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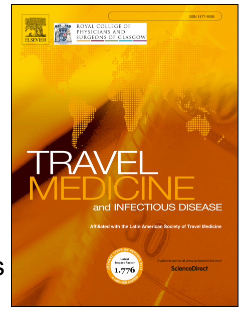

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D. Katterine Bonilla-Aldana, Jorge Luis Bonilla-Aldana, Juan J. García-Bustos, Carlos O. Lozada, Alfonso J. Rodríguez-Morales

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Original Research Article

Geographical Trends of Chikungunya and Zika in the Colombian Amazonian Gateway Department, Caqueta, 2015-2018 – Implications for Public Health and Travel Medicine

D. Katterine Bonilla-Aldana,[1,2,3,4] Jorge Luis Bonilla-Aldana,[5] Juan J. García-Bustos,[5,6] Carlos O. Lozada,[3,7] Alfonso J. Rodríguez-Morales.[3,4,8,*]

[1]*School of Veterinary Medicine and Zootechnics, Fundación Universitaria Autónoma de las Américas, Sede Pereira, Pereira, Risaralda, Colombia.*

[2]*Semillero de Zoonosis, Grupo de Investigación BIOECOS, Fundación Universitaria Autónoma de las Américas, Sede Pereira, Pereira, Risaralda, Colombia.*

[3]*Public Health and Infection Research Group, Faculty of Health Sciences, Universidad Tecnológica de Pereira, Pereira, Risaralda, Colombia.*

[4]*Committee on Tropical Medicine, Zoonoses and Travel Medicine, Asociación Colombiana de Infectología (ACIN), Bogotá, Colombia.*

[5]*Grupo de Investigación en Ciencias Animales Macagual, Universidad de La Amazonia, Florencia, Caquetá, 180002, Colombia.*

[6]*Grupo de Investigación en Patología e Inmunología – Doctorado en Medicina Tropical, Universidad del Magdalena, Santa Marta, Magdalena, 470004, Colombia*

[7]*Regional Information System, Universidad Tecnológica de Pereira, Pereira, Risaralda, Colombia*

[8]*Medical School, Faculty of Health Sciences, UniFranz, Cochabamba, Bolivia.*

Corresponding author email: arodriguezm@utp.edu.co

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Abstract

Background: Chikungunya (CHIKV) and Zika (ZIKV) significantly affected Latin America in the period 2015-2017. Most studies were reported from urban areas of Brazil and Colombia. In this paper we estimate Incidence rates for CHIKV and ZIKV in Caqueta, the Amazonian gateway area of Colombia, from 2015-2018.

Methods: Using surveillance data of CHIKV and ZIKV in Caqueta, Colombia, incidence rates were estimated (cases/100,000 population). Sixteen geographical information systems (GIS)-based municipal maps were developed. GIS software used was Kosmo 3.0®.

Results: From 1st of January 2015 to the 24th of November 2018, 825 cases of CHIK and 1079 of ZIKV were reported, yielding cumulated incidence rates of 169.42 and 221.59 cases/100,000 population respectively. In 2016, 48.7% of the CHIKV cases (402) and 96.6% of the ZIKV cases (1042) were reported. The highest number of both arboviral diseases occurred at Florencia (capital department city), 225 cases for CHIKV (127.17 cases/100,000 pop.) and 611 for ZIKV (345.34 cases/100,000 pop.).

Discussion: The temporo-spatial distribution of CHIKV and ZIKV infections in Caquetá reflected the pattern of concurrent epidemics, especially in 2016. Studies using GIS-linked maps are necessary to attain accurate epidemiological analyses for public health decisions. That is also useful for an epidemiologically based assessment of traveler risks when visiting specific areas in destination countries.

Keywords

Chikungunya virus (CHIKV); Zika virus (ZIKV); geographical information systems (GIS); travelers; arboviruses; infectious diseases epidemiology.

Introduction

Over the past five years, Colombia has been a country significantly affected by epidemics of chikungunya virus (CHIKV) and Zika virus (ZIKV) infections [1, 2]. Both epidemics began with imported cases in travelers arriving from the Caribbean islands in 2014 and from Brazil in 2015, respectively, to the department of Bolivar, including its capital, the touristic and historic city of Cartagena [3-5]. After introduction and passive detection by surveillance, these arboviral infections spread significantly in the north Colombian Caribbean region, affecting all the departments of this area [6-9]. Lately they circulated, by population movements, in all the departments of the country, especially in the northeastern departments that border with Venezuela [10], in Valle del Cauca, central and coffee-triangle regions of the country, among others but excluding cities above 2,200 meters of altitude (Bogota, Manizales, Tunja and Pasto).

Epidemics of CHIKV and ZIKV in Colombia, as well as other countries in Latin America, have been associated with multiple factors [11]. Factors such as climate change [12, 13], international travel, foreign trade [14, 15], geographical susceptibility, and other factors are associated with the outbreaks [16-21]. These viruses spread within a population that had already experienced previous endemo-epidemic seasons of urban dengue virus (DENV) and sylvatic yellow fever virus (YFV) [12, 14, 15, 21-26]. Even more, these emerging arboviral diseases have been associated with clinical conditions that have long-term consequences, such as is the case of post-CHIKV chronic disease (pCHIK-CD) [27, 28], or the congenital Zika syndrome (CSZ) and Guillain-Barre syndrome (GBS) associated with ZIKV infection [1, 4], which can led to a significant burden of disease [29].

Despite all the epidemics and the relevance of CHIKV and ZIKV, the southern and eastern regions of Colombia (Orinoquia and Amazonian) (Figure 1) have been neglected with respect to studies of arboviral diseases. Just recently a study in Huila, a department south of the central region of the country, in the Andean region (Figure 1), assessed the impact of both arboviral diseases, finding that during 2014-2016, a total of 31,704 cases of CHIKV occurred, reaching an incidence rate of 2510.04 cases/100,000 population in 2016. That department had a total of 7046 ZIKV cases in the afore-mentioned period, with five municipalities having >1000 cases/100,000 pop., including the capital [30].

The Amazonian region (Figure 1), despite its importance, has been neglected with regard to studies about arboviral diseases, especially CHIKV and ZIKV. This region in southern Colombia, above the Amazon Basin, comprises the departments of Amazonas, Caqueta, Guainía, Guaviare, Putumayo, and Vaupés, and covers an area of 403,000 km² or 35% of Colombia's total territory (Figure 1). The region is mostly covered by tropical rainforest, or jungle, which is a part of the massive Amazon rainforest. Among its departments, Caqueta is third in surface area in the region and the country (88,965 km^2) (Figure 2) and second in population in the region (483,834 inhabitants were registered in 2018).

In general, there are few studies about arboviral diseases in Caqueta [31], indeed, there is a general lack of infectious diseases investigations and general research [32, 33]. Since the FARC guerrilla movement (Revolutionary Armed Forces of Colombia—People's Army) signed a ceasefire accord with the President of Colombia, Juan Manuel Santos in Havana on June 2016, there were significant increases in the access and touristic activity in Caqueta and the Amazonian region. Caqueta is a department with vast natural resources and where biodiversity proliferates (Figure 2). A department hit by the armed conflict for decades is now considered a touristic destination in the Amazonian region, with places such as El Horeb, a nature reserve located seven kilometers from the town center of the Municipality of Belén de Los Andaquíes, and the Serranía de Chiribiquete or Chiribiquete mountains which are a group of isolated table mountains (Figure 2), among other places [34]. In 2017, according to the Colombian government estimates, up to 1,000 international travelers arrived at Caqueta. Thus, implications for travel medicine should be considered when assessing the risk of international spread and measures related in this region [9, 14, 35, 36].

Since 2014, in Colombia and all its departments, including Caqueta, CHIKV, and ZIKV surveillance and reporting is mandatory [9, 16, 30, 35, 37, 38]. In the past decade, the near real-time availability of novel and disparate internet-based data sources has motivated the development of complementary methodologies to track the incidence and spread of disease [21]. PAHO currently streamlines reports from ministries of health and reports weekly confirmed and suspected cases of CHIKV and ZIKV by country [4, 9, 16, 39-42]. These reports provide up-to-date data about the epidemiology of these arboviral diseases in affected global regions [16, 21]. However, there is no detailed information about specific places, departments or municipalities, and this is necessary in order to make more specific recommendations for travelers as well as to prioritize public health policy and practice [9, 16, 21, 35, 37, 43].

Understanding the impact of arboviruses, such as CHIKV and ZIKV, in terms of clinical complications, disability and costs to health systems require a higher number of investigations involving multiple medical specialties, including many hitherto neglected areas of Colombia, such as Caqueta. This information is essential to develop and prepare for possible future epidemics of new arboviruses [20, 22].

As part of the enhanced efforts in control and risk assessment for CHIKV and ZIKV in Colombia and Latin America, the Universidad Tecnológica de Pereira, and the Universidad de la

Amazonia, are working together in the analysis of epidemiological information of infectious diseases in regional and national scales [16, 27], including arboviral infections such as ZIKV, DENV and CHIKV [4, 9, 13, 16, 35, 42]. In this setting, this study aimed to estimate incidence rates of CHIKV and ZIKV in 2015-2018 for Caqueta and its municipalities and to develop GIS-based epidemiological maps for these arboviral diseases.

Methods

Caquetá is a department of Colombia located in the Amazonas region (Figures 1 and 2). Caquetá borders with the departments of Cauca and Huila to the west, the department of Meta to the north, the department of Guaviare to the northeast, the department of Vaupés to the east, the departments of Amazonas and Putumayo to the south covering a total area of 88,965 km², the third-largest in the country. Its capital is the city of Florencia. Caqueta is comprised of 16 municipalities (municipalities are second line administrative level regions of Colombia) (Figure 3). The Caqueta territory presents climatic, geographic and epidemiological conditions suitable for transmission of many vector-borne diseases (Figure 2) [32]. *Aedes aegypti*, the primary vector of CHIKV and ZIKV, is widely distributed over all the municipalities [44], constituting large areas where environmental factors such as temperature, humidity, precipitation, latitude, and altitude, as well as social, cultural, economic and political factors are suitable for sustained transmission (Figure 2) [21].

For this observational, retrospective study, the epidemiological data were collected from the department surveillance system, obtaining the number of cases for each municipality of Caqueta for the years 2015-2018. Data were based on clinically confirmed cases (suspected cases by clinical criteria definition) and confirmed by serology and RT-PCR, which have been revised in terms of data quality. Data analyzed for this study came from 16 primary municipal notification units, as has been reported for other studies of the group in the country [9, 16, 37, 38]. Determination of CHIKV and ZIKV infection included syndromic and laboratory surveillance (clinical definition in a place with previously CHIKV and ZIKV circulation; at least one case confirmed by serology and RT-PCR). According the US Centers for Disease Control (CDC), most arboviruses are capable of causing an acute systemic febrile illness that may include headache, myalgias, arthralgia, rash, or gastrointestinal symptoms. Some viruses also can cause more characteristic clinical manifestations, such as severe polyarthralgia or arthritis due to Chikungunya virus or other alphaviruses. In the case of ZIKV, a person with one or more of the following not explained by another etiology: clinically compatible illness that includes, acute onset of fever (measured or reported), or maculopapular rash, or arthralgia, or conjunctivitis. These clinical definitions have also been recommended by the WHO and PAHO [45, 46].

Using official reference population data (National Institute of Statistics, DANE), estimates of the annual incidence rates for all the municipalities of Caqueta were calculated (cases/100,000 pop) to provide estimates of CHIKV and ZIKV incidence by municipalities [16].

GIS-based maps, by municipalities with the distribution of CHIKV and ZIKV, were generated. Microsoft Access® was used to design the spatial databases to import incidence rates by departments, municipalities, and disease to the GIS software. The Client GIS software Open source used was Kosmo Desktop 3.0 RC1®. The shapefiles of municipalities (.shp) were linked to data table database through spatial join operation, in order to produce digital maps of annual incidence rates by municipalities [16, 40]. Monthly satellite images for Total Rainfall and Surface Temperature were obtained from the Tropical Rainfall Measuring Mission (1 month - TRMM) imagery database NASA Earth Observations (NEO, NASA, USA) (http://neo.sci.gsfc.nasa.gov/) and analyzed for Caqueta with the software Google Earth®, as described before [12, 16].

Results

From the 1st of January 2015 to the 24th of November 2018, a total of 825 cases of CHIK (4.48% confirmed by serology and/or RT-PCR) (Table 1) and 1079 of ZIKV were reported (24.3% confirmed by RT-PCR) (Table 2), for cumulated incidence rates of 169.42 and 221.59 cases/100,000 pop (Tables 1 and 2). In 2016, 48.7% of the CHIKV cases (402) (Table 1) and 96.6% of the ZIKV cases (1042) occurred (Table 2).

All 16 municipalities of Caqueta reported cases of CHIKV and ZIKV during the study period. Rates for CHIKV ranged from 0 to 1057.95 cases/100,000 pop. (San Jose del Fragua, 2016), followed by Curillo (298.20 cases/100,000 pop., 2016), Valparaiso (248.14 cases/100,000 pop., 2016) and Albania (139.93 cases/100,00 pop.) (Table 1, Figure 3). These municipalities, which are located in the western areas of Caqueta (Figure 3), together with the capital, Florencia (Figure 3), reported more than 58% of the CHIKV cases of the department (Table 1). In 2015, San Vicente del Caguan and Cartagena del Chaira were the most affected municipalities (>140 cases/100,000 pop.) (Figure 3). In Florencia, most cases were reported in the northeastern (59 cases) and south (51 cases) communes (Figure 4).

Rates for ZIKV ranged from 0 to 545.61 cases/100,000 pop. (San Jose del Fragua, 2016), followed by Florencia (334.10 cases/100,000 pop., 2016), El Doncello (333.59 cases/100,000 pop., 2016) and Belen de Los Andaquies (224.12 cases/100,00 pop.) (Table 2, Figure 5). These municipalities, which are also located in the western areas of Caqueta (Figure 5), reported more than 73% of the ZIKV cases of the department (Table 2). In 2015, only three municipalities reported ZIKV cases, Florencia, El Paujil and Morelia, all with less than 30 cases/100,000 pop. (Figure 5). In Florencia, as occurred with CHIKV, most cases of ZIKV were reported in the northeastern (181 cases) and south (134 cases) communes (Figure 6).

During the period 2015-2016, when both epidemics began, ecoepidemiological conditions at Caqueta and Florencia were prone for vector-borne diseases, as there was intense precipitation in 2015 and especially in 2016 (Figure 2). The riverain density, even in urban areas of Florencia, tends to increase the risk of floods and artificial wetlands, ideal habitats for vectors when rain is occurring (Figure 2). There were two municipalities, Curillo and Valparaiso, that had high annual incidence rates of both CHIKV and ZIKV (≥200 cases/100,000 pop.) during the same year (2016) (Tables 1 and 2) (Figure 7). There were two municipalities, Morelia and San Jose del Fragua, that had high annual incidence rates of CHIKV (≥200 cases/100,000 pop.) with and lower ZIKV incidence rates (<200) during the same year (Tables 1 and 2) (Figure 7). Finally, there were four municipalities with high incidence of ZIKV (≥200) and low CHIKV incidence (<200) (Tables 1 and 2) (Figure 7). With a non-linear regression, CHIKV slightly predicted the ZIKV distribution (r^2=0.1829; p=0.0019).

Discussion

Colombia was, without doubts, one the most affected countries to suffer CHIKV and ZIKV. With regard to CHIKV, the total number of cases was estimated to be more than 3.1 million during the 2014-2015 epidemics and for ZIKV more than 100,000 cases with approximately 20% of these cases occurring in pregnant women, during 2015-2016 [47, 48]. Although both epidemics ceased, for CHIKV in 2015 and ZIKV in 2016, these arboviral infections have now become endemic. Now, these emerging diseases and dengue virus (DENV) infection maintain sustained transmission [14]. Significant rainfall patterns and warm temperatures during the whole year (Figure 2), with high numbers of susceptible individuals and ample presence of vectors, are prone for transmission in multiple areas of the department, urban and rural (Figures 3-6), CHIKV having more presence in the rural municipalities, ZIKV in urban areas.

ZIKV followed the path of CHIKV (Figure 7) (p<0.01), as occurred in other regions of Colombia and other countries [6, 7, 9, 16, 30, 35, 37, 38, 43, 49]. Those areas with high incidence rates of these infections also exhibited the highest risk for ZIKV, as expected, the most populated urban and suburban areas of the western are of Caqueta. The western of Caqueta is border with Huila, which also exhibited high incidence rates of CHIKV and ZIKV during the period 2015-2016 [30]. Although more than 800 cases were reported in the department for CHIKV, and 1079 for ZIKV, only 4.48% and 24.3% of them respectively were laboratory-confirmed. This is directly related to the financial limitations that preclude assessment of all patients by laboratory confirmation and to a lack of readily available and reliable serological tests in the case of ZIKV. Nonetheless, we used the PAHO case definition which is based upon a clinical definition of CHIK and ZIKV infections for surveillance data, as has been described in previous studies [16, 21].

Social and eco-epidemiological conditions in Caqueta make the whole country susceptible to spread of arboviral diseases such as DENV, CHIKV, and ZIKV; therefore, analyses such as the one presented herein are relevant for understanding future emerging arboviral diseases in the region and should be extended in the near future to other departments of the Colombian Amazonian region. Other relevant arboviral diseases to consider include Mayaro (MAYV), Oropouche (OROV), Venezuelan Equine Encephalitis (VEEV), West Nile virus (WNV), among others [11, 22, 50, 51], especially considering enzootic cycles that are present in the sylvatic areas of Caqueta and the Amazonian region.

Recent social and political factors such as the impact of internal displacement, should be considered in the epidemiology of arboviral diseases in Colombia, as has been shown in Huila [52], wherein a study in its capital city, Neiva, found cases among the population of internally displaced populations (IDP) (8.8 cases of CHIKV/100,000 IDP and 46.1 for ZIKV in 2015) [52]. This should also be considered for Florencia. This capital city of Caqueta, receives domestic travelers from its airport, located 6.8 km away from the city, in the municipality La Montañita, an area that also had CHIKV and ZIKV cases in 2015-2017 (Tables 1 and 2). Since 2010, the flux of passengers through this airport has increased from 57,148 up to 112,545 in 2018. This airport is currently served by four air carriers with flights to Bogota, Cali, Neiva and Puerto Leguizamo (a town located at the border with Peru in the Putumayo river) [9, 14, 35, 36].

Although we were able to analyze cases up to November 2018, the transmission is still occurring, and Caqueta concluded that year with 12 CHIKV and 6 ZIKV cases. In 2019, both diseases continue to be reported in Colombia, with 401 CHIKV and 317 ZIKV cases up until August 24th [53]. Colombia as well as Caqueta, suffered high attack rates of these infections with a resulting decrease in the number of susceptible persons, due to the development of herd immunity, after 2016. As has been recently hypothesized for dengue [54], but also ZIKV and CHIKV, this decline is unlikely due to changes in epidemiological surveillance systems, as similar designs of surveillance systems exist across the region [21]. Also, in 2015-2016, environmental conditions in the Americas were conducive to CHIKV and ZIKV transmission [55].

From the ZIKV cases reported in Caqueta till December 2018, 378 occurred in pregnant women (200 of them, 52.9%, RT-PCR confirmed) and nine cases of GBS. Apparently, during 2016, the prevalence of congenital microcephaly and CSZ in Caqueta was ranging between 10 and 18.9 cases/10,000 live births [56]. This figure may be not accurate and may be an underestimate. Further studies are necessary to determine the correct frequency of ZIKV infection during pregnancy in Caqueta and the association of microcephaly and other congenital disabilities with ZIKV infection [57], as has been reported in other areas of Colombia, as well as in Brazil and in other countries in Latin America [4, 58-60].

In this setting, public health tools for detailed analyses, such as the use of GIS-epidemiological maps [16, 35, 40], are of great relevance for any affected country and area. In the case of the Amazonian region of Colombia, there is an evident lack of studies developing such maps for arboviral and other infectious diseases. Particularly, entomological studies are lacking over decades. In 2000, a study found *Aedes*, *Anopheles*, *Culex*, *Haemagogus*, *Psorophora*, *Sabethes*, among other hematophagous genera at the National Park of Chiribiquete [44], all vectors of potential importance in public health and travel medicine, that require and deserve updated research.

In this study, we estimated the incidence rates of CHIKV and ZIKV and generated 16 epidemiological maps for municipalities and the capital city Florencia. ZIKV appears to follow the patterns of other arboviral diseases in the department and then became both endemic. Further studies are essential to understand the epidemiological and medical characteristics of this and other arboviruses in Caqueta and other departments of the Amazon region. Although this may not provide all the answers, such information is particularly useful for public health evidenced-based decisions [61].

Use of GIS-based epidemiological maps is beneficial to develop preventative/control strategies and public health policies for joint control of these vector-borne diseases in Caqueta and other departments in the Amazon region [4, 9, 16, 35, 37], as well as other regions in Colombia. These tools such as GIS-based maps can also be developed and used for making public health decisions about other emerging diseases in Caqueta and the region.

These maps can also provide relevant information concerning the risk to individuals traveling to specific regions of the world [4, 9, 16, 35, 37, 62]. A correlated and vital role is using the data to help prevent further spread of viruses such as DENV, CHIKV, and ZIKV from other areas (imported cases) to Caqueta and other areas of Colombia as well as countries in Latin America.

Touristic areas, such as the municipality of Belén de Los Andaquíes that include the natural reserve El Horeb, had high incidence rates of ZIKV and low of CHIKV. This area should also be a focus of concern for travel medicine and public health for ZIKV and other arboviral diseases in Caqueta. Such tourist destinations are epidemiologically suitable for acquisition of ZIKV by domestic and international travelers in Caqueta.

Soon, other eco-epidemiological assessments should be performed in Caqueta for these arboviral diseases. With warm temperatures during the whole year, susceptible individuals, and high density of mosquito vectors, many municipalities have become endemic regions for ZIKV in addition to CHIKV and DENV, as occurred in other areas of Colombia and other countries in Latin America [9, 16, 21, 30, 35, 37, 38].

Limitations

Less than 25% of the cases were laboratory confirmed. We used the PAHO and CDC case definitions in surveillance to be as accurate as possible in obtaining the epidemiological data [37]. This situation is similar to other countries and other published reports about GIS-mapping of Zika and other arboviral diseases in the Americas [4, 9, 16, 35, 40]. However, indeed, in Caqueta, as in other areas of the tropical Americas, DENV also circulate with CHIKV and ZIKV, and there is overlap in their clinical features. All three viruses have similar clinical presentations, and coinfections may be more common than previously known [10, 14, 15, 50, 63, 64]. Besides, there is probably under-reporting of cases in certain areas as compared with more accurate reporting in individual municipalities. However, non-laboratory case definitions in arboviral diseases have high sensitivity for symptomatic disease and may may identify infections that would progress to more severe disease or put individuals at higher risk, as is the case especially of persons with DENV, followed by CHIKV and ZIKV infection.

Conclusions

GIS-based maps provide relevant information to assess the risk to individuals traveling to specific destinations in endemic-epidemic areas allowing detailed prevention advice as has been described before [16, 21, 37]. Such maps allow integration of prevention and control strategies, as well as public health policies, for joint control of this vector-borne disease in this and other areas of Colombia, as well as in other countries of Latin America [36]. Simultaneous or sequential arboviral infections occur and should be assessed and mapped as a subject of surveillance [10, 50, 64]. Preparedness in this setting should also consider the potential arrival of Mayaro [22, 51], Oropouche and yellow fever viruses in *Aedes* infested areas [65].

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Conflicts of Interest: The authors have no conflict of interest to disclose.

Data availability

Raw data is available and will be provided on request.

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Table 1. CHIKV incidence rates (cases/100,000 population) by municipalities, Caqueta, Colombia, 2015-2018.

	Cases					**Population**				**Rates (Cases/100,000 population)**				
Municipalities	**2015**	**2016**	**2017**	**2018**	**Total**	**2015**	**2016**	**2017**	**2018**	**2015**	**2016**	**2017**	**2018**	**Cumulated**
Florencia	119	102	4	0	225	172,341	175,395	178,449	181,514	69.05	58.15	2.24	0.00	127.17
San Jose del Fragua	5	159	0	1	165	14,921	15,029	15,125	15,223	33.51	1057.95	0.00	6.57	1094.56
San Vicente del Caguan	115	44	0	0	159	67,994	69,214	70,453	71,704	169.13	63.57	0.00	0.00	227.66
Cartagena del Chaira	48	6	0	0	54	33,391	33,908	34,429	34,953	143.75	17.69	0.00	0.00	158.03
Curillo	9	35	8	0	52	11,683	11,737	11,789	11,829	77.04	298.20	67.86	0.00	442.20
El Doncello	30	9	0	0	39	22,137	22,183	22,227	22,267	135.52	40.57	0.00	0.00	175.65
Valparaiso	0	29	0	1	30	11,629	11,687	11,731	11,772	0.00	248.14	0.00	8.49	256.31
Solita	18	0	0	0	18	9,140	9,143	9,149	9,139	196.94	0.00	0.00	0.00	196.88
Montañita	11	2	1	0	14	23,620	23,789	23,962	24,140	46.57	8.41	4.17	0.00	58.63
Morelia	4	1	0	9	14	3,813	3,836	3,863	3,892	104.90	26.07	0.00	231.24	363.54
Belen de Los Andaquies	11	0	2	0	13	11,541	11,601	11,663	11,721	95.31	0.00	17.15	0.00	111.77
Albania	2	9	0	0	11	6,430	6,432	6,435	6,434	31.10	139.93	0.00	0.00	171.00
Puerto Rico	8	0	1	1	10	33,347	33,447	33,543	33,623	23.99	0.00	2.98	2.97	29.86
El Paujil	6	1	0	0	7	20,224	20,528	20,832	21,148	29.67	4.87	0.00	0.00	33.84
Solano	0	0	2	1	3	23,663	24,131	24,603	25,074	0.00	0.00	8.13	3.99	12.31
Milan	0	1	0	0	1	11,745	11,774	11,802	11,829	0.00	8.49	0.00	0.00	8.48
Unknown	6	4	0	0	10	-		-	-	-	-	-		-
Total	392	402	18	13	825	477,619	483,834	490,055	496,262	82.07	83.09	3.67	2.62	169.42
Laboratory Confirmed*	25	10	2	0	37					5.23	2.07	0.41	0.00	7.60
%	6.38	2.49	11.1	0.00	4.48	-	-	-	-	-	-	-	-	-

*Serology and/or RT-PCR.

Table 2. ZIKV incidence rates (cases/100,000 population) by municipalities, Caqueta, Colombia, 2015-2018.

	Cases					Population				Rates (Cases/100,000 population)				
Municipalities	**2015**	**2016**	**2017**	**2018**	**Total**	**2015**	**2016**	**2017**	**2018**	**2015**	**2016**	**2017**	**2018**	**Cumulated**
Florencia	18	586	5	2	611	172,341	175,395	178,449	181,514	10.44	334.10	2.80	1.10	345.34
San Vicente del Caguan	0	103	0	0	103	67,994	69,214	70,453	71,704	0.00	148.81	0.00	0.00	147.48
San Jose del Fragua	0	82	0	1	83	14,921	15,029	15,125	15,223	0.00	545.61	0.00	6.57	550.60
El Doncello	0	74	1	0	75	22,137	22,183	22,227	22,267	0.00	333.59	4.50	0.00	337.78
El Paujil	1	64	0	0	65	20,224	20,528	20,832	21,148	4.94	311.77	0.00	0.00	314.27
Montañita	0	29	0	0	29	23,620	23,789	23,962	24,140	0.00	121.91	0.00	0.00	121.45
Belen de Los Andaquies	0	26	0	0	26	11,541	11,601	11,663	11,721	0.00	224.12	0.00	0.00	223.53
Puerto Rico	0	20	1	0	21	33,347	33,447	33,543	33,623	0.00	59.80	2.98	0.00	62.71
Solita	0	13	0	0	13	9,140	9,143	9,149	9,139	0.00	142.19	0.00	0.00	142.19
Cartagena del Chaira	0	9	2	1	12	33,391	33,908	34,429	34,953	0.00	26.54	5.81	2.86	35.12
Morelia	1	8	0	0	9	3,813	3,836	3,863	3,892	26.23	208.55	0.00	0.00	233.71
Milan	0	5	2	0	7	11,745	11,774	11,802	11,829	0.00	42.47	16.95	0.00	59.38
Albania	0	5	0	0	5	6,430	6,432	6,435	6,434	0.00	77.74	0.00	0.00	77.73
Valparaiso	0	5	0	0	5	11,629	11,687	11,731	11,772	0.00	42.78	0.00	0.00	42.72
Solano	0	4	0	0	4	23,663	24,131	24,603	25,074	0.00	16.58	0.00	0.00	16.42
Curillo	0	1	1	0	2	11,683	11,737	11,789	11,829	0.00	8.52	8.48	0.00	17.01
Unknown	1	8	0	0	9	-	-	-	-	-	-	-	-	-
Total	21	1042	12	4	1079	477,619	483,834	490,055	496,262	4.40	215.36	2.45	0.81	221.59
Laboratory Confirmed*	3	257	2	0	262					0.63	53.12	0.41	0.00	53.81
%	14.3	24.7	16.7	0.00	24.3	-	-	-	-	-	-	-	-	-

*RT-PCR.

Figure 1. Natural regions of Colombia.

Figure 2. Environmental conditions of Caqueta and Florencia. A. GIS-based map of the hydrography of Caqueta. B. GIS-based map of altitude of Caqueta. Rain patterns map from the TRMM satellite for Caqueta, during April 2015 (C) and January-June 2016 (D). E. The topography of the urban area Florencia. F. Hydrography map of the urban area of Florencia.

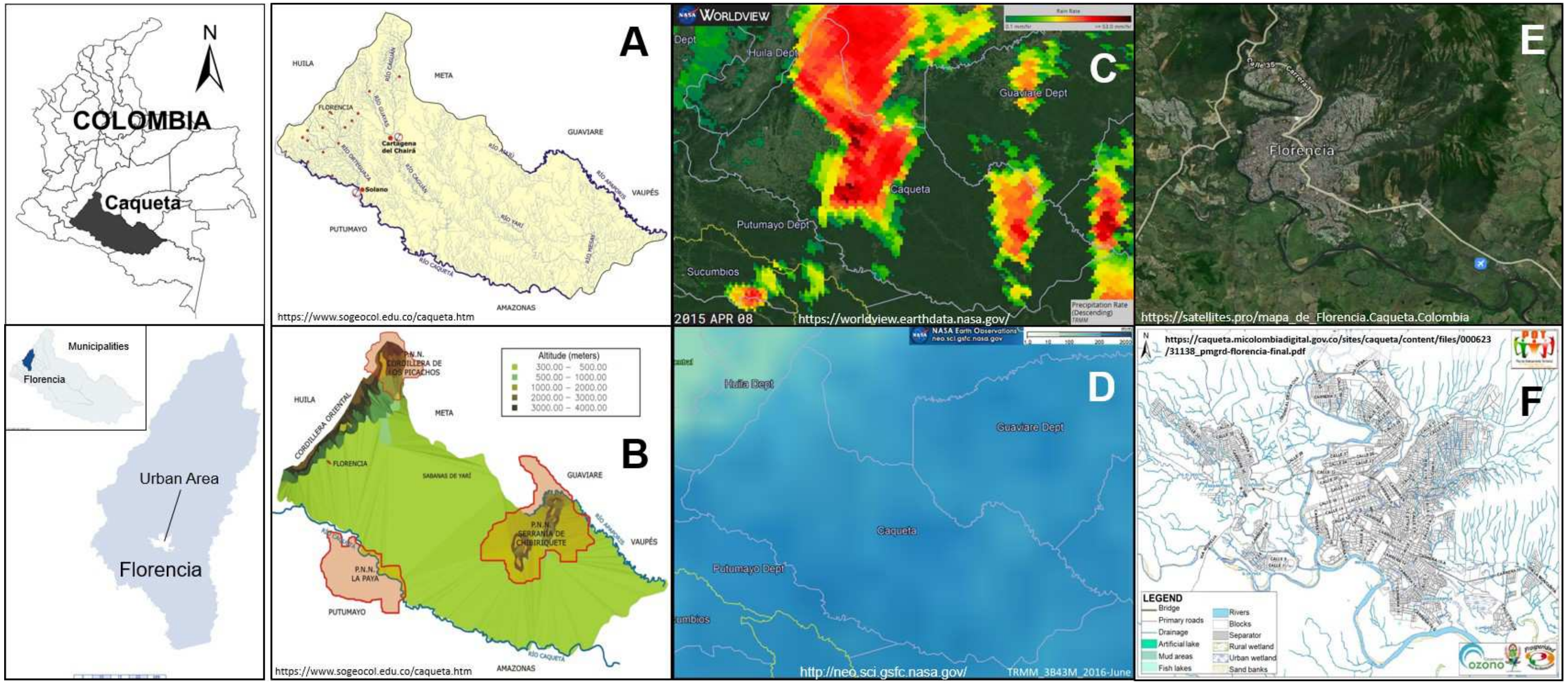


Figure 3. Geographic distribution by GIS-based map of the calculated incidence rates for CHIKV in Caqueta, Colombia, 2015-2018 by municipalities.

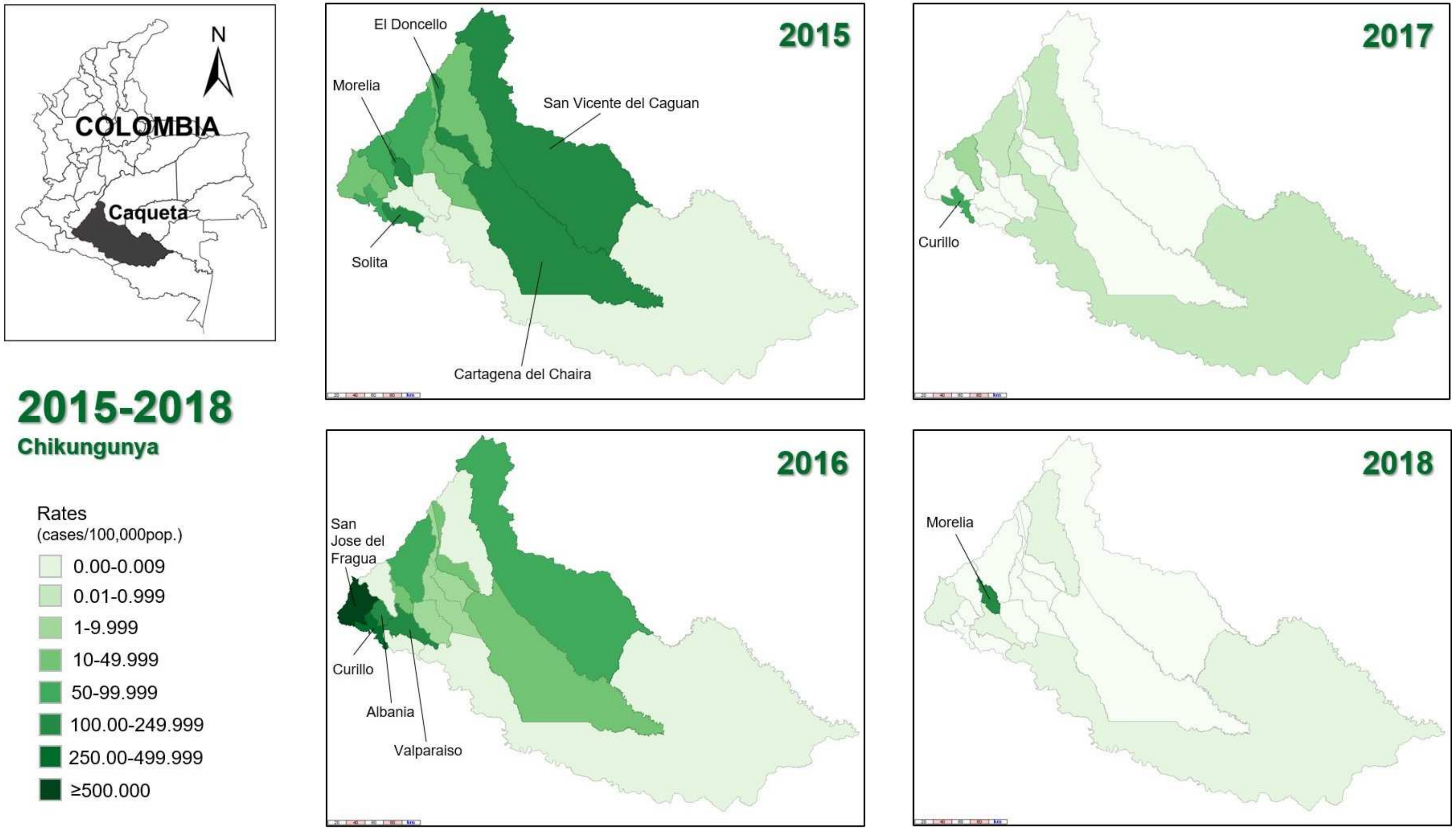


Figure 4. Geographic distribution CHIKV cases in Florencia, Caqueta, Colombia, 2015-2018 by urban communes.

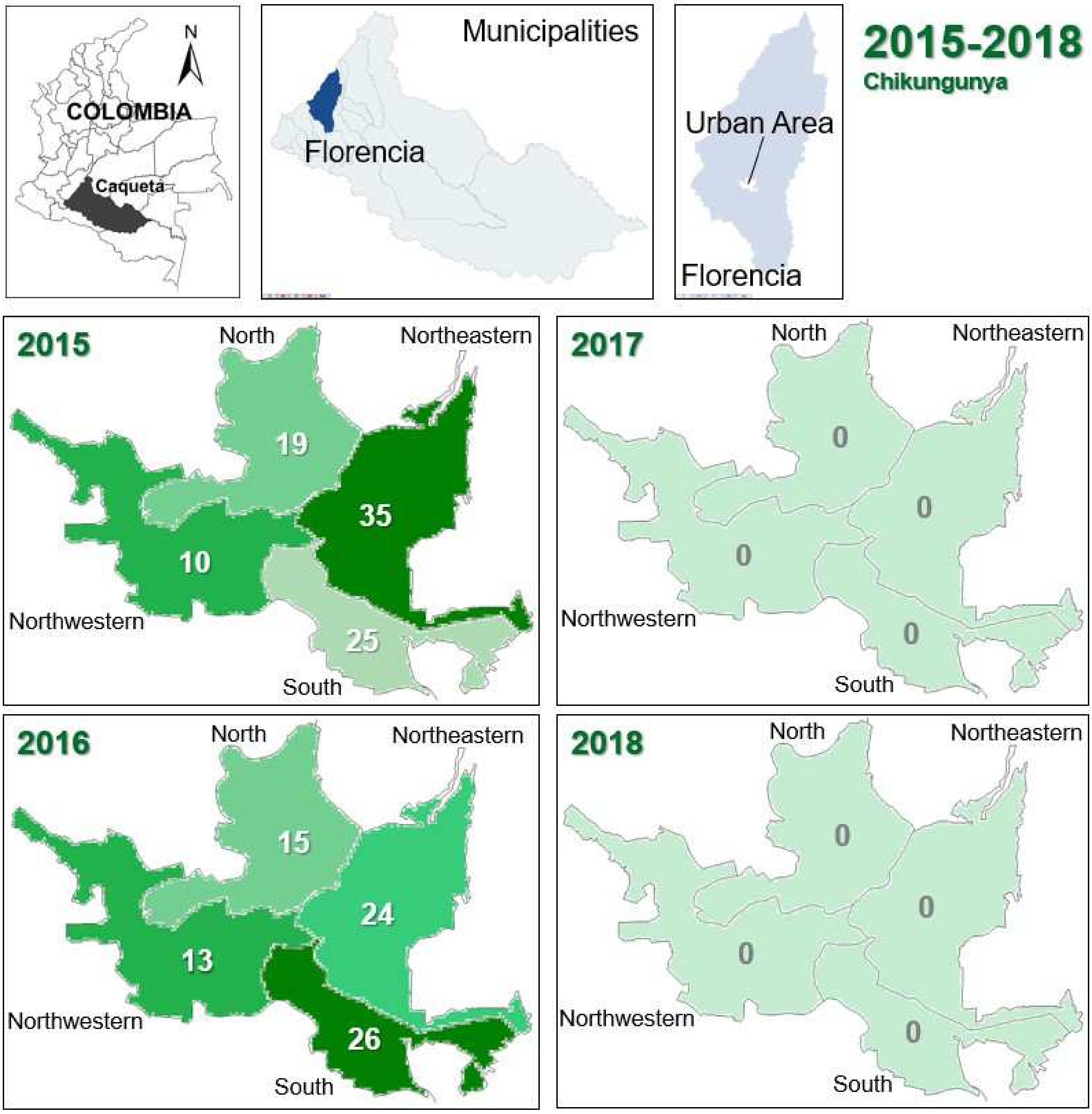


Figure 5. Geographic distribution by GIS-based map of the calculated incidence rates for ZIKV in Caqueta, Colombia, 2015-2018 by municipalities.

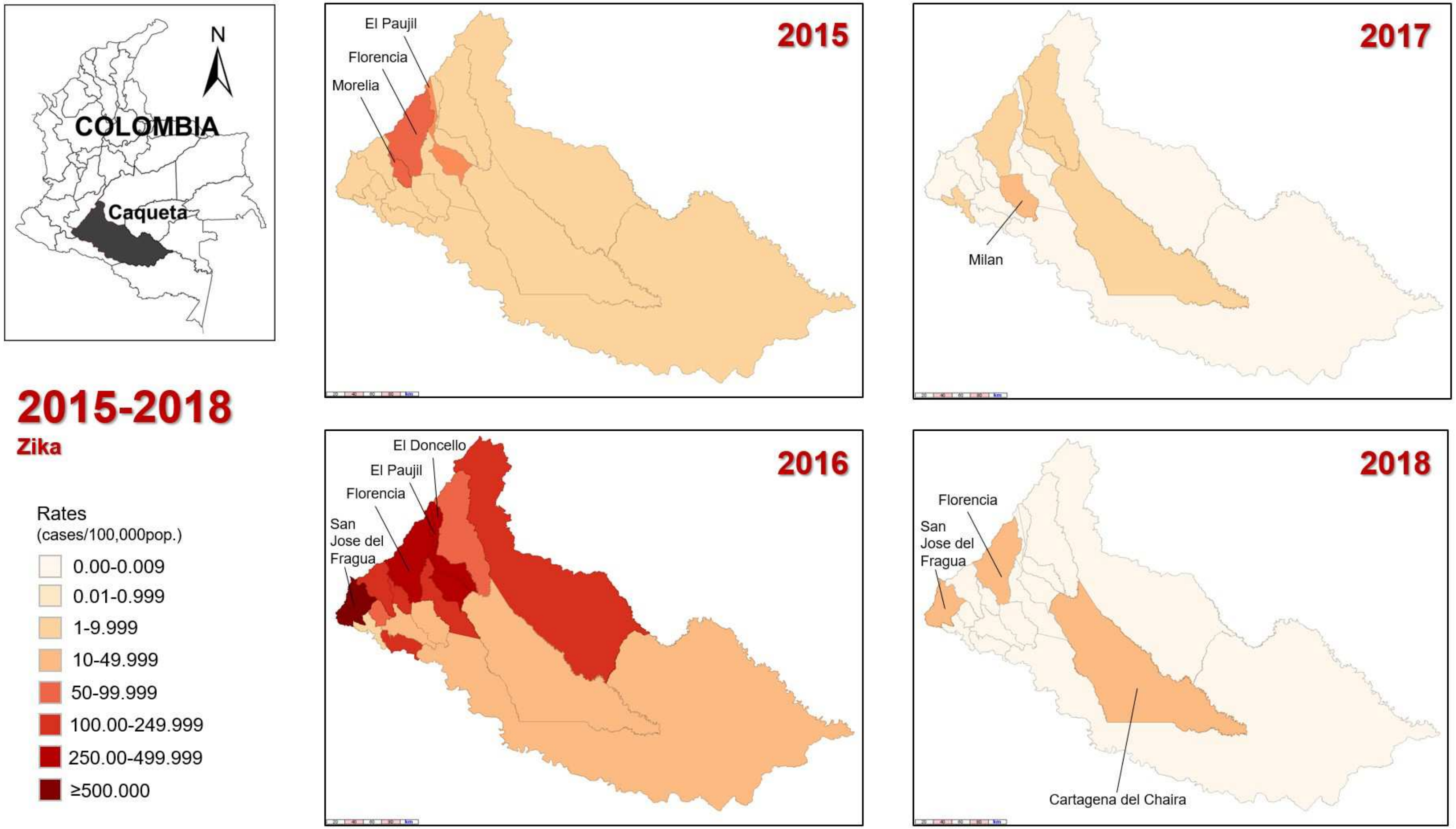


Figure 6. Geographic distribution ZIKV cases in Florencia, Caqueta, Colombia, 2015-2018 by urban communes.

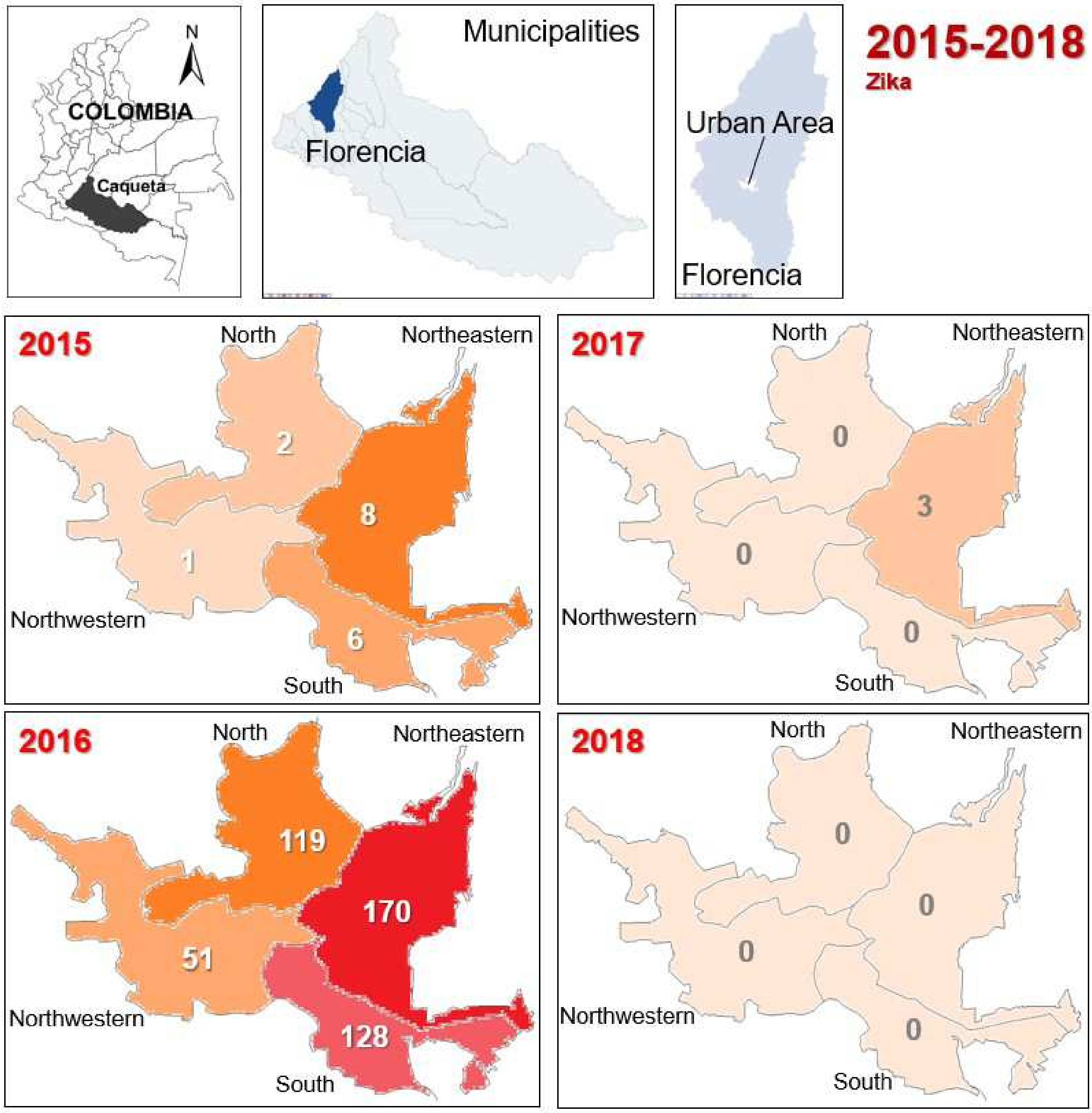
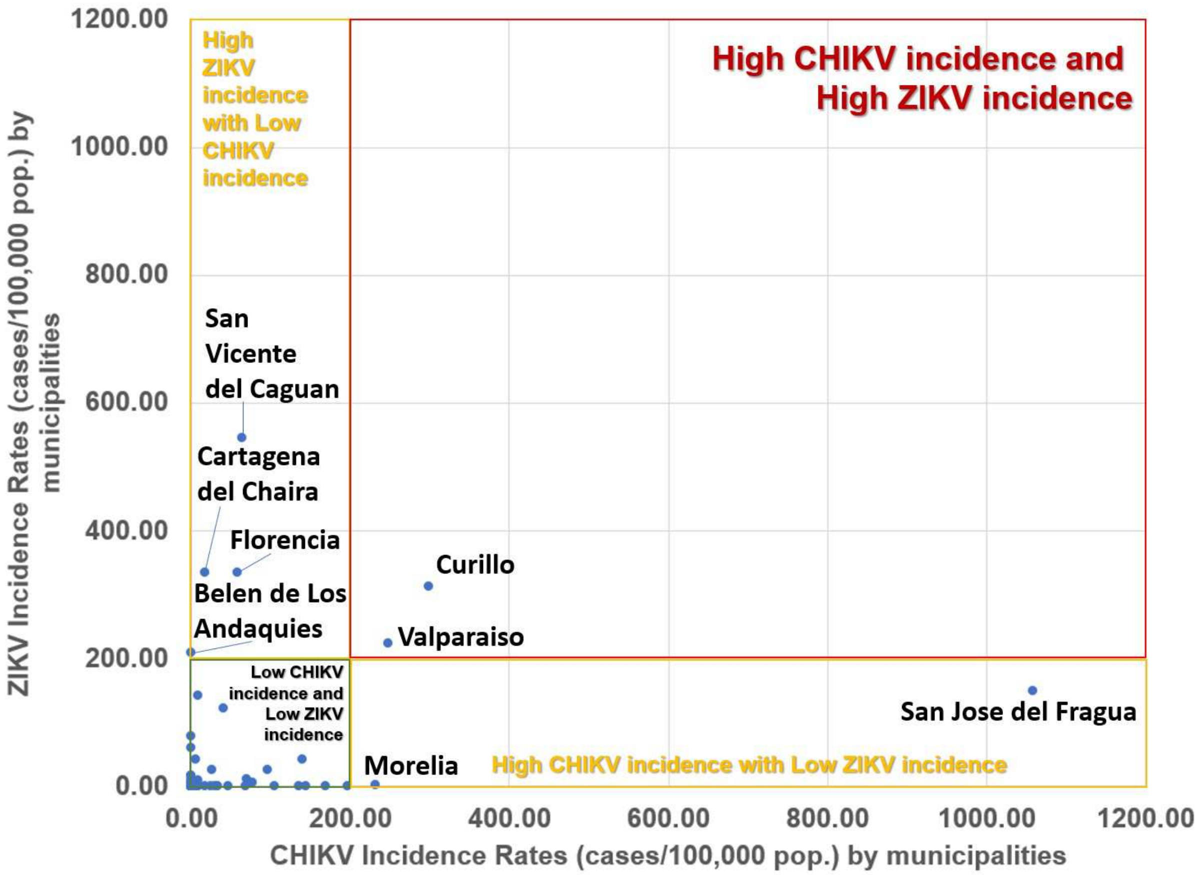


Figure 7. Geographic relationship of the distribution of CHIK and ZIKV incidence rates in Caqueta, Colombia, 2015-2018 by municipalities. With a non-linear regression, CHIKV slightly predicted the ZIKV distribution (r^2=0.1829; p=0.0019).



Credit Authorship

Study design: AJRM, DKBA, Data collection: JBA, JJGB, Data analysis: AJRM, DKBA, Writing: All authors. All authors contributed to and approved of the final version submitted.