegetation, medium leaf litter

[d]High overstory, low ground vegetation, high leaf litter

[e]High overstory, medium ground vegetation, high leaf litter

[+]Habitat

[*]Flagging

[**]Carbon dioxide baited tick traps

were obtained by the two methods during early and mid-season. In August and September when adults became inactive, the response to both techniques was very low. Carbon dioxide trap results indicated large differences in population between habitats but little differences were seen with flagging.

Large numbers of adult ticks were collected on CO_2 traps in early March in all habitats. The first major activity detected by flagging varied from early April for LML, MMM, and late April for LHL to early May for HLH and HMH. The early season CO_2:flagging ratio was ca. 200:1 (Table VI). Summer trends were somewhat similar for the two methods in all habitats with the CO_2:flagging ratio dropping to ca. 30:1 (Table VI). Decline of adult activity occurred in early and mid-June in LML and LHL (Table III). In forested habitats (MMM, HLH, and HMH) flagging shows decline in adult activity in early July, but CO_2 traps indicated activity two weeks longer in MMM and HLH and six weeks longer in HMH.

Nymphs

Great differences were obtained in the average number of numphs/ sample with the CO_2:flagging ratio being ca. 1300:1 in early season. This ratio dropped to 17:1 in mid-season and rose to 79:1 in late season (Table VI). Host-seeking activity is indicated by CO_2 traps in all habitats in early March. Flagging, however, does not show major nymph activity until early April (LML), mid-April (MMM), late April (LHL and HMH), and early May (HLH). In LHL carbon dioxide traps indicated a major early season peak of activity before flagging showed any activity of consequence.

TABLE VI

MEAN MONTHLY RATIO[a] OF LONE STAR MALES, FEMALES, NYMPHS AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING IN FIVE VEGETATIVELY DIFFERENT HABITATS, CHEROKEE COUNTY, OKLAHOMA, 1971 AND 1973

Life Stage	March CO_2**:F*	April CO_2:F	May CO_2:F	June CO_2:F	July CO_2:F	Aug. CO_2:F	Sept. CO_2:F
Male	169:1	87:1	21:1	14:1	26:1	46:1	----
Female	419:1	146:1	31:1	18:1	32:1	41:1	----
Nymphs	1307:1	115:1	24:1	17:1	27:1	22:1	79:1
Larvae	----	----	0.4:1	5:1	4:1	3:1	3:1

[a]Computed from total of monthly means of five vegetative types

*Flagging

**Carbon dioxide baited tick traps

Characteristic bimodal peaks of activity were shown by CO_2 traps in LML, MMM, HLH, and HMH but flagging did not indicate the peaks in any of the vegetative types. In MMM, CO_2 traps showed heavy nymphal activity not shown by flagging. Flagging showed high activity in late May-early June, which CO_2 traps indicate was a low period after an early season peak. Major early March peaks in MMM and HLH were shown by CO_2 traps only.

Both techniques showed decrease in activity with onset of cold weather.

The medium and heavy overstory types (MMM, HLH, and HMH) sustained over twice as much activity as the two low overstory types (LHL and LML) all season. These habitats offered good environmental conditions for host-seeking as well as longevity by creating favorable temperature and relative humidity conditions in the ground vegetation and leaf litter.

Larvae

The number of larvae/sample was greater in May with a CO_2 trap: flagging ratio of ca. 1:2 (Table VI). The ratio favored CO_2 traps for the remainder of the season with a CO_2:flagging ratio of ca. 4:1 (Table VI).

With only slight differences similar seasonal trends are shown by both methods in all the habitats studied. In LML and LHL flagging indicates presence of larvae one week earlier and one week later (LML only) than CO_2 traps. In LHL larval activity was elicited by CO_2 traps one week earlier than by flags. Both techniques indicated a decline in activity in colder weather in October except for LML that had a decline in late September.

For larval survey, it seems that one technique would be a good indicator of the other. Carbon dioxide traps have the distinct advantage of involving only a fraction of the time and effort required by the flagging technique.

Monthly Means, Variances, and Coefficients of Variation for CO_2 Traps and Flagging

The monthly means and variances of the ticks collected from CO_2 traps and flagging and the logarithms of the counts plus the monthly coefficient of variation derived from the means and standard deviation of the log counts are presented in Tables VII-XIII. These tables present these data for each life stage in each of the five vegetative types studied. Hereafter, the coefficient of variation will be written as CV. The variation among samples was high for both techniques. The use of logarithms reduced the variance to less than the mean in all but seven cases, all of which were variances for larvae. The tick counts collected were not normally distributed for either technique in any of the habitats as evidenced by the large variances in Tables VII-XIII. Computing the data in logarithms did not adjust the level of variance of CO_2 trap to the level of flagging for adults or nymphs, but it did for larvae.

Adults

The CV of the monthly means of both males and females was lower for CO_2 traps than flagging in each habitat every month of the testing

TABLE VII

MONTHLY MEANS AND VARIANCE AND MONTHLY LOGARITHMIC MEANS, VARIANCE AND CV[g] FOR LONE STAR MALES, FEMALES, NYMPHS AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING[h], CHEROKEE COUNTY, OKLAHOMA, MARCH, 1973

Habitat Type	Method	Males: Count $\overline{X}$	Males: Count Var.	Males: Log Count $\overline{X}$	Males: Log Count Var.	Females: Count $\overline{X}$	Females: Count Var.	Females: Log Count $\overline{X}$	Females: Log Count Var.
LML[a]	F*	0.19	0.13	0.06	0.01	0.03	0.03	0.01	0.00
	CO_2**	20.22	330.81	0.96	0.07	20.75	365.56	0.99	0.07
LHL[b]	F	0.38	0.70	0.09	0.03	0.28	0.28	0.01	0.00^{25}
	CO_2	29.03	541.82	1.09	0.15	28.69	760.95	1.05	0.18
MMM[c]	F	0.11	0.11	0.03	0.01	0.06	0.06	0.02	0.01
	CO_2	27.31	1407.68	1.07	0.13	28.53	1332.44	1.13	0.11
HLH[d]	F	0.08	0.08	0.03	0.01	0.00	0.00	0.00	0.00
	CO_2	43.58	17210.03	1.13	0.17	45.72	13861.41	1.27	0.13
HMH[e]	F	0.11	0.11	0.03	0.01	0.00	0.00	0.00	0.00
	CO_2	27.03	1980.97	1.16	0.14	31.17	2748.00	1.24	0.15

Habitat Type	Method	Males--CV of the Log Count	Females--CV of the Log Count
LML	F	191.66	600.00
	CO_2	28.86	26.53
LHL	F	199.40	600.00
	CO_2	35.73	40.16
MMM	F	300.00	424.26
	CO_2	33.51	29.98
HLH	F	346.41	0.00
	CO_2	34.80	28.03
HMH	F	300.00	0.00
	CO_2	32.87	30.82

TABLE VII (CONTINUED)

Habitat Type	Method	Nymphs Count $\overline{X}$	Nymphs Count Var.	Nymphs Log Count $\overline{X}$	Nymphs Log Count Var.	Larvae Count $\overline{X}$	Larvae Count Var.	Larvae Log Count $\overline{X}$	Larvae Log Count Var.
LML	F	0.03	0.03	0.01	0.0025	4.17	625.00	0.06	0.13
	CO_2	18.97	2628.10	0.76	0.18	0.00	0.00	0.00	0.00
LHL	F	0.25	0.47	0.05	0.01	0.00	0.00	0.00	0.00
	CO_2	31.47	3699.47	0.93	0.20	0.00	0.00	0.00	0.00
MMM	F	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	122.64	181463.31	0.93	0.42	0.00	0.00	0.00	0.00
HLH	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	147.92	551841.84	0.97	0.37	0.00	0.00	0.00	0.00
HMH	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	44.92	35815.54	0.82	0.23	0.00	0.00	0.00	0.00

Habitat Type	Method	Nymphs--CV of the Log Count	Larvae--CV of the Log Count
LML	F	600.00	600.00
	CO_2	55.67	0.00
LHL	F	222.85	0.00
	CO_2	47.89	0.00
MMM	F	0.00	0.00
	CO_2	69.28	0.00
HLH	F	0.00	0.00
	CO_2	62.79	0.00
HMH	F	0.00	0.00
	CO_2	58.60	0.00

[a]Low overstory, medium ground vegetation, low leaf litter

[b]Low overstory, high ground vegetation, low leaf litter

TABLE VII (CONTINUED)

[c]Medium overstory, medium ground vegetation, medium leaf litter

[d]High overstory, low ground vegetation, high leaf litter

[e]High overstory, medium ground vegetation, high leaf litter

[g]Coefficient of variation derived from mean and standard deviation

[h]Sampling technique, canvas sweep net and drag cloth, counts recorded from 25 steps

*Flagging

**Carbon dioxide baited tick traps

TABLE VIII

MONTHLY MEANS AND VARIANCE AND MONTHLY LOGARITHMIC MEANS, VARIANCE AND CV[g] FOR LONE STAR MALES FEMALES, NYMPHS AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING[h], CHEROKEE COUNTY, OKLAHOMA, APRIL, 1973

Habitat Type	Method	Males Count $\overline{X}$	Males Count Var.	Males Log Count $\overline{X}$	Males Log Count Var.	Females Count $\overline{X}$	Females Count Var.	Females Log Count $\overline{X}$	Females Log Count Var.
LML[a]	F*	0.72	1.58	0.14	0.05	0.61	2.54	0.12	0.05
	CO_2**	59.48	5369.46	1.43	0.15	63.23	4772.91	1.50	0.11
LHL[b]	F	0.61	0.45	0.13	0.02	0.48	0.63	0.12	0.03
	CO_2	25.11	687.51	1.18	0.08	28.61	865.09	1.23	0.07
MMM[c]	F	0.70	0.84	0.18	0.04	0.64	1.35	0.14	0.04
	CO_2	40.30	811.14	1.42	0.07	48.18	1480.55	1.49	0.11
HLH[d]	F	0.20	0.25	0.05	0.02	0.07	0.11	0.02	0.01
	CO_2	79.68	2188.12	1.67	0.05	87.32	3012.97	1.71	0.06
HMH[e]	F	0.66	0.80	0.16	0.04	0.11	0.11	0.03	0.01
	CO_2	45.64	1274.12	1.43	0.07	50.75	1532.11	1.48	0.09

Habitat Type	Method	Males--CV of the Log Count	Females--CV of the Log Count
LML	F	147.59	198.88
	CO_2	27.28	22.58
LHL	F	99.28	151.12
	CO_2	23.22	22.25
MMM	F	110.02	135.03
	CO_2	18.69	21.78
HLH	F	238.96	480.90
	CO_2	13.72	14.20
HMH	F	116.28	281.61
	CO_2	20.54	19.76

TABLE VIII (CONTINUED)

Habitat Type	Method	Nymphs: Count $\overline{X}$	Nymphs: Count Var.	Nymphs: Log Count $\overline{X}$	Nymphs: Log Count Var.	Larvae: Count $\overline{X}$	Larvae: Count Var.	Larvae: Log Count $\overline{X}$	Larvae: Log Count Var.
LML	F	1.84	31.42	0.21	0.11	0.00	0.00	0.00	0.00
	CO_2	156.41	116933.39	1.54	0.27	0.00	0.00	0.00	0.00
LHL	F	2.80	53.33	0.20	0.05	0.00	0.00	0.00	0.00
	CO_2	87.52	48441.42	1.31	0.31	0.00	0.00	0.00	0.00
MMM	F	0.84	2.72	0.16	0.04	0.00	0.00	0.00	0.00
	CO_2	134.93	80253.71	1.46	0.25	0.00	0.00	0.00	0.00
HLH	F	0.06	0.05	0.21	0.00	0.00	0.00	0.00	0.00
	CO_2	139.80	45599.46	1.73	0.23	0.00	0.00	0.00	0.00
HMH	F	0.52	0.90	0.12	0.04	0.00	0.00	0.00	0.00
	CO_2	178.34	155043.36	1.61	0.19	0.00	0.00	0.00	0.00

Habitat Type	Method	Nymphs--CV of the Log Count	Larvae--CV of the Log Count
LML	F	155.71	0.00
	CO_2	33.43	0.00
LHL	F	115.20	0.00
	CO_2	42.71	0.00
MMM	F	129.13	0.00
	CO_2	34.54	0.00
HLH	F	337.75	0.00
	CO_2	27.41	0.00
HMH	F	169.24	0.00
	CO_2	27.31	0.00

[a]Low overstory, medium ground vegetation, low leaf litter

[b]Low overstory, high ground vegetation, low leaf litter

TABLE VIII (CONTINUED)

[c]Medium overstory, medium ground vegetation, medium leaf litter

[d]High overstory, low ground vegetation, high leaf litter

[e]High overstory, medium ground vegetation, high leaf litter

[g]Coefficient of variation derived from mean and standard deviation

[h]Sampling technique, canvas sweep net and drag cloth, counts recorded from 25 steps

*Flagging

**Carbon dioxide baited tick traps

TABLE IX

MONTHLY MEANS AND VARIANCE AND MONTHLY LOGARITHMIC MEANS, VARIANCE AND CV[g] FOR LONE STAR MALES FEMALES, NYMPHS AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING[h], CHEROKEE COUNTY, OKLAHOMA, MAY, 1973

Habitat Type	Method	Males Count $\overline{X}$	Males Count Var.	Males Log Count $\overline{X}$	Males Log Count Var.	Females Count $\overline{X}$	Females Count Var.	Females Log Count $\overline{X}$	Females Log Count Var.
LML[a]	F*	2.54	4.05	0.41	0.06	1.79	2.60	0.35	0.05
	CO_2**	33.59	311.76	1.37	0.12	40.00	506.65	1.45	0.13
LHL[b]	F	3.22	15.23	0.47	0.07	3.41	18.36	0.47	0.06
	CO_2	26.59	630.95	1.10	0.17	31.98	955.33	1.20	0.11
MMM[c]	F	1.89	3.69	0.36	0.06	1.22	2.30	0.26	0.06
	CO_2	51.80	767.90	1.59	0.06	64.48	981.95	1.69	0.06
HLH[d]	F	1.27	3.36	0.28	0.05	0.75	4.03	0.15	0.07
	CO_2	86.75	2912.01	1.82	0.05	110.84	6113.84	1.92	0.07
HMH[e]	F	2.68	5.37	0.44	0.07	2.70	7.05	0.47	0.06
	CO_2	47.50	413.59	1.53	0.06	61.86	748.38	1.67	0.05

Habitat Type	Method	Males--CV of the Log Count	Females--CV of the Log Count
LML	F	59.65	62.23
	CO_2	25.78	24.48
LHL	F	57.78	53.35
	CO_2	37.10	27.61
MMM	F	68.68	94.38
	CO_2	15.55	14.48
HLH	F	84.24	175.40
	CO_2	12.74	13.53
HMH	F	61.39	53.93
	CO_2	16.12	13.20

TABLE IX (CONTINUED)

Habitat Type	Method	Nymphs Count $\overline{X}$	Nymphs Count Var.	Nymphs Log Count $\overline{X}$	Nymphs Log Count Var.	Larvae Count $\overline{X}$	Larvae Count Var.	Larvae Log Count $\overline{X}$	Larvae Log Count Var.
LML	F	5.39	37.45	0.60	0.18	0.00	0.00	0.00	0.00
	CO_2	135.34	46705.31	1.70	0.51	0.02	0.02	0.01	0.00
LHL	F	6.05	138.28	0.58	0.17	2.27	227.28	0.05	0.09
	CO_2	62.13	10889.47	1.29	0.19	0.00	0.00	0.00	0.00
MMM	F	2.68	2.84	0.48	0.06	0.00	0.00	0.00	0.00
	CO_2	215.14	49406.02	1.96	0.20	1.16	23.43	0.08	0.10
HLH	F	6.52	171.69	0.51	0.13	9.89	4107.38	0.08	0.18
	CO_2	243.64	113438.06	2.05	0.22	1.05	24.95	0.07	0.09
HMH	F	12.56	1045.84	0.73	0.12	0.00	0.00	0.00	0.00
	CO_2	126.39	15471.10	1.84	0.01	2.55	285.09	0.05	0.10

Habitat Type	Method	Nymphs--CV of the Log Count	Larvae--CV of the Log Count
LML	F	70.42	0.00
	CO_2	41.96	663.32
LHL	F	71.33	663.34
	CO_2	33.65	0.00
MMM	F	51.32	0.00
	CO_2	23.07	403.45
HLH	F	71.55	511.05
	CO_2	22.86	394.89
HMH	F	46.94	0.00
	CO_2	17.59	663.32

[a]Low overstory, medium ground vegetation, low leaf litter

[b]Low overstory, high ground vegetation, low leaf litter

TABLE IX (CONTINUED)

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[c]Medium overstory, medium ground vegetation, medium leaf litter

[d]High overstory, low ground vegetation, high leaf litter

[e]High overstory, medium ground vegetation, high leaf litter

[g]Coefficient of variation derived from mean and standard deviation

[h]Sampling technique, canvas sweep net and drag cloth, counts recorded from 25 steps

*Flagging

**Carbon dioxide baited tick traps

TABLE X

MONTHLY MEANS AND VARIANCE AND MONTHLY LOGARITHMIC MEANS, VARIANCE AND CV[g] FOR LONE STAR MALES, FEMALES, NYMPHS AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING[h], CHEROKEE COUNTY, OKLAHOMA, JUNE, 1971

		Males				Females			
		Count		Log Count		Count		Log Count	
Habitat Type	Method	$\overline{X}$	Var.	$\overline{X}$	Var.	$\overline{X}$	Var.	$\overline{X}$	Var.
LML[a]	F*	1.46	8.02	0.21	0.07	1.45	5.07	0.23	0.06
	CO_2**	10.07	518.06	0.64	0.10	12.50	446.46	0.67	0.10
LHL[b]	F	2.22	4.38	0.37	0.05	2.58	6.72	0.40	0.06
	CO_2	12.45	208.12	0.75	0.11	18.58	290.41	0.88	0.10
MMM[c]	F	2.18	4.97	0.37	0.05	2.42	5.82	0.41	0.06
	CO_2	22.63	376.47	1.12	0.11	34.35	983.86	1.28	0.12
HLH[d]	F	1.18	2.27	0.24	0.05	1.15	4.51	0.22	0.05
	CO_2	57.00	14154.24	1.33	0.10	69.97	17126.44	1.41	0.12
HMH[e]	F	2.52	7.63	0.42	0.08	2.55	7.69	0.43	0.07
	CO_2	35.47	1394.02	1.37	0.11	49.43	3088.09	1.50	0.12

		Males--CV of the Log Count	Females--CV of the Log Count
LML	F	127.54	111.04
	CO_2	48.46	46.35
LHL	F	58.55	58.80
	CO_2	44.34	36.59
MMM	F	61.51	62.59
	CO_2	29.34	26.63
HLH	F	91.97	105.79
	CO_2	23.43	24.14
HMH	F	67.23	60.95
	CO_2	23.97	22.64

TABLE X (CONTINUED)

Habitat Type	Method	Nymphs Count $\overline{X}$	Nymphs Count Var.	Nymphs Log Count $\overline{X}$	Nymphs Log Count Var.	Larvae Count $\overline{X}$	Larvae Count Var.	Larvae Log Count $\overline{X}$	Larvae Log Count Var.
LML	F	5.06	53.07	0.54	0.12	5.50	1192.78	0.06	0.10
	CO_2	28.35	2376.91	0.99	0.14	22.03	14760.71	0.23	0.28
LHL	F	15.53	904.91	0.85	0.11	10.66	471.11	0.17	0.05
	CO_2	117.58	171381.58	1.24	0.23	106.68	374350.14	0.31	0.25
MMM	F	6.47	42.61	0.69	0.11	0.30	3.90	0.03	0.03
	CO_2	133.22	84176.66	1.62	0.32	1.45	35.71	0.12	0.06
HLH	F	15.13	407.08	0.93	0.11	7.92	3760.42	0.04	0.12
	CO_2	456.47	1402172.06	1.92	0.23	0.40	2.43	0.01	0.04
HMH	F	14.38	283.58	0.95	0.09	0.00	0.00	0.00	0.00
	CO_2	249.17	340770.27	1.99	0.17	0.77	14.03	0.06	0.06

Habitat Type	Method	Nymphs--CV of the Log Count	Larvae--CV of the Log Count
LML	F	65.51	461.21
	CO_2	37.83	225.68
LHL	F	38.94	131.81
	CO_2	39.01	160.93
MMM	F	47.05	577.35
	CO_2	35.20	216.57
HLH	F	35.15	774.60
	CO_2	25.02	298.84
HMH	F	32.53	0.00
	CO_2	20.89	399.85

[a]Low overstory, medium ground vegetation, low leaf litter

[b]Low overstory, high ground vegetation, low leaf litter

TABLE X (CONTINUED)

[c]Medium overstory, medium ground vegetation, medium leaf litter

[d]High overstory, low ground vegetation, high leaf litter

[e]High overstory, medium ground vegetation, high leaf litter

[g]Coefficient of variation derived from mean and standard deviation

[h]Sampling technique, canvas sweep net and drag cloth, counts recorded from 25 steps

*Flagging

**Carbon dioxide baited tick traps

TABLE XI

MONTHLY MEANS AND VARIANCE AND MONTHLY LOGARITHMIC MEANS, VARIANCE AND CV[g] FOR LONE STAR MALES FEMALES, NYMPHS AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING[h], CHEROKEE COUNTY, OKLAHOMA, JULY, 1971

Habitat Type	Method	Males Count $\overline{X}$	Males Count Var.	Males Log Count $\overline{X}$	Males Log Count Var.	Females Count $\overline{X}$	Females Count Var.	Females Log Count $\overline{X}$	Females Log Count Var.
LML[a]	F*	0.11	0.10	0.03	0.01	0.09	0.09	0.27	0.01
	CO_2**	2.84	41.43	0.31	0.10	4.20	97.80	0.38	0.13
LHL[b]	F	0.07	0.11	0.02	0.01	0.16	0.17	0.05	0.01
	CO_2	1.00	2.17	0.19	0.05	1.25	4.52	0.23	0.07
MMM[c]	F	0.73	0.74	0.17	0.03	0.90	1.86	0.18	0.06
	CO_2	9.07	87.66	0.76	0.15	16.16	239.42	0.95	0.15
HLH[d]	F	0.20	0.10	0.56	0.01	0.36	0.56	0.08	0.02
	CO_2	6.64	120.33	0.62	0.12	11.27	385.27	0.84	0.11
HMH[e]	F	0.32	0.32	0.09	0.02	0.34	0.31	0.09	0.02
	CO_2	17.34	2526.04	0.89	0.13	26.50	3443.39	1.06	0.20

Habitat Type	Method	Males--CV of the Log Count	Females--CV of the Log Count
LML	F	276.16	331.66
	CO_2	102.61	96.03
LHL	F	480.90	255.93
	CO_2	118.28	115.34
MMM	F	100.44	128.97
	CO_2	51.37	40.18
HLH	F	150.94	149.76
	CO_2	56.13	40.18
HMH	F	171.38	155.77
	CO_2	40.47	42.09

TABLE XI (CONTINUED)

Habitat Type	Method	Nymphs: Count $\bar{X}$	Nymphs: Count Var.	Nymphs: Log Count $\bar{X}$	Nymphs: Log Count Var.	Larvae: Count $\bar{X}$	Larvae: Count Var.	Larvae: Log Count $\bar{X}$	Larvae: Log Count Var.
LML	F	1.18	3.53	0.20	0.06	150.57	31552.84	1.18	0.63
	CO_2	20.09	6855.97	0.59	0.29	491.02	714491.23	1.84	0.39
LHL	F	0.45	0.65	0.11	0.03	145.68	87636.74	1.10	0.69
	CO_2	8.57	899.64	0.44	0.28	200.34	336153.95	1.42	0.63
MMM	F	8.16	82.84	0.58	0.09	159.77	45553.41	1.35	0.70
	CO_2	239.75	230942.72	1.72	0.47	600.07	684657.16	1.69	1.00
HLH	F	3.05	10.17	0.38	0.05	31.36	12765.15	0.38	0.39
	CO_2	78.59	80899.52	1.34	0.13	68.39	43180.81	0.72	0.29
HMH	F	7.02	36.05	0.62	0.11	99.32	17452.27	0.88	0.16
	CO_2	192.75	159477.11	1.78	0.26	1204.57	1625530.20	1.88	0.41

Habitat Type	Method	Nymphs--CV of the Log Count	Larvae--CV of the Log Count
LML	F	119.96	66.95
	CO_2	91.23	34.00
LHL	F	149.18	75.49
	CO_2	121.91	55.93
MMM	F	50.46	61.84
	CO_2	40.14	59.33
HLH	F	59.02	163.85
	CO_2	27.36	74.47
HMH	F	52.32	45.67
	CO_2	28.41	33.93

[a]Low overstory, medium ground vegetation, low leaf litter

[b]Low overstory, high ground vegetation, low leaf litter

TABLE XI (CONTINUED)

[c]Medium overstory, medium ground vegetation, medium leaf litter

[d]High overstory, low ground vegetation, high leaf litter

[e]High overstory, medium ground vegetation, high leaf litter

[g]Coefficient of variation derived from mean and standard deviation

[h]Sampling technique, canvas sweep net and drag cloth, counts recorded from 25 steps

*Flagging

**Carbon dioxide baited tick traps

TABLE XII

MONTHLY MEANS AND VARIANCE AND MONTHLY LOGARITHMIC MEANS, VARIANCES, AND CV[g] FOR LONE STAR MALES, FEMALES, NYMPHS AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING[h], CHEROKEE COUNTY, OKLAHOMA, AUGUST, 1971

Habitat Type	Method	Males Count $\overline{X}$	Males Count Var.	Males Log Count $\overline{X}$	Males Log Count Var.	Females Count $\overline{X}$	Females Count Var.	Females Log Count $\overline{X}$	Females Log Count Var.
LML[a]	F*	0.00	0.00	0.00	0.00	0.04	0.04	0.01	0.00
	CO_2**	0.38	1.10	0.06	0.02	1.25	26.51	0.11	0.03
LHL[b]	F	0.02	0.02	0.01	0.00	0.02	0.02	0.01	0.00
	CO_2	0.15	0.12	0.04	0.01	0.38	0.79	0.08	0.03
MMM[c]	F	0.04	0.04	0.01	0.00	0.06	0.05	0.02	0.00
	CO_2	0.96	5.60	0.19	0.06	2.10	7.28	0.35	0.09
HLH[d]	F	0.00	0.00	0.00	0.00	0.06	0.06	0.02	0.01
	CO_2	1.52	8.87	0.27	0.07	2.52	10.87	0.40	0.08
HMH[e]	F	0.04	0.04	0.01	0.00	0.08	0.04	0.03	0.00
	CO_2	1.63	7.44	0.29	0.06	4.33	41.13	0.52	0.10

Habitat Type	Method	Males--CV of the Log Count	Females--CV of the Log Count
LML	F	0.00	489.90
	CO_2	244.47	163.48
LHL	F	692.82	692.82
	CO_2	228.87	197.38
MMM	F	489.90	352.77
	CO_2	124.00	83.32
HLH	F	0.00	400.00
	CO_2	100.51	71.02
HMH	F	489.90	244.95
	CO_2	88.59	60.01

TABLE XII (CONTINUED)

Habitat Type	Method	Nymphs Count $\bar{X}$	Nymphs Count Var.	Nymphs Log Count $\bar{X}$	Nymphs Log Count Var.	Larvae Count $\bar{X}$	Larvae Count Var.	Larvae Log Count $\bar{X}$	Larvae Log Count Var.
LML	F	1.85	9.01	0.29	0.11	198.75	54544.79	1.42	0.59
	CO_2	61.69	23678.06	1.04	0.27	541.52	489512.17	2.13	0.31
LHL	F	2.90	81.35	0.31	0.15	360.83	61105.56	2.12	0.39
	CO_2	31.42	5671.01	1.01	0.25	1268.58	1505812.24	2.69	0.31
MMM	F	5.65	73.81	0.54	0.13	448.02	720872.11	2.09	0.71
	CO_2	71.83	82068.65	1.76	0.39	1210.44	2337585.15	2.64	0.25
HLH	F	8.56	126.98	0.61	0.13	336.15	260274.83	1.86	0.94
	CO_2	121.23	26135.15	1.78	0.19	961.96	1329973.43	2.45	0.82
HMH	F	8.89	57.13	0.84	0.10	503.33	312974.65	2.46	0.23
	CO_2	229.77	47643.13	2.10	0.20	864.13	588191.19	2.32	0.69

Habitat Type	Method	Nymphs--CV of the Log Count	Larvae--CV of the Log Count
LML	F	113.98	54.03
	CO_2	50.02	25.95
LHL	F	124.40	29.24
	CO_2	49.39	20.80
MMM	F	67.45	40.16
	CO_2	35.39	19.03
HLH	F	59.89	52.15
	CO_2	24.74	36.99
HMH	F	37.54	19.58
	CO_2	21.13	35.53

[a]Low overstory, medium ground vegetation, low leaf litter

[b]Low overstory, high ground vegetation, low leaf litter

TABLE XII (CONTINUED)

[c]Medium overstory, medium ground vegetation, medium leaf litter

[d]High overstory, low ground vegetation, high leaf litter

[e]High overstory, medium ground vegetation, high leaf litter

[g]Coefficient of variation derived from mean and standard deviation

[h]Sampling technique, canvas sweep net and drag cloth, counts recorded from 25 steps

*Flagging

**Carbon dioxide baited tick traps

TABLE XIII

MONTHLY MEANS AND VARIANCE AND MONTHLY LOGARITHMIC MEANS, VARIANCE, AND CV[g] FOR LONE STAR MALES, FEMALES, NYMPHS AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING[h], CHEROKEE COUNTY, OKLAHOMA, SEPTEMBER, 1971

		Males				Females			
		Count		Log Count		Count		Log Count	
Habitat Type	Method	$\overline{X}$	Var.	$\overline{X}$	Var.	$\overline{X}$	Var.	$\overline{X}$	Var.
LML[a]	F*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2**	0.04	0.04	0.01	0.00	0.21	0.43	0.05	0.02
LHL[b]	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MMM[c]	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	0.18	0.13	0.05	0.01	0.07	0.07	0.02	0.01
HLH[d]	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	0.46	0.37	0.13	0.03	0.61	0.94	0.15	0.04
HMH[e]	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	0.25	0.35	0.07	0.02	0.39	0.65	0.10	0.03

		Males--CV of the Log Count	Females--CV of the Log Count
LML	F	0.00	0.00
	CO_2	529.15	286.88
LHL	F	0.00	0.00
	CO_2	0.00	0.00
MMM	F	0.00	0.00
	CO_2	202.65	374.17
HLH	F	0.00	0.00
	CO_2	122.29	138.05
HMH	F	0.00	0.00
	CO_2	226.38	168.80

TABLE XIII (CONTINUED)

Habitat Type	Method	Nymphs Count $\bar{X}$	Nymphs Count Var.	Nymphs Log Count $\bar{X}$	Nymphs Log Count Var.	Larvae Count $\bar{X}$	Larvae Count Var.	Larvae Log Count $\bar{X}$	Larvae Log Count Var.
LML	F	0.79	1.98	0.17	0.05	69.75	17606.27	0.73	0.25
	CO_2	2.89	255.99	0.70	0.13	202.50	33614.67	1.43	0.24
LHL	F	0.50	0.93	0.12	0.04	26.43	2330.95	0.66	0.71
	CO_2	113.36	227272.62	0.74	0.44	49.86	5294.88	1.32	0.29
MMM	F	1.36	3.88	0.25	0.08	258.92	185820.83	1.50	0.56
	CO_2	265.46	213741.25	1.74	0.44	922.96	742029.51	2.22	0.36
HLH	F	2.21	4.48	0.39	0.07	428.21	203827.38	1.89	1.16
	CO_2	274.86	224967.36	1.81	0.18	915.39	1938173.85	2.42	0.23
HMH	F	5.07	28.31	0.53	0.05	308.93	92958.33	2.06	0.37
	CO_2	115.64	24497.50	1.54	0.22	752.50	796057.36	2.30	0.37
		Nymphs--CV of the Log Count				Larvae--CV of the Log Count			
LML	F	138.38				67.62			
	CO_2	51.50				34.30			
LHL	F	163.93				127.51			
	CO_2	89.71				40.66			
MMM	F	109.71				49.88			
	CO_2	37.91				26.93			
HLH	F	66.95				56.94			
	CO_2	22.79				20.01			
HMH	F	44.09				29.52			
	CO_2	30.34				26.57			

[a] Low overstory, medium ground vegetation, low leaf litter

[b] Low overstory, high ground vegetation, low leaf litter

TABLE XIII (CONTINUED)

[c]Medium overstory, medium ground vegetation, medium leaf litter

[d]High overstory, low ground vegetation, high leaf litter

[e]High overstory, medium ground vegetation, high leaf litter

[g]Coefficient of variation derived from mean and standard deviation

[h]Sampling technique, canvas sweep net and drag cloth, counts recorded from 25 steps

*Flagging

**Carbon dioxide baited tick traps

period. During March and April (Tables VII and VIII) flagging CVs had from 5 to 23X more variation than CO_2 traps. In May and June, as the average number of adults/sample increased, the CV for flags decreased to less than 100% in most habitats. The CV for CO_2 traps was lower than flagging for this period by a factor of 2 to 13 with the exception of LHL, where the June CV was only 1.5X greater for flagging.

All habitats had very low early season counts with flags, but CO_2 traps revealed high levels of host-seeking activity during this period (Tables VII-X). During July, August, and September the CVs increased for both techniques during this period. The September CVs were very high for CO_2 traps, while flagging collected no adults in any habitat during this period (Table XIII).

Nymphs

Carbon dioxide traps revealed good activity with relatively low CVs during March (Table VII), while flagging collected extremely small numbers or no nymphs and subsequent high CVs. As the number of nymphs/sample increased during April and May (Tables VIII-IX), the CVs decreased for both techniques. Flagging CVs, however, remained 2X as large as CO_2 trap CVs. In May the CV for the two techniques were close to equal, both showing an increase over April. An overall drop in CV was seen in June for both habitats, followed by a moderate increase in July. The July increase was probably due to the fact that the hot weather created less favorable conditions for host-seeking. Little CV change was noted for either technique in August and September.

The trend for lower CVs in the forested types was also noticed for nymphs. Warmer weather (July) seems to increase the CV in the nonforested habitats much more than the ones with medium to heavy levels of overstory.

A similar trend was noticed in the number of adults and nymphs/ sample collected in the different vegetative types. In the high overstory habitats having medium to heavy ground vegetation, CO_2 traps indicate generally higher levels of host-seeking activity all season. Flagging indicated the opposite effect, collecting higher numbers of ticks in the low overstory habitats during early season. In June, as the daily ambient temperature increased, this trend reversed with flagging collecting higher numbers of ticks in the sheltered high overstory types (MMM, HLH, HMH).

This illustrates the dependence of flagging upon vegetative shelter for favorable temperature and relative humidity conditions for tick host seeking behavior. This also indicates that shading is an important factor in creating favorable conditions for tick longevity and host-seeking behavior, as Semtner et al. (1971b) also found.

Larvae

The CVs were extremely high in May by both techniques when larvae were collected (Table IX). The June means were also low with all CVs being high (Table X). During July the CV dropped for both techniques in conjunction with an increase in larvae/sample. In MMM the CVs were almost equal for the two methods and in August the flagging CV was lower than trapping CVs in HMH and only greater than traps by 1.2 to 2.0X in the other four vegetative types (Table XII).

The larvae collected by CO_2 traps probably migrated only a few feet to the trap. Larval collection by either method involves some degree of chance, either random sampling with flagging or randomly placing a CO_2 trap in close proximity of a larval cluster. It is believed that larvae migrated up to a few feet to a CO_2 trap, while contact had to be made with the flagging technique. Thus, even for larvae, it seems that flagging was more dependent on the physical make-up of the habitat than were CO_2 traps.

Influence of Vegetative Type on Carbon Dioxide Trap and Flagging Efficiency

The relative percent of ticks collected in each vegetative type by each survey method is given in Table XIV.

The heavy ground vegetation seems important in LHL for early season results with flagging. Results for March and April indicate that adults are more tolerant of low early season temperatures than are nymphs. Carbon dioxide traps indicate that ca. 60% of active adults and ca. 55% of active nymphs were found in HLH and HMH vegetative types. Flagging shows the higher level of adults and nymphs in LHL (Table XIV), while CO_2 traps showed this as the lowest habitat for both stages.

In July a drastic drop occurred in percentages of adults and nymphs collected in the low overstory types (LHL and LML). This drop was not evident in the medium and high overstory habitats for either technique. This substantiated the dependence of flagging on favorable environmental conditions which are more likely to be found in high overstory (forested) areas.

Carbon dioxide traps indicated that the greatest numbers of adults and nymphs were found in HLH and HMH habitats and smaller numbers in the low overstory habitats. Both methods showed a decrease in numbers

TABLE XIV

THE MONTHLY PERCENTAGES[a] OF LONE STAR ADULTS, NYMPHS, AND LARVAE COLLECTED BY CARBON DIOXIDE BAITED TICK TRAPS AND FLAGGING, CHEROKEE COUNTY, OKLAHOMA, MARCH TO SEPTEMBER, 1971 AND 1973

Hab. Type	Method	Adults							Nymphs							Larvae						
		M	A	M	J	J	A	S	M	A	M	J	J	A	S	M	A	M	J	J	A	S
LML	F*	15	29	20	15	6	8	0	11	30	16	9	6	7	8	100	0	0	23	26	11	6
	CO_2**	14	23	13	7	7	10	10	5	22	17	4	4	10	2	0	0	0	17	19	11	7
LHL	F	60	23	31	24	7	14	0	89	46	18	27	2	10	5	0	0	19	44	25	20	2
	CO_2	19	10	10	10	2	3	0	8	13	8	2	2	5	14	0	0	0	82	8	26	2
MMM	F	18	29	14	23	50	32	0	0	14	8	11	41	20	14	0	0	0	1	27	24	24
	CO_2	19	17	21	18	26	20	12	33	19	27	45	44	28	34	0	0	24	1	23	25	32
HLH	F	5	5	9	12	17	12	0	0	1	20	27	15	31	22	0	0	81	32	5	18	39
	CO_2	30	32	36	40	18	28	48	41	20	31	15	15	20	35	0	0	22	0	3	20	32
HMH	F	6	14	25	26	21	35	0	0	9	38	25	35	32	51	0	0	0	0	17	27	28
	CO_2	19	18	20	26	46	38	29	12	26	16	36	36	37	15	0	0	53	1	47	17	26

[a]Computed from total of monthly means of 5 vegetative types

*Flagging

**Carbon dioxide baited tick traps

in late season in low overstory and an increase in numbers in late season in medium and high overstory habitats. This was probably due to the more favorable environmental conditions in the MMM, HLH, and HMH habitats.

Carbon dioxide traps seemed to predict larval populations less accurately than for adults and nymphs.

No major trends are discernible from the larval percentages (Table XIV). Flagging was dependent on favorable conditions for vertical migration and CO_2 traps had to be placed within a few feet of a larval cluster to obtain migration to the CO_2.

Effective Sampling Interval

Tests for determining the shortest valid operation period for the CO_2 baited tick traps were conducted during the summer of 1971. Tests in May were conducted and results tabulated at the end of 1, 3, 6, and 12 hrs. Such a high percent of the 12 hr total was collected during the first 3 hrs that in tests after that time a 2 hr period was added to the test to determine collected percentages in 2 hrs. Tests in August were conducted to compare 6 hrs of afternoon trapping with 6 hrs of morning trapping.

Results from these tests are presented in Tables XV, XVI, and XVII. In May ca. 35% of the adult total and 29% of the nymph total were collected during the first hr. No larvae were collected during the first hr, and just over 30% during the first 3 hrs. At the end of 6 hrs in all tests ca. 90% of the adult and nymph totals had been collected, although it probably is not necessary to operate the traps that long to obtain a representative sample.

TABLE XV

MEAN NUMBER, PERCENTAGES, AND ACCUMULATED PERCENTAGES OF LONE STAR TICKS TRAPPED DURING 1, 3, 6, AND 12 HR INTERVALS VIA CO_2 BAITED TRAPS, CHEROKEE COUNTY, OKLAHOMA, MAY, 1971

Trapping Period (Hr)	Life Stage Trapped											
	Males			Females			Nymphs			Larvae		
	$\bar{X}$[a]	%[b]	Cul. %[c]	$\bar{X}$	%	Cul. %	$\bar{X}$	%	Cul. %	$\bar{X}$	%	Cul. %
0-1	138	36.2	36.2	167	34.0	34.0	530	29.0	29.0	0	0.0	0.0
1-3	142	37.3	73.5	177	36.0	70.0	796	43.5	72.5	45	31.9	31.9
3-6	67	17.6	91.1	95	19.3	89.3	342	18.7	91.2	61	43.3	75.2
6-12	34	8.9	100.0	52	10.6	100.0	160	8.8	100.0	35	24.8	100.0

[a]Replicated 9 times

[b]Percentage of 12 hr total trapped during each time period

[c]Cumulative percentage trapped from beginning of test

TABLE XVI

MEAN NUMBER, PERCENTAGES, AND ACCUMULATED PERCENTAGES OF LONE STAR TICKS TRAPPED DURING 1, 3, 6, AND 12 HR INTERVALS VIA CO_2 BAITED TRAPS, CHEROKEE COUNTY, OKLAHOMA, JUNE, 1971

Trapping Period (Hr)	Life Stage Trapped											
	Males			Females			Nymphs			Larvae		
	$\bar{X}$[a]	%[b]	Cul. %[c]	$\bar{X}$	%	Cul. %	$\bar{X}$	%	Cul. %	$\bar{X}$	%	Cul. %
0-1	8.6	39.0	39.0	13.2	40.0	40.0	33.9	27.0	27.0	0.0	0.0	0.0
1-2	7.5	34.0	73.0	8.7	26.0	66.0	33.8	26.0	53.0	0.0	0.0	0.0
2-3	2.8	13.0	86.0	5.3	16.0	82.0	23.2	18.0	71.0	0.0	0.0	0.0
3-6	2.6	12.0	98.0	4.9	15.0	97.0	27.3	21.0	92.0	0.0	0.0	0.0
6-12	.7	3.0	100.0	1.3	4.0	100.0	9.5	7.0	100.0	1.3	100.0	100.0

[a]Replicated 9 times

[b]Percentage of 12 hr total trapped during each time

[c]Cumulative percentage trapped from beginning of test

TABLE XVII

MEAN NUMBER, PERCENTAGES, AND ACCUMULATED PERCENTAGES OF LONE STAR TICKS TRAPPED DURING 1, 3, 6, AND 12 HR INTERVALS VIA CO_2 BAITED TRAPS, CHEROKEE COUNTY, OKLAHOMA, AUGUST, 1971

Trapping Period (Hr)	Life Stage Trapped											
	Males			Females			Nymphs			Larvae		
	$\overline{X}$ [a]	% [b]	Cul. % [c]	$\overline{X}$	%	Cul. %	$\overline{X}$	%	Cul. %	$\overline{X}$	%	Cul. %
0-1	0.4	27.0	27.0	0.7	29.0	29.0	33.4	14.0	14.0	13.0	4.0	4.0
1-2	0.8	53.0	80.0	0.4	17.0	46.0	48.3	21.0	35.0	16.9	5.0	9.0
2-3	0.2	13.0	93.0	1.1	46.0	92.0	79.2	34.0	69.0	116.3	37.0	46.0
3-6	0.1	7.0	100.0	0.2	8.0	100.0	73.2	31.0	100.0	171.5	54.0	100.0

[a]Replicated 9 times

[b]Percentage of 6 hr total trapped during each period

[c]Cumulative percentage trapped from beginning of test

No larvae were obtained in one hour in tests in May or June, but small numbers were collected in the August tests.

The levels of adults and nymphs were higher during May than June and were very low in August. Larval levels were low in May and June and higher in August.

The cumulative percent of adults at the end of 3 hrs was higher in the August test than in May and June, but the nymph levels were very constant. The low level of adults in August probably was a factor in these results.

No significant larval levels were obtained until the end of 3 hr in any of the tests with the range at this time period being 31 to 46% of totals collected.

The results indicated that 1 hr sampling gives representative or consistent results using the testing technique described for adults and nymphs. The extremely low numbers collected during the last 6 hr of the 12 hr test period indicated that working with a percent of the total is valid.

For larval survey these tests indicated that at least 3 hr are necessary to obtain a representative sample.

CHAPTER V

SUMMARY AND CONCLUSIONS

All stages of the lone star tick responded to CO_2 and were easily and effectively surveyed by CO_2 baited tick traps. Comparison of this method with flagging revealed that larger numbers of adults/sample were collected by CO_2, with ratios varying from 200:1 in early season to 30:1 in mid-season. Carbon dioxide traps revealed adult activity in several vegetative types from 4 to 8 weeks earlier than flagging. Flagging was more variable than CO_2 traps with CVs from 5 to 23X higher in early season and 2 to 13X higher in mid-season. General mid-season adult population trends in the different habitats were similar by both methods, although the number of adults/sample was much higher for CO_2 traps. The higher numbers are essential to lower the variation in survey for this tick species. Results reveal that HLH and HMH vegetative types supported the highest adult numbers and LML and LHL have the lowest adult numbers.

The habitats having the most environmental protection, MMM, HLH, and HML, also seemed to have less variation among samples than the low overstory types (LHL and LML) for both techniques.

Carbon dioxide traps collected larger numbers of nymphs/sample with the CO_2 flagging ratio varying from 1300:1 in early season to 17:1 in mid-season to 79:1 in late season. Traps revealed early spring and late summer (dimodal) peaks of nymphal activity in four of the five habitats, while flagging did not indicate the peaks in any habitats. Strong early season (late March) peaks of activity were revealed in MMM, HLH, and HMH habitats by CO_2 traps, but not indicated by flagging. The number of nymphs collected/sample was over 2X larger in the heavy and medium overstory plots than in the low overstory types. The effect of shading seems very important in tick behavior and longevity.

The CO_2:flagging ratio for larvae was ca. 4:1 during most of the season. Similar season trends are shown by the two methods. The flagging CV was lower than CO_2 traps in only one habitat (HMH) for one month (August) in all the tests. Flagging CVs in July and August varied from almost equal to 2X larger than CO_2 trap CVs.

Larvae probably migrate only a few feet to a trap. Flagging involved chance contact for survey for all stages; likewise, a trap had to be placed in close proximity of a larval cluster to effectively attract them.

Carbon dioxide traps had the advantages of: 1) involving less time and effort for tick survey; 2) greater number of ticks/sample, thus reduced variation among samples; 3) being effective at times of year that were previously impossible to get survey results; 4) giving accurate predictions of tick populations in an area regardless of vegetative composition.

Flagging had two main factors that governed its effectiveness: 1) presence of ground vegetation to permit ticks to be available for flagging; and 2) presence of overstory and leaf litter to help create favorable conditions of temperature and relative humidity, which allow vertical migration on vegetation. A large proportion of the Ozark area where this tick species is such a tremendous problem has only one of these two factors but only a small proportion will have both factors. Presence of either factor without the other seemed to seriously limit the ability of flagging to give an accurate estimate of the tick population of an area. Carbon dioxide traps were not as dependent on physical factors and probably gave more valid estimates of tick populations in all habitats.

One hour operating time for CO_2 traps was determined sufficient for lone star adult and nymph survey. A minimum of three hr sampling period was necessary to obtain a representative larval sample. Mean numbers of ticks/trap collected in comparison studies with trap types A and B reveal similar means. Should type B be utilized in future tests, results could validly be compared with data collected with type A.

The responsiveness of lone star adults and nymphs to carbon dioxide make the possibility of incorporating this gas into some form of control measure seem feasible. A source of CO_2 that could be more easily managed and stored for long periods would be very helpful in field studies, both for control and survey.

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VITA

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