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The Effects of Temperature and Precipitation on *Culex quinquefasciatus* (Diptera: Culicidae) Abundance: A Case Study in the Greater Waco City, Texas

David S Kang, Romin Tomas and Cheolho Sim*

Abstract

The southern house mosquito, *Culex quinquefasciatus* Say is a major mosquito vector of West Nile virus in the southern United States. The regional temperature and precipitation are key factors to the population dynamics of the mosquito *Culex quinquefasciatus*. The understanding of the relations between climatic conditions and Culex mosquito dynamics has an important implication for the management of WNV outbreaks in the southern United States and elsewhere. We analyzed the monthly averages of minimum and maximum temperatures, precipitation amount, and mosquito samplings in two years 2011-2012. Warm temperature along with at least above precipitation during the study period appears to have facilitated the mosquito abundance. An important finding is the potential influence of early warmer spring with relatively high rainfalls increased the WNV vector population in 2012. In addition, continuous precipitation in the summer period maintains the vector population, which appears to be a causative factor of the WNV outbreak in the region. Awareness of such two climate factors at beginning of the spring and summer may help to predict the WNV disease risk.

Keywords

Culex quinquefasciatus; West Nile virus

Introduction

West Nile virus (WNV) was first identified in the United States in the New York City in the fall of 1999, and since then has been a public health threat in United States. Again in 2012, WNV emerged as nationwide outbreak, which caused the total 5387 WNV cases and 243 deaths in 49 states, compared with the total 712 WNV cases and 43 deaths in 2011 (http://www.cdc.gov /ncidod/dvbid/westnile/). Among the inflicted 49 states, the state of Texas has been the worst with 34 percent of the nation's WNV cases, total 1,834 cases and 86 deaths. In particular, The Dallas/ Fort Worth region was the focal point of the nation's worst outbreak of WNV in 2012 (http://www.dshs.state.tx.us/idcu/arboviral/westnile/).

In general, WNV is maintained in nature through a bird-mosquito cycle usually involving bird-biting *Culex* species mosquitoes and a range of bird reservoirs. In addition, humans and other animals are incidental and dead-end hosts for the viruses [1,2]. *Culex pipiens* complex species are the main mosquito vectors of WNV disease in North America, and are distributed worldwide as well. The taxonomic status of each form belongs to this complex is still subject to controversy, yet the complex can be approximately subdivide into three groups; *Culex pipines* form *pipiens*, *Culex p.* form *molestus*, and *Culex quinquefasciatus*. Since its introduction to North America, the different *Culex* species can contribute WNV transmission cycle, which varies regionally. In cases of *C. pipiens,* it has been reported that this mosquito is an important vector of WNV in the Midwest and parts of the Northeastern U.S [1,3]. However, *C. quinquefasciatus* doesn't have a diapause characteristic like *C. pipiens* has, resulting in limiting the distribution to tropical or subtropical regions. It has been also reported that the mosquito *C, quinquefasciatus* is as an important vector of WNV in many southern states [4,5].

In our study, individual field samples of *Culex quinquefasciatus* were trapped at six collection sites in the greater Waco City area over the last year (April 2011-December 2012). Alfalfa infused CDC gravid traps (John W. Hock model 1712 CDC) were placed at the sites during the late afternoon and retrieved the following morning, and repeat this event at biweekly intervals. Adult mosquitoes were preserved in 95% ethanol and kept chilled until identification on a stereomicroscope [7,8]. The Waco Metropolitan Statistical Area consists of McLennan County, which had a 2010 population of 234,906 (US Census Bureau). It is situated along the Brazos River and I-35, and lies approximately 90 miles south of Dallas/Fort Worth. The monthly average precipitation and maximum and minimum average temperature were recorded from a station at the Waco Regional Airport.

An essential component for developing control strategy of vector-borne diseases is a proper prediction of spatial and temporal abundance of the mosquito vectors. Temperature and precipitation affect the population dynamics of mosquitoes including *C. quinquefasciatus*. This is because mosquitoes are poikilotherms and therefore highly dependent on ambient conditions to reach operational body temperatures and larvae develop in aquatic habitats created directly or indirectly by precipitation as well. Several studies reported that warm temperature increase mosquitoes' rates of development, reproduction and host seeking behavior [8-10]. It appears that warm conditions are crucial causes of the WNV outbreaks. This has been proven experimentally that temperature directly related to the incubation period and WNV transmission[11].

The year 2011 was the hottest summer on record for Waco. The average minimum temperature was the hottest since 1940. The period of June through September registered an average maximum temperature above 100°F for 87 days. Texas was also in a drought in 2011, and it was exceptionally dry year carried the period between July and August with no measurable precipitation. Precipitation deficits continue to mount across Waco after the 5th driest summer on record. Continuously, the year of 2012 started with a warmer spring with temperatures above normal in Waco. The above 50°F of minimum temperature begin from April, compared with May in 2011(Figure 1). In addition, it was wetter than 2011 with a more than 8 inches of average precipitation in March and higher precipitation

***Corresponding author:** Cheolho Sim, Department of Biology, Baylor University, Waco, TX 76798, USA, Tel+1-254-710-2087; E-mail: cheolho_sim@baylor.edu

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during the summer 2012. Interestingly, the precipitation patterns were noticeably different between 2011 and 2012. The drought period was during July and August in 2011, but the October-November 2012 period was driest with below average precipitation (Figure 1).

The warming tendency appears to be linked to the increased population size of the WNV vector *C. quinquefasciatus* during the spring 2012 in Waco, compared to no mosquitoes captured in the spring 2011 (Figure 2). It is worth noting that the minimum temperature is the most important climatic factor that maintains the mosquito population. During winter and early spring (November-March), the average minimum temperature is below 40°F and no mosquitoes were captured the period of December-January. This pattern was also found in other studies, in which they suggest that developmental threshold temperature estimated approximately 50°F (equal to 10 °C), and if the mosquito kept at 5°C, females only survive for 7 weeks with 15% sugar solution [12,13]. However, how the mosquito *C. quinquefasciatus* overwinter in the region including central and north Texas is still elusive.

The effect of precipitation is also a limiting factor for the mosquito population size. The amount of spring precipitation determines the availability of surface water for early season mosquito reproduction, whereas accumulated precipitation appears to be a strong influence on the peak of the mosquito population in the spring 2012 (Figure 2). These patterns alter the abundance of *C. quinquefasciatus* from a single peak (September –November) in 2011 to a bimodal pattern with spring (April and May) and summer peaks (July) in the Waco City in 2012. An increase in rainfalls in the spring of 2012 may expand aquatic larval habitats, where birds may take water, and thus increase the chance to be bitten by female mosquitoes, leading to amplify WNV transmission in the bird reservoir. Later, the peaks of the mosquitoes in the summer may be served as a bridge vector to transmit WNV to humans. The summer peak of the mosquito in 2012 was possible by higher rainfall compared to the no measurable rain during summer in 2011. It is worth noting that the summer peak of the WNV vector is coincided with the starting month (July 2012) of WNV outbreaks in Dallas/Fort worth cities.

Another finding in the current observation, central and north Texas including Waco and Dallas/Fort Worth cities is recorded that Southwestern limit of another WNV vector *Culex restuans* distribution [7]. However, the mosquito *C. restuans* was not captured in our survey in the greater Waco City. This mosquito has been reported as a competent vector of WNV in Midwest and the parts of Northeast of U.S [14,15]. In the Midwest, *C. restuans* is most abundant during the spring and early summer, whereas *C. pipiens* reaches its peak abundance in late summer to early fall [16,17]. Thus, the temporal pattern of abundance indicates bimodal peaks and crossover in the two *Culex* species. If this species doesn't exist around Dallas/Fort Worth, it may imply different dynamics of WNV disease transmission in the region.

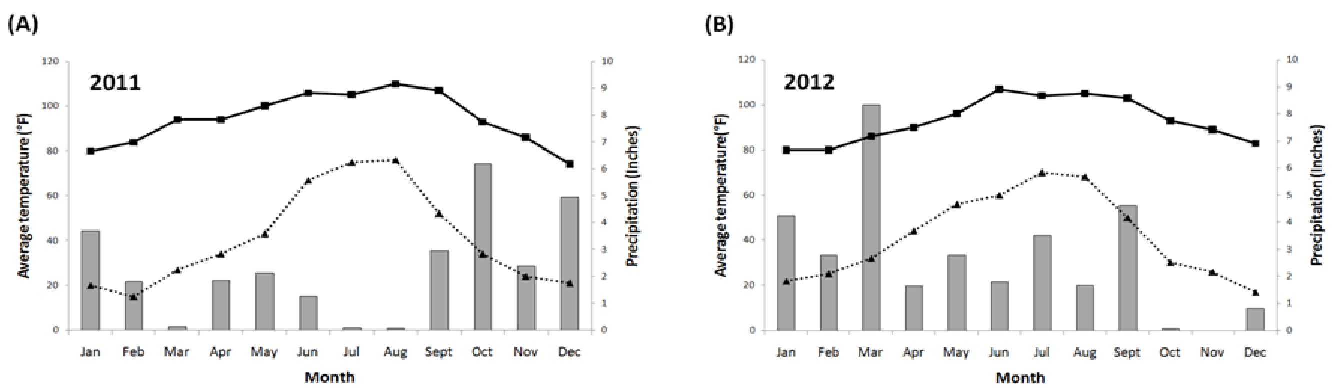

Figure 1: Monthly averages of maximum (solid line) and minimum temperature (dotted line) and precipitation (bars) during 2011 (A) and 2012 (B). Little precipitation fell during the months March, July and August in 2011 and October and November in 2012.

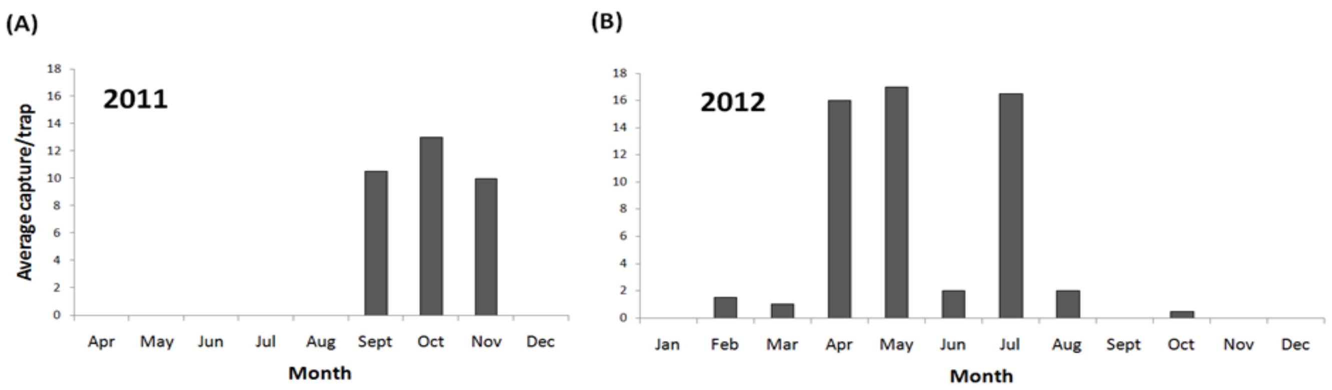

Figure 2: Monthly average numbers of mosquitoes collected over all sites in the greater Waco city. The summer (July) peak of the WNV vector in 2012 is coincided with the starting month of WNV outbreak in the Waco and Dallas/Fort worth cities.

Based on our findings, we hypothesize that two indicators, rainy and earlier spring and summer with continuous rainfalls than one large rain event, may allow to the aquatic habitats remain wet for the length of the mosquito's aquatic life cycle, leading to WNV outbreak. Obviously, the effects of other factors including food quality, inter and intra vector species competition, and an overwintering strategy, are needed to be included in population dynamic model to predict WNV vector abundance.

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Author Affiliations

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Department of Biology, Baylor University, Waco, TX 76798, USA