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Original Research Article

Spatial Distribution of Zika in Honduras during 2016-2017 using Geographic Information Systems (GIS) – Implications in Public Health and Travel Medicine◊

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Abstract

Background: Zika virus (ZIKV) infection has affected significantly Latin America in 2015-2017. However, most studies have been reported from Brazil and Colombia, but few of them in Central America. For these reasons we analyzed the incidence, incidence rates and evolution of cases of Honduras during 2016-2017.

Methods: Using epidemiological weeks (EW) surveillance data on the ZIKV epidemics in Honduras, we estimated incidence rates (cases/100,000 population), and developed maps at national, departments and municipal levels.

Results: From January 1, 2016 to December 31, 2017, a total of 32,607 cases of Zika were reported (98.5% in 2016 for an incidence rate of 36.85 cases/100,000 pop; 1% confirmed by RT-PCR). The highest peak was reached on the EW 6°, 2016 (2,559 cases; 29.34 cases/100,000 pop). The department with the highest number of cases and incidence rate was Cortés (13,128 cases, 791.08 cases/100,000 pop in 2016).

Discussion: Pattern and evolution of Zika in Honduras has been like those that occurred for chikungunya in 2015, that we analyzed and previously reported, affecting predominantly the central and capital area of the country, reaching also high incidences there >750 cases/100,000 pop. Studies using geographical information systems, to map its epidemiology, as well on the clinical aspects linked to, are necessary in this country, as well for the assessment of risk for travelers who visit specific areas in a destination country.

Keywords

Zika virus (ZIKV); geographical information systems (GIS); public health; travelers; arboviruses; infectious diseases epidemiology; Honduras.

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Introduction

During the last few years, a significant number of unexposed tropical and subtropical geographic areas has been threatened by an unprecedented explosion of emerging arboviral outbreaks [1], due to a number of factors such as climate change [2, 3], increasing international travel, foreign trade [4, 5], susceptible geographical areas, among other factors [6-10]. In December 2013, Chikungunya virus (CHIKV) arrived to the Americas [11], followed shortly by Zika virus (ZIKV) in 2013-2015 [12], but certainly in addition to previous endemoepidemic seasons of urban Dengue virus (DENV) and sylvatic Yellow fever virus (YFV) [2, 4, 5, 13, 14].

In the case of Central America, according the Pan-American Health Organization (PAHO) [15], at this region, 71,316 cases of Zika were reported between 2015-2017 (11% confirmed by RT-PCR), with >45% of them occurring just in Honduras (Figure 1), posing this country as the one with the highest number reported in the region. Although that, there is lack of studies about ZIKV in this country [16-20], except for a letter to the editor on a multicountry series including Honduras about ZIKV-associated Guillain–Barré Syndrome reporting an analysis of the surveillance of both conditions between April 1, 2015, to March 31, 2016 [21]; and some case reports about neurological complications such as the sensory polyneuropathy [22]. Besides that, these have highlighted the relevant source of imported cases to other countries overseas, given the touristic attractions in the country, including the Roatán and the Bay Islands [17-19].

ZIKV was first detected in Honduras in late December 2015 [23, 24]. After that, mandatory surveillance of ZIKV and their complications was established in the country, including the participation in the World Federation of Neurology Task Force on ZIKV [25]. Coincidence with the beginning of the epidemics in the country (Figure 1), it was declared as a public health emergency by the World Health Organization (WHO) since February 2016, when it has spread to more than

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148 countries around the world, especially, in Latin America, where facilitating factors converge and have challenged the existing response capacities of local health systems [5, 7, 16, 26].

The ZIKV epidemics in countries such as Brazil and Colombia stimulated multiple epidemiological, basic and clinical studies, given the fact there are still no licensed vaccinations or treatment for ZIKV available. Also, the control of the *Aedes aegypti* mosquito is critical to curb the spread of the virus [18, 24, 26, 27]. Then, many preventive measures have been taken focused on controlling the propagation of vectors, as in community actions for detection and elimination of mosquito-breeding, and GIS-based epidemiological maps, that allow to integrate preventive and control strategies. Previous assessments for DENV and CHIKV in Honduras have been performed by our group showing its relevance for public health decisions and travel advice [6]. This has been also showed in other countries in Latin America [6, 8, 9, 13, 28, 29].

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. For example, the PAHO currently streamlines reports from ministries of health, and reports weekly confirmed and suspected cases of ZIKV by country [26, 29-34]. These reports have allowed to know about the global situation of the region regard ZIKV [6], nevertheless there is no detailed information about specific places, departments or municipalities or cities, which certainly are necessary to make more specific recommendations to travelers as well for public health prioritization and policies [30, 32, 35, 36].

Understanding the impact of arboviruses, especially from ZIKV, in terms of clinical compromise, disability and costs to the health system, requires a greater proportion of investigations involving multiple medical specialties, mainly in susceptible countries such Honduras, in order to be prepared to control possible future epidemics of new arboviruses [10, 13].

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As part of enhanced efforts in control and risk assessment for ZIKV in Latin America (as well for other arboviral and tropical diseases), the Public Health and Infection Research Group, of the Universidad Tecnológica de Pereira, the Ministry of Health of Honduras and the Universidad Nacional Autónoma de Honduras, among other international institutions, are working together in the academic analysis of epidemiological information of infectious diseases in regional and national scales [6, 37], including diseases such as ZIKV, DENV and CHIKV [3, 6, 29-32, 35]. In this setting, this study was aimed to estimate incidence rates of ZIKV in 2016-2017 for Honduras and its departments and municipalities and to develop GIS-based epidemiological maps for this arboviral disease in the country.

Methods

Honduras is a Central American country constituted by 18 departments (main administrative level) (Figure 2) and 298 municipalities (second administrative level) (Figures 3 and 4). The Honduran territory presents climatic, geographic and epidemiological conditions suitable for transmission of multiple infectious diseases, particularly vector-borne diseases. *Aedes aegypti*, vector of zika, is widely distributed all over the territories [6, 38]. As other tropical countries, these compromise 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 [6].

For this observational, retrospective and cross-sectional study, the epidemiological data were collected from national surveillance system, obtaining the number of cases for each department and each municipality of the country by year 2016-2017 (detailed by weeks). Data used for this study are constituted from clinically confirmed cases (suspected cases by clinical criteria

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definition) and confirmed by RT-PCR, which have been revised in terms of data quality. Data proceed for this study from 298 primary municipal notification units, collected at the 18 department notification units, later consolidated and centralized in Tegucigalpa (Francisco Morazán department, Capital District, CD) [6].

Using official reference population data (National Institute of Statistics, INE), estimates of the annual incidence rates for all the departments and municipalities of the country during the study period were calculated (cases/100,000 pop) to provide estimates of ZIKV incidence in the country and by department and municipalities [6].

In addition, national GIS-based maps, by departments and municipalities with the distribution of zika were generated. The software Microsoft Access® was the platform to design the spatial databases used, 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 departments (.shp) were linked to data table database through spatial join operation, in order to produce digital maps of annual incidence rates by departments and municipalities [6, 30, 33].

Results

From January 1, 2016 to December 31, 2017, a total of 32,607 cases of Zika were reported (1% confirmed by RT-PCR for ZIKV), 98.5% of them in 2016 for an incidence rate of 36.85 cases/100,000 pop.

The highest peak was reached on the epidemiological week (EW) 6°, 2016 (2,559 cases; 29.34 cases/100,000 pop) (Figure 1). During the first 10 EW, a total of 16,415 cases were reported (50%

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of the 2016-2017 period). Number of cases decreased till EW 12° to 93 cases (1.07 cases/100,000 pop). Then, a second peak of cases was reached during EW 24° occurred reaching 988 cases (11.33 cases/100,000 pop) (Figure 1). By the EW 35° more than 95% of the cases of the period, were reported.

Of the 18 departments of Honduras, all except Gracias a Dios, reported cases during the study period. Rates ranged from 0 to 791.08 cases/100,000 (Cortés, 2016, 40.4% of the country cases), followed by Francisco Morazán (663.53 cases/100,000, 2016; 32.7%), Yoro (350.93 cases/100,000, 2016; 6.6%), Santa Barbara (308.64 cases/100,000, 2016; 4.2%), and Olancho (265.65 cases/100,000, 2016; 4.5%) (Figure 2, Table 1). These 5 departments reported more than 88% of the ZIKV cases of the country (Table 1), being located in the central and northwestern area of the country (Figure 2).

Comparing Cortés and Francisco Morazán incidence over the time clear differences were evident. At Cortés there was a high number of cases reported during the first 12 EWs of 2016 reaching up to 109.8 cases/100,000 pop (1815 cases) during that week, for a cumulated of 11,514 cases in the three first months (35% of the cases reported in Honduras during 2016-2017) (Figure 1). In contrast, there was a low incidence in Francisco Morazán (below 20 cases/100,000 or <300 cases per week) during the same period. After that, there was a low report of cases in Cortés (<10 cases/100,000 pop) and a significant increase in Francisco Morazán that reached its peak during the EW 23° with 50.3 cases/100,000 (793 cases that week) for a cumulated of 5453 cases (17% of the cases reported in Honduras during 2016-2017) (Figure 1). Between both departments, till EW 23° more than 52% of the cases of the 2016-2017 epidemics were reported, showing a concentrated occurrence in the most populated departments having the capital (Tegucigalpa, Francisco Morazán) and second largest city of the country (San Pedro Sula, Cortés) (Table 1).

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From the total number of municipalities (298) of Honduras, 69.4% of them reported cases of ZIKV (Table 2). Rates ranged from 0 to 2,495.79 cases/100,000 (Ceguapa, Santa Barbara department, 2016), followed by Cane (La Paz department, 1,648.91 cases/100,000, 2016), San Vicente Centenario (Santa Bárbara department, 1.565,18 cases/100,000, 2016), Villanueva (Cortés department, 1.092,14 cases/100,000, 2016), and San Pedro Sula (1.063,84 cases/100,000, 2016; representing 24.6% of the cases of the country) (Figure 3, Table 2). In addition to that, Tegucigalpa, at the Capital District, reported 10,386 cases in 2016 for a rate of 860,03 cases/100,000 pop. (Figure 3).

At Francisco Morazán department, closer areas to Tegucigalpa, presented high incidence, such as Santa Lucia (193.13 cases/100,000pop) and San Buenaventura (101.25 cases/100,000pop), among others (Figure 4). Similarly, at Cortés department, municipalities such as Villanueva, Choloma, Puerto Cortes, San Manuel, La Líma, San Francisco de Yojoa, Omóa, San Antonio de Cortes and Potrerillos, surround the department capital of San Pedro Sula, with incidence rates >100 cases/100,000 pop (Figure 4) (Table 2).

Discussion

As expected, after the arrival of ZIKV to Brazil and other countries in Latin America [12, 30], Honduras would be significantly affected as is showed here in the present study. As occurred with DENV and CHIKV in 2015 [6], Francisco Morazán and Cortés, the most populated departments, were the most affected. ZIKV followed the path of dengue and chikungunya in Honduras. Those areas with high incidence rates of these, resulted to be also of high risk for ZIKV [6]. Although more than 32,000 cases were reported in the country, unfortunately, only 1% of cases have been confirmed by RT-PCR. This is related to economical limitations that does not allow to assess all the patients by laboratory (not affordable) and because still there is lack of reliable serological

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tests. Nevertheless, also PAHO use in surveillance cases that have been reported based just on clinical definition.

Social and ecoepidemiological conditions of Honduras are prone across the whole territory for arboviral diseases, such as DENV, CHIKV and ZIKV [3, 6], making such analyses relevant for future emerging arboviral diseases in the region and the country. This probably would be the case of Mayaro (MAYV), Oropouche (OROV), Venezuelan Equine Encephalitis (VEEV) or West Nile Virus (WNV), among others [1, 13, 39, 40]. Even more, considering new conditions of forced migration, originating from this country moving forward to United States of America, crossing Guatemala and Mexico, these populations would be carrying ZIKV and other arboviruses. Although last case of ZIKV was officially reported in mid-December 2017, transmission still occur with a lower number of cases (between 0 and 13 cases/week during firs 38 EW of 2018).

Central America needs more studies assessing and modeling the patterns of transmission of ZIKV and other arboviral diseases. In the region, as mentioned, Honduras was the country with highest number of cases [15]. However, small countries such as Belize, presented higher incidence rate (636 cases/100,000pop), with more than 2.000 cases during 2015-2017, but there is also a lack of studies from this country on ZIKV [41-43]. A similar situation also is seen in Panama [44, 45] and other countries in the region. Adding the cases of Central America to the rest of the continent, more than 800,000 cases were reported [15].

So far, in Honduras only 8 cases of congenital Zika syndrome (CSZ) have been reported. But this deserve further careful studies about in order to assess the frequency of ZIKV infection during pregnancy in the country and the association of microcephaly and other birth defects with ZIKV infection [20], as has been reported in Brazil and Colombia, among other countries in Latin America [46, 47].

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253 In this setting, public health tools for detailed analyses, such as the use of GIS-epidemiological
254 maps [6, 33, 35], are of high relevance for any affected country. In the case of Central American
255 territories, there is a clear lack of studies developing such maps for infectious diseases, even
256 more for DENV, CHIKV, ZIKV and the emerging arboviruses. In Honduras, a previous
257 assessment for DENV and CHIKV using GIS mapped both arboviral diseases for 2015, found
258 similar spatial distribution of them regard ZIKV in 2016 (Figures 2-4). In 2016, according the
259 Ministry of Health of Honduras, 22,961 cases of DENV and 15,896 cases of CHIKV were reported.
260 Combining the three arboviral diseases, almost 71,000 cases were reported. Although that, there
261 is a lack, not only of studies on ZIKV, but also on CHIKV and DENV, despite the fact that Honduras
262 has been particularly affected from the last, since many decades ago [48].

263

264 In the case of Honduras, the application of toolkits developed by WHO for the care and support
265 of people affected by complications associated with ZIKV have been implemented to serve as a
266 model guides, with the goal of enhancing country preparedness for ZIKV outbreaks. Such toolkits
267 are intended to provide a systems approach involving public health planners and managers so
268 that the necessary infrastructure and resources can be identified and incorporated as needed, as
269 well as technical and practical guidance for health care professionals and community workers
270 [49].

271

272 The toolkit includes three manuals to provide countries with tools to effectively recognize people
273 affected by Zika virus and deliver comprehensive care and support:

274

275 In this study, we estimated the incidence rates of ZIKV, and generated epidemiological maps for
276 them in two geographical levels (departments and municipalities). ZIKV appears to followed the
277 patterns of other arboviral diseases in the country [6], then, as we did, integral epidemiological

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study is essential from now and go on for this arbovirus. Although, as has been stated, this may not provide all the answers, particularly from the clinical point of view is particularly useful for public health evidenced-based decisions [50]. Developed maps, would provide a baseline epidemiological information for multiple assessment of the differentiated risk related of acquire such diseases in certain areas (departments and municipalities) of Honduras, as has been proposed particularly for DENV and CHIKV [3, 6].

Use of GIS-based epidemiological maps allow to integrate preventive and control strategies, as well public health policies, for joint control of these vector-borne diseases in Honduras [6, 30-32, 35, 36], which also should be followed by other countries in Central America. For other emerging arboviruses, these tools would be also important to be developed. GIS-based maps for emerging diseases are of utmost importance for public health decisions in Honduras.

In addition to the public health implications, use of these maps would also provide relevant information in order to assess the risk of travelers with specific destinations in highly transmission areas with the idea of giving prevention advice [6, 30-32, 35, 36, 51], even more because they play also an important role in the virus spread, as occurs with the arrival of chikungunya and Zika from other countries (imported cases) to Honduras and other countries in Latin America.

In the case of ZIKV, previous studies at the department of Islas de la Bahía (Bay Islands), which include Roatan, is a highly visible and visited destination among tourists during all seasons. This area has a considerable occurrence of DENV and CHIKV, as showed previously [6], then highlighting the need for increased prevention of national and international travelers visiting this touristic areas. Recently, a study specifically at Roatán found with molecular diagnosis the co-circulation of ZIKV, DENV and CHIKV [18].

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Roatan is constantly receiving international cruise ships, with the consequent epidemiological implications, as above described [6]. Now, in the department of Colon (with 47.39 cases/100,000 pop of ZIKV in 2016), which includes Trujillo (3.14 cases/100,000 pop of ZIKV in 2016) with its port Puerto Castilla, there is large industrial development with an international hub for cruise ships. This last, is also for consideration regard travel medicine and public health for ZIKV and other arboviral diseases in Honduras. In fact, these conditions have been suitable for acquisition of ZIKV by international travelers in Honduras, as has been reported in Madrid, Spain [19], in a young female visiting Tegucigalpa and Choluteca (both above 200 cases/100,000pop in the current study). That patient also acquired CHIKV.

In the near future, other ecoepidemiological assessments should be performed in Honduras for these arboviral diseases. With warmer temperatures during the whole year, susceptible individuals and high presence of vectors, particularly of these municipalities, now they are becoming endemic for ZIKV in addition to CHIKV and DENV [6].

Finally, GIS-based maps provide relevant information to assess the risk of travelers to specific destinations in highly transmission areas allowing detailed prevention advices [36]. Use of GIS-based epidemiological maps allows to integrate prevention and control strategies, as well as public health policies, for joint control of this vector-borne disease in this and other countries of the region [52]. Simultaneous or sequential arboviral infections occur and should be also assessed and eventually mapped if is subject of surveillance [53-55]. Preparedness in this setting should also consider the potential arrival of Mayaro [13, 40], Oropouche and Yellow Fever in *Aedes* infested areas [56].

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Data availability

Raw data for is available and will be provided on request.

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Table 1. ZIKV incidence rates (cases/100,000pop) by departments, Honduras, 2016-2017.

	Cases		Population		Rates*	
Department	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Cortés	13,082	90	1,653,699	1,686,094	791.08	5.34
Francisco Morazán	10,465	189	1,577,178	1,601,291	663.53	11.80
Yoro	2,092	58	596,138	604,844	350.93	9.59
Santa Bárbara	1,364	13	441,939	448,942	308.64	2.90
Olancho	1,450	12	545,835	554,282	265.65	2.16
Choluteca	1,037	3	453,360	458,871	228.74	0.65
El Paraíso	905	13	465,864	473,277	194.26	2.75
Copán	361	6	388,810	394,890	92.85	1.52
La Paz	181	3	209,783	213,499	86.28	1.41
Atlántida	373	19	457,031	464,288	81.61	4.09
Islas de la Bahía	51	0	67,704	69,493	75.33	0.00
Comayagua	392	22	521,748	531,676	75.13	4.14
Valle	101	1	180,772	182,996	55.87	0.55
Colón	154	19	324,950	330,105	47.39	5.76
Ocotepeque	58	25	154,251	157,018	37.60	15.92
Intibucá	45	1	246,258	250,959	18.27	0.40
Lempira	21	1	339,310	345,489	6.19	0.29
Gracias a Dios	0	0	96,384	98,337	0.00	0.00
Total	32,132	475	8,721,014	8,866,351	368.44	0.54

*Cases per 100,000 pop.

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Table 2. ZIKV incidence rates (cases/100,000pop) by municipalities, Honduras, 2016-2017.

		Cases		Population		Rates*				Cases		Population		Rates*	
Departments	**Municipalities**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**Departments**	**Municipalities**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Santa Bárbara	Ceguapa	131	5	5,249	5,353	**2,495.79**	93.41	El Paraíso	San Matías	1	1	5,250	5,321	19.05	18.79
La Paz	Cáne	66	1	4,003	4,150	**1,648.91**	24.10	Colón	Santa Fé	1	0	5,390	5,376	18.55	0.00
Santa Bárbara	San Vicente Centenario	58	0	3,706	3,736	**1,565.18**	0.00	Santa Bárbara	San Pedro de Zacapa	2	0	10,790	10,868	18.54	0.00
Cortés	Villanueva	1,765	14	161,609	165,602	**1,092.14**	8.45	Colón	Santa Rosa de Aguan	1	0	5,463	5,498	18.30	0.00
Copán	San Pedro Sula	**8,022**	29	754,061	765,999	**1,063.84**	3.79	Comayagua	Ajuterique	2	0	11,579	11,655	17.27	0.00
Santa Bárbara	Quimistan	474	0	52,884	54,638	896.30	0.00	Comayagua	Lejamani	1	0	5,831	5,883	17.15	0.00
El Paraíso	Jacaleapa	36	1	4,126	4,186	872.55	23.89	Atlántida	Lamasica	5	2	30,619	31,034	16.33	6.44
Yoro	El Progreso	1,678	52	193,567	195,247	866.88	26.63	Olancho	Yocon	2	0	12,375	12,566	16.16	0.00
Francisco Morazán	Tegucigalpa M.D.C.	**10,386**	189	1,207,635	1,225,043	860.03	15.43	Intibucá	Intibuca	9	0	60,264	61,695	14.93	0.00
Cortés	Choloma	2,100	14	249,217	255,625	842.64	5.48	Comayagua	San José del Potrero	1	0	7,018	7,125	14.25	0.00
Olancho	Silca	65	0	8,087	8,135	803.73	0.00	Ocotepeque	San Marcos	3	7	21,068	21,448	14.24	32.64
Santa Bárbara	La Arada	79	1	10,220	10,433	773.00	9.58	Olancho	Salamá	1	0	7,778	7,859	12.86	0.00
Olancho	Juticalpa	821	9	132,484	135,076	619.70	6.66	Francisco Morazán	Villa de San Francisco	1	0	8,641	8,755	11.57	0.00
Santa Bárbara	Nuevo Celilac	49	0	8,166	8,185	600.04	0.00	Choluteca	Orocuína	2	0	18,578	18,676	10.77	0.00
Islas de la Bahía	Utila	24	0	4,277	4,400	561.08	0.00	Intibucá	Colomoncagua	2	1	18,613	18,737	10.75	5.34
Copán	Santa Rosa	354	6	65,233	66,629	542.67	9.01	El Paraíso	Soledad	1	0	9,352	9,352	10.69	0.00
Santa Bárbara	San Jose de Colinas	104	2	19,266	19,407	539.82	10.31	La Paz	Yarula	1	0	9,356	9,522	10.69	0.00
Santa Bárbara	Trinidad	101	0	20,325	20,563	496.93	0.00	Olancho	San Francisco de La Paz	2	0	19,937	20,183	10.03	0.00
Choluteca	San Antonio de Flores	27	1	5,463	5,470	494.25	18.28	Ocotepeque	La Labor	1	0	10,012	10,188	9.99	0.00
Olancho	Guayape	60	0	13,027	13,152	460.60	0.00	Valle	Langue	2	0	21,275	21,387	9.40	0.00
Santa Bárbara	Concepción del Sur	25	0	5,514	5,517	453.42	0.00	Francisco Morazán	Ojona	1	0	10,872	11,017	9.20	0.00
Choluteca	Pespire	106	0	24,024	24,063	441.22	0.00	Francisco Morazán	Vallecillos	1	0	10,981	11,147	9.11	0.00
Olancho	Santa María del Real	47	0	10,823	10,875	434.25	0.00	Colón	Sonagera	4	1	44,574	45,073	8.97	2.22
Cortés	Puerto Cortes	538	25	127,968	129,961	420.42	19.24	Olancho	Manto	1	0	11,697	11,748	8.55	0.00
Cortés	San Manuel	241	1	58,927	61,159	408.98	1.64	La Paz	Santa Ana	1	0	12,304	12,486	8.13	0.00
Choluteca	San Isidro	14	0	3,765	3,793	371.81	0.00	Francisco Morazán	Santa Ana	1	0	16,661	16,889	6.00	0.00
Yoro	El Negrito	170	0	47,104	47,663	360.91	0.00	Santa Bárbara	Protección	1	0	17,013	17,220	5.88	0.00
Valle	San Francisco de Coray	35	0	9,859	9,910	355.00	0.00	Francisco Morazán	Valle de Angeles	1	0	18,189	18,747	5.50	0.00
Choluteca	Choluteca	549	2	159,739	162,125	343.69	1.23	Atlántida	Arizona	1	0	24,345	24,578	4.11	0.00
El Paraíso	Danlí	688	8	206,922	210,742	332.49	3.80	Copán	Santa Rita	1	0	31,072	31,455	3.22	0.00
La Paz	San Antonio del Norte	9	0	2,817	2,851	319.49	0.00	Colón	Trujillo	2	6	63,622	64,688	3.14	9.28
La Paz	San Júan	8	0	2,539	2,571	315.03	0.00	Copán	Copan Ruinas	1	0	40,219	40,952	2.49	0.00
Santa Bárbara	Santa Barbara	123	2	44,182	45,002	278.40	4.44	Copán	Nueva Arcadia	1	0	42,590	43,346	2.35	0.00
Choluteca	Marcóvia	121	0	46,725	47,113	258.96	0.00	Atlántida	San Francisco	0	0	15,277	15,531	0.00	0.00
Olancho	Catacámas	318	2	124,599	126,982	255.22	1.58	Colón	Iriona	0	0	21,461	21,716	0.00	0.00
Comayagua	San Jerónimo	53	0	22,064	22,441	240.21	0.00	Comayagua	Lajas	0	0	15,038	15,284	0.00	0.00
Islas de la Bahía	Guanaja	13	0	5,595	5,663	232.34	0.00	Comayagua	La Trinidad	0	0	4,694	4,755	0.00	0.00
Cortés	La Líma	177	0	76,823	78,596	230.40	0.00	Comayagua	Meambar	0	0	13,092	13,287	0.00	0.00
Santa Bárbara	Nueva Frontera	29	3	13,395	13,504	216.49	22.22	Comayagua	San José de Comayagua	0	0	7,882	7,909	0.00	0.00
Choluteca	El Triunfo	99	0	45,741	46,490	216.44	0.00	Comayagua	Lamaní	0	0	7,176	7,239	0.00	0.00
Choluteca	Santa Ana de Yusguare	30	0	14,717	14,813	203.84	0.00	Copán	Cabañas	0	0	14,725	15,082	0.00	0.00
El Paraíso	Yuscaran	30	0	14,974	15,271	200.34	0.00	Copán	Concepción	0	0	8,311	8,524	0.00	0.00
Santa Bárbara	Petoa	25	0	12,501	12,617	199.98	0.00	Copán	Corquin	0	0	17,542	17,940	0.00	0.00
Choluteca	Morolíca	10	0	5,007	5,012	199.70	0.00	Copán	Cucuyagua	0	0	17,042	17,379	0.00	0.00
Francisco Morazán	Santa Lucía	26	0	13,463	14,065	193.13	0.00	Copán	Dolores	0	0	6,777	6,902	0.00	0.00
El Paraíso	Alauca	18	1	9,354	9,433	192.43	10.60	Copán	Dulce Nombre	0	0	6,116	6,273	0.00	0.00
Cortés	San Francisco de Yojoa	42	0	23,097	23,499	181.84	0.00	Copán	El Paraíso	0	0	20,053	20,104	0.00	0.00
El Paraíso	Liure	19	0	10,808	10,852	175.80	0.00	Copán	Florida	0	0	29,134	29,400	0.00	0.00
Francisco Morazán	La Libertad	5	0	2,869	2,900	174.25	0.00	Copán	La Jigua	0	0	9,579	9,677	0.00	0.00
Santa Bárbara	Concepción del Norte	16	0	9,303	9,405	171.98	0.00	Copán	La Union	0	0	16,463	16,612	0.00	0.00
Ocotepeque	Nueva Ocotepeque	38	12	24,337	24,770	156.14	48.45	Copán	San Agustin	0	0	5,721	5,801	0.00	0.00
Santa Bárbara	El Nispero	13	0	8,580	8,745	151.52	0.00	Copán	San Antonio	0	0	10,064	10,185	0.00	0.00
Olancho	Patuca	40	0	27,433	27,671	145.81	0.00	Copán	San Jeronimo	0	0	5,097	5,120	0.00	0.00
Comayagua	Humuya	2	1	1,378	1,399	145.10	71.49	Copán	San José	0	0	7,152	7,218	0.00	0.00
Santa Bárbara	Ilama	13	0	9,137	9,160	142.28	0.00	Copán	San Juan de Opoa	0	0	9,750	9,788	0.00	0.00
Ocotepeque	Sinuapa	13	6	9,371	9,601	138.73	62.49	Copán	San Nicolas	0	0	7,932	8,068	0.00	0.00
Atlántida	La Ceíba	285	11	207,733	211,327	137.20	5.21	Copán	San Pedro	0	0	7,716	7,772	0.00	0.00
Santa Bárbara	Macuelizo	49	0	36,058	36,607	135.89	0.00	Copán	Veracrus	0	0	3,399	3,447	0.00	0.00
Yoro	Jocom	13	0	9,687	9,710	134.20	0.00	Choluteca	Apacilagua	0	0	9,084	9,093	0.00	0.00
Choluteca	San José	6	0	4,543	4,633	132.08	0.00	Choluteca	Concepción de Maria	0	0	27,469	27,687	0.00	0.00
Cortés	Omóa	63	5	48,495	49,749	129.91	10.05	El Paraíso	Guinópe	0	0	8,949	9,107	0.00	0.00
Cortés	San Antonio de Cortes	29	1	22,386	22,498	129.54	4.44	El Paraíso	Oropolí	0	0	6,053	6,090	0.00	0.00
Olancho	Campamento	27	0	21,283	21,814	126.86	0.00	El Paraíso	San Antonio de Flores	0	0	5,729	5,783	0.00	0.00
Olancho	El Rosário	5	0	4,282	4,298	116.76	0.00	Francisco Morazán	Alubaren	0	0	5,566	5,576	0.00	0.00
Olancho	San Esteban	30	0	26,488	26,781	113.26	0.00	Francisco Morazán	Curaren	0	0	20,775	20,924	0.00	0.00
Comayagua	Siguatepeque	114	12	101,316	103,506	112.52	11.59	Francisco Morazán	La Venta	0	0	6,353	6,421	0.00	0.00
La Paz	La Paz	52	1	47,452	48,640	109.58	2.06	Francisco Morazán	Lepaterique	0	0	21,245	21,767	0.00	0.00
Cortés	Potrerillos	26	0	24,626	24,958	105.58	0.00	Francisco Morazán	Maraita	0	0	6,867	6,927	0.00	0.00
Santa Bárbara	Naranjito	13	0	12,447	12,637	104.45	0.00	Francisco Morazán	Marale	0	0	9,183	9,199	0.00	0.00
La Paz	Aguanqueterique	5	0	4,846	4,888	103.17	0.00	Francisco Morazán	Nueva Armenia	0	0	3,782	3,880	0.00	0.00
Yoro	Yorito	21	0	20,372	20,926	103.09	0.00	Francisco Morazán	Oríca	0	0	14,398	14,604	0.00	0.00
Comayagua	La Libertad	28	0	27,652	28,275	101.26	0.00	Francisco Morazán	Reitoca	0	0	10,735	10,761	0.00	0.00
Francisco Morazán	San Buenaventura	3	0	2,963	3,029	101.25	0.00	Francisco Morazán	San Antonio De Oriente	0	0	15,446	15,598	0.00	0.00
Colón	Balfate	13	0	13,273	13,326	97.95	0.00	Francisco Morazán	San Miguelito	0	0	1,943	1,957	0.00	0.00
Yoro	Olanchito	105	5	110,437	112,444	95.08	4.45	Francisco Morazán	Talanga	0	0	36,285	36,733	0.00	0.00
El Paraíso	El Paraíso	43	1	45,638	45,920	94.22	2.18	Francisco Morazán	Tatumbla	0	0	7,799	8,018	0.00	0.00
Colón	Sava	29	0	30,949	31,402	93.70	0.00	Gracias a Dios	Puerto Lempira	0	0	51,702	53,131	0.00	0.00
Choluteca	San Marcos de Colon	26	0	28,102	28,679	92.52	0.00	Gracias a Dios	Brus Laguna	0	0	13,505	13,801	0.00	0.00
El Paraíso	Morocelí	16	0	17,458	17,764	91.65	0.00	Gracias a Dios	Ahuas	0	0	8,539	8,694	0.00	0.00
Colón	Tocóa	87	10	96,360	98,602	90.29	10.14	Gracias a Dios	Juan Francisco Bulnes	0	0	6,417	6,428	0.00	0.00
Comayagua	Comayagua	139	6	155,948	159,904	89.13	3.75	Gracias a Dios	Ramón Villeda Morales	0	0	10,348	10,365	0.00	0.00
Choluteca	Duyure	3	0	3,529	3,537	85.01	0.00	Gracias a Dios	Wampusirpe	0	0	5,873	5,919	0.00	0.00
Santa Bárbara	San Luis	21	0	25,033	25,166	83.89	0.00	Intibucá	Dólores	0	0	5,434	5,537	0.00	0.00
Yoro	Victória	29	0	34,848	35,475	83.22	0.00	Intibucá	Magdalena	0	0	4,455	4,489	0.00	0.00
Choluteca	Namasigue	26	0	31,536	32,096	82.44	0.00	Intibucá	Masaguara	0	0	16,566	16,794	0.00	0.00

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Cortés	Santa Cruz de Yojoa	70	0	86,590	88,054	80.84	0.00	Intibucá	San Isidro	0	0	4,701	4,812	0.00	0.00
Valle	San Lorenzo	34	1	43,977	44,917	77.31	2.23	Intibucá	San Júan	0	0	14,138	14,390	0.00	0.00
Valle	Caridad	3	0	3,980	4,000	75.37	0.00	Intibucá	San Marcos de La Sierra	0	0	9,123	9,285	0.00	0.00
Intibucá	Jesus de Otoro	22	0	30,073	30,663	73.15	0.00	Intibucá	San Miguelito	0	0	8,006	8,236	0.00	0.00
El Paraíso	Yauyupe	1	0	1,378	1,394	72.57	0.00	Intibucá	Santa Lucia	0	0	5,382	5,434	0.00	0.00
Choluteca	El Corpus	18	0	25,337	25,591	71.04	0.00	Intibucá	Yamarangíla	0	0	21,946	22,258	0.00	0.00
Olancho	Gualaco	16	0	22,552	22,769	70.95	0.00	Intibucá	San Francisco de Opalaca	0	0	11,685	12,024	0.00	0.00
El Paraíso	Potrerillos	3	0	4,553	4,663	65.89	0.00	Islas de la Bahía	Jose Santos Guardiola	0	0	11,698	11,823	0.00	0.00
Yoro	Santa Ríta	13	0	20,710	20,841	62.77	0.00	La Paz	Cabañas	0	0	3,492	3,579	0.00	0.00
Comayagua	San Luis	7	0	11,561	11,718	60.55	0.00	La Paz	Lauterique	0	0	3,040	3,060	0.00	0.00
Comayagua	Villa de San Antonio	15	1	24,824	25,234	60.43	3.96	La Paz	Mercedes de Oriente	0	0	1,124	1,138	0.00	0.00
Yoro	Morazán	26	1	43,163	44,188	60.24	2.26	La Paz	Opatoro	0	0	7,662	7,754	0.00	0.00
La Paz	Santiago de Puringla	10	0	16,782	16,978	59.59	0.00	La Paz	San Pedro de Tutule	0	0	7,290	7,421	0.00	0.00
Intibucá	Camasca	4	0	6,924	6,977	57.77	0.00	La Paz	Santa Elena	0	0	12,904	13,139	0.00	0.00
Francisco Morazán	El Porvenir	13	0	22,611	23,655	57.49	0.00	Lempira	Belen	0	0	7,477	7,720	0.00	0.00
El Paraíso	Texiguat	5	0	8,817	8,841	56.71	0.00	Lempira	Candelaria	0	0	6,896	6,931	0.00	0.00
El Paraíso	Teupasénti	25	0	44,442	45,417	56.25	0.00	Lempira	Cololaca	0	0	9,401	9,715	0.00	0.00
Copán	Trinidad	4	0	7,122	7,215	56.17	0.00	Lempira	Erandique	0	0	15,823	16,009	0.00	0.00
Atlántida	Jutiápa	20	1	35,690	36,207	56.04	2.76	Lempira	Gualcince	0	0	11,697	11,826	0.00	0.00
Comayagua	Ojos de Agua	6	0	10,739	10,873	55.87	0.00	Lempira	Guarita	0	0	8,577	8,646	0.00	0.00
Valle	Guascoran	8	0	14,441	14,489	55.40	0.00	Lempira	La Campa	0	0	7,172	7,408	0.00	0.00
Santa Bárbara	Azacualpa	11	0	21,693	22,240	50.71	0.00	Lempira	La Iguala	0	0	27,508	28,219	0.00	0.00
Atlántida	Téla	51	5	100,650	102,018	50.67	4.90	Lempira	Las Flores	0	0	6,662	6,682	0.00	0.00
Santa Bárbara	Santa Rita	2	0	4,020	4,036	49.75	0.00	Lempira	La Unión	0	0	10,005	10,172	0.00	0.00
El Paraíso	Vado Ancho	2	0	4,050	4,071	49.38	0.00	Lempira	La Virtud	0	0	13,463	13,791	0.00	0.00
Yoro	Sulaco	9	0	18,517	18,866	48.60	0.00	Lempira	Lepaera	0	0	38,445	39,004	0.00	0.00
La Paz	Chinacla	4	0	8,232	8,366	48.59	0.00	Lempira	Mapulaca	0	0	4,338	4,360	0.00	0.00
Santa Bárbara	Las Vegas	12	0	25,196	25,596	47.63	0.00	Lempira	Piraera	0	0	14,306	14,485	0.00	0.00
La Paz	Guajiquiro	7	0	15,138	15,317	46.24	0.00	Lempira	San Andres	0	0	13,807	14,028	0.00	0.00
Cortés	Pimienta	9	1	19,899	20,394	45.23	4.90	Lempira	San Francisco	0	0	9,205	9,260	0.00	0.00
La Paz	Marcala	13	1	30,504	31,148	42.62	3.21	Lempira	San Juan de Guarita	0	0	2,693	2,710	0.00	0.00
Francisco Morazán	Sabana Grande	9	0	21,445	21,781	41.97	0.00	Lempira	San Manuel de Colohete	0	0	14,854	15,123	0.00	0.00
Colón	Bonito Oriental	12	0	29,087	29,313	41.25	0.00	Lempira	San Rafael	0	0	13,938	14,109	0.00	0.00
Lempira	Gracias	21	1	51,635	53,018	40.67	1.89	Lempira	San Sebastian	0	0	11,069	11,279	0.00	0.00
Valle	Alianza	3	0	7,544	7,562	39.77	0.00	Lempira	Santa Cruz	0	0	7,258	7,429	0.00	0.00
Ocotepeque	Santa Fe	2	0	5,090	5,174	39.30	0.00	Lempira	Talgua	0	0	10,908	11,071	0.00	0.00
Olancho	Dulce Nombre del Culmi	12	1	30,836	31,118	38.92	3.21	Lempira	Tambla	0	0	3,291	3,360	0.00	0.00
Santa Bárbara	San Marcos	6	0	15,709	15,857	38.20	0.00	Lempira	Tomalá	0	0	6,574	6,652	0.00	0.00
Olancho	La Unión	3	0	7,949	8,038	37.74	0.00	Lempira	Valladolid	0	0	3,774	3,802	0.00	0.00
Intibucá	San Antonio	2	0	5,614	5,658	35.62	0.00	Lempira	Virginia	0	0	2,588	2,605	0.00	0.00
Colón	Limón	5	2	14,770	15,112	33.85	13.23	Lempira	San Marcops de Caiquin	0	0	5,946	6,076	0.00	0.00
Santa Bárbara	San Nicolas	5	0	15,112	15,360	33.09	0.00	Ocotepeque	Belen Gualcho	0	0	16,276	16,568	0.00	0.00
Intibucá	La Esperanza	4	0	12,955	13,413	30.88	0.00	Ocotepeque	Concepción	0	0	5,344	5,439	0.00	0.00
Yoro	Yoro	28	0	91,751	93,489	30.52	0.00	Ocotepeque	Dolores Merendon	0	0	4,140	4,287	0.00	0.00
Islas de la Bahía	Roatan	14	0	46,133	47,608	30.35	0.00	Ocotepeque	Fraternidad	0	0	5,769	6,111	0.00	0.00
El Paraíso	Las Trojes	15	1	50,047	51,011	29.97	1.96	Ocotepeque	Lucerna	0	0	6,083	6,157	0.00	0.00
Comayagua	El Rosario	9	2	30,687	31,339	29.33	6.38	Ocotepeque	Mercedes	0	0	7,423	7,491	0.00	0.00
Comayagua	Esquias	6	0	21,262	21,514	28.22	0.00	Ocotepeque	San Fernando	0	0	7,126	7,184	0.00	0.00
Comayagua	San Sebastian	1	0	3,631	3,629	27.54	0.00	Ocotepeque	San Francisco del Valle	0	0	9,946	10,051	0.00	0.00
Valle	Nacaome	16	0	59,291	59,970	26.99	0.00	Ocotepeque	San Jorge	0	0	5,258	5,336	0.00	0.00
Santa Bárbara	San Francisco de Ojuera	2	0	7,441	7,595	26.88	0.00	Ocotepeque	Sesenti	0	0	11,776	11,881	0.00	0.00
La Paz	Santa María	3	0	11,250	11,404	26.67	0.00	Olancho	Concordia	0	0	8,418	8,498	0.00	0.00
Atlántida	Esparta	5	0	19,125	19,364	26.14	0.00	Olancho	Esquipulas del Norte	0	0	11,135	11,496	0.00	0.00
Atlántida	El Porvenir	6	0	23,592	24,228	25.43	0.00	Olancho	Guarizama	0	0	7,896	7,942	0.00	0.00
El Paraíso	San Lucas	2	0	7,963	8,057	25.12	0.00	Olancho	Guata	0	0	12,236	12,385	0.00	0.00
Francisco Morazán	San Júan de Flores	4	0	16,457	16,857	24.31	0.00	Olancho	Jano	0	0	4,943	5,083	0.00	0.00
Francisco Morazán	Guaimáca	7	0	29,438	29,923	23.78	0.00	Olancho	Mangulile	0	0	9,481	9,495	0.00	0.00
Comayagua	Minas de Oro	3	0	13,445	13,548	22.31	0.00	Olancho	San Francisco de Becerra	0	0	10,096	10,318	0.00	0.00
Francisco Morazán	San Ignacio	2	0	9,036	9,119	22.13	0.00	Santa Bárbara	Atima	0	0	18,752	19,132	0.00	0.00
La Paz	San José	2	0	9,047	9,086	22.11	0.00	Santa Bárbara	Chinda	0	0	4,886	4,947	0.00	0.00
Comayagua	Taulabe	5	0	24,930	25,158	20.06	0.00	Santa Bárbara	Gualala	0	0	5,361	5,416	0.00	0.00
Francisco Morazán	Cedros	5	0	25,539	26,003	19.58	0.00	Valle	Amapala	0	0	13,020	13,302	0.00	0.00
Intibucá	Concepción	2	0	10,379	10,557	19.27	0.00	Valle	Aramecina	0	0	7,384	7,460	0.00	0.00
Ocotepeque	La Encarnación	1	0	5,232	5,330	19.11	0.00	Yoro	Arenal	0	0	5,983	5,995	0.00	0.00
									Total	32,132	475	8,721,014	8,866,351	368.44	5.36

*Cases per 100,000 pop.

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Figure 1. Temporal distribution by epidemiological weeks of number of cases of Zika in Honduras, 2015-2016 (A), and the comparison between the evolution during 2016 at Cortés and Francisco Morazán departments (B).

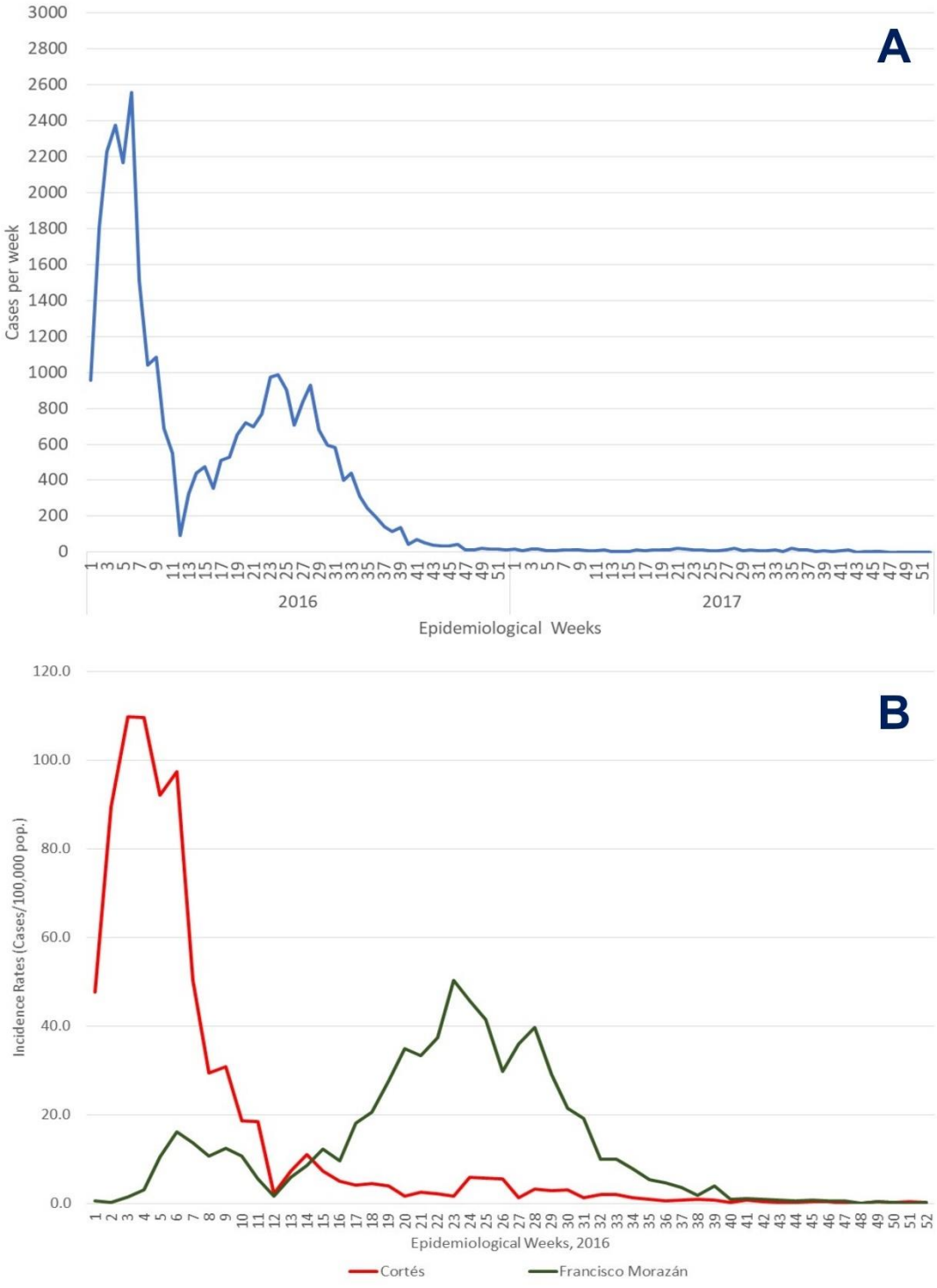

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Figure 2. Geographic distribution by GIS-based map of the calculated incidence rates for Zika in Honduras, 2016-2017 by departments.

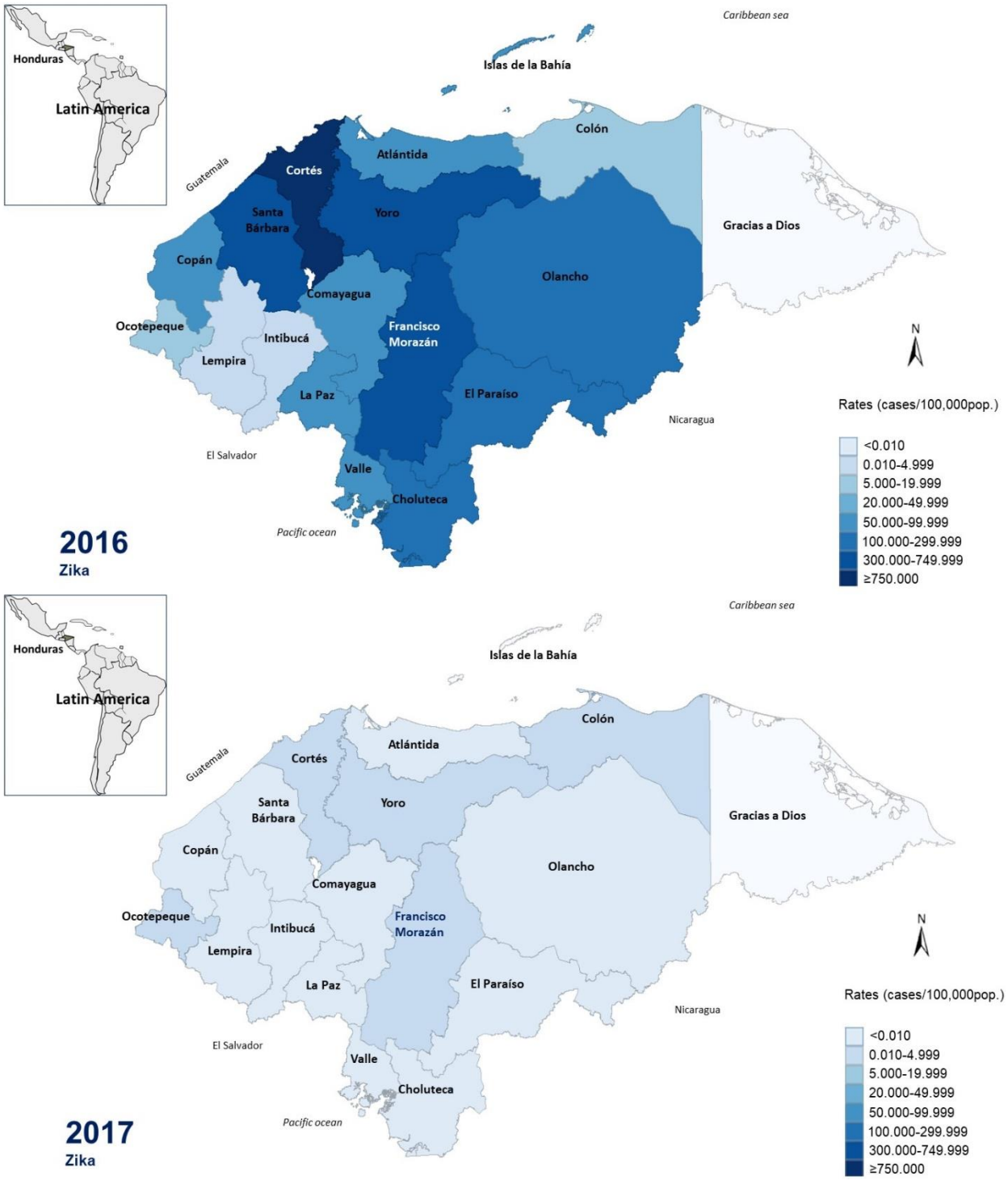

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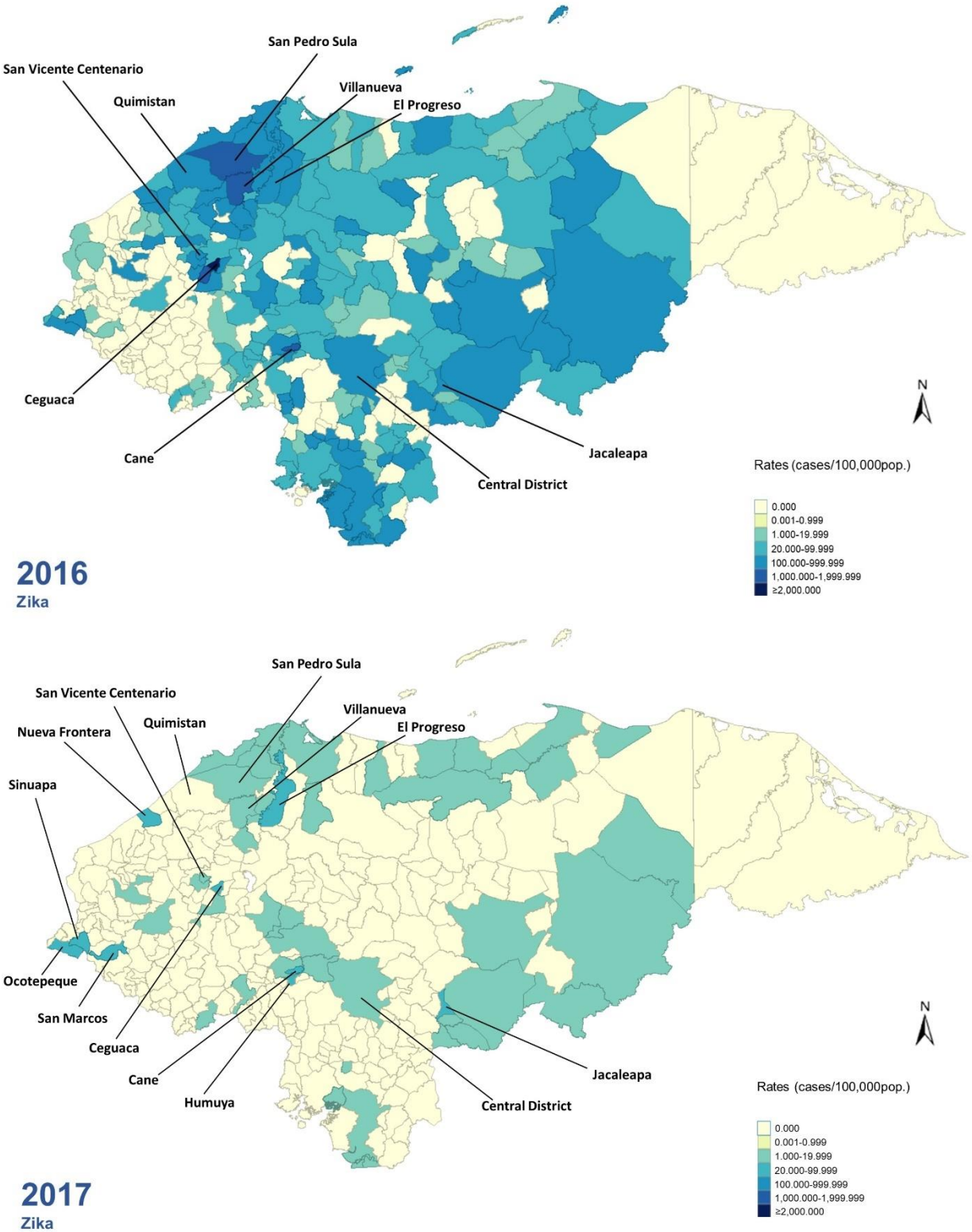
Figure 3. Geographic distribution by GIS-based map of the calculated incidence rates for Zika in Honduras, 2016-2017 by municipalities.



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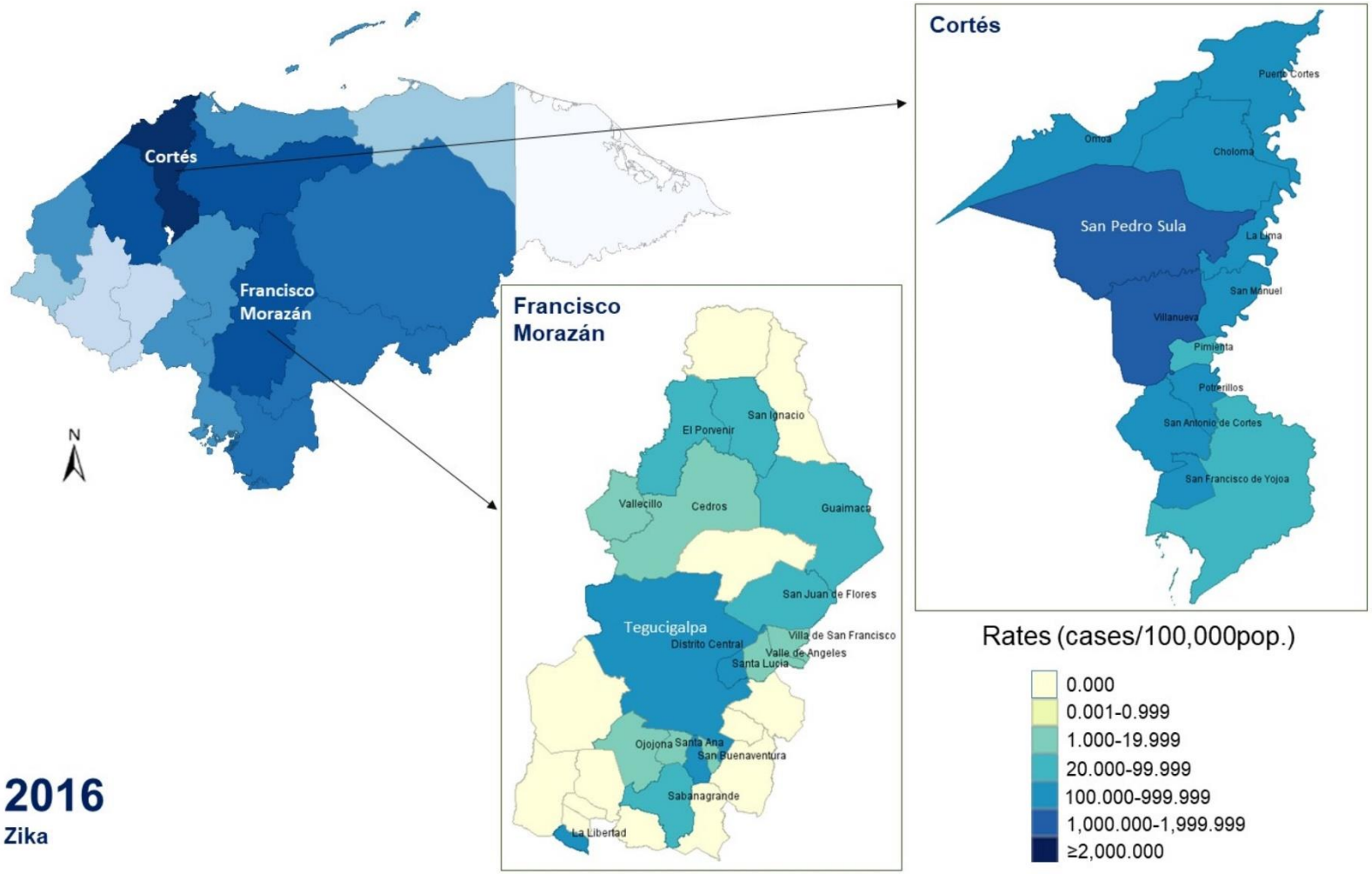
Figure 4. Geographic distribution by GIS-based map of the calculated incidence rates for Zika in municipalities of Cortés and Francisco Morazán departments, Honduras, 2016.