METEOROLOGICAL FACTORS REGULATING THE POPULATION EXPANSION AND CONTRACTION OF *AMBLYOMMA MACULATUM* (ACARI: IXODIDAE) IN TEXAS

A Thesis

by

JORDAN MCQUADE COBURN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2009

Major Subject: Entomology

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Approved by:

Chair of Committee,	Pete D. Teel
Committee Members,	Jeffery K. Tomberlin
	Michael T. Longnecker
	John W. Nielsen-Gammon
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ABSTRACT

Meteorological Factors Regulating the Population Expansion and Contraction of *Amblyomma maculatum* (Acari: Ixodidae) in Texas. (August 2009)

Jordan McQuade Coburn, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Pete D. Teel

The interaction of tick species and the microclimate that they inhabit is a subject that is frequently studied. The known biology of the Gulf Coast tick, *Amblyomma maculatum* Koch (Acari: Ixodidae), was used to conduct analyses to determine which meteorological factors regulate Gulf Coast tick survivorship in an area of Texas that is known for reduced occurrence of this tick species.

Gulf Coast tick collection records, that indicated the collection of a single tick or multiple ticks from one animal or multiple animals at livestock markets, were obtained from the Texas Animal Health Commission. These records were used as an indicator of adult Gulf Coast tick abundance during each year in the 90 county study area and were used as the dependent variable in linear, quadratic, and cubic regression analyses. Independent variables used in these analyses were precipitation and differing drought thresholds during the peak activity time of the four life stages of the Gulf Coast tick and during combined life stage peak activity times.

Linear, quadratic, and cubic regression analyses to measure the effect of precipitation during differing peak activity times of the Gulf Coast tick on adult Gulf

Coast tick collection records were not statistically significant. These three regression analyses were also used to measure the effect of increasing drought thresholds, measured using a Keetch-Byram Drought Index, on adult Gulf Coast tick collection records. A determination was made that increasing drought thresholds during the peak activity time of differing Gulf Coast tick life stages reduce the number of Gulf Coast tick collection records the following year.

DEDICATION

I dedicate this thesis to my parents.

ACKNOWLEDGMENTS

I am highly appreciative of the support and guidance of my committee chair, Dr. Pete Teel, who has been a mentor for many years, and the other members of my committee: Dr. Jeffery Tomberlin, Dr. Michael Longnecker, and Dr. John Nielsen-Gammon. I also thank Otto Strey for assisting me with various phases of this project.

The hard work and dedication of the Texas Animal Health Commission is most appreciated. I thank the directors Dr. Dee Ellis, Dr. Dale Preston and other administrators for meeting with me on several occasions as my project was developing. I am also very grateful for the diligence of all Texas Animal Health Commission tick inspectors in all that they do on and off livestock sale markets. I also thank the Texas Animal Health Commission staff members Juanita Esparza, Cynthia King, and Sue Vittek for providing me with tick collection records and records on cattle that are tested for brucellosis.

Much time and effort of processing drought index data was saved by Elvis Takow, who wrote a computer script to quickly transfer drought data to an Excel spreadsheet. I also thank Dr. Maria Tchakerian for assisting me in producing graphical representations of livestock markets. I thank Dr. Jay Angerer from the Spatial Sciences Laboratory of Texas A&M University for providing information on obtaining precipitation data. The assistance of Taesoo Lee, also from the Spatial Sciences Laboratory, in providing me with Keetch-Byram Drought Index data is greatly appreciated. Lastly, I thank my parents, Janice and Edward Zavodny, and the rest of my family for their love and support during my time at Texas A&M University.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Gulf Coast tick, *Amblyomma maculatum* Koch (Acari: Ixodidae), is of concern to medical and veterinary fields. This blood-feeding ectoparasite has a wide host range that includes ground-dwelling birds and rodents for immature ticks (Clark 1998, Teel et al. 1998, Barker et al. 2004) and livestock (cattle, sheep, and goats), horses, dogs, and humans for adult ticks (Bishopp and Trembley 1945, Durden et al. 1991, Kocan et al. 1999, Barker et al. 2004). The aggregation of Gulf Coast ticks on cattle can result in irritation and ear damage (Bishopp and Hixson 1936). These conditions can cause weight loss and poor body condition (Williams et al. 1977, Williams et al. 1978), which will result in a reduction in cattle sale price.

The Gulf Coast tick is recognized as an important vector of several pathogens. The Gulf Coast tick is a recognized vector of *Rickettsia parkeri*, a causative agent of spotted fever in humans (Lackman et al. 1949, Paddock et al. 2004, Sumner et al. 2007). The Gulf Coast tick is also recognized as the vector of *Hepatozoon americanum* causative agent of American canine hepatozoonosis in canines (Ewing et al. 2002). Furthermore, the Gulf Coast tick has been experimentally demonstrated to be a putative and efficient vector of *Ehrlichia ruminantium* (Uilenberg 1982, Mahan et al. 2000), an African tick-borne pathogen that is the causative agent of heartwater, a disease that is highly fatal to ruminants.

This thesis follows the style of the Journal of Medical Entomology.

The presence of *E. ruminantium* in the Caribbean and spread of an African tick, *Amblyomma variegatum*, increases the risk of the introduction of this pathogen to the United States mainland.

Gulf Coast tick distribution has been historically described to be areas within approximately 160 km of the Gulf Coast and areas of a few states along the Atlantic Coast (Bishopp and Trembley 1945). However, its distribution and/or abundance inland appear to fluctuate between wet and dry years. A single, inland permanent population of Gulf Coast ticks can be found in Kansas (Brillhart et al.1994) and Oklahoma (Barker et al. 2004).

The one-year life cycle of the Gulf Coast tick consists of egg, larval, nymphal, and adult stages with a seasonal period of presence or activity throughout much of the year (Fleetwood 1985). Adult Gulf Coast ticks are mostly found from May through August in inland areas of Texas (Figure 1). After acquiring a bloodmeal, engorged adult female Gulf Coast ticks detach from the host and waterproof their eggs twice, during oviposition in the leaf litter, using the Gené's organ. Most eggs then hatch during September and October following their incubation period. Larvae and nymphs are mostly present from November through February in the Gulf Coast region of Texas (Teel et al. 1988, Teel et al. 1998). Nymphs can also be collected through April in the Gulf Coast region of Texas. Adults are then able to extend their life cycle to two years for reproduction if necessary.

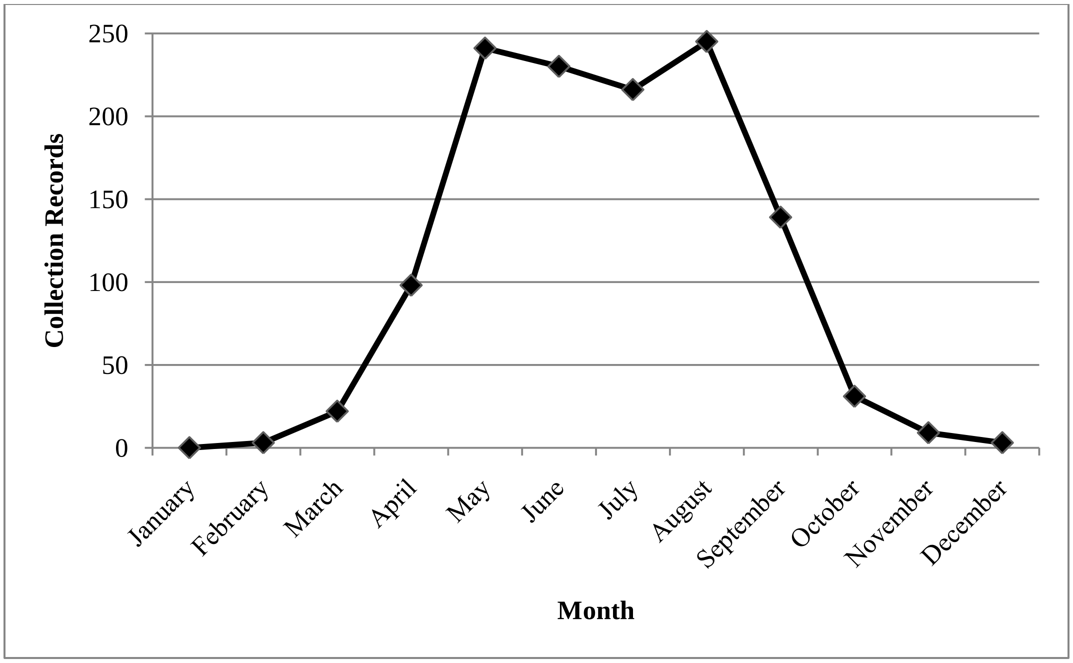

Figure 1. Summary of Gulf Coast tick collection record occurrences in the study area from 1992 through 2006.

Desiccation is a constant threat to the survival of ixodid (Acari: Ixodidae) ticks due to passive water loss through the cuticle. Ticks are most at risk to desiccation during periods between feeding due to exposure to varying meteorological factors such as temperature and relative humidity. These periods are known as an off-host phase, which constitutes greater than 90% of the life cycle of an ixodid tick (Needham and Teel 1991). Among ixodid ticks, the larval stage is at the highest risk to desiccation due to its high surface area-to-volume ratio (Edney 1977). This ratio in larval ixodid ticks provides for an increased amount of water loss through the cuticle. Desiccation begins to occur once the critical equilibrium activity (CEA) level is reached. The CEA is defined as the point at which the rate of water intake equals the rate of body water loss through the cuticle (O'Donnell and Machin 1988). The CEA level of the Gulf Coast tick is estimated to be between 86 – 93% RH (Needham and Teel 1991). Once the RH drops below the CEA level, ixodid ticks can attempt to retrieve some body water that is lost through their cuticle by utilizing active water vapor sorption. This process consists of a tick producing a salt-rich solution from their salivary glands onto their mouthparts. This solution then draws in moisture from the surrounding air, which is then imbibed by the tick for rehydration (Kahl and Knülle 1988).

Meteorological factors such as RH, dewpoint, precipitation, air temperature and drought conditions are possible factors that can be analyzed for their effect on Gulf Coast tick survivorship in all life stages. For example, decreased soil moisture would reduce vegetation cover, resulting in decreased RH and browsing for potential hosts. In contrast, increased soil moisture would increase the RH and availability of vegetation for browsing, resulting in increased stocking rates of livestock and the availability of hosts for all parasitic life stages. Therefore, my null hypothesis is that variation of certain meteorological factors is independent from the population expansion and contraction of Gulf Coast ticks in Texas. I will seek to test this hypothesis by completing two objectives: 1.) Define the spatial and temporal characteristics of Gulf Coast tick population change in Texas, and 2.) Determine whether meteorological factors can be associated with the population expansion and contraction of the Gulf Coast tick in Texas.

MATERIALS AND METHODS

Tick-collection records utilized in this study were obtained from the Texas Animal Health Commission (TAHC), Austin, TX. After reviewing collection records for the time period of 1992 through 2008, it was determined that Gulf Coast tick populations are established in 90 counties in northeast Texas, an area extending north of this species' traditional 160 km Gulf Coast distribution (Figure 2) (Table 1). The time period of 1992 through 2008 was selected due to a statewide sustained increase in tick surveillance activity by TAHC inspectors. This 90 county area is characterized as having increasing precipitation from the western to the eastern edge and containing soil texture types of silt, clay, and sand. Thus, collection records from this area and time period were used to define Gulf Coast tick population changes in a diverse and less optimal ecological area of Texas for Gulf Coast tick survivorship.

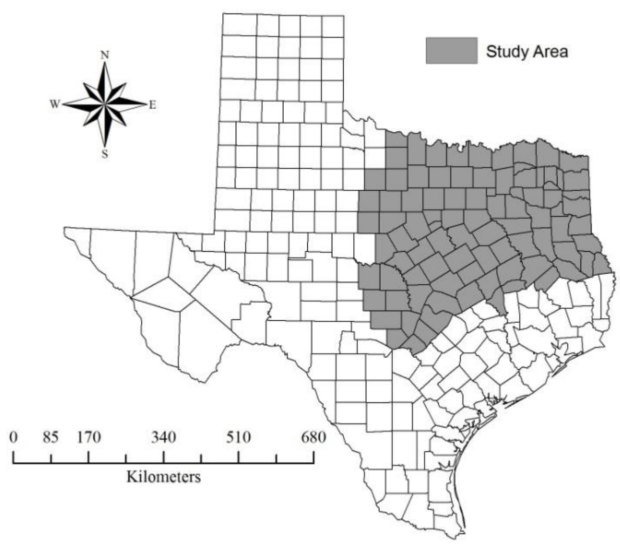

Figure 2. Geographic representation of the 90 county study area representing the inland population range of the Gulf Coast tick in Texas.

Table 1. Texas counties included in the study area of the Gulf Coast tick inland distribution

County				
Anderson	Cooke	Henderson	McCulloch	San Saba
Angelina	Coryell	Hill	McLennan	Shackelford
Archer	Dallas	Hood	Milam	Shelby
Bell	Delta	Hopkins	Mills	Smith
Blanco	Denton	Houston	Montague	Somervell
Bosque	Eastland	Hunt	Morris	Stephens
Bowie	Ellis	Jack	Nacogdoches	Tarrant
Brazos	Erath	Johnson	Navarro	Throckmorton
Brown	Falls	Kaufman	Palo Pinto	Titus
Burnet	Fannin	Kendall	Panola	Travis
Callahan	Franklin	Lamar	Parker	Trinity
Camp	Freestone	Lampasas	Rains	Upshur
Cass	Gillespie	Leon	Red River	Van Zandt
Cherokee	Grayson	Limestone	Robertson	Wichita
Clay	Gregg	Llano	Rockwall	Williamson
Collin	Hamilton	Madison	Rusk	Wise
Comal	Harrison	Marion	Sabine	Wood
Comanche	Hays	Mason	San Augustine	Young

Methods used to analyze the effect of the number of cattle tested for brucellosis on the number of Gulf Coast tick collection records. TAHC supervisors provided guidance on standards used by tick inspectors for animal inspection and tick-collecting methods, and for selection of livestock markets with dependable and sustained inspection reliability within the study area. Only livestock markets that primarily sell cattle and only those markets having surveillance efforts that were historically reliable were used. Ticks were collected from cattle by TAHC inspectors in the study area as they were testing female cattle that exceeded 18 months of age for brucellosis. At this point, ticks were collected, mainly from the head and rear areas, assigned a collection record number, and later identified to species. Ticks were also collected from other livestock species as time permitted and recorded in the same manner. TAHC surveillance defined a “collection record” as the collection of an adult tick or multiple adult ticks from an individual animal or from a group of animals (defined as a pen or herd). As the general tick population increased, the number of "collection records" should have hypothetically increased due to generally more favorable environmental conditions for tick survivorship. The effect of the number of cattle sold at these markets from 1997 through 2008 on the amount of Gulf Coast tick collection records was evaluated using linear, quadratic, and cubic regression analyses (SPSS, Inc. 2006). These analyses were used to determine if periods of drought, which may increase the number of cattle sold and tested for brucellosis, resulted in a biased increase in tick collection records. The model for these analyses was: Gulf Coast tick collection records from 1997 through 2008 (y) = cattle tested for brucellosis from 1997 through 2008 (x).

Methods used to analyze the effect of precipitation on the number of Gulf Coast tick collection records. Precipitation data were obtained for the time period of 1993 through 2008 from a website of the Center for Natural Resource Information Technology (CNRIT) of Texas A&M University, College Station, TX (CNRIT 2008). This website has a data system that allows the user to input longitude and latitude coordinates and receive precipitation data, with an option to interpolate missing data, for user-defined time periods at a grid resolution of 0.25 degrees latitude by 0.25 degrees longitude. The original data source for the CNRIT gridded precipitation analyses appears to be the National Oceanic and Atmospheric Administration Climate Prediction Center's daily retrospective and real-time precipitation analyses (Higgins et al. 2000, Climate Prediction Center 2009). These analyses are produced from rain gauge measurements from a variety of sources, including approximately 100 gauges within the study area. One point was selected, to avoid duplicated precipitation data, from the geometric center of each county in the study area, to obtain a representation of precipitation data for each county. Precipitation data were organized into groups that coincide with the peak activity time (PAT) of each developmental stage (eggs, larvae, nymphs, and adults) of the Gulf Coast tick (Tables 2 and 3). A total precipitation value was then obtained, to create an independent variable for each test group by combining the sum precipitation for each county in the study area. This independent variable was then used, in linear, quadratic, and cubic regression analyses for each test group, to analyze the effect of precipitation on the number of Gulf Coast tick collection records. For example, one of the models for these analyses was: Gulf Coast tick collection records from 1993 through 2008 (y) = the sum of precipitation during the PAT of the egg stage from 1992 through 2007 (x). The one year difference was in place because the precipitation during the PAT of the egg stage affected the survivorship of eggs in 1992 and their ability to reach the adult stage in 1993. Reduced or increased numbers of larvae emerging from eggs would then favor a decrease or increase, respectively, in the number of Gulf Coast tick collection records that occurred in 1993.

Table 2. Summary of peak activity times of the Gulf Coast tick in the study area

Life Stage	Peak Activity Time
Egg	9/1 – 10/31
Larva	11/1 – 2/28(29)
Nymph	11/1 – 4/30
Adult	5/1 – 8/31
All Immatures	9/1 – 4/30
All Stages	9/1 – 8/31
Lagged Adults*	5/1 – 8/31
Lagged All Stages**	5/1 – 4/30

* Measurement of the effect of meteorological conditions during the PAT of the adult stage from the first year on the Gulf Coast tick collection records of the second year.

** Measurement of the effect of meteorological conditions during the PAT of all life stages from the first and second years on the Gulf Coast tick collection records of the second year.

Table 3. Description of independent variables used to analyze the relationship between precipitation data and Gulf Coast tick collection records

Independent Variable	Variable from Year(s)	Affecting
Sum –Egg	1	Year 2 Adults
Sum – Larva	1 & 2	Year 2 Adults
Sum – Nymph	1 & 2	Year 2 Adults
Sum – Adult	2	Year 1 Adults
Sum – All Immatures	1 & 2	Year 2 Adults
Sum – All Stages	1 & 2	Year 2 Adults
Sum – Lagged Adults	1	Year 2 Adults
Sum – Lagged All Stages	1 & 2	Year 2 Adults

Obtaining drought data. Ground based estimates of precipitation and land surface temperature were obtained using several Next Generation Weather Radars (NEXRAD) and an Advanced Very High Resolution Radiometer (AVHRR), respectively, at a resolution of 1 km^2. These estimates were then interpolated manually by the Texas Forest Service to generate a Keetch-Byram Drought Index (KBDI) to determine fire potential throughout Texas (Texas Weather Connection 2008). The Texas

Weather Connection of the Spatial Sciences Laboratory of Texas A&M University, College Station, TX then stored these data and published them to their website (Texas Weather Connection 2008). Daily, county-level KBDI summaries were obtained via the Spatial Sciences Laboratory's website for the time period of 1995 through 2008.

Calculating a KBDI. KBDI values indicate how many hundredths of an inch of soil are saturate. A scale of 0 to 800 is used where 0 represents no soil moisture deficit and 800 represents maximum soil moisture deficit. Cumulative rainfall in inches is first obtained for a 24-hour duration. Net rainfall is then calculated by subtracting 0.20 inches from the cumulative rainfall value if rainfall did not occur on the previous day. Net rainfall is calculated, as 0.20 inches of rainfall would be intercepted by the tree canopy and leaf litter, quickly evaporated, and would not reach the soil layer. Any value above 0 net rainfall is then subtracted from the KBDI value of the previous day. For example, 0.50 inches of net rainfall would change a KBDI value of 700 from the previous day to 650 (Keetch and Byram 1968). After net rainfall is used to alter the current day's KBDI value, the drought factor is calculated and added to the new KBDI value. The drought factor value is dependent on the mean annual rainfall of the area in question and the maximum land surface temperature of the day which both increase the drought factor, and the KBDI value of the previous day, or the KBDI value as reduced by net rainfall, which decreases the drought factor. Areas with high mean annual rainfall have vegetation with thicker, deeper taproots resulting in increased transpiration rates, reducing soil moisture content. Increased land surface temperatures, the air temperature as measured a few inches above the leaf litter, increase the rate of evapotranspiration.

As the total number of days since the last occurrence of rainfall increases, the upper soil layers become dry, hardened, and form an insulating layer, reducing the evaporation of soil moisture. For example, an area that has a mean annual rainfall value between 40 through 59 inches, with a KBDI value from the previous day between 50 through 99, and with a maximum land surface temperature of the day between 98 through 100 has a drought factor of 37 (Keetch and Byram 1968). Therefore, the net rainfall reduced KBDI value of 650 from the previous example would increase to 687 once the drought factor is added to the present day's KBDI value. Thus, a KBDI value of 687 indicates that the upper 6.87 inches of soil are without moisture, impacting the tick microclimate.

Methods used to analyze the effect of KBDI threshold conditions on the number of Gulf Coast tick collection records. Drought data were organized to enable the number of days to be counted in each county where a certain drought threshold occurred. The total number of days where a certain KBDI threshold was surpassed were counted for each county and then combined to form a sum for the number of days in the county where the KBDI threshold in question occurred (Table 4). This method was used instead of using the average KBDI value for the study area because KBDI values can change very rapidly from rainfall. This was especially evident on the eastern side of the study area which typically has very saturated soil from increased precipitation as opposed to the western side of the study area which has varying levels of soil saturation. For example, in 1995 during the PAT of the egg stage, there were a total of 5459 days in the study area where the KBDI value was above 50. This sum was then combined with all remaining years with KBDI data available to form an independent variable. This independent variable was then used in linear, quadratic, and cubic regression analyses to analyze the relationship between KBDI values above 50 and the number of Gulf Coast collection records (Table 5). An example of this model is: Gulf Coast tick collection records from 1996 through 2008 (y) = the total number of days in the study area where KBDI values were above 50 for the PAT of the egg stage from 1995 through 2007 (x). As previously mentioned, this lag was used as drought that occurred in 1995 would reduce the number of eggs that could reach the adult stage in 1996.

Table 4. Description of KBDI threshold conditions analyzed

Independent Variable	Description
50	Value above 50
100	Value above 100
150	Value above 150
200	Value above 200
250	Value above 250
300	Value above 300
350	Value above 350
400	Value above 400
450	Value above 450
500	Value above 500
550	Value above 550
600	Value above 600
650	Value above 650
700	Value above 700
750	Value above 750

Value above represents “Total number of days in each county when the KBDI value was above”.

Table 5. Description of independent variables used to analyze the relationship between differing drought thresholds and Gulf Coast tick collection records

Independent Variable	Variable from Year(s)	Affecting
Drought –Egg	1	Year 2 Adults
Drought – Larva	1 & 2	Year 2 Adults
Drought – Nymph	1 & 2	Year 2 Adults
Drought – Adult	2	Year 1 Adults
Drought – All Immatures	1 & 2	Year 2 Adults
Drought – All Stages	1 & 2	Year 2 Adults
Drought – Lagged Adults	1	Year 2 Adults
Drought – Lagged All Stages	1 & 2	Year 2 Adults

Some meteorological data that may have been potentially useful were not able to be analyzed with known techniques. Soil temperature data were attainable but would not represent conditions occurring in the study area as only three weather stations that record these data on a daily basis were present in the study area. Dewpoint data were collected from PRISM Group of Oregon State University, Corvallis, OR (Daly 1997). Interpreted maps from PRISM Group of monthly dewpoint conditions for the United States were available but could not be used in a statistical analysis. Raster-based data of these dewpoint conditions, that could be used in ArcMap were available from PRISM Group, however, an interpretation of these data was not able to be performed.

RESULTS

Methods used to evaluate all statistical analyses. The results of the cubic regression analyses were used as the main indicator of statistical significance. This was an exploratory study where a relatively high type 1 error was acceptable so that weak relationships could be observed. A p-value of 0.20 and below was accepted when determining if the null hypothesis that the independent and dependent variables in question were independent could be rejected. Acceptable R^2 values were 0.25 and above to indicate that least 25% of the variation of the dependent variable can be explained by the independent variable.

The effect of the number of cattle tested for brucellosis on Gulf Coast tick collection records. There were 32 livestock markets that were selected that satisfied the previously mentioned requirements (Figure 3). Less than 20% of the variation in the number of Gulf Coast tick collection records could be explained by the number of cattle tested for brucellosis (R^2 = 0.191) (Table 6) (Figure 4). Furthermore, the analysis failed to reject the null hypothesis that the number of Gulf Coast tick collection records are independent from the number of cattle tested for brucellosis (*P* = .386). To further examine this null hypothesis, analyses were conducted to examine the contribution of differing drought thresholds and cattle tested for brucellosis to the explanation of variation in the number of Gulf Coast tick collection records. All analyses that were conducted indicated that drought conditions explain the variation in the number of Gulf Coast tick collection records more than the number of cattle tested for brucellosis.

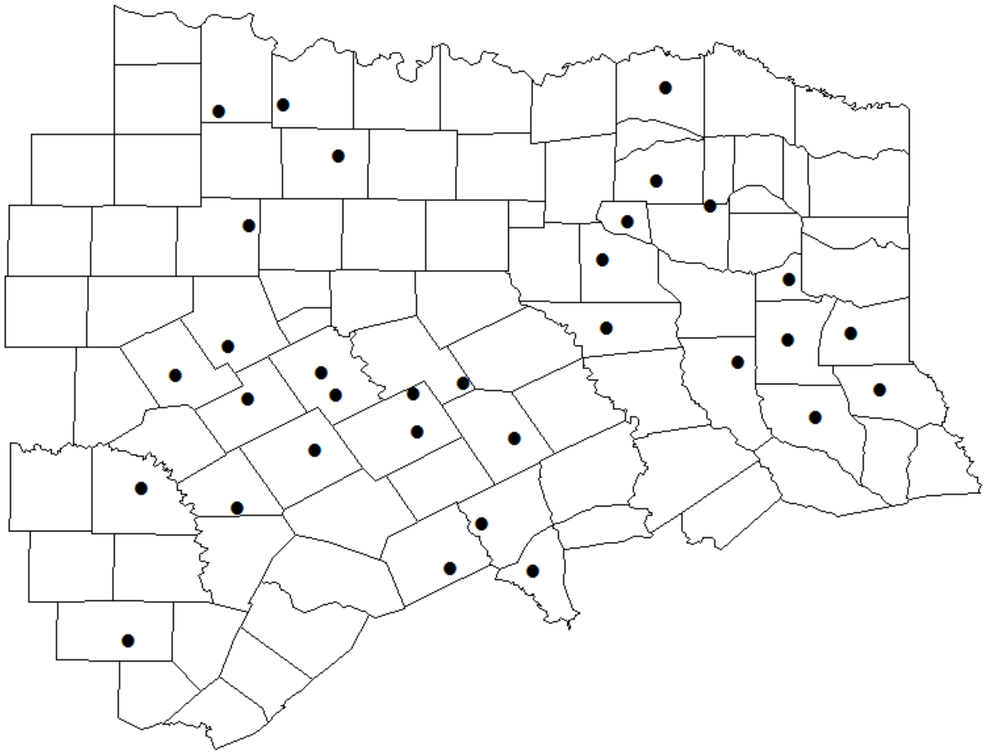

Figure 3. Geographic representation of the locations of the 32 livestock markets within the study area that primarily sell cattle and have historically reliable surveillance efforts.

Table 6. Comparison of regression model statistics testing the effect of the number of cattle tested for brucellosis on the number of Gulf Coast tick collection records

Regression Model	R^2	P
Linear	0.053	0.474
Quadratic	0.189	0.389
Cubic	0.191	0.386

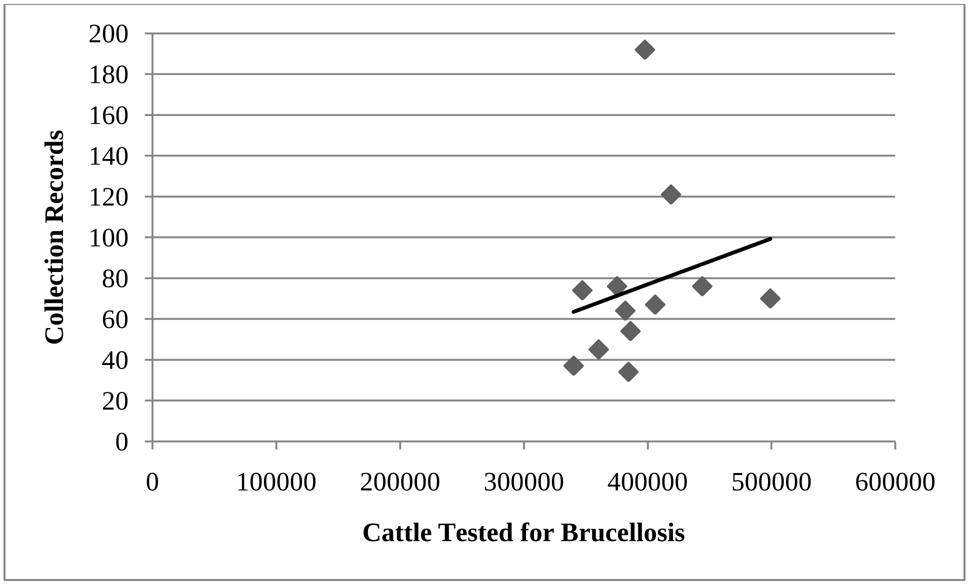

Figure 4. Graphical representation of the analyses used to measure the effect of the number of cattle tested for brucellosis on the number of Gulf Coast tick collection records.

The effect of precipitation on the number of Gulf Coast tick collection records. All analyses of the effect of precipitation on Gulf Coast tick collection records did not result in significant R^2 values or p-values. However, analyses of precipitation during the PAT of nymphs and all stages did graphically demonstrate an insignificant decrease in Gulf Coast tick collection records as precipitation increased (Figures 5 and 6).

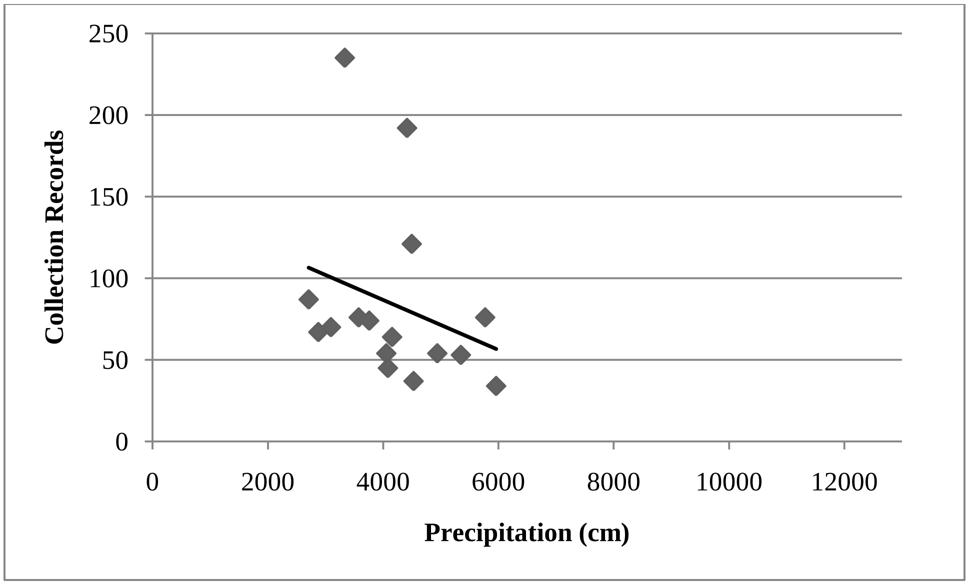

Figure 5. Analysis of the effect of precipitation during the peak activity time of the nymph stage on the number of Gulf Coast tick collection records.

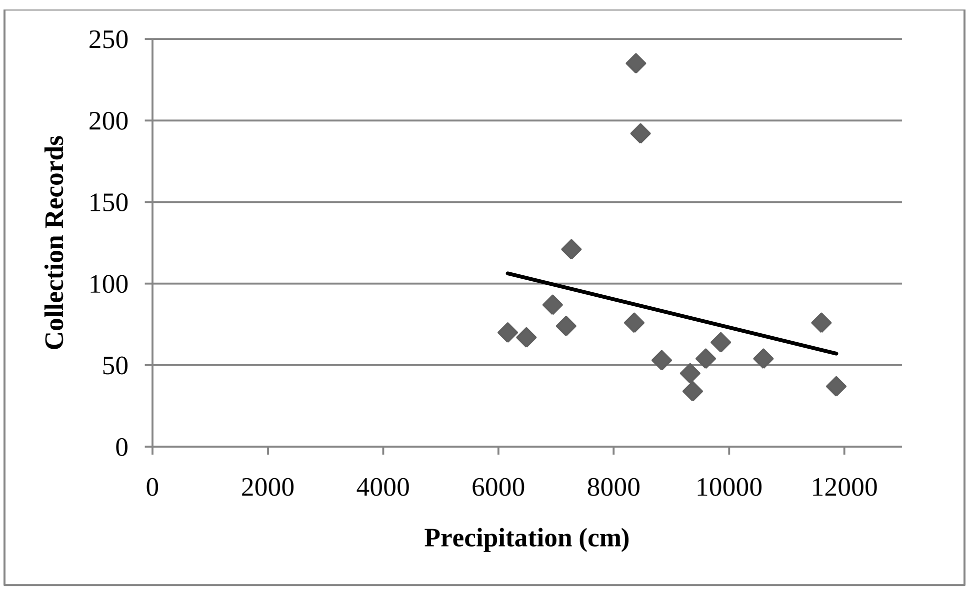

Figure 6. Analysis of the effect of precipitation during the peak activity time of all stages on the number of Gulf Coast tick collection records.

The effect of differing KBDI threshold conditions on the number of Gulf Coast tick collection records. In general, a relationship between differing drought thresholds and Gulf Coast tick survivorship was observed. A negative correlation was observed, that explained more than 40% of the variation of Gulf Coast tick collection records, beginning when KBDI values were above 150 for the PAT of lagged adults (R^2 = 0.413) (Figure 7). Another negative correlation was observed, that explained more than 50% of the variation of Gulf Coast tick collection records beginning when KBDI values were above 300 for the PAT of lagged all stages (R^2 = 0.526) (Figure 8). Additionally, the p-values were significant for these two analyses (P = 0.169 and P = 0.07 respectively). Therefore, these analyses rejected the null hypothesis that the number of Gulf Coast tick collection records is independent from KBDI thresholds. Lastly, a positive correlation was observed that explained more than 57% of the variation of collection records, beginning when the KBDI values were above 150 during the PAT of the adult stage (R^2 = 0.577) (Figure 9). The null hypothesis was also rejected in this analysis (P = 0.029).

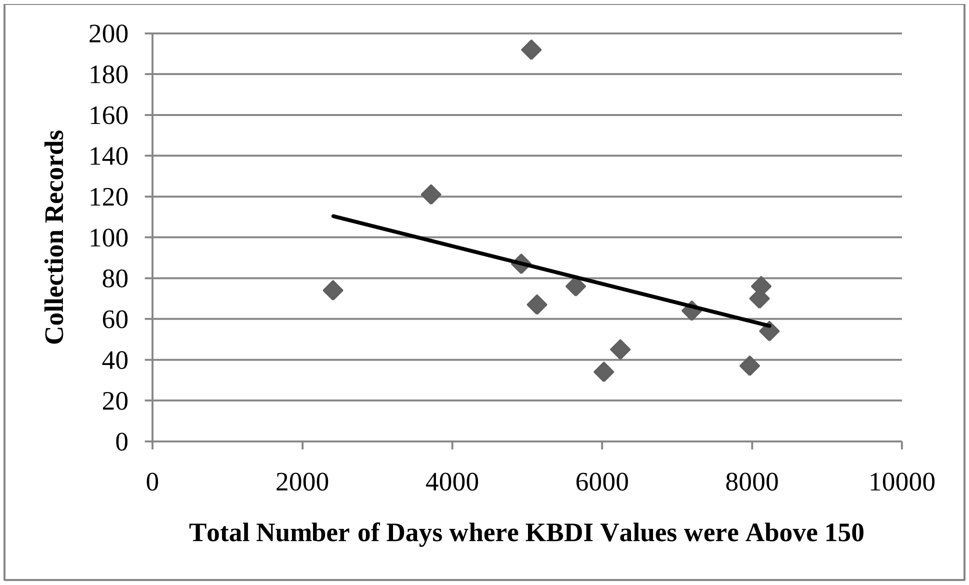

Figure 7. Analysis of the effect of KBDI values above 150 during the PAT of the adult stage of the first year on the number of Gulf Coast tick collection records the following year.

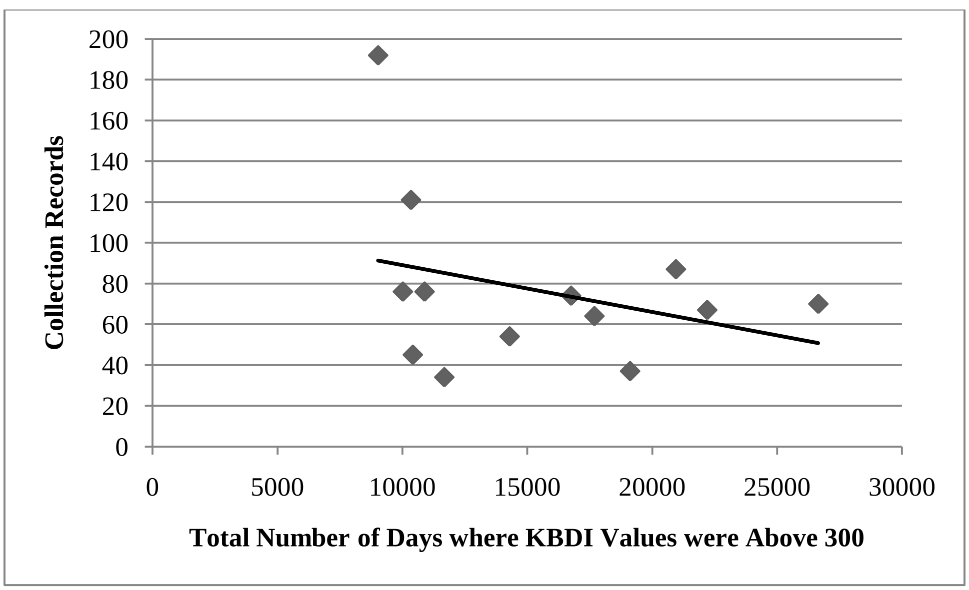

Figure 8. Analysis of the effect of KBDI values above 300 during the PAT of all life stages beginning with the adults of the first year and ending with the nymphs of the following year on the number of Gulf Coast tick collection records the following year.

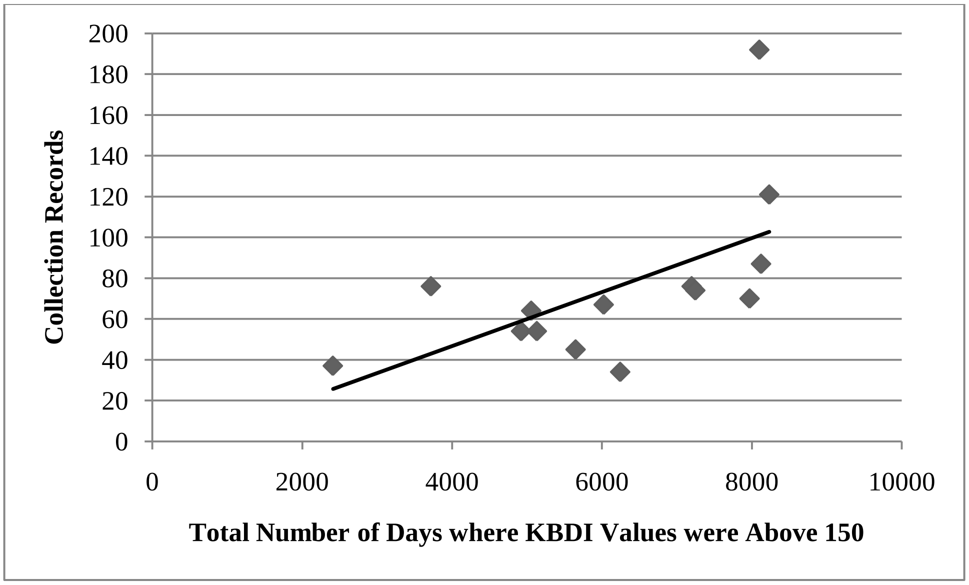

Figure 9. Analysis of the effect of KBDI values above 150 during the peak activity time of the adult stage on the number of Gulf Coast tick collection records that year.

DISCUSSION AND CONCLUSION

Several variables were taken into account to use Gulf Coast tick collection records from livestock markets. Discussions with three inspectors indicated that some inspectors compete with each other to collect more ticks. Another caveat to consider is that many ticks are identified only to genus and reported by the TAHC, potentially resulting in several missing Gulf Coast tick collection records per year. Also, some Gulf Coast ticks from collection records may not have originated in the study area. This can result if a rancher from outside the study area transports their livestock to a market within the study area.

A potential caveat was that only female cattle greater than 18 months old were tested for brucellosis and checked for ticks at the livestock market. Ticks were possibly missed due to this exemption and could have caused a misrepresentation of the true Gulf Coast tick population density for each year. However, cattle that were tested for brucellosis had the same potential for host utilization by Gulf Coast ticks as cattle that were not tested for brucellosis. Therefore, cattle tested for brucellosis were considered to be a representation of the total number of Gulf Coast ticks present at livestock markets.

There were positive aspects to using collection records from the TAHC to monitor Gulf Coast tick population changes. Surveying a region as large as the study area using methods such as flagging for an equivalent time period would have been very costly and required much labor and time. Livestock markets typically have sales once per week, allowing for weekly tick population monitoring from TAHC inspectors. Tick surveillance at this scale would not be possible by conventional field collecting methods. Also, ticks that were collected in this study area were exposed to a variety of meteorological factors depending on their county of origin.

It was shown that the number of cattle tested for brucellosis and collection records are independent. Furthermore, it was determined that differing drought thresholds have a more significant influence on the number of collection records than the number of cattle tested for brucellosis. In contrast, an analysis on the effect of drought during the PAT of the adult stage on Gulf Coast tick collection records indicated that increased levels of drought during that time period resulted in more tick collections. However, it should be noted that the number of inspectors at livestock markets does not increase when larger than average cattle sales occur. Therefore, this increase in Gulf Coast tick collection records may be due to an unknown factor.

The analyses of the effect of precipitation on Gulf Coast tick survivorship were expected to produce more statistically significant results. A statistically significant relationship indicating an increase in larval tick abundance the year following increased precipitation was observed when examining *Ixodes scapularis* Say (Acari: Ixodidae) populations (Jones and Kitron 2000). Low correlation between precipitation during the PAT of lagged adults and lagged all stages and the number of Gulf Coast tick collection records ($R^2 = 0.073$ and $R^2 = 0.001$ respectively) did not indicate a similar lagged response. Perhaps this was due to the generally abundant precipitation in a large portion of the study area. Also, the biology of *I. scapularis* is very different from the Gulf Coast tick, so obtaining similar results may not be possible.

Drought appeared to be more significant predictor of Gulf Coast tick population change than precipitation. This result was expected as a KBDI includes precipitation, land surface temperature, vegetation, and soil texture type. All of these factors have an influence on the microclimate that the Gulf Coast tick inhabits and desiccation. Similar results were obtained in other studies that measured the effect of drought on the survivorship on other tick species (Jones and Kitron 2000, Cumming 2002).

The analyses of the PAT of lagged adults and lagged all stages provided some insight into the effect of drought on Gulf Coast tick survivorship. For example, drought that occurred during the PAT of the adult stage in 2005 resulted in an increase in the number of Gulf Coast tick collection records that occurred, possibly due to an unknown factor. However, the analyses using KBDI thresholds during the PAT of lagged adults indicated that the number of Gulf Coast tick collection records the following year decreased. This is most likely due to a decrease in the population of adult Gulf Coast ticks from 2005 that can lay eggs that would become adults in 2006. It is because of this lagged population change that I believe that drought conditions can be used to predict Gulf Coast tick population change and survivorship within the study area.

There were some limitations to using naturally occurring drought conditions to predict changes in the number of Gulf Coast tick collection records. A KBDI value of 700 and above in the study area, representing very high soil moisture deficiency, would likely result in a significant decrease of Gulf Coast tick populations due to increased desiccation. However, this threshold was not frequently reached during most of the time period studied as this condition was mostly unnatural in the majority of the study area.

Exceptions to this occurrence were during the majority time period studied during the PATs of the egg stage. Larva and nymph PAT analyses began having zeroes, for the number of days of a certain drought threshold in the study area, once KBDI values reached 500. The increasing amount of zeroes that occurred in the remainder of the increasing KBDI thresholds for larvae and nymph PAT introduced problems in the analyses which resulted in non-significant correlation. These zeroes first occurred at 450 due to a very wet summer in 2007 for much of the state during the PATs of the adult and lagged adult stages. The amount of zeroes began to increase for these two analyses once the KBDI threshold reached 600. Thus, the results of all drought analyses should only be used to indicate significance when there were not multiple zeroes present for the total number of days in the study area where a certain KBDI threshold was reached.

Several methods will be used to further refine the precipitation and KBDI threshold analyses. The counties that are typically serviced by each livestock market will be determined to conduct more refined analyses on the effect of precipitation and KBDI thresholds on Gulf Coast tick collection records. This restructuring is especially necessary at the three selected livestock markets that are located in counties bordering Oklahoma, and the two selected livestock markets that are located in counties bordering Louisiana, as these livestock markets may receive cattle from these neighboring states. Additionally, month by month analyses of the effect of precipitation and KBDI thresholds on month by month Gulf Coast tick collection records will be conducted for the PAT of the adult stage. These analyses will provide more replication points and potentially yield more significant results.

Additional field applications of this research project are necessary. Weather monitoring stations could be placed at certain points in the study area that collect relative humidity and precipitation data. Containers would then be placed at these weather monitoring stations that contain laboratory reared cohorts of Gulf Coast ticks in the corresponding life stage, depending on the time of the year. These containers should then be monitored at least on a monthly basis to determine survivorship of each life stages. Continued monitoring of drought conditions would also be beneficial for a redesigned field experiment.

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APPENDIX A

SUMMARY OF DATA USED IN ALL ANALYSES

Summary of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the adult Gulf Coast tick life stage. These data were used to measure whether the number of cattle tested for brucellosis or increasing KBDI thresholds have a more significant effect on the number of Gulf Coast tick collection records

			KBDI Threshold			
Year	Collection Records	Cattle Tested for Brucellosis	50	100	150	200
1997	76	375,171	6852	5107	3718	2664
1998	121	418,773	8311	8299	8231	7986
1999	54	386,021	7714	6603	5131	3680
2000	67	405,971	7771	6989	6023	4969
2001	34	384,378	7863	7126	6243	5225
2002	45	360,320	7681	6597	5648	4709
2003	76	443,986	8083	7686	7196	6572
2004	64	381,818	7717	6487	5056	3591
2005	192	397,698	8298	8247	8099	7723
2006	70	499,004	8286	8172	7969	7657
2007	37	340,122	6026	3988	2410	1256
2008	74	347,132	8202	7820	7245	6706

Continued

KBDI Threshold										
250	300	350	400	450	500	550	600	650	700	750
2038	1586	1180	798	494	238	69	7	0	0	0
7576	7018	6312	5397	4468	3683	2967	2288	1602	781	95
2545	1664	1054	601	332	147	53	19	13	4	0
4049	3281	2626	2075	1570	973	437	146	31	18	0
4264	3295	2466	1885	1368	905	492	207	47	5	0
3840	3024	2169	1369	724	260	33	1	0	0	0
5620	4420	3135	2009	1137	540	175	28	0	0	0
2371	1466	845	465	251	104	15	0	0	0	0
7056	6214	5306	4442	3663	2747	1752	801	139	0	0
7154	6530	5905	5123	4246	3234	2252	1438	699	208	0
592	235	83	27	8	4	0	0	0	0	0
6017	5308	4673	4025	3336	2605	1885	1101	441	77	0

Summary of the total amount of precipitation (cm) received in a 90 county study area of Texas during the peak activity time of individual and combined Gulf Coast tick life stages. These data were used to analyze the effect of precipitation on the number of Gulf Coast tick collection records

Year	Collection Records	Egg	Larva	Nymph	Adult
1993	53	1060.7	3633.2	5349.0	2347.3
1994	235	2016.9	2194.8	3333.2	3345.7
1995	54	2331.8	3090.9	4939.4	3355.2
1996	87	1045.3	1373.9	2706.2	4085.4
1997	76	1805.7	3823.8	5770.7	3142.0
1998	121	1250.3	3433.9	4495.6	1632.3
1999	54	2416.0	2673.7	4053.9	2473.0
2000	67	847.0	1467.6	2873.4	2719.6
2001	34	1156.7	4507.5	5961.3	2952.4
2002	45	1635.8	2595.0	4082.3	3219.2
2003	76	2124.2	2957.2	3574.3	2846.1
2004	64	1584.0	2535.9	4154.5	4429.9
2005	192	1535.0	3586.9	4414.1	2536.7
2006	70	620.3	1535.6	3092.3	1929.6
2007	37	1707.0	2650.2	4527.6	5861.9
2008	74	1184.7	1711.2	3757.0	2893.4

Continued

All Immatures	All Stages	Lagged Adults	Lagged All Stages
6409.7	8833.9	3307.2	9716.9
5350.1	8386.3	2347.3	7697.4
7271.2	10598.4	3345.7	10616.9
3751.5	6942.6	3355.2	7106.7
7576.4	11604.0	4085.4	11661.8
5745.9	7267.7	3142.0	8887.9
6469.9	9597.4	1632.3	8102.2
3720.4	6486.6	2473.0	6193.4
7118.0	9371.0	2719.6	9837.6
5718.1	9326.8	2952.4	8670.5
5698.5	8357.1	3219.2	8917.7
5738.5	9858.7	2846.1	8584.6
5949.1	8466.5	4429.9	10379.0
3712.6	6163.0	2536.7	6249.3
6234.6	11861.6	1929.6	8164.2
4941.7	7175.7	5861.9	10803.6

Summary of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the egg stage of the Gulf Coast tick. These data were used to measure the effect of these differing KBDI thresholds on the number of Gulf Coast tick collection records that occurred the year following each peak activity time of the egg stage

		KBDI Threshold							
Year	Collection Records	50	100	150	200	250	300	350	400
1996	87	5459	5407	5354	5220	4994	4701	4288	3746
1997	76	5058	4454	3766	2930	2044	1246	631	187
1998	121	5477	5455	5419	5324	5183	5018	4790	4439
1999	54	4925	4461	4102	3772	3445	3087	2782	2486
2000	67	5490	5490	5490	5490	5490	5490	5489	5470
2001	34	5490	5472	5460	5427	5389	5330	5245	5148
2002	45	5344	5036	4534	3897	3274	2582	1896	1367
2003	76	5246	4987	4815	4609	4435	4156	3736	3278
2004	64	5450	5342	5157	4966	4729	4437	3883	3238
2005	192	5490	5480	5415	5323	5074	4669	4079	3271
2006	70	5489	5481	5474	5458	5432	5372	5252	5061
2007	37	5444	5377	5352	5345	5324	5236	5114	4962
2008	74	5490	5483	5452	5377	5251	5006	4586	4026

Continued

KBDI Threshold						
450	500	550	600	650	700	750
3031	2207	1392	722	500	297	26
29	0	0	0	0	0	0
3924	3409	2643	1509	432	0	0
2244	2040	1822	1534	1243	765	115
5419	5275	5083	4767	4045	2094	431
5033	4734	4385	3870	3222	2465	562
876	470	186	33	0	0	0
2754	2112	1360	630	268	64	0
2521	1855	1059	363	16	0	0
2363	1636	974	536	168	6	0
4827	4482	3996	3236	2377	1213	138
4693	4193	3692	2945	1946	879	59
3250	2272	1275	599	114	0	0

Summary of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the larval stage of the Gulf Coast tick. These data were used to measure the effect of these differing KBDI thresholds on the number of Gulf Coast tick collection records that occurred the year following each peak activity time of the larval stage

		KBDI Threshold							
Year	Collection Records	50	100	150	200	250	300	350	400
1996	87	10648	10393	10075	9757	9138	8048	6151	4185
1997	76	4153	2004	1051	674	421	261	111	38
1998	121	4516	3664	3068	2382	1784	1258	823	504
1999	54	6016	3852	2553	1971	1540	1200	974	643
2000	67	10890	10877	10822	10613	10401	10045	9469	8373
2001	34	3502	1623	845	566	385	307	181	140
2002	45	6907	4758	3923	3138	2422	1679	1069	713
2003	76	6337	3423	1926	1029	518	250	141	76
2004	64	9898	9285	8760	8090	7179	6020	4705	3445
2005	192	5150	2411	1434	1097	861	647	491	219
2006	70	10674	10614	10536	10384	10236	10033	9789	9451
2007	37	7921	6912	6278	5591	5005	4359	3489	2551
2008	74	10506	10210	9870	9526	9011	8381	7395	6020

Continued

KBDI Threshold						
450	500	550	600	650	700	750
2627	1460	584	112	10	0	0
15	0	0	0	0	0	0
249	87	0	0	0	0	0
386	173	27	4	1	0	0
6985	5470	4116	2709	907	68	0
92	49	27	14	6	0	0
504	185	18	0	0	0	0
24	0	0	0	0	0	0
2482	1539	837	332	100	0	0
79	26	1	0	0	0	0
9010	8339	7385	5665	3280	1387	46
1520	713	157	39	0	0	0
4585	3007	1482	441	101	0	0

Summary of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the nymphal stage of the Gulf Coast tick. These data were used to measure the effect of these differing KBDI thresholds on the number of Gulf Coast tick collection records that occurred the year following each peak activity time of the nymphal stage

		KBDI Threshold							
Year	Collection Records	50	100	150	200	250	300	350	400
1996	87	16138	15818	15362	14780	13649	11900	9338	6630
1997	76	5866	2260	1056	674	421	261	111	38
1998	121	7756	5886	4471	2862	1851	1259	823	504
1999	54	10016	6537	4182	2836	2018	1451	1088	672
2000	67	16181	15679	14948	14069	13176	12292	11319	9842
2001	34	5938	3000	1550	861	472	313	181	140
2002	45	10695	7119	5352	4017	2807	1817	1128	752
2003	76	10542	6342	3871	2162	1035	435	203	85
2004	64	14139	12223	10500	8793	7376	6085	4730	3445
2005	192	9553	5384	3232	2005	1171	713	495	219
2006	70	15824	15442	15005	14332	13569	12654	11729	10841
2007	37	12246	9713	7787	6296	5391	4586	3620	2594
2008	74	14731	13421	12486	11689	10783	9825	8517	6857

Continued

KBDI Threshold						
450	500	550	600	650	700	750
4248	2131	759	135	10	0	0
15	0	0	0	0	0	0
249	87	0	0	0	0	0
387	173	27	4	1	0	0
7943	6002	4316	2755	908	68	0
92	49	27	14	6	0	0
528	195	18	0	0	0	0
24	0	0	0	0	0	0
2482	1539	837	332	100	0	0
79	26	1	0	0	0	0
9996	9002	7749	5831	3350	1413	46
1533	724	157	39	0	0	0
5211	3437	1729	516	114	0	0

Summary of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the adult stage of the Gulf Coast tick. These data were used to measure the effect of these differing KBDI thresholds on the number of Gulf Coast tick collection records

		KBDI Threshold							
Year	Collection Records	50	100	150	200	250	300	350	400
1995	73	7214	6103	4921	3954	3132	2446	1835	1287
1996	87	8284	8229	8122	7926	7560	7018	6302	5369
1997	76	6852	5107	3718	2664	2038	1586	1180	798
1998	121	8311	8299	8231	7986	7576	7018	6312	5397
1999	54	7714	6603	5131	3680	2545	1664	1054	601
2000	67	7771	6989	6023	4969	4049	3281	2626	2075
2001	34	7863	7126	6243	5225	4264	3295	2466	1885
2002	45	7681	6597	5648	4709	3840	3024	2169	1369
2003	76	8083	7686	7196	6572	5620	4420	3135	2009
2004	64	7717	6487	5056	3591	2371	1466	845	465
2005	192	8298	8247	8099	7723	7056	6214	5306	4442
2006	70	8286	8172	7969	7657	7154	6530	5905	5123
2007	37	6026	3988	2410	1256	592	235	83	27
2008	74	8202	7820	7245	6706	6017	5308	4673	4025

Continued

KBDI Threshold						
450	500	550	600	650	700	750
765	336	98	15	0	0	0
4297	3118	1790	754	167	19	0
494	238	69	7	0	0	0
4468	3683	2967	2288	1602	781	95
332	147	53	19	13	4	0
1570	973	437	146	31	18	0
1368	905	492	207	47	5	0
724	260	33	1	0	0	0
1137	540	175	28	0	0	0
251	104	15	0	0	0	0
3663	2747	1752	801	139	0	0
4246	3234	2252	1438	699	208	0
8	4	0	0	0	0	0

Summary of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of all immature stages of the Gulf Coast tick. These data were used to measure the effect of these differing KBDI thresholds on the number of Gulf Coast tick collection records that occurred the year following the beginning of each peak activity time of the egg stage

		KBDI Threshold							
Year	Collection Records	50	100	150	200	250	300	350	400
1996	87	21597	21225	20716	20000	18643	16601	13626	10376
1997	76	10924	6714	4822	3604	2465	1507	742	225
1998	121	13233	11341	9890	8186	7034	6277	5613	4943
1999	54	14941	10998	8284	6608	5463	4538	3870	3158
2000	67	21671	21169	20438	19559	18666	17782	16808	15312
2001	34	11428	8472	7010	6288	5861	5643	5426	5288
2002	45	16039	12155	9886	7914	6081	4399	3024	2119
2003	76	15788	11329	8686	6771	5470	4591	3939	3363
2004	64	19589	17565	15657	13759	12105	10522	8613	6683
2005	192	15043	10864	8647	7328	6245	5382	4574	3490
2006	70	21313	20923	20479	19790	19001	18026	16981	15902
2007	37	17690	15090	13139	11641	10715	9822	8734	7556
2008	74	20221	18904	17938	17066	16034	14831	13103	10883

Continued

KBDI Threshold						
450	500	550	600	650	700	750
7279	4338	2151	857	510	297	26
44	0	0	0	0	0	0
4173	3496	2643	1509	432	0	0
2631	2213	1849	1538	1244	765	115
13362	11277	9399	7522	4953	2162	431
5125	4783	4412	3884	3228	2465	562
1404	665	204	33	0	0	0
2778	2112	1360	630	268	64	0
5003	3394	1896	695	116	0	0
2442	1662	975	536	168	6	0
14823	13484	11745	9067	5727	2626	184
6226	4917	3849	2984	1946	879	59
8461	5709	3004	1115	228	0	0

Summary of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of all life stages of the Gulf Coast tick. These data were used to measure the effect of these differing KBDI thresholds on the number of Gulf Coast tick collection records that occurred the year following the beginning of each peak activity time of the egg stage

		KBDI Threshold							
Year	Collection Records	50	100	150	200	250	300	350	400
1996	87	32514	31986	31231	30177	28280	25516	21579	17183
1997	76	20517	14530	11203	8859	6996	5464	4103	2938
1998	121	24298	22383	20842	18848	17219	15758	14182	12292
1999	54	25414	20360	16174	13045	10755	8935	7640	6457
2000	67	32201	30917	29220	27287	25473	23815	22154	20030
2001	34	22050	18357	16012	14272	12884	11688	10628	9891
2002	45	26479	21510	18287	15373	12670	10143	7863	6094
2003	76	26630	21770	18621	16043	13683	11412	9248	7217
2004	64	30065	26811	23472	20109	17231	14737	12159	9703
2005	192	26085	21810	19384	17597	15707	13764	11677	9295
2006	70	32352	31812	31118	30060	28670	26964	25158	23126
2007	37	26475	21837	18310	15662	14075	12827	11588	10354
2008	74	31168	29410	27731	26102	24084	21824	19159	15968

Continued

KBDI Threshold						
450	500	550	600	650	700	750
12791	8438	4690	2095	918	372	27
2144	1373	733	412	238	75	0
10038	7985	5941	3836	2022	774	90
5603	4850	4211	3552	2677	1542	301
17440	14525	11745	9082	5827	2462	443
9161	8292	7346	6117	4656	2947	565
4620	3114	2049	1192	505	122	4
5340	3649	2124	919	335	65	0
7501	5310	3083	1223	221	9	0
7063	5032	3062	1450	321	6	0
21001	18436	15479	11666	6965	2896	184
9003	7674	6562	5529	4052	2106	250
12490	8646	4962	2213	658	77	0

Summary of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the adult stage of the Gulf Coast tick. These data were used to measure the effect of these differing KBDI thresholds on the number of Gulf Coast tick collection records that occurred the following year

		KBDI Threshold							
Year	Collection Records	50	100	150	200	250	300	350	400
1996	87	7214	6103	4921	3954	3132	2446	1835	1287
1997	76	8284	8229	8122	7926	7560	7018	6302	5369
1998	121	6852	5107	3718	2664	2038	1586	1180	798
1999	54	8311	8299	8231	7986	7576	7018	6312	5397
2000	67	7714	6603	5131	3680	2545	1664	1054	601
2001	34	7771	6989	6023	4969	4049	3281	2626	2075
2002	45	7863	7126	6243	5225	4264	3295	2466	1885
2003	76	7681	6597	5648	4709	3840	3024	2169	1369
2004	64	8083	7686	7196	6572	5620	4420	3135	2009
2005	192	7717	6487	5056	3591	2371	1466	845	465
2006	70	8298	8247	8099	7723	7056	6214	5306	4442
2007	37	8286	8172	7969	7657	7154	6530	5905	5123
2008	74	6026	3988	2410	1256	592	235	83	27

Continued

KBDI Threshold						
450	500	550	600	650	700	750
765	336	98	15	0	0	0
4297	3118	1790	754	167	19	0
494	238	69	7	0	0	0
4468	3683	2967	2288	1602	781	95
332	147	53	19	13	4	0
1570	973	437	146	31	18	0
1368	905	492	207	47	5	0
724	260	33	1	0	0	0
1137	540	175	28	0	0	0
251	104	15	0	0	0	0
3663	2747	1752	801	139	0	0
4246	3234	2252	1438	699	208	0
8	4	0	0	0	0	0

Summary of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of all life stages of the Gulf Coast tick. These data were used to measure the effect of these differing KBDI thresholds on the number of Gulf Coast tick collection records that occurred the year following the beginning of each peak activity time of the adult stage

		KBDI Threshold							
Year	Collection Records	50	100	150	200	250	300	350	400
1996	87	31444	29860	28029	26204	23851	20946	17115	13097
1997	76	21949	17650	15603	14114	12509	10884	9211	7501
1998	121	22839	19193	16334	13534	11692	10340	9069	7717
1999	54	26011	22056	19274	17351	15786	14289	12898	11253
2000	67	32144	30531	28328	25998	23969	22198	20582	18556
2001	34	21958	18220	15792	14016	12669	11674	10788	10081
2002	45	26661	22039	18882	15889	13094	10414	8160	6610
2003	76	26228	20681	17073	14180	11903	10015	8278	6570
2004	64	30431	28010	25612	23090	20477	17683	14442	11242
2005	192	25504	20050	16341	13465	11025	9025	7227	5330
2006	70	32364	31887	31248	30126	28572	26648	24559	22445
2007	37	28735	26021	23867	22057	20628	19111	17397	15432
2008	74	28992	25578	22897	20653	18660	16750	14569	11975

Continued

KBDI Threshold						
450	500	550	600	650	700	750
9257	5658	2999	1356	751	353	27
5943	4250	2457	1161	405	94	0
6088	4564	3067	1576	434	0	0
9739	8384	7118	5817	4265	2316	391
16202	13701	11368	8967	5824	2462	443
9362	8359	7288	6049	4623	2942	565
5259	3744	2489	1375	541	127	4
4917	3365	1976	891	335	65	0
8388	5747	3242	1251	221	9	0
3666	2405	1341	656	182	6	0
20418	17952	14992	11053	6431	2697	184
13218	10877	8783	6936	4725	2305	250
9168	6052	3088	1123	228	0	0

APPENDIX B

SUMMARY OF THE RESULTS OF ALL ANALYSES CONDUCTED

Comparison of regression model statistics testing whether the number of cattle tested for brucellosis or the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the adult Gulf Coast tick life stage have a more significant effect on the number of Gulf Coast tick collection records

Independent Variables	Cattle Tested P	Drought Threshold P
Cattle Tested, 50	0.906	0.196
Cattle Tested, 100	0.700	0.108
Cattle Tested, 150	0.560	0.065
Cattle Tested, 200	0.502	0.048
Cattle Tested, 250	0.478	0.040
Cattle Tested, 300	0.486	0.037
Cattle Tested, 350	0.536	0.040
Cattle Tested, 400	0.612	0.046
Cattle Tested, 450	0.677	0.047
Cattle Tested, 500	0.776	0.053
Cattle Tested, 550	0.919	0.078
Cattle Tested, 600	0.942	0.166
Cattle Tested, 650	0.756	0.374
Cattle Tested, 700	0.684	0.446
Cattle Tested, 750	0.584	0.365

The lower p-value indicates a stronger effect on the number of Gulf Coast tick collection records.

Comparison of regression model statistics used to analyze the effect of precipitation (cm) in a 90 county study area of Texas during the peak activity time of individual and combined Gulf Coast tick life stages on the number of Gulf Coast tick collection records

	Regression Model		
Independent Variable	Linear	Quadratic	Cubic
Sum – Egg	R^2 = 0.014 P = 0.663	R^2 = 0.052 P = 0.707	R^2 = 0.112 P = 0.688
Sum – Larva	R^2 = 0.003 P = 0.842	R^2 = 0.023 P = 0.862	R^2 = 0.037 P = 0.926
Sum – Nymph	R^2 = 0.072 P = 0.314	R^2 = 0.089 P = 0.545	R^2 = 0.088 P = 0.551
Sum – Adult	R^2 = 0.039 P = 0.462	R^2 = 0.049 P = 0.722	R^2 = 0.065 P = 0.839
Sum – All Immatures	R^2 = 0.027 P = 0.540	R^2 = 0.129 P = 0.406	R^2 = 0.120 P = 0.434
Sum – All Stages	R^2 = 0.027 P = 0.540	R^2 = 0.129 P = 0.406	R^2 = 0.120 P = 0.434
Sum – Lagged Adult	R^2 = 0.026 P = 0.564	R^2 = 0.041 P = 0.778	R^2 = 0.073 P = 0.834
Sum – Lagged All Stages	R^2 = 0.001 P = 0.920	R^2 = 0.001 P = 0.992	R^2 = 0.001 P = 0.994

Comparison of regression model statistics used to analyze the effect of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the egg stage of the Gulf Coast tick on the number of Gulf Coast tick collection records that occurred the year following each peak activity time of the egg stage

	Regression Model											
KBDI Threshold	Linear				Quadratic				Cubic			
50	R^2	0.044	P	0.492	R^2	0.061	P	0.731	R^2	0.062	P	0.726
100	R^2	0.051	P	0.459	R^2	0.100	P	0.591	R^2	0.102	P	0.585
150	R^2	0.045	P	0.484	R^2	0.071	P	0.692	R^2	0.070	P	0.697
200	R^2	0.037	P	0.530	R^2	0.047	P	0.788	R^2	0.044	P	0.799
250	R^2	0.020	P	0.644	R^2	0.020	P	0.902	R^2	0.023	P	0.890
300	R^2	0.009	P	0.762	R^2	0.028	P	0.866	R^2	0.292	P	0.352
350	R^2	0.001	P	0.915	R^2	0.067	P	0.709	R^2	0.291	P	0.355
400	R^2	0.003	P	0.849	R^2	0.116	P	0.539	R^2	0.226	P	0.490
450	R^2	0.026	P	0.599	R^2	0.148	P	0.448	R^2	0.152	P	0.668
500	R^2	0.049	P	0.468	R^2	0.132	P	0.494	R^2	0.153	P	0.666
550	R^2	0.079	P	0.352	R^2	0.117	P	0.536	R^2	0.185	P	0.586
600	R^2	0.106	P	0.277	R^2	0.110	P	0.559	R^2	0.266	P	0.403
650	R^2	0.141	P	0.207	R^2	0.162	P	0.414	R^2	0.237	P	0.465
700	R^2	0.185	P	0.143	R^2	0.210	P	0.308	R^2	0.251	P	0.434
750	R^2	0.138	P	0.212	R^2	0.157	P	0.425	R^2	0.227	P	0.487

Comparison of regression model statistics used to analyze the effect of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the larval stage of the Gulf Coast tick on the number of Gulf Coast tick collection records that occurred the year following the beginning of each peak activity time of the larval stage

	Regression Model											
KBDI Threshold	Linear				Quadratic				Cubic			
50	R^2	0.034	P	0.546	R^2	0.036	P	0.834	R^2	0.041	P	0.811
100	R^2	0.039	P	0.516	R^2	0.077	P	0.669	R^2	0.155	P	0.661
150	R^2	0.036	P	0.535	R^2	0.075	P	0.676	R^2	0.101	P	0.800
200	R^2	0.031	P	0.565	R^2	0.071	P	0.693	R^2	0.081	P	0.850
250	R^2	0.028	P	0.585	R^2	0.063	P	0.722	R^2	0.063	P	0.892
300	R^2	0.026	P	0.597	R^2	0.056	P	0.749	R^2	0.064	P	0.890
350	R^2	0.024	P	0.612	R^2	0.042	P	0.807	R^2	0.060	P	0.899
400	R^2	0.025	P	0.608	R^2	0.048	P	0.784	R^2	0.083	P	0.845
450	R^2	0.021	P	0.634	R^2	0.045	P	0.793	R^2	0.076	P	0.861
500	R^2	0.015	P	0.694	R^2	0.029	P	0.861	R^2	0.045	P	0.933
550	R^2	0.009	P	0.752	R^2	0.017	P	0.918	R^2	0.021	P	0.977
600	R^2	0.007	P	0.781	R^2	0.013	P	0.935	R^2	0.022	P	0.976
650	R^2	0.005	P	0.817	R^2	0.011	P	0.945	R^2	0.011	P	0.945
700	R^2	0.003	P	0.866	R^2	0.008	P	0.961	R^2	0.008	P	0.961
750	R^2	0.002	P	0.875	R^2	0.002	P	0.875	R^2	0.002	P	0.875

Comparison of regression model statistics used to analyze the effect of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the nymphal stage of the Gulf Coast tick on the number of Gulf Coast tick collection records that occurred the year following the beginning of each peak activity time of the nymphal stage

	Regression Model											
KBDI Threshold	Linear				Quadratic				Cubic			
50	R^2	0.010	P	0.740	R^2	0.026	P	0.876	R^2	0.019	P	0.911
100	R^2	0.015	P	0.691	R^2	0.015	P	0.927	R^2	0.151	P	0.671
150	R^2	0.015	P	0.688	R^2	0.023	P	0.890	R^2	0.100	P	0.802
200	R^2	0.016	P	0.678	R^2	0.049	P	0.778	R^2	0.075	P	0.865
250	R^2	0.018	P	0.665	R^2	0.072	P	0.686	R^2	0.073	P	0.868
300	R^2	0.018	P	0.665	R^2	0.073	P	0.683	R^2	0.083	P	0.845
350	R^2	0.017	P	0.671	R^2	0.048	P	0.780	R^2	0.084	P	0.842
400	R^2	0.018	P	0.662	R^2	0.040	P	0.813	R^2	0.112	P	0.770
450	R^2	0.017	P	0.673	R^2	0.033	P	0.845	R^2	0.086	P	0.838
500	R^2	0.013	P	0.710	R^2	0.023	P	0.889	R^2	0.038	P	0.948
550	R^2	0.009	P	0.757	R^2	0.015	P	0.926	R^2	0.018	P	0.982
600	R^2	0.007	P	0.782	R^2	0.013	P	0.936	R^2	0.020	P	0.979
650	R^2	0.005	P	0.818	R^2	0.011	P	0.945	R^2	0.011	P	0.945
700	R^2	0.003	P	0.866	R^2	0.008	P	0.961	R^2	0.008	P	0.961
750	R^2	0.002	P	0.875	R^2	0.002	P	0.875	R^2	0.002	P	0.875

Comparison of regression model statistics used to analyze the effect of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the adult stage of the Gulf Coast tick on the number of Gulf Coast tick collection records

	Regression Model											
KBDI Threshold	Linear				Quadratic				Cubic			
50	R^2	0.239	P	0.076	R^2	0.358	P	0.087	R^2	0.372	P	0.077
100	R^2	0.300	P	0.043	R^2	0.432	P	0.045	R^2	0.457	P	0.035
150	R^2	0.345	P	0.027	R^2	0.458	P	0.034	R^2	0.577	P	0.029
200	R^2	0.367	P	0.022	R^2	0.450	P	0.037	R^2	0.512	P	0.058
250	R^2	0.377	P	0.019	R^2	0.427	P	0.047	R^2	0.436	P	0.112
300	R^2	0.381	P	0.019	R^2	0.401	P	0.060	R^2	0.405	P	0.142
350	R^2	0.375	P	0.020	R^2	0.376	P	0.075	R^2	0.419	P	0.128
400	R^2	0.368	P	0.021	R^2	0.369	P	0.080	R^2	0.436	P	0.112
450	R^2	0.376	P	0.020	R^2	0.378	P	0.074	R^2	0.431	P	0.117
500	R^2	0.377	P	0.020	R^2	0.380	P	0.072	R^2	0.396	P	0.153
550	R^2	0.353	P	0.025	R^2	0.368	P	0.080	R^2	0.368	P	0.186
600	R^2	0.261	P	0.062	R^2	0.309	P	0.131	R^2	0.425	P	0.122
650	R^2	0.133	P	0.200	R^2	0.138	P	0.441	R^2	0.384	P	0.167
700	R^2	0.099	P	0.273	R^2	0.108	P	0.535	R^2	0.108	P	0.754
750	R^2	0.108	P	0.252	R^2	0.108	P	0.252	R^2	0.108	P	0.252

Comparison of regression model statistics used to analyze the effect of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of all immature stages of the Gulf Coast tick on the number of Gulf Coast tick collection records that occurred the year following the beginning of each peak activity time of the egg stage

	Regression Model											
KBDI Threshold	Linear				Quadratic				Cubic			
50	R^2	0.008	P	0.771	R^2	0.026	P	0.877	R^2	0.021	P	0.901
100	R^2	0.010	P	0.744	R^2	0.012	P	0.943	R^2	0.094	P	0.818
150	R^2	0.009	P	0.759	R^2	0.009	P	0.956	R^2	0.064	P	0.890
200	R^2	0.008	P	0.768	R^2	0.010	P	0.953	R^2	0.052	P	0.918
250	R^2	0.009	P	0.759	R^2	0.011	P	0.948	R^2	0.042	P	0.938
300	R^2	0.009	P	0.757	R^2	0.009	P	0.955	R^2	0.030	P	0.962
350	R^2	0.010	P	0.745	R^2	0.010	P	0.949	R^2	0.022	P	0.975
400	R^2	0.016	P	0.683	R^2	0.016	P	0.924	R^2	0.030	P	0.963
450	R^2	0.025	P	0.608	R^2	0.029	P	0.861	R^2	0.051	P	0.919
500	R^2	0.030	P	0.570	R^2	0.044	P	0.798	R^2	0.078	P	0.857
550	R^2	0.039	P	0.519	R^2	0.078	P	0.666	R^2	0.100	P	0.803
600	R^2	0.053	P	0.451	R^2	0.123	P	0.517	R^2	0.142	P	0.694
650	R^2	0.087	P	0.329	R^2	0.204	P	0.319	R^2	0.212	P	0.522
700	R^2	0.144	P	0.201	R^2	0.228	P	0.274	R^2	0.231	P	0.479
750	R^2	0.139	P	0.210	R^2	0.152	P	0.437	R^2	0.227	P	0.486

Comparison of regression model statistics used to analyze the effect of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the all life stages of the Gulf Coast tick on the number of Gulf Coast tick collection records that occurred the year following the beginning of each peak activity time of the egg stage

	Regression Model											
KBDI Threshold	Linear				Quadratic				Cubic			
50	R^2	0.000	P	0.980	R^2	0.021	P	0.899	R^2	0.020	P	0.904
100	R^2	0.001	P	0.920	R^2	0.019	P	0.907	R^2	0.020	P	0.903
150	R^2	0.006	P	0.807	R^2	0.034	P	0.841	R^2	0.050	P	0.922
200	R^2	0.011	P	0.736	R^2	0.051	P	0.769	R^2	0.073	P	0.869
250	R^2	0.012	P	0.724	R^2	0.056	P	0.749	R^2	0.082	P	0.848
300	R^2	0.011	P	0.739	R^2	0.058	P	0.743	R^2	0.084	P	0.842
350	R^2	0.007	P	0.790	R^2	0.052	P	0.766	R^2	0.067	P	0.883
400	R^2	0.001	P	0.913	R^2	0.029	P	0.862	R^2	0.031	P	0.961
450	R^2	0.001	P	0.927	R^2	0.012	P	0.941	R^2	0.015	P	0.987
500	R^2	0.008	P	0.774	R^2	0.009	P	0.955	R^2	0.030	P	0.962
550	R^2	0.028	P	0.586	R^2	0.033	P	0.845	R^2	0.074	P	0.867
600	R^2	0.063	P	0.409	R^2	0.092	P	0.619	R^2	0.138	P	0.704
650	R^2	0.121	P	0.245	R^2	0.163	P	0.412	R^2	0.202	P	0.544
700	R^2	0.185	P	0.142	R^2	0.187	P	0.356	R^2	0.194	P	0.563
750	R^2	0.195	P	0.130	R^2	0.197	P	0.334	R^2	0.198	P	0.554

Comparison of regression model statistics used to analyze the effect of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of the adult stage of the Gulf Coast tick on the number of Gulf Coast tick collection records that occurred the following year

	Regression Model											
KBDI Threshold	Linear				Quadratic				Cubic			
50	R^2	0.075	P	0.366	R^2	0.174	P	0.385	R^2	0.172	P	0.390
100	R^2	0.134	P	0.220	R^2	0.194	P	0.341	R^2	0.185	P	0.359
150	R^2	0.166	P	0.167	R^2	0.186	P	0.358	R^2	0.413	P	0.169
200	R^2	0.187	P	0.140	R^2	0.187	P	0.354	R^2	0.435	P	0.144
250	R^2	0.200	P	0.126	R^2	0.207	P	0.314	R^2	0.408	P	0.174
300	R^2	0.202	P	0.123	R^2	0.237	P	0.258	R^2	0.363	P	0.235
350	R^2	0.200	P	0.125	R^2	0.279	P	0.195	R^2	0.327	P	0.290
400	R^2	0.196	P	0.129	R^2	0.319	P	0.146	R^2	0.327	P	0.290
450	R^2	0.186	P	0.141	R^2	0.340	P	0.125	R^2	0.345	P	0.261
500	R^2	0.170	P	0.161	R^2	0.299	P	0.169	R^2	0.388	P	0.200
550	R^2	0.154	P	0.185	R^2	0.204	P	0.320	R^2	0.355	P	0.247
600	R^2	0.130	P	0.225	R^2	0.174	P	0.384	R^2	0.191	P	0.572
650	R^2	0.088	P	0.324	R^2	0.166	P	0.403	R^2	0.182	P	0.593
700	R^2	0.062	P	0.413	R^2	0.154	P	0.434	R^2	0.154	P	0.434
750	R^2	0.027	P	0.591	R^2	0.027	P	0.591	R^2	0.027	P	0.591

Comparison of regression model statistics used to analyze the effect of the total number of days above corresponding KBDI thresholds in a 90 county study area of Texas during the peak activity time of all life stages of the Gulf Coast tick on the number of Gulf Coast tick collection records that occurred the year following the beginning of each peak activity time of the adult stage

	Regression Model											
KBDI Threshold	Linear				Quadratic				Cubic			
50	R^2	0.020	P	0.643	R^2	0.030	P	0.858	R^2	0.028	P	0.869
100	R^2	0.041	P	0.505	R^2	0.053	P	0.761	R^2	0.056	P	0.749
150	R^2	0.057	P	0.430	R^2	0.132	P	0.494	R^2	0.132	P	0.494
200	R^2	0.073	P	0.373	R^2	0.213	P	0.302	R^2	0.213	P	0.302
250	R^2	0.087	P	0.328	R^2	0.256	P	0.229	R^2	0.256	P	0.229
300	R^2	0.098	P	0.299	R^2	0.259	P	0.224	R^2	0.526	P	0.070
350	R^2	0.112	P	0.264	R^2	0.261	P	0.221	R^2	0.406	P	0.178
400	R^2	0.137	P	0.212	R^2	0.335	P	0.130	R^2	0.426	P	0.155
450	R^2	0.161	P	0.175	R^2	0.430	P	0.060	R^2	0.497	P	0.090
500	R^2	0.163	P	0.171	R^2	0.456	P	0.048	R^2	0.532	P	0.066
550	R^2	0.162	P	0.172	R^2	0.419	P	0.066	R^2	0.552	P	0.055
600	R^2	0.169	P	0.163	R^2	0.344	P	0.122	R^2	0.443	P	0.137
650	R^2	0.201	P	0.124	R^2	0.320	P	0.145	R^2	0.348	P	0.257
700	R^2	0.247	P	0.084	R^2	0.258	P	0.224	R^2	0.306	P	0.326
750	R^2	0.227	P	0.099	R^2	0.239	P	0.255	R^2	0.262	P	0.410

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