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Relation between dengue and climate trends in the Northwest of Mexico

Díaz-Castro, S., Moreno-Legorreta, M., Ortega-Rubio, A. and Serrano-Pinto, V.*
Centro de Investigaciones Biológicas del Noroeste, La Paz, B.C.S. Mexico
*Corresponding author e-mail: vserrano04@cibnor.mx
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Abstract. Dengue is native to tropical areas. It has expanded into temperate and arid zones in Mexico. Due to climate change, it is urgent to study the behavior of this disease in northwestern Mexico. Incidence of dengue fever and monthly maximum and minimum temperature and rainfall were obtained for 1990–2013 for the State of Baja California Sur. The relation between monthly and seasonal climate data with dengue records was analyzed by Pearson's correlation. The analysis shows that the minimum temperature has increased and the climate factor significantly correlates with dengue. Temperature variations have decreased. In this state, incidence of dengue cases directly correlates with minimum monthly temperature. It is expected that, as minimum temperatures increase to the end of this century, it will likely lead to increasing incidence of dengue. Preventive actions are recommended.

INTRODUCTION

A major implication of climate change is the health of human populations (Patz *et al.*, 2005). To understand, prevent, and find potential solutions to health effects of climate change on a specific disease, a deeper understanding on the relationship among factors between climate and diseases is necessary (Epstein, 2005). It is also necessary to understand the changes that is occuring in each region (Fuller *et al.*, 2009; Hii *et al.*, 2009; Lambrechts *et al.*, 2010). Many studies relate climate to disease, especially those diseases transmitted by mosquitoes (Rogers & Randolph, 2000; Small *et al.*, 2003, EBI *et al.*, 2005).

One vector-borne infectious disease most widely distributed around the world is dengue, mainly in tropical regions, reaching numbers exceeding 400 million cases a year (Bhatt *et al.*, 2013). Since the 1970s, dengue is present throughout Latin America including Mexico, where large outbreaks have occurred in recent years (Guzmán *et al.*, 2006).

The dengue virus (DENV) is transmitted by the female mosquitoes, mainly *Aedes aegypti* (Linnaeus, 1762) and *Ae. albopictus* (Skuse, 1894) (Fernández, 2009). Four serotypes of the virus cause dengue fever, dengue hemorrhagic fever, and dengue shock syndrome (Chiparelli y Schelotto, 2002). Both mosquito species are vectors of dengue fever and yellow fever (Kettle, 1984; Harwood y James 1993). *Ae. aegypti* is also the vector of chikungunya fever (Yanola *et al.*, 2011) and the Zika virus (Hayes, 2009).

Weather has a direct impact on mosquito populations (Gubler *et al.*, 2001), several studies have shown the potential associations that variables in climate plays a significant role with this disease (Thai & Anders, 2011). Temperature impacts vector development ,behavior, particularly fertility and mortality rates (Christophers, 1960; Rueda *et al.*, 1990; Tun-Lin *et al.*, 2000). Temperature also affects DENV replication rate (Watts *et al.*, 1987).

Rainfall creates additional habitats for mosquito larval and pupal development (Morin *et al.*, 2013), especially when temperature is high. Other environmental elements – soil and cultivation, economic quality of residential areas, forest cover, and vegetation indexes directly support or restrict the quality and availability of mosquito habitats (Van Benthem *et al.*, 2005; Troyo *et al.*, 2009). Human behavior enhances or restrains mosquito populations in specific environments (Chang *et al.*, 1997; Vanwambeke *et al.*, 2007).

It is widely documented that changes in temperature and rainfall influence the incidence of dengue (Gluber, 1997; Morin *et al.*, 2013). Temperature between 20–30ºC benefit populations of *Ae. aegypti* (Tun-Lin *et al.*, 2000). What is not so well documented is the influence of daily temperature fluctuations on vector behavior (Carrington *et al.*, 2013a). Under natural conditions variations between the minimum at night and the maximum during the day, daily temperature range (DTR) also modifies the behavior of mosquitoes (Meyer *et al.*, 1990; Lambrechts *et al.*, 2010; Carrington *et al.*, 2013b).

Rainfall is directly related to mosquito distribution and abundance due to increase in numbers of pools and puddles of water where females lay their eggs (Gómez y Rodríguez, 1994).

Correlations of dengue incidence with climate factors is not unifactorial or linear because human activities are involved; therefore, interaction among weather variables and dengue are usually correlated using multi-factorial models (Gluber, 1997; Morin *et al.*, 2013). Dengue information was given in Mexico, where 549 deaths from 1980 to 2009 caused by DENV were registered (Gaxiola *et al.*, 2012). Although death rates have decreased since then, the incidence has increased (SINAVE, 2014). While dengue fever arose as a tropical disease (Chang *et al.*, 1997; Ebi *et al.*, 2005; Hii *et al.*, 2009), it is no longer exclusive to the tropics, now expanded into arid and temperate regions. The State of Baja California Sur (BCS) is dominated by arid climate with summer temperatures reaching above 40ºC (CNA, 2015), and the population has been impacted by dengue fever for at least three decades. Incidence for the past 30 years has been published (Moreno-Legorreta *et al.*, 2015) total number of cases, general population, gender, age groups, serotypes, mortality, and incidence data were analyzed, with a 650% increase in reported cases in 2012–2014. With this increase, it is necessary to understand the ecology of the disease.

Our objective was to analyze trends in weather and incidence of dengue fever and to forecast trends to provide actions to reduce outbreaks in the state.

MATERIAL AND METHODS

Medical data on dengue fever incidence

This information was obtained from the online database of the annual morbidity reports of the National Epidemiological Surveillance System (Sistema Nacional de Vigilancia Epidemiológica), which is an information system of the General Director of Epidemiology (Dirección General de Epidemiología; DGEPI) of the Secretary of Health (Secretaría de Salud), covering 1990 through 2013 (SINAVE, 2014).

Climate data

Total monthly precipitation data, as well as maximum and minimum temperatures from 17 meteorological stations representatives from Baja California Sur state were obtained from the Mexican National Meteorological Service in La Paz, BCS (CNA, 2015).

Statistical analysis

Temperature and rainfall data averaged were obtained to get the monthly series from 1990 to 2013. In order to search if dengue affect more in a specific part of a year, the data were added by seasons: Winter records included November and December from previous year, and January and February. Dry season from March to May. Summer from June through October. Pearson's correlation analysis was performed, identifying series with significant trends ($P < 0.05$.) The monthly temperature spread in the series was analyzed in relation to reported cases.

RESULTS

Figure 1 shows the geographic area of study. Figure 2 shows annual dengue incidence for BCS; 1991, 1997, 2003, 2006, 2010, 2012, and 2013 had outbreaks.

Average rainfall data from 1990 through 2013 show that summers with the highest rainfall correlates with the highest temperatures, both from July through October, with rainfall peaks in August and September. Rainfall for each season is shown in Figure 3.

The secondary axis of the ordinate plots of rainfall for the dry season reveals its variability. Summer variations are not similar to winter variations because rainfall derives from different climatic processes. High summer rainfall occurred in 1997, 1998, 2003, 2007, and 2012; high winter rainfall occurred in 1995, 2006, 2010, and 2013. In 1992, the dry season had a very high value.

Figure 4 shows annual maximum, mean, and minimum temperatures for 1990 through 2013. No trend occurred in maximum temperatures, but starting in 2006, a significant increase in minimum temperatures is evident, which also is reflected in a change in annual mean temperature.

Table 1 summarizes results from correlations between climate data and dengue incidence. No significant correlations were found for rainfall data in different seasons and dengue incidence. However, significant correlations between disease incidence and minimum monthly temperature and monthly variations were found. In most months, the minimum temperature was correlated with the number of dengue cases. For monthly temperature spread, a negative correlation was observed, suggesting that a narrow spread influences the incidence of dengue.

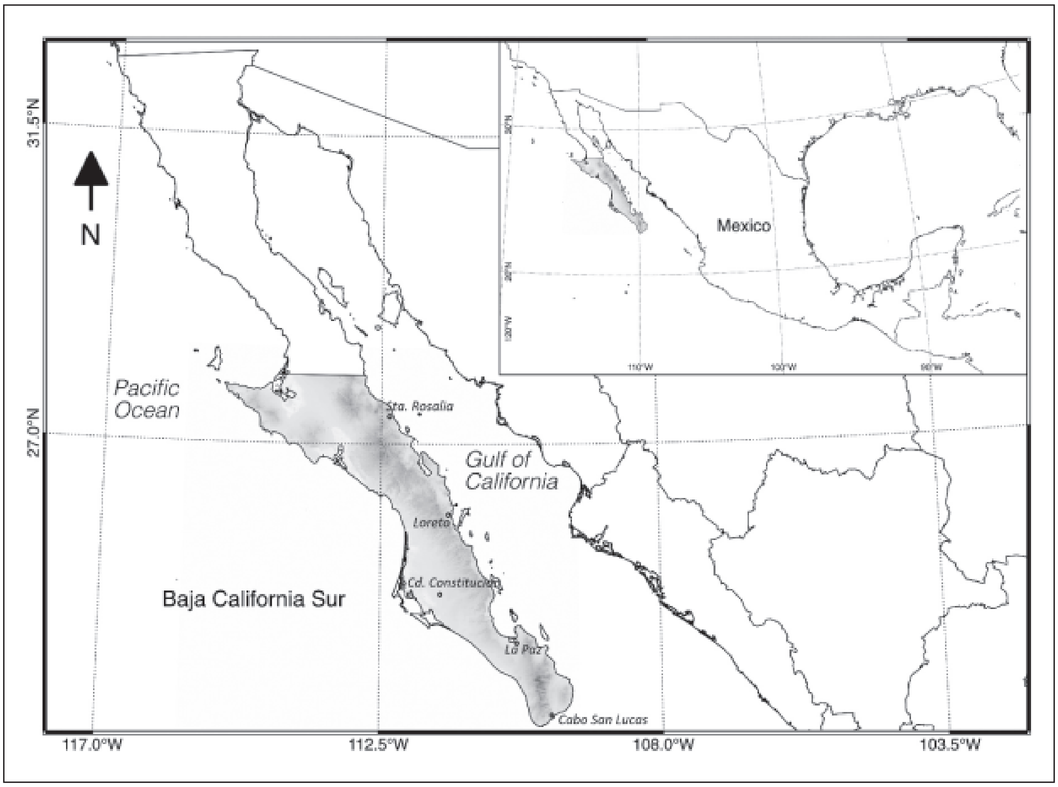

Figure 1. Geographic study area.

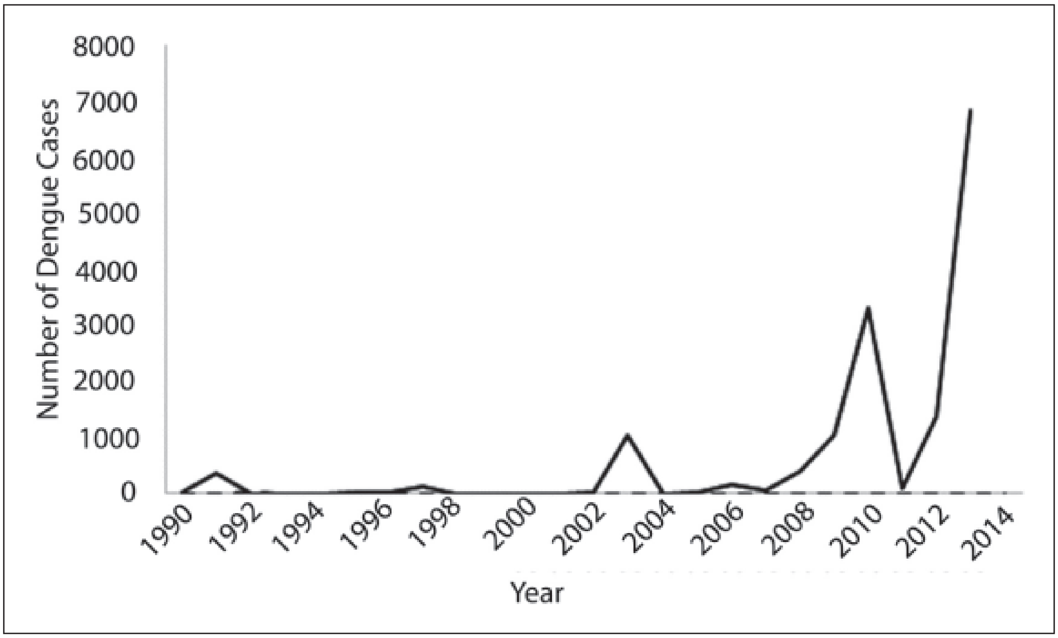

Figure 2. Incidence variability in dengue cases reported in BCS, Mexico, from 1990 to 2013.

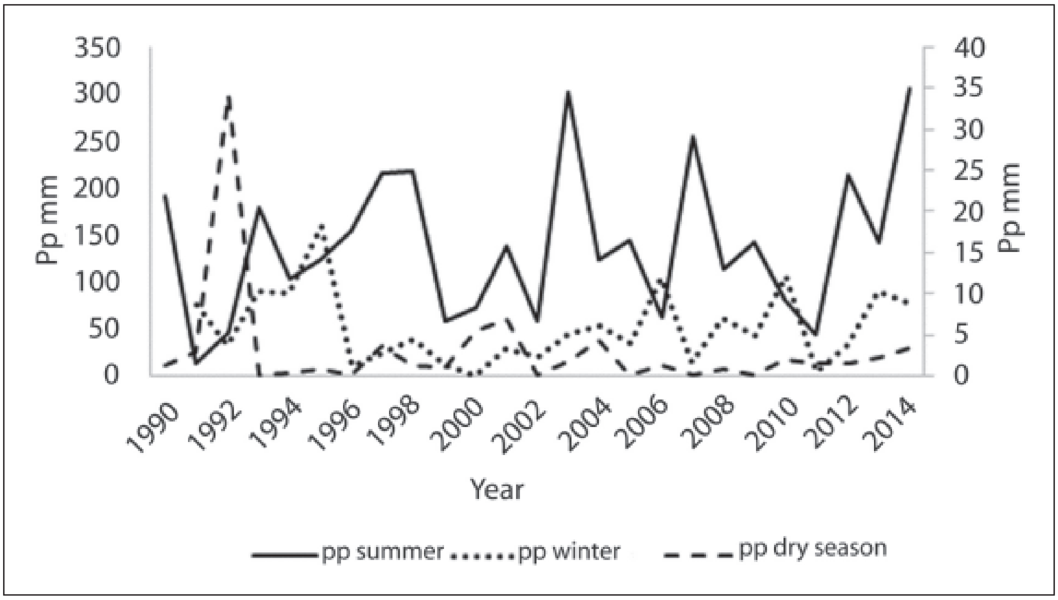

Figure 3. Seasonal rainfall (pp) reported for BCS, Mexico, from 1990 to 2013.

DISCUSSION

Incidence of dengue in BCS state is directly correlated with monthly minimum and mean temperature, and inversely correlated with temperature spread. Correlation with minimum temperature is similar to other studies (Abdalmagid & Alhusein, 2008; Carrington *et al.*, 2013 a; Carrington *et al.*, 2013 b).

According to Chen and Hsieh (2012), the oviposition rate is given in the range of 15°C

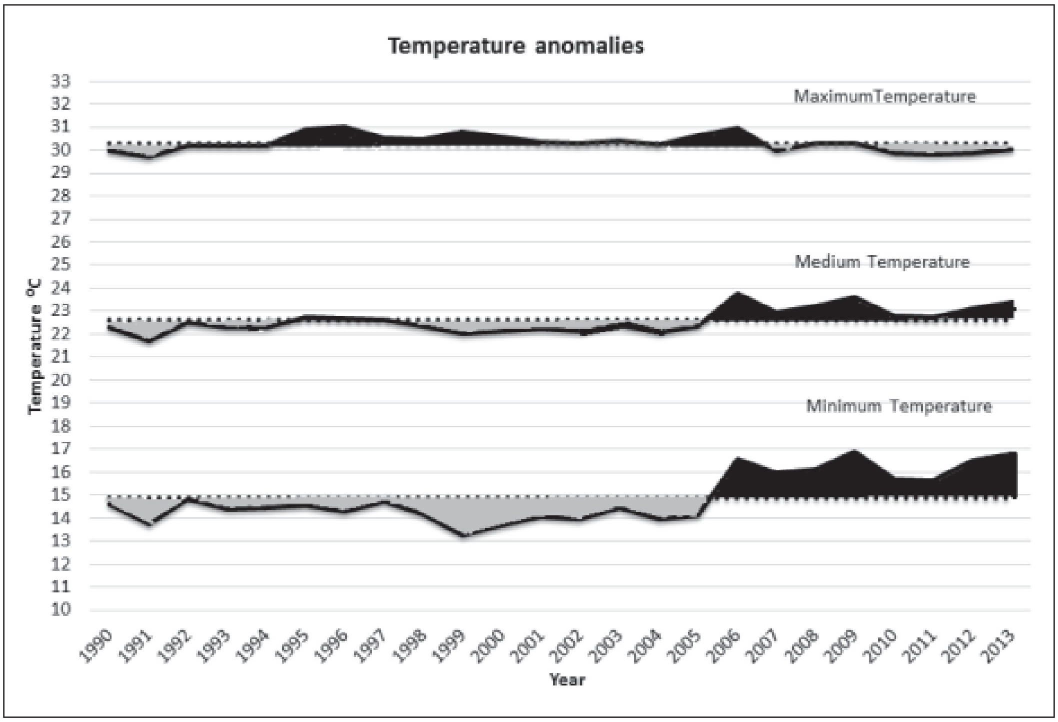

Figure 4. Annual temperature variations in BCS, Mexico, from 1990 to 2013. Years warmer than the period average are shaded in black, and years colder are shaded in grey.

Table 1. Correlations of climate factors with dengue incidence in BCS, Mexico, from 1990 to 2013. Numbers with * are significant (p<0.05). MTS (Monthly Temperature Spread)

Months	Precipitation	Min T	Mean T	Max T	MTS
Jan	-0.099856	0.46422*	0.191311	-0.141488	-0.398050
Feb	0.029958	0.42412*	0.109321	-0.253160	-0.58721*
Mar	-0.087725	0.56791*	0.46650*	0.170132	-0.42552*
Apr	-0.147669	0.48301*	0.244778	-0.272225	-0.51079*
May	0.44710*	0.41199*	0.284326	-0.096840	-0.45842*
Jun	0.44938*	0.41584*	0.233192	-0.205737	-0.53645*
Jul	-0.066844	0.390721	0.166192	-0.311728	-0.53756*
Ags	0.071657	0.51795*	0.402197	-0.000669	-0.47914*
Sep	0.043024	0.41859*	0.226555	-0.241859	-0.51573*
Oct	0.41527*	0.351732	0.178351	-0.204165	-0.42957*
Nov	-0.074816	0.41211*	0.264880	-0.087521	-0.45977*
Dec	-0.077789	0.44351*	0.47214*	0.103428	-0.483363
Annual	0.097456	0.52416*	0.43336*	-0.320809	

to 30ºC. In the state from 2006, the minimum temperatures ranged between 16º and 17ºC. Some authors mentioned that higher densities occur at values above 17.5ºC (Scott *et al.*, 1993; Barrera *et al.*, 2011). Azil *et al.* (2010) suggest that the minimum temperature and average temperature is the most important factor vector abundance is associated in the short and long term.

According to the Intergovernmental Panel on Climate Change (IPCC, 2013) forecasts for climate change indicate that cold days and nights are becoming less common. This trend is expected to continue through this century, suggesting that dengue in the state will increase. Since no trend towards an increase in high temperatures was observed, average monthly means of temperature spread is reduced, which leads to an increase in dengue cases (Kah *et al.*, 2009).

No significant correlation was found for rainfall data, monthly or seasonally, with dengue cases (Chen & Hsieh, 2012) also found that rainfall is not as relevant for reproduction of *Ae. aegypti*. Contrary to this, Arcari *et al.* (2007) indicate that rainfall is an agent of major climate change affecting the pattern of temporal and geographical distribution of the incidence of dengue cases, while the temperature seems to play a critical role in the intensity of the outbreak.

As dengue cases in the state continue to increase, all health authorities search for measures to control the rise of this serious disease.

Our assessment clarifies our understanding of climate trends and its impact on the incidence of dengue. Factors affecting dengue in arid environments include inadequate urban sewage management, fumigation campaigns in specific local environments implemented to avoid insecticide resistant mosquitoes, and increasing public awareness, including maintaining clean and dry patios and removing domestic trash from property. Without active programs, this region will see a rise in the incidence of dengue.

According to the results, even in BCS, the most arid and isolated state of the Mexican republic (Fig. 1), cases of dengue is directly correlated to a rise in the minimum monthly temperature and inversely correlated with temperature spread; hence, as temperature rises, so will the incidence of dengue. It is predicted that temperature in this region will rise, and because the same vector also spreads chikungunya and Zika virus, preventive actions and more research are imperative.

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