THE RELATIONSHIP BETWEEN INCREASE IN DENGUE FEVER CASES AND WEATHER VARIATION IN TEXAS, 1995-2003

THESIS

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CHAPTER I

INTRODUCTION

Background

In 1780, Dengue Fever (DF) was first documented in response to the observance of the Philadelphia, PA, epidemic (Monath 1994). DF, an acute viral disease, and other arboviral diseases have seen a marked re-emergence on a global scale in the past two decades (Gubler 2002). Arboviruses are arthropod-borne diseases spread to humans and animals alike by tick and/or mosquito vectors (Solomon and Mallewa 2001). Primarily, the *Aedes* mosquito is the vector responsible for the transmission of DF. The international health community considers DF to be the flavivirus of greatest concern worldwide (Solomon and Mallewa 2001; Hales *et al.* 2002). The Flaviviridae family consists of close to seventy viruses, with notable examples including the viruses that cause Yellow Fever and West Nile. Millions of people suffer annually from one of the four serotypes of the virus, with tropical regions bearing the largest impact (Monath 1994; Hales *et al.* 2002). Incidence patterns of DF are seasonally cyclical; pointing to the possibility that virus transmission is affected by climatological factors (Kuno 1997; Keating 2001).

The *Aedes aegypti* species is the predominant DF vector in the state of Texas and it is well suited to living in areas of high human population density (Hales *et al.* 2002).

They breed in containers holding standing water such as birdbaths, discarded tires, gutters, toys, and flowerpots. Dengue transmission occurs through the bite of an adult mosquito already infected by a blood meal containing the virus. A blood meal involves the vector feeding on human or animal blood for sustenance. The vector can only pass the virus to a susceptible person after becoming infective, which requires an incubation period of 10–12 days (Rigau-Perez *et al.* 1998).

Presently, there is no vaccination or drug therapy approved to manage DF. Vector eradication and control strategies are the only reliable means with which to manage the disease before an outbreak occurs. The Americas discontinued large-scale mosquito eradication measures in the 1970s after a precipitous decrease in disease incidence (Monath 1994). Since the *Aedes* mosquito eradication program was discontinued in the 1970s, the mosquito is reinfesting many areas, and according to the Centers for Disease Control (CDC), its spatial distribution is now more extensive than before eradication efforts began (Centers for Disease Control and Prevention 2003). Health agencies worldwide have documented a resurgence of the disease in the past decade. Although Dengue Fever is not yet considered endemic (prevalent) in the United States, there have been cases documented in Texas, Florida, and other southeastern states. The northward trend in Dengue Fever distribution is attributed to factors such as global warming and travel, which facilitate the distribution of the responsible vector and bring people into endemic regions (Hales *et al.* 2002).

Temperature is a major limiting factor related to the survival and functionality of the *Aedes aegypti* mosquito. The temperature in which the mosquito actively breeds and feeds ranges from 68 to 102 degrees Fahrenheit.

Their range for peak functionality is approximately 80 to 87 degrees Fahrenheit. When temperatures reach 50 degrees Fahrenheit on the low end and 102 degrees Fahrenheit on the high end, the vector becomes motionless or inactive. Temperatures below 32 degrees Fahrenheit or above 105 degrees Fahrenheit are fatal to the species.

CHAPTER II

STATEMENT OF THE PROBLEM

Purpose

The purpose of this study is to determine whether a relationship exists between temperature and precipitation variability in Texas and the occurrence of Dengue Fever (DF). As Diaz and McCabe (1999) point out in their research on Yellow Fever, a virus spread by the same vector as DF, the presence of optimum climatic conditions appears to assist in development and dispersal of vector-borne disease. The working hypothesis for this study is that an above-average number of DF cases occurs during years with climatic conditions favorable to *Aedes aegypti* functionality. In this study, I intend to discern whether there is a connection between the number of DF cases and changes in minimum and maximum mean monthly temperature, extreme high and low monthly temperature, and total monthly precipitation for affected Texas counties during the timeframe 1995 to 2003.

Significance of Study

Dengue Fever is a re-emergent threat to public health on a global scale, and considering the significant outbreaks of the virus in Texas up until the 1950s, investigation of factors related to its spread are valid areas of inquiry.

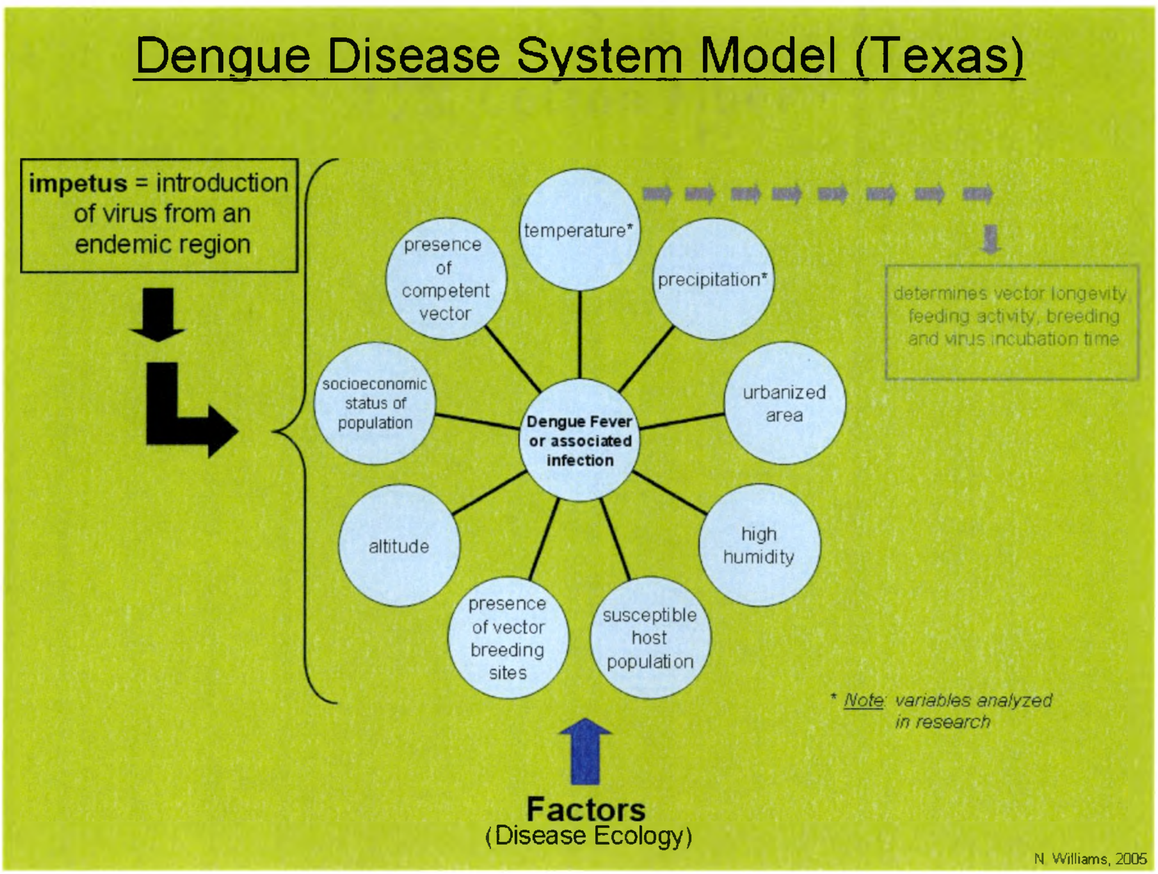
Previous research on DF in Texas has not taken the approach of trying to distinguish differences in temperature and precipitation patterns of high incidence years versus other years for a particular period. Most studies focusing on Texas have examined several disease factors associated with a single year or outbreak duration. Some recent studies focus on socioeconomic and relevant lifestyle factors that appear to influence DF transmission but do not attempt to better define the variables of the physical environment that support the vector. The perception is that DF is a disease of the tropics, and while that assumption is generally true, documented outbreaks have occurred in temperate regions. Moreover, proponents of global warming speculate that rising temperature will allow the spread of vector-borne tropical diseases to trend northward, thus becoming endemic in new areas with non-immune populations. My study examines the two environmental factors, temperature and precipitation, which are key vector support components in the DF disease system. Some of the cases in Texas are the result of autochthonous (indigenous) transmission. This study looks into the influence of climatic conditions on infection incidence.

Theoretical Framework

My research seeks to assess the relationship between temperature and precipitation variation on cases of DF in Texas. Landscape epidemiology, the paradigm underpinning my research, posits that by defining the disease ecology (cultural and environmental) parameters for the maintenance of particular pathogens, it is possible to relate the disease system variables to the spatiotemporal risk of virus transmission (Center for Health Applications of Aerospace Related Technologies 2005).

Environmental variables such as temperature, rainfall, and humidity influence vector breeding, feeding, development, and life expectancy. When coupled with behavior, socioeconomic status, and other human factors, the dynamics of the disease system relate to the risk of transmission (Figure 1).

Figure 1. Dengue Fever Disease Ecology Model. The model below illustrates the disease ecology factors associated with Dengue Fever transmission based on the principles of landscape epidemiology.



CHAPTER III

LITERATURE REVIEW

I have organized the literature pertaining to Dengue Fever into two separate sections. The first section investigates the linkages between the disease and weather and climate variation (e.g., temperature, precipitation, and humidity). The second concentrates on DF outbreaks and cases in Texas, the United States, and other countries in close geographic proximity.

Weather Variation

Yellow Fever is a viral disease of the same family as Dengue Fever, also transmitted by the *Aedes aegypti* vector. The summer of 1878 saw a widespread outbreak of Yellow Fever (YF) in the southern part of the United States. Diaz and McCabe (1999) posit that the YF outbreak of 1878 is connected to the El Nino event of 1877-1878 that caused notable climate variability. Due to their viral family relation and shared vector, variables that affect YF are valid areas of inquiry for DF causation. Diaz and McCabe (1999) also speculate that the higher than normal precipitation in months prior to YF outbreaks combined with warm temperatures from spring through the summer contributed to above normal mosquito concentration.

Mosquitoes proliferate in wet and humid environments. Mosquito development and frequency of blood meals from which they acquire parasites and viruses are regulated by temperature (Patz *et al.* 2000). The increase in vector concentration should logically lead to an increase in disease incidence in areas of non-immune human population.

The established fact that temperature governs mosquito activity makes it a prime variable to focus on when studying the spread of mosquito-borne diseases. Dengue transmission follows a cyclical (seasonal) pattern in Puerto Rico, with higher incidents occurring in the months September through November, which are normally higher in temperature and humidity (Rigau-Perez *et al.* 1994; Keating 2001; Rigau-Perez *et al.* 2001).

The potential exists for disease importation due to the perpetual presence of the Dengue vector *Aedes aegypti* in southern Texas coupled with frequent cross-border transportation (Centers for Disease Control and Prevention 1996). In addition, Central American and Caribbean countries experienced epidemics of DF in 1995. This trend is reflected in the higher than average number of infections reported in Texas in the same year (Centers for Disease Control and Prevention 1998). Virus importation is not limited to areas of shared borders in this age of global transportation. Travelers can bring Dengue back to Texas from any number of foreign tropical/subtropical locations. Once introduced, it is possible, given the climate in Texas, that the conditions will be right to spread DF to a susceptible population through mosquito bites.

Geographic Proximity

DF epidemics have occurred throughout the Americas including Mexico and several Caribbean islands. Due to the close spatial proximity of epidemics in other countries, the possibility of disease infection exists for Texas. Past DF epidemics caused high morbidity rates in Texas (Rawlings *et al.* 1998). DF infected more than 40,000 Texans in 1922, but for the next 26 years, outbreaks were reported as affecting less than one thousand people, with the average being 78 cases annually (Rawlings *et al.* 1998). Between 1950 and 1980, the disease disappeared from the Texas medical landscape, but unfortunately, during the 1980s, reports of DF reemerged in Texas. More than one-third of the patients diagnosed with DF in the 1980s did not have a recent history of international travel, thus suggesting autochthonous (indigenous) transmission of the disease (Rawlings *et al.* 1998). This trend continued in the 1990s. The persistent trend of locally acquired infections suggests that DF might be endemic in the state of Texas. DF continues to be a public health issue in neighboring countries. "In 1995, there were reports of more than 189,000 cases of Dengue in South America, 68,000 in Central America, and 17,000 in Mexico" (Rawlings *et al.* 1998, 95).

The urban occurrence of Dengue infection is common in the Americas but has been infrequent in the last 50 years in the United States. However, in 1999, an outbreak affected Nuevo Laredo, Tamaulipas, Mexico, and Laredo, Texas, which is effectively a single city divided by the U.S./Mexico border (Centers for Disease Control and Prevention 1996; Reiter *et al.* 2003).

Dengue Fever "is the most prevalent mosquito borne disease in the world" (Cheng 2000a, 1).

It is commonly assumed that areas having an appropriate climate and a population of competent vectors will promote widespread Dengue infection. Moreover, the assertion is that global warming will allow the disease to move higher in latitude and altitude (Cheng 2000b; Reiter *et al.* 2003).

Currently, health researchers have not reached a consensus on DF being endemic in Texas. Cheng (2000b) asserts that the disease is moving further northward. Dr. Diane Griffin, a researcher at the John Hopkins University School of Public Health, states that she would not be surprised if DF is endemic in Texas (Cheng 2002b). However, Gary Clark, chief of the Centers for Disease Control and Prevention, Dengue Branch, in San Juan, Puerto Rico, asserts that Dengue infection is limited to the months of August through December in southern Texas and manifests in small outbreaks attributed to cross-border migration (Cheng 2000b). Julie Rawlings, an investigator with Texas Department of State Health Services (TDSHS), asserts that local transmission of DF has increased recently in frequency and scope, but more cases contracted during peak season are required to consider it endemic (Cheng 2002b). Mitigating factors on transmission such as air conditioning, higher standards of sanitation, fewer people occupying living quarters, and the likelihood of people to remain indoors during summer days, in Texas relate to socioeconomic and behavioral patterns outside the scope of this study.

Although Florida is also within close proximity to countries with outbreaks, it has not yet seen a persistent pattern of autochthonous outbreaks (Gill *et al.* 1999; Gill *et al.* 2000). This is of interest because parts of Florida have similar temperature and humidity conditions to affected areas of Texas. However, Florida is outside of the spatial range for this study.

IV

STUDY DESIGN

Method

My study identifies years and regions during the study period that have above-mean incidence of DF. Therefore, the starting point is determining whether there are years and areas with above-mean incidence. To make that distinction, I calculated the baseline (mean) incidence of locally acquired DF over the study period and compared the mean to the number of cases each year. Three main regions took shape from clusters of adjacent counties with disease incidence: Brownsville, Dallas, and Laredo. Next, I chose a representative weather station from each region with elevated DF incidence to serve as the norm for the variables monthly mean minimum temperature, monthly mean maximum temperature, and total monthly precipitation (Table 1). Then, the temperature and precipitation mean values for each designated region were compared over the study range using the independent-samples t test procedure with a 95% confidence interval. Using the independent-samples t test, the comparison was made between years with no cases versus years with cases of DF. Output from the t test analysis provides evidence regarding whether or not the difference of means is statistically significant.

The null hypothesis for this study states that there are no differences in weather variables (temperature and/or precipitation) for years with less than or equal to baseline DF cases versus years with greater than average cases of Dengue.

Using this method, I expect to affirm my research hypothesis, asserting a difference between high and low incidence years, by quantifying the relationship between DF and weather variation. In addition to statistical analysis, I examined the data variables monthly extreme minimum and maximum temperature to determine whether they exceeded the vector's survival parameters. I also reviewed the Texas Department of State Health Services (TDSHS) data, which includes information on county, race, age, sex, and travel history of those diagnosed with DF for associated demographic trends.

In order to prepare the data obtained from the National Climatic Data Center and the TDSHS for analysis, I imported the information into Excel spreadsheets to form a database. After formatting the data in Excel, I imported it into SPSS to perform statistical analyses, including mean average calculations and independent-samples t testing. Spatial representations of the data were achieved using ArcGIS 9.0. I created a compilation map displaying the location of counties reporting cases of Dengue Fever from 1995 through 2003. County basemap coverages and shapefiles were available, at no expense, from the Texas Natural Resources Information System (TNRIS) digital download webpage.

Hypotheses

Research Hypothesis

During the period 1995 to 2003, the occurrence of years with above-average cases of Dengue Fever is due to anomalies in temperature and precipitation that made conditions optimal for the *Aedes aegypti* mosquito to transmit the disease.

Working Hypotheses

a. During years of higher than average Dengue Fever incidence, the extreme monthly temperatures do not exceed the vectors' survival parameters.

b. The winter months preceding a year with higher than average incidence of the disease exhibit milder than normal winter temperatures for the study period.

c. Years of increased incidence experience higher than average precipitation on a monthly basis.

d. Years of increased Dengue cases in Texas coincide with outbreaks/epidemics internationally, specifically in Mexico.

e. Most of the people infected by DF in Texas had recently traveled to an endemic country or reside in a county that borders Mexico.

Statistical Hypotheses

a. Null Hypothesis: There is no difference between years with greater than average cases of Dengue Fever and years with less than or equal to average DF cases regarding the variables of extreme minimum temperature for the month, extreme maximum temperature for the month, monthly mean minimum temperature, monthly mean maximum temperature, and total monthly precipitation.

b. Alternative Hypothesis: Years with greater than average cases of Dengue Fever are not equal to years with less than or equal to average DF cases regarding the variables of extreme minimum temperature for the month, extreme maximum temperature for the month, monthly mean minimum temperature, monthly mean maximum temperature, and total monthly precipitation.

Study Area

My study area for this research is the state of Texas, more specifically the twenty-four counties in Texas with reported incidence of Dengue Fever from 1995 through 2003 (Figure 2). The counties included are Bastrop, Bell, Bexar, Cameron, Comal, Collin, Dallas, Denton, Ellis, El Paso, Fort Bend, Galveston, Harris, Hays, Hidalgo, Lubbock, Nueces, Rusk, Starr, Tarrant, Travis, Waller, Webb, and Willacy. Out of the twenty-four, only fifteen counties documented locally acquired DF cases (Figure 3). Three main regions exhibit higher disease incidence during the study range: Brownsville, Dallas, and Laredo.

The Brownsville region (Starr, Hidalgo, Willacy, and Cameron counties), is in south Texas along the US/Mexico Border. Also, in south Texas, not adjacent to the Brownsville region but sharing a border with Mexico is the Laredo region (Webb County). In northeastern Texas is the Dallas region consisting of Denton, Collin, Tarrant, Dallas, and Ellis counties.

Figure 2. Dengue Fever Cases, 1995-2003. The map below illustrates the spatial distribution of counties affected by the disease for the timeframe 1995-2003.

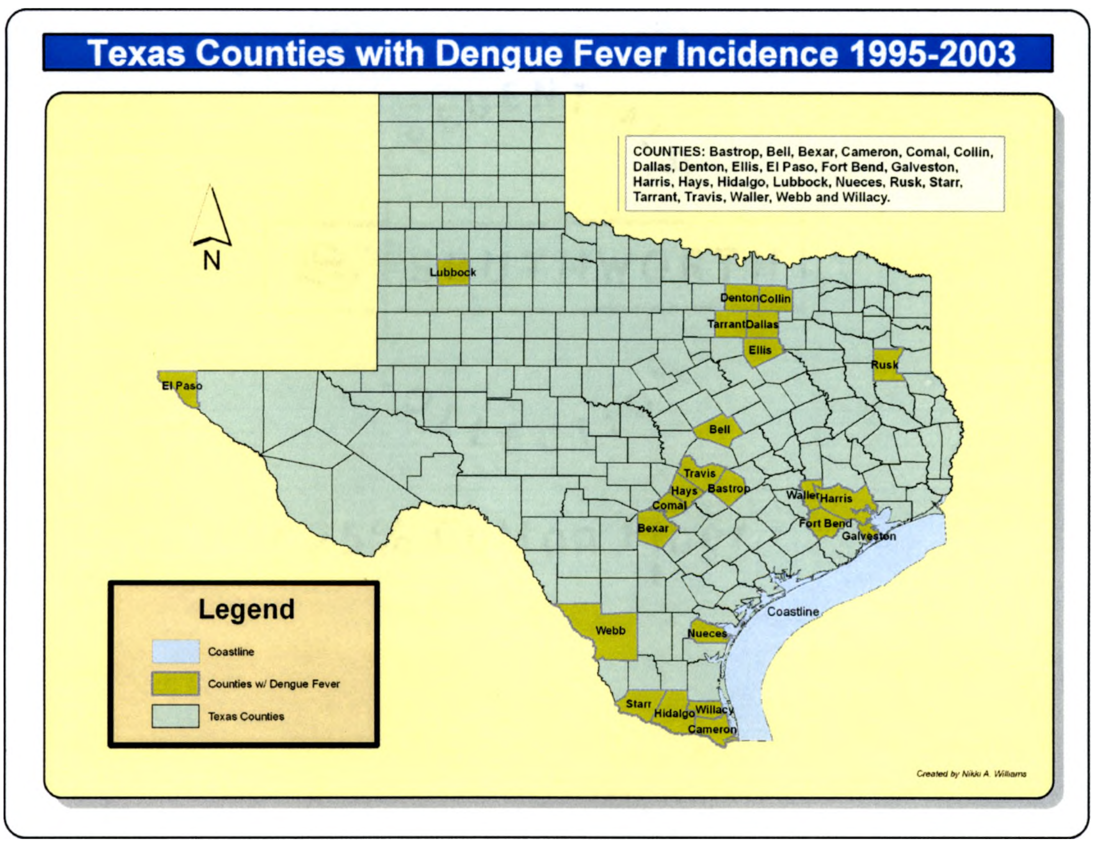
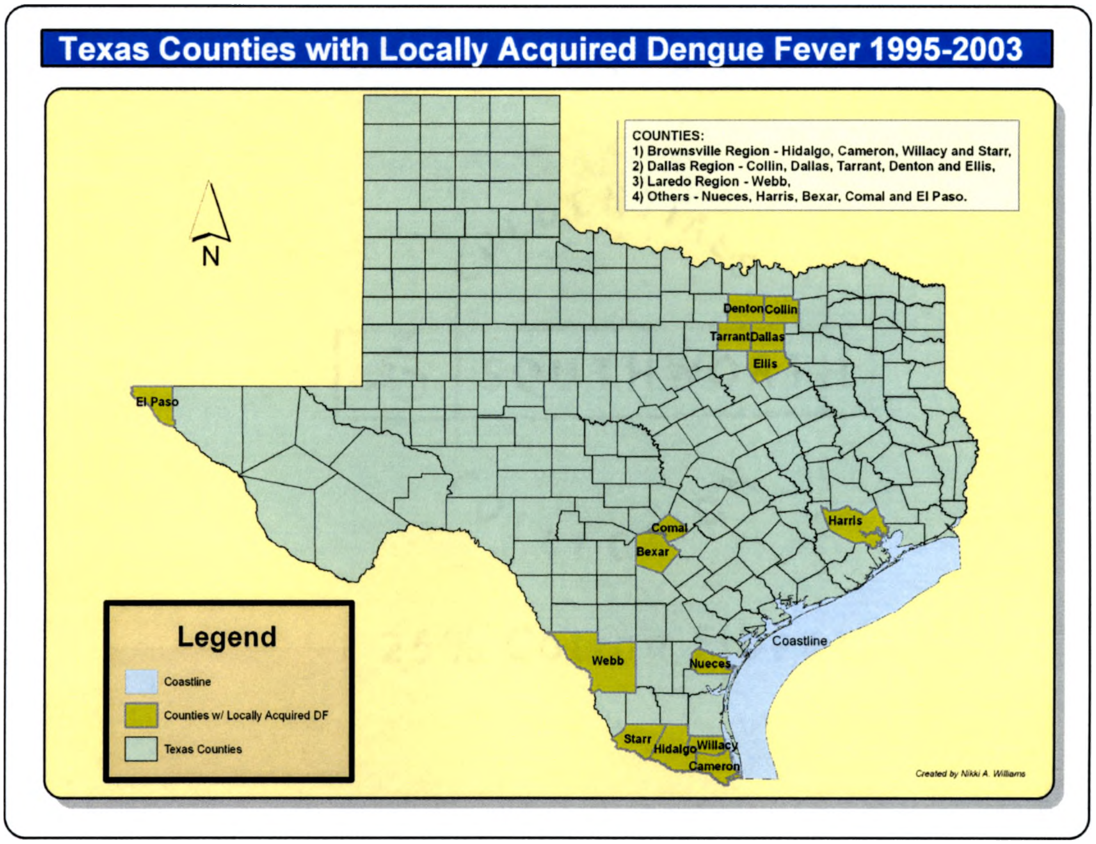


Figure 3. Locally Acquired Dengue Fever Cases, 1995-2003.



Data

The monthly temperature and precipitation data are available from the National Climatic Data Center (NCDC) archives (Table 2). Statistics regarding the incidence of Dengue Fever (DF) are accessible through the Texas Department of State Health Services (formerly the Texas Department of Health) (Table 2). Data from the TDSHS consists of county level data on Dengue cases with supporting demographic information.

Table 1. Weather Stations. The table below displays the county weather stations where the National Weather Service (NWS) collected temperature and precipitation data archived at the National Climatic Data Center (NCDC).

COUNTY	COOP ID	STATION NAME
BASTROP	411541	Cedar Creek 4 SE
BELL	418910	Temple
BEXAR	417945	San Antonio INTL AP
CAMERON	**411136**	**Brownsville AP**[1]
COLLIN	413370	Frisco
COMAL	416276	New Braunfels
DALLAS	412244	Dallas Love AP
DENTON	412404	Denton 2 SE
ELLIS	412925	Ennis
EL PASO	412797	El Paso INTL AP
FORT BEND	418728	Sugar Land
GALVESTON	413430	Galveston
HARRIS	414300	Houston Bush INTL AP
HAYS	419815	Wimberley 1 NW
HIDALGO	415702	McAllen Miller INTL AP
LUBBOCK	415411	Lubbock RGNL AP
NUECES	412015	Corpus Christi INTL AP
RUSK	414081	Henderson
STARR	417622	Rio Grande City 1 SE
TARRANT	**412242**	**Dallas-Fort Worth INTL AP**[1]
TRAVIS	410428	Austin Camp Mabry
WALLER	419448	Waller
WEBB	**415060**	**Laredo 2**[1]
WILLACY	417458	Raymondville

Representative Weather Station:

[1]Weather station measurements used in statistical analysis.

Table 2. Data Sources. The table below describes the data sources, variables, and variable descriptions for the data.

Variable	Description	Source
Dengue Fever cases in Texas	county level data including race, onset date, age, travel status	TDSHS
Extreme minimum temperature for month	minimum temperature	NCDC
Extreme maximum temperature for month	maximum temperature	NCDC
Monthly mean minimum temperature	average minimum temperature	NCDC
Monthly mean maximum temperature	average maximum temperature	NCDC
Total monthly precipitation	cumulative precipitation	NCDC

1) Disease data for each DF case in Texas from 1995 to 2003 at the county level (TDSHS)
   a. County: The unit of measurement for the spatial analysis of Dengue Fever in Texas.
   b. Race: The race of the patient might expose tendencies or rate disparities in disease infection.
   c. Date of Disease Onset: When do cases occur and what was the climate like in the months preceding disease incidence?
   d. Age of Patient: Are certain age groups more susceptible to infection?
   e. Travel Status: Did the infection occur locally or did the patient bring it back from an endemic country?

2) Climate data 1995-2003 for Texas counties with DF cases (NCDC, http://www.ncdc.noaa.gov/oa/ncdc.html)
    a. Extreme minimum temperature for the month (EMNT)
    b. Extreme maximum temperature for the month (EMXT)
    c. Monthly mean minimum temperature (MMNT)
    d. Monthly mean maximum temperature (MMXT)
    e. Total monthly precipitation (TPCP)

Definitions and Measurements

1. A probable case of Dengue Fever is defined by diagnosis of an illness consistent with DF in conjunction with a positive antibody test on a serum specimen. Confirmed case definitions follow the same guidelines as probable cases while adding any of three criteria: a) isolation of one of the four virus serotypes, b) fourfold change in antibody titers (the concentration of a substance in solution determined by titration), or c) detection of virus antigen (Rigau-Perez *et al.* 1994).
2. Definition of the five weather measurement variables:

    a) EMNT - Extreme minimum temperature for the month in degrees Fahrenheit

    b) EMXT - Extreme maximum temperature for the month in degrees Fahrenheit

    c) MMNT - Monthly mean minimum temperature in tenths of degree Fahrenheit

    d) MMXT - Monthly mean maximum temperature in tenths of degree Fahrenheit

    e) TPCP - Total monthly precipitation in hundredths of inches

Limitations

The major limitations associated with my research are due to both TDSHS and NCDC data inadequacies of availability, time range, and completeness. Data on DF is only available from the TDSHS from 1995 through 2003, a definitive factor in establishing the time range for my study. The study range and small number of cases decreases the statistical power of my research results. In addition, DF data from the TDSHS is only available at county-level resolution without clearance through a lengthy security process to obtain finer scale information. Medical confidentiality is an important precaution; it protects patients from being identified by censoring public access to records documenting reportable diseases. DF is one of many diseases that the state of Texas requires TDSHS notification on if a medical professional encounters a confirmed or suspected case. The initial flu-like symptoms, coupled with a general lack of familiarity with the disease in the United States, increases the likelihood of underreporting of DF infections to the TDSHS (Cheng 2000b). Possible record duplication is another issue encountered with the data. Disease underreporting and duplication affect data accuracy by introducing error into the equation before statistical analysis. Other shortcomings of the TDSHS data include incomplete collection of both recent travel history and race of those infected with the virus. In addition, due to data inconsistencies, I assume that cases lacking travel history information as well as those with an unknown travel history are locally acquired.

The temperature and precipitation data from NCDC suffered from missing measurement values.

No data are available for Ellis County for the entire study period. Bastrop County was missing mean minimum/maximum temperature variable for 1995-2000 and precipitation for 1999. Collin and Hays counties' mean minimum and maximum temperature variables were absent, leaving only the precipitation variable. The data for Waller County had the same temperature variable shortcomings, in addition to missing the precipitation variable for 1999-2003. Galveston County did not have mean minimum/maximum temperature or precipitation variables for 2002. Hidalgo County was missing minimum/maximum temperature or precipitation variables for 1997-1998. Throughout the data set, there were random values missing which were not taken into consideration in mean calculations or statistical analysis (t testing). Missing data introduces error into every calculation and statistical test in this study. In my study missing data values were excluded from statistical calculations.

My study investigates temperature and precipitation variables, it is not designed to take into account all of the disease ecology factors relevant to DF transmission. By focusing primarily on aspects of the physical environment, I am leaving out the vital human part of the disease equation. Thus, the conclusions drawn from this research can at best describe only part story behind the phenomena of incidence increase.

CHAPTER V

RESULTS AND ANALYSIS

Results of t Testing

During the nine years that this study examines, there were a total of one hundred fifty-five cases of DF occurring in twenty-five Texas counties. Out of the one hundred fifty-five cases, only fifty-two were locally acquired (Appendix A). In 1995, seven indigenous cases of the disease were confirmed in two counties: Hidalgo (4) and Cameron (3). DF was not transmitted in Texas during 1996. The three people who contracted the virus in 1997 lived in Hidalgo (2) and Cameron (1). 1998 saw two patients in Cameron (1) and Hidalgo (1). The year 1999 experienced twenty cases spread across nine counties: Webb (9), Cameron (3), Dallas (2), Willacy (1), Starr (1), Nueces (1) Bexar (1), Harris (1), and Hidalgo (1). No local incidences of DF were reported in 2000. In 2001, two counties, El Paso (1) and Comal (1), documented two cases of the disease. Eight incidences occurred in 2002, in Dallas (5), Bexar (2), and Tarrant (1) counties. Five counties, Denton (3), Cameron (3), Collin (2), Ellis (1), and Dallas (1), confirmed ten cases of DF in 2003. For the study period, the mean annual incidence of indigenous DF in Texas is approximately six cases. Half of the years under investigation fall below the annual mean, but 1995 (7 cases), 1999 (20 cases), 2002 (8 cases), and 2003 (10 cases) were higher.

Overall, three regions comprise 86.5% of the locally acquired DF cases between 1995 and 2003. The Brownsville region (Starr, Hidalgo, Willacy and Cameron) in south Texas had 40.3% of DF cases. The Dallas region (Denton, Collin, Tarrant, Dallas, and Ellis), experienced 28.9% of the infections. And the remaining 17.3% of the reported cases were diagnosed in Webb County, the Laredo region. The other cases did not cluster in any particular geographic region; instead, they were distributed over El Paso, Nueces, Bexar, Comal, and Harris counties (Appendix A). The variable means, monthly mean minimum temperature, monthly mean maximum temperature, or total monthly precipitation, were not different by a statistically significant margin from the regional norm (Appendix B-J).

Monthly Mean Maximum Temperature

For the variable monthly mean maximum temperature, the Brownsville region measurements were one to three degrees cooler for years with DF versus years without. November and December were the exception, having mean values for case years slightly warmer than non-case years (Appendix B). The Dallas region is split; January, March, April, August, November, and December had higher means for case years, while February, May, June, July, September, and October saw lower values for affected years (Appendix E). Except in June, the Laredo area DF years had higher temperature means than non-case years by one to six degrees (Appendix H).

Monthly Mean Minimum Temperature

March, June, and November experienced higher monthly mean minimum temperatures for case years in the Brownsville region, but January, February, April, May, July, August, September, October, and December had lower minimums than non-case years (Appendix C). For the Dallas region January, February, March, May, June, July, and September minimum values measured lower for DF years. In the same region, April, August, October, November, and December recorded higher minimum temperatures in DF years as compared to non-case years (Appendix F). In the Laredo region, January means were equal; February, March, April, June, November, and December means were higher; and May, July, August, September, and October means were lower than non-DF years (Appendix I).

Total Monthly Precipitation

August, November, and December mean measurements for total monthly precipitation in the Brownsville region are lower for case years versus non-case years. The same area saw higher mean precipitation values for January, February, March, April, May, June, July, September, and October (Appendix D). Precipitation mean values in DF years were lower in the Dallas region for February, March, April, June, July, August, October, November, and December but higher in January, May, and September (Appendix G). In the Laredo region, DF years recorded lower precipitation means for January, February, April, July, September, October, November, and December. In addition, in the Laredo area, March, May, June, and August had higher rainfall means in DF years (Appendix J).

To review, the statistical analysis did not affirm statistically significant mean differences for the variables monthly mean minimum temperature, monthly mean maximum temperature, or total monthly precipitation. All three regions saw lower means in June for the maximum temperature variable during DF years. November means for the minimum temperature variable are consistently higher in DF years, while May, July, and September means are lower. Regarding precipitation means, December and November means measured lower in DF years, but May mean values were higher.

Evaluation of Results and Demographic Trends

The data availability for this study decreased the number of indigenous DF cases, which in turn reduced the statistical power of the t tests. In addition, the environmental conditions in each region display a relative homogeneity. In an attempt to discern weather patterns outside the scope of statistical significance, I examined the temperature and precipitation variables by season, spring (March and April), summer (May, June, July, August, and September), and fall (October and November). I also looked to see whether extreme minimum and maximum temperatures exceeded the vector's lower survival threshold of thirty-two degrees Fahrenheit or the upper limit of one hundred five degrees Fahrenheit. Realizing that weather variation is a fraction of the overall DF disease system, I considered pertinent demographic trends in the data.

Examining the variables monthly mean minimum temperature, monthly mean maximum temperature, and total monthly precipitation from a seasonal perspective also failed to highlight any noticeable patterns.

With few exceptions, the monthly mean minimum and monthly mean maximum seasonal temperature averages fell between fifty and one hundred two degrees Fahrenheit (the vector activity range) for all years (Appendix K and L). Looking at the variable total monthly precipitation on a seasonal basis, no trend emerged concerning years with DF or years prior to case occurrences (Appendix M). Keating (2001) discusses the possibility of peak onset for DF taking place approximately three months after the highest reported monthly mean temperature. His research focus was Puerto Rico, and the same trend did not present itself in Texas over the study period.

The seasonal variation in climate hypothesized to foster virus transmission is consistently present in the three regions investigated and does not explain why the disease occurs in some years and not others. Guha-Sapir and Schimmer (2005) characterize the direct link between weather and increase in vector-borne disease as an oversimplification of disease systems. Moreover, they suggest along with other studies that climate is seldom the key factor associated with vector-borne diseases, and past outbreaks of DF in higher latitudes seem to support that idea (Guha-Sapir and Schimmer 2005). The lack of significant weather differences in case years versus those without points to other factors having influence on the seasonally cyclical nature of DF infections. Variables including artificial containers filled with water in addition to precipitation, susceptible populations due to herd immunity dynamics, and the introduction of new DF serotypes into an area as well as demographic transition may have an impact on the cyclical transmission of the disease (Guha-Sapir and Schimmer 2005; Keating 2001).

Extreme minimum temperature values fell below vector parameters in high incidence years for the Laredo region (1999) and the Dallas region (2002 and 2003).

This breach happened in January, February, and December of all three years, as well as March and November of 2002 and 2003. During above incidence years, extreme maximum temperature measurements exceeded the mosquito survival threshold in the Laredo region (1999) and the Dallas region (2003). The extreme temperatures happened in August of both years and in April, May, June, and July of 1999. Mosquitoes can avoid lethal temperatures by hiding in sewers, near water, or in protected crevasses of buildings and then they or their offspring can re-emerge when temperatures are more conducive to activity.

The highest number of autochthonous DF cases occurred in 1995, 1999, 2002, and 2003. Three general trends emerged from the focus regions: 1) the majority of cases occurred among females, especially in the Brownsville region, 2) most of the patients were of Hispanic descent, and 3) all but five cases presented between the end of July and the middle of November. I suspect that the trend toward infections in females may correspond to lifestyle and gender roles. The number of patients reporting Hispanic descent appears to relate to the Brownville and Laredo areas' proximity to Mexico. And case onset falling between July and November is logical given the peak transmission time of DF being August through December. Furthermore, cases in reported in 1995 coincide with a major outbreak of Dengue in Reynosa, Mexico, across the border from Hidalgo County (Texas Department of Health 1995; Centers for Disease Control and Prevention 1996). Nuevo Laredo, Tamaulipas, Mexico, across the Rio Grande from Laredo, Texas, in Webb County experienced a DF outbreak in 1999, the highest incidence year in my study range (Pena *et al.* 2001; Texas Department of Health 1999).

CHAPTER VI

SUMMARY

Conclusions

In conclusion, temperature and precipitation variation does not play the deciding role in explaining increased incidence of Dengue Fever during the study period. Texas climatic conditions provide a hospitable environment for the primary disease vector, but a significant difference does not exist in years with DF versus those with no cases. Travel outside the United States contributes the majority of DF cases diagnosed in Texas (over sixty percent during the study period). Half of the residents in the state are of Hispanic origin and travel back to endemic countries including Mexico, Puerto Rico, and several Latin American, South American, and Caribbean destinations. The reality of widespread international travel coupled with the fact that Texas shares a border with Mexico increases the risk of imported and autochthonous infections. Both 1995 and 1999 saw sizeable outbreaks of DF in Mexico border regions, which is not a coincidence. The debate concerning whether the virus is endemic in Texas is ongoing, but it only takes one takes one infected person and a competent vector to spread the disease among a susceptible population. High incidence years seem to be a result of interaction with an endemic region or DF serotype new to the area, but once introduced, conditions can sustain further localized transmission.

Suggestions for Further Research

Further research on the topic of Dengue Fever in Texas would require either finer resolution data to investigate human factors including relationships between those infected, socioeconomic variables (education, living conditions, etc.), lifestyle variables (recreation, daily patterns, etc.), and risk awareness. Personal information could assist in understand where and how human/vector interactions take place. The interaction zone is where DF or any other like virus propagates by moving from vector to host and back again.

Obtaining Texas data over a longer range and complete information regarding travel history would assist in better understanding the error inherent in my study. An increase in the number of cases would improve the statistical power of the analysis. Applying the study design to a more robust sample would test the accuracy of the method, results, and conclusions derived from this study. In addition, carrying out the same research in different DF-impacted areas would add to the body of knowledge on climate variation and vector-borne diseases.

Looking at the mitigation and eradication strategies employed in the fight against DF could also be an interesting path for further research, such as choosing several endemic areas using different methods to control the mosquito vector and comparing them with areas that lack an organized program. An investigation of the differences in incidence rates, mortality and economic impact for locations with similar demographic, cultural, and environmental features. A complementary study could examine the public health toll of eradication techniques such as pesticide spraying.

APPENDIX A

LOCALLY ACQUIRED DENGUE FEVER, 1995-2003

County	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
Cameron [1]	3		1	1	3				3	11
Hidalgo [1]	4		2	1	1					8
Starr [1]					1					1
Willacy [1]					1					1
Webb [3]					9					9
Collin [2]									2	2
Dallas [2]					2			5	1	8
Denton [2]									3	3
Ellis [2]									1	1
Tarrant [2]								1		1
Harris					1					1
El Paso							1			1
Bexar					1			2		3
Nueces					1					1
Comal							1			1

Regions:

[1] Brownsville Region.

[2] Dallas Region.

[3] Laredo Region.

APPENDIX B

BROWNSVILLE REGION MONTHLY MEAN MINIMUM T TEST RESULTS

Month	T-Value	Sig. (2-tailed)	Mean Difference
January	.091 .088	.930 .933	.1800 .1800
February	.324 .304	.755 .775	.8300 .8300
March	-.335 -.304	.747 .778	-.7600 -.7600
April	.586 .561	.576 .598	1.3600 1.3600
May	.315 .327	.762 .754	.4250 .4250
June	-.061 -.069	.953 .948	-.0650 -.0650
July	.115 .114	.912 .913	.0700 .0700
August	.283 .267	.786 .801	.1650 .1650
September	.054 .058	.959 .956	1.0266 .9494
October	.926 .914	.385 .395	1.3750 1.3750
November	-.635 -.691	.545 .516	-1.0950 -1.0950
December	.432 .425	.679 .685	.8550 .8550

APPENDIX C

BROWNSVILLE REGION MONTHLY MEAN MAXIMUM T TEST RESULTS

Month	T-Value	Sig. (2-tailed)	Mean Difference
January	.664 .692	.528 .512	1.6200 1.6200
February	-.319 -.308	.759 .770	-.8500 -.8500
March	.622 .577	.554 .593	1.0500 1.0500
April	1.892 1.958	.100 .091	3.1750 3.1750
May	.687 .774	.514 .480	.9400 .9400
June	1.348 1.436	.220 .197	1.3750 1.3750
July	.874 .891	.411 .403	.9650 .9650
August	.282 .292	.786 .779	.3400 .3400
September	.853 .813	.422 .453	.9200 .9200
October	.901 .910	.398 .394	.8150 .8150
November	-.011 -.011	.992 .991	-.0200 -.0200
December	-.138 -.127	.894 .906	-.2450 -.2450

APPENDIX D

BROWNSVILLE REGION TOTAL MONTHLY PRECIPITATION T TEST RESULTS

Month	T-Value	Sig. (2-tailed)	Mean Difference
January	-.751 -.696	.477 .523	-.14150 -.14150
February	-.637 -.634	.544 .548	-.26250 -.26250
March	-.963 -1.026	.368 .342	-1.28650 -1.28650
April	-.420 -.473	.687 .660	-.44250 -.44250
May	-.113 -.120	.913 .908	-.10200 -.10200
June	-1.211 -1.310	.265 .238	-1.38850 -1.38850
July	-.010 -.011	.992 .992	-.00700 -.00700
August	.049 .051	.963 .961	.08050 .08050
September	-.712 -.747	.499 .480	-2.13400 -2.13400
October	-.269 -.266	.796 .799	-.88250 -.88250
November	.001 .001	.999 .999	.00150 .00150
December	3.269 3.427	.014 .011	.56050 .56050

APPENDIX E

DALLAS REGION MONTHLY MEAN MINIMUM TEMPERATURE T TEST RESULTS

Month	T-Value	Sig. (2-tailed)	Mean Difference
January	.194 .231	.852 .825	.4833 .4833
February	1.383 1.041	.209 .393	2.8667 2.8667
March	.261 .329	.802 .752	.5667 .5667
April	-1.988 -2.369	.087 .053	-4.0000 -4.0000
May	.649 .835	.537 .431	1.2667 1.2667
June	.052 .053	.960 .960	.0833 .0833
July	1.101 1.425	.307 .197	1.5000 1.5000
August	-.452 -.450	.665 .676	-.6500 -.6500
September	.540 .645	.606 .541	1.1333 1.1333
October	-.098 -.142	.925 .892	-.1833 -.1833
November	-.868 -.809	.414 .470	-2.4333 -2.4333
December	-1.050 -1.349	.329 .219	-1.9833 -1.9833

APPENDIX F

DALLAS REGION MONTHLY MEAN MAXIMUM TEMPERATURE T TEST RESULTS

Month	**T-Value**	**Sig. (2-tailed)**	**Mean Difference**
January	-.680 -.691	.519 .525	-1.4333 -1.4333
February	.757 .643	.474 .568	2.6333 2.6333
March	-.044 -.062	.966 .952	-.1000 -.1000
April	-1.906 -2.687	.098 .037	-2.9833 -2.9833
May	.765 .961	.469 .369	1.9833 1.9833
June	.947 1.279	.375 .244	1.6333 1.6333
July	1.139 1.168	.292 .303	2.1333 2.1333
August	-.902 -.934	.397 .398	-2.4000 -2.4000
September	.040 .043	.969 .967	.1167 .1167
October	.161 .113	.877 .920	.3333 .3333
November	-1.716 -1.585	.130 .201	-5.3833 -5.3833
December	-1.588 -1.914	.156 .100	-4.5667 -4.5667

APPENDIX G

DALLAS REGION TOTAL MONTHLY PRECIPITATION T TEST RESULTS

Month	T-Value	Sig. (2-tailed)	Mean Difference
January	-.075 -.065	.942 .952	-.10167 -.10167
February	1.099 1.393	.308 .206	1.98333 1.98333
March	.175 .140	.866 .899	.29000 .29000
April	.140 .156	.893 .882	.24667 .24667
May	-.632 -.644	.548 .553	-1.03000 -1.03000
June	.034 .031	.974 .977	.04333 .04333
July	.688 .727	.514 .501	.85000 .85000
August	.743 .930	.482 .383	.90667 .90667
September	-1.071 -1.042	.320 .359	-.95333 -.95333
October	.551 .505	.599 .645	.98167 .98167
November	1.177 1.420	.278 .201	2.05000 2.05000
December	.629 .708	.549 .507	.90500 .90500

APPENDIX H

LAREDO REGION MONTHLY MEAN MINIMUM TEMPERATURE T TEST RESULTS

Month	T-Value	Sig. (2-tailed)	Mean Difference
January	.000	1.000	.0000 .0000
February	-1.146	.290	-4.7125 -4.7125
March	-.835	.431	-3.5000 -3.5000
April	-1.025	.339	-4.0125 -4.0125
May	.525	.616	1.2125 1.2125
June	-.034	.974	-.0625 -.0625
July	1.478	.183	1.2250 1.2250
August	.700	.506	.7375 .7375
September	.940	.379	1.0875 1.0875
October	1.860	.105	3.7875 3.7875
November	-.419	.688	-1.3125 -1.3125
December	-.038	.971	-.1250 -.1250

APPENDIX 1

LAREDO REGION MONTHLY MEAN MAXIMUM TEMPERATURE T TEST RESULTS

Month	T-Value	Sig. (2-tailed)	Mean Difference
January	-1.158	.285	-5.7125 -5.7125
February	-1.868	.104	-7.3625 -7.3625
March	-1.316	.230	-4.4000 -4.4000
April	-1.015	.344	-3.8000 -3.8000
May	-.220	.832	-.7375 -.7375
June	.430	.680	1.3500 1.3500
July	-.024	.982	-.1000 -.1000
August	-1.377	.211	-3.4375 -3.4375
September	-.215	.836	-.7750 -.7750
October	-.039	.970	-.0750 -.0750
November	-1.939	.094	-5.8250 -5.8250
December	-.480	.646	-1.7500 -1.7500

APPENDIX J

LAREDO REGION TOTAL MONTHLY PRECIPITATION T TEST RESULTS

Month	T-Value	Sig. (2-tailed)	Mean Difference
January	.592	.572	.25750 .25750
February	1.233	.257	.73750 .73750
March	-.921	.388	-1.03000 -1.03000
April	.857	.420	.69625 .69625
May	-1.356	.217	-1.44750 -1.44750
June	-.217	.834	-.47625 -.47625
July	.425	.684	1.02250 1.02250
August	-.988	.356	-2.33250 -2.33250
September	1.105	.306	2.34000 2.34000
October	.689	.513	1.48375 1.48375
November	1.836	.109	1.73250 1.73250
December	.469	.653	.19000 .19000

APPENDIX K

REGIONAL MONTHLY MEAN MINIMUM TEMPERATURE SEASONAL AVERAGE

Region	Year	DF	Spring	Summer	Fall
Brownsville	1995	7	61.6	74.9	62.7
Brownsville	1996	0	58.3	75.7	63.4
Brownsville	1997	3	62.7	73.9	61.8
Brownsville	1998	2	61.0	76.4	66.6
Brownsville	1999	6	66.0	74.1	60.0
Brownsville	2000	0	66.0	74.4	62.6
Brownsville	2001	0	63.0	75.0	63.1
Brownsville	2002	0	65.2	75.0	63.8
Brownsville	2003	3	62.8	75.2	64.3
Dallas	1995	0	50.3	70.1	48.7
Dallas	1996	0	45.8	71.4	50.7
Dallas	1997	0	49.1	69.5	50.0
Dallas	1998	0	48.7	74.9	55.0
Dallas	1999	2	52.2	72.0	53.8
Dallas	2000	0	52.8	72.5	51.4
Dallas	2001	0	51.2	70.4	51.6
Dallas	2002	6	51.5	70.1	50.1
Dallas	2003	7	50.4	70.3	53.7
Laredo	1995	0	59.4	73.8	57.6
Laredo	1996	0	55.4	74.4	59.9
Laredo	1997	0	58.3	73.6	57.2
Laredo	1998	0	58.1	76.1	62.8
Laredo	1999	9	63.8	73.9	58.7
Laredo	2000	0	64.8	75.0	59.6
Laredo	2001	0	60.3	74.8	61.7
Laredo	2002	0	62.7	75.2	59.5
Laredo	2003	0	61.2	75.2	61.0

APPENDIX L

REGIONAL MONTHLY MEAN MAXIMUM TEMPERATURE SEASONAL AVERAGE

Region	Year	DF	Spring	Summer	Fall
Brownsville	1995	7	79.7	91.4	80.6
Brownsville	1996	0	79.0	92.3	82.1
Brownsville	1997	3	78.1	91.3	78.1
Brownsville	1998	2	78.9	93.7	82.4
Brownsville	1999	6	82.5	91.7	83.5
Brownsville	2000	0	84.1	93.2	80.8
Brownsville	2001	0	82.0	93.0	83.6
Brownsville	2002	0	83.3	92.9	80.7
Brownsville	2003	3	80.7	91.5	82.5
Dallas	1995	0	70.7	90.0	73.9
Dallas	1996	0	71.6	90.7	71.1
Dallas	1997	0	69.5	89.2	69.2
Dallas	1998	0	70.0	95.8	72.1
Dallas	1999	2	72.1	92.4	78.3
Dallas	2000	0	73.4	93.6	68.0
Dallas	2001	0	68.5	89.9	73.1
Dallas	2002	6	71.7	89.6	68.6
Dallas	2003	7	72.7	90.5	74.5
Laredo	1995	0	84.6	99.1	81.4
Laredo	1996	0	84.6	99.5	83.1
Laredo	1997	0	80.7	100.1	79.0
Laredo	1998	0	85.3	102.9	81.4
Laredo	1999	9	88.3	99.7	83.4
Laredo	2000	0	87.5	99.1	76.7
Laredo	2001	0	81.4	98.0	82.8
Laredo	2002	0	86.4	96.3	78.5
Laredo	2003	0	82.9	96.4	80.7

APPENDIX M

REGIONAL TOTAL MONTHLY PRECIPITATION SEASONAL SUM

Region	Year	DF	Spring	Summer	Fall
Brownsville	1995	7	0.77	16.42	10.62
Brownsville	1996	0	0.50	15.08	12.15
Brownsville	1997	3	10.72	10.10	13.90
Brownsville	1998	2	0.66	9.48	7.31
Brownsville	1999	6	3.15	14.35	3.46
Brownsville	2000	0	3.28	7.95	3.12
Brownsville	2001	0	1.46	9.56	2.78
Brownsville	2002	0	0.86	12.59	12.53
Brownsville	2003	3	0.97	23.88	7.34
Dallas	1995	0	13.52	15.76	1.49
Dallas	1996	0	4.50	14.75	12.10
Dallas	1997	0	8.94	14.73	6.67
Dallas	1998	0	5.70	5.27	10.55
Dallas	1999	2	5.58	10.97	2.57
Dallas	2000	0	7.20	9.26	11.33
Dallas	2001	0	6.16	17.15	2.97
Dallas	2002	6	13.07	14.42	6.96
Dallas	2003	7	2.75	13.62	3.93
Laredo	1995	0	0.84	17.70	4.28
Laredo	1996	0	1.16	19.16	2.33
Laredo	1997	0	5.33	7.35	7.02
Laredo	1998	0	1.16	4.04	4.13
Laredo	1999	9	2.33	12.38	1.56
Laredo	2000	0	3.55	5.03	5.91
Laredo	2001	0	1.74	10.23	3.04
Laredo	2002	0	0.32	13.31	5.06
Laredo	2003	0	1.87	15.07	6.44

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VITA

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