THE ROLE OF CLIMATIC AND ENVIRONMENTAL VARIABILITY ON THE OCCURRENCE OF WEST NILE VIRUS IN HARRIS COUNTY, TEXAS, 2006-2007

A Thesis

by

STEPHEN AMAN BERHANE

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

May 2009

Major Subject: Geography

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Approved by:

Chair of Committee,	Daniel Z. Sui
Committee Members,	Hongxing Liu
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ABSTRACT

The Role of Climatic and Environmental Variability on the Occurrence of West Nile
Virus in Harris County, Texas, 2006-2007. (May 2009)
Stephen Aman Berhane, B.S., Louisiana State University
Chair of Advisory Committee: Dr. Daniel Z. Sui

Between the years 2006-2007, Harris County, located at the heart of the Houston metropolitan area, experienced a nearly 90% decline in the number of female mosquitoes which tested positive for the West Nile virus. Different theories exist as to why such a precipitous drop occurred and this study attempts to determine the extent to which climatic variability between the two years played a role. The Mosquito Control Division of Harris County Public Health and Environmental Services gathered the data on vectors and reservoirs. Then using GIS, spatial analysis, and geostatistical tools the vector and reservoir data was compared to climatic data to investigate any changes in viral distribution.

Previous studies of the area until now have used a limited amount of climatic data; this study seeks to improve the resolution of climatic data analyzed. A higher resolution of data was achieved by including as-of-yet unused data from a network of over 150 gauges maintained by various state and local agencies in addition to previously used data from NOAA COOP stations. Using this dense network of station's values for precipitation, temperature and other climatic variables were interpolated for all of Harris County and used in the analysis.

Based on results, water availability was the most likely out of all the climatic variables to the precipitous drop of West Nile virus positive female mosquitoes from 2006-2007. Correlations between all climatic variables and mosquito abundance and West Nile virus positives showed mixed results compared to a previous study in the same area.

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NOMENCLATURE

CDC	Centers for Disease Control and Prevention
COOP	Cooperative Observer Program
EIP	Extrinisic Incubation Period
GIS	Geographic Information Systems
HCMC	Harris County Mosquito Control
HCOEM	Harris County Office of Homeland Security and Environmental Management Depatment
HCPHES	Harris County Public Health and Environmental Services
IDW	Inverse Distance Weighting
LULC	Land Use/Land Cover
MIR	Minimum Infection Rate
NCDC	National Climatic Data Center
NOAA	National Oceanographic and Atmospheric Administration
P-E	Precipitation minus Evaporation
SLE	St. Louis Encephalitis virus
TDSHS	Texas Department of State Health Services
UTMB	University of Texas Medical Branch
WNv	West Nile virus

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CHAPTER I

INTRODUCTION

West Nile virus (WNv) has caused the deaths of thousands of human beings and domesticated animals, and countless more wild animals, since its introduction to the Western Hemisphere in 1999. Between the years 2006 and 2007, Harris County, the center of the Houston metropolitan area, experienced a nearly 90% decline in the number of mosquito samples which tested positive for the West Nile virus in 2007 as compared to 2006. Different hypotheses exist as to why such a precipitous drop occurred and what biological, environmental, and climatic factors played a role. The goal of this study is to use GIS and spatial analysis to determine what effect different environmental and climatic factors might have on the dynamics of WNv and to what extent climatic variability between the two years played was involved in the reduction in West Nile prevalence between 2006 and 2007.

Wild birds serve as the reservoir hosts (organisms that host and maintain the infection) of WNv, and mosquitoes of the genus *Culex* serve as the pathogen's primary vector (mechanism of infection) in urbanized regions of the eastern half of Texas. Humans and animals, such as horses or dogs, are considered non-amplifying incidental hosts of the virus, meaning they do not contribute to transmission. Approximately 20% of infected humans will develop West Nile fever, a flu-like syndrome, with 1 in 150 diagnosed cases developing West Nile encephalitis neurological disease that can result in paralysis, neurological damage, and death (Petersen et al., 2003). In some cases, WNv might be transmitted to these incidental hosts by the same vectors that maintain the virus cycle with reservoirs.

This thesis follows the style of *The Professional Geographer.*

It is thought that climate and land use/land cover of the environment largely controlthe populations of vectors and reservoirs and consequently, the extent of the disease. As a result, the infection of humans and domesticated animals is largely seasonal in the United States, lasting from approximately June to November. It has been shown that unusual precipitation events (prolonged droughts followed by flooding) can result in higher mosquito populations (Shaman et al, 2005; Cooke et al., 2006). It has also been found that higher ambient temperatures, up to a threshold, will result in a similar upsurge in mosquito population (Ward, 2005; Tachiiri et al., 2006).

The use of remotely sensed data and GIS databases for temperature, precipitation and land use/land cover makes it possible to predict the spread of the disease as a function of environmental conditions (Ward, 2005; Gibbs et al., 2006; Tachiiri et al., 2006). Hence, it is possible to model the spread of an infectious disease, such as West Nile virus, using geospatial techniques (GIS, remote sensing, spatial analysis) and proxies for these factors to potentially predict epidemics and prevent future loss of life. In order to do this the proper parameters must be identified and used in the model.

Harris County, Texas was selected as the study area because of the availability of fine-scale case data that allows for high-resolution analysis, an important consideration in epidemiological research. A second consideration was Harris County's high incidence of infection and the amount of epidemiological data made available by the Mosquito Control Division of the Harris County Public Health and Environmental Services Department (HCMC). Thirdly, the Houston area was selected because of its sizable human population. Geographic analyses have been conducted on human WNv epidemics in the major metropolitan areas of New York City and Chicago, respectively the largest and 3rd largest metropolitan areas in the nation. Logically the next step should be research on Harris County and Houston, the 3rd largest county and the 6th largest metropolitan area in the United States.

In this study, the relationship between environmental factors (climate and land cover) and incidence of the West Nile virus for the years 2006 and 2007 was examined. This study used a variety of data gathered from a number of local, state, and federal sources for analysis. Once all necessary data had been gathered and processed, the amount of correlation these different factors have with West Nile in Harris County was determined to identify if any meaningful relationships exist. The specific aims of this study were to:

- Identify and quantify the climatic and environmental factors that are associated with abundance of vectors and reservoir hosts and the dynamics of the West Nile virus
- Compare environmental factors to infection and vector and reservoir host abundance data to identify important associations
- Determine variations in climatic record that maybe responsible for the sharp decline in the number of mosquitoes positive for WNv from 2006 to 2007

CHAPTER II

LITERATURE REVIEW

A. West Nile Virus

The West Nile virus (WNv) is a member of the *Flaviviridae* family of viruses that have caused many epidemics in the past, such as Yellow Fever, Dengue, and St. Louis encephalitis. Insect and other arthropod vectors primarily spread viruses in this family. Mosquitoes, to include those of the genus *Culex* transmit WNv and other flaviviruses such as Japanese encephalitis and St. Louis encephalitis (Hayes, 2001). First isolated in a 37 year-old female native of the West Nile region of Uganda in 1937 (Smithburn et al., 1940), the virus remained endemic to the Eastern Hemisphere until 1999 when it was first detected in the Western Hemisphere in New York City (Hayes, 2001). From that time on it spread rapidly across the country reaching the state of Texas by 2002. Since its introduction to the Western Hemisphere in 1999, the West Nile virus has been responsible for the deaths of over 1000 people and many times more birds and mammals in the United States alone (DeGroote et al., 2008).

B. West Nile Virus and Mosquitoes

In recent epidemics of WNv in Romania (1996), southern Russia (1999), and Israel (2000) *Culex pipiens*, the “common house mosquito”, has been implicated as the main vector (Hayes, 2001; Petersen et al., 2003). However, *Culex quinquefasciatus*, the “southern house mosquito”, has been found to be the dominant *Culex* species below 36° N latitude and the main vector for West Nile transmission in Texas and the southern United States (Savage & Miller, 1995; Lillibridge et al., 2004). In epidemiological terms, they are considered a common exposure source or one that is continuous or intermittent.

Members of the complex tend to breed in highly eutrophic water full of decomposing organic material like that found in underground water catchments (e.g. storm sewers and catch basins) and in surface septic ditches and ground pools in urban areas (Savage & Miller, 1995; Epstein, 2001; Lampman et al., 2006). As adults, this species rests in the same storm sewers and other sheltered areas where their larvae occur to find moderate temperatures and moister conditions and emerge at dusk to feed when these conditions occur at ground level. At dusk, they find easier targets to attack in humans outside doing recreational activities (Ruiz, et al., 2007) and birds that are beginning to roost (Ward et al., 2006). This species is generally considered non-migratory but females may travel up to 1100m in a single night to find blood meals (Savage & Miller, 1995).

Culex quinquefasciatus is by far the most abundant and important species in terms of West Nile ecology in the Houston area. Trapping yields approximately 17 times more *Culex quinquefasciatus* (>95%) than *Aedes albopictus*, the species which accounts for the second highest number of positive cases in the area and acts as a bridge (secondary) vector for WNv (Dennett et al., 2007b). In a study by Vanlandingham et al. (2007) *Cx. quinquefasciatus* that were reared from egg rafts in Harris County were found to the most susceptible to West Nile viremia with 100% infection and oral dissemination rates when exposed and tested under lab conditions. The time for a mosquito to have the virus in their midgut after ingesting infected blood to the time it takes for the virus to disseminate to the salivary glands, i.e. the extrinsic incubation period (EIP), in *Culex quinquefasciatus* is anywhere between 4-24 days depending on temperature (Dohm et al., 2002; Girard et al., 2004).

Once the virus has reached the mosquito's salivary glands, it is able to transmit WNv to any susceptible creature it bites with it saliva which it injects into a bloodmeal host while feeding. Blood meal analyses have shown that *Cx. quinquefasciatus* in the area are opportunistic feeders but are not generally ornithophilic. Molaei et al. (2007) found that out of nearly 800,000 specimens collected between March-November 2005 and 672 tested that 39.1% fed solely on birds, 52.5% fed solely on mammals with 8.3% feeding on both. Interestingly enough, human blood was found in only 0.4% of all specimens. This host preference has led others to suspect other vectors such as *Aedes albopictus* are responsible for a large number of human infections (Dennett et al., 2007a). Numerous *Aedes* species have been found to have the capacity to transmit the virus to reservoir and amplifying hosts. Under lab conditions, *Aedes albopictus* and *Aedes aegypti* were found by Vanlandingham et al., (2007) to be infected at similar but lesser rates than *Culex quinquefasciatus*. Based on this they concluded *Cx. quinquefasciatus* to be the "more competent vector". Given its sheer numerical advantage over other species and more ornithophilic tendencies, *Culex quinquefasciatus* is considered to be the primary vector in the Houston area.

In addition to transmitting the virus to other types of animal species (horizontal transmission), infected females can also transmit WNv to their offspring through vertical or transovarial transmission (Anderson et al., 2008). If this occurs before the mosquito's normal period of hibernation (diapause), the virus will 'overwinter' in eggs. With females, typically laying between 140-300 eggs per raft the amount of potential vectors can increase exponentially (Savage & Miller, 1995). For this reason larval surveillance and larvaciding is oftentimes carried out in conjunction with that aimed at their adult counterparts.

Mosquito activity is governed to a large extent by temperature as they are poikilotherms. This is particularly true in regards to *Culex quinquefasciatus*. It has been found that higher average ambient temperatures, to an upper threshold of approximately 34℃ (93.2℉), will result in an increase in *Culex* mosquito blood feeding, egg production, and populations (Rueda et al., 1990). Peak activity for *Culex* populations occurs at an average temperature range of approximately 20-30℃ (68-86℉) (Rueda et al., 1990). Salazar and Moncada (2004) found the development from egg to adult took between 13-24 days at 15℃ (59℉) with the same process taking between 8-12 days in summer (Savage and Miller, 1995).

Culex mosquitoes may enter diapause (a state of dormancy) when temperatures fall below the freezing point 0° C (32° F) (Spielman, 2001). When temperatures rise above this threshold during warmer periods of the winter, they will become active again (Spielman, 2001). Harris County is characterized as having a humid subtropical climate where temperatures rarely stay below freezing point (0℃) for prolonged periods. As a result, mosquitoes in the area do become inactive but do not enter “true diapause” and have been captured during warm periods throughout the winter as indicated by field observations and trapping results (Tesh et al., 2004, Dennett et al., 2007a). Field observations in urban areas like Houston and San Antonio indicate that *Culex* mosquitoes will rest under buildings and in storm drains and sewers for longer cold periods (Strickman & Lang, 1986; Tesh et al., 2004). Because *Culex* mosquitoes do not truly enter diapause in the Houston area, their development is not interrupted which extends the life cycle (Strickman & Lang, 1986).

C. West Nile Virus and Birds

West Nile is maintained in a cycle between its mosquito vectors and wild bird reservoir hosts, which female mosquitoes use as one potential source for their bloodmeals. Because of their migratory patterns, birds are more than likely the reason why West Nile has spread across the continent. Unlike mosquitoes, the location of birds in a particular area within in a season is not controlled by climate but rather by available water and land cover. After entering Texas, WNv was able to become endemic and permanently established in bird populations (Tesh et al., 2004; McLean, 2006). Like mosquitoes, numerous bird species within several genera are very vulnerable to infection. Unlike mosquitoes, birds can contract the virus in several ways. Like other hosts, they can be infected via an infected mosquito but, unlike other hosts, they can spread the virus from individual to individual at a high rate. This can occur during roosting, particularly in crows because they always roost communally, through oral and cloacal shedding of the virus as well as through the ingestion of other infected birds (Komar et al., 2003, Ward et al., 2006). High levels of the virus from oral and cloacal samples have been found for days after death (Komar et al., 2002; McLean, 2006)

In both hemispheres, Passerine birds (Order: *Passeriformes*) have been consistently found to be the most vulnerable and competent avian WNv hosts, whereas non-passerines are found to be much poorer hosts (Komar et al., 2003; Peterson et al., 2004; Ezenwa et al., 2006). Within this group, Corvid species (family: *Corvidae*) including Blue Jays (*Cyanocitta cristata*) and American crows (*Corvus brachyrhynchos*) are consistently found to be the most affected (Komar et al., 2003; Tesh et al., 2004). Many studies have found WNv infections in these species to be good predictors of future infections in humans (Ezenwa et al., 2006; Ward et al., 2006). However, how much infection spread can be traced to birds is unknown because their spatial distribution and the intensity of such outbreaks has not been fully quantified (McLean, 2006). In crows, viremia lasts on average between 3-5 days and those infected usually die after 7 days

(Mclean et al., 2001; Komar et al., 2003; McLean, 2006). For a long time sentinel chickens were used to monitor WNv but given that Corvid species are more likely to yield the virus than other bird species and experience such a high mortality from WNv they are now more commonly used for disease surveillance than chickens (Lillibridge et al., 2004; Tesh et al., 2004; McLean, 2006).

As previously described in Harris County, both live and dead birds are tested for WNv. The infection rate in dead birds peaked in August at 50% (Tesh et al., 2004, McLean 2006). This study found a consistent rate for all birds in August 2006 with a 47% infection rate. For *Cx. quinquefasciatus* in the Houston area, the Mourning Dove (*Zenaida macroura*) in the *Columbidae* family was the most attacked avian species (48.1%) according to blood meal analysis (Molaei et al., 2007). However, the same study found that birds in the aforementioned Corvid species were responsible for 82% of the positive West Nile results.

D. West Nile Virus in Humans and Mammals

Other non-avian species in which West Nile fever or neurological disease can occur, most notably human beings and horses, are considered non-amplifying “incidental hosts” as the virus cannot be passed by these species (Ruiz et al., 2004). Unlike birds, mammals do not produce enough viremia in their peripheral bloodstream to serve as reservoirs for the virus to biting female mosquitoes. Incidence of mosquito to human transmission generally corresponds with prevalence in the vectors and reservoirs (Cooke et al., 2006; Gibbs et al., 2006). Cooke et al. (2006) found a correlation of 46% between human and bird cases in Mississippi. As such, monitoring the virus in birds and mosquitoes is key to preventing West Nile infection in humans.

In humans, West Nile is widely underreported, as 80% of those infected remain asymptomatic while the remaining 20% develop West Nile fever, a flu-like syndrome that infected individuals often confuse for the common cold or flu (Petersen et al. 2003). On the other hand, 1 in 150 diagnosed cases develop West Nile encephalitis neurological disease that can cause paralysis, hepatitis, pancreatitis, neurological damage, and even death (Petersen et al., 2003). WNv is rarely fatal, however the more severe manifestations occur primarily in those 50 or older and in those who are immunologically weak. In some cases, WNv might be transmitted to these incidental hosts by the same vectors that maintain the virus cycle with avian reservoirs. In humans, the intrinsic incubation period, the time between an infective bite and the development of clinical symptoms, was found to be between 2-14 days (Petersen and Marfin, 2002; Heymann 2004).

Spatial analyses using social and demographic variables including average income, population density, age, and mosquito abatement strategies provide a more accurate model of West Nile exposure and infection in humans than studies lacking these variables (Ruiz et al., 2004; Ward 2005). This is particularly true in large urban areas where the human populations are dense and highly diverse in regards to socioeconomic status and ethnicity (Ruiz et. al, 2004). All ages and both sexes are considered equally susceptible to infection but elderly populations have been found to be more susceptible to severe infection and mortality (Campbell et al., 2002; Petersen et al., 2003). Therefore, identification of exposure risks particularly to such populations at high risk for infection will hopefully reduce the number of WNv cases. Mosquito abatement strategies can have a significant effect on risk by controlling vector populations; however, little modeling research has been conducted that has included this variable. Modification of these vector control policies could reduce risk and prevent infection in birds, humans, and other vertebrates (Ruiz et al., 2004).

E. West Nile Virus, Precipitation and Water

The infection of humans and domesticated animals by WNv is largely seasonal in the United States, lasting from approximately April to November (Dennett et al., 2007a). In regards to climatic variables like precipitation and temperature, there are diverging hypotheses as to their influence on the cycling of WNv. Conventional wisdom states that more mosquitoes will be breed better in hot and wet conditions when there is a surplus of water. However, heavy rains can flood out *Culex* breeding sites and otherwise make them more accessible to frogs, fish, and dragonflies that prey on mosquitoes. On the other hand, the “drought hypothesis” states that West Nile is more prevalent in years when there is a mild winter with a long spring drought followed by significant rain events (Epstein, 2001; Cooke et al., 2006). This hypothesis was based on assumptions that during droughts the drains and pools where *Culex* mosquitoes breed become richer in decomposing organic material instead of being diluted and/or flushed out by rainfall. Drought also encourages birds to gather around increasingly fewer and smaller sources of water, which increases the contact between birds and mosquitoes and makes it easier for the virus to circulate (Epstein, 2001). To support the theory, Epstein points out these conditions were present in the spring and summer of 1999 in New York, the location of the initial WNv outbreak in the Western Hemisphere.

In southern Florida, it has also been shown that abnormal levels of precipitation, weeks-long drought in the spring followed by a significant rain event, result in increased mosquito reproduction and increased contact between vulnerable reservoirs and *Culex* *nigripalpus* (Shaman et al., 2005). In Mississippi, Cooke et al. used precipitation (P-E) to determine whether increased or decreased breeding area influences risk of WNV infections. Their results were inconclusive in their seasonal scale analysis, showing a positive correlation only for the summer months. On the other hand, a study in Iowa found the opposite was true with high virus prevalence coinciding with middle of the season rainfall (DeGroote et al., 2008)

In Houston, an extensive network of creeks, canals, bayous, and storm sewers supply and control surface water as part of the flood-management system (Molaei et al., 2007). The county's "abundant rainfall, soil composition, and relatively low elevation" make it susceptible to periodic flooding (Lillibridge et al., 2004; Molaei et al., 2007). This floodwater drains into the storm sewers and during relatively dry periods will sit in the storm sewers, instead of being flushed out, creating favorable conditions for breeding and larval development (Strickman and Lang, 1986; Lillibridge et al., 2004; Molaei et al., 2007). Analyzing precipitation on a monthly scale in Houston, Dennett et al. (2007a) found that precipitation was "weakly correlated" with gravid trapping collection and pool numbers.

F. West Nile Virus and Temperature

Like precipitation, studies have looked at temperature's relationship with West Nile by looking at its effects on the mosquito's life cycle. As mentioned before, the life cycle and activity of a mosquito are governed largely by temperature because they are cold-blooded (poikilotherms). It has also been found that higher temperatures accelerate the development of West Nile within mosquitoes (Epstein, 2001). Dohm et al. (2002) found EIP to occur as fast as 4 days in *Culex pipiens* at 30℃ , the high end of the aforementioned peak range, and as slow as 24 days at 18℃ (64.4℉). In *Culex quinquefasciatus* from Houston, EIP was found to be 8 days at 28℃ (82.4℉) (Girard et al., 2004) and 10 days in Aedes albopictus held at 26℃ (78.8℉) (Sardelis et al., 2002). Conversely, 14.3℃ (57.7℉) has been suggested as a minimum threshold for infection in *Culex tarsalis* with no females testing positive at 10℃ (50℉) (Reisen et al., 2006).

Peak activity for *Culex* populations occurs at an average temperature range of approximately 20-30℃ (68-86℉) (Rueda et al., 1990). Salazar and Moncada (2004) found the development from egg to adult took between 13-24 days at 15℃ (59℉) with the same process as little as 8 days in summer (Savage and Miller, 1995, Henn et al., 2008). *Culex* mosquitoes may enter diapause (a state of dormancy) when temperatures fall below the freezing point 0°C (32°F) (Spielman, 2001). When temperatures rise above this threshold during warmer periods of the winter, they become active again (Spielman, 2001). With Harris County having a humid subtropical climate temperatures rarely stay below freezing point (0℃) for prolonged periods. As a result, mosquitoes in the area do become inactive but do not enter "true diapause" and have been captured during warm periods throughout the winter through field observations and trapping results (Tesh et al., 2004, Dennett et al., 2007a). Field observations in urban areas like Houston and San Antonio indicate that mosquitoes will rest under buildings and in storm drains and sewers for longer cold snaps as they would during warmer periods of the day in the summer (Strickman & Lang, 1986; Tesh et al., 2004).

Modeling using temperature has found an association between higher ambient temperatures and West Nile encephalitis in equine populations (Ward et al., 2004). This association with temperature has also been found among mosquitoes in Vancouver, Canada among *Culex tarsalis* (Tachiiri et al., 2006).

G. West Nile Virus and the Environment

Numerous studies have pointed towards the role of land use/cover, elevation, and factors in influencing the incidence of West Nile, as these environmental factors can have a substantial effect on amount of the interaction between vector and reservoir populations. Land use/land cover is highly varied in the state of Texas ranging from bayous and urban areas in the east to deserts and mountains in the west. The effect that different land cover (natural and artificial) and other environmental conditions have on the transmission of West Nile is largely unknown and still under investigation using geospatial tools like remote sensing and GIS. Previous research has implicated several different land cover classes in amplifying mosquito and West Nile activity. The role that these factors play varies from location to location and cannot be applied universally, so it is necessary to examine each situation independently.

In Mississippi, high road density, low stream density, and gentle slopes correlated well with the virus (Cooke at al., 2006). In Iowa, it was found that deciduous forest land cover and alluvial soil that is conducive to water ponding correlated well to the number of *Aedes trivattus* (r^2=0.51) and *Aedes vexans* (r^2=0.35) (DeGroote et al., 2007). Another study in Iowa found that built environment classes (roads, buildings, residencies) were negatively correlated with WNv, indicating urban species like Cx. pipiens were less important in the area than the rural species C*x. tarsalis* (DeGroote et al., 2008). On the other hand, in Georgia, Gibbs et al. (2006) found that human-altered environments have provided more favorable habitats and chances for interaction between mosquitoes and birds, while elevation had a negative effect on disease incidence.

H. Research Objectives and Significance

Between the years 2006 and 2007, Harris County, Texas experienced a sharp decline in the number of mosquito samples that tested positive for West Nile from 842 in 2006 to 86 in 2007 (Figure 1).

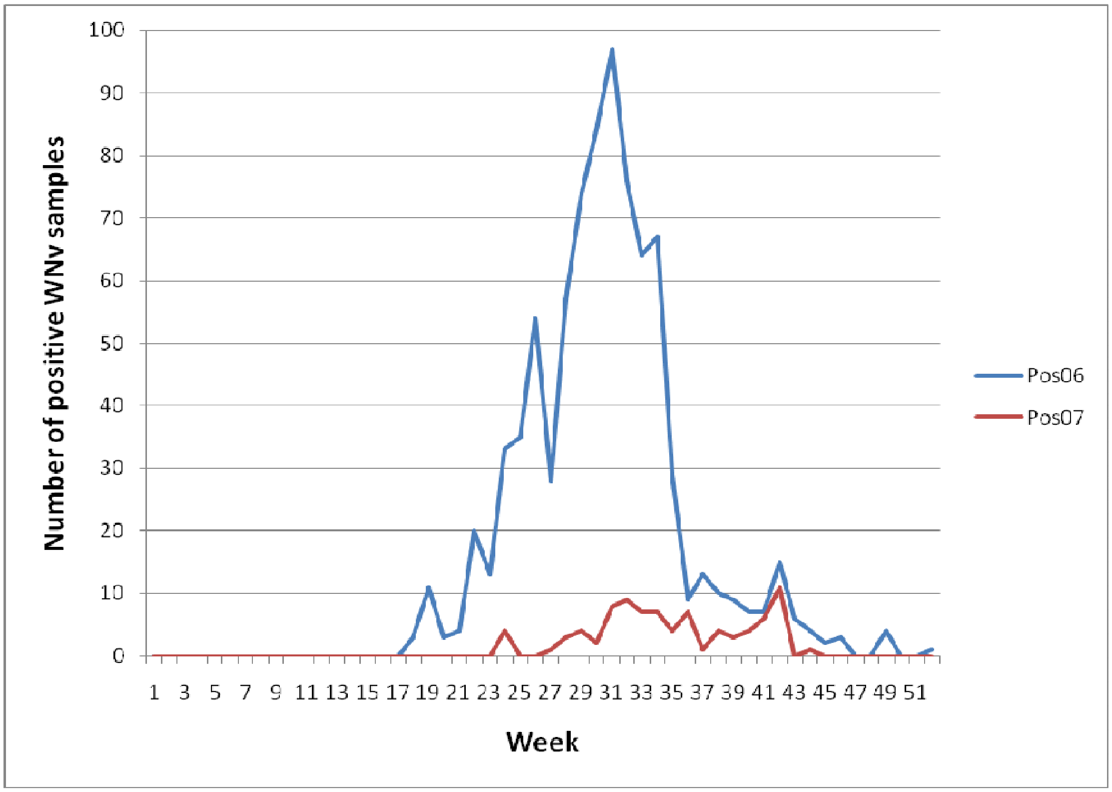


Figure 1: Comparison of WNv positive female mosquito samples, 2006-2007

The reason for this decline is unknown but it is hypothesized to be related to different climatic conditions between the two years. In this thesis, I propose to examine environmental conditions that dictate the dynamics of West Nile virus in the Houston metropolitan area in an attempt to answer the question: To what extent did environmental conditions play in the sharp decline in the incidence of the West Nile virus in Harris County between 2006 and 2007?

Previous studies of the area have used a far lower spatial and temporal resolution of climate data than that used in this study. In a county as large and environmentally diverse as Harris County this can play an important role in the controlling the dynamics of West Nile virus. Past spatial analysis in Harris County has been conducted focusing on human cases, environmental data, and socioeconomic characteristics but not on climatic characteristics (Rios et al., 2006). Others who have considered climate have relied on a very limited amount of data from one location at the monthly scale to account for all the climatic variability in the extremely diverse area (Dennett et al., 2007a). The use of a single station is problematic however because the change detected from year-to-year may not be caused by real changes in climate (Peterson et al., 1998)

This study uses a much larger set of weather stations at a weekly scale to get a more accurate and higher resolution climatic picture of the area. It also considers land cover and the additional climatic factors of evaporation and the availability of water. Filling this gap should result in a better understanding of the relationship between the disease and environment and could result in the development of better targeting of mosquito abatement strategies and better personal protection when high-risk environmental conditions are present

Using GIS, spatial analysis, and geostatistics, the relationship between environmental factors (climate and land cover) and incidence of the West Nile virus for the years 2006 and 2007 was examined. Precipitation and evaporation was examined to determine if drought (low P-E) which decreases the number of breeding areas or a water surplus (high P-E) which increases breeding areas have an influence on the number of WNv infections. The minimum, maximum, and average temperature were examined to determine the effect temperature has on the abundance and life cycle of mosquitoes. and use/land cover was also examined using remotely sensed images to determine which habitats amplify mosquito and West Nile activity in birds and mosquitoes.

Temperature and precipitation data gathered from three (3) different sets of meteorological stations were used in this study to determine the association between climate and reported cases of West Nile. Land use and land cover were assessed using remotely sensed images to determine their association with vectors and reservoir populations. Data on infected birds and mosquitoes from the Mosquito Control Division of the Harris County Public Health and Emergency Services (HCMC) were used to identify locations where samples of infected reservoirs and vectors were found. Once all necessary data were gathered and processed the amount of correlation these different factors have with West Nile was determined to identify if any meaningful relationships exist.

Epstein (2001) believed early on that “assessing the climatic conditions conducive to outbreaks of West Nile virus and using seasonal (e.g. 3-month) climatic forecasts may prove helpful for mobilizing timely and environmentally friendly public health interventions”. The expectation of this study was to gain a better understanding of the influence that environmental factors have on controlling the extent of West Nile at a high temporal resolution and thereby improve the accuracy of disease models using all the aforementioned variables in the future. This could potentially facilitate a reduction in cases of the disease due to better targeting of mosquito abatement strategies and better personal protection when high-risk environmental conditions are identified.

CHAPTER III

DATA AND METHODS

A. Study Area

Harris County is home to the city of Houston and is the third most populous county in the nation. Despite this fact, Harris has over 25% of its 1,728 square miles dedicated to ranch and farmland (Lillibridge et al., 2004). Since the introduction of West Nile into the state, Harris has had an outbreak of the virus every year and had among the most cases of infection and death of any county in the state. In 2007, of the 257 confirmed human cases in Texas Harris County was responsible for 26 cases down from a high of 105 cases in 2002.

In the Harris County Public Health and Environmental Services Mosquito Control Division (HCPHES-MCD or HCMC) the county has one of the largest and best-funded mosquito surveillance and control operations in the entire country. The division focuses more on vector-borne disease prevention rather than simple nuisance mosquito control (Parsons, 2003). HCMC has approximately 60 fulltime and 40 seasonal employees which is a result of the division's responsibility for dealing with West Nile as well as with St. Louis Encephalitis (SLE) that has been endemic in the county for years and caused by a virus which belongs to same *Flaviviridae* family of viruses as WNv (Lillibridge et al., 2004).

HCMC maintains disease surveillance by collecting, testing, and monitoring mosquito and bird species susceptible to encephalic viruses in all parts of the county, not just the city of Houston. Trapping locations are chosen on the basis of three (3) main criteria: favorable habitats for hosts, mosquito behavior, and areas of human activity. Mosquitoes are caught by means of CDC light traps baited with CO_2 (dry ice) placed down in storm sewers and by customized gravid mosquito traps baited with approximately a 3.7-

4.7L of 10-14 day old Coastal Bermuda grass hay infusion and setup in backyards of residential areas at the highest risk. Traps are allowed to lure and catch oviposition-ready gravid female mosquitoes for 18-24 hours. All mosquitoes are brought to HCMC and knocked down in cold storage to be sorted, sexed, and identified to species (Lillibridge et al., 2004; Dennett et al., 2007a). Afterwards specimens of each species are grouped into pools of up to 50 females to be tested for arboviruses. Unlike the vast majority of other counties around the state, HCMC has its own virology laboratory that allows it to test mosquitoes for West Nile and SLE. This allows HCMC to maintain a timelier surveillance schedule than other counties that have to ship their samples to the Texas Dept. of State Health Services (TDSHS) lab in Austin for testing. It is very important that the cold chain be maintained through the whole process to prevent loss of viremia so they are transported in coolers, sorted on chill tables, and stored in cold storage (Dennett et al., 2007b).

Live birds were collected using mist nets set up in parks in a few locations around the county where they are bled, identified, and released. Their sera are then tested for arboviruses back at HCMC. Dead birds are reported to HCMC through a hotline and are picked up at a residence or in times of high call volume picked up at a number of drop-off locations. In order to test for virus the head must be intact so only species that have been determined to be not too badly decomposed are kept frozen (-75℃) to be sent to UTMB for testing. (Lillibridge et al., 2004) Because of the extensive testing, there is a wealth of surveillance data to be explored and analyzed to test the aforementioned hypotheses regarding environmental controls on West Nile. Additionally, HCMC obtains data from neighboring counties to maintain as large a network of resources as possible in their fight. This study examines a small portion of the vast archives of data.

B. Vector and Reservoir Analysis

1. Data Collection

The Harris County Public Health and Environmental Services Mosquito Control division (HCMC) collected the data on mosquitoes used in this project. To match temporal standards used by the CDC the data was provided in a weekly summary table for the number of mosquitoes collected and tested, the type of trap used in collection, and the number of mosquito pools but withheld were the average size of pools and the locations of test sites used for the years 2006-2007.

The type of trap employed plays a big role in the number of female mosquitoes collected. The number of specimens collected from gravid traps during the study period is often more than three (3) times the amount caught by light traps in storm sewers. The effect that the collection method used has on disease incidence was considered because it indicated the environment where mosquitoes were caught, above ground in the case of gravid traps or below ground in the sewers in the case of the light traps. Data on which species were caught and tested were not provided but evidence suggests that the vast majority of both total and positive mosquitoes represent *Culex quinquefasciatus* (Dennett et al., 2007b, Vanlandingham et al. 2007), while the majority of birds are assumed to be Corvids due to their increased testing given their high vulnerability (Tesh et al., 2004).

These numbers were summarized and examined at a sub-county level using the operational areas (n=268) employed by HCMC (Figure 2) to conduct its mosquito surveillance and control program. The area configuration map for Harris County, which is an adaptation of a county KeyMap in the 1980s, was developed to make surveillance and control of rampant St. Louis encephalitis around the county more efficient (Parsons, 2003). This area map has not been updated since its initial development and does not take into account the significant population and development increase that has occurred in the county, particularly in the west over the past 25 years. As a result, the operational areas around the downtown area in the southern parts of the county, where the HCMC office is located, are much smaller than the areas in the northern and western areas of the county.

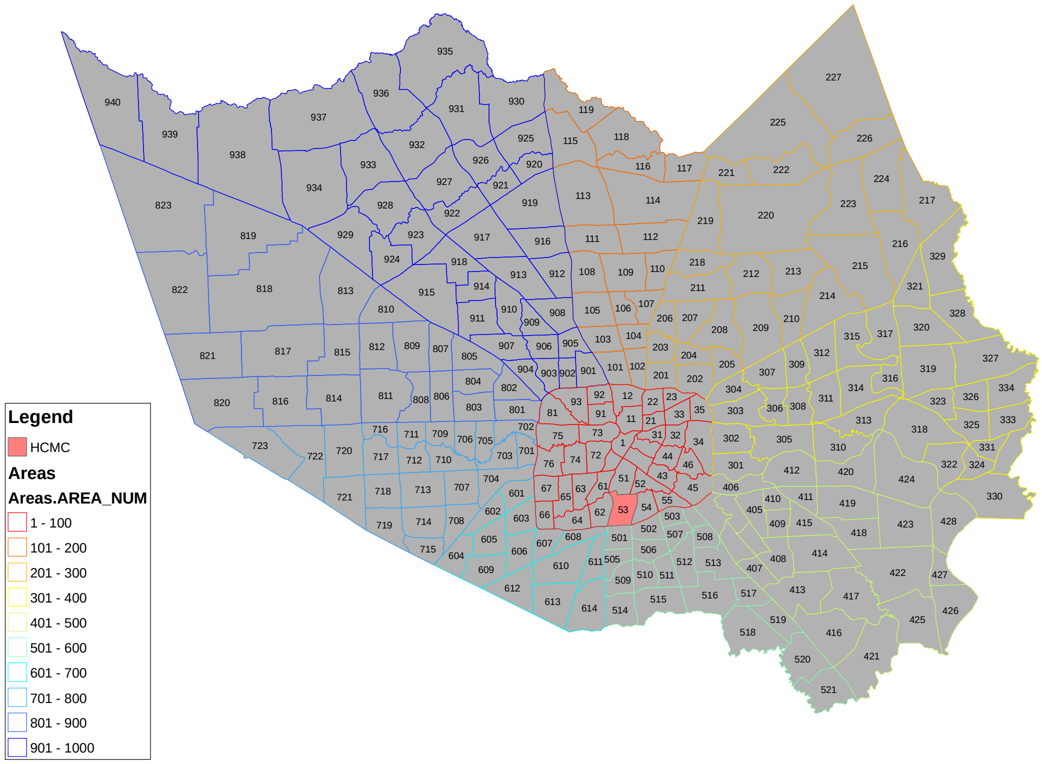


Figure 2: HCMC operational areas identified by area

2. Data Processing

Using the data provided, the overall minimum mosquito WNv infection rate (MIR) per area and for the whole county for each type of trap used was calculated using the formula cited in Condotta et al., 2004:

$$\mathbf{MIR = Pos/Total * 1000}$$

Pos	No. of confirmed WNv pools
Total	Total no. of mosquitoes tested

This formula yields rates of positives per 1,000 pools consistent with the format used in common epidemiological rates such as the attack rate. MIR is, however, a rather conservative estimation of the number of positive mosquitoes, because it assumes only one mosquito in each pool (n ≤ 50) is positive (Dennett et al. 2007a). This leaves open the possibility that 50 times the amount of mosquitoes are positive however unlikely that scenario may be. Gu et al. (2003) pointed out the problem with this formula and suggested the use of maximum likelihood estimation (MLE) however this calculation could not be used because it requires mean pool size to be known. For statistical analysis, count data was log (Y+1) transformed to remove the data effects of areas which had no mosquito collections. Using MIR normalized the data and did not just identify areas that had the highest counts of positives which logically can be correlated to those with the most collections. The results of MIR calculations are shown in Figure 3.

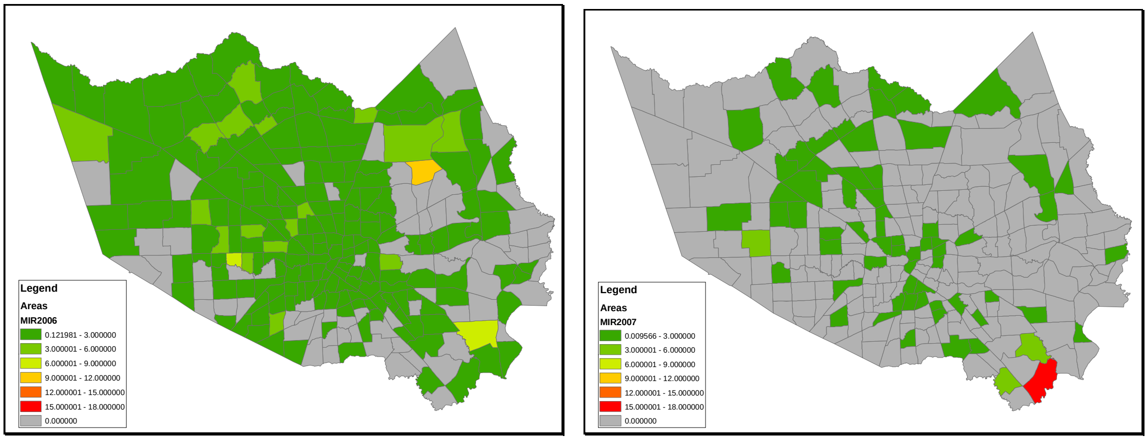


Figure 3: Comparison of MIR, 2006-2007

C. Climatic Analysis

1. Data Collection

Based on the literature, a number of variables were either collected or derived to determine their relationship to mosquito, bird and virus activity (Table 1).

Table 1: Summary of variables used in study

Variable	Relation to ecology of WNv vector mosquitoes
Mean temperature	Mosquito activity
Minimum temperature	Minimum threshold for WNv infection (14.3° C)
Maxiimum temperature	Upper threshold of peak mosquito activity (34° C)
Precipitation	Timing of breeding site appearance
Evaporation	Timing of breeding site appearance
Water availability	Timing of breeding site appearance
Land cover	Location of breeding sites

The climatic data used in this project was derived from two main (2) sources: NOAA COOP and HCOEM stations. The National Oceanographic and Atmospheric Administration (NOAA) maintains the Cooperative Observer Program (COOP) stations and their data is available to download from the National Climatic Data Center’s (NCDC) website. A network of 55 stations was found in the vicinity of which only 18 collected data on temperature and/or precipitation for the period in question (Figure 4).

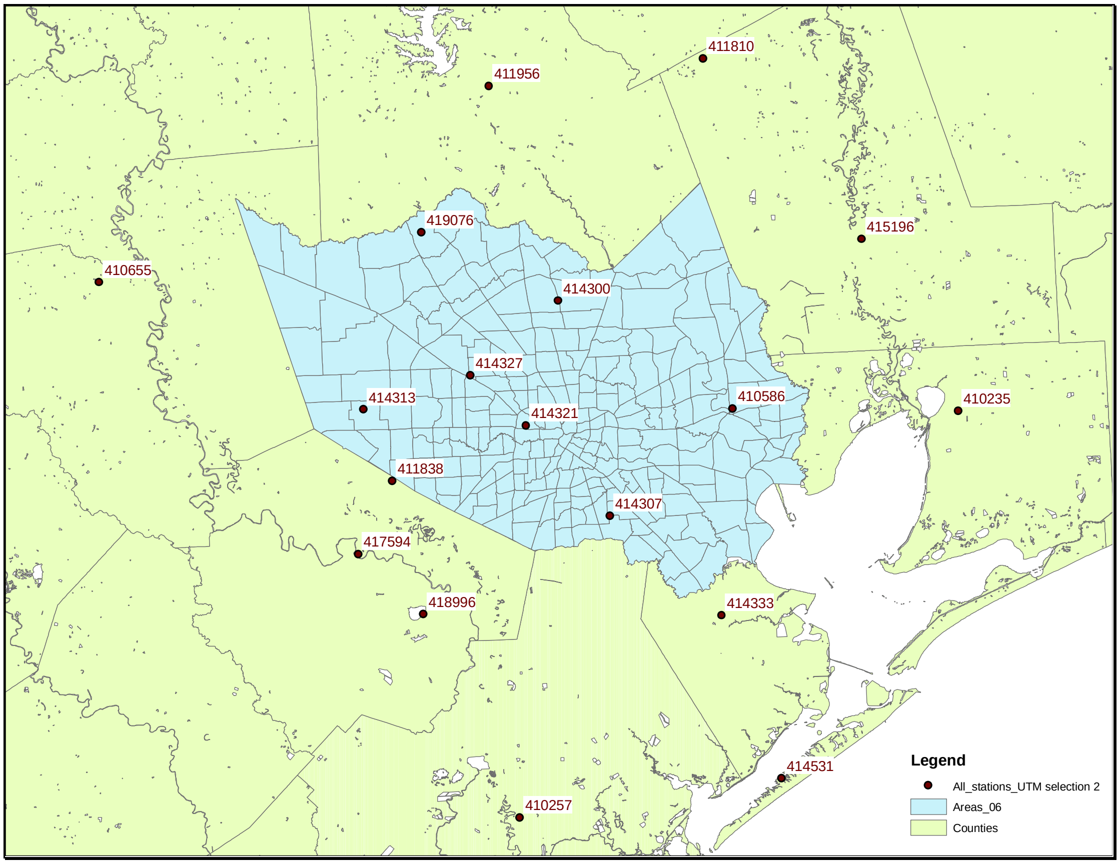


Figure 4: NOAA COOP stations used to determine climatic variables

The other network of gauges was maintained by the Harris County Office of Emergency Management (HCOEM) (http://www.hcoem.org/) as part of the Houston TransStar consortium. The Houston TranStar consortium is a partnership of four (4) government agencies responsible for providing that manage transportation and emergencies in the region. As part of this mission, the Harris County Office of Homeland Security and Emergency Management (HCOEM) has maintained a network of gauges in and around Harris County since the fall of 2000. These gauges collect a variety of data regarding weather and road conditions including real-time rainfall and stream level data to determine if any flash flooding is occurring (Benz et al., 2003). In accordance with their purpose, the vast majority of gauges are located at the intersections of major roads and the many creeks, lakes, and bayous present in the region (Figure 5).

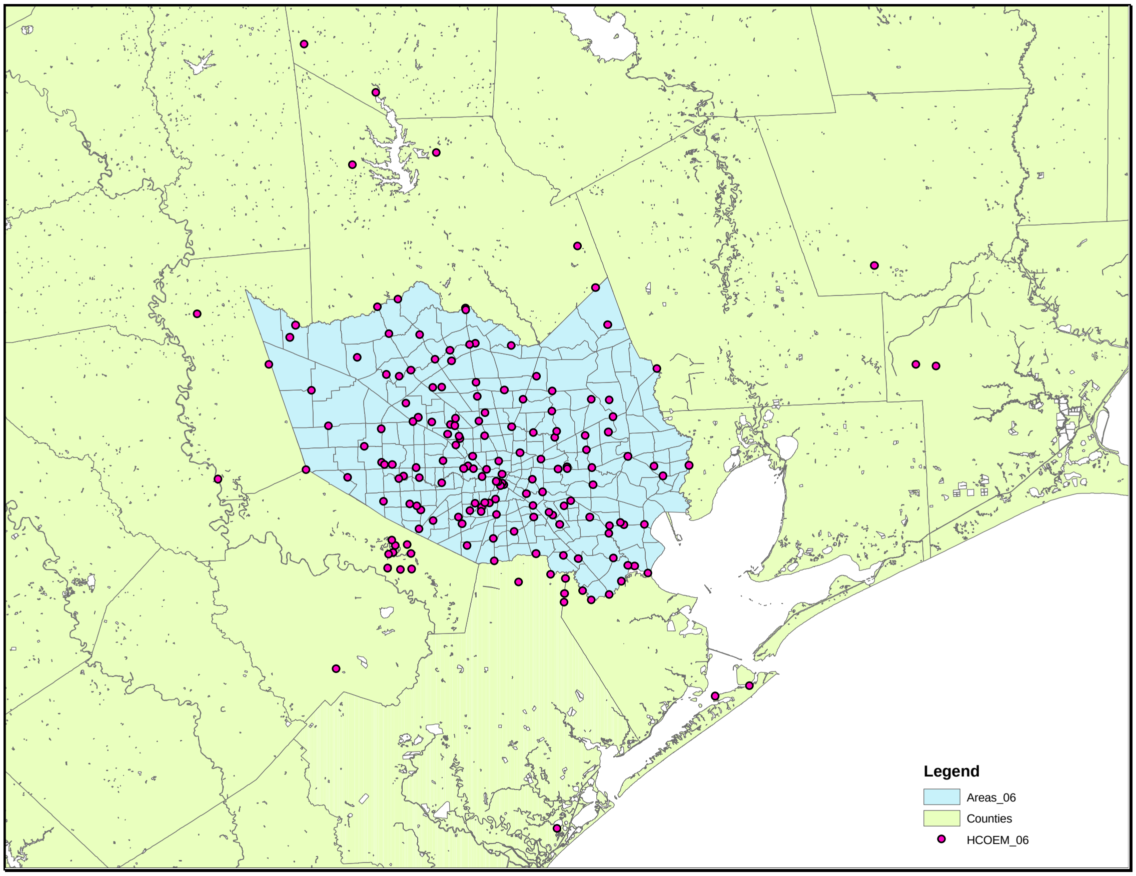


Figure 5: HCOEM stations used to determine climatic variables

With over 700 gauges in 243 locations in and around the county currently in operation, this network was used because it provided a much denser coverage of data than the NOAA COOP stations. The stations included in the network come from a variety of agencies with most being provided by HCOEM itself (Appendix A). If any data were recorded, a text file was provided the date and time of every temperature or precipitation recording.

Weather stations were located using their Cartesian coordinates then reprojected along with all other shapefiles and images in ArcMap to “Lambert Conformal Conic” using the “NAD 1983 StatePlane Texas South Central FIPS 4204 Feet” datum to match the projection of the HCMC operational areas. For both sets of stations, all temperature readings were in degrees Fahrenheit (℉) and all precipitation totals were given in inches (in). To conform to academic standards, temperature values were converted to degrees Celsius (℃) while precipitation values were converted to millimeters (mm). The precipitation gauges used by the HCOEM were tipping bucket recording gauges that recorded the time every time 0.03937 inches of rain falls into the bucket, with a minimum repeat interval of 5 minutes. This means that a minimum of 5 minutes must past before another reading is recorded, which during rapid rain events resulted in successive records being different by a factor of more than 0.03937 inches. Additionally, there is a maximum recording interval of 12 hours regardless whether precipitation fell or not which ensured a minimum of two records per day barring mechanical error.

2. Data Processing

a. Precipitation

In order to compare the climatic data to the aforementioned data from HCMC they needed to be aggregated to the daily and then weekly scale. However, this could not be done immediately given the number of problems present in the HCOEM dataset. Using the station data files, an initial exploration of the data was undertaken to determine the quality of the data. Two (2) stations from each of the three largest contributing agencies

(HCOEM, TXDOT, and the City of Sugarland) were processed manually using Microsoft Excel. Doing this allowed for assessment of the problems in the data that needed to be solved before processing.

The major problem encountered was that a large number of days were simply missing from the record, which resulted in a number of stations having an insufficient amount of data available. This ranged from a couple of days to several weeks worth of missing or incomplete data. Fortunately given the density of data available (Figure 6), a number of stations with missing data were still able to be included by using interpolated values from nearby stations to fill in missing days. Data from stations were not used if the station had more than 5% or eighteen (18) days of data missing from the record given the great density of data.

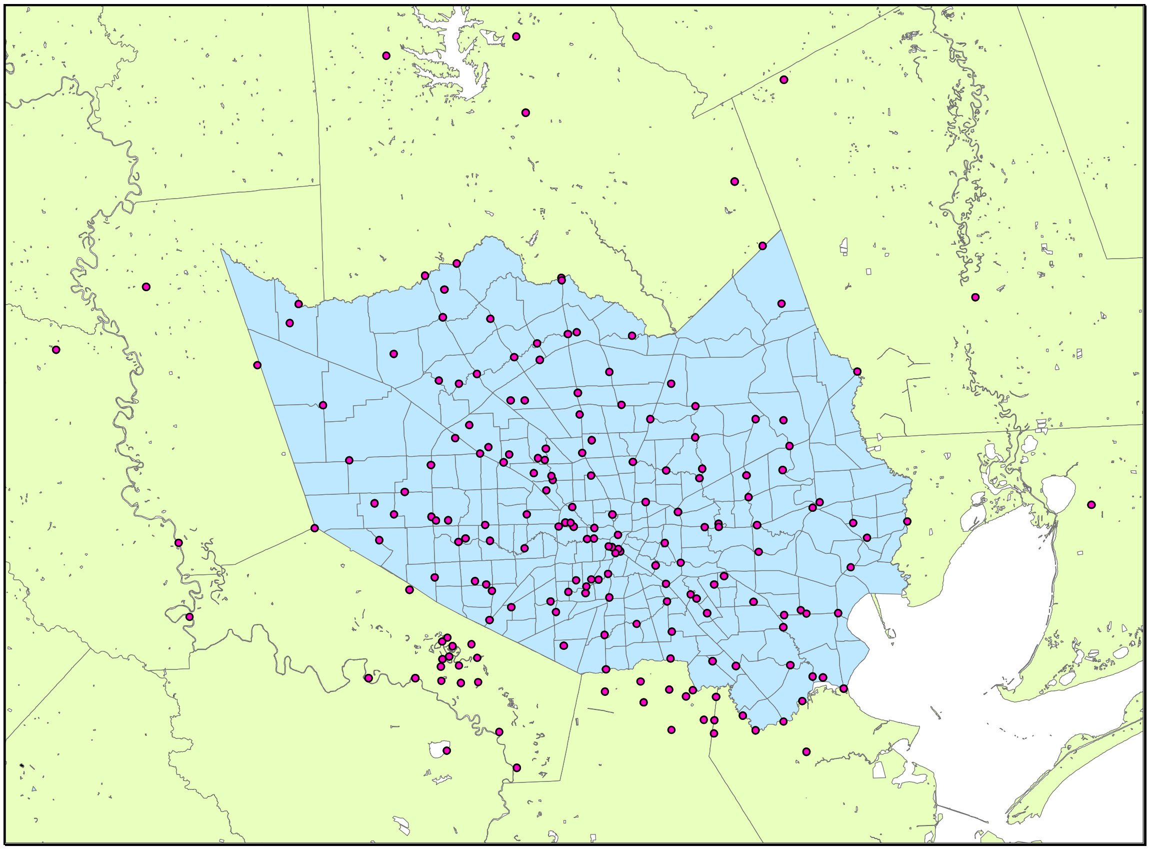


Figure 6: Stations used to determine precipitation

Next, the values themselves were examined to identify the number of recording errors in the dataset. A number of the stations had records with totals that carried over from the previous year. Many of these stations also had records that would reset to zero in the middle of the year once or multiple times. When either of these problems occurred, the values needed to be adjusted to produce accurate values.

Given the multiple and varied issues with such a large amount of information, the data gathered from HCOEM were processed automatically rather than undergoing the arduous task of manually processing them via a spreadsheet program like Excel. With the assistance of Dr. Steven Quiring of the Texas A&M Department of Geography a FORTRAN program was developed which would read in the precipitation data files for each station and correct the aforementioned issues in order to have a record which began at 0.00 and continuously recorded the aggregation of precipitation throughout the year. This record was then used in another FORTRAN program to identify missing values in the data to aggregate precipitation to a daily scale and weekly scale. The daily aggregated files were compiled into one database and examined to find and correct missing days identified by “-99”. Each such record was interpolated by totaling the precipitation values for the three (3) closest HCOEM or COOP stations for that day and using their average to fill in the missing value. If one of these stations was also missing its value for a given day then the next closest station’s values was used to in the calculation. If the next closest station also did not have a valid reading, then the reading from the nearest COOP station would be used regardless of its proximity to the station in question.

Over the study period, every week contained the normal 7 days except for the 52nd and final week of each year, which contained 8 days. Additionally the weeks were numbered continuously from 1 through 104 starting in January 2006 with Week 53 beginning on the first day of 2007. If any week contained one or more days that were missing values, then its value would be greatly affected by the inclusion of this missing value. After the daily records were filled weekly values were recalculated to complete that record.

Once aggregated, precipitation values were checked to make sure they were “realistic”. Using Thiessen polygons, each of the HCOEM stations was allocated to the nearest COOP station and compared to the other stations allocated to the same polygon. Stations were eliminated from consideration if their total yearly values were not in line with the totals from the COOP stations. If stations were found to be more than 50% different from the highest or lowest acceptable values they were eliminated.

b. Temperature

The same programming process used in compiling the precipitation data was undertaken for temperature readings; however processing the HCOEM stations to obtain temperature values was impractical given the unreliability of such a large dataset. The number of locations in the area that recorded temperature was about the same 12 for the NCDC dataset vs. 14 for the HCOEM (Figure 7). Ideally, these datasets would have been combined as was done for precipitation but given the relative homogeneity of temperature the use of far fewer stations was considered acceptable. However, the coverage of NCDC stations was not adequate enough to the west of the county to interpolate values for the western edges of the county.

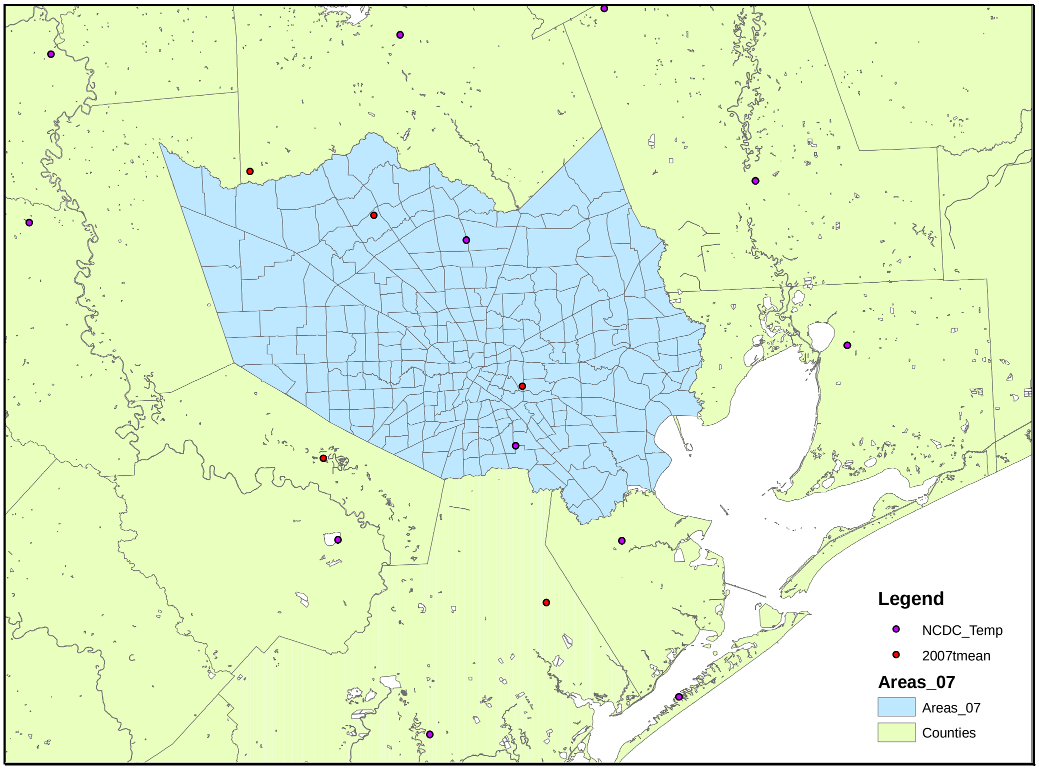


Figure 7: Stations used to determine temperature

To remedy this problem, additional data were gathered from the Weather Underground (www.weatherunderground.com) from weather stations at Hooks Memorial, Sugarland Hull, Memorial Northwest and Skydive Houston Airports that were determined to be reliable through comparison to nearby COOP stations. With both precipitation and temperature records complete, it was now possible to derive evaporation values.

c. Evaporation and Water Availability

Using a FORTRAN program created by Dr. Quiring, daily evapotranspiration values were derived by using the Priestly-Taylor equation:

$$\text{RefET}_{pot} = \frac{\text{PT}_c \cdot \text{Slope}_{vpf} \cdot (\text{Rad}_{net} - \text{SoilHeatFlux})}{(\text{Slope}_{vpf} + \lambda)}$$

PT_c	(unitless)	the Priestley-Taylor constant location parameter
Rad_{net}	((MJ/m^2)/day)	the net radiation
Slope_{vpf}	(kPa/℃)	the slope of saturation vapor pressure function of temperature
λ	(kPa/C)	is the psychometric constant
SoilHeatFlux	((MJ/m^2)/day)	is the soil heat flux.

Because temperature values are needed for this derivation, only stations that measured temperature and precipitation values were calculated. The program was customized for each of the twelve COOP (12) stations that were used (Figure 8). By inputting only the daily maximum and minimum temperatures, annual precipitation, and the latitude for each location, the program was able to derive the variables found in the Priestly-Taylor equation. Net radiation was calculated by using latitude and the temperature extremes based on the methods developed by Kimball et al. (1997) and Mahmood & Hubbard (2002). Slope of the saturation vapor curve was calculated using the daily mean temperature. The psychrometric constant was calculated using latent vaporization, which was also derived from mean temperature. Soil heat flux is assumed to be 10% of net radiation (Kimball et al., 1997). Once calculated, each station provided a daily evaporation value (mm/day) which was then subtracted from precipitation values to estimate the amount of water available for each station. Each of these variables were aggregated on the same weekly scale as all other variables. In addition, water availability was stored weekly as a running total.

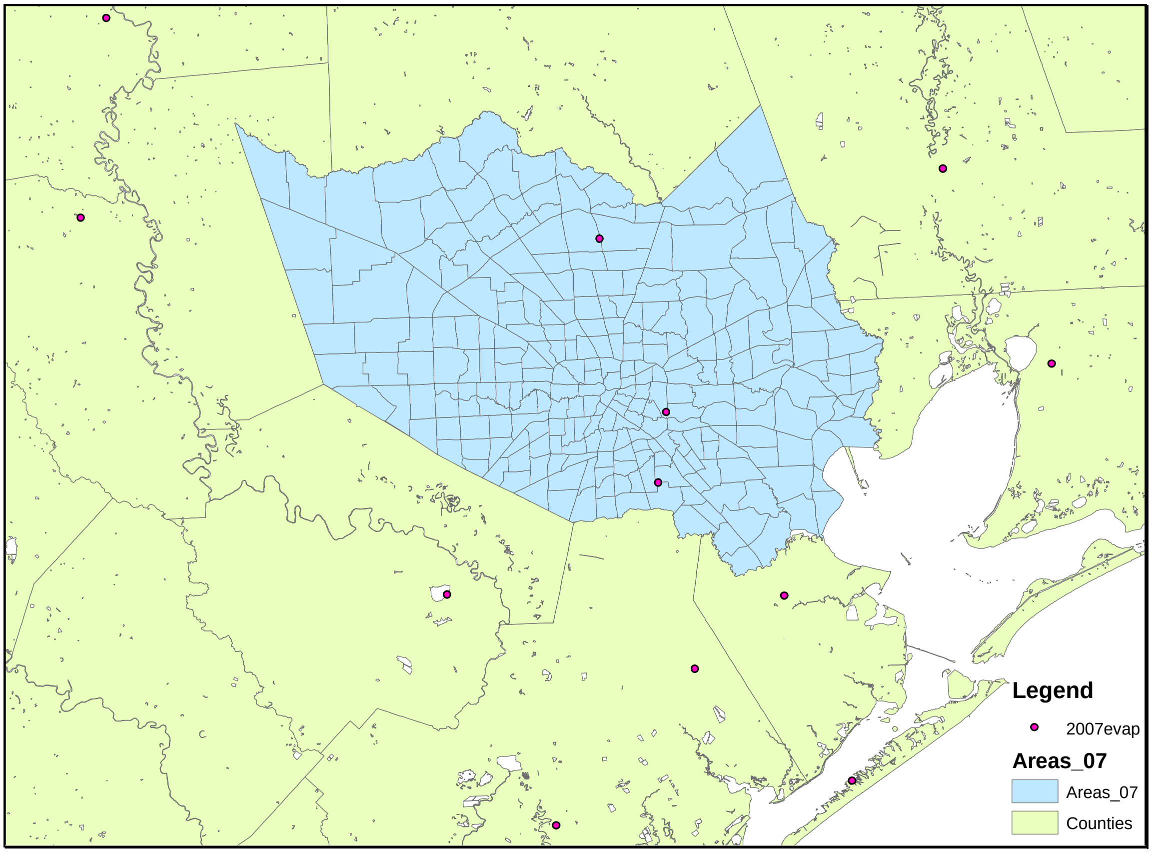


Figure 8: Stations used to determine evaporation

d. Regression Analysis

Linear regression analysis was undertaken to determine if any collinearity issues existed between temperature, precipitation, evaporation and water availability. As expected this analysis found significant correlations between the temperature and evaporation but not between any other variables. Without the presence of such collineraity all climatic variables were used in the analysis.

e. Interpolation

Spatial interpolation was undertaken to create surfaces with climatic values to cover the entire Houston area once all of the data were deemed to be as realistic and accurate as possible. Due to the oftentimes-localized nature of precipitation, the best method was determined to be inverse distance weighting (IDW). As its name implies, IDW assigns higher weights to sampled values according to the inverse of its distance, meaning that points in the immediate proximity to the estimated point will play a bigger role in its estimation. Stations such as those along the Gulf Coast in Brazoria and Galveston County were not included in the interpolation of precipitation due to their distance from Harris County. Using the 12 nearest stations within a 10-mile radius, surfaces for total weekly precipitation for all 104 weeks of the study period were created.

Temperature was interpolated using the kriging method, while evaporation was interpolated using the curvature spline technique. These smoother interpolation methods were used given that temperature and evaporation are generally more spatially homogenous. Even though the common interpolation methods such as minimum curvature spline, inverse distance weighting (IDW), and kriging vary drastically in terms of their methods, there is little difference in their interpolation results of air temperature. Kriging has consistently been found to be the most accurate of the interpolation methods for air temperature. The ordinary kriging method was chosen over other kriging because there was no noticeable overriding trend in the data used. Temperature was interpolated without considering the effect of elevation given the lack of relief in the area. The complete spline technique was chosen to following the methods of Cooke et al. (2006) which was the only study I found that considered evaporation or water availability in their analysis of WNv. They chose to use this method because it allowed for more variability in close areas.

D. Land Cover Analysis

To determine the effect that the physical and built environment had on WNv, the distribution of land cover was considered. Land use/land cover data for the study area was derived from a classification of the Gulf Coast commissioned by the NOAA Coastal Services Center (CSC) (Figure 9).

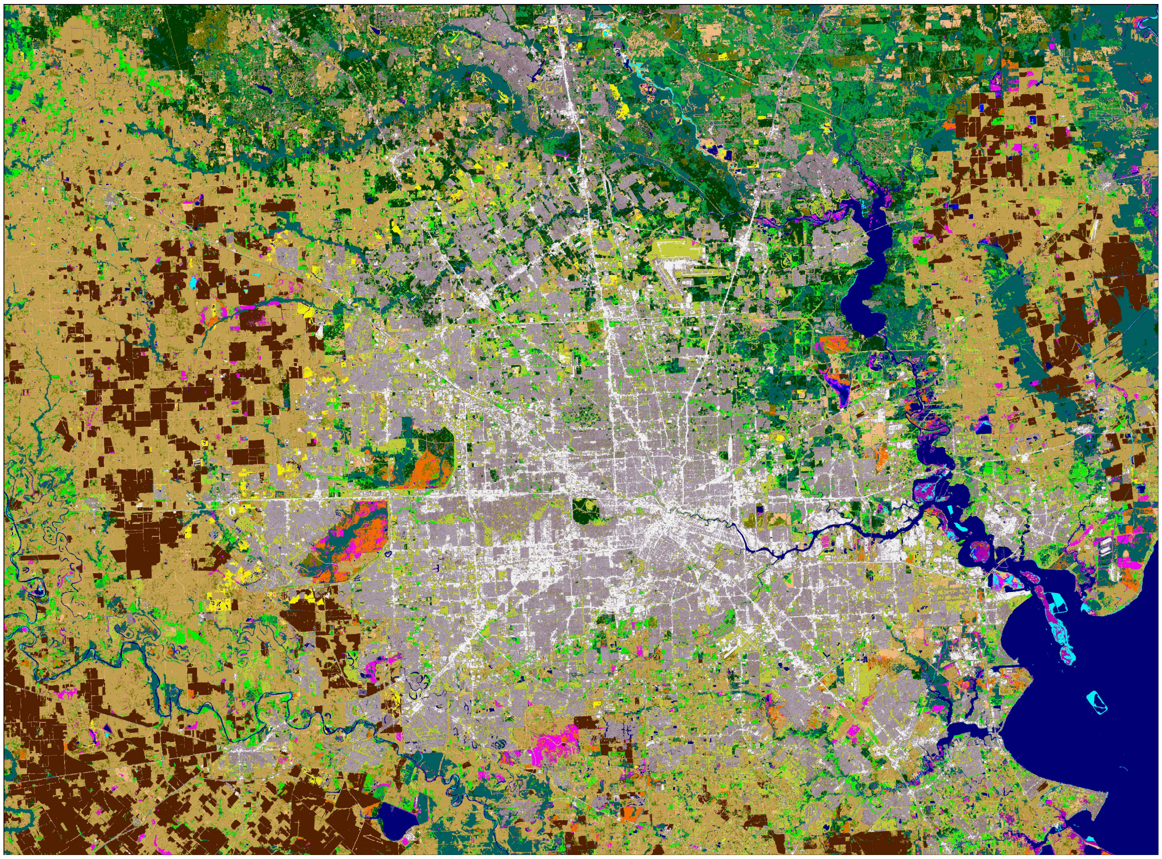


Figure 9: NOAA CSC classification Image

This classification was commissioned to determine what effect Hurricanes Katrina and Rita had on Gulf Coast land cover. Eighteen (18) full or partial Landsat 5 Thematic Mapper scenes from 2005 (resolution 30 x 30m) were utilized in the classification of the area to determine pre-hurricane conditions. These images were then analyzed using the

Coastal Change Analysis Program (C-CAP) protocol to classify land cover. While similar data for 2006 was used, the classification did not provide coverage of Harris County therefore the 2005 classification was used. This classification used twenty-three (23) land cover classes that covered several coastal, rural, urban, and suburban land cover types (Appendix B).

Using the same operational areas as the previous processing steps, a zonal histogram was created to determine the amount of each land cover class that occurred in each operational area of Harris County. This was then converted to a simple value of overall percentage per area for easy comparison between all areas.

E. Statistical Analysis and Comparison

Using the gridded climate fields created by interpolating the data in Spatial Analyst was used to calculate zonal statistics for each of the HCMC operational areas. This allowed for average values for each area, or zonal means, to be calculated for every week of the year. After this step, all the raw data was finally collected and processed to match one another. Using this dataset, additional variables representing the lag of precipitation, temperature, evaporation, and water availability were created. This was done to represent conditions present when oviposition and the different stages of the mosquito life cycle or the extrinsic incubation period for the disease occurred. Based on the literature and in line with epidemiological methods, lag values for each week were created for one to eight weeks (>2 incubation periods) prior when possible. After this step, all variables were ready for analysis.

Statistical analysis was conducted to determine the relationships between the various factors included in this study. First, pairwise Pearson’s r correlations were conducted for *all areas by week* to identify which climatic and environmental variables were significantly associated with population and infection rates. This temporal analysis did not allow for examination of land cover characteristics, a static variable. This step was conducted again but for *all weeks by area* to determine significance. This spatial analysis did not allowed for examination of the various lag values. Undertaking these steps allowed later spatiotemporal analysis to pinpoint and focus only on the variables found to be most relevant in controlling disease incidence. Two-tailed significance was tested at the 0.01 at 0.05 levels and unless stated otherwise all p-values where significant at $\alpha = 0.01$.

To determine why the incidence of WNv dropped so sharply between 2006 and 2007 in Harris County and how climatic differences between the two years were related to this, the differences in relevant variables were compared. Weeks and operational areas that with the greatest number of positive pools (hotspots) were spatiotemporally analyzed (individual area by week) to determine what factors at what times of the year made these locations and periods exceptionally at risk for West Nile. Initially the operational areas with the highest MIR value, areas 807 and 921, were to be examined. However, their high MIRs are a more a result of a single positive pool found in areas with low mosquito collection totals. With only four pools tested from Area 921 (MIR=47.6 per 1,000), this gives the area’s mosquitoes apparently at least a 25% raw infection rate. With only five pools tested this gives area 807 (MIR=41.66 per 1,000) an apparent 20% raw infection rate but given the extremely small sample size these values should for all intents and purposes be considered an anomaly.

CHAPTER IV

RESULTS

A. Overview

Statistical results showed that a number of biological and environmental factors associated with the occurrence of West Nile virus cycling in the area around Harris County, Texas correlated well with one another and identified some potentially significant associations (Appendix C). The results indicated better correlations when analyzing the data on a weekly basis (temporally) rather than analyzing the data by each HCMC operational area (spatially). As expected, datasets from 2006 showed stronger and more significant correlations ($\alpha=0.05$ or 0.01) with one another than datasets from 2007 in almost all instances. In this section the results of these correlations will be revealed.

B. Temperature

In both years of the study, it was found that the peak, in terms of both the number of mosquitoes and minimum WNv infection rate (MIR) occurred in August, following the trends in the Harris County area as previously reported by Dennett et al. (2007a). The WNv infectious peak coincided with the highest temperatures of the year, but this only tells half the story. What happens during cooler months of the year when temperatures are not as favorable for mosquitoes?

As one can see in Tables A2, A3, and A4 (Appendix C) all three measures of temperature were highly and significantly correlated to nearly every measure of mosquito abundance and WNv infection rates in mosquitoes. In general, temperature data from the year 2006 had far stronger correlations than 2007. For example in 2006, mean temperature correlated with WNv positive mosquito pools with correlation values ranging from 0.654 ($p=0.000$) for an 8-week lag to 0.840 ($p=0.000$) for one-week lag (Appendix C:

Table A2). In 2007, mean temperature correlated with WNv positive mosquito pools with correlation values ranging from 0.590 (p=0.000) for an eight-week lag to 0.667 (p=0.000) for two-week lag. Virtually all correlations with temperature generally followed this same trend where correlation values decreased as the amount of lag in the variables increased.

Overall, minimum temperature produced greater correlations with all biological variables in 2006 (Appendix C: Table A4). Temperature-related lag values experienced an increasing trend in correlation values as the amount of lag in the data was reduced. This is consistent with the numerous studies that indicate the strong control that temperature has on the mosquito life cycle. This peaked at r=0.851 (p=0.000) for WNv positive mosquitoes with one-week lag. In 2007, minimum temperature had a smaller influence. Correlations for positives were slightly lower on average with 1-week lag at r=0.680 (p=0.000). Again, the strong correlations for lag values are those associated with minimum temperature for WNv positive mosquito pools.

For the bird-related variables correlation with minimum temperature peaked at 0.836 (p=0.000) for dead bird calls from the public with no lag and 0.717 (p=0.000) for WNv positive dead birds with a two-week lag (Appendix C: Table B3). The only variables that did not exhibit strong correlations with temperature were the data related to the capture and testing of live birds which showed insignificant correlation values ($r \leq 0.3$) for all three measures. Of course, this is due to the fact that birds that were caught and tested when alive were much less likely to have contracted the virus than dead birds. Also, it is important to remember that bird populations and abundance are not affected by temperature to the same degree as mosquitoes.

C. Precipitation

Precipitation was found to be only weakly correlated with a few mosquito-related variables (Appendix C: Table A6). For example, when synchronous precipitation from 2006 was correlated with WNv MIR in mosquito samples this produced correlations of 0.326 (p=0.018) for gravid trap mosquito collections, 0.158 (p=0.277) for storm sewer mosquito light traps, and 0.323 (p=0.019) overall. Using data from 2007, r values for MIR declined to the point of no significance, .010 (p=0.941) for gravid trap collections, 0.125 (p=0.386) for storm sewer trap collections, and .053 (p=0.710) overall. Similarly, when synchronous precipitation was correlated with the number of positive WNv pools found a correlation of 0.306 (p=0.027) in 2006 but was insignificant in 2007 (r=0.144, p=0.310). When correlated with bird-based variables, correlations were slightly negative (r=-0.113) and insignificant (p=0.430) when compared to the percentage of birds that were found to be positive for WNv (Appendix C: Table B5).

D. Evaporation and Water Availability

Like temperature, correlations of evaporation versus mosquito-based variables yielded strong associations across the board (Appendix C: Table A5). Given the strong relationship of evaporation to temperature, it only makes sense that the lagged values of temperature and evaporation would exhibit similar relationships. In 2006, synchronous evaporation yielded a correlation value of 0.659 (p=0.000) for confirmed WNv positive pools of mosquitoes which decreased to 0.454 (p=0.001) in 2007. When correlated with total female mosquitoes trapped, synchronous evaporation showed strong associations in both 2006 (r=0.808, p=0.000) and 2007 (r=0.770, p=0.000). When lagged, evaporation correlated between 0.824 (p=0.000) for one-week lag and 0.405 (p=0.006) for eight-week lag in 2006 and 0.680 (p=0.000) for one-week lag and 0.289 (.057) for eight-week lag in 2007 with WNv positive pools. Like temperature, evaporation exhibited the same declining trend in correlations with WNv positive pools as the amount of lag increased.

In stark contrast, water accumulation was negatively correlated to mosquito-based values in 2006 (Tables 2 and 3).

Table 2: Water accumulation correlations for mosquito variables, 2006-2007

	GV	SS	Log	Pos_GV	Pos_SS	Positive	MIR_GV	MIR_SS	MIR
2006	-.591**	-.557**	-.702**	-.135	-.201	-.353*	-.113	-.099	-.105
	.000	.000	.000	.341	.154	.010	.426	.500	.460
2007	.163	.367**	.240	.494**	.411**	.578**	.409**	.403**	.437**
	.247	.007	.087	.000	.002	.000	.003	.004	.001

Table 3: Water accumulation correlations for bird variables, 2006-2007

	Calls	DTest	PctTest	Dpos	PctDPos	Live_Log	Lpos	PctLPos	Birds	Bird_Pos	PctBPos
2006	-.730**	-.614**	.423**	-.327*	-.243	-.154	-.154	-.241	-.586**	-.302*	-.320*
	.000	.000	.002	.018	.082	.356	.410	.191	.000	.030	.022
2007	-.189	-.158	.091	.560**	.468**	.131	-.238	-.409*	-.024	.232	.332*
	.180	.265	.519	.000	.001	.446	.161	.013	.867	.098	.017

Comparison of means showed that the difference in annual water accumulation between 2006 and 2007 was over 300 mm (~12 in) more available water in 2007. The number of mosquitoes captured was strongly negatively correlated to water accumulation (r= -0.702, p=0.000) while the number of WNv positive mosquito pools followed the same trend (r= -0.353, p=0.000). However, these trends reversed in 2007 and these correlations became strongly positive for both total mosquitoes trapped (r=0.240, p=0.087) and positive pools (r=0.578, p=0.000). Bird-based variables experienced similar correlations but not to the same magnitude as their mosquito counterparts. For example, the percentage of birds that tested WNv positive went from a value of -0.320 (p=0.022) in

2006 to 0.332 (p=0.017) in 2007 (Table 3). In 2007 the correlations between WNv positive dead birds was even stronger (r=0.560, p=0.000).

E. Biological

The type of trap used to collect mosquito samples had an important effect on correlations. In every significant correlation found in 2006 variables, mosquitoes caught in gravid traps had stronger negative and positive correlations across the board. This is to be expected as gravid traps, which are placed on the surface, would be more exposed to the elements than the traps sheltered underground in the storm sewer (Dennett et al., 2007b). This trend generally continued into 2007 with the differences between the collections results from gravid and storm sewer traps diminishing. In some cases, correlations between gravid trap caught mosquitoes and important variables such as MIR were lower than the correlations found between the same variable and storm sewer mosquito trapping results (r=0.325 vs. r=0.362) (Appendix C: Table A6).

The number of live and dead birds that tested positive for WNv was comparable between the two years (192 in 2006 and 190 in 2007) indicating a similar level of disease prevalence in birds for both years. As expected the number of positive dead birds was strongly correlated to the number of positive mosquito pools found (r=0.772, p<0.0001). This was not the case however for their live counterparts (r=0.022, p=0.908). This led to an overall correlation of 0.620 (p<0.0001) which was largely a result of the positive dead birds (Appendix C: Table A6).

F. Land Cover

When comparing variables pertaining to land cover in Harris County, the only static variable for both study years, correlation values were magnitudes smaller when analyzed by area rather than by week. The only spatiotemporal variable that was significantly correlated to WNv MIR in mosquitoes spatially was evaporation (r=0.255). When land cover was examined, it revealed some associations of note. First, high and medium intensity developed areas (See Appendix B) were moderately but significantly correlated to the number of mosquitoes captured (r=0.398 & 0.402) and positive mosquitoes (r=0.237 & 0.294) in 2006 (Appendix C: Tables C1-C6). This association remained similar for total mosquitoes (r=0.334 & 0.323) in 2007 but not positive (r=0.034 & .097). Other land cover classes showed relatively weak but significant degrees of correlations with mosquito and West Nile variables. In contrast to the study by DeGroote et al. (2007) which found deciduous forest land cover to be a disease amplifier it was negatively correlated to the total mosquitoes (r=-0.266) and positives (r=-0.290) in 2006.

G. Spatiotemporal Analyses

Conducting spatiotemporal analyses allowed for the identification of temperature with lag, evaporation, WNv positive birds, water aggregation and developed land cover as the most relevant variables in relation to mosquito and disease activity. Using these variables, spatiotemporal analysis was carried out on operational areas with a high number of positive pools or a high MIR to determine what climatic and environmental factors made them hotspots. In this study Weeks 31 and 83, the weeks at the center of the epidemic peak in each year 2006 and 2007 respectively, were analyzed to determine the variation in climate that may have caused the sharp decline in WNv positive pools from 97 in 2006 to just 9 in 2007.

This 90% decline in the number of WNv positive mosquito pools is virtually the same as yearly total (Table 4). However, both years were weakly correlated for all variables examined (Appendix C: Tables D1-D7). The strongest correlation of any significance was mean temperature lagged one week to the total number of mosquitoes collected (r=0.302). Examining Area 22, the operational area that yielded the most positive cases, did not uncover any new associations either (Appendix C: Table E7). Correlations were similar but not as strong.

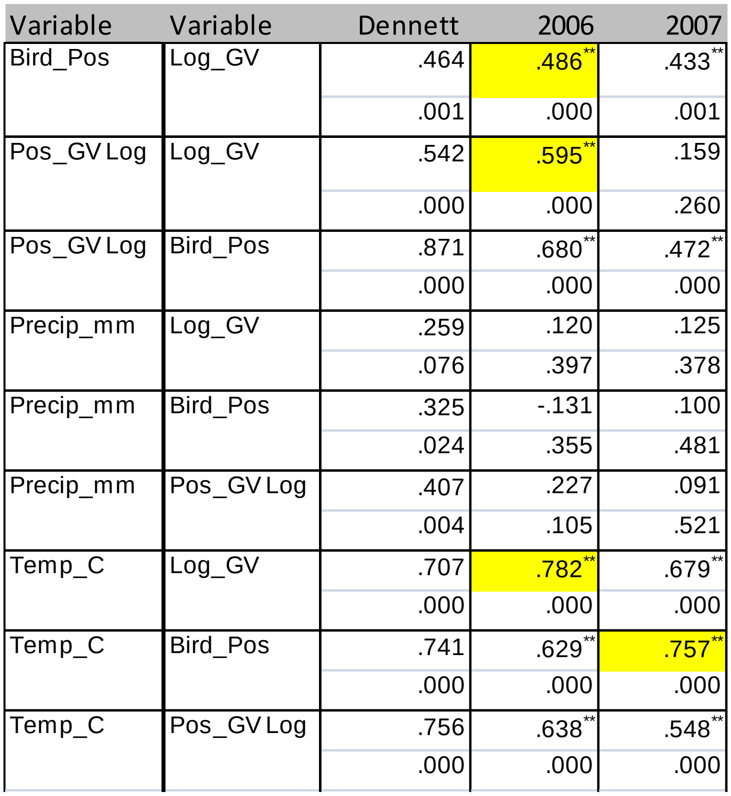
CHAPTER V

DISCUSSION

A. Overview

The increased resolution of climatic data used in this study allowed for a much more in-depth analysis of such a critical component in the mosquito life cycle and West Nile virus ecology as it pertains to Harris County, Texas. It revealed a number of associations that were not found looking at the lower resolution data. However, when compared like-for-like to the correlations and results found in the HCMC's previous study of the area conducted by Dennett et al., (2007a) this was not apparent (Table 4).

Table 4: Comparison to Dennett et al., 2007a



Variable	Variable	Dennett	2006	2007
Bird_Pos	Log_GV	.464	.486**	.433**
		.001	.000	.001
Pos_GV Log	Log_GV	.542	.595**	.159
		.000	.000	.260
Pos_GV Log	Bird_Pos	.871	.680**	.472**
		.000	.000	.000
Precip_mm	Log_GV	.259	.120	.125
		.076	.397	.378
Precip_mm	Bird_Pos	.325	-.131	.100
		.024	.355	.481
Precip_mm	Pos_GV Log	.407	.227	.091
		.004	.105	.521
Temp_C	Log_GV	.707	.782**	.679**
		.000	.000	.000
Temp_C	Bird_Pos	.741	.629**	.757**
		.000	.000	.000
Temp_C	Pos_GV Log	.756	.638**	.548**
		.000	.000	.000

Dennett et al.’s study (2007) relied on a single weather station at Houston’s Hobby Airport for all its climatic data and only examined gravid trapping (GV) results while the current study used nearly 200 stations and examined both gravid and storm sewer (SS) trapping results. In some cases correlations improved on Dennett et al.’s results such as the r value of mean temperature and the number of females mosquitoes from gravid traps in 2006 improving from 0.707 (p=0.000) in Dennett’s results to 0.782 (p=0.000) in this study. However, at the same time the same correlation was slightly lower in 2007 (r=0.679, p=0.000). This lower value was similar to the trend for the nine (9) correlations compared between the two studies.

Because the data used in these two studies wer quite different, whether the mixed results found in Table 4 indicate anything meaningful is questionable. Dennett et al. had much higher resolution mosquito and bird data while this study had a much higher resolution of climatic data. Either of these difference could have caused the true results to be masked or altered. After determining the effectiveness of the increased resolution of data the focus of this discussion turns to determining why there was such a sharp decline in West Nile virus positives in mosquito collections from 2006 to 2007 in Harris County.

B. Biological

Prevalence of the disease in reservoir hosts indicated by the number and percentage of positive birds was nearly the same in both 2006 and 2007 (Table 5). After coming to this conclusion, the question then becomes, why was WNv not transmitted from birds to mosquitoes at an equivalent rate in 2007?

Table 5: Biological variables, 2006-2007

Variable	2006	2007	Difference
Gravid trapped mosquitoes	645342	689980	44638
Storm sewer mosquitoes	312195	220412	-91783
Total Mosquitoes	957537	910392	-47145
WNv+ Mosquitoes	842	86	-756
Mosquito WNv MIR	0.879	0.094	-89.30602958
Live Birds	735	973	238
Dead Birds	495	666	171
Total	1230	1632	402
WNv + Birds	190	192	2
Pct Birds WNv Positive	15.45%	11.76%	3.69%

The fact that there are no major differences in the numbers in Table 5 aside from the number of positive mosquitoes indicates that the amount of testing was not the reason for the decline. However, it is fairly clear that a sampling bias towards areas inside and in close proximity to the I-610 loop exists (Figure 3). Nearly all of the areas that yielded more than single digit positive pools were located inside the 610 Loop. These areas generally had the greatest number of mosquitoes collected as well. The areas that had the most positive pools in 2006 generally saw their collection numbers increase greatly in 2007.

Whether the amount of trapping increased in these hotspots or not is unknown from the data provided but any possible changes in trapping appears to have decreased total collections elsewhere around the county. This is likely due to the fact the HCMC operations center is located in operational area 53 near the southern edge of the loop which makes trapping in this part of the county the cheapest and most efficient.

C. Temperature

As expected, temperature had a very important influence on all mosquito-related variables. According to the National Weather Service in Houston/Galveston, 2006 was the 8th warmest year on record with 2007 being only slightly cooler. Both WNv and mosquito activity are highly temperature-dependent phenomena (Rueda et al., 1990; Spielman 2001, Dohm et al. 2002, Tesh et al.2004) and comparison of means showed little difference between the two years for mean temperature (Figure 10).

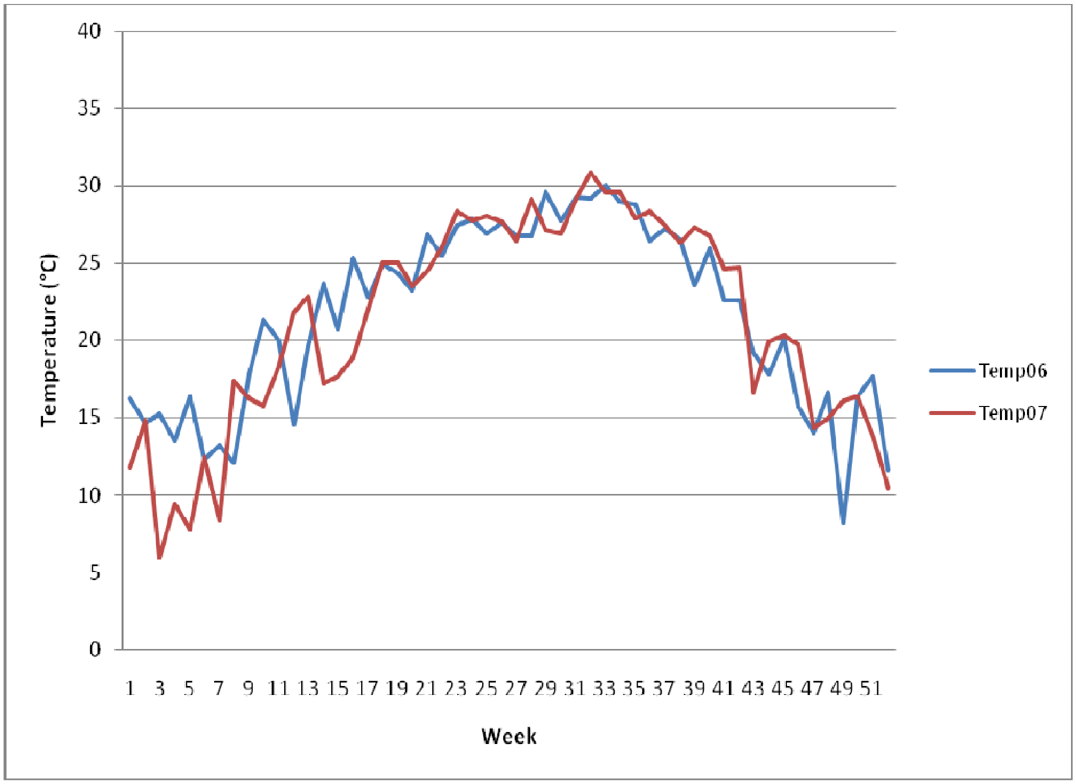


Figure 10: Comparison of mean temperature, 2006-2007

The high correlations found for temperature (Appendix C: Tables A2, A3, and A4) are in line with the numerous studies that found that activity in mosquitoes increases as temperature increases (Rueda et al., 1990; Spielman 2001, Dohm et al. 2002, Tesh et al.2004). The slightly lower mean temperatures in 2007 (21.1℃) compared to 2006 (21.6℃) appears to have caused a drop in the strength and number of significant correlations but did not affect the overall association between temperature, mosquito abundance, and WNv activity (Table 6).

Table 6: Climatic variables (means), 2006-2007

Variable	2006	2007	Difference
Temperature (Mean)	21.6	21.14	-0.46
Temperature (Max)	24.69	25.97	1.28
Temperature (Min)	16.2	16.04	-0.16
Precipitation	1370.56	1639.91	269.35
Evaporation	1375.2	1316.38	-58.82
Water Availability (P-E)	-100.78	-18.45	82.33
Water Aggregation	-4.64	323.54	328.18

If the findings by Dohm et al. (2002) that it only takes 4 days from bloodmeal to infection in mosquitoes are to be believed then the temperatures in August which hover around 30℃ mean that the no lag or a one-week lag temperature should correlate well with the number of mosquitoes. Data from both 2006 and 2007 produced significant correlations between temperature variables and mosquito-related variables. Correlation values between mean temperature and total mosquitoes (2006: 0.840; 2007: 0.751) and WNv positive pools (2006: 0.780; 2007: 0.646) seem to confirm these relationships.

Comparison of means for maximum temperature was the most divergent between the two years of this study (Figure 11). Maximum temperature in 2007 was approximately 1.3℃ higher than 2006 (Table 5). Only a few weeks in either year even approached the 34℃ average temperature threshold that Rueda et al . (1990) mentioned as the upper threshold for increased mosquito activity. Correlations between mosquito-based variables and maximum temperature (Appendix C: Table A3) were slightly weaker than those found using mean and minimum temperature, but were very strong overall with correlations generally greater than 0.8.

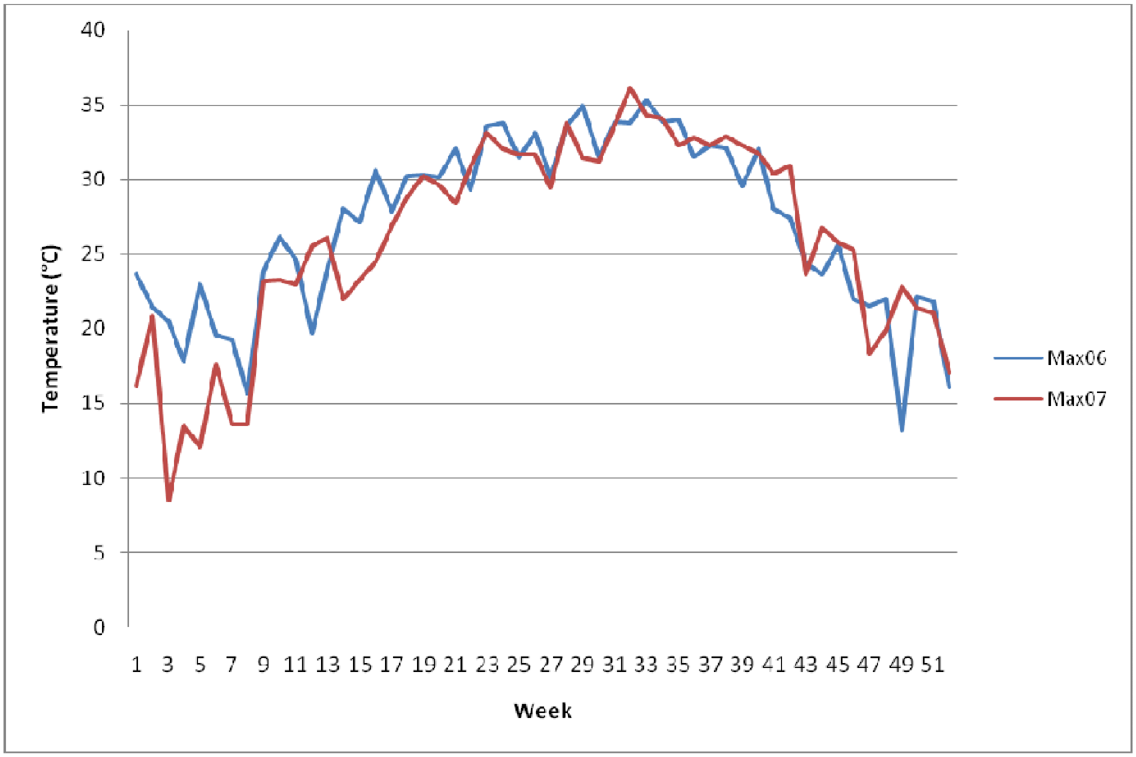


Figure 11: Comparison of maximum temperature, 2006-2007

Comparison of means for minimum temperatures showed the smallest differences between both years for any of the three temperature measures (Table 6). Minimum temperature was slightly lower in 2007 (16.04℃) than in 2006 (16.2 ℃) but temperatures were still above the 14℃ infection threshold indicated by Riesen et al., (2006) during the spring and summer months of both years (Figure 12). Correlations between mosquito-based variable and minimum temperature (Appendix C: Table A4) were overall the strongest of any of the three (3) measure of temperatures peaking at 0.851 (p=0.000) for positives and one week of lag.

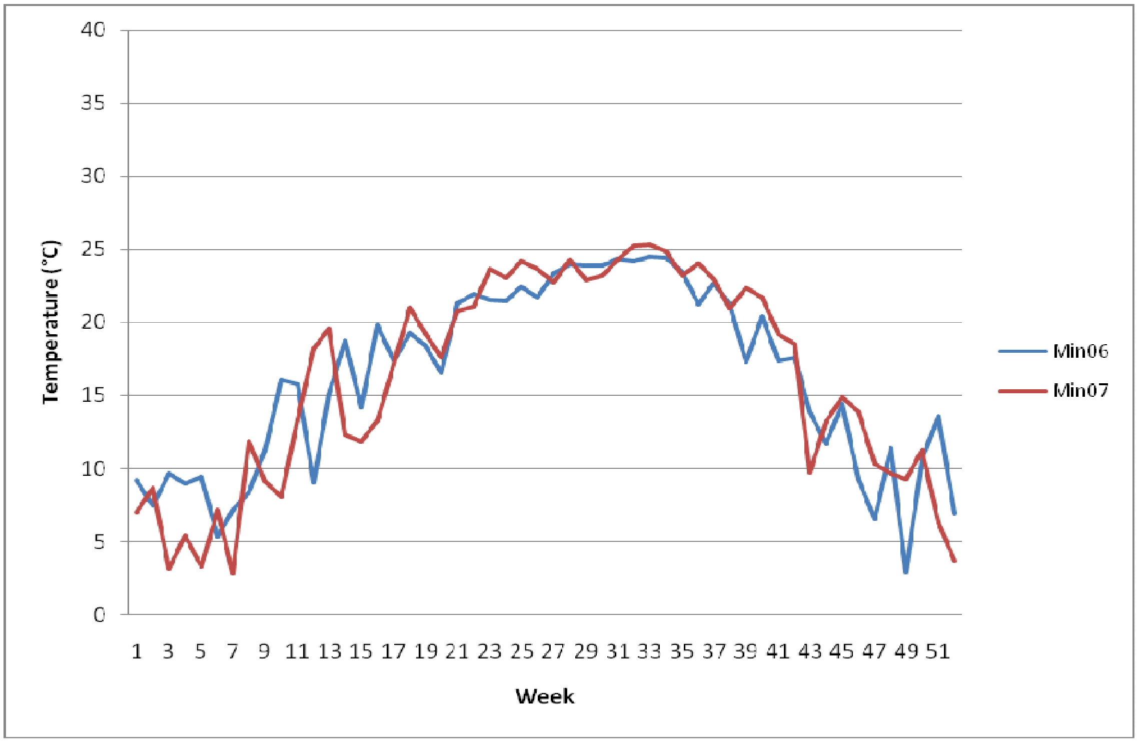


Figure 12: Comparison of minimum temperature, 2006-2007

With such strong correlation values, it was initially believed that temperature was responsible for the sharp decline in WNv positive mosquitoes given the critically important role it plays in the mosquito and West Nile life cycles. The slightly lower temperatures in 2007 may have played a small part in the decline of WNv positive mosquito pools but average temperatures for both years were both in the 20-30℃ peak range for *Culex* activity (Rueda et al., 1990). The effect that temperature has on infections certainly should not be ignored but because temperature was similar in both years and because both sets of correlations were significantly positive it was ruled out as a reason for the decline in the number of WNv positive pools from 2006-2007.

D. Precipitation, Evaporation, and Water Availability

Evaporation and precipitation are two forces that are invariably connected to one another. Precipitation occurs because water from the surface is evaporated into the atmosphere only to return to the surface in the form of rain; without one the other cannot occur. Analyzing precipitation and evaporation separately proved this fact.

It was initially believed that a difference in terms of the pattern and timing of rainfall played an important role in the number of WNv positive mosquito pools in Harris County, however statistical analysis seems to have proven this hypothesis wrong. Precipitation and biological variables were only weakly correlated and showed neither a positive or negative inclination (Figure 13). Additionally, differences in precipitation on a week-to-week basis (Figure 14) showed insignificant correlations with all biological variables.

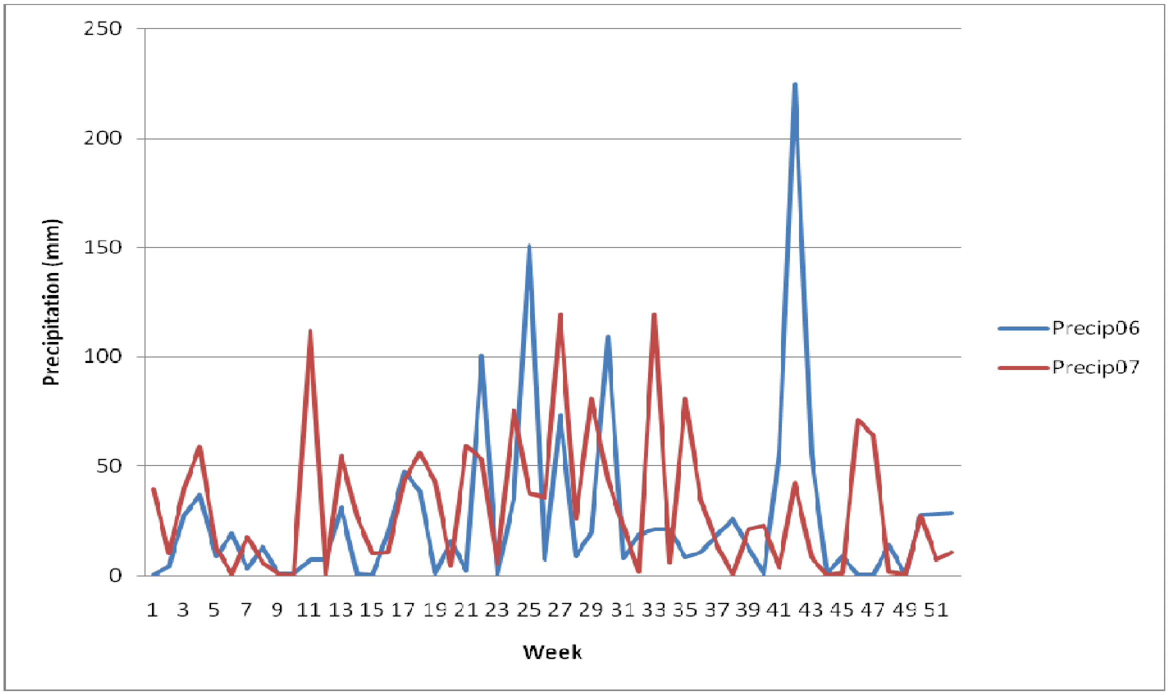


Figure 13: Comparison of precipitation, 2006-2007

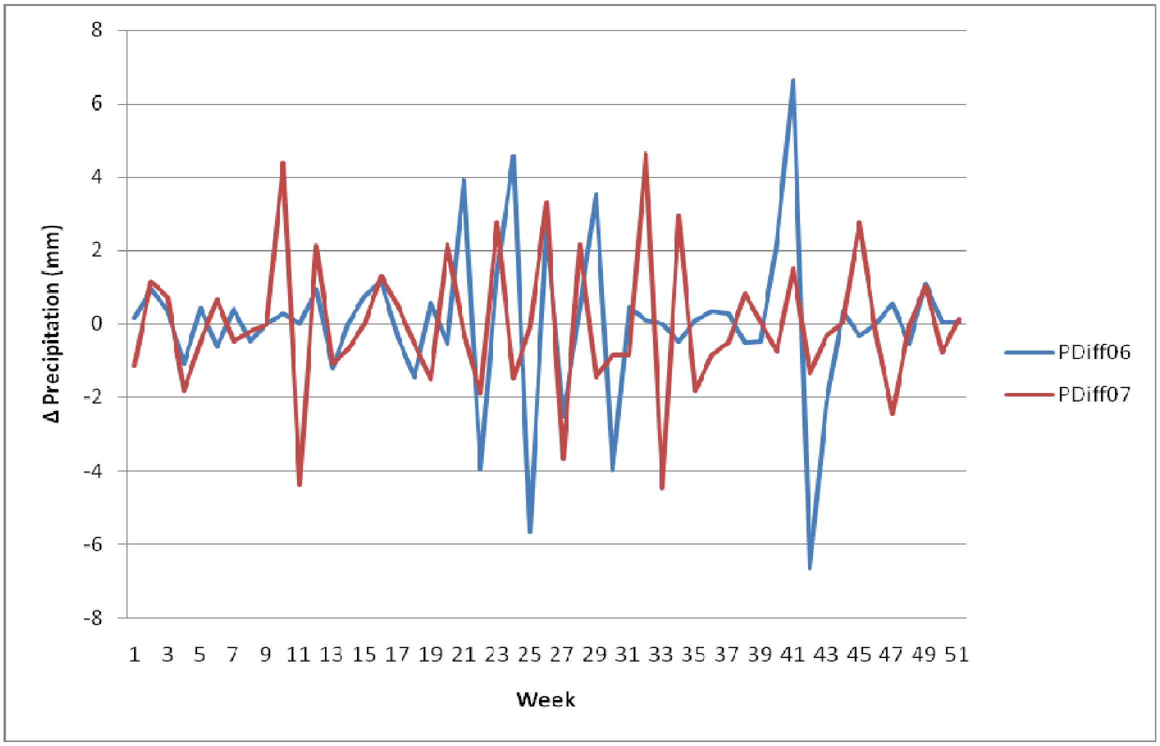


Figure 14: Comparison of weekly precipitation difference, 2006-2007

The unpredictable and heterogeneous nature of precipitation makes it very difficult to connect indirectly related phenomena such as the variables in this study. Unfortunately, unlike temperature there is no way to determine the ideal amount of rainfall to accelerate the mosquito life cycle and increase mosquito activity.

Evaporation, derived in this study using annual rainfall, latitude, and temperature, produced similarly significant and strongly positive correlations to infections. This of course was expected because temperature plays such a major role in its calculation. Like temperature before it, the difference in evaporation from year to year was not very different: 1375.2 mm in 2006 vs 1316.28 in 2007 (Table 6). Additionally the trend in evaporation was very similar throughout the year (Figure 15).

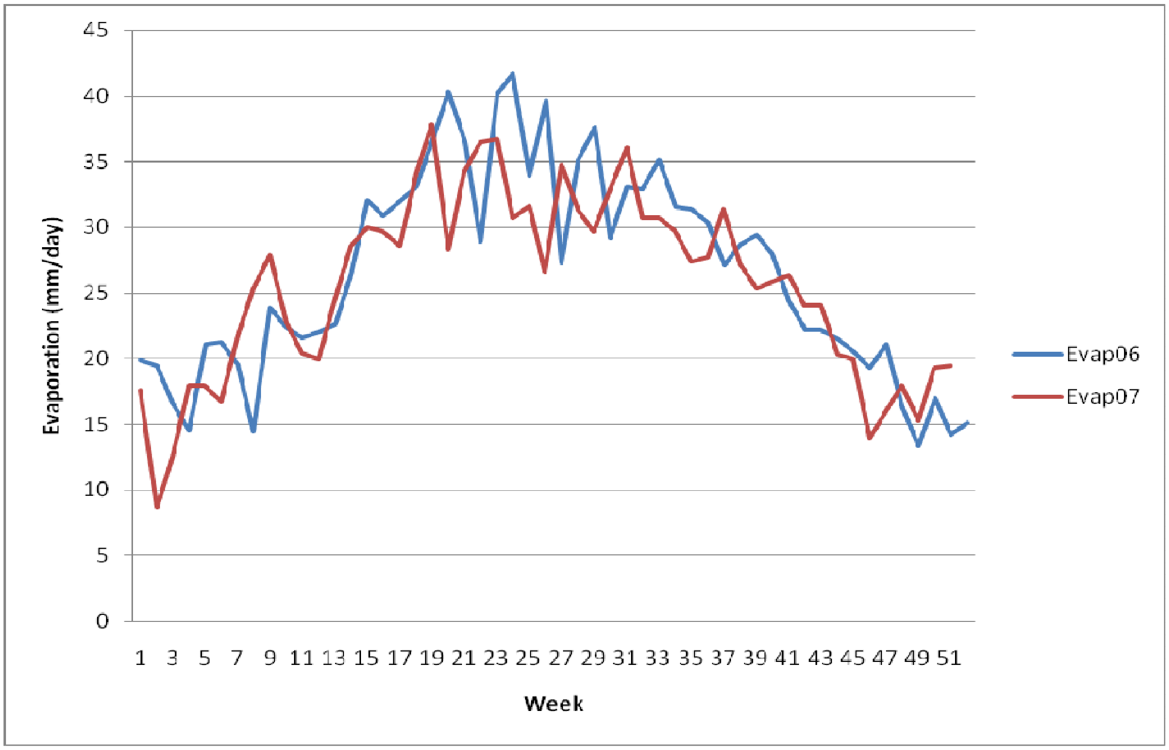


Figure 15: Comparison of weekly evaporation, 2006-2007

Precipitation minus evaporation was examined as a running total to determine the accumulation of water available in the environment. Unlike Cooke et al. (2006) who examined and modeled their P-E data seasonally and only found significant associations during the summer, this study found very different but significant associations for both years included in the current study.

Both 2006 and 2007 were wetter than average years but 2007 far outstripped 2006 in terms of rainfall (Table 6). Compared to 2006, 2007 averaged a much higher amount of precipitation accumulated 1639 mm of rain compared to the 1370.6 mm that fell in 2006 for a difference of 275 mm (10.94 in). This occurred even though the area experienced a significant flooding event that dropped 224 mm of rainfall (8.8 in) in October 2006. Before this event the area was at a 188mm deficit which falls in with Epstein's 'drought hypothesis' (2001) except that it seems to have occurred too late to have a large effect on infection period in late 2006 or early 2007. This combined with lower temperatures and therefore lower evaporation rates resulted in a water surplus. (Figure 16)

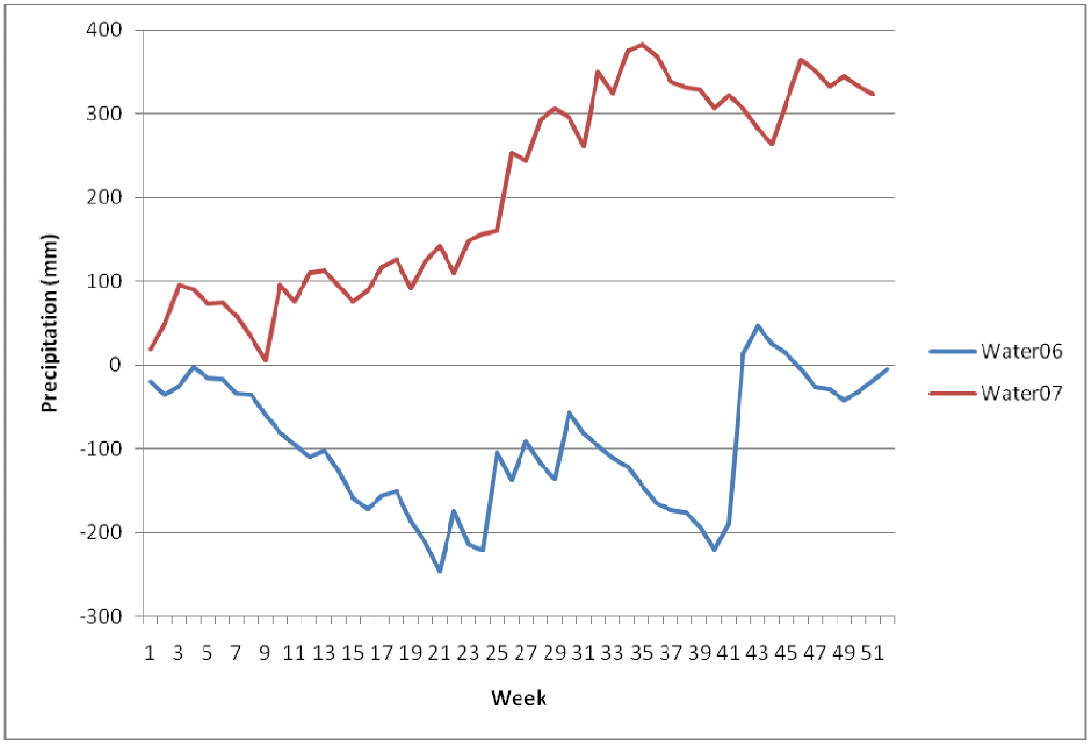


Figure 16: Comparison of water availability, 2006-2007

As pointed out by Cooke et al. (2006), when a water surplus occur,s this is more likely to increase the number of mosquito breeding areas. When this occurs the amount of contact between the birds that reservoir the disease and mosquitoes decreases which breaks an important part of the transmission cycle (Epstein, 2001). The dramatic shift in correlations for water accumulation from strongly negative in 2006 to strongly positive in 2007 points to too much available water as the reason for the dramatic decline in the number of positive pools (Appendix C: Table A7).

Though not as strong as the correlations to temperature, the r-values of water accumulation are significant at α=0.01. This is consistent with the drought hypothesis put forward earlier in the decade and proven numerous times since (Epstein, 2001; Shaman et al., 2005; Cooke et al., 2006). High P-E (water surplus) increases the number of breeding areas for mosquitoes (Cooke et al., 2006). This results in reduced contact between possibly infected birds and mosquitoes. When this critical part of the transmission cycle is broken, the risk of spreading the virus to humans and other mammals is substantially reduced. To a layman, wetter conditions and a water surplus would point towards more mosquitoes in the environment and therefore higher levels of the disease. In Houston in 2006, there were 54 human cases reported in the county. This number fell to only 26 cases in 2007. While this decrease was not as dramatic as the one experienced by mosquitoes, it does illustrate the slowing down of the transmission cycle caused by decreased contact of infected individuals.

On the other hand, precipitation in 2006 was 275 mm (10.94 in) lower than 2007. This coupled with higher evaporation rates (Table 6) appears to have resulted in the storm sewers and other above ground pools of water which area mosquitoes rely on for breeding to become more and more stagnant and therefore richer in organic material. When this happened the breeding activity of mosquitoes was increased, which when coupled with increased contact with birds appears to have resulted in high WNv infection rates for the year.

E. Land Cover

The significant correlations for high and medium intensity developed areas (Appendix C: Table D1-4) seem to agree with the findings of Cooke et al. (2006) who determined that road density correlates well with WNv. High and medium intensity development was moderately but significantly correlated to the number of mosquitoes captured (r=0.398 & 0.402) and positive mosquitoes (r=0.237 & 0.294) in 2006. This association remained similar for total mosquitoes (r=0.334 & 0.323) in 2007 but not for WNv positive pools (r=0.034 & .097).

In these two land classes, vegetation is highly restricted, which may seem counterintuitive because *Culex quinquefasciatus* does rely on organic material for oviposition. Conversely, these areas are covered by impervious surfaces such as roads, houses, and large buildings that could force rain and floodwater to pool depending on topography and drainage efficiency. In cases of poor drainage, the water would sit and stagnate allowing mosquitoes to use it for oviposition (Strickman and Lang, 1986; Lillibridge et al., 2004; Molaei et al., 2007).

Other land cover classes showed relatively weak but significant degrees of correlations with mosquito and West Nile variables. In contrast to studies by De Groote et al. (2007) which found deciduous forest land cover to be a disease amplifier, this land cover class was negatively correlated to the total mosquito collections (r=-0.266) and positive pools (r=-0.290) in Harris County during 2006. This is because De Groote was looking at more rural areas while the current study looks at a highly urbanized one.

F. Limitations and Solutions

While this study was able to identify meaningful associations between the environment, climate, and West Nile virus, it was not without its difficulties and limitations. This presented a spatial problem because coordinate data was unavailable which may have skewed the results due to an areal aggregation problem (Cooke et al., 2006). Even with the high resolution of climatic data used, having to match this to the HCMC data provided may have skewed the resulting statistics higher because the aggregation generalized the data towards the mean or lower because it reduced the variation in the original data. A better study would have been carried out if point data on birds and mosquitoes were made available. Given their greater spatial resolution, it would have been possible to match the high spatial resolution of the combined climatic data and the high-resolution NOAA classified image. Using such a high resolution of data, maybe even more meaningful associations could have been identified. It is important to remember that were this study conducted in the future with collection point data for mosquitoes and birds it would not be possible to transfer the aggregated relationships found in the current study to individuals because it would be an ecological fallacy.

A major flaw of the current study is the fact that the species of mosquito captured and tested was not known as this data was not provided . While it can be assumed that the vast majority (>95%) of the nearly 2,000,000 specimens in the study are going to be *Culex quinquefasciatus* it is not particularly prudent to assume that the same species is responsible for an equal proportion of positive pools (Parsons, 2003; Dennett et al., 2007a). The vectorial competence of *Aedes* species has been proven and even though their abundance is not nearly at the level of *Cx. quinquefasciatus* its capacity to vector WNv cannot be ignored (Vanlandingham et al., 2007). This is important because even though these species inhabit the same diverse environment they rely on different bionomics to thrive.

Human activity has a very large part to play in the population dynamics of every species of animal and plant on Earth. In the case of mosquitoes, this is because of our modification of and encroachment on the environment and our abatement efforts against them (Ruiz et al., 2004). While this study looked at the former, it did fail to examine the latter because the appropriate data was not provided. Including this information could have yielded spatially meaningful associations given the widely varied abatement strategies in effect around the county. A larger temporal sample of data would be needed to determine if the associations found in this study could be applied longitudinally. Using only two years is not really considered climatologically sound so a longer of data would be ideal to apply these results longitudinally (Peterson et al., 1998). Other potentially important factors in WNv bionomics such as soil data and elevation were not considered for either lack of time or lack of data.

It is also important to remember that results and associations found in this study should not necessarily be applied to just anywhere. Every area, state, or region has different species with different bionomics from the ones in this study that serve as the vector and reservoirs for the WNv. With different species controlling the transmission cycle, different environmental characteristics need to be considered carefully on a case-by-case basis.

CHAPTER VI

CONCLUSION

In conclusion, two major findings were identified. Firstly, the abundance of mosquitoes and the prevalence of WNv birds were highly correlated to a number of climatic variables. Chief among these were temperature and evaporation, a value derived from temperature. Secondly the nearly 90% decline in the number of WNv positive mosquito pools in Harris county was most likely a result of too much water being available in 2007. This results in an increased number of breeding area for mosquitoes, particularly *Culex quinquefasciatus*, which in turn reduces their contact with the birds that reservoir the disease. When this apparently occurred in 2007, it caused the number of female mosquitoes found positive to plummet.

Given the minor differences in climatic variables like temperature and evaporation these variables were ruled out as having a significant effect on WNv cycling. Though there was a notable difference in the amount of rainfall (approximately 11 in) from year to year no strong significant correlations emerged from statistical analysis. However, when precipitation, temperature and evaporation were integrated into a single variable (water availability) the association was revealed.

Additionally this study has proven that an increased resolution of climatic data is worth pursuing, as it provides a truer picture of conditions and their associations with WNv. Performing analysis using weekly scaled very high resolution data yielded more significant correlations than a previous study of the same area (Dennett et al., 2007a) that used monthly scale data from a single station. Though no important associations were found, examining the data spatially allowed for observation of the amount of variability in such an area as represented by Harris County, Texas was a worthwhile exercise and could be put to good use in future studies. Similarly when examined simultaneously and examined temporally and spatially, the results proved insignificant.

It is important to remember that results and associations found in this study should not necessarily be applied to just anywhere. Every area, state, or region has unique environmental characteristics that need to be carefully considered on a case-by-case basis. And perhaps more importantly each area has different mosquito species with different bionomics from the ones in this study that serve as the vector and reservoirs for the WNv.

Ideally, this study would have also been conducted on a larger point-based scale. It is felt that the use of these data would have made the associations brought out in this study even more relevant given the high resolution of climatic data available. Unfortunately, data on human infections were not provided, which was something originally planned to be examined as part of this study. Logically, the next step would be to examine the effect of these variables on human infections in order to determine their relationship and the implications the virus has on society. Doing so could lead to the discovery of important associations and result in the development of better mosquito abatement and personal protection strategies in high-risk areas and during high-risk periods therefore reducing the number of West Nile virus infections in people.

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APPENDIX A

HCOEM STATIONS

Agency	Initial Gauges	Quality Controlled
Brazoria County	→ 6 gauges	→ 2 gauges
City of Houston	→ 3 gauges	
Fort Bend OEM	→ 2 gauges	→ 1 gauge
HCOHSEM	→ 137 gauges	→134 gauges
METRO	→ 6 gauges	→ 3 gauges
Pearland	→ 9 gauges	→ 3 gauges
San Jacinto RA	→ 11 gauges	→ 0 gauges
Sugarland	→ 19 gauges	
Trinity RA	→ 12 gauges	→ 0 gauges
TXDOT	→ 38 gauges	

APPENDIX B

LAND COVER CLASSES

Source: Dobson, J. et al, NOAA Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation, NOAA Technical Report NMFS 123, U.S. Department of Commerce, April 1995.

1. Unclassified
This class contains no data due to cloud conditions or data voids.

2. **High Intensity Developed**
Contains little or no vegetation. This subclass includes heavily built-up urban centers as well as large constructed surfaces in suburban and rural areas. Large buildings (such as multiple family housing, hangars, and large barns), interstate highways, and runways typically fall into this subclass. Impervious surfaces account for 80-100 percent of the total cover.

3. Medium Intensity Developed
Contains substantial amounts of constructed surface mixed with substantial amounts of vegetated surface. Small buildings (such as single-family housing, farm outbuildings, and large sheds), typically fall into this subclass. Impervious surfaces account for 50-79 percent of the total cover.

4. Low Intensity Developed
Contains constructed surface mixed with vegetated surface. This class includes features seen class 3, with the addition of streets and roads with associated trees and grasses. Impervious surfaces account for 21-49 percent of the total cover.

5. Developed Open Space
Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. This subclass includes parks, lawns, athletic fields, golf courses, and natural grasses occurring around airports and industrial sites. Impervious surfaces account for less than 20 percent of total cover.

6. Cultivated Land
Includes herbaceous (cropland) and woody (e.g., orchards, nurseries, and vineyards) cultivated lands.

7. Pasture/Hay
Characterized by grasses, legumes or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.

8. Grassland
Dominated by naturally occurring grasses and non-grasses (forbs) that are not fertilized, cut, tilled, or planted regularly.

9. Deciduous Forest

Includes areas dominated by single stemmed, woody vegetation unbranched 0.6 to 1 meter above the ground and having a height greater than 5 meters and cover more than 20% of land area. More than 75 percent of the tree species shed foliage simultaneous in response to seasonal change.

10. Evergreen Forest
Includes areas in which more than 67 percent of the trees remain green throughout the year. Both coniferous and broad-leaved evergreens are included in this category. Trees must be taller than 5 meters and more than 20% of the land cover.

11. Mixed Forest
Contains all forested areas in which both evergreen and deciduous trees are growing and neither predominate. Trees must be taller than 5 meters and more than 20% of the land cover.

12. Scrub/Shrub
Areas dominated by woody vegetation less than 5 meters in height. This class includes true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions. Includes both evergreen and deciduous scrub.

13. Palustrine Forested Wetland
Includes all non-tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 parts per thousand (ppt).

14. Palustrine Scrub/Shrub Wetland
Includes all non-tidal wetlands dominated by woody vegetation less than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 ppt.

15. Palustrine Emergent Wetland
Includes all non-tidal wetlands dominated by persistent emergents, emergent mosses, or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 ppt.

16. Estuarine Forest Wetland
Includes all tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is above 0.5 parts per thousand (ppt).

17. Estuarine Scrub/Shrub Wetland
Includes all tidal wetlands dominated by woody vegetation less than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is above 0.5 ppt.

18. Estuarine Emergent Wetland
Characterized by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens) that are present for most of the growing season in most years. Perennial plants usually

dominate these wetlands. All water regimes are included except those that are subtidal and irregularly exposed.

19. Unconsolidated Shore

Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms, such as beaches, bars, and flats, all of which are included in this class.

20. Bare Land

Composed of bare soil, rock, sand, silt, gravel, or other earthen material with little or no vegetation.

21. Open Water

Includes all areas of open water with less than 25 percent cover of vegetation or soil.

22. Palustrine Aquatic Bed

Includes wetlands and deepwater habitats dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years. Salinity due to ocean-derived salts is below 0.5 ppt.

23. Estuarine Aquatic Bed

Includes widespread and diverse Algal Beds in the Marine and Estuarine Systems, where they occupy substrates characterized by a wide range of sediment depths and textures. They occur in both the Subtidal and Intertidal Subsystems and may grow to depths of 30 m (98 feet). This includes kelp forests. Salinity due to ocean-derived salts is equal to or above 0.5 ppt.

APPENDIX C

CORRELATION RESULTS

Color Key: Orange= significant at α=0.01,
Yellow= significant at α=0.05
Blue= Significant strong (r>0.7) positive correlations
Red= Significant negative correlation

All statistics are Pearson's r

Section A: Mosquito Correlations

Key: **Vector**

Total_GV= Total mosquitoes from gravid traps
Total_SS= Total mosquitoes from storm sewer traps
Total= Total mosquitoes trapped
Pos_GV=Positive mosquito pools from gravid traps
Pos_SS=Positive mosquito pools from storm sewer traps
Positive=Positive mosquito pools from all trapping
MIR_GV= Minimum infection rate for gravid trapping
MIR_SS= Minimum infection rate for storm sewer trapping
MIR= Minimum infection rate for all trapping

Birds

Calls= Number of calls reporting dead birds
DTest= Number of dead birds tested for arboviruses
DPos= Number of dead birds found positive for WNv
PctDPos= Percentage of dead birds found positive (positive/tested)
Live= Number of live birds captured and tested
LPos= Number of live birds found positive for WNv
PctLPos= Percentage of live birds found positive (positive/tested)
Birds= Total of live and dead birds tested
Birds_Pos= Total of live and dead birds positive for WNv
PctBPos= Percentage of all birds found positive (positive/tested)

Climatic

Temp_C= Mean temperature (℃)
Max_C= Maximum temperature (℃)
Min_C= Minimum temperature (℃)
Precip_mm= Precipitation (mm)
Evap= Evaporation (mm/day)
P-E= Precipitation-evaporation (mm)
Water= Available water (mm)

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Total_GV	.804**	.683**	.601**	.565**	.166	-.107	-.264	.636**	.486**	.478**
	.000	.000	.000	.000	.319	.568	.151	.000	.000	.000
Total_SS	.658**	.554**	.352*	.306*	-.024	.066	.091	.493**	.315*	.332*
	.000	.000	.010	.027	.885	.725	.627	.000	.023	.017
Total	.862**	.727**	.588**	.530**	.085	-.080	-.184	.673**	.470**	.469**
	.000	.000	.000	.000	.612	.670	.323	.000	.000	.001
Pos_GV	.537**	.476**	.807**	.825**	.357*	.137	-.052	.534**	.680**	.573**
	.000	.000	.000	.000	.028	.461	.783	.000	.000	.000
Pos_SS	.487**	.478**	.744**	.684**	.352*	.269	.171	.543**	.684**	.542**
	.000	.000	.000	.000	.030	.144	.357	.000	.000	.000
Positive	.687**	.549**	.809**	.772**	.206	.022	-.008	.585**	.620**	.545**
	.000	.000	.000	.000	.215	.908	.964	.000	.000	.000
MIR_GV	.518**	.441**	.789**	.793**	.313	.197	.008	.533**	.678**	.549**
	.000	.001	.000	.000	.056	.288	.965	.000	.000	.000
MIR_SS	.451**	.453**	.769**	.754**	.322*	.322	.233	.501**	.738**	.590**
	.001	.001	.000	.000	.049	.078	.207	.000	.000	.000
MIR	.518**	.456**	.805**	.808**	.319	.210	.051	.532**	.703**	.579**
	.000	.001	.000	.000	.051	.257	.785	.000	.000	.000

Table A1: a) Correlations between mosquito and birds, 2006

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Total_GV	.492**	.451**	.233	.119	.481**	.450**	-.122	.500**	.433**	.332*
	.000	.001	.096	.406	.003	.006	.479	.000	.001	.017
Total_SS	.355**	.252	.376**	.298*	.726**	.442**	-.167	.432**	.538**	.511**
	.010	.072	.006	.034	.000	.007	.331	.001	.000	.000
Total	.507**	.451**	.299*	.172	.578**	.454**	-.212	.529**	.486**	.399**
	.000	.001	.031	.228	.000	.005	.214	.000	.000	.004
Pos_GV	.279*	.333*	.649**	.382**	.165	-.085	-.256	.347*	.472**	.301*
	.045	.016	.000	.006	.335	.621	.132	.012	.000	.032
Pos_SS	.247	.322*	.602**	.401**	.171	.008	-.157	.331*	.473**	.318*
	.077	.020	.000	.004	.318	.961	.361	.017	.000	.023
Positive	.364**	.400**	.801**	.515**	.227	-.102	-.332*	.427**	.596**	.391**
	.008	.003	.000	.000	.183	.553	.048	.002	.000	.005
MIR_GV	.035	.154	.393**	.273	.075	-.020	-.090	.114	.273	.278*
	.804	.276	.004	.053	.663	.908	.601	.420	.050	.048
MIR_SS	.133	.243	.501**	.360*	.050	-.047	-.116	.190	.344*	.290*
	.357	.089	.000	.011	.776	.789	.508	.187	.014	.043
MIR	.085	.210	.489**	.350*	.087	-.012	-.099	.161	.347*	.328*
	.551	.135	.000	.012	.615	.943	.567	.253	.012	.019

b) Correlations between mosquito and birds, 2007

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Temp_C	.782** .000	.623** .000	.840** .000	.638** .000	.607** .000	.780** .000	.643** .000	.633** .000	.652** .000
-1	.742** .000	.536** .000	.799** .000	.635** .000	.588** .000	.840** .000	.669** .000	.626** .000	.680** .000
-2	.682** .000	.502** .000	.753** .000	.604** .000	.579** .000	.828** .000	.666** .000	.637** .000	.667** .000
-3	.719** .000	.609** .000	.780** .000	.567** .000	.564** .000	.813** .000	.621** .000	.615** .000	.625** .000
-4	.615** .000	.430** .002	.670** .000	.552** .000	.511** .000	.837** .000	.623** .000	.580** .000	.629** .000
-5	.522** .000	.393** .006	.584** .000	.530** .000	.503** .000	.794** .000	.612** .000	.578** .000	.608** .000
-6	.470** .001	.298* .044	.499** .000	.479** .001	.445** .002	.734** .000	.532** .000	.518** .000	.543** .000
-7	.299* .046	.146 .338	.337* .024	.436** .003	.401** .006	.671** .000	.527** .000	.484** .001	.519** .000
-8	.219 .152	.127 .411	.216 .158	.408** .006	.404** .007	.654** .000	.502** .001	.477** .001	.500** .001

Table A2: (a) Correlations between mean temp lag and mosquito rates, 2006

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR_
Temp_C	.679** .000	.717** .000	.751** .000	.548** .000	.471** .000	.646** .000	.353* .010	.382** .006	.394** .004
-1	.501** .000	.646** .000	.596** .000	.528** .000	.484** .000	.646** .000	.341* .014	.406** .004	.394** .004
-2	.494** .000	.631** .000	.586** .000	.541** .000	.491** .000	.667** .000	.394** .005	.437** .002	.445** .001
-3	.424** .002	.574** .000	.529** .000	.538** .000	.480** .000	.658** .000	.408** .004	.429** .003	.451** .001
-4	.364* .011	.576** .000	.494** .000	.551** .000	.436** .002	.653** .000	.403** .005	.376* .010	.424** .003
-5	.259 .079	.562** .000	.427** .003	.542** .000	.455** .001	.660** .000	.402** .005	.380* .010	.424** .003
-6	.144 .341	.483** .001	.321* .030	.519** .000	.481** .001	.649** .000	.409** .005	.405** .006	.435** .002
-7	.072 .640	.396** .007	.241 .110	.498** .000	.449** .002	.612** .000	.392** .008	.390** .010	.419** .004
-8	-.048 .757	.295 .052	.116 .452	.519** .000	.425** .004	.590** .000	.436** .003	.383* .012	.446** .002

(b) Correlations between mean temp lag and mosquito rates, 2007

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Max_C	.749**	.603**	.821**	.604**	.609**	.760**	.614**	.624**	.622**
	.000	.000	.000	.000	.000	.000	.000	.000	.000
-1	.725**	.538**	.783**	.613**	.555**	.820**	.638**	.596**	.650**
	.000	.000	.000	.000	.000	.000	.000	.000	.000
-2	.656**	.479**	.724**	.599**	.531**	.822**	.665**	.604**	.662**
	.000	.000	.000	.000	.000	.000	.000	.000	.000
-3	.690**	.600**	.752**	.550**	.558**	.805**	.612**	.606**	.610**
	.000	.000	.000	.000	.000	.000	.000	.000	.000
-4	.589**	.422**	.640**	.527**	.512**	.830**	.598**	.565**	.607**
	.000	.003	.000	.000	.000	.000	.000	.000	.000
-5	.490**	.367*	.552**	.532**	.504**	.791**	.612**	.573**	.607**
	.000	.011	.000	.000	.000	.000	.000	.000	.000
-6	.453**	.264	.468**	.496**	.422**	.729**	.547**	.506**	.553**
	.002	.076	.001	.000	.003	.000	.000	.000	.000
-7	.294*	.099	.302*	.438**	.375*	.656**	.523**	.473**	.515**
	.050	.517	.044	.003	.011	.000	.000	.001	.000
-8	.184	.100	.179	.406**	.415**	.633**	.505**	.467**	.496**
	.232	.519	.245	.006	.005	.000	.000	.002	.001

Table A3: (a) Correlations between max temperature lag and mosquito rates, 2006

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR_
Max_C	.692**	.745**	.765**	.556**	.480**	.650**	.375**	.389**	.411**
	.000	.000	.000	.000	.000	.000	.006	.005	.002
-1	.469**	.649**	.572**	.516**	.483**	.635**	.346*	.405**	.396**
	.001	.000	.000	.000	.000	.000	.013	.004	.004
-2	.483**	.654**	.579**	.523**	.468**	.641**	.393**	.423**	.436**
	.000	.000	.000	.000	.001	.000	.005	.003	.002
-3	.390**	.569**	.499**	.509**	.464**	.624**	.399**	.424**	.444**
	.006	.000	.000	.000	.001	.000	.005	.003	.001
-4	.366*	.578**	.497**	.532**	.422**	.625**	.414**	.373*	.431**
	.011	.000	.000	.000	.003	.000	.003	.011	.002
-5	.239	.550**	.406**	.494**	.412**	.605**	.374**	.346*	.392**
	.105	.000	.005	.000	.004	.000	.010	.020	.006
-6	.137	.474**	.310*	.459**	.433**	.586**	.376*	.366*	.397**
	.364	.001	.036	.001	.003	.000	.010	.015	.006
-7	.048	.352*	.209	.447**	.399**	.556**	.356*	.349*	.376*
	.752	.018	.168	.002	.007	.000	.016	.022	.011
-8	-.082	.251	.077	.490**	.385**	.551**	.413**	.344*	.412**
	.599	.101	.620	.001	.010	.000	.005	.026	.005

(b) Correlations between max temperature lag and mosquito rates, 2007

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Min_C	.799**	.625**	.842**	.659**	.598**	.790**	.662**	.633**	.672**
	.000	.000	.000	.000	.000	.000	.000	.000	.000
-1	.748**	.523**	.800**	.656**	.616**	.851**	.688**	.656**	.699**
	.000	.000	.000	.000	.000	.000	.000	.000	.000
-2	.697**	.501**	.763**	.626**	.591**	.828**	.671**	.646**	.678**
	.000	.000	.000	.000	.000	.000	.000	.000	.000
-3	.736**	.603**	.793**	.603**	.575**	.818**	.641**	.627**	.649**
	.000	.000	.000	.000	.000	.000	.000	.000	.000
-4	.620**	.427**	.681**	.575**	.544**	.835**	.651**	.606**	.652**
	.000	.002	.000	.000	.000	.000	.000	.000	.000
-5	.540**	.403**	.597**	.525**	.520**	.788**	.612**	.597**	.613**
	.000	.005	.000	.000	.000	.000	.000	.000	.000
-6	.470**	.315*	.509**	.473**	.477**	.732**	.537**	.548**	.551**
	.001	.033	.000	.001	.001	.000	.000	.000	.000
-7	.300*	.175	.354*	.424**	.419**	.670**	.514**	.507**	.512**
	.045	.250	.017	.004	.004	.000	.000	.001	.000
-8	.228	.156	.237	.389**	.374*	.648**	.481**	.463**	.483**
	.137	.313	.121	.009	.012	.000	.001	.002	.001

Table A4: (a) Correlations between min temperature lag and mosquito rates, 2006

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR_
Min_C	.497**	.631**	.585**	.527**	.481**	.646**	.335*	.404**	.389**
	.000	.000	.000	.000	.000	.000	.016	.004	.005
-1	.479**	.601**	.568**	.551**	.499**	.680**	.391**	.440**	.444**
	.000	.000	.000	.000	.000	.000	.005	.002	.001
-2	.443**	.577**	.545**	.563**	.488**	.683**	.415**	.424**	.453**
	.001	.000	.000	.000	.000	.000	.003	.003	.001
-3	.369**	.560**	.495**	.554**	.453**	.667**	.396**	.388**	.423**
	.010	.000	.000	.000	.001	.000	.005	.008	.003
-4	.266	.548**	.434**	.563**	.485**	.687**	.419**	.410**	.448**
	.071	.000	.002	.000	.001	.000	.003	.005	.002
-5	.156	.466**	.330*	.560**	.507**	.688**	.433**	.427**	.462**
	.301	.001	.025	.000	.000	.000	.003	.004	.001
-6	.069	.404**	.240	.530**	.467**	.641**	.410**	.402**	.437**
	.652	.006	.112	.000	.001	.000	.005	.007	.003
-7	-.047	.315*	.119	.526**	.451**	.608**	.437**	.406**	.459**
	.761	.037	.443	.000	.002	.000	.003	.008	.002
-8	.228	.156	.237	.389**	.374*	.648**	.481**	.463**	.483**
	.137	.313	.121	.009	.012	.000	.001	.002	.001

(b) Correlations between min temperature lag and mosquito rates, 2007

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Evap	.720**	.584**	.808**	.505**	.530**	.659**	.498**	.478**	.496**
	.000	.000	.000	.000	.000	.000	.000	.001	.000
-1	.781**	.587**	.824**	.550**	.423**	.714**	.525**	.433**	.532**
	.000	.000	.000	.000	.002	.000	.000	.002	.000
-2	.753**	.544**	.795**	.600**	.453**	.786**	.631**	.493**	.616**
	.000	.000	.000	.000	.001	.000	.000	.000	.000
-3	.746**	.566**	.791**	.574**	.551**	.812**	.613**	.551**	.601**
	.000	.000	.000	.000	.000	.000	.000	.000	.000
-4	.736**	.483**	.753**	.591**	.522**	.844**	.593**	.533**	.609**
	.000	.001	.000	.000	.000	.000	.000	.000	.000
-5	.684**	.447**	.716**	.697**	.569**	.873**	.703**	.604**	.699**
	.000	.002	.000	.000	.000	.000	.000	.000	.000
-6	.656**	.360*	.645**	.708**	.504**	.863**	.723**	.574**	.716**
	.000	.014	.000	.000	.000	.000	.000	.000	.000
-7	.540**	.248	.516**	.665**	.518**	.825**	.704**	.577**	.698**
	.000	.100	.000	.000	.000	.000	.000	.000	.000
-8	.410**	.206	.405**	.639**	.636**	.801**	.714**	.636**	.701**
	.006	.180	.006	.000	.000	.000	.000	.000	.000

Table A5: a) Correlations between evaporation lag and mosquito rates, 2006

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Evap	.725**	.648**	.770**	.374**	.346*	.454**	.187	.240	.225
	.000	.000	.000	.006	.012	.001	.186	.094	.108
-1	.610**	.598**	.680**	.367**	.337*	.458**	.176	.243	.219
	.000	.000	.000	.008	.016	.001	.216	.093	.122
-2	.600**	.630**	.666**	.374**	.315*	.461**	.212	.260	.249
	.000	.000	.000	.007	.026	.001	.139	.075	.081
-3	.588**	.529**	.646**	.382**	.375**	.486**	.242	.346*	.306*
	.000	.000	.000	.007	.008	.000	.094	.017	.033
-4	.545**	.556**	.629**	.487**	.383**	.575**	.333*	.327*	.361*
	.000	.000	.000	.000	.007	.000	.021	.027	.012
-5	.426**	.546**	.544**	.423**	.343*	.541**	.254	.263	.279
	.003	.000	.000	.003	.018	.000	.084	.081	.057
-6	.317*	.552**	.459**	.379**	.386**	.535**	.256	.300*	.296*
	.032	.000	.001	.009	.008	.000	.085	.048	.046
-7	.245	.357*	.379*	.458**	.401**	.586**	.306*	.339*	.337*
	.105	.016	.010	.002	.006	.000	.041	.026	.023
-8	.145	.321*	.289	.595**	.400**	.647**	.401**	.305*	.387**
	.347	.034	.057	.000	.007	.000	.007	.049	.009

(b) Correlations between evaporation lag and mosquito rates, 2007

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Precip_mm	.120	.087	.104	.227	-.003	.306*	.326*	.158	.323*
	.397	.539	.463	.105	.981	.027	.018	.277	.019
-1	.100	.146	.129	.253	.180	.318*	.357*	.228	.312*
	.485	.308	.368	.073	.206	.023	.010	.116	.026
-2	.199	.132	.203	.150	.238	.273	.140	.189	.159
	.166	.360	.157	.298	.096	.055	.333	.198	.270
-3	.279	.181	.261	.203	.150	.241	.183	.126	.194
	.052	.213	.071	.161	.302	.095	.208	.398	.182
-4	.227	-.065	.149	.327*	.223	.274	.323*	.262	.306*
	.122	.660	.311	.023	.127	.060	.025	.078	.035
-5	.077	-.423**	-.072	.235	.021	.150	.147	.251	.185
	.609	.003	.631	.112	.890	.313	.324	.096	.214
-6	.061	.032	.056	.216	.237	.140	.196	.215	.198
	.688	.832	.713	.149	.113	.353	.192	.161	.186
-7	.099	.081	.060	.186	.285	.212	.186	.176	.194
	.519	.596	.694	.222	.058	.163	.222	.260	.201
-8	-.095	-.015	-.125	.133	.143	.088	.129	.167	.160
	.539	.925	.420	.389	.353	.570	.405	.292	.299

Table A6: a) Correlations between precipitation lag and mosquito rates, 2006

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Precip_mm	.125	-.004	.140	.091	.092	.144	.010	.125	.053
	.378	.980	.321	.521	.517	.310	.941	.386	.710
-1	.087	.130	.080	.066	.033	.080	.009	.030	.044
	.545	.362	.579	.646	.820	.579	.952	.838	.762
-2	.089	.083	.090	.025	.184	.164	-.043	.155	.044
	.541	.567	.533	.865	.201	.254	.766	.293	.760
-3	.126	.074	.138	.335*	.003	.242	.144	-.092	.075
	.388	.611	.346	.019	.983	.094	.324	.540	.607
-4	.199	.272	.218	.091	.061	.125	-.093	-.033	-.072
	.174	.061	.137	.540	.680	.399	.531	.826	.625
-5	.184	.079	.226	.288*	.240	.325*	.122	.154	.116
	.216	.600	.127	.050	.105	.026	.415	.312	.436
-6	.188	-.067	.158	.233	.300*	.349*	.062	.298*	.168
	.210	.658	.294	.120	.043	.017	.684	.050	.265
-7	-.016	.243	.077	.476**	.352*	.450**	.495**	.328*	.463**
	.919	.107	.617	.001	.018	.002	.001	.032	.001
-8	-.050	.075	-.022	.039	.242	.204	-.060	.259	.085
	.745	.630	.889	.799	.113	.184	.700	.098	.582

(b) Correlations between precipitation lag and mosquito rates, 2007

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
P-E	-.018	-.023	-.050	.128	-.105	.176	.226	.067	.224
	.900	.870	.726	.365	.460	.213	.106	.647	.110
Water	-.591**	-.557**	-.702**	-.135	-.201	-.353*	-.113	-.099	-.105
	.000	.000	.000	.341	.154	.010	.426	.500	.460
-1	-.045	.036	-.025	.148	.099	.180	.254	.146	.209
	.756	.803	.864	.302	.491	.205	.072	.316	.141
-2	.061	.034	.058	.039	.153	.126	.023	.099	.045
	.671	.816	.689	.787	.289	.382	.874	.504	.758
-3	.144	.081	.118	.099	.050	.093	.071	.029	.084
	.324	.582	.418	.500	.733	.525	.628	.845	.566
-4	.100	-.146	.021	.221	.130	.124	.216	.169	.196
	.499	.323	.890	.131	.378	.403	.140	.262	.181
-5	-.038	-.491**	-.189	.114	-.076	.000	.026	.110	.064
	.800	.000	.203	.444	.612	.999	.860	.471	.669
-6	-.049	-.027	-.051	.095	.149	-.006	.072	.116	.076
	.747	.861	.735	.532	.323	.971	.635	.452	.617
-7	.009	.040	-.024	.073	.197	.074	.067	.080	.077
	.952	.792	.875	.634	.195	.627	.663	.611	.617
-8	-.158	-.045	-.184	.026	.038	-.044	.009	.060	.042
	.305	.771	.231	.868	.808	.778	.954	.707	.786

Table A7: a) Correlations between water availability lag and mosquito rates, 2006

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
P-E	-.035	-.146	-.030	.008	.015	.043	-.031	.067	.003
	.803	.302	.835	.953	.914	.763	.830	.643	.984
Water	.163	.367**	.240	.494**	.411**	.578**	.409**	.403**	.437**
	.247	.007	.087	.000	.002	.000	.003	.004	.001
-1	-.047	-.001	-.070	-.015	-.041	-.021	-.030	-.023	-.005
	.742	.992	.626	.917	.774	.882	.835	.877	.973
-2	-.043	-.055	-.056	-.057	.113	.062	-.089	.098	-.010
	.767	.703	.701	.694	.434	.667	.540	.507	.943
-3	-.001	-.039	-.002	.249	-.077	.136	.091	-.161	.009
	.997	.790	.991	.084	.601	.352	.535	.278	.949
-4	.081	.150	.081	-.014	-.021	.001	-.162	-.100	-.148
	.584	.308	.582	.926	.889	.994	.273	.508	.317
-5	.091	-.037	.108	.194	.163	.205	.066	.099	.056
	.542	.807	.471	.192	.273	.166	.658	.518	.710
-6	.121	-.179	.062	.152	.217	.236	.009	.233	.105
	.422	.234	.681	.313	.147	.115	.955	.128	.486
-7	-.066	.168	-.002	.378*	.267	.326*	.428**	.258	.390**
	.667	.270	.989	.010	.076	.029	.003	.095	.008
-8	-.080	.008	-.081	-.083	.157	.069	-.141	.193	.005
	.607	.960	.602	.590	.308	.658	.360	.221	.975

(b) Correlations between water availability lag and mosquito rates, 2007

Section B: Bird Correlations

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Temp_C	.856**	.769**	.718**	.669**	.394*	.240	.267	.728**	.629**	.627**
	.000	.000	.000	.000	.014	.193	.147	.000	.000	.000
-1	.791**	.675**	.681**	.621**	.191	.044	.128	.626**	.548**	.520**
	.000	.000	.000	.000	.250	.816	.491	.000	.000	.000
-2	.740**	.669**	.703**	.645**	.093	.132	.154	.605**	.553**	.518**
	.000	.000	.000	.000	.581	.480	.407	.000	.000	.000
-3	.702**	.581**	.671**	.629**	-.024	-.055	.037	.462**	.457**	.467**
	.000	.000	.000	.000	.885	.770	.842	.001	.001	.001
-4	.592**	.441**	.641**	.591**	-.021	-.062	.053	.390**	.452**	.460**
	.000	.002	.000	.000	.901	.739	.776	.006	.001	.001
-5	.520**	.349*	.636**	.622**	-.055	-.041	.103	.288*	.427**	.421**
	.000	.016	.000	.000	.742	.828	.583	.049	.003	.004
-6	.352*	.198	.567**	.539**	-.172	-.116	-.025	.101	.328*	.347*
	.017	.186	.000	.000	.301	.533	.892	.506	.026	.019
-7	.199	.077	.512**	.497**	-.163	-.071	.038	.034	.267	.247
	.189	.613	.000	.001	.327	.703	.841	.823	.077	.106
-8	.024	-.074	.436**	.460**	-.161	-.195	-.041	-.125	.202	.220
	.878	.631	.003	.002	.334	.294	.825	.419	.188	.157

Table B1: (a) Correlations between mean temperature lag and bird rates, 2006

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Temp_C	.708**	.644**	.660**	.352*	.520**	.259	-.288	.715**	.757**	.518**
	.000	.000	.000	.011	.001	.128	.088	.000	.000	.000
-1	.565**	.498**	.652**	.362**	.484**	.140	-.358*	.615**	.698**	.469**
	.000	.000	.000	.010	.003	.415	.032	.000	.000	.001
-2	.519**	.427**	.692**	.423**	.378*	.124	-.328	.522**	.683**	.516**
	.000	.002	.000	.002	.023	.473	.051	.000	.000	.000
-3	.376**	.309*	.682**	.383**	.418*	.096	-.343*	.466**	.637**	.403**
	.008	.031	.000	.007	.011	.576	.041	.001	.000	.005
-4	.329*	.207	.689**	.475**	.428**	.087	-.457**	.353*	.589**	.493**
	.022	.158	.000	.001	.009	.615	.005	.014	.000	.000
-5	.167	.123	.661**	.474**	.430**	.102	-.374*	.269	.532**	.423**
	.263	.409	.000	.001	.009	.554	.025	.068	.000	.003
-6	.077	.009	.621**	.460**	.332*	.033	-.432**	.150	.442**	.410**
	.612	.955	.000	.001	.048	.849	.009	.320	.002	.005
-7	-.016	-.031	.588**	.469**	.344*	-.063	-.500**	.098	.332*	.312*
	.916	.842	.000	.001	.040	.717	.002	.523	.026	.039
-8	-.088	-.093	.567**	.467**	.229	-.125	-.517**	-.017	.247	.284
	.569	.546	.000	.002	.187	.476	.001	.913	.105	.065

(b) Correlations between mean temperature lag and bird rates, 2007

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Max_C	.856**	.765**	.711**	.651**	.421**	.276	.285	.744**	.626**	.612**
	.000	.000	.000	.000	.008	.133	.120	.000	.000	.000
-1	.777**	.667**	.650**	.598**	.116	-.039	.079	.583**	.487**	.473**
	.000	.000	.000	.000	.487	.837	.672	.000	.000	.001
-2	.708**	.624**	.672**	.615**	.065	.092	.119	.574**	.517**	.467**
	.000	.000	.000	.000	.700	.621	.523	.000	.000	.001
-3	.688**	.554**	.668**	.632**	-.043	-.020	.066	.449**	.463**	.463**
	.000	.000	.000	.000	.799	.916	.724	.001	.001	.001
-4	.570**	.409**	.621**	.554**	-.030	-.095	.024	.362*	.414**	.433**
	.000	.004	.000	.000	.860	.613	.899	.011	.003	.002
-5	.497**	.334*	.622**	.607**	-.064	-.070	.080	.274	.398**	.374*
	.000	.022	.000	.000	.701	.710	.669	.062	.006	.010
-6	.311*	.170	.565**	.556**	-.196	-.125	-.064	.067	.323*	.342*
	.036	.258	.000	.000	.239	.501	.732	.660	.028	.021
-7	.177	.063	.507**	.490**	-.167	-.068	.003	.018	.261	.233
	.246	.682	.000	.001	.316	.718	.987	.908	.083	.129
-8	-.004	-.105	.442**	.465**	-.118	-.157	-.065	-.126	.228	.243
	.982	.499	.003	.001	.481	.400	.728	.416	.137	.117

Table B2: (a) Correlations between max temperature lag and bird rates, 2006

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Max_C	.651**	.578**	.644**	.366**	.613**	.309	-.238	.672**	.737**	.536**
	.000	.000	.000	.008	.000	.067	.161	.000	.000	.000
-1	.504**	.422**	.621**	.356*	.413*	.189	-.229	.534**	.661**	.475**
	.000	.002	.000	.011	.012	.271	.180	.000	.000	.000
-2	.445**	.381**	.656**	.431**	.350*	.085	-.315	.484**	.628**	.505**
	.001	.006	.000	.002	.037	.621	.062	.000	.000	.000
-3	.301*	.212	.641**	.407**	.483**	.142	-.450**	.396**	.601**	.432**
	.036	.144	.000	.004	.003	.409	.006	.005	.000	.002
-4	.258	.139	.646**	.468**	.442**	.108	-.461**	.310*	.554**	.494**
	.077	.347	.000	.001	.007	.531	.005	.032	.000	.000
-5	.092	.036	.605**	.452**	.409*	.105	-.342*	.210	.472**	.399**
	.538	.812	.000	.002	.013	.541	.041	.156	.001	.006
-6	.027	-.063	.575**	.440**	.347*	.059	-.428**	.109	.405**	.379*
	.861	.676	.000	.002	.038	.731	.009	.472	.005	.010
-7	-.081	-.075	.538**	.439**	.365*	-.036	-.495**	.072	.294	.270
	.597	.624	.000	.003	.029	.836	.002	.637	.050	.076
-8	-.145	-.144	.527**	.463**	.223	-.128	-.518**	-.056	.199	.252
	.348	.350	.000	.002	.199	.464	.001	.717	.196	.103

(b) Correlations between max temperature lag and bird rates, 2007

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Min_C	.836**	.752**	.716**	.673**	.361*	.209	.230	.701**	.617**	.623**
	.000	.000	.000	.000	.026	.258	.214	.000	.000	.000
-1	.787**	.661**	.708**	.652**	.250	.115	.169	.642**	.597**	.561**
	.000	.000	.000	.000	.130	.538	.362	.000	.000	.000
-2	.750**	.689**	.717**	.661**	.110	.142	.148	.608**	.563**	.551**
	.000	.000	.000	.000	.510	.447	.427	.000	.000	.000
-3	.703**	.596**	.677**	.637**	.011	-.076	.011	.474**	.469**	.476**
	.000	.000	.000	.000	.947	.683	.953	.001	.001	.001
-4	.598**	.457**	.660**	.623**	-.020	-.047	.070	.399**	.481**	.484**
	.000	.001	.000	.000	.907	.803	.708	.005	.001	.001
-5	.526**	.361*	.635**	.611**	-.044	.006	.126	.301*	.445**	.448**
	.000	.013	.000	.000	.795	.976	.500	.040	.002	.002
-6	.372*	.220	.572**	.541**	-.131	-.072	.027	.136	.357*	.364*
	.011	.142	.000	.000	.434	.701	.884	.366	.015	.014
-7	.205	.090	.526**	.514**	-.142	-.059	.072	.053	.292	.275
	.176	.558	.000	.000	.394	.751	.698	.728	.052	.071
-8	.042	-.048	.421**	.441**	-.181	-.208	-.011	-.121	.175	.197
	.788	.757	.004	.003	.277	.260	.955	.433	.257	.205

Table B3: (a) Correlations between min temperature lag and bird rates, 2006

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Min_C	.712**	.650**	.661**	.337*	.469**	.245	-.246	.714**	.757**	.498**
	.000	.000	.000	.016	.004	.151	.148	.000	.000	.000
-1	.585**	.509**	.665**	.360*	.501**	.153	-.390*	.634**	.718**	.467**
	.000	.000	.000	.010	.002	.374	.019	.000	.000	.001
-2	.538**	.433**	.704**	.407**	.397*	.124	-.378*	.536**	.701**	.490**
	.000	.002	.000	.004	.017	.471	.023	.000	.000	.000
-3	.423**	.346*	.704**	.373**	.409*	.075	-.367*	.490**	.655**	.382**
	.002	.015	.000	.009	.013	.663	.028	.000	.000	.007
-4	.372**	.256	.710**	.475**	.415*	.056	-.476**	.381**	.597**	.467**
	.009	.079	.000	.001	.012	.745	.003	.008	.000	.001
-5	.217	.191	.692**	.483**	.417*	.086	-.378*	.307*	.563**	.430**
	.142	.199	.000	.001	.011	.618	.023	.036	.000	.003
-6	.123	.080	.648**	.466**	.316	.006	-.427**	.192	.463**	.413**
	.416	.598	.000	.001	.060	.971	.009	.202	.001	.005
-7	.039	.019	.619**	.489**	.329	-.075	-.479**	.128	.362*	.341*
	.800	.902	.000	.001	.050	.663	.003	.400	.015	.024
-8	-.049	-.035	.593**	.477**	.212	-.149	-.496**	.020	.262	.287
	.751	.821	.000	.001	.222	.395	.002	.897	.085	.062

(b) Correlations between min temperature lag and bird rates, 2007

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Evap	.917**	.808**	.600**	.502**	.455**	.254	.127	.860**	.544**	.448**
	.000	.000	.000	.000	.004	.167	.497	.000	.000	.001
-1	.865**	.775**	.543**	.483**	.124	-.109	-.072	.677**	.373**	.359*
	.000	.000	.000	.000	.460	.559	.699	.000	.007	.010
-2	.829**	.701**	.611**	.543**	.214	.068	.025	.710**	.495**	.391**
	.000	.000	.000	.000	.198	.715	.894	.000	.000	.005
-3	.824**	.669**	.700**	.645**	.103	.109	.084	.632**	.531**	.484**
	.000	.000	.000	.000	.537	.560	.655	.000	.000	.000
-4	.752**	.605**	.651**	.545**	.130	-.033	-.039	.561**	.418**	.410**
	.000	.000	.000	.000	.438	.859	.833	.000	.003	.004
-5	.689**	.534**	.699**	.669**	.135	-.053	-.020	.519**	.480**	.402**
	.000	.000	.000	.000	.419	.779	.917	.000	.001	.006
-6	.559**	.424**	.721**	.715**	-.021	-.084	-.102	.344*	.465**	.456**
	.000	.003	.000	.000	.900	.654	.583	.019	.001	.002
-7	.459**	.344*	.676**	.624**	-.003	-.002	-.055	.286	.420**	.368*
	.002	.021	.000	.000	.987	.992	.768	.056	.004	.014
-8	.297	.180	.684**	.674**	.056	.010	-.059	.176	.464**	.421**
	.050	.243	.000	.000	.737	.956	.751	.253	.002	.005

Table B4: a) Correlations between evaporation lag and bird rates, 2006

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Evap	.812**	.666**	.463**	.155	.715**	.500**	-.227	.789**	.744**	.406**
	.000	.000	.001	.277	.000	.002	.183	.000	.000	.003
-1	.741**	.661**	.470**	.143	.433**	.316	-.083	.709**	.664**	.360*
	.000	.000	.001	.323	.008	.061	.632	.000	.000	.010
-2	.707**	.631**	.538**	.262	.451**	.323	-.085	.699**	.696**	.448**
	.000	.000	.000	.069	.006	.054	.620	.000	.000	.001
-3	.578**	.501**	.557**	.306*	.462**	.312	-.227	.632**	.683**	.428**
	.000	.000	.000	.034	.005	.064	.183	.000	.000	.002
-4	.524**	.403**	.613**	.326*	.522**	.263	-.350*	.573**	.706**	.472**
	.000	.005	.000	.025	.001	.121	.037	.000	.000	.001
-5	.408**	.268	.596**	.329*	.478**	.185	-.366*	.467**	.602**	.370*
	.004	.068	.000	.025	.003	.281	.028	.001	.000	.011
-6	.337*	.217	.662**	.377*	.441**	.166	-.318	.401**	.628**	.386**
	.022	.148	.000	.011	.007	.334	.059	.006	.000	.009
-7	.210	.189	.630**	.348*	.394*	.061	-.452**	.319*	.508**	.272
	.165	.213	.000	.021	.017	.723	.006	.033	.000	.074
-8	.184	.104	.653**	.440**	.341*	.000	-.535**	.238	.495**	.340*
	.233	.502	.000	.003	.045	.999	.001	.119	.001	.026

(b) Correlations between evaporation lag and bird rates, 2007

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Precip_mm	.088	.059	-.047	-.039	-.192	-.316	-.255	-.019	-.131	-.113
	.534	.676	.740	.786	.249	.084	.165	.896	.355	.430
-1	.194	.100	.215	.211	.069	.187	.029	.244	.234	.039
	.174	.483	.129	.137	.682	.314	.878	.085	.099	.789
-2	.171	.138	.217	.213	-.231	-.292	-.259	.004	.024	.112
	.234	.340	.129	.137	.163	.112	.159	.976	.870	.445
-3	.168	.165	.172	.136	-.022	-.224	-.277	.156	.023	.030
	.250	.256	.237	.353	.896	.226	.131	.283	.877	.839
-4	.102	.068	.267	.367*	.055	-.066	-.145	.079	.233	.176
	.489	.645	.067	.010	.743	.725	.438	.593	.111	.237
-5	-.021	-.099	.201	.206	-.005	-.003	.012	-.076	.119	.130
	.887	.507	.175	.165	.974	.987	.949	.613	.427	.390
-6	.000	-.053	.202	.168	.331*	.306	.135	.088	.220	.104
	.998	.729	.177	.265	.043	.094	.469	.562	.142	.498
-7	-.120	-.205	.213	.228	.045	-.075	-.019	-.114	.093	.321*
	.432	.176	.160	.133	.790	.689	.918	.455	.542	.034
-8	-.129	-.066	.102	.044	.147	.156	.327	-.043	.056	.056
	.406	.670	.511	.778	.379	.403	.073	.783	.718	.723

Table B5: a) Correlations between precipitation lag and bird rates, 2006

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Precip_mm	.178	.302*	.157	-.025	-.169	-.070	.170	.238	.100	.072
	.206	.030	.266	.863	.325	.683	.323	.089	.481	.617
-1	.204	.110	.250	.128	.142	.050	-.089	.190	.309*	.141
	.151	.443	.077	.375	.409	.771	.605	.181	.027	.328
-2	.266	.158	.333*	.043	.340*	.165	-.203	.262	.362**	.101
	.061	.275	.018	.772	.043	.338	.235	.066	.010	.491
-3	.214	.214	.260	-.008	.132	-.072	-.257	.217	.226	.005
	.141	.140	.071	.955	.442	.678	.131	.135	.118	.973
-4	.223	.177	.277	.087	.138	.017	-.176	.207	.216	.068
	.127	.230	.057	.560	.423	.923	.306	.159	.141	.649
-5	.192	.216	.239	-.018	.165	-.039	-.244	.260	.254	.009
	.197	.146	.105	.905	.337	.823	.151	.077	.085	.953
-6	.238	.225	.266	.223	.135	-.025	-.222	.182	.187	.055
	.112	.132	.074	.142	.433	.884	.194	.226	.212	.721
-7	.242	.290	.322*	.101	-.051	-.027	.129	.201	.278	.178
	.110	.053	.031	.513	.767	.876	.455	.185	.064	.249
-8	.211	.239	.383*	.358*	-.057	-.276	-.193	.171	.197	.073
	.170	.118	.010	.018	.745	.109	.267	.266	.200	.644

(b) Correlations between precipitation lag and bird rates, 2007

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
P-E	-.086	-.092	-.161	-.134	-.251	-.360*	-.278	-.181	-.234	-.196
	.547	.519	.253	.342	.128	.047	.130	.200	.096	.169
Water	-.730**	-.614**	-.327*	-.243	-.154	-.154	-.241	-.586**	-.302*	-.320*
	.000	.000	.018	.082	.356	.410	.191	.000	.030	.022
-1	.030	-.044	.111	.118	.051	.211	.039	.115	.163	-.024
	.833	.761	.439	.408	.763	.255	.836	.420	.253	.867
-2	.022	.011	.104	.112	-.255	-.296	-.256	-.124	-.067	.038
	.879	.939	.473	.439	.123	.106	.164	.391	.642	.794
-3	.020	.045	.045	.019	-.033	-.227	-.279	.044	-.070	-.052
	.891	.760	.759	.898	.843	.219	.128	.765	.635	.725
-4	-.026	-.034	.151	.268	.038	-.060	-.137	-.016	.158	.103
	.863	.817	.306	.065	.821	.748	.464	.913	.284	.490
-5	-.136	-.186	.080	.090	-.031	.011	.016	-.161	.037	.061
	.363	.210	.591	.548	.854	.955	.933	.280	.807	.687
-6	-.092	-.120	.078	.045	.337*	.320	.162	.034	.138	.025
	.545	.428	.604	.765	.039	.079	.384	.824	.360	.870
-7	-.190	-.256	.097	.120	.047	-.080	-.008	-.157	.021	.232
	.210	.090	.526	.432	.777	.668	.967	.303	.890	.129
-8	-.170	-.089	-.009	-.067	.127	.155	.342	-.067	-.021	-.015
	.271	.565	.952	.666	.447	.406	.060	.667	.893	.923

Table B6: a) Correlations between water availability lag and bird rates, 2006

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
P-E	-.001	.153	.054	-.058	-.262	-.136	.198	.064	-.064	-.017
	.992	.278	.702	.685	.123	.430	.246	.654	.652	.905
Water	-.189	-.158	.560**	.468**	.131	-.238	-.409*	-.024	.232	.332*
	.180	.265	.000	.001	.446	.161	.013	.867	.098	.017
-1	.040	-.036	.145	.097	.078	.004	-.077	.033	.161	.063
	.779	.804	.311	.502	.650	.980	.657	.816	.258	.662
-2	.110	.018	.212	-.016	.270	.115	-.189	.107	.207	.001
	.449	.900	.140	.915	.111	.505	.269	.461	.150	.994
-3	.088	.105	.138	-.073	.059	-.121	-.221	.080	.078	-.086
	.548	.474	.343	.620	.731	.483	.195	.587	.593	.560
-4	.109	.089	.143	.016	.047	-.028	-.114	.082	.063	-.034
	.461	.550	.333	.914	.785	.869	.507	.578	.671	.822
-5	.103	.155	.110	-.086	.068	-.074	-.167	.158	.123	-.069
	.492	.297	.460	.568	.694	.670	.330	.290	.409	.651
-6	.166	.178	.127	.143	.038	-.061	-.151	.098	.057	-.025
	.271	.236	.399	.350	.826	.723	.379	.518	.708	.871
-7	.196	.249	.189	.028	-.136	-.040	.225	.134	.171	.120
	.196	.099	.213	.856	.428	.817	.186	.380	.260	.439
-8	.171	.215	.244	.263	-.131	-.272	-.073	.120	.093	.002
	.268	.161	.110	.088	.454	.114	.677	.436	.548	.991

(b) Correlations between water availability lag and bird rates, 2007

Section C: Spatial Correlations

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Precip_mm	-.020 .750	-.041 .504	.011 .864	.084 .171	.034 .585	.020 .750	-.096 .132	.056 .472	-.017 .787
PDiff_mm	-.089 .147	-.206** .001	-.298** .000	-.111 .069	-.173** .005	-.234** .000	.005 .939	-.003 .971	-.027 .660
Evap	-.041 .499	-.033 .588	-.141* .021	-.086 .162	.139* .022	.100 .101	.105 .098	.190* .014	.255** .000
Water	.026 .668	.003 .955	.124* .043	.130* .034	.052 .394	.072 .242	-.095 .137	.022 .779	-.055 .366
Water_Agg	-.005 .935	-.026 .674	.049 .425	.096 .116	-.011 .862	-.012 .850	-.112 .078	-.006 .942	-.086 .158
Temp_C	.129* .034	.167** .006	.368** .000	.201** .001	.056 .359	.194** .001	-.035 .582	-.097 .216	-.118 .053
Max_C	.084 .170	-.028 .645	.091 .139	.056 .363	.179** .003	.169** .006	.021 .739	.148 .058	.149* .015
Min_C	.076 .213	.145* .017	.295** .000	.170** .005	-.005 .934	.103 .093	-.061 .337	-.131 .094	-.169** .006
Calls_Log	-.105 .088	.237** .000	.060 .324	.000 .995	.184** .002	.154* .012	.131* .039	.038 .628	.134* .028
DTest_Log	-.089 .148	.179** .003	.033 .594	-.041 .501	.182** .003	.110 .073	.076 .236	-.010 .901	.093 .128
PctTest	.014 .833	.021 .746	.026 .681	-.056 .380	.069 .286	.004 .956	-.074 .272	-.061 .444	-.040 .535
DPos_Log	-.052 .399	.060 .329	-.015 .812	-.033 .591	.247** .000	.153* .012	.083 .192	-.021 .785	.207** .001
PctDPos	-.007 .923	-.092 .193	-.068 .339	-.054 .451	.021 .766	.025 .724	.033 .652	-.015 .865	.117 .098
Live_Log	.066 .285	-.103 .093	.025 .678	.016 .798	-.053 .389	.075 .223	.034 .595	.000	.048 .430
LPos_Log	.075 .219	-.007 .913	.102 .097	-.014 .818	.011 .855	.045 .467	-.032 .613	-.024 .755	-.013 .838
PctLPos	.431 .334	.274 .552	.519 .233	-.512 .240	-.122 .794	-.680 .093	-.547 .203	-.048 .952	-.751 .052
Bird_Pos	.061 .317	-.019 .755	.073 .237	.004 .942	.089 .145	.120* .049	.024 .712	-.024 .759	.076 .213
PctBPos	.008 .915	-.090 .202	-.043 .547	-.056 .430	.013 .852	.019 .787	.026 .721	-.019 .823	.103 .143

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Table C1: Correlations between temperature, mosquito, and bird variables, 2006

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Precip_mm	.142*	.023	.159**	.138*	.025	.117	.166**	.020	.053
	.020	.703	.009	.024	.688	.055	.007	.807	.395
PDiff_mm	-.108	.068	-.095	.065	-.022	.057	.075	-.058	.207**
	.077	.268	.122	.291	.718	.349	.228	.469	.001
Evap	-.030	.004	-.053	.046	.063	.072	.083	.025	-.044
	.624	.950	.385	.458	.303	.239	.180	.754	.480
Water	-.073	-.044	-.059	-.031	-.064	-.072	-.056	.006	.068
	.234	.474	.338	.617	.295	.238	.364	.938	.273
Water_Agg	.131*	.019	.152*	.106	.003	.081	.119	.009	.057
	.032	.757	.013	.084	.956	.189	.054	.912	.352
Temp_C	.145*	.093	.242**	.009	.031	.031	-.047	.009	-.027
	.017	.131	.000	.880	.617	.617	.448	.911	.667
Max_C	.086	-.001	.144*	-.064	-.019	-.092	-.153*	-.067	-.053
	.162	.985	.018	.294	.760	.132	.013	.404	.389
Min_C	-.085	-.044	-.085	-.015	-.061	-.075	-.009	-.023	-.020
	.163	.476	.168	.808	.320	.220	.887	.777	.742
Calls_Log	-.039	.034	.017	-.006	-.058	-.033	.022	-.070	-.024
	.520	.577	.787	.918	.341	.586	.720	.384	.702
DTest_Log	-.109	.193**	.002	.003	.088	.077	.079	.069	-.007
	.075	.001	.968	.967	.153	.209	.204	.391	.913
PctTest	-.057	.039	-.033	-.071	.008	-.042	-.032	-.013	-.086
	.374	.542	.601	.267	.897	.511	.619	.870	.177
DPos_Log	-.007	.030	-.087	.025	.173**	.132*	.188**	.321**	.098
	.903	.630	.155	.680	.005	.031	.002	.000	.114
PctDPos	.048	-.070	-.101	.020	.131	.093	.109	.335**	.169*
	.495	.320	.155	.782	.064	.189	.126	.000	.017
Live_Log	.132*	.144*	.180**	.058	.203**	.187**	-.031	.054	.000
	.031	.018	.003	.340	.001	.002	.614	.502	.994
LPos_Log	-.001	.043	.033	-.035	.057	.009	-.025	.078	.013
	.992	.483	.592	.565	.354	.879	.686	.332	.832
PctLPos	.154	-.107	.095	.027	-.051	.008	-.001	.014	.243**
	.094	.246	.301	.770	.583	.933	.989	.908	.008
Bird_Pos	.040	.097	.072	.051	.077	.116	.109	.109	.072
	.515	.111	.238	.403	.209	.058	.076	.175	.243
PctBPos	.170*	-.127	.044	.045	.072	.082	.074	.229**	.294**
	.010	.057	.513	.501	.282	.221	.276	.006	.000

Table C2: Correlations between temperature, mosquito, and bird variables, 2007

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_ Log	MIR_GV	MIR_SS	MIR
Developed (High Intensity)	.074	.217**	.398**	.140*	.155*	.237**	.014	-.056	-.085
	.226	.000	.000	.022	.011	.000	.822	.475	.163
Developed (Medium Intensity)	.077	.272**	.402**	.266**	.092	.294**	.022	-.110	-.070
	.207	.000	.000	.000	.131	.000	.731	.158	.252
Developed (Low Intensity)	-.030	.183**	.085	.044	.109	.140*	.097	-.033	.078
	.627	.003	.165	.471	.076	.022	.127	.671	.206
Developed (OpenSpace)	-.175**	-.014	-.241**	-.191**	-.120	-.251**	-.025	.118	-.074
	.004	.814	.000	.002	.050	.000	.692	.130	.226
Cultivated	.029	-.142*	-.096	-.043	-.089	-.064	-.015	-.029	.009
	.631	.020	.116	.481	.147	.297	.808	.715	.886
PastureHay	.000	-.269**	-.207**	-.098	-.176**	-.198**	-.073	-.058	-.063
	.998	.000	.001	.108	.004	.001	.253	.456	.301
Grassland	-.105	-.065	-.224**	-.145*	-.115	-.274**	-.094	.004	-.031
	.085	.288	.000	.017	.060	.000	.139	.957	.618
DeciduousForest	-.042	-.150*	-.266**	-.179**	-.129*	-.290**	-.142*	.057	-.092
	.496	.014	.000	.003	.035	.000	.026	.465	.132
EvergreenForest	-.034	.040	-.084	-.076	.225**	.101	.056	.122	🟪
	.577	.511	.169	.214	.000	.097	.383	.116	.000
MixedForest	.033	-.088	-.133*	-.065	.026	-.049	.010	.078	.080
	.589	.150	.029	.286	.674	.426	.874	.320	.192
ScrubShrub	.041	-.182**	-.232**	-.126*	-.103	-.190*	-.060	.018	.031
	.500	.003	.000	.039	.093	.002	.345	.816	.613
ForestedWetland (Palustrine)	-.007	-.219**	-.239**	-.106	-.102	-.181**	.004	.057	.047
	.907	.000	.000	.082	.095	.003	.946	.465	.446
ScrubShrubWetland	-.013	-.160**	-.209**	-.051	-.083	-.094	.011	🟪	🟪
	.838	.009	.001	.409	.174	.124	.869	.048	.024
EmergentWetland (Palustrine)	.014	-.198**	-.218**	-.069	-.048	-.103	.035	.057	.105
	.823	.001	.000	.264	.439	.094	.581	.470	.085
ForestedWetland (Estuarine)	.029	-.128*	-.086	-.043	-.111	-.133*	-.020	-.069	-.055
	.634	.037	.159	.482	.070	.029	.753	.376	.367
ScrubShrubWetland (Estuarine)	-.054	-.023	-.106	-.032	-.068	-.104	-.039	.005	-.074
	.376	.713	.083	.605	.270	.089	.538	.948	.227
EmergentWetland (Estuarine)	-.042	-.071	-.150*	-.042	-.089	🟪	-.032	.012	-.070
	.493	.245	.014	.492	.148	.043	.622	.883	.256
UnconsolidatedShore	-.038	-.025	-.121*	-.050	.026	-.090	-.055	-.004	-.032
	.532	.680	.048	.414	.666	.142	.388	.955	.598
BareLand	-.032	.009	-.110	-.062	.040	.001	-.006	.023	.060
	.599	.887	.073	.308	.513	.987	.929	.764	.326
Water1	-.027	-.108	-.174**	-.056	-.044	-.085	.051	.103	.063
	.658	.078	.004	.365	.469	.164	.422	.186	.301
AquaticBed (Estuarine)	.014	-.093	-.084	-.036	.011	-.057	-.023	.039	-.006
	.817	.130	.170	.555	.855	.350	.715	.616	.927
AquaticBed (Estuarine)	-.025	-.070	-.106	-.038	-.095	-.099	.003	.039	-.066
	.684	.251	.083	.531	.121	.107	.964	.614	.283

Table C3: Spatial correlations between land cover and mosquito rates, 2006

	Log_GV	Log_SS	Total_Log	Pos_GV	Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Developed (High Intensity)	.088	.150*	.334**	.017	.044	.034	-.031	-.015	-.034
	.150	.014	.000	.785	.469	.575	.618	.849	.579
Developed (Medium Intensity)	.095	.229**	.323**	.083	.028	.097	-.003	-.015	-.038
	.122	.000	.000	.175	.647	.114	.962	.848	.534
Developed (Low Intensity)	.011	.127*	.038	.051	.024	.060	.077	.002	-.016
	.852	.037	.537	.407	.691	.325	.211	.982	.791
Developed (OpenSpace)	-.138*	.010	-.273**	-.113	.054	-.047	-.012	.090	.052
	.024	.876	.000	.064	.378	.448	.840	.263	.402
Cultivated	-.039	-.127*	-.114	-.066	-.081	-.116	-.045	-.071	-.059
	.524	.038	.061	.278	.184	.058	.464	.381	.343
PastureHay	-.017	-.212**	-.146*	-.030	-.096	-.084	-.008	-.042	.011
	.786	.000	.017	.620	.117	.169	.894	.599	.853
Grassland	-.115	-.045	-.149*	-.062	.022	-.039	-.025	.098	.062
	.060	.459	.015	.313	.714	.521	.689	.224	.314
DeciduousForest	-.007	-.107	-.189**	-.061	.004	-.044	.001	.015	.040
	.914	.080	.002	.319	.943	.473	.991	.855	.522
EvergreenForest	-.054	.083	-.063	.077	.137*	.140*	.087	-.012	.031
	.376	.177	.306	.210	.025	.022	.158	.883	.611
MixedForest	.048	-.107	-.059	.039	.023	.030	.013	.018	-.018
	.438	.081	.339	.525	.702	.620	.830	.825	.772
ScrubShrub	.007	-.173**	-.145*	.015	.014	.007	.008	.081	.055
	.911	.004	.017	.810	.818	.904	.900	.314	.374
ForestedWetland (Palustrine)	-.018	-.188**	-.180**	-.074	-.012	-.073	-.044	.111	.030
	.773	.002	.003	.227	.839	.232	.477	.169	.627
ScrubShrubWetland	-.007	-.147*	-.122*	-.056	-.030	-.073	-.040	.085	-.024
	.910	.016	.045	.360	.623	.234	.517	.293	.700
EmergentWetland (Palustrine)	.026	-.180**	-.129*	-.008	-.106	-.080	.054	-.085	.085
	.675	.003	.035	.894	.084	.193	.383	.289	.167
ForestedWetland (Estuarine)	.034	-.134*	-.071	-.044	-.028	-.058	-.023	.093	-.011
	.577	.028	.250	.475	.650	.345	.716	.247	.853
ScrubShrubWetland (Estuarine)	-.017	-.052	-.090	-.009	-.034	-.026	-.016	-.012	-.017
	.786	.395	.144	.878	.579	.666	.791	.883	.778
EmergentWetland (Estuarine)	-.082	-.043	-.115	.010	-.057	-.019	.015	-.043	.074
	.182	.479	.060	.877	.352	.759	.806	.592	.229
UnconsolidatedShore	-.097	.006	-.076	-.039	-.065	-.077	-.011	-.069	.028
	.113	.916	.216	.526	.288	.207	.865	.393	.651
BareLand	-.079	.029	-.089	.041	-.011	.022	.047	-.068	-.004
	.195	.635	.146	.503	.856	.722	.452	.396	.943
Water1	-.076	-.074	-.193**	-.020	-.081	-.059	-.022	-.082	-.001
	.217	.228	.001	.750	.189	.339	.725	.307	.987
AquaticBed (Estuarine)	.027	-.093	-.043	-.017	-.040	-.040	-.017	-.072	-.028
	.655	.130	.483	.779	.511	.517	.786	.371	.656
AquaticBed (Estuarine)	.025	-.100	-.172**	.019	-.061	-.011	-.009	-.035	-.034
	.682	.102	.005	.756	.318	.854	.878	.667	.580

Table C4: Spatial correlations between land cover and mosquito rates, 2007

	Calls_Log	DTest_Log	DPos_Log	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Developed (High Intensity)	.044	.005	-.064	.056		.502	.093	.090	-.072
	.476	.934	.300	.362	.004	.251	.127	.141	.309
Developed (Medium Intensity)				.109		-.594	.166**	.155*	-.036
	.000	.000	.047	.074	.010	.160	.006	.011	.608
Developed (Low Intensity)		.083	.075	.027	.010	-.348	.023	.044	.067
	.000	.174	.221	.666	.867	.445	.709	.476	.342
Developed (OpenSpace)	.083	.010	-.085	-.047	-.091	-.402	-.062	-.093	-.066
	.173	.876	.167	.443	.139	.372	.316	.129	.352
Cultivated		-.126*	-.089	-.020	-.036		-.041	-.052	-.061
	.001	.039	.148	.746	.558	.000	.504	.400	.388
PastureHay		-.136*	-.087	-.042	-.075	.248	-.070	-.081	-.016
	.000	.026	.155	.498	.221	.592	.251	.185	.820
Grassland		-.129*	-.051	-.055	-.094	.057	-.087	-.086	.040
	.000	.036	.403	.374	.126	.903	.156	.158	.573
DeciduousForest		-.182**	-.064	-.066	-.121*	.706		-.113	.117
	.000	.003	.298	.280	.049	.076	.044	.066	.097
EvergreenForest	.081	.117		-.049	-.090	.229	-.038	-.013	.079
	.189	.056	.002	.424	.141	.622	.531	.832	.267
MixedForest	-.068	-.017	.048	-.043	-.079	-.059	-.047	-.033	.034
	.266	.780	.436	.479	.199	.900	.442	.593	.634
ScrubShrub		-.082	.031	-.059	-.111	-.382	-.087	-.075	.101
	.003	.183	.614	.333	.070	.398	.154	.218	.153
ForestedWetland (Palustrine)		-.160**	-.049	-.046	-.089	-.599	-.074	-.073	.001
	.000	.009	.427	.452	.148	.155	.225	.231	.990
ScrubShrubWetland	-.211**		-.090	-.021	-.038	-.123	-.044	-.051	-.066
	.001	.013	.144	.732	.533	.793	.469	.405	.348
EmergentWetland (Palustrine)	-.221**		-.039	-.035	-.064		-.051	-.047	-.013
	.000	.041	.526	.564	.298	.000	.409	.445	.859
ForestedWetland (Estuarine)	-.148*	-.106	-.046	-.017	-.030		-.037	-.034	.014
	.015	.082	.451	.785	.623	.000	.551	.582	.848
ScrubShrubWetland (Estuarine)	-.126*	-.097	-.049	-.011	-.020		-.028	-.028	-.018
	.040	.115	.428	.859	.749	.000	.646	.648	.799
EmergentWetland (Estuarine)			-.050	-.016	-.028		-.039	-.036	.010
	.002	.032	.414	.799	.646	.000	.523	.561	.885
UnconsolidatedShore		-.093	-.039	-.022	-.031		-.038	-.030	-.031
	.002	.129	.520	.724	.611	.028	.531	.629	.663
BareLand		.206**		-.039	-.069	.149	-.015	-.023	-.037
	.001	.001	.048	.530	.261	.749	.803	.709	.606
Water1		-.143*	-.010	-.030	-.042		-.051	-.029	.075
	.001	.019	.871	.626	.493	.048	.410	.637	.287
AquaticBed (Estuarine)		-.092	.022	-.014	-.029	-.523	-.023	-.008	.089
	.046	.133	.719	.816	.631	.228	.709	.891	.206
AquaticBed (Estuarine)			-.046	-.016	-.029		-.040	-.036	.066
	.010	.040	.454	.796	.640	.000	.518	.558	.353

Table C5: Spatial correlations between land cover and bird rates, 2006

	Calls_Log	DTest_Log	DPos_Log	Live_Log	LPos_Log	PctLPos	Birds	Bird_Pos	PctBPos
Developed (High Intensity)	.013	.053	-.083	.148*	.036	.159	.092	.078	.061
	.836	.385	.173	.015	.559	.082	.133	.205	.360
Developed (Medium Intensity)	.222**	.349**	-.001	.105	.064	.045	.314**	.156*	-.051
	.000	.000	.992	.085	.300	.625	.000	.010	.449
Developed (Low Intensity)	.125*	.220**	-.021	.020	.065	-.106	.181**	.069	-.177**
	.041	.000	.731	.751	.287	.248	.003	.261	.008
Developed (OpenSpace)	.043	.017	.008	-.070	.002	-.084	-.030	-.053	-.075
	.486	.776	.899	.252	.972	.363	.622	.391	.260
Cultivated	-.067	-.124*	.033	-.033	-.025	-.045	-.101	-.051	.053
	.276	.042	.592	.592	.686	.626	.100	.401	.428
PastureHay	-.115	-.189**	.041	-.061	-.019	-.148	-.167**	-.116	.067
	.059	.002	.504	.321	.751	.106	.006	.057	.313
Grassland	-.120*	-.235**	-.012	-.075	-.053	.008	-.186**	-.114	.073
	.049	.000	.845	.223	.391	.928	.002	.063	.272
DeciduousForest	-.139*	-.260**	-.056	-.049	-.051	-.081	-.288**	-.207**	-.026
	.023	.000	.360	.428	.408	.381	.000	.001	.695
EvergreenForest	-.006	.105	.137*	-.079	-.060	-.001	-.055	.023	-.027
	.927	.087	.025	.196	.327	.992	.372	.714	.689
MixedForest	-.091	-.094	.006	-.070	-.053	-.028	-.079	-.008	-.030
	.139	.124	.921	.256	.386	.760	.200	.896	.656
ScrubShrub	-.095	-.148*	.078	-.059	-.050	-.037	-.094	-.049	.046
	.120	.016	.201	.337	.418	.685	.127	.421	.489
ForestedWetland (Palustrine)	-.111	-.207**	.026	-.081	-.043	.034	-.213**	-.070	.083
	.070	.001	.673	.184	.480	.713	.000	.251	.211
ScrubShrubWetland	-.048	-.109	.064	-.034	-.025	.008	-.095	-.020	.077
	.436	.076	.296	.578	.681	.927	.120	.746	.249
EmergentWetland (Palustrine)	-.050	-.183**	-.036	-.057	-.018	-.043	-.108	-.033	.043
	.412	.003	.555	.353	.770	.639	.078	.588	.516
ForestedWetland (Estuarine)	-.025	-.179**	-.080	.028	.017	.002	-.107	-.058	.026
	.683	.003	.192	.651	.779	.981	.081	.344	.700
ScrubShrubWetland (Estuarine)	-.057	-.147*	-.060	-.018	-.014	.191*	-.054	.000	.211**
	.353	.016	.327	.769	.824	.036	.381	.994	.001
EmergentWetland (Estuarine)	-.082	-.170**	-.086	-.026	-.020	.208*	-.083	-.033	.183**
	.183	.005	.160	.674	.750	.022	.175	.586	.006
UnconsolidatedShore	-.077	-.181**	-.071	-.028	-.027	.006	-.072	-.025	.055
	.207	.003	.248	.646	.659	.946	.241	.689	.410
BareLand	.087	.283**	.254**	-.059	.035	-.030	.160**	.201**	.047
	.157	.000	.000	.337	.569	.749	.009	.001	.478
Water1	-.102	-.210**	-.115	-.021	-.036	-.008	-.066	-.057	.006
	.096	.001	.060	.738	.559	.927	.278	.350	.932
AquaticBed (Estuarine)	-.057	-.046	-.035	-.030	-.012	-.013	-.056	-.038	-.014
	.350	.455	.566	.629	.843	.891	.359	.533	.838
AquaticBed (Estuarine)	-.083	-.202**	-.073	-.026	-.020	.106	-.059	-.039	.142*
	.175	.001	.234	.668	.746	.251	.337	.528	.032

Table C6: Spatial correlations between land cover and bird rates, 2007

Section D: Spatiotemporal Correlations

	Log_GV	Log_SS	Total_Log	GVPos_Log	SSPos_Log	Positive_Log	MIR_GV	MIR_SS	MIR
Temp_C	.099	.153*	.243**	.212**	.084	.229**	.049	-.038	-.009
	.107	.012	.000	.000	.171	.000	.541	.659	.879
-1	.110	.135*	.230**	.208**	.061	.216**	.069	-.049	-.010
	.072	.028	.000	.001	.319	.000	.393	.567	.874
-2	.122*	.121*	.228**	.217**	.136*	.257**	.123	.070	.084
	.046	.048	.000	.000	.026	.000	.127	.410	.170
-3	.133*	.132*	.248**	.219**	.111	.249**	.141	.056	.084
	.030	.031	.000	.000	.070	.000	.081	.511	.174
-4	.133*	.132*	.248**	.219**	.111	.249**	.141	.056	.084
	.030	.031	.000	.000	.070	.000	.081	.511	.174
-5	.088	.154*	.236**	.199**	.078	.215**	.068	-.027	.006
	.152	.012	.000	.001	.205	.000	.401	.749	.929
-6	.111	.137*	.236**	.210**	.094	.233**	.113	.020	.051
	.069	.025	.000	.001	.125	.000	.163	.812	.405
-7	.052	.137*	.177**	.181**	.069	.194**	.065	-.040	-.006
	.395	.025	.004	.003	.260	.001	.420	.643	.929
-8	-.013	-.063	-.061	-.073	-.084	-.102	-.007	-.062	-.037
	.830	.303	.319	.235	.172	.095	.935	.468	.553

Table D1: (a) Correlations between mean temperature lag and mosquito rates, Week 31

	Log_GV	Log_SS	Total_Log	GVPos_Log	SSPos_Log	Positive_Log	MIR_GV	MIR_SS	MIR
Temp_C	.099	.153*	.243**	.212**	.084	.229**	.049	-.038	-.009
	.107	.012	.000	.000	.171	.000	.541	.659	.879
-1	.105	.081	.221**	-.082	.003	-.064	-.049	-.011	-.037
	.087	.186	.000	.184	.961	.295	.568	.899	.548
-2	.043	.115	.196**	-.012	.088	.043	.097	.109	.084
	.484	.061	.001	.840	.150	.486	.258	.220	.175
-3	.139*	.135*	.334**	-.050	.012	-.033	-.046	.000	-.036
	.023	.028	.000	.420	.840	.595	.590	.998	.562
-4	.144*	.089	.263**	-.098	-.020	-.091	-.133	-.051	-.106
	.018	.146	.000	.109	.750	.137	.120	.566	.087
-5	.100	.080	.200**	-.059	-.025	-.063	-.145	-.074	-.117
	.105	.195	.001	.334	.688	.306	.090	.404	.059
-6	.158**	.096	.298**	-.052	-.005	-.045	-.064	-.027	-.052
	.010	.117	.000	.400	.933	.464	.460	.765	.409
-7	.070	.149*	.255**	-.042	.031	-.015	-.017	.022	-.015
	.256	.015	.000	.497	.616	.803	.841	.803	.810
-8	.118	.136*	.304**	-.054	.043	-.018	-.006	.046	.001
	.054	.026	.000	.376	.485	.765	.941	.602	.992

(b) Correlations between mean temperature lag and mosquito rates, Week 83

	Log_GV	Log_SS	Total_Log	GVPos_Log	SSPos_Log	Positive_Log	MIR_GV	MIR_SS	MIR
Max_C	.020	.025	.012	.077	.106	.117	.143	.121	.127*
	.748	.686	.839	.208	.083	.055	.076	.155	.039
-1	.024	.001	.001	.058	.093	.094	.125	.121	.120
	.701	.986	.993	.346	.127	.124	.120	.154	.050
-2	.035	.000	.008	.060	.104	.102	.130	.138	.135*
	.571	.995	.890	.324	.088	.097	.106	.103	.028
-3	.041	.038	.047	.104	.118	.146*	.146	.123	.128*
	.502	.531	.444	.091	.054	.017	.071	.148	.037
-4	.021	-.004	-.009	.048	.100	.088	.130	.139	.136*
	.738	.949	.881	.436	.104	.151	.106	.101	.027
-5	.047	-.009	.019	.079	.090	.111	.121	.129	.124*
	.445	.878	.758	.197	.143	.070	.133	.129	.044
-6	.007	.024	.001	.069	.102	.108	.136	.117	.123*
	.909	.696	.987	.264	.097	.079	.091	.168	.046
-7	-.017	.021	-.018	.043	.044	.058	.063	.027	.036
	.776	.737	.768	.482	.473	.345	.440	.754	.557
-8	-.005	-.009	-.035	.028	.068	.055	.094	.096	.093
	.934	.886	.566	.651	.268	.368	.247	.261	.133

Table D2: (a) Correlations between max temperature lag and mosquito rates, Week 31

	Log_GV	Log_SS	Total_Log	GVPos_Log	SSPos_Log	Positive_Log	MIR_GV	MIR_SS	MIR
Max_C	-.001	.143*	.181**	-.038	.077	.015	-.069	.131	-.030
	.981	.019	.003	.538	.210	.802	.421	.140	.636
-1	.013	.143*	.187**	-.046	.073	.006	-.040	.109	-.013
	.835	.020	.002	.454	.237	.921	.644	.222	.829
-2	.035	.132*	.204**	-.040	.029	-.015	-.046	.044	-.026
	.565	.032	.001	.514	.642	.803	.591	.623	.676
-3	.080	.094	.207**	-.063	.027	-.035	-.024	.029	-.010
	.193	.127	.001	.307	.660	.574	.782	.746	.872
-4	.063	.034	.119	.014	.091	.066	.063	.128	.062
	.305	.579	.053	.815	.136	.280	.465	.151	.323
-5	.113	.100	.251**	-.026	.063	.017	.013	.074	.022
	.065	.105	.000	.668	.302	.788	.879	.407	.721
-6	.113	.100	.251**	-.026	.063	.017	.013	.074	.022
	.065	.105	.000	.668	.302	.788	.879	.407	.721
-7	.003	-.015	-.028	-.006	-.056	-.038	-.025	-.109	-.030
	.957	.813	.647	.922	.364	.533	.774	.220	.628
-8	.034	.098	.158**	-.088	.023	-.058	-.094	.036	-.061
	.580	.108	.010	.150	.712	.347	.276	.689	.326

(b) Correlations between max temperature lag and mosquito rates, Week 83

	Log_GV	Log_SS	Total_Log	GVPos_Log	SSPos_Log	Positive_Log	MIR_GV	MIR_SS	MIR
Min_C	.058	.128*	.191**	.140*	.040	.144*	.014	-.056	-.032
	.341	.036	.002	.022	.515	.018	.866	.509	.608
-1	.058	.140*	.198**	.153*	.066	.168**	.043	-.026	.000
	.342	.022	.001	.012	.284	.006	.593	.758	.994
-2	.041	.085	.132*	.055	.004	.053	.007	-.053	-.031
	.506	.168	.030	.366	.952	.385	.930	.535	.620
-3	.090	.117	.211**	.144*	.077	.166**	.049	.014	.026
	.143	.057	.000	.018	.208	.007	.541	.869	.670
-4	.105	.158**	.237**	.235**	.133*	.272**	.148	.053	.087
	.085	.010	.000	.000	.029	.000	.067	.530	.160
-5	.067	.139*	.208**	.161**	.062	.173**	.037	-.033	-.008
	.278	.023	.001	.008	.313	.004	.647	.703	.903
-6	.080	.155*	.228**	.191**	.087	.211**	.070	-.010	.020
	.192	.011	.000	.002	.155	.000	.389	.907	.750
-7	.055	.135*	.195**	.144*	.053	.154*	.032	-.037	-.011
	.371	.027	.001	.019	.384	.012	.696	.664	.853
-8	.041	.125*	.169**	.115	.039	.122*	.034	-.045	-.015
	.499	.040	.005	.060	.528	.046	.673	.599	.808

Table D3: (a) Correlations between min temperature lag and mosquito rates, Week 31

	Log_GV	Log_SS	Total_Log	GVPos_Log	SSPos_Log	Positive_Log	MIR_GV	MIR_SS	MIR
Min_C	-.037	-.009	-.062	-.027	-.093	-.077	-.106	-.140	-.094
	.544	.879	.309	.655	.130	.206	.218	.114	.133
-1	.043	.018	.069	-.009	-.086	-.059	-.031	-.138	-.037
	.481	.773	.264	.878	.163	.338	.720	.119	.554
-2	-.045	-.020	-.089	-.025	-.088	-.073	-.112	-.137	-.098
	.460	.744	.148	.682	.151	.234	.193	.122	.116
-3	-.036	-.109	-.209**	-.025	-.043	-.046	-.087	-.090	-.072
	.557	.076	.001	.680	.484	.452	.312	.311	.249
-4	.011	-.070	-.098	-.002	-.071	-.044	-.031	-.130	-.036
	.864	.256	.110	.970	.248	.471	.723	.145	.562
-5	-.029	.023	-.007	-.028	-.082	-.071	-.116	-.116	-.098
	.641	.703	.914	.650	.184	.245	.176	.194	.116
-6	.013	.082	.112	-.032	-.038	-.049	-.102	-.056	-.079
	.829	.184	.068	.600	.533	.425	.234	.533	.207
-7	.029	.044	.092	-.041	-.087	-.085	-.091	-.121	-.076
	.634	.471	.136	.509	.157	.167	.291	.174	.224
-8	.028	.106	.169**	-.066	.026	-.038	-.122	.058	-.073
	.654	.083	.006	.285	.675	.540	.157	.516	.240

(b) Correlations between minimum temperature lag and mosquito rates, Week 83

	Log_GV	Log_SS	Total_Log	GVPos_Log	SSPos_Log	Positive_Log	MIR_GV	MIR_SS	MIR
Evap	.006	-.097	-.093	-.077	.003	-.067	-.007	.113	.072
	.920	.111	.130	.209	.955	.275	.932	.185	.245
-1	-.039	-.052	-.100	-.039	.006	-.034	.029	.035	.029
	.527	.393	.103	.529	.924	.582	.722	.677	.638
-2	.018	-.089	-.079	-.047	.032	-.028	.049	.121	.095
	.775	.144	.196	.442	.598	.648	.547	.153	.124
-3	-.003	-.039	-.066	.004	.051	.025	.089	.093	.088
	.955	.522	.279	.950	.406	.678	.271	.274	.151
-4	-.060	-.115	-.181**	-.122*	-.032	-.125*	-.015	.051	.027
	.328	.061	.003	.045	.604	.041	.855	.551	.660
-5	-.065	-.094	-.170**	-.099	-.013	-.096	.026	.057	.045
	.290	.124	.005	.107	.828	.116	.745	.502	.471
-6	-.043	-.054	-.115	-.040	.013	-.031	.054	.052	.049
	.478	.379	.059	.512	.828	.611	.507	.542	.423
-7	-.040	-.039	-.091	-.030	.011	-.024	.020	.029	.022
	.515	.522	.137	.627	.857	.701	.806	.735	.717
-8	-.036	-.108	-.148*	-.104	-.012	-.100	.006	.067	.044
	.562	.078	.015	.090	.839	.102	.939	.434	.475

Table D4: a) Correlations between evaporation lag and mosquito rates, Week 31

	Log_GV	Log_SS	Total_Log	GVPos_Log	SSPos_Log	Positive_Log	MIR_GV	MIR_SS	MIR
Evap	-.069	-.110	-.212**	.012	-.094	-.046	-.100	-.108	-.085
	.262	.073	.000	.841	.126	.453	.247	.224	.172
-1	-.069	-.114	-.219**	-.041	-.114	-.102	-.165	-.134	-.135*
	.264	.062	.000	.502	.062	.097	.054	.131	.030
-2	-.004	-.080	-.113	-.121*	-.132*	-.177**	-.278**	-.163	-.212**
	.949	.194	.065	.048	.031	.004	.001	.065	.001
-3	.096	.000	.090	-.158**	-.134*	-.208**	-.266**	-.175*	-.208**
	.116	.999	.143	.010	.029	.001	.002	.048	.001
-4	-.076	-.121*	-.238**	.023	-.085	-.033	-.085	-.097	-.074
	.218	.048	.000	.714	.164	.593	.321	.275	.237
-5	.023	-.075	-.079	-.148*	-.159**	-.215**	-.298**	-.196*	-.233**
	.705	.222	.197	.015	.009	.000	.000	.026	.000
-6	-.071	-.111	-.223**	-.024	-.092	-.075	-.140	-.109	-.113
	.251	.070	.000	.690	.136	.225	.104	.221	.070
-7	-.011	-.091	-.142*	-.120*	-.138*	-.180**	-.244**	-.172	-.193**
	.859	.139	.020	.050	.024	.003	.004	.052	.002
-8	.027	-.070	-.066	-.153*	-.143*	-.209**	-.304**	-.180*	-.232**
	.659	.256	.283	.012	.020	.001	.000	.042	.000

(b) Correlations between evaporation lag and mosquito rates, Week 83

	Log_GV	Log_SS	Total_Log	GVPos_Log	SSPos_Log	Positive_Log	MIR_GV	MIR_SS	MIR
P-E	.052	.030	.080	.122*	.118	.160**	.155	.134	.131*
	.392	.624	.192	.046	.054	.009	.054	.115	.033
Water	.085	.026	.142*	.070	.033	.075	-.105	.065	.004
	.166	.666	.020	.256	.590	.224	.192	.448	.954
-1	-.049	-.080	-.090	-.116	-.123*	-.162**	-.201*	-.075	-.121*
	.428	.192	.143	.057	.043	.008	.012	.377	.049
-2	-.065	.006	-.072	-.038	-.066	-.062	-.058	-.087	-.073
	.290	.920	.242	.538	.279	.308	.475	.304	.239
-3	-.075	.019	-.050	-.104	.062	-.066	-.038	.125	.066
	.223	.762	.412	.090	.310	.278	.640	.142	.286
-4	.079	.010	.097	.072	-.044	.043	-.102	-.140	-.130*
	.198	.866	.114	.237	.477	.478	.207	.099	.035
-5	-.054	-.024	-.090	-.124*	-.036	-.129*	-.096	.018	-.010
	.377	.690	.141	.043	.556	.035	.234	.835	.865
-6	.066	.067	.152*	.048	.046	.063	-.101	.045	.001
	.280	.274	.012	.431	.455	.303	.212	.597	.992
-7	.148*	.048	.206**	.207**	.022	.196**	-.025	.001	-.007
	.015	.437	.001	.001	.723	.001	.761	.989	.910
-8	.036	.108	.148*	.104	.012	.100	-.006	-.067	-.044
	.562	.078	.015	.090	.839	.102	.939	.434	.475

Table D5: a) Correlations between water availability lag and mosquito rates, Week 31

	Log_GV	Log_SS	Total_Log	GVPos_Log	SSPos_Log	Positive_Log	MIR_GV	MIR_SS	MIR
P-E	-.101	-.091	-.221**	.129*	.189**	.217**	.291**	.299**	.253**
	.098	.138	.000	.034	.002	.000	.001	.001	.000
Water	.016	.028	.079	.028	.104	.085	.117	.152	.104
	.790	.650	.199	.648	.089	.166	.173	.087	.094
-1	.065	.032	.125*	.019	.014	.024	.053	.053	.044
	.293	.602	.041	.755	.822	.699	.539	.556	.479
-2	.094	-.084	.044	.048	.043	.065	.079	.071	.068
	.126	.174	.473	.430	.481	.289	.361	.425	.276
-3	-.041	-.061	-.116	.057	-.062	.009	-.061	-.081	-.054
	.501	.322	.059	.353	.316	.879	.478	.365	.386
-4	-.047	.089	.067	-.024	.077	.027	.078	.130	.069
	.446	.146	.274	.701	.208	.658	.365	.142	.270
-5	-.086	-.027	-.107	.083	.109	.133*	.193*	.123	.149*
	.159	.666	.080	.175	.075	.030	.024	.167	.016
-6	.015	-.102	-.105	-.103	-.098	-.142*	-.181*	-.127	-.143*
	.802	.095	.088	.093	.109	.020	.034	.152	.022
-7	-.044	.021	-.010	-.063	.029	-.034	-.031	.007	-.023
	.470	.735	.866	.302	.633	.583	.717	.938	.716
-8	.105	.081	.221**	-.082	.003	-.064	-.049	-.011	-.037
	.087	.186	.000	.184	.961	.295	.568	.899	.548

(b) Correlations between water availability lag and mosquito rates, Week 83

	Calls_Log	DTest_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds_Log	Bpos_log	PctBPos
Temp_C	-.054	-.147*	-.094	.008	.056	.323	-.117	.017	-.908
	.376	.016	.581	.902	.362	.479	.055	.782	.092
-1	-.160**	-.126*	-.337*	.046	-.010	-.508	-.061	-.129*	.[a]
	.009	.039	.044	.458	.871	.245	.317	.035	.000
-2	-.211**	-.223**	-.245	.071	.065	.243	-.123*	-.029	.[a]
	.001	.000	.150	.251	.289	.600	.045	.632	.000
-3	-.056	-.092	-.264	-.019	.073	.519	-.082	-.011	.[a]
	.364	.133	.120	.761	.235	.233	.180	.857	.000
-4	.054	-.090	-.133	-.070	.026	.344	-.113	.021	.[a]
	.382	.142	.440	.253	.677	.450	.064	.733	.000
-5	-.138*	-.200**	-.227	.033	.072	.266	-.129*	-.010	.[a]
	.024	.001	.183	.594	.239	.564	.036	.871	.000
-6	.018	-.089	-.269	-.059	-.013	-.057	-.102	-.024	.[a]
	.765	.146	.112	.336	.839	.903	.097	.693	.000
-7	-.183**	-.178**	-.309	.051	.039	-.060	-.100	-.067	.[a]
	.003	.003	.067	.406	.522	.897	.104	.274	.000
-8	.064	-.085	-.041	-.069	.006	.218	-.107	.055	.[a]
	.295	.166	.814	.262	.918	.639	.080	.374	.000

Table D6: (a) Correlations between mean temperature lag and bird rates, Week 31

	Calls_Log	DTest_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds_Log	Bpos_log	PctBPos
Temp_C	.071	.044	-.012	-.026	-.067	-.425	.023	-.022	.791
	.245	.473	.942	.676	.275	.342	.711	.722	.209
-1	.118	.148*	.074	-.063	-.056	-.013	.087	-.040	.936
	.054	.015	.662	.305	.363	.978	.157	.516	.064
-2	.216**	.131*	.299	-.071	-.015	.267	.051	.114	.[a]
	.000	.032	.076	.249	.812	.562	.404	.063	.000
-3	.123*	.117	-.020	-.018	-.064	-.439	.088	.061	.980*
	.044	.056	.906	.770	.299	.324	.150	.316	.020
-4	.003	-.083	-.146	.003	.036	.261	-.067	.044	.216
	.962	.173	.388	.958	.557	.571	.275	.477	.784
-5	-.054	-.147*	-.094	.008	.056	.323	-.117	.017	-.908
	.376	.016	.581	.902	.362	.479	.055	.782	.092
-6	-.114	-.038	-.009	.110	.065	-.001	.031	-.001	-.555
	.063	.535	.956	.072	.291	.999	.611	.987	.445
-7	.099	.075	.239	-.101	-.001	.508	.003	.086	-.035
	.105	.218	.154	.098	.986	.244	.964	.159	.965
-8	.633**	.642**	.103	-.011	-.013	-.480	.531**	.685**	1.000**
	.000	.000	.543	.863	.837	.275	.000	.000	.000

(b) Correlations between mean temperature lag and bird rates, Week 83

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds_Log	Bpos_log	PctBPos
Max_C	.071	.044	.009	-.012	-.026	-.067	-.425	.023	-.022	.791
	.245	.473	.883	.942	.676	.275	.342	.711	.722	.209
-1	.221**	.062	.047	.[a]	.018	.018	.995	.062	.050	.087
	.000	.313	.446	.	.774	.764	.065	.314	.418	.777
-2	.228**	.056	.038	.[a]	.002	.003	.993	.049	.033	.030
	.000	.357	.541	.	.971	.958	.073	.428	.587	.923
-3	.196**	.088	.032	.[a]	.035	.036	.983	.093	.047	.032
	.001	.150	.605	.	.572	.559	.118	.127	.445	.916
-4	.249**	.057	.072	.[a]	.009	.010	.998*	.053	.066	.093
	.000	.353	.242	.	.879	.869	.041	.387	.282	.763
-5	.204**	.086	.068	.[a]	-.001	.000	1.000**	.072	.057	-.181
	.001	.158	.264	.	.989	.994	.005	.239	.351	.553
-6	.239**	.070	.075	.[a]	.039	.040	.996	.081	.086	.254
	.000	.251	.219	.	.524	.516	.057	.187	.162	.402
-7	.169**	.046	.027	.[a]	.064	.064	-.998*	.074	.059	.568*
	.006	.455	.660	.	.299	.297	.038	.228	.338	.043
-8	.245**	.043	.067	.[a]	.025	.025	.999*	.050	.071	.299
	.000	.481	.274	.	.685	.679	.025	.413	.249	.322

Table D7: (a) Correlations between max temperature lag and bird rates, Week 31

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds_Log	Bpos_log	PctBPos
Max_C	-.114	-.038	-.033	-.009	.110	.065	-.001	.031	-.001	-.555
	.063	.535	.588	.956	.072	.291	.999	.611	.987	.445
-1	-.157*	-.066	-.052	-.016	.070	.070	.225	-.004	-.001	.[a]
	.010	.281	.397	.925	.251	.257	.628	.951	.990	.000
-2	-.201**	-.066	-.042	.029	.057	.083	.357	-.015	.015	.[a]
	.001	.281	.492	.867	.355	.176	.432	.807	.805	.000
-3	-.222**	-.088	-.092	-.073	.051	.087	.488	-.037	-.023	.[a]
	.000	.150	.133	.672	.405	.155	.266	.542	.710	.000
-4	-.189**	-.140*	-.115	-.042	.119	.052	-.362	-.027	-.062	.[a]
	.002	.022	.061	.808	.052	.395	.424	.660	.312	.000
-5	-.288**	-.182**	-.100	-.044	.103	.088	.425	-.072	-.029	.[a]
	.000	.003	.103	.799	.094	.151	.341	.238	.640	.000
-6	-.288**	-.182**	-.100	-.044	.103	.088	.425	-.072	-.029	.[a]
	.000	.003	.103	.799	.094	.151	.341	.238	.640	.000
-7	.093	.113	.073	.101	-.154*	-.006	.529	-.020	.056	.[a]
	.131	.065	.232	.559	.012	.923	.222	.751	.361	.000
-8	-.109	.004	-.054	-.085	.014	.071	.457	.008	-.002	.[a]
	.075	.949	.377	.624	.815	.251	.303	.891	.974	.000

(b) Correlations between max temperature lag and bird rates, Week 83

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds_Log	Bpos_log	PctBPos
Min_C	-.243**	.065	-.079	.[a]	.027	.027	.536	.070	-.051	-.365
	.000	.288	.200	.	.665	.657	.640	.257	.409	.220
-1	-.214**	.085	-.053	.[a]	.030	.031	.735	.088	-.027	-.390
	.000	.167	.386	.	.626	.615	.474	.152	.657	.188
-2	-.235**	.032	-.098	.[a]	.018	.019	.246	.037	-.072	-.146
	.000	.599	.108	.	.768	.758	.842	.545	.240	.633
-3	-.201**	.071	-.073	.[a]	-.010	-.009	.865	.054	-.066	-.389
	.001	.247	.235	.	.865	.883	.334	.381	.279	.189
-4	-.059	.141*	-.037	.[a]	.051	.052	.866	.147*	-.001	-.334
	.337	.021	.552	.	.409	.393	.333	.016	.984	.264
-5	-.215**	.084	-.067	.[a]	.028	.029	.779	.086	-.040	-.385
	.000	.172	.277	.	.653	.641	.431	.162	.516	.194
-6	-.170**	.109	-.053	.[a]	.043	.044	.797	.116	-.020	-.385
	.005	.074	.387	.	.487	.475	.413	.059	.746	.193
-7	-.226**	.076	-.063	.[a]	.027	.028	.595	.079	-.037	-.395
	.000	.217	.301	.	.658	.647	.595	.199	.542	.182
-8	-.220**	.063	-.067	.[a]	.038	.039	.271	.074	-.034	-.264
	.000	.306	.274	.	.535	.526	.825	.228	.574	.383

Table D8: (a) Correlations between minimum temperature lag and bird rates, Week 31

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds_Log	Bpos_log	PctBPos
Min_C	-.243**	.065	-.079	.[a]	.027	.027	.536	.070	-.051	-.365
	.000	.288	.200	.	.665	.657	.640	.257	.409	.220
-1	-.068	-.019	.080	.170	-.058	.033	.491	-.057	.084	.[a]
	.268	.756	.195	.321	.348	.590	.263	.354	.169	.000
-2	.151*	.103	.159**	.248	-.109	-.008	.541	.004	.124*	.[a]
	.014	.092	.009	.145	.074	.893	.210	.951	.042	.000
-3	.213**	.085	.131*	.125	-.166**	-.042	.725	-.044	.081	.[a]
	.000	.164	.033	.469	.007	.491	.065	.472	.187	.000
-4	.092	.019	.135*	.181	-.139*	.002	.731	-.081	.111	.[a]
	.136	.761	.027	.291	.024	.974	.062	.189	.070	.000
-5	.066	.061	.145*	.263	-.069	.013	.473	-.003	.125*	.[a]
	.281	.323	.018	.121	.258	.839	.284	.959	.041	.000
-6	-.087	-.063	.077	.185	.031	.063	.452	-.031	.100	.[a]
	.156	.301	.212	.279	.618	.305	.309	.617	.103	.000
-7	-.114	-.079	.074	.174	.026	.051	.448	-.047	.090	.[a]
	.064	.199	.230	.311	.676	.410	.313	.449	.142	.000
-8	-.182**	-.120	-.042	.042	.145*	.084	-.035	.003	.016	.[a]
	.003	.051	.496	.808	.018	.170	.941	.956	.792	.000

(b) Correlations between minimum temperature lag and bird rates, Week 83

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds_Log	Bpos_log	PctBPos
Evap	.203**	-.075	.032	.[a]	-.073	-.074	-.419	-.104	-.015	-.121
	.001	.218	.608	.	.233	.229	.725	.089	.806	.695
-1	.203**	-.005	.035	.[a]	.015	.015	.292	.004	.037	.546
	.001	.937	.573	.	.806	.806	.812	.944	.541	.054
-2	.227**	-.012	.045	.[a]	-.056	-.055	.972	-.041	.007	.000
	.000	.841	.461	.	.364	.366	.150	.501	.912	1.000
-3	.233**	.033	.078	.[a]	.019	.019	.837	.039	.077	.268
	.000	.585	.201	.	.758	.756	.368	.529	.211	.375
-4	.240**	-.057	.078	.[a]	-.023	-.024	-.653	-.061	.052	.359
	.000	.349	.204	.	.702	.691	.547	.318	.399	.229
-5	.219**	-.030	.084	.[a]	.005	.004	-.600	-.022	.073	.440
	.000	.628	.171	.	.933	.942	.590	.718	.234	.133
-6	.222**	.006	.064	.[a]	.026	.026	-.394	.020	.068	.499
	.000	.917	.299	.	.667	.671	.742	.744	.266	.083
-7	.205**	-.009	.060	.[a]	.024	.024	-.687	.006	.064	.632*
	.001	.886	.327	.	.696	.699	.518	.923	.297	.020
-8	.249**	-.036	.099	.[a]	-.031	-.032	.385	-.048	.065	.257
	.000	.558	.107	.	.610	.606	.748	.438	.288	.397

Table D9: a) Correlations between evaporation lag and bird rates, Week 31

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds_Log	Bpos_log	PctBPos
Evap	.216**	.131*	.151*	.299	-.071	-.015	.267	.051	.114	.[a]
	.000	.032	.014	.076	.249	.812	.562	.404	.063	.000
-1	.221**	.184**	.134*	.265	-.074	-.030	.303	.089	.091	.[a]
	.000	.003	.028	.118	.228	.626	.509	.146	.137	.000
-2	.235**	.203**	.118	.156	-.112	-.022	.502	.078	.083	.[a]
	.000	.001	.053	.363	.067	.724	.251	.201	.175	.000
-3	.110	.087	.052	.010	-.096	-.001	.429	.005	.042	.[a]
	.073	.154	.398	.954	.118	.990	.336	.938	.497	.000
-4	.236**	.156*	.146*	.313	-.074	-.027	.231	.068	.102	.[a]
	.000	.011	.017	.063	.228	.657	.619	.266	.095	.000
-5	.178**	.177**	.103	.168	-.087	-.012	.510	.077	.077	.[a]
	.003	.004	.092	.326	.158	.840	.242	.210	.212	.000
-6	.263**	.199**	.139*	.251	-.103	-.036	.347	.082	.091	.[a]
	.000	.001	.023	.140	.094	.554	.445	.180	.138	.000
-7	.219**	.215**	.111	.187	-.104	-.032	.526	.095	.071	.[a]
	.000	.000	.070	.275	.089	.602	.226	.122	.247	.000
-8	.199**	.186**	.099	.115	-.102	-.011	.512	.073	.074	.[a]
	.001	.002	.105	.504	.096	.862	.240	.234	.225	.000

(b) Correlations between evaporation lag and bird rates, Week 83

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds_Log	Bpos_log	PctBPos
P-E	-.085	.216**	.045	.[a]	.081	.083	.378	.227**	.085	-.273
	.167	.000	.460	.	.185	.177	.753	.000	.167	.367
Water	-.077	-.040	-.076	.[a]	-.098	-.095	.903	-.088	-.118	-.241
	.207	.510	.213	.	.111	.120	.283	.150	.054	.427
-1	.022	-.160**	-.076	.[a]	-.139*	-.139*	.985	-.211**	-.142*	-.248
	.722	.009	.213	.	.023	.023	.110	.000	.020	.415
-2	-.030	-.030	-.022	.[a]	-.013	-.016	-.921	-.033	-.027	-.225
	.626	.620	.724	.	.834	.800	.254	.594	.660	.459
-3	-.126*	-.064	.050	.[a]	.089	.090	.860	-.005	.092	.837**
	.039	.293	.419	.	.147	.142	.340	.938	.132	.000
-4	.104	-.072	-.031	.[a]	-.037	-.033	.751	-.081	-.045	-.083
	.091	.241	.610	.	.548	.589	.459	.187	.463	.787
-5	.188**	-.104	.004	.[a]	-.097	-.097	.726	-.141*	-.051	-.561*
	.002	.089	.944	.	.113	.113	.482	.021	.405	.046
-6	-.115	-.029	-.081	.[a]	-.080	-.079	.921	-.069	-.113	-.330
	.059	.637	.184	.	.189	.197	.255	.260	.065	.271
-7	-.006	.109	-.099	.[a]	-.012	-.011	.155	.085	-.090	-.492
	.922	.074	.104	.	.843	.863	.901	.164	.144	.088
-8	-.249**	.036	-.099	.[a]	.031	.032	-.385	.048	-.065	-.257
	.000	.558	.107	.	.610	.606	.748	.438	.288	.397

Table D10: a) Correlations between water availability lag and bird rates, Week 31

	Calls_Log	DTest_Log	DPos_Log	PctDPos	Live_Log	LPos_Log	PctLPos	Birds_Log	Bpos_log	PctBPos
P-E	.123*	.117	.100	-.020	-.018	-.064	-.439	.088	.061	.980*
	.044	.056	.103	.906	.770	.299	.324	.150	.316	.020
Water	.003	-.083	.030	-.146	.003	.036	.261	-.067	.044	.216
	.962	.173	.619	.388	.958	.557	.571	.275	.477	.784
-1	-.116	-.193**	.031	-.141	.059	.017	-.297	-.106	.035	.[a]
	.058	.002	.618	.412	.340	.787	.518	.085	.571	.000
-2	-.088	-.211**	.022	-.131	.021	.144*	.689	-.154*	.103	.[a]
	.152	.001	.721	.448	.729	.019	.087	.012	.092	.000
-3	.125*	.096	.109	.211	-.058	.003	.518	.028	.090	.[a]
	.042	.118	.076	.217	.346	.964	.234	.652	.142	.000
-4	-.085	.035	-.068	-.324	.021	-.006	-.430	.045	-.059	.[a]
	.167	.573	.267	.054	.732	.922	.335	.463	.337	.000
-5	-.036	-.022	-.100	-.214	.071	.018	-.043	.029	-.071	.[a]
	.557	.723	.102	.210	.251	.773	.928	.642	.248	.000
-6	.203**	.132*	.160**	.204	-.060	.036	.834*	.058	.151*	.[a]
	.001	.031	.009	.234	.325	.560	.020	.346	.013	.000
-7	.075	.050	.078	.096	-.066	-.042	.211	-.004	.038	.[a]
	.220	.419	.202	.578	.283	.490	.650	.943	.532	.000
-8	.004	-.029	.021	-.045	-.063	-.045	-.036	-.062	-.009	.[a]
	.953	.639	.729	.793	.308	.465	.938	.316	.878	.000

(b) Correlations between water availability lag and bird rates, Week 83

	Log_GV	Log_SS	Total_Log	Log_Pos_GV	Log_Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Evap	.576**	.384**	.622**	.626**	.283*	.628**	.495**	.110	.486**
	.000	.005	.000	.000	.042	.000	.000	.505	.000
PE	-.073	-.205	-.146	.140	-.179	.121	.159	-.140	.227
	.606	.144	.302	.323	.205	.394	.261	.395	.106
@0	-.331*	-.521**	-.442**	-.165	-.052	-.173	-.059	-.011	-.046
	.016	.000	.001	.241	.712	.219	.680	.946	.746
Temp_C	.693**	.300*	.672**	.651**	.328*	.665**	.490**	.249	.510**
	.000	.031	.000	.000	.018	.000	.000	.126	.000
Max_C	.659**	.306*	.645**	.609**	.328*	.625**	.450**	.257	.467**
	.000	.027	.000	.000	.018	.000	.001	.114	.000
Min_C	.713**	.273	.678**	.650**	.303*	.663**	.484**	.248	.513**
	.000	.051	.000	.000	.029	.000	.000	.128	.000

Table D11: a) Correlations for Area 22, 2006

	Log_GV	Log_SS	Total_Log	Log_Pos_GV	Log_Pos_SS	Positive_Log	MIR_GV	MIR_SS	MIR
Evap	.627**	.532**	.632**	-.013	.[a]	-.013	-.021	.[a]	-.021
	.000	.000	.000	.925	.	.925	.886	.	.886
PE	.091	.080	.091	-.052	.[a]	-.052	-.051	.[a]	-.051
	.520	.573	.522	.713	.	.713	.723	.	.723
@0	.047	.306*	.066	.157	.[a]	.157	.156	.[a]	.156
	.740	.028	.643	.267	.	.267	.275	.	.275
Temp_C	.590**	.498**	.597**	.117	.[a]	.117	.117	.[a]	.117
	.000	.000	.000	.408	.	.408	.413	.	.413
Max_C	.579**	.519**	.588**	.117	.[a]	.117	.118	.[a]	.118
	.000	.000	.000	.409	.	.409	.411	.	.411
Min_C	.558**	.480**	.564**	.115	.[a]	.115	.114	.[a]	.114
	.000	.000	.000	.417	.	.417	.427	.	.427

b) Correlations for Area 22, 2007

VITA

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