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Original Research Article

Relationship between epidemiologic surveillance with geo-climatic variables during Zika outbreak in Guerrero State, Mexico 2016

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ABSTRACT

Background: Zika like dengue and chikungunya represent public health problems. Cases of ZIKV infection are emerging in the Americas, from Argentina spread until Brazil and Colombia, later entry to Mexico and managed to establish itself in most of the states.
Methods: The cases (2016-2017) of epidemiological surveillance of the first outbreak of Zika in Guerrero were used. The incidence rates (IR) for each municipality were estimated (cases/100 000 inhabitants) to develop the first maps at the municipal and state level; which aimed to explore the relationship between Zika cases and geo-climatic variables.
Results: At January 3, 2017 in Guerrero State [epidemiological week (SE) 52 of the year 2016] were reported 861 confirmed ZIKV cases (10.06% of total registered cases at federal level). Guerrero State it was placed within the six states with the largest number of cases: Veracruz (1967), Yucatan (1284), Nuevo Leon (844), Chiapas (804) and Oaxaca (507); concentrated 73.26% (6 267/8 554) of the country's cases. In this study we identified the geo-environmental factors associated with ZIKV occurrence in each municipality of the Guerrero State: very high rain (1201-1460 mm), low elevation (2-398 masl) and high population density (≥62071 inhabitants/km^2).
Conclusions: This study represents the first approach to Zika outbreak in Guerrero State. Although tests of spatial nature are not presented; the maps presented show how the characteristics by region have high influence and that the most affected areas were the coastal areas: Acapulco, Small Coast and Big Coast.

Keywords: Zika, Infectious diseases, Epidemiology, Rainfall, México

INTRODUCTION

The Zika virus infection cases (ZIKV) have affected different countries of the American Continent.[1] During to 2015 to 2017 period, 28 States of Mexico with 11917 autochthonous cases were affected, which 7001 were pregnant women; the cases began in the Nuevo Leon State in October 2015; later in December, another 18 autochthonous cases were presented, including outbreaks in Chiapas, Jalisco and Oaxaca.[2]

Historically in the Guerrero State, a large number of Dengue cases occur due to characteristics necessary for vector proliferation: *Aedes aegypti;* for this reason, the affectation by ZIKV behaved in the same sense; from 2015 to 2017 there were 885 autochthonous cases of which 481 were in pregnant women; with respect to 2016, the first Zika cases were presented in January, later in May there were 50 cases, in July the highest number of cases occurred (434); which coincides with the rainy season and finally in December 861 cases were accumulated.[2] For 2016 at Federal level, 799 cases of

ZIKV were confirmed for Guerrero State and, at the State level, 800 cases were reported, which 706 were autochthonous and 94 were foreign. Only the autochthonous cases were considered for the analysis.[2]

The National Epidemiological Surveillance System (SINAVE) of Mexico, it is of vital importance for registration of ZIKV outbreaks, however, it only represents an approximation of real impact of disease, but it can be fed by non-traditional surveillance such as printed, electronic and personal communications notes from health authorities in social networks like Facebook© and Twitter©.[3-5] The outbreaks presence, indicates active transmission of disease and depends on social, economic and demographic factors; however, environmental variables (temperature, elevation and rainfall) have a high influence on *Ae. aegypti* biology and, with the ability to transmit viral diseases.[6-10] The aim of this study was to estimate the incidence rates (IR) (cases/100 000 inhabitants) of first Zika outbreak in Guerrero State to develop the first maps at municipal and State level related to temperature, rainfall, elevation and population density.

METHODS

The study area

The Guerrero State has a territorial extension of 63 600 km^2 divided politically into 81 municipalities grouped into seven regions (Center, Mountain, North, Hot Land, Big Coast, Small Coast and Acapulco) where 3 533 251 inhabitants live; the municipalities with the highest population density are: Acapulco, Iguala, Ometepec, Zihuatanejo and Chilpancingo. The 82% of the State has subhumid warm climate, 9% is dry and semi-dry, 5% is temperate subhumid, 3% is warm humid and 1% is humid temperate. The average annual temperature is 25°C. The average minimum temperature is 18°C and the maximum temperature is 32°C. The rains occur in summer, in the months of June to September, the average rainfall of the State is 1200 mm per year and has an average and maximum altitude of 1161; 3550 masl respectively.[11]

Study design and data sources

An ecological study was designed that includes information on the Guerrero State, the 81 municipalities that make up the State were included and were defined as unit of analysis. The cartography used was obtained from INEGI (National Institute of Geography): Population and Housing Count 2015 and National Geostatistical Framework 2017. The geospatial database was designed with the software SPSS v. 23 where the cases of ZIKV obtained from the SINAVE of the Secretary of Health of the Guerrero State (SES-Gro) were recorded and the IR at the municipal level were calculated; subsequently the data was manipulated in Arc-Map 10.3, they were complemented with the environmental variables: rain, temperature and elevation obtained from Global Climate Monitor, National Water Commission (CNA) and the variable population density was obtained from INEGI. The spatial information databases were linked to the shape files (.shp) to obtain the Zika risk maps in Guerrero at the municipal level and establish their relationship with the geo-environmental variables.

Different sources of information were used to create the geocoded data base by municipality; the data was geo-processed from original sources of digital cartography of Guerrero State. The dependent variable was the presence of ZIKV cases by municipality from January 3, 2016 to January 3, 2017. Four geo-environmental factors were included in the analysis as independent variables: elevation (geographic); temperature, rainfall (environmental) and level of urbanization (population density). These layers and environmental data in raster format were obtained from open access data sources, geo-processed and integrated to each municipality in the database as variables. A background layer of the municipal distribution of Guerrero State was used to make the maps.

Variables and data analysis

The variables included in this article include: (1) number of ZIKV cases reported in Guerrero at the municipal level by SES-Gro for 2016, (2) geo-environmental variables: average monthly temperature (°C), rainfall (millimeters), elevation (meters above sea level) and population density; the data were analyzed using the Statistical Package for Social Sciences (SPSS) 23.0.

ZIKV cases: The cases on epidemiological surveillance of ZIKA were requested to the SES-Gro; which were geo-coded by municipality and added to the database in SPSS.

Zika incidence rate (ZIKV IR): Zika data are used to calculate incidence rates at municipal level (cases/100 000 inhabitants).

Municipalities positive to ZIKV (ZP): Municipalities with one or more Zika cases during the study period were considered as "Zika positive municipalities" (ZP).

Temperature: This variable was measured in degrees Celsius (°C), the annual average temperature of Global Climate Monitor database was obtained. The data was geo-processed in Arc Map 10.3 for each municipality.

Rain: The annual average precipitation data (mm) were obtained from Global Climate Monitor database and geo-processed in Arc Map 10.3 for each municipality.

Elevation: Corresponds to altitude data at the municipal level and were obtained from INEGI using the digital elevation model (DEM) of the United Mexican States and are measured in meters above sea level (masl).

Population density (PD): The relation between the territory surface of each municipality and the number of people who inhabit it was established and is expressed in inhabitants/km^2.

Coastal municipality: Under the criterion of the border of the 81 municipalities of Guerrero State with the Pacific Ocean, they were classified as coastal and not coastal.

Region: The main political division of Guerrero State includes seven regions (Center, Mountain, North, Hot Land, Big Coast, Small Coast and Acapulco).

All the digital cartographic variables and attributes were assembled using different sources; the information was geo-processed and incorporated into each municipality.

Statistical analysis and geo-environmental factors related to ZIKV presence

The data was analyzed with the SPSS software (v 23.0). The IR of ZIKV cases was considered as a dependent variable (quantitative) for each of the 81 municipalities. The geo-environmental and demographic factors (described above) were included in the analysis as independent variables. As part of the descriptive analysis, incidence rates were calculated at the municipal and regional levels; for each of the variables, a preliminary analysis was implemented that included normality tests (Kolmogorov-Smirnov) using a 0.05 significance level; subsequently, due to the absence of normality, the Spearman Rho correlation coefficient (r value) was used to measure the correlation level of each independent variable on the dependent variable: ZIKV IR.

To analyze and describe the independence between coastal and non-coastal municipalities, the Mann-Whitney U test was used to measure the difference of IT ZIKV for each municipality; significant differences were considered with a value p<0.05. The non-parametric H test of Kruskal-Wallis was used to evaluate the ZIKV IR differences in each of the seven regions of Guerrero State. In all cases, significant differences were considered with a value p<0.05. The final analysis included multiple logistic regression models, for this purpose the dependent variable ZIKV IR was transformed into the dichotomous variable ZP (absence or presence of ZIKV occurrence).

RESULTS

In Guerrero State from 3 January 2016 to 3 January 2017 (SE 52 2016) there were 706 autochthonous ZIKV cases (global incidence of 20.83 cases/100 000 inhabitants) distributed in 25 of the 81 municipalities (30.9 %) of the State. The municipalities with the highest IR expressed in cases/100 000 inhabitants were Ometepec (68.51), Acapulco (63.29) and Escudero (61.57) which individually represented the triple of the global state. The 29.6% (27/81) of municipalities are coastal and 70.4% (57/81) non-coastal; with 58.3% (14/24) vs 19.3% (11/57) of positivity to ZIKV cases respectively; presenting significant differences (Mann Whitney U=377, p<0.001).

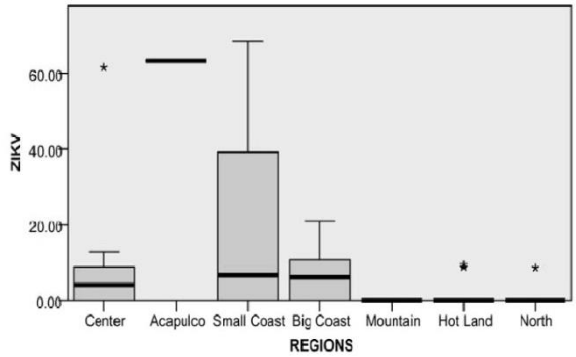

Figure 1: ZIKV IR grouped by each region of Guerrero State during 2016. The ZIKV IR were compared using the Kruskal-Wallis test.

All regions of the State, except Mountain were affected with ZIKV cases; the greatest affectation was in Acapulco region (63.29) followed by the Small Coast (19.54); in contrast, the Central (8.66) and Big Coast (6.82) regions were moderately affected and Hot Land (2.00) and North (0.53) regions were the least affected. When the comparison of municipalities ZP and ZN was made, significant differences were obtained for seven regions (H of Kruskal-Wallis =28.92, p<0.000); in the case of Mountain where there were no Zika cases, compared to the North, Hot Land and Big Coast, no significant differences were observed; however, with Center Region (Kruskal-Wallis H=22.46, p<0.025) and Small Coast (Kruskal-Wallis H=24.47, p<0.005) there were significant differences. The North Region compared to Hot Land Region, Center, Big Coast and Acapulco did not show significant differences; however, with Small Coast Region it showed significant differences (H of Kruskal-Wallis=22.185, p<0.028) (Figure 1).

Exploratory analysis of geo-environmental and demographic variables

Rain: Regarding rain conditions; for study area, a median annual rainfall average of 1 200.40 mm (864.37-1 460.10 mm) was obtained. The municipalities positive to ZIKV presented a median rainfall of 1 223.40 mm (1 028.40 - 1 460.10 mm); significant differences were found between groups when compared with ZN municipalities: rainfall mean 1 200.40 mm (Mann Whitney U=925, p<0.021); the data suggest that median rainfall in the ZP municipalities was approximately 23 mm more abundant than in the ZN municipalities. The data indicate a moderate correlation (r=0.258; p<0.020) between the increase in rainfall and Zika occurrence (Figure 2).

Temperature: Regarding temperature conditions, for study area, a median annual average temperature 25.1°C (18.7-34.1°C) was obtained. The ZP municipalities presented a median temperature 29.3°C (22.9-34.1°C); significant differences were found between groups when compared with municipalities ZN: median temperature 23.8°C (Mann Whitney U=1139, $p<0.000$). The results suggest that median temperature in the ZP municipalities is approximately 6°C above the temperature in the Zika-negative municipalities. A strong correlation was observed ($r=0.502$, $p<0.000$) which indicates that the Zika occurrence is broadly correlated with the increase in temperature (Figure 3).

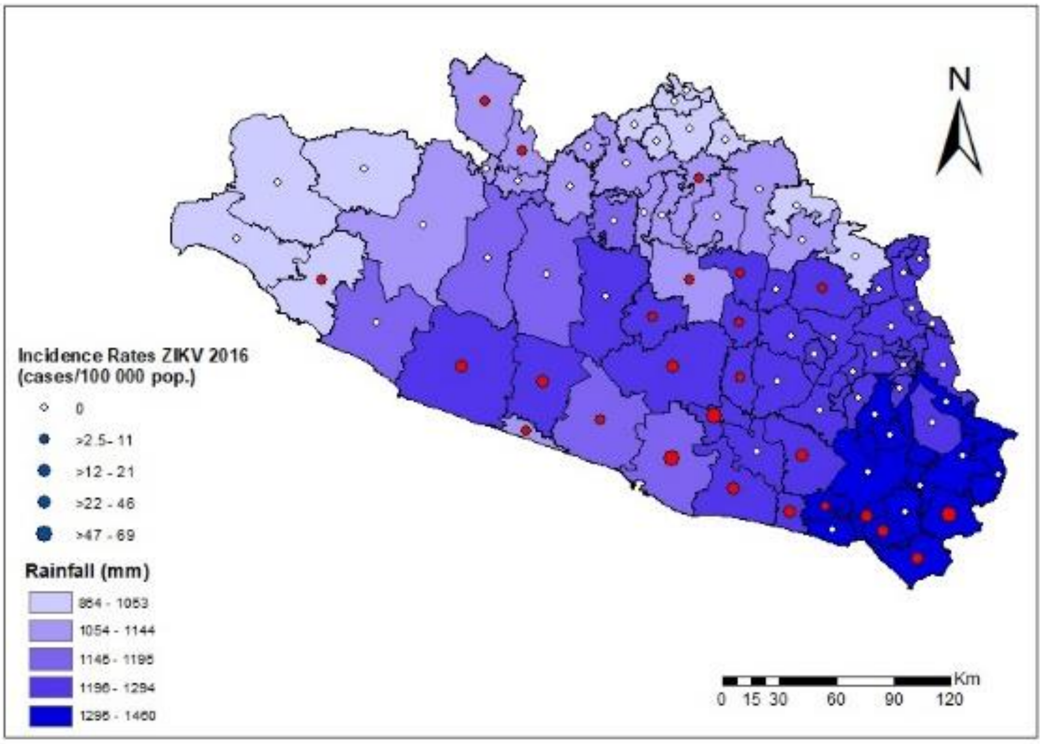

Figure 2: ZIKV incidence according to rain variable for each municipality of Guerrero State during 2016.

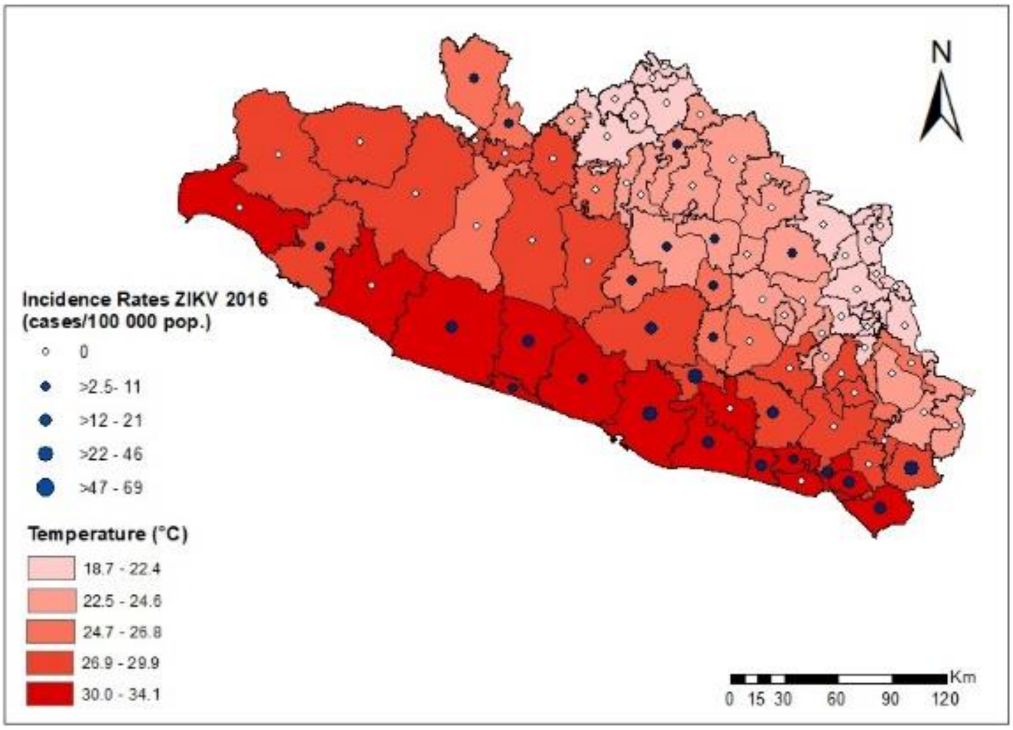

Figure 3: ZIKV incidence according to the temperature variable for each municipality of Guerrero State during 2016.

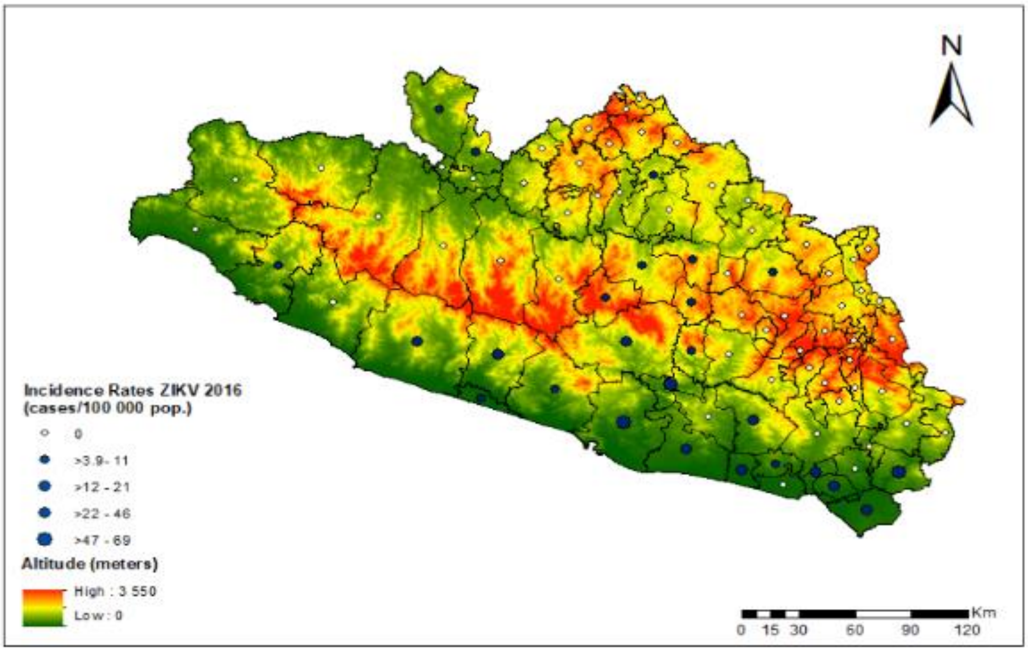

Figure 4: ZIKV incidence according to elevation variable for each municipality of Guerrero State during 2016.

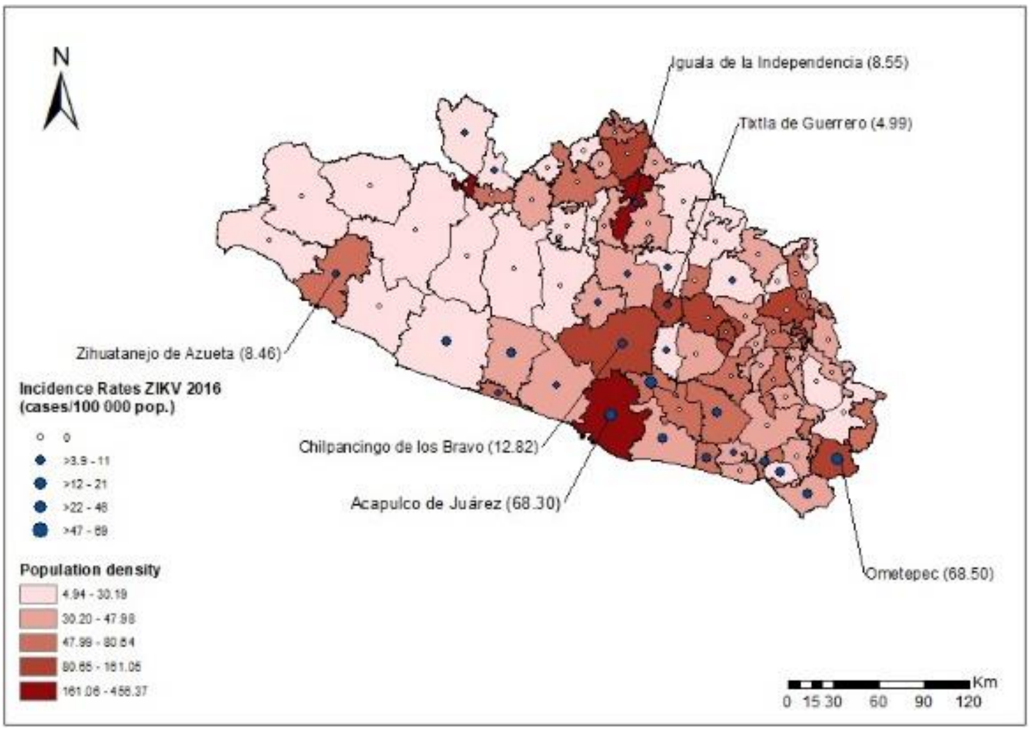

Figure 5: ZIKV incidence according to the population density variable for each municipality of the Guerrero State during 2016.

Elevation: The median elevation for study area was 882 masl (2-2020). The ZP municipalities presented a median elevation of 262 masl (2-1477); significant differences were found between groups when compared with ZN municipalities: median elevation 1 088 masl (Mann Whitney U=303, p<0.000). The data suggest that the median rainfall in the ZP municipalities was approximately 826 masl lower than in the ZN. The figure 4 shows in the elevation case, it was strongly correlated, but in a negative sense (r=-0.454, p<0.000) which indicates that Zika presence of cases decreases with the increase in elevation, which is consistent because above 1 700 masl the vector, it cannot survive (Figure 4).

Population density: The median population density for study area was 21388 inhabitants/km^2 (5706-789971 inhabitants/km^2). The ZP municipalities presented a PD median of 25 922 inhabitants/km^2 (7166-789971 inhabitants/ km^2); significant differences were found between groups when compared with ZN municipalities: median rainfall 18 834 inhabitants/ km^2 (Mann Whitney U=972, p<0.005). The data suggest that median population density in the ZP municipalities is more abundant (7088 inhabitants/km^2 above) than in the ZN municipalities. A moderate correlation was observed (r=0.311, p<0.005) which indicates that the Zika presence of cases are correlated with high population densities (Figure 5) where it is assumed that there is a greater Zika transmission cases.

Table 1: Bivariate and multivariate analysis of geo-environmental factors contributing to ZIKV presence cases in Guerrero State; Mexico, 2016.

Variables	ZP n (%)	ZN n (%)	OR_{crude} ($CI_{95\%}$)	P-value[a]	OR_{adj} ($CI_{95\%}$)	P-value[a]
Rainfall (mm)						
1201-1460	17 (68)	17 (30)	4.88 (1.77-13.45)	0.002	6.49 (1.75-24.01)	0.005
864-1200	8 (32)	39 (70)				
Temperature (°C)						
28-34.1	15 (60)	9 (16)	7.83 (2.68-22.88)	0.000	1.68 (0.33-8.58)	0.533
18.7-27.9	10 (40)	47 (84)				
Elevation (masl)						
2-398	17 (68)	14 (25)	6.38 (2.26-17.95)	0.000	5.47 (1.05-28.39)	0.043
401-2020	8 (32)	42 (75)				
Population density (pop/Km^2)						
62071-789971	7 (38)	3 (5.4)	6.87 (1.61-29.42)	0.009	11.20 (1.82-68.80)	0.009
5706-61316	18 (62)	53 (94.6)				

Crude= bivariate analysis simple logistic regression; adj= adjusted by multiple logistic regression analysis. a =p<0.05; CI 95%=Intervals of Confidence at 95%.

Bivariate and multivariate analysis

When performing the simple logistic regression analysis model, the four variables submitted presented significant associations with the dependent variable ZP (p<0.05): the variable Rain with values 1 201-1 460 mm was associated with a moderate odds with ZP (OR 4.88). Temperature 28-34.1 °C (OR 7.83) presented the highest odds, Elevation 2-398 masl (OR 6.38) and population density ≥62 071 (inhabitants/km^2) (OR 6.87) was significantly associated with the ZP presence. The final multiple logistic regression model only identified three significant variables as factors associated with the presence of Zika cases in the municipalities of Guerrero (p<0.05) (Table 1). The variable Rain with values 1 201-1 460 mm was associated with a moderate odds of ZP (OR 6.49), Elevation of 2-398 masl was significantly associated with the presence of ZP (OR 5.47) and population density ≥62 071 (inhabitants/km^2) presented the highest odds (OR 11.20) within the model as an associated factor for ZP presence. The final model adjusted well with the data using the Hosmer-Lemeshow test. The results of the bivariate and multivariate analysis of the factors associated with the presence of positive cases of Zika (ZP) by municipality are shown in Table 1.

DISCUSSION

In this study, the geo-environmental factors associated with the occurrence of Zika cases in each municipality of the Guerrero state were identified: high rainfall (1 201-1 460 mm), low elevation (2-398 masl) and high population density (≥62 071 inhabitants/km^2). There is sufficient evidence to conclude that Zika presence outbreaks is agglutinated in certain regions and Guerrero State municipalities due to the characteristics of environmental and demographic variables. Although it is necessary to carry out more research that includes the quality services such as water supply and collection of solid urban waste or factors that demonstrate the characteristics of the population such as overcrowding or poverty and lag rates as has been done in other studies.[12]

Several studies have shown that rain (precipitation) is an important factor and, it is highly correlated with high densities of *Ae. aegypti* vector.[13-15] In addition, the increase in precipitation corresponds to Dengue high incidence rates of cases, which corresponds largely to the findings of the present research, where the highest Zika number of cases, it was located in municipalities with high rainfall (1 201-1 460 mm).[12,16]

The height above sea level (elevation) forms a biological gradient and, it is an important factor for the presence of Zika cases. The interesting thing, about this variable is the negative correlation that exists, contrary to the rest of variables analyzed; high elevations (401-2 020 meters above sea level) are associated with Zika decrease or absence of cases. On the other hand, low elevations or sea level (coastal areas) maintain a high correlation with the Zika presence of cases (r=-0.454 p <0.000) such findings are consistent with other studies.[12,17,18] Previous studies have shown that density population is an important factor in the transmission of ETV's such as Zika, which is consistent with the moderate correlation observed ($r=0.311$ $p<0.005$) which indicates that Zika cases are correlated with high population densities where there is supposed to be a greater Zika transmission of cases.[12,19,20]

The variables identified by this study directly affect the vector biology and therefore the occurrence of outbreaks, so it is very important to conduct more research where entomological information. The use of tools such as GIS, they are useful for mapping outbreaks of diseases transmitted by vector (ETV's). They help in making decisions when planning prevention and control strategies. In this way, it seeks to make efficient economic and human resources.[21,22] In addition, they allow identifying priority areas; especially with Dengue disease in areas or municipalities that repeat cases over time.[23] In the present study, the areas where Zika outbreaks occurred and their relationship with geo-climatic variables were identified. In addition to the implications for public health; the present maps establish the bases for the possible evaluation of risk by the visit of international travellers coming from areas of high transmission of ETV's mainly those transmitted by the *Aedes aegypti* mosquito.

This study represents the first approach to Zika outbreak in Guerrero State. Although tests of spatial nature are not presented; the maps presented show how the characteristics by region have high influence and that the most affected areas were the coastal areas: Acapulco, Small Coast and Big Coast. In future studies it is recommended to include data from other States of Mexico and apply spatial statistics. In addition, the inclusion of other climatological variables related to ETV's to obtain models capable of predicting the ZIKV occurrence of cases. It is important to consider human population dynamics (mainly migration), in addition to underreporting (asymptomatic cases) factors that directly affect the calculation of incidence by municipality. Due to characteristics of disease, it is difficult to include more years of study. Regularly people who get sick from Zika are no longer sick due to a single virus; all people in contact with Zika virus remain immune; very different, compared to Dengue that has four serotypes of the virus and that immunity to a serotype does not protect against the rest.

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