TEMPORAL AND SPATIAL DISTRIBUTION OF THE BLACK-LEGGED TICK, *IXODES SCAPULARIS*, IN TEXAS AND ITS ASSOCIATION WITH CLIMATE VARIATION

An Undergraduate Research Scholars Thesis

By

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ABSTRACT

Temporal and spatial distribution of the black-legged tick, *Ixodes scapularis*, in Texas and its association with climate variation (May 2013).

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On average approximately 80 cases of Lyme Disease are diagnosed in Texas annually, yet recent studies conclude Texas is considered at low risk for exposure to the disease pathogen, *Borrelia burgdorferi*, based upon collections of immature stages of the tick vector, *Ixodes scapularis*. This study extracted more than 950 collection records of adult *I. scapularis* from the state-federal tick surveillance program conducted by the Texas Animal Health Commission and USDA, APHIS, Veterinary Services from 1990-2012. These collections were obtained from 11 different host-types from October to March, suggesting subsequent immature activity in spring and early summer. County-level data show *I. scapularis* collections from East Texas to the Rio Grande, with the greatest prevalence in East Texas Pineywoods, Post Oak Savannah, and Blackland Prairies ecoregions. Trends in annual collections of *I. scapularis* in East Texas as an indicator of population change align with the periodicity and severity of drought when assessed against drought severity designations from the National Drought Monitor produced by a consortia of agencies. Sensitivity of *I. scapularis* to dessication in the off-host life and results from this assessment suggests *I. scapularis* is best suited for survivorship in more mesic environments than other Ixodid species and is strongly influenced by climate variation.

CHAPTER I

INTRODUCTION

Ixodes scapularis, the black-legged tick, is a three host tick that spends the majority of its life cycle off-host and is a very general feeder on mammals. Cattle, deer, dogs and hogs are often rather heavily infested (Bishop and Trembley 1945). The black-legged tick is recognized as the vector of pathogens of Lyme Disease, human ehrlichiosis, and human babesiosis, as well as anaplasmosis of cattle (Diuk-Wasser et al. 2006). On average 80 new cases of Lyme Disease are diagnosed in Texas annually (http://www.cdc.gov/lyme/stats/chartstables/reportedcases_statelocality.html), yet a recent national-level study concluded Texas is considered at low risk for exposure to the Lyme Disease pathogen, *Borrelia burgdorferi* (Diuk-Wasser et al. 2006). The referenced study was based upon collections of immature *I. scapularis* ticks at specific geo-referenced locations in Texas, field work was conducted from June-August. This period of field work was likely conducted after the seasonal activity periods of tick larvae and nymphs, and was supported by collections of adult *I. scapularis* at the same collection sites during subsequent winter months. During the summer the immature stages are found on hosts more commonly than are the adults (Bishop and Trembley 1945). Due to the seasonality of *I. scapularis* ticks, these results likely underestimated the risk of exposure to the agent of Lyme Disease in Texas. No assessment of the geographic or temporal distribution of *I. scapularis* in Texas has been made presently. Additionally, no association has been made between the climate variation and the population frequency of *I. scapularis*. However, global climate change has been implicated in having a potentially serious effect on the future spatial and temporal distribution of vector-borne diseases (Gray 2007). The abiotic environment plays a vital role in the survival of *I. scapularis;* both water stress and temperature regulate off-host mortality (Needham and Teel, 1991). Because 98% of the 2-year life cycle occurs off the host, climate should act as an essential determinant of distribution of established tick populations across North America (Fish, 1993). Public health officials and scientists exploring the epidemiology of this tick and associated disease pathogens would benefit from these ecological findings.

CHAPTER II

METHODS

Geographical distribution & seasonal activity: Collection data for *I. scapularis* were extracted and compiled from the state-federal tick surveillance program conducted by the Texas Animal Health Commission, USDA, APHIS and Veterinary Services from 1990-2012. This surveillance program focuses on the collection of ticks primarily from livestock at public livestock auction facilities. These livestock include cattle, sheep, goats and horses, but may also include wildlife and other sources. Collection data were compiled and analyzed using Microsoft Excel by county, and year, and were then translated onto the Texas state county map using Microsoft Power Point and Photoshop.

Graphic analyses: A map of the frequency distribution of *I. scapularis* collections by county was created to show the geographic distribution of all collections and to assess ecological and climatological associations. The county frequency map was overlaid with the state precipitation map and with a map of the ecoregions of Texas to assess these associations. Drought severity among counties that exhibited high frequency of tick collections were then analyzed for their respective drought activity using the national drought monitor system. Drought severity for counties along the north east portion of Texas, north and east of the Trinity River, was recorded.

National drought monitor system: The national drought monitor system was used in assessing the cyclical drought periods in relation to the highest frequency of *I. scapularis* collections per county. This system uses a Standardized Precipitation Index (SPI) to calculate a variety of time scales used for both short-term agricultural and long term hydrological applications reflecting these values in severity levels and was implemented at the start of the year 2000. The national drought monitor system recorded drought severity as such and were based on: D0 (abnormally dry), D1 (moderate), D2 (severe), D3 (Extreme) and D4 (Exceptional). Counties with the highest frequency of collections were analyzed for drought severity of ≥D2 and ≥D3 and were recorded and compared with their collection frequencies for that year. By using drought severity levels between D2 through D4 we were then able to cross reference the geographical distribution and seasonality of the adult ticks and attempt to make an association between these factors; given the nature of water balance physiology characteristics of *I. scapularis* which suggest it is best suited for survivorship in more mesic environments.

CHAPTER III

RESULTS

The Tick Surveillance Program yielded 971 collections of adult *I. scapularis* obtained from 11 different host species from 1990-2012 (Figure 1). After reviewing all of the sources of hosts that these collections were derived from, we were able to ascertain that the hosts were primarily livestock species. This was due to the collections being focused on livestock auctions. Cattle were the highest collected and comprised 54% of all host collections. This became the base for our data analysis. In approaching the geographic distribution elements of the results we were able to see the frequency distribution of collections in Texas. The general distribution displayed collections along the eastern border of Texas, to the Wichita Falls area, to the Del Rio area and with incidental collections along the northern panhandle of Texas. We are able to deduce that the collections occurring in the northern regions of Texas are a result of receiving cattle from Oklahoma. Also, the border counties of South Texas receive cattle from Mexico. Counties with the highest frequency distribution (Figure 2) were in the eastern part of the state demarcated by the Trinity River. Collection frequencies by county gradually decreased toward the western regions of Texas possibly displaying an association with the climate of Texas. I compared the county collection frequency data with a map of the annual precipitation data of Texas (Figure 3), and found that higher precipitation from west to east was positively associated with the distribution of tick collections. A similar comparison was made with a map of the ecoregions of Texas (Figure 4) which interprets climatic zones in an ecological context including diversity and abundance of vegetation communities. The eastern portion of Texas that yielded the greater frequency of *I. scapularis* collections was located within the ecoregions of the East Texas pineywoods, Gulf Coast prairies and marshes, Post oak savannah and Blackland prairies. Seasonal activity of adult *I. scapularis,* the period in which adult ticks are most active,was assessed by the mean monthly number of collections (Figure 6). While collections were made throughout the year, the highest numbers of collections occurred between the months of October through March (Figure 6). The months of June had a mean collection of 5, July and August had a mean collection of 6 and September had a mean collection of 11.

Figure 7 displays a subset of the tick collection frequencies east of the Trinity River from 1990-2012 and shows that this major data subset is not dissimilar to the overall state data in the same period. Figure 8 displays a further subset for the collection frequencies from 2000-2012 to coincide with available drought stress data from the National Drought Monitor. Figure 9 summarizes the frequency of counties in which drought stress was equal to or exceeded severe or extreme categories for each year, while Figure 10 summarizes the frequency of counties by year in which drought stress equaled or exceeded severe or extreme categories from February to July, the annuall period in which immature *I. scapularis* ticks would be active. There was a positive association between tick collections and drought stress when these data were overlaid (Figure 8 with 9), and similarly with (Figure 8 with 10). The drought periods that occurred in the years of 2000, 2005, 2006 and 2011 (Figures 9 and 10) coincided with corresponding decreases in the number of collections of adult *I. scapularis* suggesting that these extended and severe dry periods have detrimental effects on the general population of host-seeking ticks.

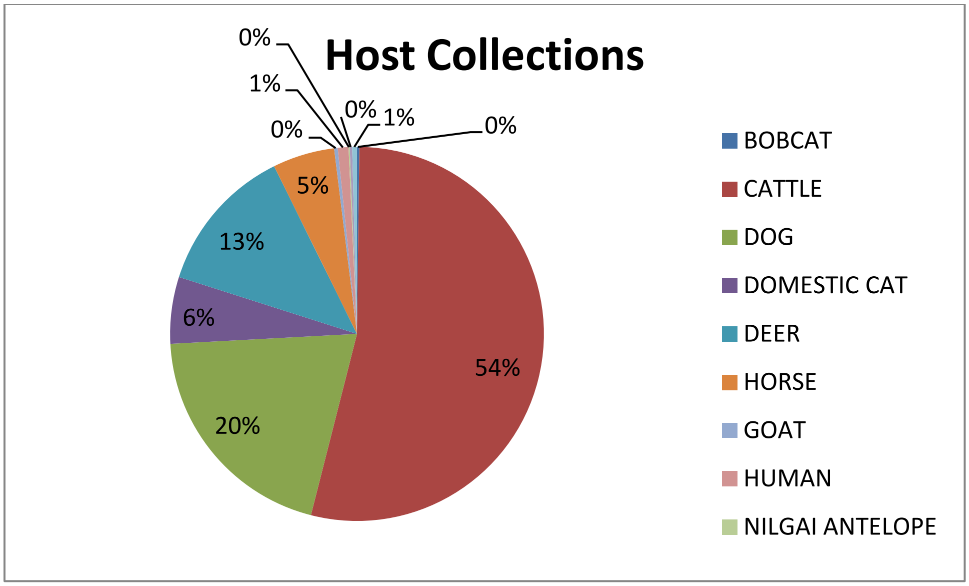

Figure 1: Frequency distribution of hosts associated with collections of Ixodes scapularis in the state-federal tick surveillance program for Texas from 1990-2012.

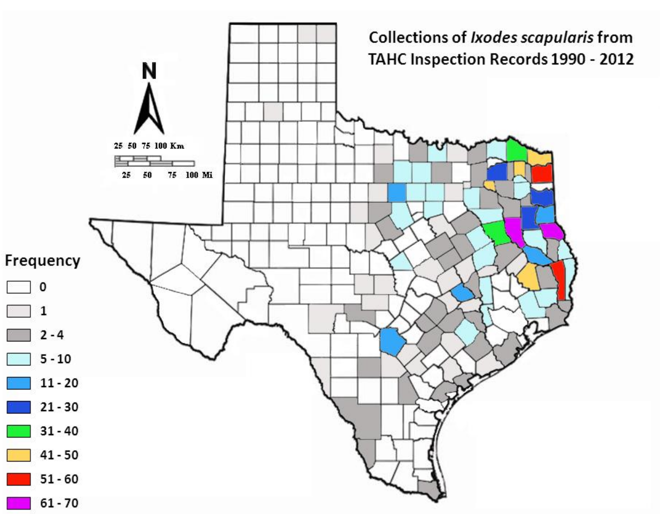

Figure 2: Geographic distribution of county frequency counts of adult Ixodes scapularis collections from the state-federal tick surveillance program 1990-2012.

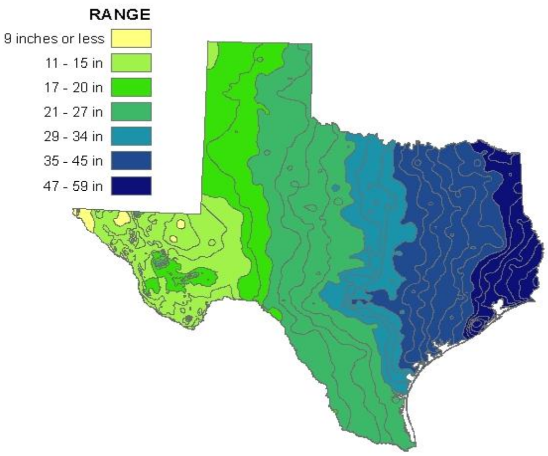

Figure 3: Range in annual precipitation data for Texas

http://www.worldatlas.com/webimage/countrys/namerica/usstates/weathermaps/txprecip.htm

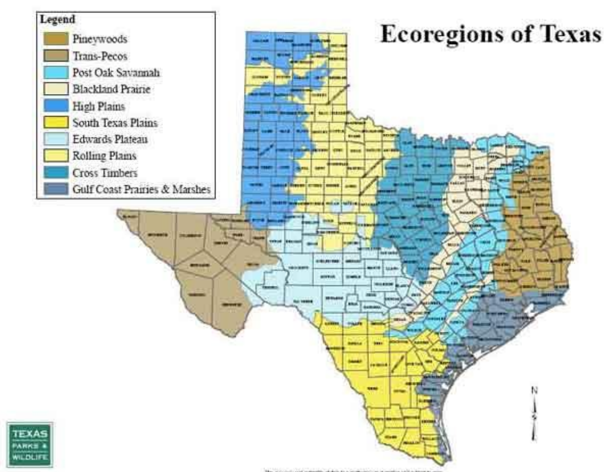

Figure 4: Ecoregions of Texas

http://www.tpwd.state.tx.us/huntwild/wild/wildlife_diversity/wildscapes/ecoregions/

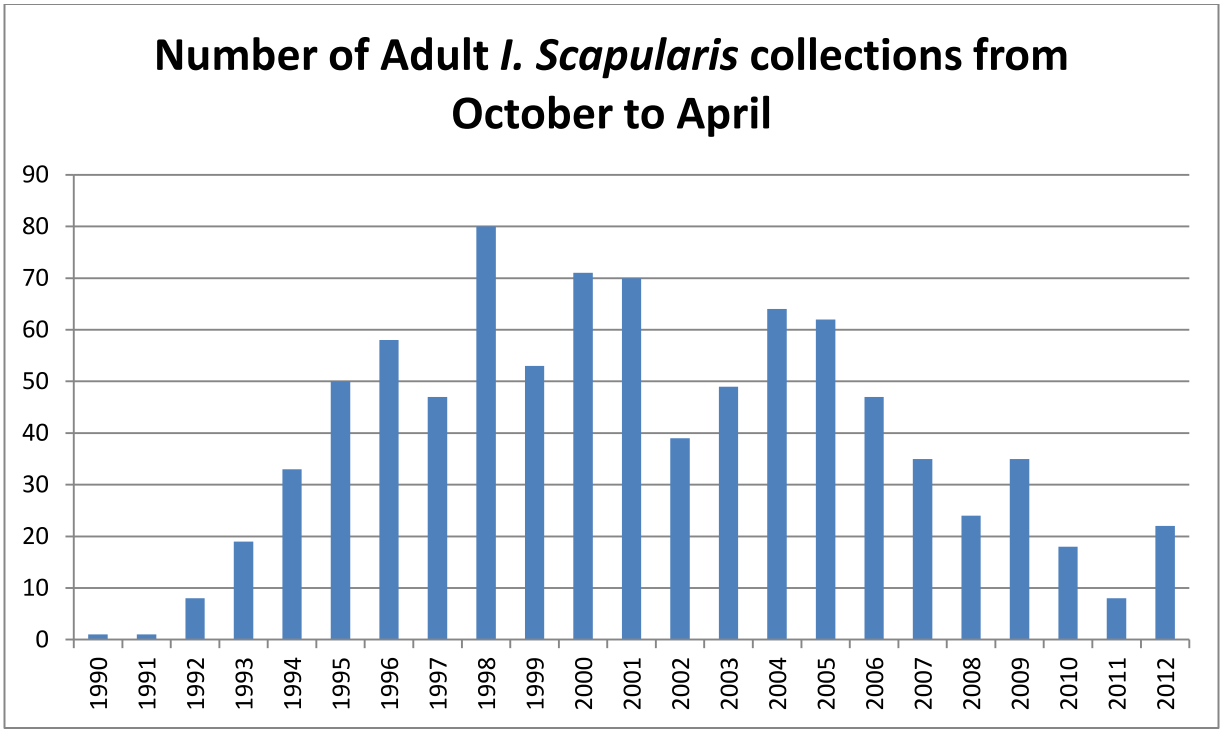

Figure 5: Summary of annual collections of adult *Ixodes scapularis* from 1990-2012 between the months of October to April.

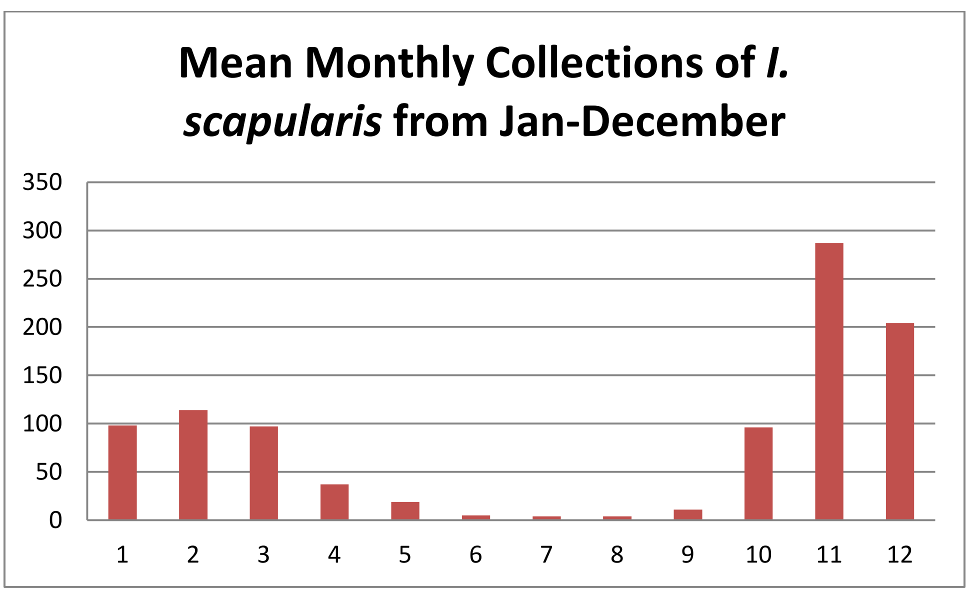

Figure 6: Mean monthly collections of adult Ixodes scapularis in Texas from January (1) through December (12) for all state federal collections obtained 1990-2012.

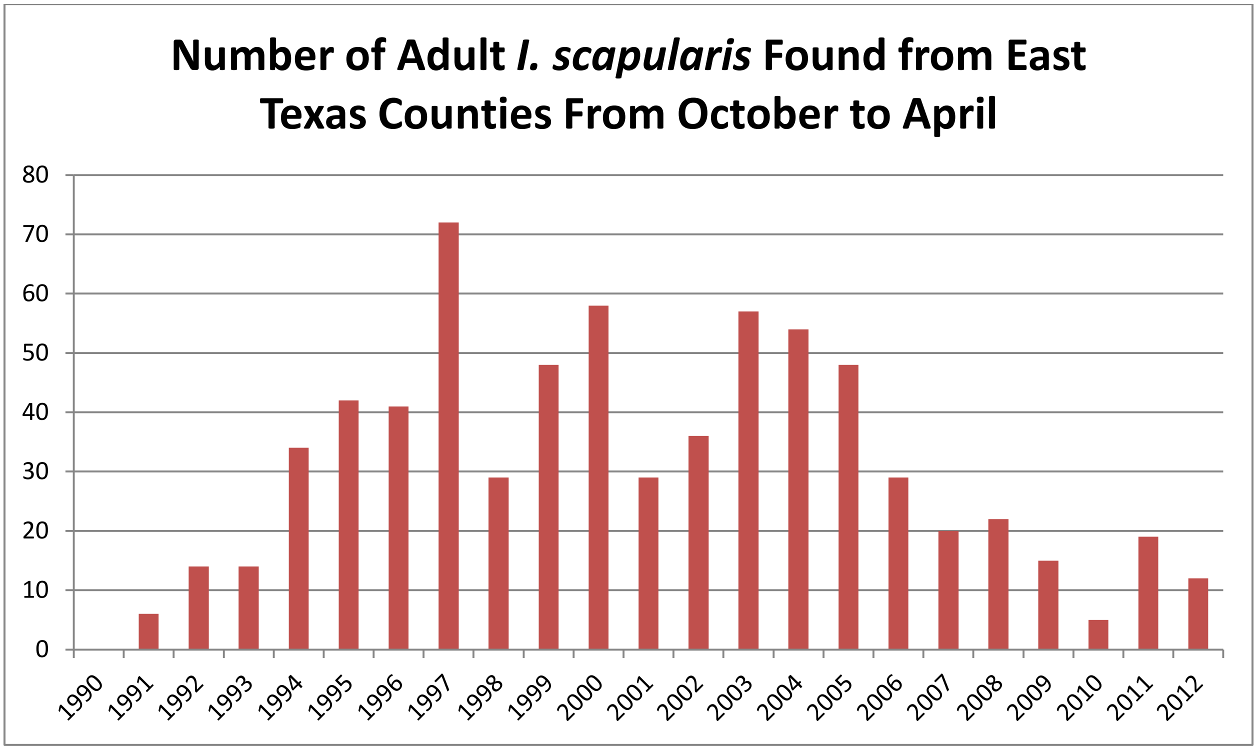

Figure 7: Summary of annual collections of *I. scapularis* found only in counties east of the Trinity River in Texas between the months of October through April for the 22 year period 1990-2012.

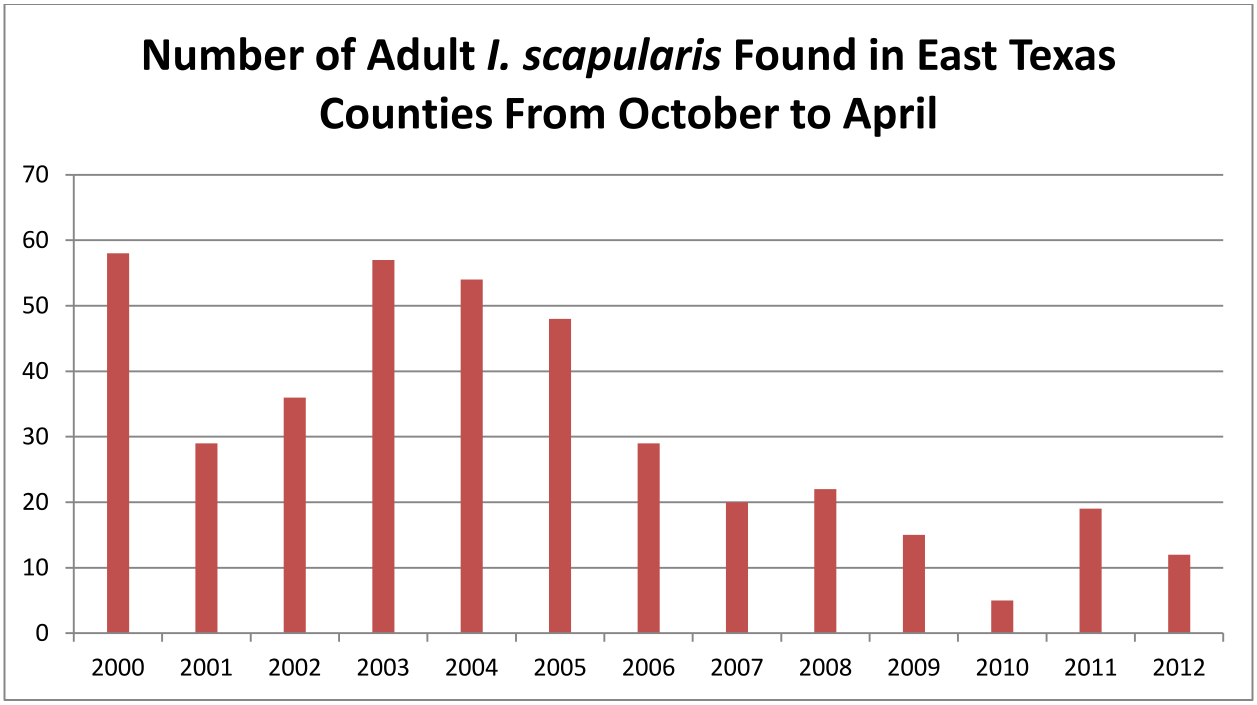

Figure 8: Summary of collections of *I. scapularis* found only in counties east of the Trinity River in Texas between the months of October through April only from 2000-2012.

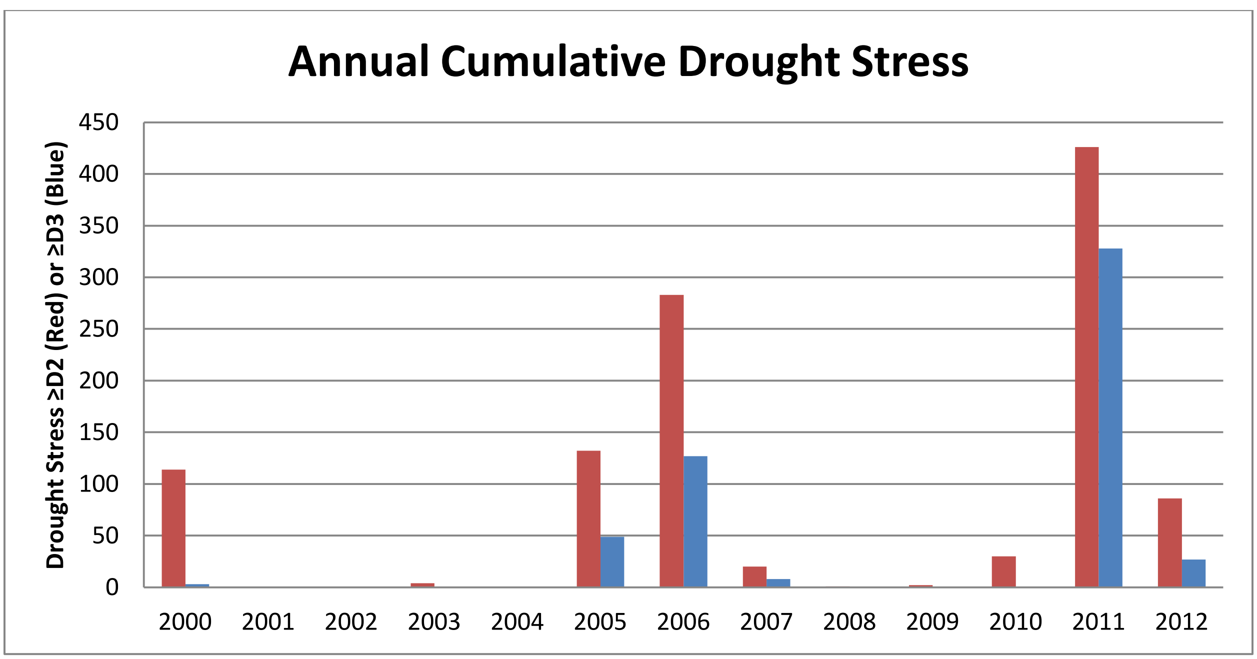

Figure 9: Summary of the number of times counties east of the Trinity River equaled or exceeded monthly drought stress ratings from severe (D2) through exceptional (D4) by year.

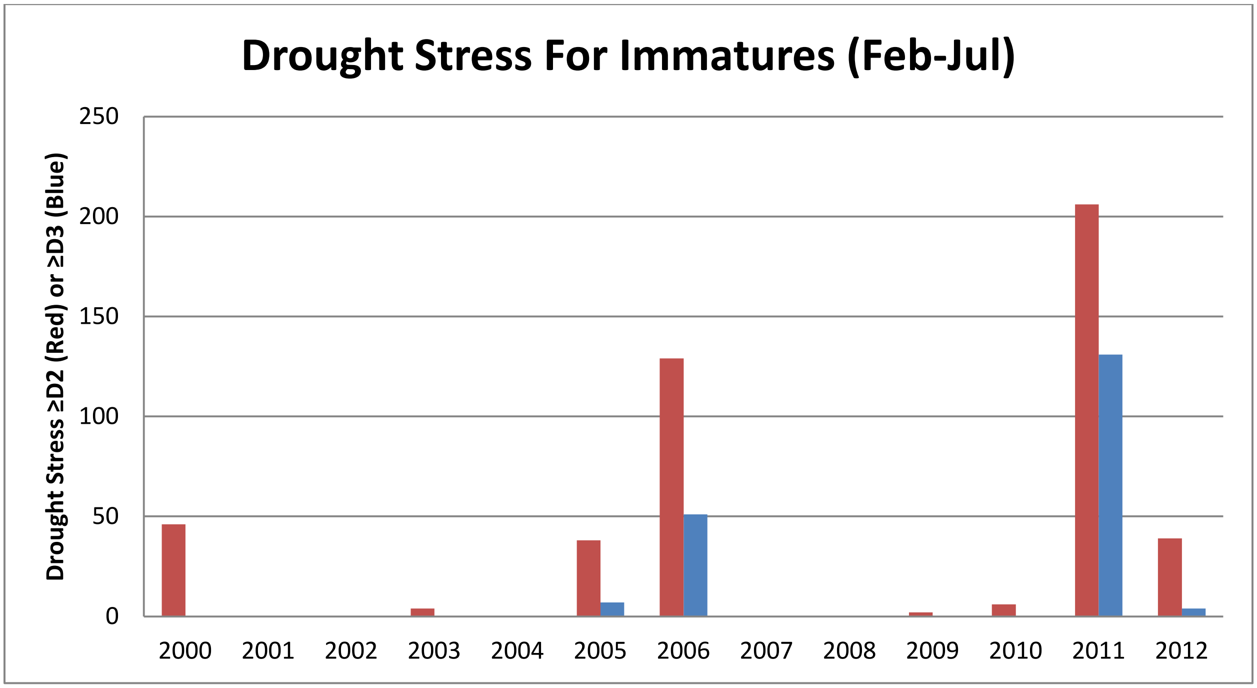

Figure 10: Summary of the number of times counties east of the Trinity River equaled or exceeded monthly drought stress ratings from severe (D2) through exceptional (D4) for the corresponding months of February to July.

CHAPTER IV

CONCLUSION

Our findings provide a quantitative assessment of the overall geographic and spatial distribution of *I. scapularis* in Texas. The distribution of *I. scapularis* appears limited by precipitation and other climatological factors arranged west to east in Texas and are reflective of ticks that are more commonly associated with comparatively mesic environments (Needham and Teel 1991).

The number of collections by year show a continuous fluctuation in tick populations. Annual collections throughout Texas yielded results that displayed adult tick seasonality to be highest between the months of October through March (Figure 6). This correlates to the physiological and ecological data we currently know in that this tick is a three host tick and spends approximately 90% of its life cycle off host. Eastern counties in Texas, east of the Trinity River, were found to be wetter in cyclical climate according to the U.S. Drought Monitor Archives. As figure 9 and figure 10 display, overall drought stress was moderate and did not exhibit great drought stress except in the years of 2005, 2006 and 2011. When overlaid with the collection subset data found in figure 8, tick populations started to decline during the years where drought stress was evident, thus displaying an association between the higher frequency of tick populations and counties with mesic environments or drought stress during the years that displayed drought stress.

In conclusion, our evaluations show that drought stress is associated with substantial impacts on the survival rate of this tick. My findings were comparable and in line with the conclusive data Gray (2007) presented in that seasonal activity changes in response to rising temperatures. Brownstein et al. (2005) also displayed how a climate based prediction can provide some evidence of future distribution of ticks. As such, the survival of this tick is based on desiccation susceptibility of *I. scapularis*, associated with water balance characteristics; *I. scapularis* is a very leaky tick. Due to its physiological characteristics, this makes the tick very vulnerable to water loss during its off host period. Mesic environments are clearly more preferable to its survival. Thus cyclical drought stress is associated with declines in estimated population changes.

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