SEASONAL DEVELOPMENT AND SURVIVAL OF *AMBLYOMMA MACULATUM* KOCH IN CENTRAL OKLAHOMA

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IN CENTRAL OKLAHOMA

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CHAPTER I

INTRODUCTION

The Gulf Coast tick, *Amblyomma maculatum* Koch, is a tropical tick which has become established in the southern coastal regions of the United States, the Caribbean Islands, and the coastal regions of Central and South America (Fig 1). These regions generally have a high relative humidity, high temperature, and annual rainfall of over 100 cm (Bishopp and Trembley, 1945; Williams *et al.*, 1977; Barre' and Garris, 1987; Solis, 1987).

Amblyomma maculatum was first studied extensively in the United States by Hooker *et al.* (1912) and again by Bishopp and Hixon (1936). During these early studies the tick was distributed along the U. S. coastal regions ranging from North Carolina to the Gulf Coast regions of Texas. However, by the early 1970's, *A. maculatum* was recorded in northeastern Oklahoma, Kansas, and as far north as Kentucky (Semtner and Hair, 1973; Wiedl, 1981; Snoddy, 1984). In 1942, Gulf Coast tick was first recorded in Oklahoma. A male tick was found on a dog in Pittsburg, Co. (Cooley & Kohls, 1944). Oklahoma State University archives has record of this tick species also discovered on dogs, in Johnston and Mayes counties in the mid 1960's. Gulf Coast ticks were first found on cattle in 1968 in Mayes county. This tick was first discovered on cattle in the Lake Carl Blackwell area in 1983.

Amblyomma maculatum is a three-host tick which adults attack primarily large wild and domestic animals including cattle, sheep, horses, goats, dogs, swine, wolves, deer, coyotes, and can be found on humans (Durden *et al.*, 1991; Felz *et al.*, 1996). *Amblyomma maculatum* adults were the most abundant ticks found on white-tailed deer *Odocoilus virginianus* in Texas (Samuel and Trainer, 1970). Larval and nymphal stages of *A. maculatum* feed primarily on ground dwelling birds. Meadowlarks (*Sturnella magna*) have been found to be the most suitable host for *A. maculatum* larvae and nymphs because of their wide migratory range and the area they cover in their search for food. Meadowlarks are also abundant across the southern United States (Bequaert, 1946; Semtner and Hair, 1973; Williams and Hair, 1974; Stacey, 1977; Bull and Farrand, 1977). *Amblyomma maculatum* larvae and nymphs can also be found on small wild mammals such as mice, voles, wood rats, squirrels, shrews and lagomorphs (Bishopp and Hixon, 1936; Hixon, 1940).

It is very important from a pest management standpoint to know the biology and effects of the various environmental influences of the life cycle of this economically important species of tick. *Amblyomma maculatum* is an important economic pest of cattle because the adults attach primarily on the peripheral areas of the ears of the host. The severity of the bite, in combination with the hosts' immune response, may cause painful swelling, skin lesions, and eventual deformity of the ears, causing a condition known as "gotch ear". When infestations are high and prolonged, ear cartilage becomes destroyed causing the ears to thicken, droop and curl downward. Domestic cattle, especially young calves are susceptible to this type of ear deformation (Hooker *et al.*, 1912; Gladney,1976).

Lesions caused by *A. maculatum* are often large and bloody, in which the ears become covered with a wet, sticky coating of serum mixed with blood. Adult *A. maculatum* can live underneath a hard and crusty scab, which may form during heavy infestations. Secondary infections or infestations may occur inside these lesions if left untreated (Gladney, 1976). The screwworm fly, *Cochliomyia hominivorax* Coquerel; causes a type of secondary infestation which has been eradicated in the United States, but still is a problem in Mexico, Central and South America. The female of this fly lays her eggs in an open wound predisposed by *A. maculatum* feeding. Emerging *C. hominivorax* larvae feed on the living tissue surrounding the lesion of the host (Spicer and Dove, 1938; Gladney, 1976; Ahrens *et al.*, 1977). If left untreated *C. hominivorax* infestations can be fatal to the animal. The southwestern screwworm fly eradication program which began in 1962, successfully controlled *C. hominivorax* populations in Texas, Oklahoma, Missouri and New Mexico (Rogers, 1962). Even without the intervention of *C. hominivorax*, economic losses attributed to *A. maculatum* infestation can include weight loss and ear deformity of the animals (Semtner and Hair, 1973; Williams *et al.*, 1977 & 1978, and Johnson, 1990).

Amblyomma maculatum has been linked to tick paralysis along the mid-Atlantic seaboard, Tennessee valley, and the southern Midwest parts of the United States (Harwood and James, 1979). Tick paralysis affects the myoneural junctions, acting on the motor nerves by diminishing the liberation of acetylcholine and causing damage to the receptor sites (McLennon and Oikawa, 1972). In the Caribbean Islands, Mexico, Central and South America where the tick originated, *A. maculatum* has become an experimental vector of heartwater, Cowdriosis in ruminants (Uilenberg *et al.*, 1984; Yunker, 1996). Under laboratory conditions, transstadial transmission of the heartwater organism, *Cowdria ruminantium* was successful between experimental *A. maculatum* larvae and nymphs (Uilenberg, 1982).

Biological studies done in southern Georgia, southeastern Texas, and northeastern Oklahoma have shown the seasonal activity of *A. maculatum* to be diverse. These three areas of the country vary in seasonal climate and vegetative habitat. Studies in southern Georgia recorded *A. maculatum* adults being most active from mid-July to mid-October (Bishopp and Hixon, 1936; Hixon, 1940). The larvae were most abundant between mid-July to mid-November. Nymphs were found on meadowlarks (*S. magna*) and other ground dwelling birds throughout the year, but they were most abundant in late February and early March (Bishopp and Hixon, 1936). In a Texas study, *A. maculatum* adults were found to be active from April to October with peak populations occurring between mid-July and mid-September. Larval activity began in July, with the greatest numbers found between November and January. Nymphs were most abundant and active from November to April (Fleetwood, 1985). The dispersal of *A. maculatum* is more than 500 km north of the Texas coastal plain, which indicates the distribution potential of this tick (Ahrens, *et al.* 1977). Both the Georgia and Texas studies were conducted by collecting immature stages on meadowlarks, (*Sturnella magna*) other ground dwelling birds and small mammals throughout the year. Adults were collected from experimental cattle used as sentinels placed in the infested areas. Cattle were used to monitor adult *A. maculatum* numbers throughout the year.

In an Oklahoma study of *A. maculatum* populations, adults were most active from late May to early July (Semtner and Hair, 1973). Also, larvae were found from mid-June through early September with peaks recorded in early July. Nymphs were recovered from early July to early October with peaks occurring in early August. This Oklahoma study was conducted in the spring and summer months with an emphasis on ground-dwelling birds. Small mammal specimens were also taken to observe differences in host-parasite interaction. In another Oklahoma study adult *A. maculatum* infested cattle were monitored from April-August (Johnson, 1990). The recent establishment of *A. maculatum* in northwest regions of Oklahoma suggests that this tick is very adaptable and capable of surviving in regions of lower humidity and temperature compared to coastal areas. As of 1998, *A. maculatum* adults reported on cattle include 32 counties along the southern and eastern half of the state as compared to only 18 Oklahoma counties in 1972 (Fig 2 & 3).

The objective of this study was to determine survival and development of each tick life stage. Observations were made on female oviposition, egg viability, engorged larval and nymphal molting times, larval and nymphal seasonal longevity and overwintering capabilities of all *A. maculatum* life stages. Observations of abiotic factors: quantity of rainfall, relative humidity, air and soil temperature, and soil moisture that might influence *A. maculatum* survival were also made.

CHAPTER II

MATERIALS AND METHODS

Habitats

The initial part of this study involved the selection of three different field vegetative habitat types. In each habitat, experiments were designed to obtain information on *Amblyomma maculatum*: (1) semi-engorged female preoviposition and oviposition times; (2) larval eclosion time in relation to natural environmental humidity and temperature; (3) larva and nymph attachment to host birds; (4) molting times of engorged larvae and nymphs, and (5) overwintering status of all life stages. Laboratory experiments were also conducted in an incubation chamber under controlled environment (25^0C and 85% humidity) to obtain information on (1) duration of female oviposition; (2) the minimum oviposition weight of partially engorged females, and (3) larval eclosion times.

There were two study areas: one area was selected at the Lake Carl Blackwell (LCB) north range, located approximately 10 km west of Stillwater, OK. The Oklahoma State University Department of Animal Science managed this area. The other study area selected was pasture 15, located approximately 2 km west of Stillwater, OK. The Oklahoma State University Department of Entomology and Plant Pathology managed this area.

There were three vegetative habitats selected within each study area: meadow, shrubs and wooded. Within each habitat at LCB, a 5m x 1.5m welded wire livestock panel was used to enclose a study area, where as the habitats on the pasture 15 study area were open and not enclosed by livestock panels. The meadow habitat consisted of short to medium little blue stem, *Schizachyrium scoparium*, approximately 30 cm in height. This habitat contained no overhead cover such as trees or shrubs. The second habitat was an area of thick heavy shrubs approximately 2-3 m in height, primarily winged sumac, *Rhus copallina* (L.). Occupying understory of this habitat was primarily round head *Lespedeza lesepedeza capitata*, big blue stem, *Andropogan gerardii*, common yarrow, *Achilea lanulosa*, and sedge, Carex (spp). Winged sumac provided shade for a large portion of the habitat. Finally, the wooded habitat consisted primarily of blackjack oak, *Quercus marilandica* (L.), these trees were approximately 10-15 m in height, which provided shade for most of the soil surface. The primary cover at the soil surface was leaf litter accumulation with sparse vegetative cover of big blue stem. The leaf litter provided a moister environment at the soil litter interface than the other habitats. The three habitats located at pasture 15 were comparable to LCB in both vegetative type and canopy cover. Past studies have shown that these three habitat types contain the highest incidence of hosts for *A. maculatum* and provide an environment that supports tick survival (Semtner and Hair, 1973; Stacey, 1977 and Johnson, 1990). A primary difference between the two study areas was that cattle had not grazed pasture 15 for approximately ten years.

Experimental Ticks

Adult *A. maculatum* ticks used in this study were collected, counted, and recorded from a herd of cattle located at LCB which was maintained by the Oklahoma State University Animal Science Department. The animals in this herd were primarily a Hereford-angus cross which had been pastured at the same location for three consecutive years. Initial counts of adult *A. maculatum* were first recorded weekly on 50 cows beginning on 19 April and ending on 10 May of 1995. These counts were in association with ear tag studies performed by Dr. Russell Wright. These initial counts recorded the incidence and number of adult *A. maculatum*, with no distinction between the ratio of male and female ticks, or host ear tissue damage. In March of 1996, thirty-four animals (18 cows and 16 calves) were selected for counting and collection of adult *A. maculatum* ticks. In March of 1997, adult ticks were counted on only 20 selected animals (10 cows and 10 calves). Observations of the location of tick attachment on cattle, host ear tissue damage resulting from *A. maculatum* tick feeding, and the number of male and female *A. maculatum* per animal were made from March to June 1996 & 1997. Weekly tick collections of partially engorged females in 1996 began on 10 April and ended 26 June. The total number of partially engorged female *A. maculatum* collected from cattle in 1996 was 216. These partially fed females weighed between 20 mg to 1,160 mg. The female ticks were divided into three weight classes: small females <90 mg, medium females 90 to 250 mg and large females >250 mg. The partially engorged ticks collected were randomly placed into arenas in the three different vegetative habitats at LCB between 1 to 4 days after removal from cattle. Partially engorged females, numbers 1 to 189 were placed in the three habitats at LCB: 63 females in the meadow habitat, 62 females in the sumac habitat and 64 females in the wooded habitat. Each arena contained a mean of seven partially engorged female ticks. Partially engorged females 190 to 216 were stored in an incubation chamber at 25^0C to 28^0C and 85 to 90% humidity. These ticks were used as a backup in case the ticks released in the study areas had high mortality and additional immature *A. maculatum* were needed to complete the study.

Nine circular metal arenas measuring 30 cm in diameter by 15 cm high were selectively placed within each LCB habitat and colored flags were used to mark the location of each arena. Yellow, red and blue flags were used for the meadow, sumac and wooded habitats, respectively.

Observation of Larval Activity

We checked for living larvae in the arenas at LCB by placing a white-gloved hand into the arena. We would look for unfed larvae crawling onto the glove. Once living larvae were observed within arenas at LCB, adult Bobwhite quail, *Colinus virginianus* were placed one per arena to allow larval ticks to infest and attach. The quail were confined in a wire mesh cage (19 cm x 8 cm x 8 cm), which prevented the bird from grooming the larvae off. There were six quail infestation dates in each habitat at LCB: 16-19 June 1996, 22 June 1996 and 23 June 1996. Each quail infestation period lasted approximately 15-20 minutes, allowing enough time for a sufficient number of ticks to contact and to prevent exposure of the birds to high ambient temperatures of over 35^0C. Infested quail were brought back to the lab and placed in holding cages approximately 40 cm x 20 cm x 20 cm. These holding cages were suspended in 50-cm x 30 cm x 30-cm tubs containing a thin layer of water. After 2-6 days, engorged larvae were collected from the water as they fell off the birds. After engorged larvae were collected from quail, the study site was moved to pasture 15 in mid-June of 1996. Three circular metal arenas with the same dimensions were selectively placed within each habitat. A total of 119, 569, and 954 engorged larval ticks were collected from quail exposed in the meadow, sumac and wooded habitats at LCB, respectively. These engorged larvae were equally divided and released among the three habitats at pasture 15 on six dates: 21-24 June 1996, 27 June 1996 and 1 July 1996. To aid in determining molting times of these engorged larvae, sentinel vials of ticks were placed into each arena/habitat during each release time. These sentinels were 7-ml glass vials containing approximately 7-10 engorged larvae with a gauze plug at one end to allow for air exchange.

Observation of Nymphal Activity

Newly emerged nymphs were collected from the habitat by exposing quail in the arenas as described for collecting larvae. Quail were exposed to nymphs in all three habitats at pasture 15 on four dates in 1996: 17 July, 29 July, 7 September and 22 October. As the engorged nymphs dropped from these quail they were divided into three equal groups for exposure in the three habitats. For exposure the ticks were placed in a 5 cm length x 1 cm internal diameter piece of tygon®tubing. A cloth gauze was attached to each end of the tube which allowed for ambient air exchange, while confining the ticks inside the tube. These tubes were placed into the field habitats at pasture 15 and observed for molting times and longevity. Engorged nymphs were placed in the three habitats on four dates in 1996: 23 July 21 engorged nymphs with seven ticks/habitat; 6 August 33 engorged nymphs with 11 ticks/habitat; 13 September 72 engorged nymphs 24 ticks/habitat; and 28 October 21 engorged nymphs with seven ticks/habitat.

Overwintering Observations

All life stages of *A. maculatum,* except unfed larvae were made in the field habitats at pasture 15. Biweekly observations on longevity of unfed larvae was made on those that remained in three different field habitats at LCB.

To obtain engorged larvae for overwintering observations approximately 180 unfed *A. maculatum* larvae that were stored in the incubation chamber were infested on a quail. The resulting engorged larvae were divided into equal groups and enclosed in 15-cm length x 1-cm internal diameter piece of tygon®tubing. The tubes were placed among all three arenas in each habitat at pasture 15 on 27 November 1996. Biweekly observation for molting time, survival and longevity was done for six months.

Unfed nymphs placed in tygon®tubing that had molted from the engorged larvae, released in late June 1996 at pasture 15 arenas were observed for longevity. Unfed adults that had molted from engorged nymphs placed in pasture 15 in late July to mid September 1996 were also observed for longevity. Nine fully engorged *A. maculatum* females per habitat were released in pasture 15 on 9 December 1996. These fully engorged females were reared at the Oklahoma State University tick rearing facility on an ovine host. These female ticks were observed for ovipositional activity during the winter months.

Observation of Environmental Parameters in Relation to Tick Survival

Environmental parameters were measured throughout this study and the relationship of these factors on the survival of all life stages of *A. maculatum* were correlated. Rainfall, relative humidity, air and soil temperature, and soil moisture have been shown to directly affect ixodid tick development and survival (Knulle, 1966; Hair *et al.*, 1975; Stacey, 1977 and Johnson, 1990). The macro-environment parameters of rainfall, ambient relative humidity and air temperature were measured daily from January 1995 to September 1997 by the Oklahoma State Automated Weather Station Network System (Mesonet), located at the Marena weather testing station. The Marena test station was 3-4 km south of LCB and 2 km southwest of pasture 15 study site. Micro-environmental parameters such as air and soil temperature and soil moisture were measured from May 1996 to February 1997 between the hours of 3pm and 5pm with a portable YSI tele-thermometer and moisture meter, respectively. The portable moisture meter was inserted approximately 3 cm directly into the ground inside the arena for 5-10 minutes. Moisture readings registered 10% to 30% for dry soil, 40% to 70% for moist soil, and 80% to 100% represented wet soil. Ambient macro-environment and micro-environment readings were compared and all similarities and differences were noted.

Statistical Analysis

This experiment was a completely randomized design. Analysis of variance procedures were performed using PROG GLM (SAS, 1988) on adult male and female *A. maculatum* counted on cows and calves and weights of collected partially engorged females. The treatments of interest were the three vegetative habitats selected for this study. A square root transformation was used on the counts (Steel and Torrie, 1980, p.236).

CHAPTER III

RESULTS

Habitat Development

Seasonal changes had an affect on the vegetation of all three habitats of both study areas. In early March of 1996, the meadow habitat at both study areas contained dead and dry medium bluestem, while the sumac habitat at both study areas contained primarily dead and decaying understory. The sumac brush had begun to produce leaves, but was still primarily bare. The wooded habitat at LCB contained only sparse pockets of medium bluestem at the soil surface while the blackjack oak trees had only begun to produce leaves. However, the wooded habitat at pasture 15 had large quantities of leaf litter at the soil surface, which had accumulated over several years. By late spring and early summer of 1996 the prairie grasses in the meadow habitats of LCB and pasture 15 had become green and thick which engulfed many of the arenas placed within it. The sumac habitats of both study areas had also become thick with heavy understory. The blackjack oak trees in the wooded habitats of both study areas had fully leafed out and had provided the study area with large amounts of shade. By late fall of 1996 and early winter of 1997, the vegetation in all three habitats of both study areas was reduced and resembled that of early spring of 1996.

Adult Seasonal Activity

In 1995, between 19 April to 10 May adult *A. maculatum* numbers on average over 20-ticks/cow and over 7 ticks/calf (Fig 4). Adult *A. maculatum* were first recorded on cattle in mid-March 1996 and 1997 and were primarily males. *Amblyomma maculatum* populations peaked in early May 1996 with a mean of 29 ticks/cow and 16.7

ticks/calf (Fig 5). Adult *A. maculatum* numbers on cows and calves gradually decreased until the last count in late June, averaging 3.35 ticks/cow. Similar population patterns were observed in 1997, when numbers of adult *A. maculatum* peaked in mid-May with a mean of 13.5 ticks/cow and 4.6 ticks/calf after which the numbers gradually decreased (Fig. 6).

The ratios of male to female *A. maculatum* on cattle during the peak seasonal activity periods in both 1996 and 1997 were at approximately 1:1. In 1996, the ratio of male to female *A. maculatum* on calves, during late April to early May was approximately 2:1. In 1997, the ratio of male to female *A. maculatum* on calves during the same time period was slightly higher at approximately 3:1 (Tables 1 & 2). These data were analyzed using ANOVA techniques with SAS PROG GLM (SAS, 1988). Separate analyses were performed for each combination of year and cow/calf. The model utilized was a randomized complete block design with date as block and sex as treatment. The response variable, number of ticks, was transformed using the square-root transformation (Steel and Torrie, 1980, p. 236). The total tick sex ratio was significantly different on cows and calves in 1996 ($p= 0.0001$ and $p= 0.0136$, respectively) Table 1 and in 1997, ($p=0.0001$ and $p=0.0002$) Table 2.

Preoviposition, Oviposition and Egg Viability

Preoviposition refers to the time between female tick engorgement on the host's blood and the time its starts to lay eggs. Ovipostion refers to the actual time of laying eggs by the female tick (Dipeolu, 1991). The distribution and percentage of partially engorged *A. maculatum* females divided among three weight classes (Table 3). Female ticks that weighed <90 mg, 90-250 mg, and >250 mg constituted 32.8%, 38.6% and 28%

of the partially engorged females released, in field habitats at LCB, respectively. These data were further analyzed using ANOVA techniques with SAS PROG GLM (SAS, 1988). The model used was a randomized complete block design with date as block and weight class as treatment. The response variable, number of ticks, was transformed using the square root transformation (Steel & Torrie, 1980 p. 236). The three weight classes were not significantly different in the ANOVA ($p=0.3347$). When females weigh less than their maximum effective engorgement weight (MEEW), it usually indicates a substantial decline in egg production (Dipeolu, 1991). Partially engorged females < 90 mg observed in the laboratory failed to lay eggs. Mating may not have occurred between these smaller females; therefore, these females did not exhibit rapid engorgement, which is common in mated female Ixodid ticks. Under laboratory conditions (temperature of 25^{0}C and 85% relative humidity), it was observed the minimum weight at which an *A. maculatum* female would lay viable eggs was approximately 90 mg. Preoviposition and oviposition times of females in the laboratory, weighing between 90-250 mg were 7-10 days and 30-35 days, respectively. The egg mass size of these females was less than females weighing > 250 mg. In the laboratory, preoviposition and oviposition times of females weighing > 250 mg were 2-5 days and 18-20 days, respectively.

Many of the partially engorged females released at LCB were never observed in the field and several of the ticks oviposited prior to being placed into the field (Table 4). Eggs from these ticks desiccated within 48 hours of being released. Female tick preoviposition and oviposition times in the meadow and sumac habitats were unknown because we were unable to locate any living partially engorged females. Three engorged females of the >250 mg weight class were discovered in the wooded habitat at LCB.

Preoviposition and oviposition times of these females were approximately 4-5 days and 26-28 days, respectively.

Larval Tick Activity

Unfed larval ticks were first found at LCB in the meadow habitat on 13 June 1996. Hatching or eclosion time of the larvae was discovered to be 2-3 days later in the sumac and wooded habitats than in the meadow habitat. It was observed that unfed larval ticks did not ascend vegetation and seek a host during times of peak solar rays, instead they aggregated at the base of the vegetation, crawled under leaf litter, or buried themselves into the loose topsoil.

Larval ticks attached readily to quail at LCB and the resulting engorged larvae dropped off the quail over a 2-6 day period. The sentinel ticks in the glass vials quickly filled with moisture and built up mold and fungus causing many of the engorged larvae inside to die. This made it difficult to get exact molting times of the engorged larvae in all three habitats. Total numbers of engorged larval ticks actually collected in the meadow, sumac and wooded habitats were 119, 569 and 954, respectively. The engorged larvae released into the pasture 15 habitats crawled to the base of the vegetation or under leaf litter and debris within minutes after being deposited.

Nymphal Tick Activity

Newly molted nymphs from the engorged larvae deposited at pasture 15 were first observed in the sumac and wooded habitats on 12 July 1996 approximately 19-26 days post release. Newly molted nymphs were not observed in the meadow habitat until 19 July 1996 approximately 26-33 days post release. During the nymphal infestation dates, a total of seven engorged nymphs were recovered in the meadow habitat at pasture 15.

Under laboratory conditions (i.e., 25^0C and 85% humidity), engorged larvae molted in approximately 17 days. The nymphs engorged and dropped off the quail in approximately 3-8 days. Under laboratory conditions, at 25^0C and 85% humidity engorged nymphs molted into adults in approximately 16 days.

The first set of engorged nymphs was placed in the meadow habitat at pasture 15 on 23 July 1996. All of these engorged nymphs molted into adults in approximately 20 days, while all of the engorged nymphs placed in the sumac and wooded habitats at pasture 15 molted in 22 days. Engorged nymphs placed in the pasture meadow habitat on 6 August 1996 had 100% molt in 28 days, while 100% of the engorged nymphs in the sumac habitat and wooded habitat molted in 31 days, and 33 days, respectively. Engorged nymphs placed in the meadow habitat at pasture 15 on 13 September 1996 had 100% molt in approximately 33 days. Engorged nymphs in the pasture 15 sumac habitat molted in 33 days, with 67% surviving, while engorged nymphs in the wooded habitat molted in 43 days, with less than 10% surviving. The tubes in the wooded habitat were badly chewed by rodents and it was possible some engorged nymphs were lost or eaten. The final set of engorged nymphs placed in pasture 15 on 28 October 1996 in the meadow habitat had total mortality by late January 1997. The engorged nymphs in the sumac habitat had total mortality by mid-February 1997, while all of the engorged nymphs in the wooded habitat molted in early-May 1997, this was approximately 190 days after being placed in the field (Table 5).

<u>Tick Longevity and Overwintering Observations</u>

Unfed larval ticks which had eclosed 5 months earlier at LCB were last observed in early September 1996 in the wooded habitat, while living larval ticks were absent by mid to late August of 1996 in the meadow and sumac habitats. All 180 engorged larvae deposited in each habitat at pasture 15 on 27 November 1996 died within 7 days.

Unfed nymphs were last observed in the wooded and sumac habitats in late October 1996, while unfed nymphs in the meadow habitat which were last observed in early November 1996. Most of the engorged nymphs released prior to the 23 October 1996 had molted into adults and successfully overwintered. However, none of these adults survived past mid May 1997. The engorged nymphs placed in the meadow and sumac habitats of pasture 15 on 23 October 1996 failed to molt and died in late February and early March of 1997. The engorged nymphs placed in the wooded habitat of pasture 15 in 23 October 1996, successfully overwintered as engorged nymphs and molted into adults in early May 1997; however, these adults died in late June 1997.

One replete female in the meadow habitat of the total nine replete females released on 9 December 1996 at pasture 15 survived until mid-January 1997. Replete females in the sumac and meadow habitats at pasture 15 died within 72 hours post release. Replete females placed in the wooded habitat at pasture 15 died within 6 days post release.

Observation of Environmental Parameters in Relation to Tick Survival

Macro-Climate

In 1995, rainfall at the both study areas averaged approximately 15 cm from May to mid-August. However, beginning in October the amount of rainfall decreased to less than 6 cm/month. This decrease in rainfall continued on into the first four months of 1996. Rainfall in 1996 was less than 2 cm until late June when rainfall increased to more than 10 cm. However, the mean yearly rainfall was still below normal for that region. In

1997, rainfall in the area was less than 2 cm/month from January to September. The study areas received little or no rainfall from May through September 1997 (Fig 7).

Ambient relative humidity in 1995 was consistently over 80% throughout the entire year. In 1996, the monthly humidities were slightly lower than in 1995, however, the humidities were over 90% between May through September. Monthly mean humidities in 1997 were approximately 10% lower than the previous two years (Fig 8).

The monthly mean differences in ambient air temperatures between 1995-1997 were did not greatly differ. Seasonal air temperatures between the three years also did not differ greatly (Fig 9).

Micro-Climate at LCB

Air temperatures in 1996, for all three habitats were similar at LCB until mid-June (Fig 10). Air temperatures during this time in the meadow habitat were 8-10 degrees higher than the wooded habitat while temperatures in the sumac habitat were 3-5 degrees higher than in the wooded habitat.

A greater difference in the three habitats at LCB occurred within the soil temperatures (Fig 11). From mid-May to mid-June 1996 the meadow, sumac, and wooded habitats had soil temperatures between 22^0C and 47^0C, 22^0C and 41^0C, and 22^0C and 30^0C, respectively.

The greatest differences between the three habitats at LCB were the soil moisture readings (Fig 12). Soil moisture content would drop in all three habitats several days after a rainfall. The meadow habitat exhibited soil moisture fluctuations from extremely dry (< 10%) to becoming saturated (80% to 90%) after a substantial rainfall, however, after 3-4 days the soil moisture content would become negligible. The sumac habitat maintained a moderate amount of soil moisture approximately (30% to 40%), having fluctuations of approximately 20% soil moisture during the dry periods and 60% soil moisture during the moist periods. Similar to the meadow habitat, but not as extreme.

The wooded habitat consistently maintained its soil moisture to an average of 60% at the end of May 1996.

Micro-Climate at Pasture 15

Differences in air temperatures at pasture 15 habitats peaked in June to mid-August 1996 (Fig 13). During this time, the sumac had the highest temperatures, which were approximately 5 degrees higher than the meadow habitat and 10 degrees higher than the wooded habitat. Beginning mid-August and through the remainder of the study, temperatures varied by only 2-3 degrees among the three habitats (Fig. 14).

Through the periods between late June and late August 1996, soil temperatures also peaked in all three habitats (Fig 15). In early July 1996, the wooded habitat had lower soil temperatures by approximately 5-10 degrees than the sumac or meadow habitats. By late August 1996 through the remainder of the study, soil temperatures between the three habitats differed by only a few degrees (Fig 16).

Soil moistures recorded in late June and early July were extremely low for all three habitats < 10% (Fig 17). Differences did not occur until a substantial rainfall in early July. The meadow habitat recorded higher soil moisture than the wooded or sumac habitats by several percentage points for the remainder of the study.

CHAPTER IV

DISCUSSION

Adult Seasonal Activity

Activity on the Host

Adult *A. maculatum* were first observed on the ears of cattle in mid-March 1996-97. The number of ticks on cattle peaked in late April and early May and diminished by late June. This information slightly contradicts studies done by Semtner and Hair (1973). They reported that adult *A. maculatum* were most active in late May to early July. However, the study done by Semtner and Hair (1973) was conducted in northeastern Oklahoma and this region of the state has slightly cooler spring temperatures than central Oklahoma where the present study was conducted. *Amblyomma maculatum* may not have been active until later that spring.

The severity of ear lesions on cattle increased as the number of ticks increased, but "gotch ear" in these cattle was not detected. Ear cartilage still appeared rigid with no signs of deterioration. *Amblyomma maculatum* males were the first sex observed on cattle in mid-March 1996-97. Female *A. maculatum* were not observed in substantial numbers until mid-April 1996-97. A possible explanation for the larger number of males is that females will mate with males, engorge, and drop to the ground. The males remain on the host and mate with more females that attach later. Other explanations of this higher incidence of male to female adult *A. maculatum* is the possibility of a male sex pheromone and/or aggregation pheromone (Berger, *et al.* 1971; Gladney, 1971; Gladney, *et al.* 1974; Sonenshine *et al.* 1974). Sex pheromones attract females for mating while aggregation pheromones act as an attractant to a blood meal. Gladney 1971 observed that female *A. maculatum* did not readily attach to a host in the absence of males; when males were attached to a host, 80 of 92 females attached within 1 cm of the attached males. Aggregation phermones used to counter host grooming was studied by Rechav *et al* (1977). Male *Amblyomma hebraeum* which had fed for more than seven days produced an aggregation-attachment pheromone (AAP). These males survive on hosts for months while the AAP attracts females and other males to form clusters on specific parts of the body.

Activity Off the Host

We had observed that adult *A. maculatum* ticks became active off the host at an ambient temperatures greater than 20°C. When temperatures were lower than 20^0C, A. maculatum adults remained inactive until temperatures rose above 20^0C. Sweatman (1967) found that the adult brown dog tick, *Rhipicephalus sanguineus* were active at approximately the same temperature. The previous studies on *A. maculatum* in northeastern Oklahoma, stated that unfed adult *A. maculatum* could successfully overwinter, but for only one year. These overwintering adults would have to find a host or they would eventually die later that same year (Semtner and Hair, 1973). This also agrees with observations done in this study, however, unfed *A. maculatum* adults that had successfully overwintered were too few in number to give an accurate determination of unfed adult *A. maculatum* survival. In this study replete females placed in the field in late November 1996, failed to survive. These females may not have been able to acclimate to field conditions because they were raised in a laboratory environment. More work needs to be done on overwintering of nymphal and adult *A. maculatum* life stages in Oklahoma.

Preoviposition, Oviposition and Egg Viability

Preoviposition refers to the time period after the engorged female tick detaches and drops off the host to the time she begins to oviposit (Nagar, 1968a). Mortality among the 189 partially engorged females may have been to more prolonged host-seeking activity by the smaller <90mg female ticks. Partially engorged female *A. maculatum* <90 mg may be incapable of oviposition and must find another host in order to survive. The wax layer of the tick cuticle helps maintain body water content in the tick. Partially engorged ticks may be more susceptible to water loss than unfed ticks because the cuticular wax layer has expanded and becomes thin due to physiological processes associated with mating and egg production (Sonenshine and Tigner, 1969; Hair *et al.*, 1975). This fact, in association with their prolonged host-seeking behavior may cause desiccation of the ticks. Partially engorged females from this study deposited into the three habitats at LCB were difficult to locate without disturbing the habitat. Initial searches for these females ticks indicated only three partially engorged females found in the wooded habitat at LCB had survived. However, *A. maculatum* larvae were found in approximately 50% of the arenas of all three habitats at LCB in mid June of 1996, indicating that at least some of the engorged females managed to oviposit in the field. Ixodid ticks have a solute driven vapor uptake mechanism rather than a cuticle that absorbs the surrounding moisture or sometimes called a hydrophilic cuticle. This solute driven adaptation enables ticks to take moisture from the air even if the surrounding environment is void of moisture (Shih *et al.*, 1973; Needham and Teel, 1991). Partially engorged ticks that survived and oviposited during late April and early May 1996 may have been able to absorb moisture from the surrounding air. Ambient relative humidity prior to mid-May 1996 was between 70%-80%. Rainfall in the study area prior to mid-May 1996 was extremely low, registering less than 2 cm/month. However, ambient air temperatures were between 20-25^{0}C and a substantial amount of rain had fallen in mid-May 1996. This may have provided adequate soil moisture for the surviving partially engorged females to oviposit and produce viable eggs. As stated earlier, exact preoviposition and oviposition times of partially engorged *A. maculatum* females in the meadow and sumac habitats at LCB were not recorded due to the inability to locate living females. Previous Oklahoma studies have recorded preoviposition and oviposition times of engorged females released in mid-May to be approximately 8 days and 21-22 days, respectively for both the meadow and sumac habitats at LCB (Semtner and Hair, 1973; Stacey, 1977).

The three engorged females discovered in the wooded habitat had preoviposition and oviposition times of 4-5 days and 26-28 days, respectively. These preoviposition and oviposition times of *A. maculatum* in the persimmon habitat at LCB coincide with work done by Semtner and Hair (1973) and Stacey, (1977). When overhead and groundcover is inadequate, replete Ixodid tick females will conserve water by hiding themselves in soil, debris and oviposit. (Bishopp and Hixon, 1936; Hixon, 1940; Drummond, 1967 Drummond and Whetsone, 1970). The three *A. maculatum* females found in the wooded habitat of this study hid under leaf litter and vegetative debris, and had direct contact with the soil.

Oviposition

Approximately 1/3 of the 189 *A. maculatum* females deposited in the field had weights >250mg and of those 1/3 only three females had weights close to their maximum effective engorgement weight (MEEW) of 1,100 mg. Replete *A. maculatum* females have the ability to attain a weight of over 1,400 mg and have the ovipostional potential to lay up to as many as 8,000-9,000 eggs (Dipeolu, 1991). Linear regression analysis of engorged female *Rhipicephalus sanguineus, Dermacentor variabilis* and *A. maculatum* shows a direct relationship between tick weight and oviposition efficiency (Nagar, 1968b; Drummond and Whetstone, 1970; Dipeolu, 1991). Fully engorged female *A. maculatum* are capable of utilizing 70% of their body weight for egg production (Wright, 1971). Two-thirds of the females placed in the field had weights far below their (MEEW) which may have reduced their ovipostional potential (Dipeolu, 1991). Under laboratory conditions, partially engorged ticks 90-250 mg oviposited a small egg mass, but only after 7-10 days of continuous movement. Partially engorged females >250mg began to oviposit 2-5 days after leaving the bovine host. The egg mass was larger than female ticks weighing 90-250 mg, but considerably less than a fully replete female. Predators such as birds, small rodents and reptiles may also have proved to be a factor in partially engorged tick mortality as has been observed in previous biological studies of this nature (Stacey, 1977; Johnson, 1990).

The 27 engorged females deposited in the three habitats in December of 1996 all died however, if the replete females had engorged earlier in the year and under more natural conditions, some of the females may have survived the winter and oviposited that spring in all three habitats.

Egg viability

During March through June of 1996, mean monthly air temperatures in Oklahoma were approximately between 7.1^{0}C and 15.1^{0}C. However, the meadow habitat received more solar rays with a higher humidity for *A. maculatum* eggs during the spring months, which would be suitable for the larval eclosion. The air and soil temperatures in the meadow habitat were consistently over 35^{0}C during the months of June, July and early August 1996. Soil moisture fluctuated from 8 to 10%, after a heavy rain, to $<2\%$ after 48-72 hours of air temperatures between 35^{0}C to 40^{0}C. Lack of sufficient overhead and ground cover may have allowed long periods for solar rays to penetrate to the soil and cause rapid desiccation of *A. maculatum* eggs and immature life stages. Previous studies have shown *A. maculatum* eggs and immature ticks are more susceptible to the extreme conditions contained in the meadow habitat than in habitats with denser vegetation (Semtner and Hair, 1973 and Stacy, 1977).

The sumac habitat of both study areas was the most consistent of the three vegetative sites. The vegetation canopy did allow solar rays to penetrate the soil, but there was enough overhead protection to maintain an adequate amount of soil moisture and higher relative humidity (Stacey, 1977). This vegetative environment did provide suitable habitat for *A. maculatum* eggs and immatures during the spring and summer months.

Eggs oviposited in a wooded habitat during the months of late March and April would take longer to hatch, because of the cooler temperatures created by the thick vegetative canopy (Semtner and Hair, 1973; Stacey, 1977; Johnson, 1990). This factor in combination with sufficient overhead cover would allow the wooded habitat to be suitable for *A. maculatum* eggs during the mid-summer season.

Immature Tick Seasonal Activity

Unfed larvae were first observed in the meadow habitat, but few larvae were collected. This agrees with previous studies in which the unfed larvae were first observed in the meadow habitat (Semtner and Hair, 1973). This fact does not conclude however, that there was a higher larval mortality in the meadow habitat. Vapor pressure deficiency occurs during times of high temperature and low relative humidity. Collection of unfed larvae was done during times between 3pm and 5pm which was peak solar activity and low humidity. During this time of the day the host-seeking behavior of larvae would be reduced due to high temperatures of $> 40^0$C and low humidities $< 70\%$ located above the vegetation. The low numbers of larvae collected may have been a direct result of these environmental parameters (Fleetwood and Teel, 1983). The greatest number of larvae collected was from the wooded habitat. This habitat was able to maintain higher soil moisture content during the hottest times of the year when ambient air temperatures were over 40^0C. Micro soil temperatures reached $>40^0$C in June and July 1996, causing the soil to become dry in all three habitats and relative humidity to decrease. The ability of ticks to survive for long periods of time in the absence of a host is influenced by the relative humidity (Knulle, 1966). Critical equilibrium humidity for *A. maculatum* was determined to be approximately 92-93% (Hair *et al.*, 1975). The same environmental factors in the three different habitats affecting *A. maculatum* eggs would be similar with *A. maculatum* larvae. Unfed nymphs were first observed in the wooded habitat, followed by nymphs in the sumac habitat and later nymphs in the meadow habitat. Molting times of the larvae differed by 7 days between the meadow habitat and the wooded and sumac habitats. Engorged larvae were placed in the field at pasture 15 in late June and early July of 1996. During that 21 day period, there was little or no rainfall in the area. Micro air and soil temperatures reached over 40^0C in the sumac and meadow habitats. Flat nymphs were not observed at pasture 15 until after there was a substantial amount of rainfall in the area. The sumac habitat provided enough overhead protection and a high enough humidity to enable engorged larvae to molt. The wooded habitat maintained cooler air and soil temperatures provided by the leaf litter. These observations contradict part of the previous work of Semtner and Hair (1973) in which they found shorter molting times of engorged larvae within the meadow habitat during the spring months. However, these same studies also show the wooded habitat to be the most favorable for *A. maculatum* immature survival during the late summer months when soil moisture is minimal for all three habitats. The wooded habitat in both study areas was able to maintain higher soil moisture content and have lower micro air temperatures than the ambient temperature. This habitat provided substantial shade and shelter for all life stages of *A. maculatum*. During the late fall and winter months, the soil temperature in the wooded habitat at pasture 15 became higher than the ambient temperature, due to the large amounts of leaf litter at the soil surface. This leaf litter provided adequate protection for the ticks from the elements. If rainfall is inadequate within an area, the habitat which can best sustain its soil moisture and maintain and high relative humidity of > 85%, will be the most suitable habitat for *A. maculatum*. Previous *A. maculatum* and *Amblyomma americanum* studies using these vegetative types have shown that persimmon habitats generally have lower micro air and soil temperatures than habitats containing prairie grasses and shrubbery. Thus, maintaining higher soil moisture content during periods of little or no rainfall (Semtner, 1972, Semtner and Hair, 1973; Stacey, 1977 and Johnson, 1990).

Season had an effect on molting time in all three-habitat types. Molting times of engorged nymphs were generally shorter during the warmer months of late July and early September 1996 and longest time were found in the engorged nymphs in mid-September and late October 1996. Soil moisture was adequate in all three habitats from late summer of 1996 to the May 1997. Engorged nymphs in the meadow habitat had shorter molting times on all three-deposit dates with the exception of 28 October 1996 when the engorged nymphs died. Engorged nymphs placed in the wooded habitat on 28 October 1996 molted in May of 1997. This observation of engorged nymphs successfully overwintering in Oklahoma disagrees with previous studies done by Semtner and Hair (1973), Stacy (1977) and Johnson (1990). They concluded that *A. maculatum* unfed adults were the only life that overwintered in Oklahoma. The wooded habitat in pasture 15 contained large amounts of leaf litter, which provided insulation for the engorged nymphs, while the vegetation in the sumac and meadow habitats had died by late fall 1996 exposing the soil surface to the harsh environmental factors.

Immature Longevity

Unfed larvae in the wooded habitat survived longer than larvae in the sumac or meadow habitats. The soil moisture content of the wooded habitat remained higher than the other two habitats for three to four weeks from mid-May to mid-June 1996. This soil moisture data agrees with previous work done by Semtner (1972), Stacey (1977), and Johnson (1990). Soil moisture content in the meadow and sumac habitats was adequate for *A. maculatum* egg development and larval eclosion, but soil moisture dropped to extremely dry in all three habitats for approximately 20 days in late June to mid July 1996. The wooded habitat maintained a moderate amount of soil moisture during this time period. Newly molted larvae may have required more moisture in order to survive longer in the meadow and sumac habitats.

Unfed nymphs were observed in all three arenas. However, numbers of unfed nymphs in the meadow habitat may have been reduced due to the extreme heat and lack of soil moisture. Nymphal numbers in the sumac habitat were also reduced. The greatest number of unfed nymphs survived in the wooded habitat. The wooded habitat provided the greatest overhead protection from the high mid-afternoon solar rays. Unfed nymphs in the wooded and sumac habitats were last recorded in late October 1996, while unfed nymphs were present in the meadow habitat until early November. The meadow habitat received more solar rays than the other two habitats, but air temperatures in late fall of 1996 were lower between 20^0C and 30^0C. These cooler temperatures allowed the meadow habitat to maintain its soil moisture content with moderate air and soil temperatures. During the fall months of 1996 the meadow habitat was more suitable habitat to the unfed nymphs than the sumac or wooded habitat. Total numbers of engorged nymphs collected throughout the study were low.

Host Suitability

Ground dwelling birds have been recorded to be the primary hosts of *A. maculatum* larvae (Bequaert, 1946; Semtner and Hair, 1973; Williams and Hair, 1974; Stacey, 1977; Bull and Farrand, 1977). When quail were infested with *A. maculatum* larvae, the larvae attached more quickly and a larger number of larvae remained attached until engorgement. By 1973, cattle egrets *Bubulcus ibis* had large populations in eastern

Oklahoma. These birds walk along side domestic cattle and eat the insects that the cattle disturb. Cattle egrets spend the winters in Central and South America, the Caribbean and along the gulf coast of the United States. The birds' migratory behavior is extensive sometimes traveling several thousand miles as far north as southern Canada in search of a nesting site. This migratory behavior may also aid in moving this tick northward. Cattle egrets were first seen nesting in North America in 1952 (Telfair II and Marcy, 1984).

Small mammals have also been recorded as secondary hosts (Semtner and Hair, 1973). An extensive study using small mammals as hosts for *A. maculatum* immatures is required to fully understand what role these hosts would play in the population dynamics of *A. maculatum* in the field.

The importance of this study was to monitor and observe Gulf Coast tick behavior on and off the host. If gone unchecked, this tick has been proven to cause extensive damage to the ears of domesticated animals (Gladney, 1976). The distribution of *A. maculatum* has advanced steadily northward and adapted to more extreme climatic conditions. This study revealed that *A. maculatum* engorged nymphs could survive in temperatures below 5^0C through winter and molt into adults in spring. However, more extensive studies using larger numbers of immatures and adults is necessary to fully understand the behavioral limits of this tick.

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Figure 1. Present *Amblyomma maculatum* distribution in the Western Hemisphere.

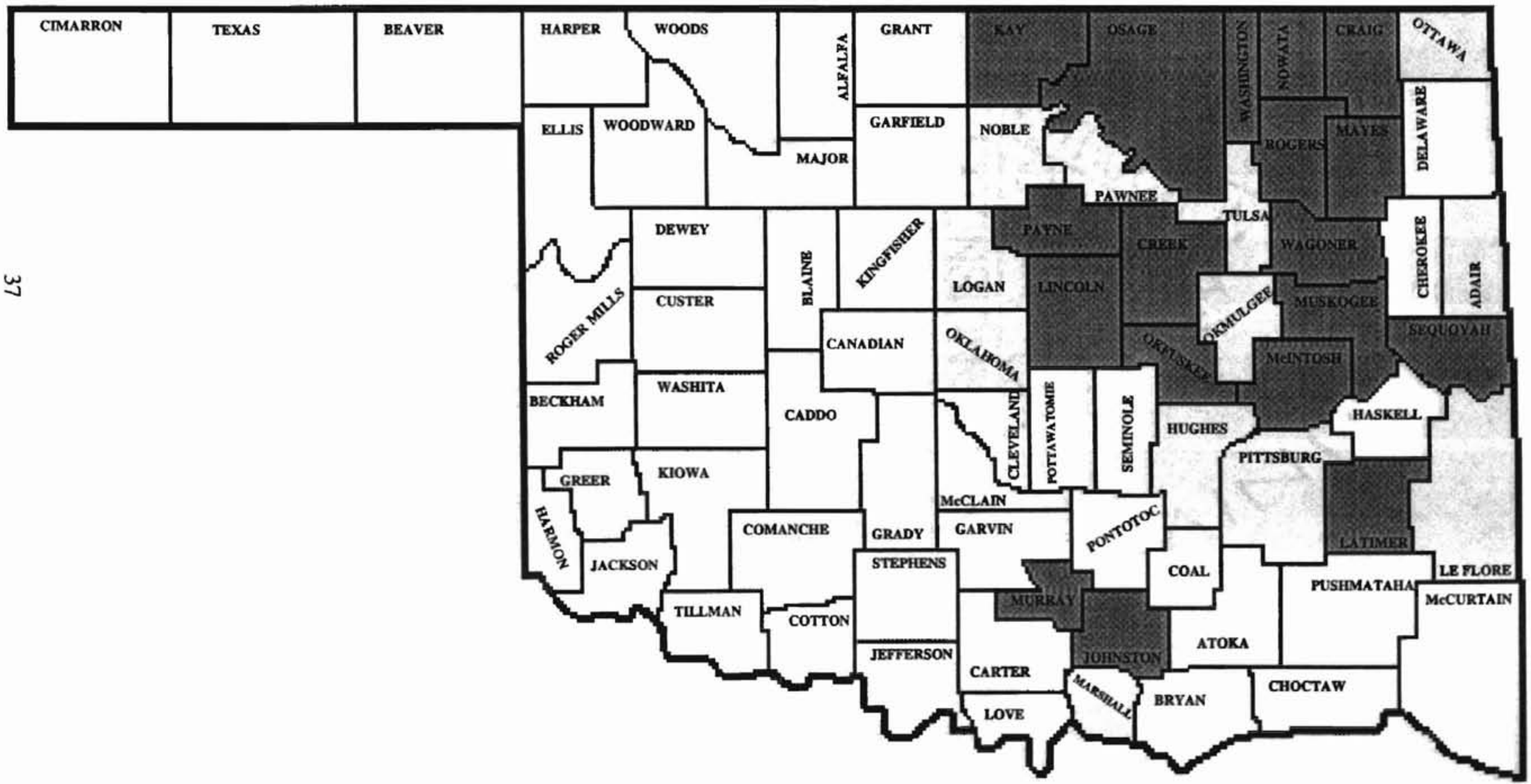

Figure 2. Gulf Coast Tick Distribution in Oklahoma from 1942 to 1972.

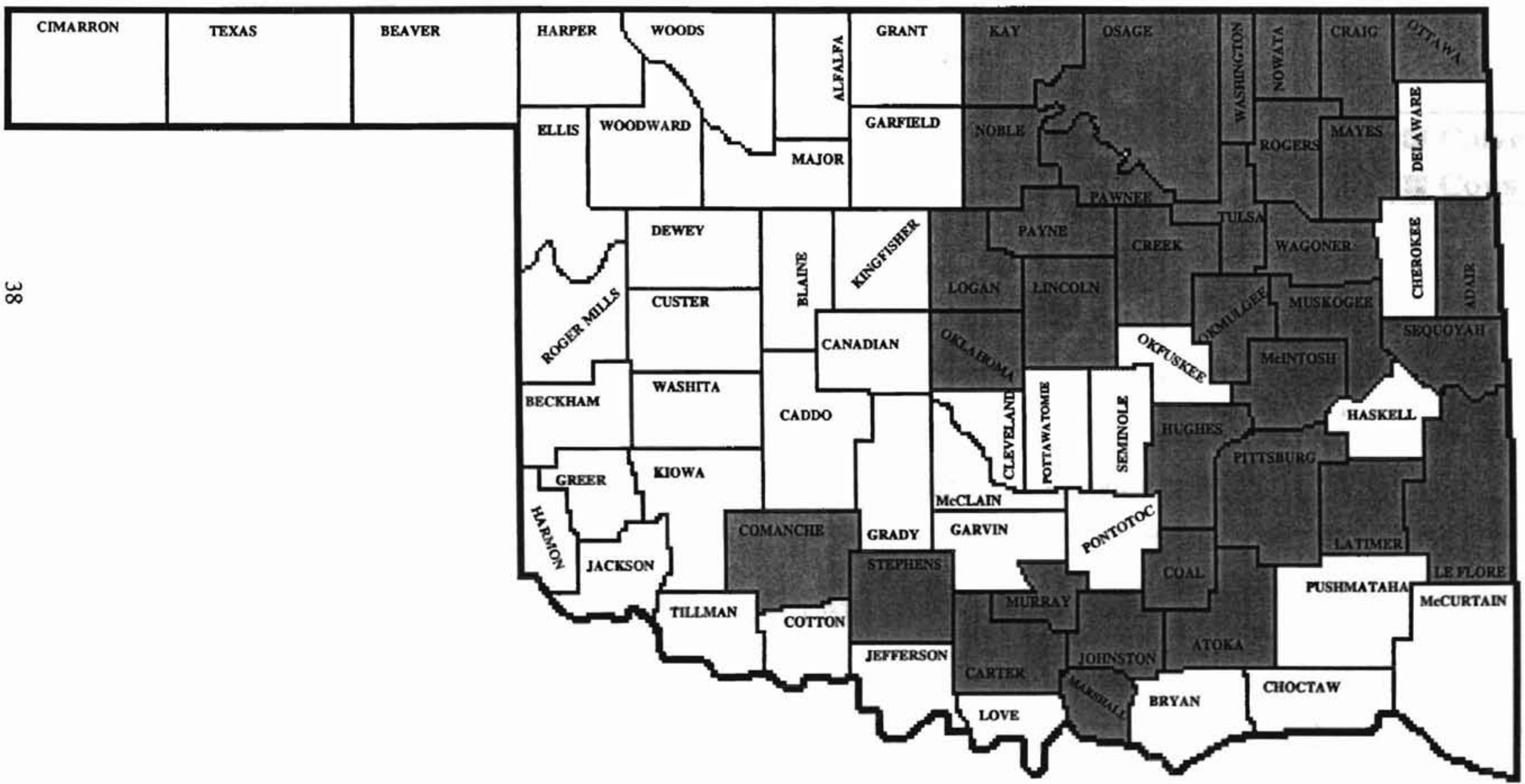

Figure 3. Gulf Coast Tick Distribution in Oklahoma from 1972 to 1998.

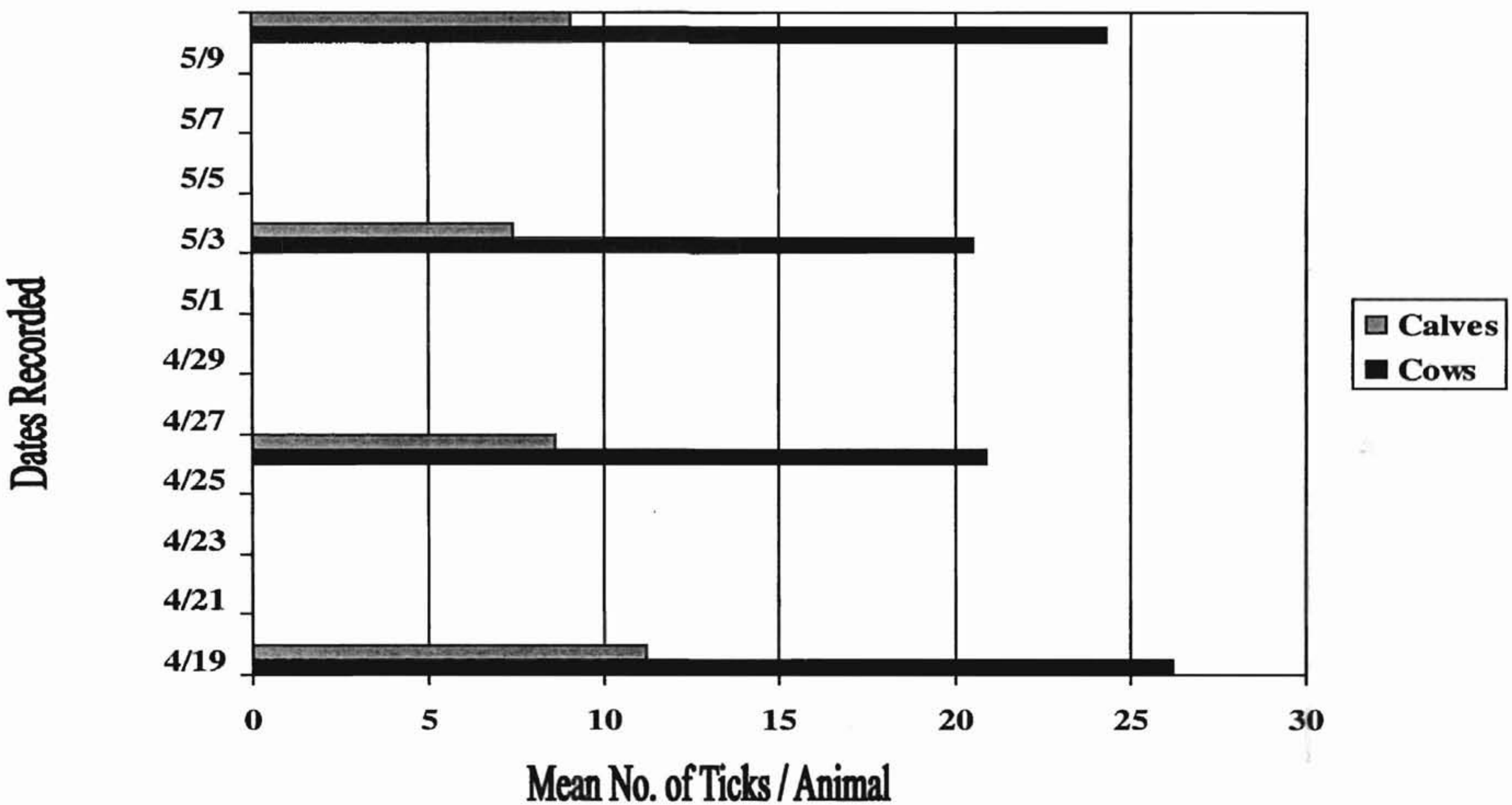

Figure 4. Mean No. of Adult Gulf Coast Ticks Found on Cattle Located at the Lake Carl Blackwell, North Range Pasture, Noble County, Oklahoma During 19 April to 10 May 1995.

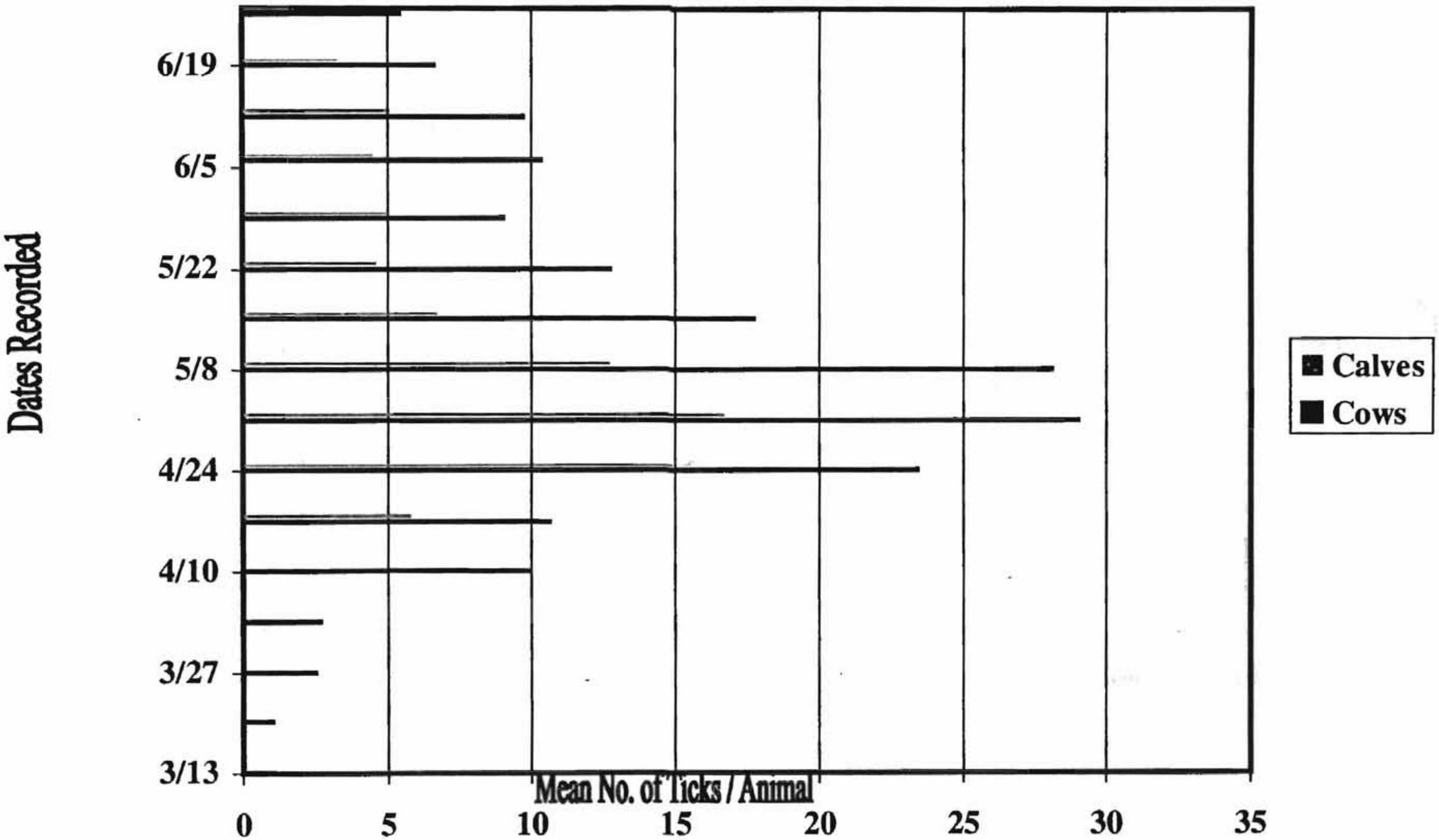

Figure 5. Mean No. of Adult Gulf Coast Ticks Found on Cattle Located at the Lake Carl Blackwell, North Range Pasture, Noble County, Oklahoma During 13 March to 26 June 1996.

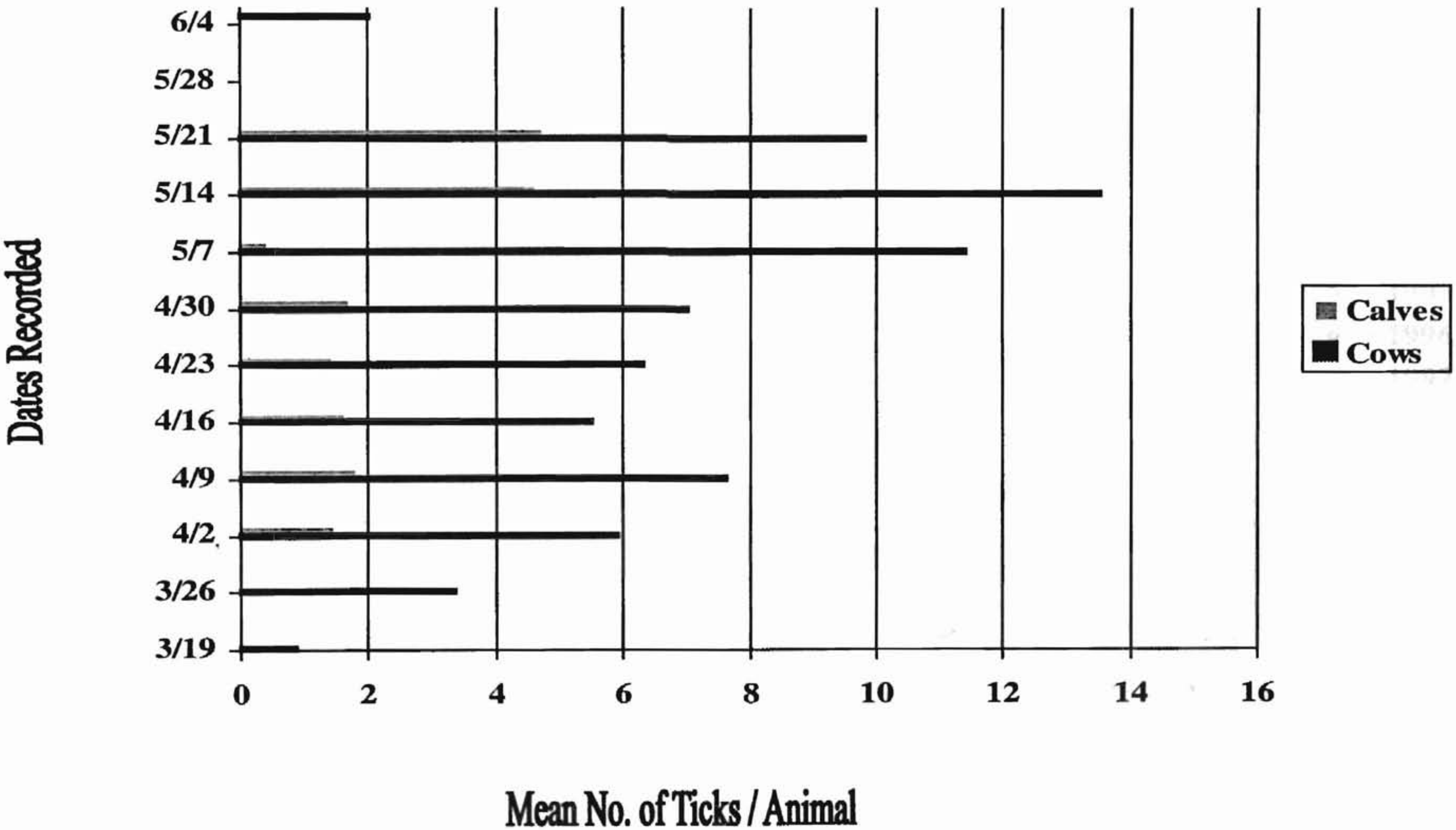

Figure 6. Mean No. of Adult Gulf Coast Ticks Found on Cattle Located at the Lake Carl Blackwell, North Range Pasture, Noble County, Oklahoma During 19 March to 5 June 1997.

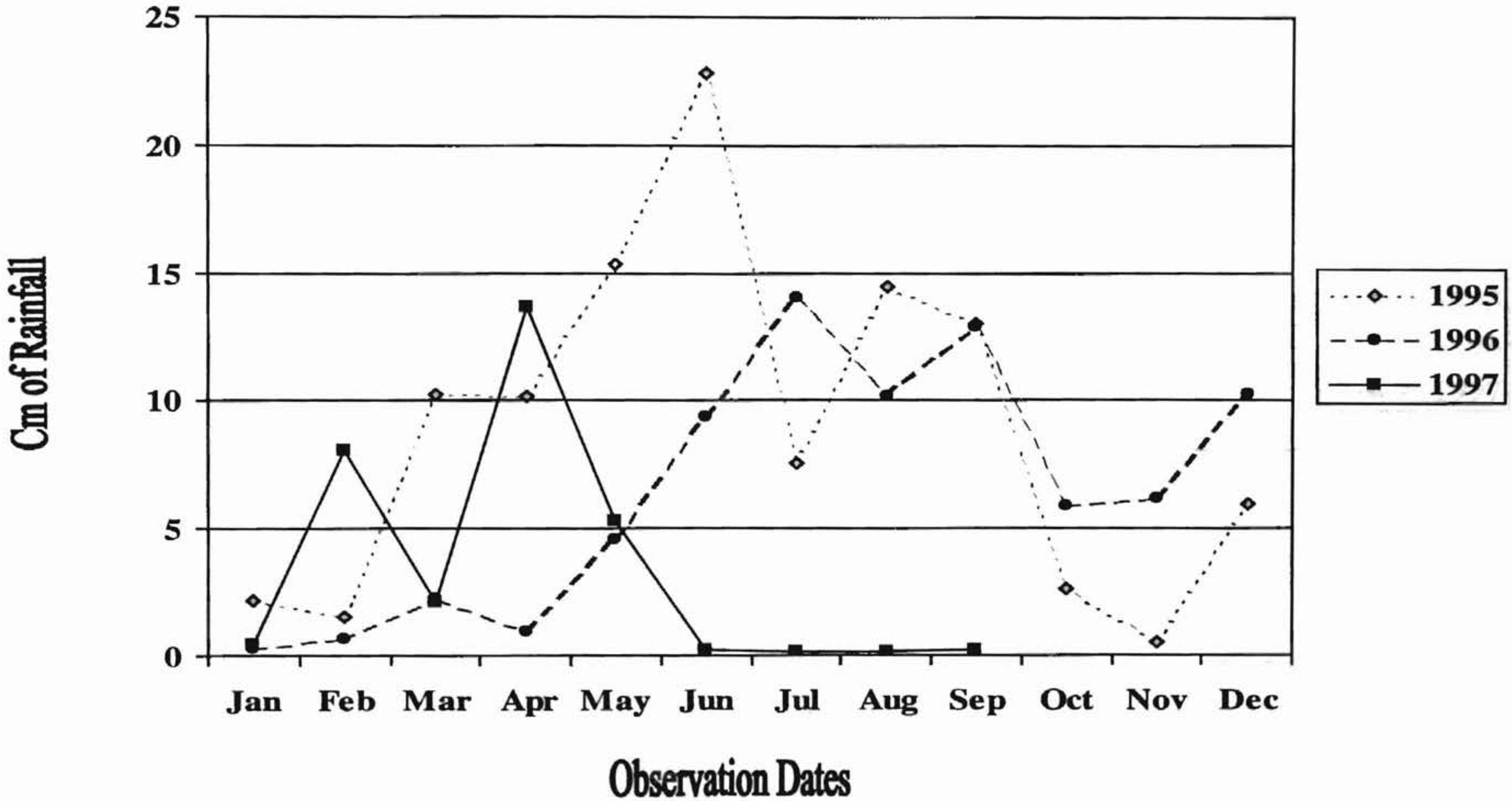

Figure 7. Mean Monthly Rainfall Taken from the Oklahoma State Automated Weather Station Network System (Mesonet) Marena Station, Payne County, Oklahoma, January 1995 to September 1997.

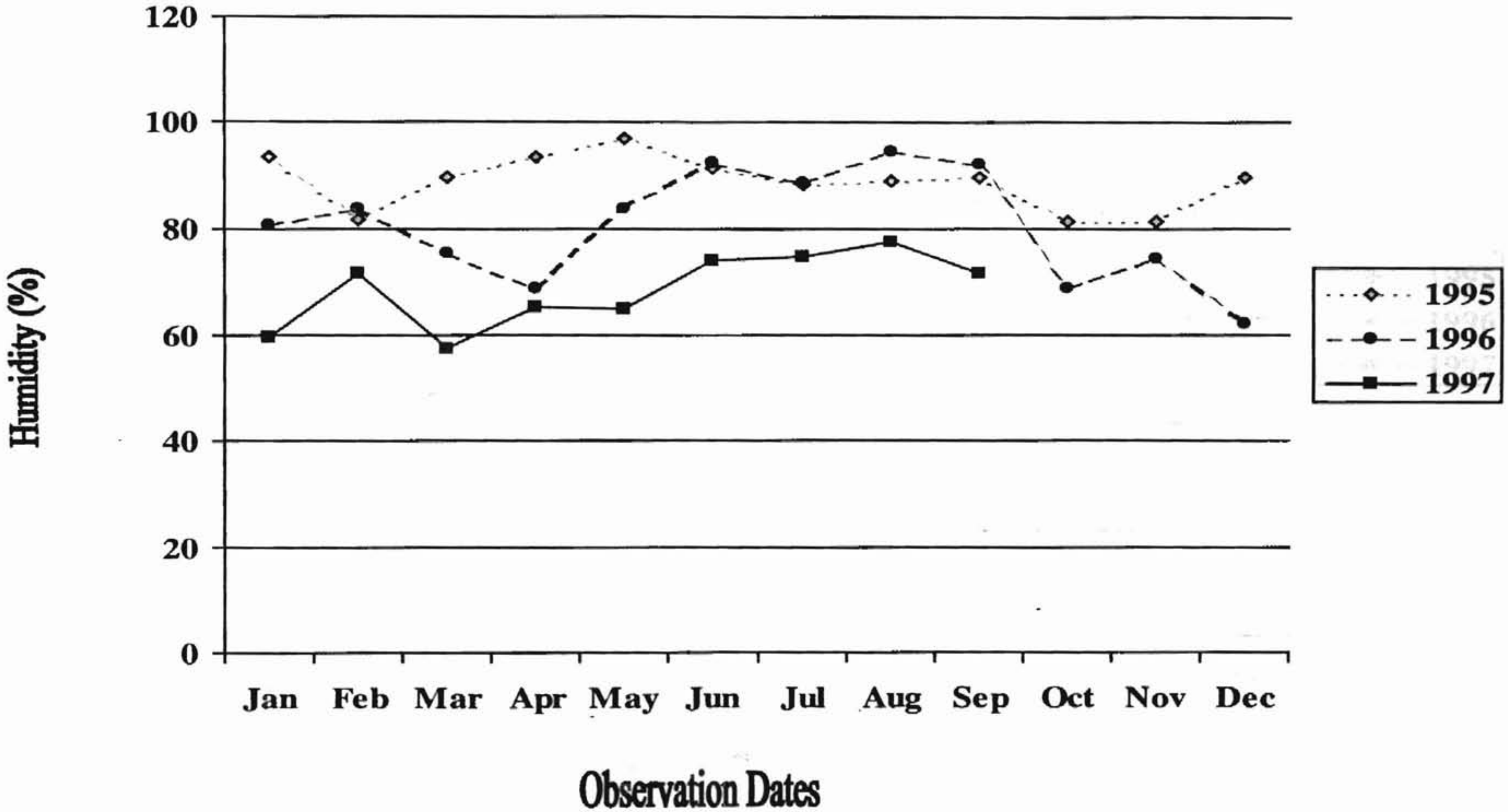

Figure 8. Mean Monthly Relative Humidity Taken from the Oklahoma State Automated Weather Station Network System (Mesonet) Marena Station, Payne County, Oklahoma, January 1995 to September 1997.

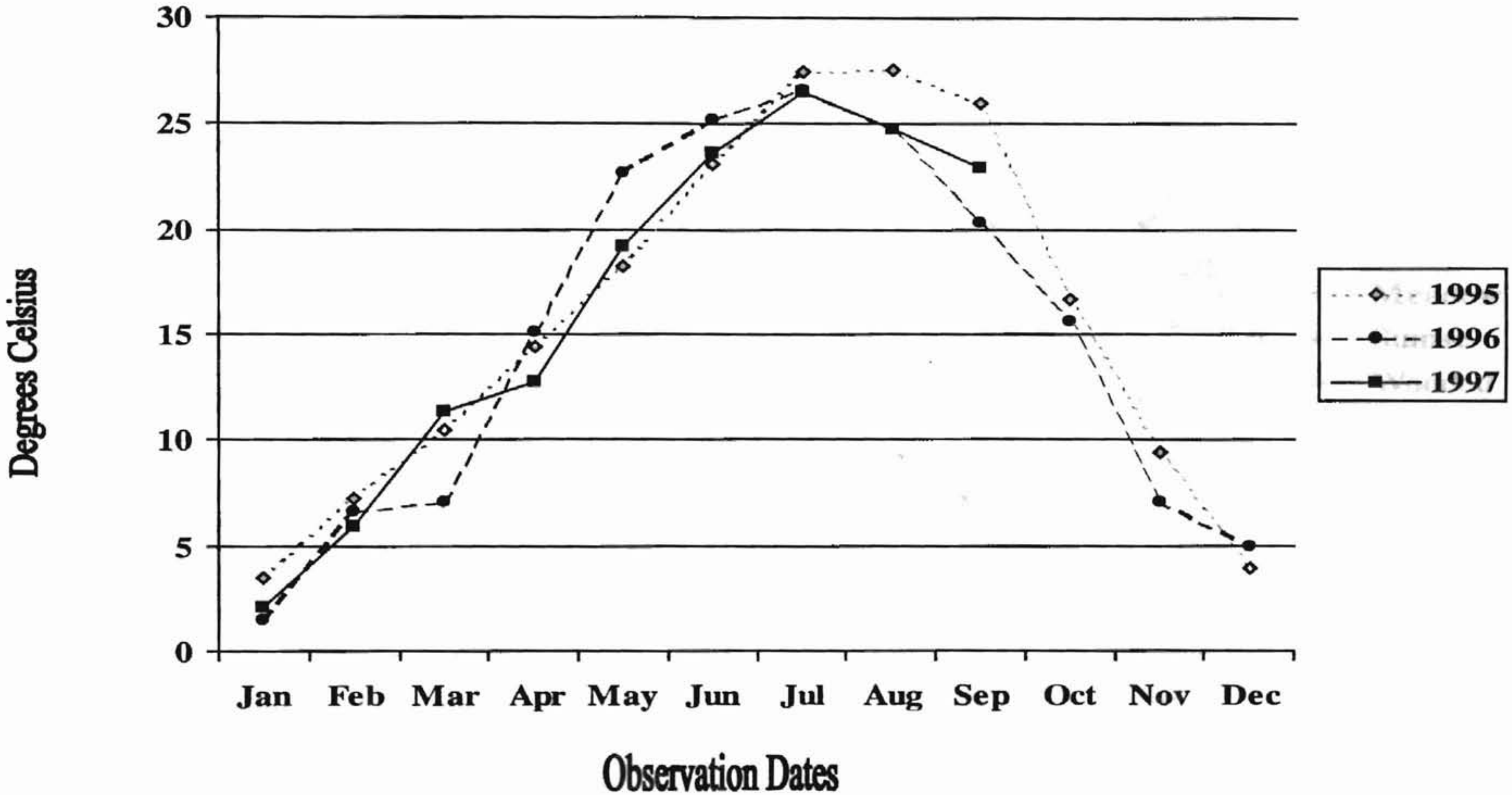

Figure 9. Mean Monthly Air Temperatures Taken from the Oklahoma State Automated Weather Station Network System (Mesonet) Marena Station, Payne County, Oklahoma, January 1995 to September 1997.

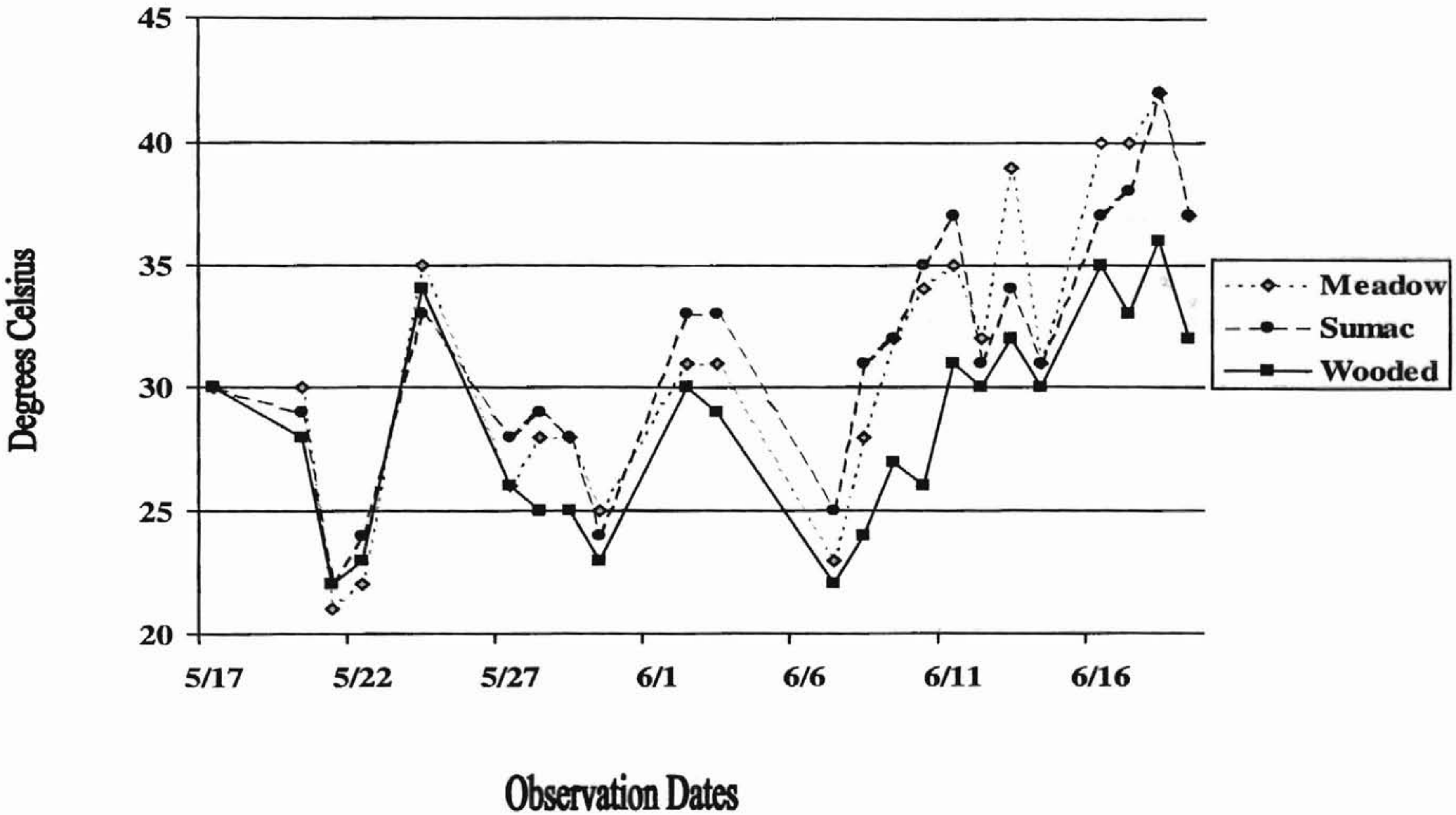

Figure 10. Mean Air Temperature Taken from a Random Sampling of Three of Nine Arenas Located at Lake Carl Blackwell, North Range Pasture, Noble County, Oklahoma Using the Portable Tele-thermometer During 17 May to 19 June 1996.

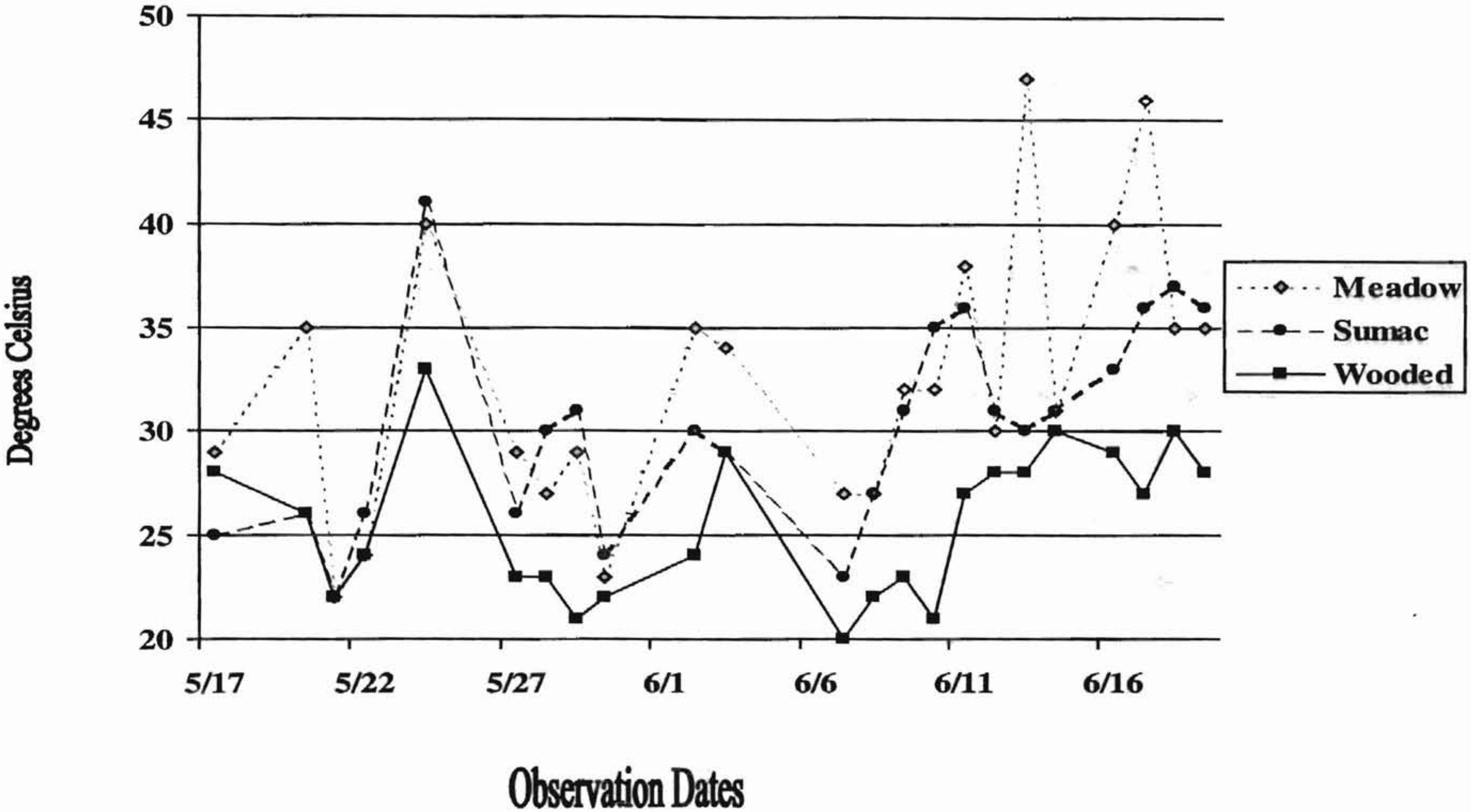

Figure 11. Mean Soil Temperature Taken from a Random Sampling of Three of Nine Arenas Located at Lake Carl Blackwell, North Range Pasture, Noble County, Oklahoma Using the Portable Tele-thermometer During 17 May to 19 June 1996.

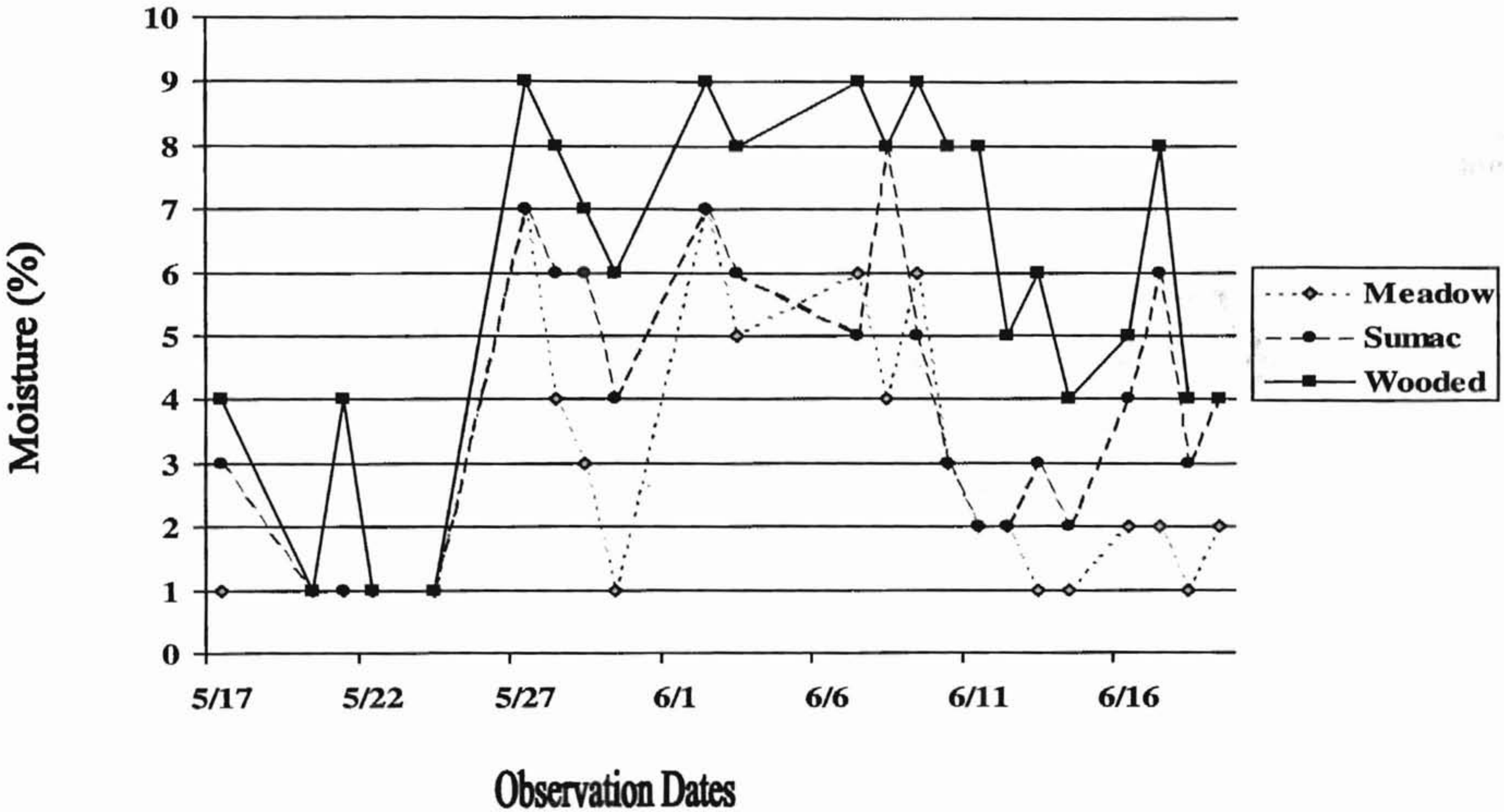

Figure 12. Mean Soil Moisture Taken from a Random Sampling of Three of Nine Arenas Located at Lake Carl Blackwell, North Range Pasture, Noble County, Oklahoma Using the Portable Soil Moisture Meter During 17 May to 19 June 1996.

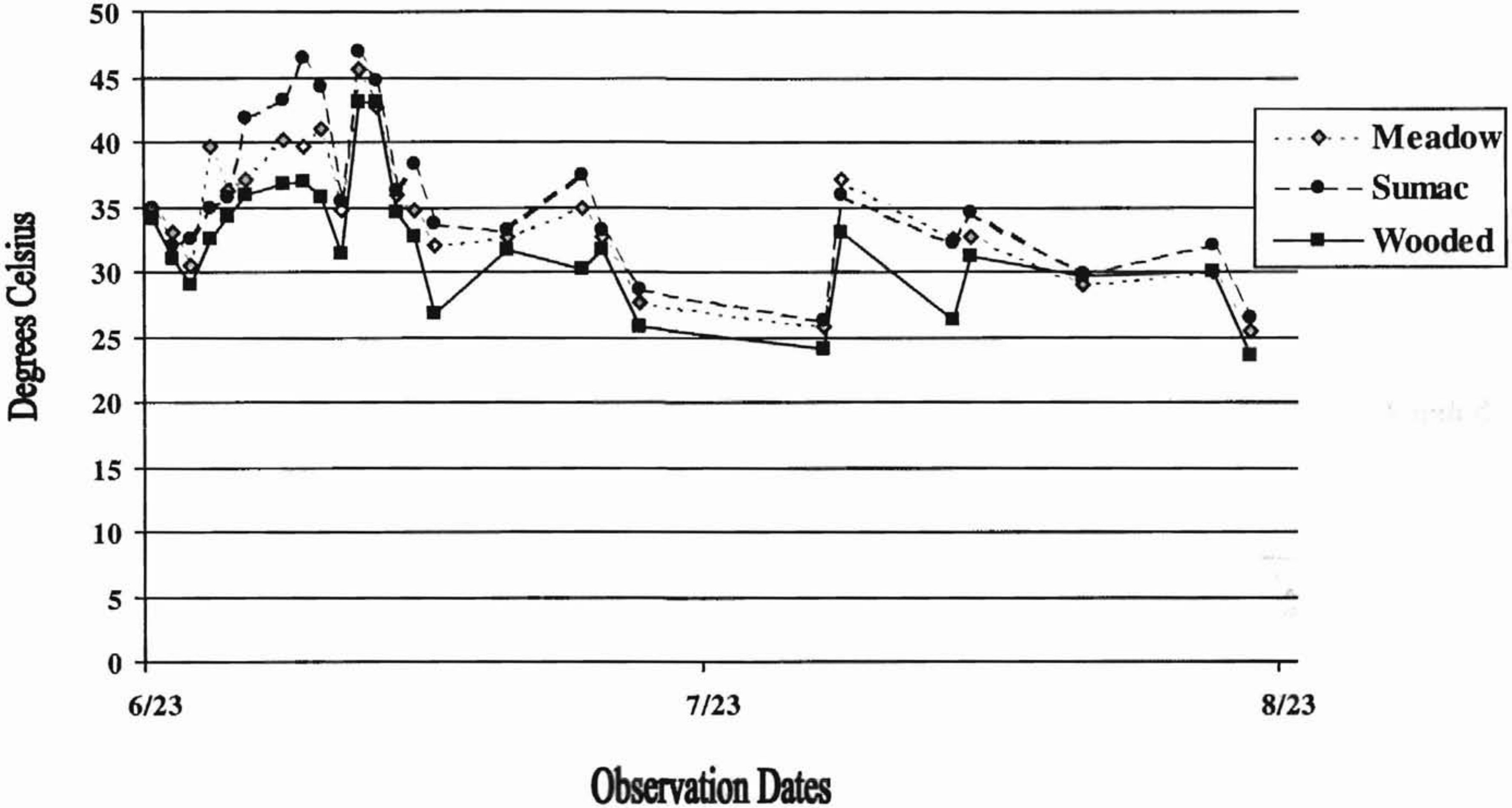

Figure 13. Mean Air Temperatures in 1996, Taken on 24 Dates During Peak Times From 23 June to 21 August at Pasture 15, Payne County, Oklahoma. Recorded From Three Arenas/Habitat Using the Portable Tele-thermometer.

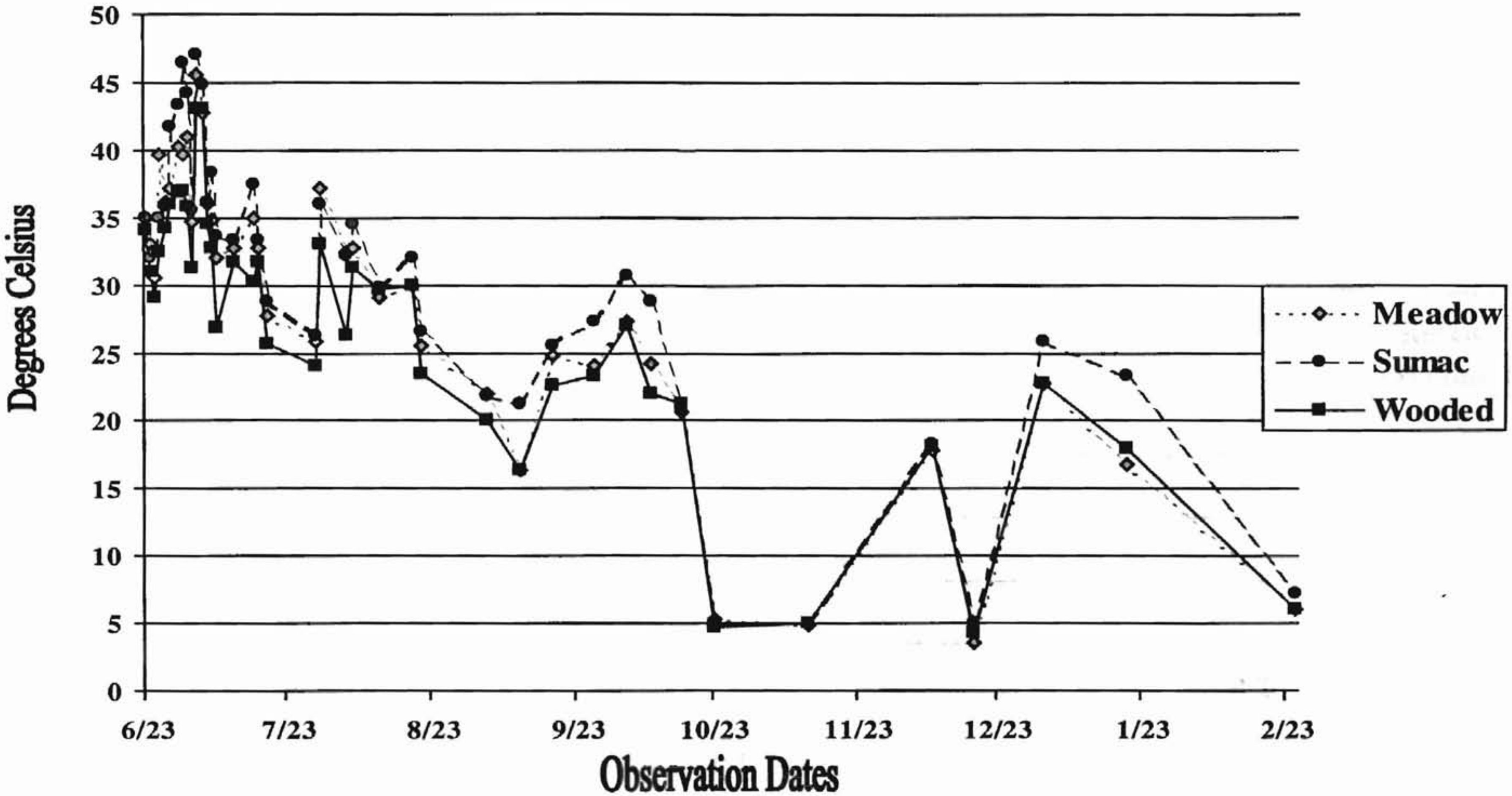

Figure 14. Mean Air Temperature Taken on 38 Dates From Three Arenas/Habitat Located at Pasture 15, Payne County, Oklahoma, Using the Portable Tele-thermometer during 23 June 1996 to 25 February 1997.

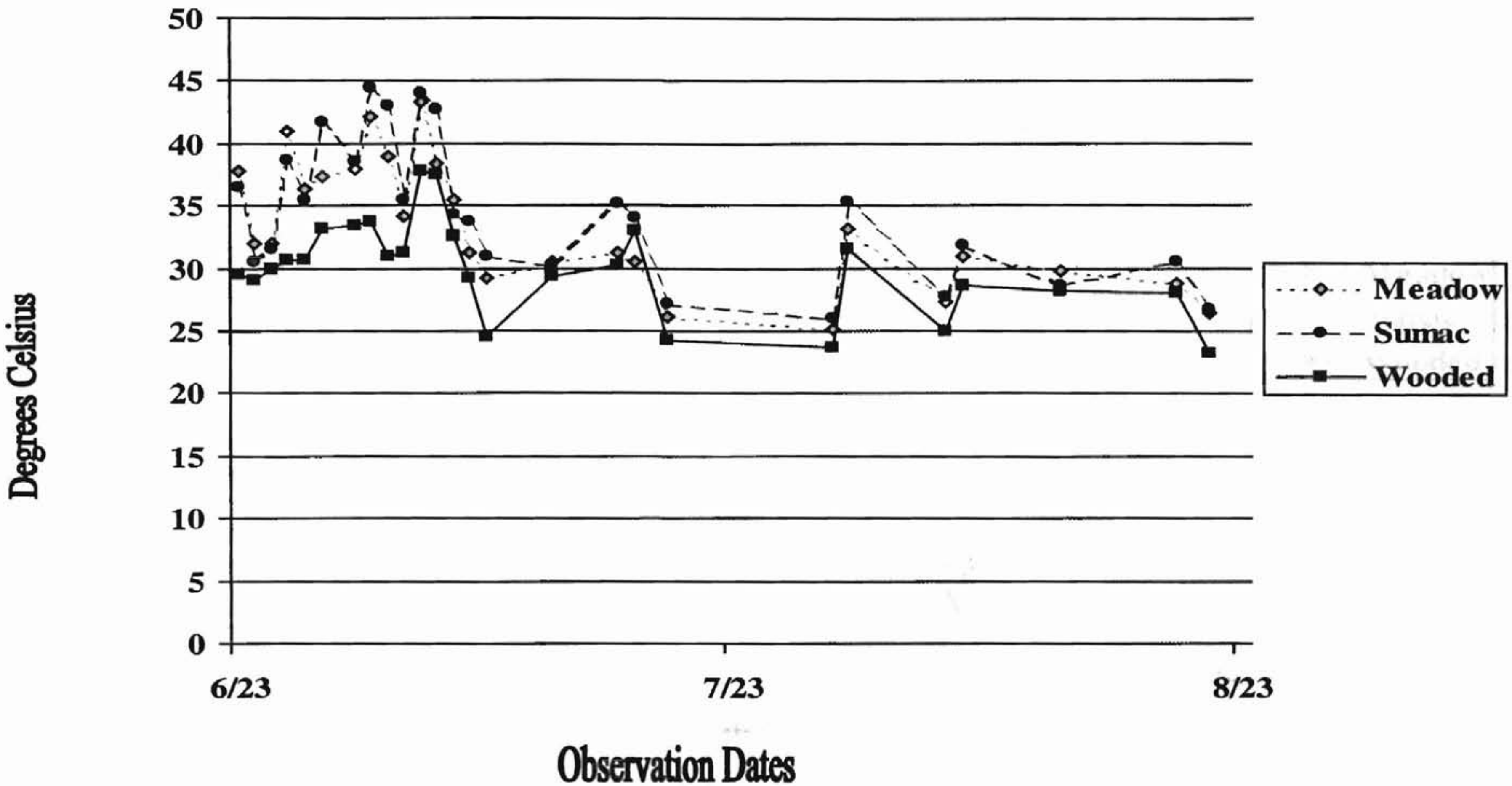

Figure 15. Mean Soil Temperatures in 1996, Taken on 24 Dates During Peak Times From 23 June to 21 August at Pasture 15, Payne County, Oklahoma. Recorded From Three Arenas/Habitat Using the Portable Tele-thermometer.

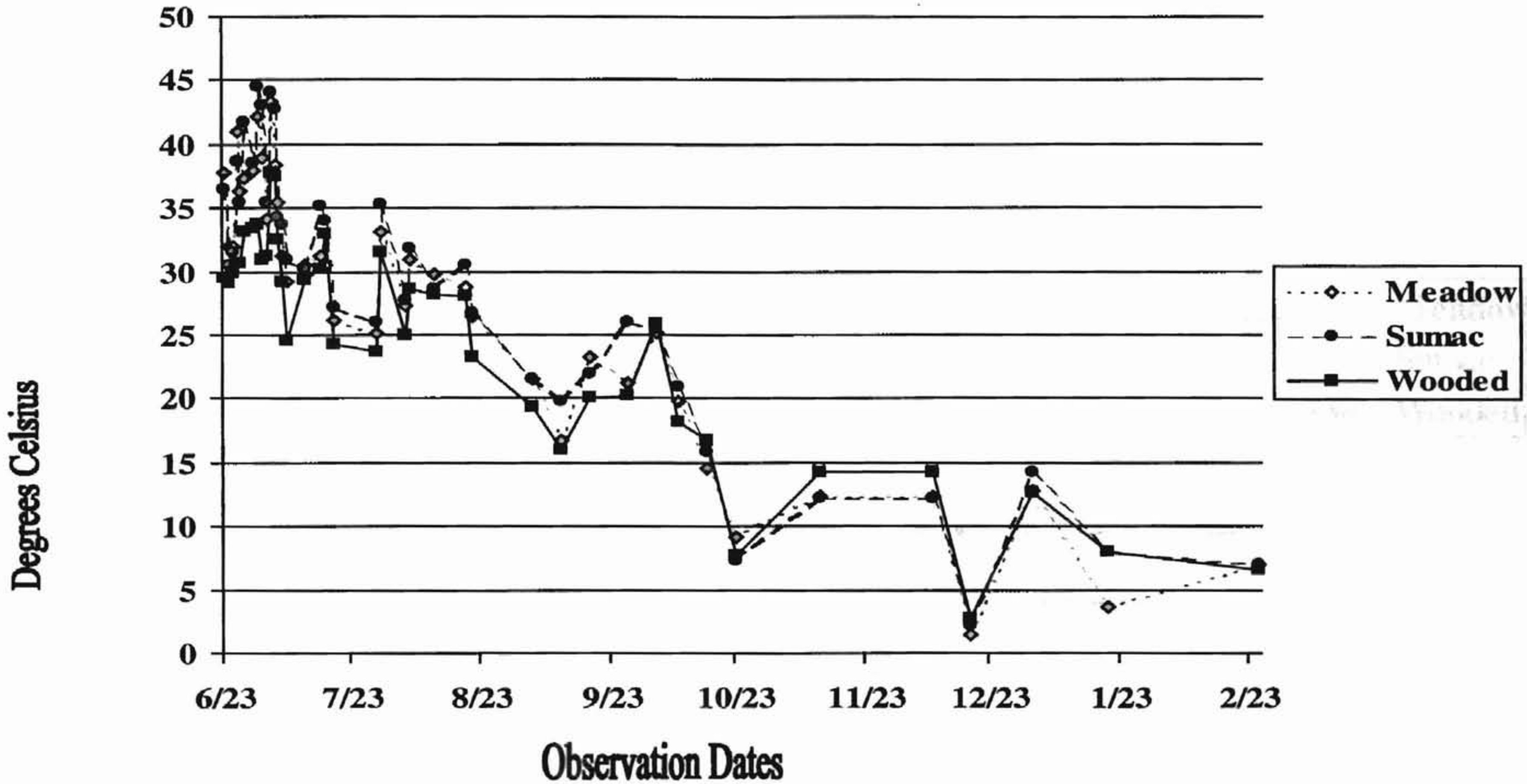

Figure 16. Mean Soil Temperature Taken on 38 Dates From Three Arenas/Habitat Located at Pasture 15, Payne County, Oklahoma, Using the Portable Tele-thermometer during 23 June 1996 to 25 February 1997.

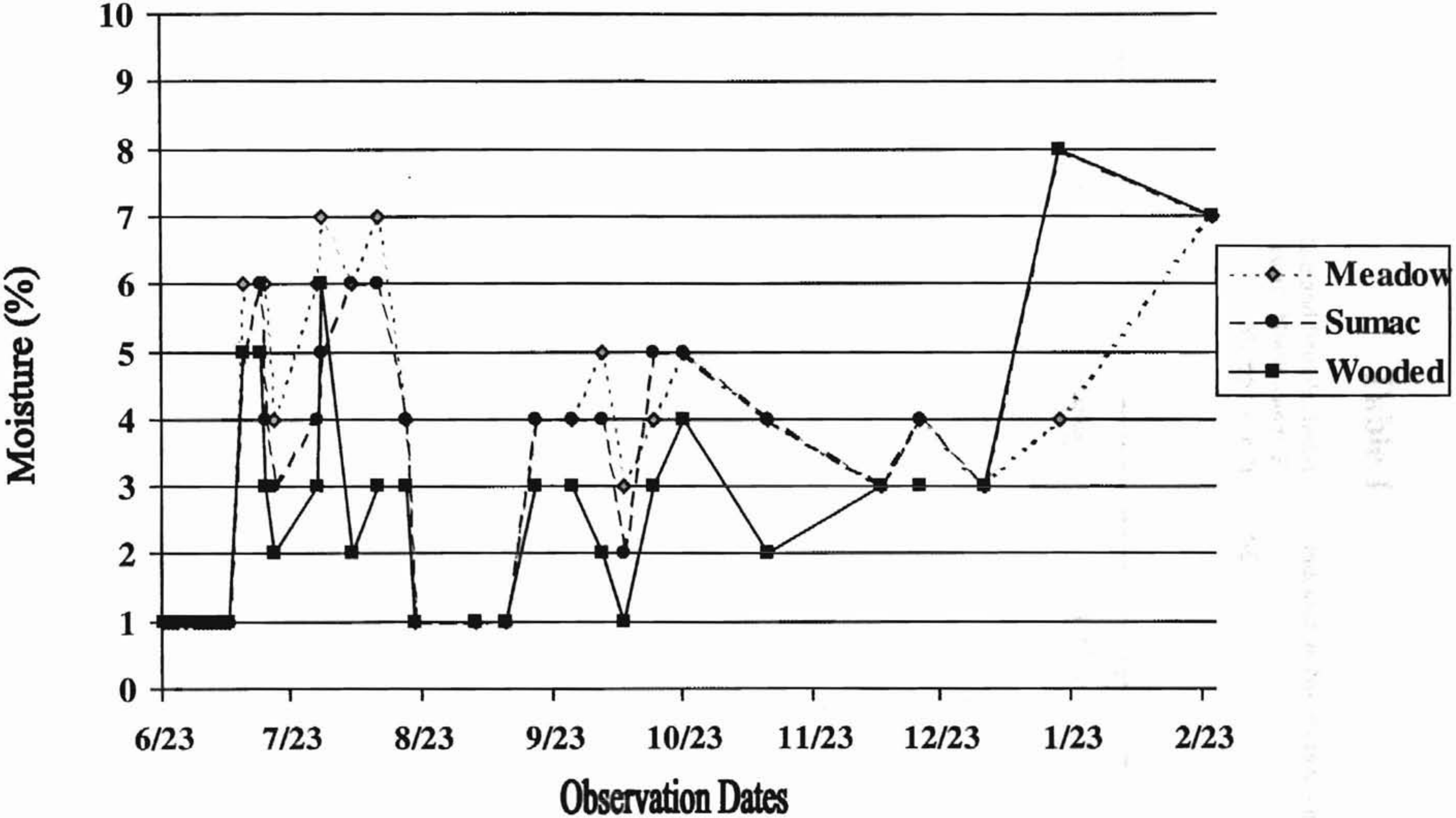

Figure 17. Mean Soil Moisture Taken on 38 Dates From Three Arenas/Habitat Located at Pasture 15, Payne County, Oklahoma, Using the Portable Soil Moisture Meter, 23 June 1996 to 25 February 1997.

Table 1

Differences in Adult Male and Female *Amblyomma maculatum* Numbers Counted on Cattle at Lake Carl Blackwell, North Range Pasture, Noble County, Oklahoma from 13 March to 26 June 1996.

Dates	COWS		CALVES	
Recorded	No. of Males	No. of Females	No. of Males	No. of Females
3/13	7	2	N/A	N/A
3/20	11	1	N/A	N/A
3/27	20	5	N/A	N/A
4/3	57	18	N/A	N/A
4/10	104	74	N/A	N/A
4/17	140	50	N/A	N/A
4/24	243	132	128	107
5/1	216	148	124	154
5/8	308	142	100	103
5/15	229	54	63	38
5/22	184	32	53	21
5/29	127	17	63	19
6/6	124	40	40	32
6/12	123	32	46	35
6/19	71	36	47	29
6/26	66	24	28	20
Mean*	126.9a	50.4b	70.2a	53b
	p=0.0001		**p=0.0136**	

***Lower case letter pertain to column means; column means proceeded by the same letter are not significantly different.**

Table 2

Differences in Adult Male and Female *Amblyomma maculatum* Numbers Counted on Cattle at Lake Carl Blackwell, North Range Pasture, Noble County, Oklahoma from 19 March to 5 June 1996.

Dates	COWS		CALVES	
Recorded	No. of Males	No. of Females	No. of Males	No. of Females
3/19	4	1	N/A	N/A
3/26	5	1	8	1
4/2	42	17	8	5
4/9	46	30	11	7
4/16	41	14	1	5
4/23	46	17	12	2
4/30	50	20	15	2
5/7	88	26	26	8
5/14	87	48	34	12
5/21	66	32	38	9
5/29	34	0	19	0
6/5	19	1	N/A	N/A
Mean*	44a	7.25b	20.22a	5.67b
	p=0.0001		**p=0.0042**	

***Lower case letter pertain to column means; column means proceeded by the same letter are not significantly different.**

Table 3

Weight Classes of Partially Engorged Female *Amblyomma maculatum* Collected From Cattle at Lake Carl Blackwell, North Range Pasture, Noble County, Oklahoma from 11 April to 8 June 1996.

Dates Collected	Ticks collected in weight class < 90mg	Ticks collected in weight class 90 -250 mg	Ticks collected in weight class > 250 mg
4//11	1	2	4
4/17	9	11	13
4/18	15	11	12
4/24	13	13	11
5/8	8	15 (1⊕)	6
5/9	12	16	4
5/15	2 (1⊕)	4 (2⊕)	4 (2⊕)
5/16	4 (1⊕)	6	1
5/18*	1	1	1
5/22*	3	4	0
5/29*	2	2	1
5/30*	0	0	2
6/2*	0	0	1
6/8*	0	0	2
Total Collected^	70a	85a	61a

^Values for the total ticks with the same letter are not significantly different. P=.3347
***Reserve colony**
⊕ Denotes number of dead females recorded

Table 4

Number and Percentage of Survival of Partially Engorged Female *Amblyomma maculatum* Released in three Habitats Located at lake Carl Blackwell, Noble County, Oklahoma 1996.

Semi-Engorged Females Collected	Meadow	Sumac	Wooded
Number of Partially Engorged Females Released	39	38	38
Number of Partially Engorged Females Observed	0	0	3
Percentage of Survival	Unknown*	Unknown*	Unknown*

*Unknown - Living larvae were found however, no accurate number of semi-engorged females ovipositing could be counted.

Table 5

Molting Times and Percentage of Survival *Amblyomma maculatum* Nymphs Placed in Three Different Habitats Located at Pasture 15, Payne County, Oklahoma 1996.

Release Date	**Meadow** Molting Time*	% Survival	**Sumac** Molting Time*	% Survival	**Wooded** Molting Time*	% Survival
7/23	20	100	22	100	22	100
8/6	28	100	31	100	33	100
9/13	33	100	33	67	43	100
10/28	No molt	0	No molt	0	190	100

* Denotes number of Days

VITA

Darryl Andre Forest

Candidate for the Degree of

MASTER OF SCIENCE

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