

## Original Research Article

**Spatial Distribution of COVID-19 in Honduras at the Early Phase of the Pandemic Using Geographic Information Systems (GIS)**

Lysien I. Zambrano,<sup>1,2,3</sup> Manuel Antonio Sierra-Santos,<sup>3,4,5,6</sup> Homer Mauricio Mejía-Santos,<sup>7</sup> Elsa Yolanda Palou,<sup>3,8</sup> Fausto Muñoz-Lara,<sup>3,8,9</sup> Ivette Lorenzana,<sup>3,10</sup> Tito Alvarado,<sup>3,4</sup> Itzel Carolina Fuentes-Barahona,<sup>11,12</sup> Glaucia Luciano da Veiga,<sup>13</sup> Ivan Rodriguez-Núñez,<sup>14</sup> Víctor Manuel Valladares-Rosa,<sup>15</sup> Arturo Gerardo Corrales-Alvarez,<sup>3,15</sup> Kovy Arteaga-Livias,<sup>16,17</sup> D. Katterine Bonilla-Aldana,<sup>2,18,19</sup> Alfonso J. Rodríguez-Morales.<sup>2,16,19,20,\*</sup>

<sup>1</sup>*Departamento de Ciencias Fisiológicas y Morfológicas, Facultad de Medicina, Ciencias, Universidad Nacional Autónoma de Honduras (UNAH), Tegucigalpa, Honduras.*

<sup>2</sup>*Latin American Network of Coronavirus Disease 2019-COVID-19 Research (LANCOVID-19). Electronic address: <https://www.lancovid.org>.*

<sup>3</sup>*Plataforma Todos Contra el COVID-19, Tegucigalpa, Honduras.*

<sup>4</sup>*Instituto de Enfermedades Infecciosas y Parasitología Antonio Vidal, Tegucigalpa, Honduras.*

<sup>5</sup>*Facultad de Ciencias Médicas, UNAH, Tegucigalpa DC, Honduras.*

<sup>6</sup>*Facultad de Ciencias de la Salud, Universidad Tecnológica Centroamericana, Tegucigalpa DC, Honduras.*

<sup>7</sup>*Unidad de Vigilancia de La Salud (Health Surveillance Unit), Secretaría de Salud, Tegucigalpa, Honduras.*

<sup>8</sup>*Department of Internal Medicine, Facultad de Ciencias Médicas (FCM), Universidad Nacional Autónoma de Honduras (UNAH), Tegucigalpa DC, Honduras.*

<sup>9</sup>*Department of Internal Medicine, Hospital Escuela, Tegucigalpa, Honduras*

<sup>10</sup>Escuela de Microbiología, Instituto de Investigaciones en Microbiología, Centro de Investigaciones Genéticas, Universidad Nacional Autónoma de Honduras (UNAH), Tegucigalpa, Honduras.

<sup>11</sup>Facultad de Ciencias Médicas, Universidad Nacional Autónoma de Honduras (UNAH), Tegucigalpa, Honduras.

<sup>12</sup>Departamento de Ginecología y Obstetricia, Hospital Escuela, Tegucigalpa, Honduras.

<sup>13</sup>Departamento Análises Clínicas, Centro Universitario Saude ABC/FMABC, Santo André, Brazil.

<sup>14</sup>Departamento de Kinesiología, Facultad de Medicina, Universidad de Concepción, Chile.

<sup>15</sup>Ingeniería Gerencial, Tegucigalpa, Honduras.

<sup>16</sup>Universidad Científica del Sur, Lima, Peru.

<sup>17</sup>Facultad de Medicina, Universidad Nacional Hermilio Valdizán, Huánuco, Peru.

<sup>18</sup>Incubator in Zoonosis (SIZOO), Biodiversity and Ecosystem Conservation Research Group (BIOECOS), Fundación Universitaria Autónoma de las Américas, Sede Pereira, Pereira, Risaralda, Colombia.

<sup>19</sup>Public Health and Infection Research Group, Faculty of Health Sciences, Universidad Tecnológica de Pereira (UTP), Pereira, Risaralda, Colombia.

<sup>20</sup>Grupo de Investigación Biomedicina, Faculty of Medicine, Fundación Universitaria Autónoma de las Américas, Pereira, Risaralda, Colombia.

\*Corresponding author email: [arodriguezm@utp.edu.co](mailto:arodriguezm@utp.edu.co). Universidad Científica del Sur, Lima, Peru.

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## Abstract

*Background:* The epidemic of Coronavirus Disease 2019 (COVID-19) have affected all the regions of the world, nevertheless, in some countries there is a lack of studies on its main clinical and epidemiological features. We analyzed the incidence, incidence rates, and evolution of COVID-19 cases in Honduras from February 18-April 24, 2020.

*Methods:* Using daily epidemiological data from surveillance about COVID-19 in Honduras, we calculated the rates of incidence (cases/100,000 population), and developed at national, departmental, and municipal levels GIS-based maps.

*Results:* February 18 - April 24, 2020, a sum of 3,169 suspected COVID-19 cases have been assessed by RT-PCR, 533 (16.8%) of them were positive, for an incidence rate of 5.73 cases/100,000 pop. The highest peak was reached on March 31 (48 cases). The department with the highest number of cases and incidence rate was Cortes (383 cases, 71.9% of the total, 21.45 cases/100,000 pop).

*Discussion:* The pattern and evolution of COVID-19 epidemic in Honduras has been particularly focused in the major urban areas, San Pedro Sula and Tegucigalpa, the capital city. Studies using geographical information systems linked with clinical disease characteristics are necessary to attain accurate epidemiological data for public health systems. Such information is also useful for assessment of the evolution of the pandemic and monitoring interventions.

## Keywords

SARS-CoV-2; COVID-19; geographical information systems (GIS); coronavirus; epidemiology of infectious diseases; public health.

## Background

Over last few weeks, our world has been affected by a new emerging coronavirus, the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) (1). This virus is a newly emerging zoonotic agent that appeared in December 2019, or earlier (2), and causes the Coronavirus Disease 2019 (COVID-19) that led to the declaration of an ongoing pandemic, since March 11, 2020 (3-6).

Among the affected regions due to COVID-19 so far, is included Latin America (7-10), where some studies already have reflected the negative impact of this pandemic (11-13). This region has been the epicenter of other emerging epidemics from other viral pathogens since December 2013 (14), such as the case of vector-borne viruses, as chikungunya (CHIKV) (15), Zika (ZIKV) (16) and dengue (DENV) (17).

Now this region is becoming the new epicenter of the COVID-19 pandemic due to uncontrolled situation in Brazil (18, 19). Despite this, few is discussed and analyzed in more neglected areas, such as is the case of Central America, where is located Honduras. This country have suitable terms, such as the meteorological factors (20, 21), foreign travel, international trade (22, 23), spatial sensitivity, that may it be related to introduction and transmission of the SARS-CoV-2 (24-28).

As published earlier, in general, there is a lack of reports on viral infectious pathologies in Honduras (29-34), some directly evaluating the Geographic Information Systems (GIS) usefulness to assess the epidemiology of other infectious pathologies, such as CHIKV, ZIKV, and DENV (17, 34-36).

In the case of COVID-19 in Latin America, there is still a lack of epidemiological studies using GIS to assess the spatial distribution and epidemiology of this pandemic (37-41).

The impact of COVID-19 needs to be evaluated in detail to understand and prepare for public health interventions in the country (28, 41, 42).

Previous studies using GIS for such assessment have been done as product of the international collaboration with Colombian and Honduran institutions (24, 43), e.g. for DENV, CHIKV, and ZIKV (21, 24, 37-39, 44, 45). In this setting, this study aimed to estimate incidence rates of COVID-19 in March-April 2020 for Honduras and its departments and municipalities and to develop GIS-based epidemiological maps for this coronavirus.

## Methods

Honduras is a Central American country constituted by 18 departments (main administrative level) and 298 municipalities (second administrative level). The Honduran country has meteorological, spatial, and social factors prone for the transmissibility of multiple viral infectious diseases (41), such as temperature, humidity, precipitation, latitude, and altitude, as well as social, cultural, economic and political factors (24, 41).

This is an observational, cross-sectional retrospective study. The data were collected from the national system of surveillance, collecting the cases number for all the departments and municipalities in the nation, during February-April 2020 (detailed by days). Data information was comprised derived from the cases, suspected by the clinical definitions, and confirmed by rRT-PCR for SARS-CoV-2. Data quality was evaluated. Data evaluated for this analysis was derived

from a total of 298 primary notification units at the municipalities, gathered at the notification units of the 18 departments, later congregated in the capital district Tegucigalpa (24).

With the 2020 official reference data of the population (Instituto Nacional de Estadísticas, INE), the annual rates of incidence of the corresponding municipalities and departments of Honduras were estimated (cases/100,000 pop), obtaining COVID-19 incidences by municipalities and departments (24, 41).

Microsoft Access® was used to design the geographical databases to import rates of incidence by municipalities and departments to the GIS software. The Client GIS software Open source used was Kosmo Desktop 3.0 RC1®. The shapefiles of departments (.shp) were associated to the data table database through spatial join operation, to produce digital maps of annual incidence rates by departments and municipalities (24, 39, 41, 46).

## Results

From February 18 to April 23, 2020, a total of 3,169 suspected cases of COVID-19 were investigated, 533 of them (16.8%), resulting positive by RT-PCR detection of the RNA of the SARS-CoV-2, for a cumulated national incidence rate of 5.73 cases/100,000 pop, varying at departments from 0.0 cases/100,000 pop (in five departments without cases), to 21.45 cases/100,000 pop (in Cortes). From March 12 to May 24, 2020, a total of 3,950 cases were confirmed (Figure 1), cumulated national incidence rate of 42.45 cases/100,000 pop.

The highest peak was reached on May 23 (273 cases) (Figure 1A). Up to April 23, 22 deaths were confirmed, for a national cumulated national incidence rate of 0.24 deaths/100,000 pop. But up to May 24, 2020, 180 deaths, 1.93 deaths/100,000 pop (Figure 1B).

In major cities, Tegucigalpa and San Pedro Sula, more than 2,000 RT-PCR for COVID-19 have been applied (Figure 2A), for rates of over 50 tests/100,000 pop (Figure 2B). In the largest populated departments, such as Cortes and Francisco Morazán, more than 50 tests/100,000 pop were applied in multiple municipalities (Figure 3).

Confirmed cases have been identified especially at Cortes and Francisco Morazán (more than 100 cases in both) (Figure 4A). All the departments except Gracias a Dios, Olancho, El Paraíso, Intibucá, and Ocotepeque, have reported cases (Figure 4B). The highest incidence rates were reached in Cortes and Colon (Figure 4B).

At municipality levels, in the most populated areas, more than 500 tests per municipality have been applied (Figure 5A), with multiple reaching more than 50 tests/100,000 pop (Figure 5B). Nevertheless, multiple municipalities in the country, yet have not applied enough or none tests for COVID-19.

The municipality with the highest number of cases is San Pedro Sula (Figure 6A). At the capital city, Tegucigalpa 58 cases have been confirmed (Figure 6A). Santa Fe, at Colon department, reached 231.71 cases/100,000 pop (Figure 6B), followed by Pimienta (77.36) at Cortes department and San Jose (40.73) at Choluteca department (40.73) (Figure 6B).

From those patients analyzed up to April 22, 2020 (3,169) (Table 1), among confirmed cases there were predominantly males (58%), 7.3% younger than 20 years old, and 16.9% older than 60 years old (Table 1). The highest detection (positivity) was found among those in the group 60-69 years old (31.4%) (Table 1).

Among those asymptomatic, 25.3% were positive for COVID-19 (Table 1). Among confirmed cases, 61.5% presented cough and 60.2% fever, among other findings (Table 1). From the total COVID-19 cases, 85.7% presented comorbidities, 10.3% of the cases with hypertension, 9.8% with diabetes, among other (Table 1). In this group, 22 died (4.1%).

Diabetes and hypertension were associated with higher risk of death (OR=3.79, 95%CI 1.41-10.16, and OR=2.71, 95%CI 1.01-7.66). All the patients that died have comorbidities, and among those with comorbidities 4.8% died, compared to those without it where no deaths occurred (Table 2).



## Discussion

As expected, COVID-19 in Honduras has affected all the age groups, with a higher proportion of deaths among those above 60 years-old and with comorbidities, as other studies have reported in the region and abroad (6, 47, 48). The GIS-based maps allow to see that the epidemic in the country is affecting mostly those urban populated centers, such as San Pedro Sula, and surrounding municipalities and the capital district, Tegucigalpa, and its neighbouring areas (Figure 6). This is similar to the observed situation in other countries of Latin America, such as Brazil, Colombia, Bolivia and Mexico (11, 13, 18, 49), although so far, no studies using GIS have been published from these countries.

Francisco Morazán and Cortés departments, those with highest population, were the most compromised by COVID-19 till now. Socio-eco-epidemiological characteristics in Honduras are suitable for the entire country sensitive to the spreading of viral infectious diseases such as COVID-19. These conditions make complicated the effective control and containment of this epidemic that is progressing (50). Analyses such as the one presented herein are relevant for understanding future emerging epidemics in the region and the country, as early described (24, 41).

Yet, in Honduras we have to wait to see the impact of seasonal station and environmental conditions on the epidemiology of COVID-19. In the case of seasonal influenza, some studies in the region revealed a proportional association between influenza activity and specific humidity in selected areas from Honduras, Costa Rica and Nicaragua (51).

The use of GIS-epidemiological maps is critical (24, 37, 46), are of high relevance for any affected country (41). In the case of Central American territories, there is an evident lack of studies

developing such maps for emerging viral infectious diseases. In Honduras, previous assessments using GIS mapped DENV, CHIKV and ZIKV, were useful for health authorities at national and local levels (17, 34-36). In addition to all the above, coinfections between COVID-19 and DENV, should be also considered, as these may overlap in the country, as is being reported in other countries in Latin America (52).

Further studies are essential to understand the epidemiological and medical characteristics of this and other emerging infectious diseases in Honduras. Although this may not provide all the answers, such information is particularly useful for public health evidenced-based decisions (41, 53). Developed maps would provide baseline epidemiological information for the assessment of the differentiated risk related to acquiring such diseases in certain areas (departments and municipalities) of Honduras. Similar recommendations have previously been made for DENV, CHIKV, and other arboviral diseases (21, 24, 41).

Use of GIS-based epidemiological maps is beneficial for preventative/control strategies in Honduras (24, 37-40, 44), as well as other countries in Central and South America. These tools, such as GIS-based maps can also be developed and used for making public health decisions about other emerging diseases in Honduras (41, 54).

Shortly, other eco-epidemiological evaluations would be done in the country for these emerging diseases, as has been done for vector-borne disease epidemics in the country (24, 41).

## Limitations

Massive scale testing has not yet performed in the country. The RT-PCR SARS-CoV-2 diagnosis is mostly centralized. This scenario is like other nations in the region of Latin America. Besides, there is likely cases under-reporting in some zones as derived from the comparison with precise reporting in some municipalities.

## Conclusions

GIS-based maps are a source of important information for the evaluation of the individuals risk in certain areas allowing detailed prevention advice (40, 41, 54). Such maps allow integration of prevention and control strategies, as well as public health policies, for joint control of this emerging disease in this and other countries of the region (55). Preparedness in this setting should also consider the potential occurrence of new associated complications of the disease. Finally, considering the emergence of COVID-19 in not previously affected areas, as indicated, in the country would be useful for preventive actions.

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**Table 1.** Demographic and clinical features of positive and negative patients assessed for COVID-19 in Honduras, March 10-April 22, 2020.

		Positive (n=533)		Negative (n=2636)		Total	%	p
		n	%	n	%			
Sex	Male	309	58.0	1287	48.8	1596	50.4	<0.001
	Female	224	42.0	1349	51.2	1573	49.6	
Age group	0 - 4	7	4.3	156	95.7	163	100.0	<0.001
	5 - 9	4	4.6	83	95.4	87	100.0	
	10 - 14	7	10.0	63	90.0	70	100.0	
	15 - 19	21	12.7	144	87.3	165	100.0	
	20 - 29	84	12.1	612	87.9	696	100.0	
	30 - 39	116	16.2	601	83.8	717	100.0	
	40 -49	115	22.6	394	77.4	509	100.0	
	50 - 59	86	21.8	308	78.2	394	100.0	
	60 - 69	55	31.4	120	68.6	175	100.0	
	70 - 79	26	27.4	69	72.6	95	100.0	
	>80	9	13.4	58	86.6	67	100.0	
Asymptomatic	Yes	135	25.3	2126	80.7	2261	71.3	<0.001
	No	398	74.7	510	19.3	908	28.7	
Symptoms	Cough	328	61.5	347	13.2	675	21.3	<0.001
	Fever	321	60.2	271	10.3	592	18.7	
	Dyspnea	186	34.9	157	6.0	343	10.8	
	Sore throat	147	27.6	168	6.4	315	9.9	
Comorbidities	Yes	457	85.7	805	30.5	1262	39.8	<0.001
	No	76	14.3	1831	69.5	1907	60.2	
	Hypertension	55	10.3	72	2.7	127	4.0	
	Diabetes	52	9.8	47	1.8	99	3.1	
	Cardiovascular disease	31	5.8	35	1.3	66	2.1	
	Obesity	25	4.7	41	1.6	66	2.1	
	COPD	21	3.9	46	1.7	67	2.1	
	Asthma	14	2.6	25	0.9	39	1.2	
	Pregnancy	9	1.7	21	0.8	30	0.9	
	Alcoholism	5	0.9	2	0.1	7	0.2	
	Cancer	1	0.2	5	0.2	6	0.2	
Outcome	Death	22	4.1	4	0.2	26	0.8	<0.001
	Survived	511	95.9	2632	99.8	3143	99.2	

COPD, chronic obstructive pulmonary disease.

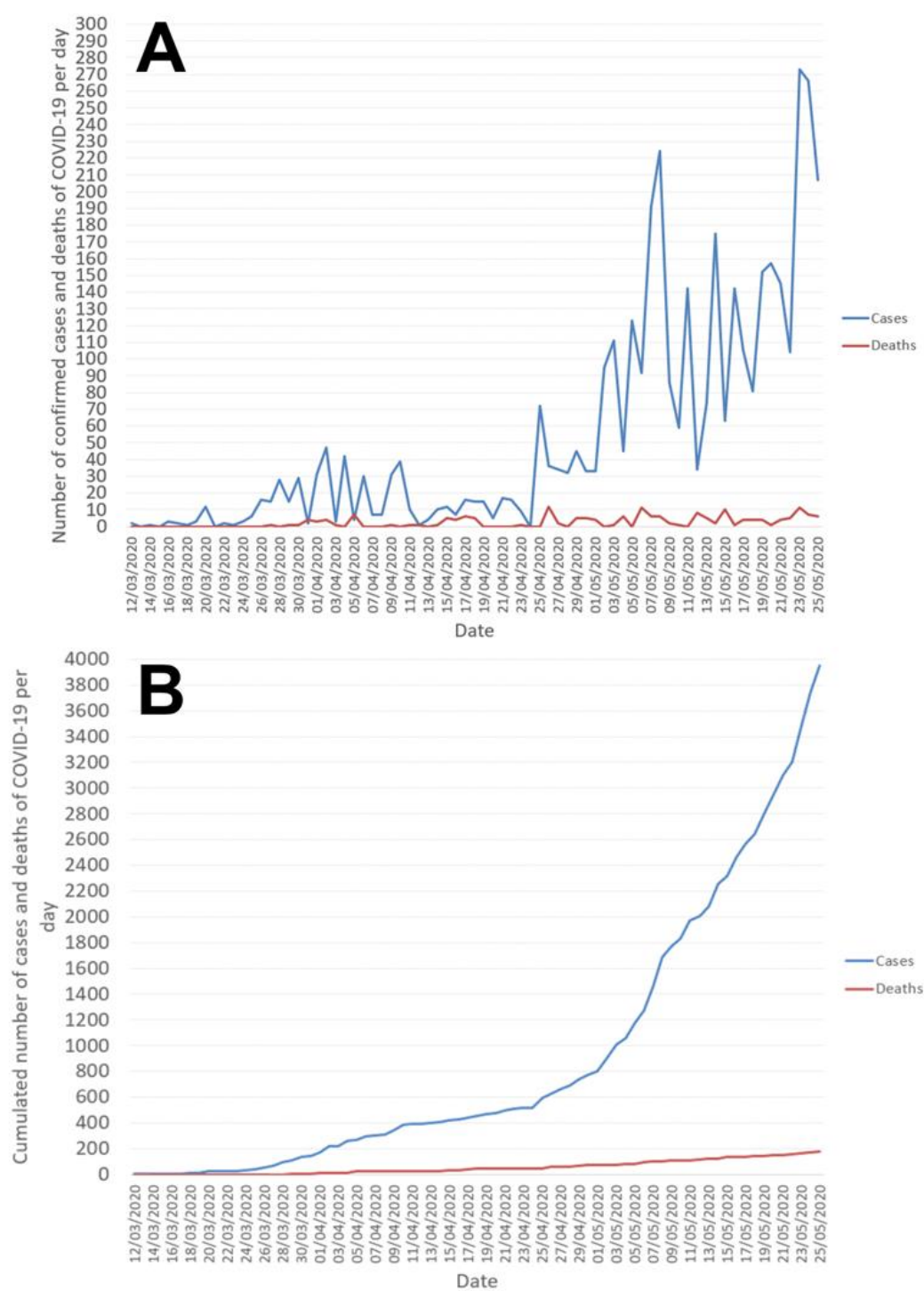
**Table 2.** Comparison of selected variables between those patients COVID-19 that died and survived in Honduras, March 10-April 22, 2020.

		Dead (n=22)		Survived (n=511)		Total		
		n	%	n	%			
Sex	Male	17	77.3	292	57.1	309	58.0	0.061
	Female	5	22.7	219	42.9	224	42.0	
Age group	0 - 4	0	0.0	7	100.0	7	100.0	0.085
	5 - 9	0	0.0	4	100.0	4	100.0	
	10 - 14	0	0.0	7	100.0	7	100.0	
	15 - 19	0	0.0	21	100.0	21	100.0	
	20 - 29	0	0.0	84	100.0	84	100.0	
	30 - 39	5	4.3	111	95.7	116	100.0	
	40 -49	4	3.5	111	96.5	115	100.0	
	50 - 59	3	3.5	83	96.5	86	100.0	
	60 - 69	6	10.9	49	89.1	55	100.0	
	70 - 79	3	11.5	23	88.5	26	100.0	
	>80	1	11.1	8	88.9	9	100.0	
Comorbidities	Yes	22	<b>4.8</b>	435	95.2	457	100.0	0.051
	No	0	0.0	76	100.0	76	100.0	
	Diabetes	6	<b>27.3</b>	46	9.0	9.8	100.0	<b>0.005</b>
	Hypertension	5	<b>22.7</b>	50	9.8	10.3	100.0	<b>0.035</b>
	Cardiovascular disease	3	13.6	28	5.5	5.8	100.0	0.055
	Obesity	2	9.1	23	4.5	4.7	100.0	0.106
	COPD	0	0.0	21	4.1	3.9	100.0	0.078
	Asthma	0	0.0	14	2.7	2.6	100.0	0.097
	Pregnancy	0	0.0	9	1.8	1.7	100.0	0.113
	Alcoholism	0	0.0	5	1.0	0.9	100.0	0.128
	Cancer	0	0.0	1	0.2	0.2	100.0	0.144

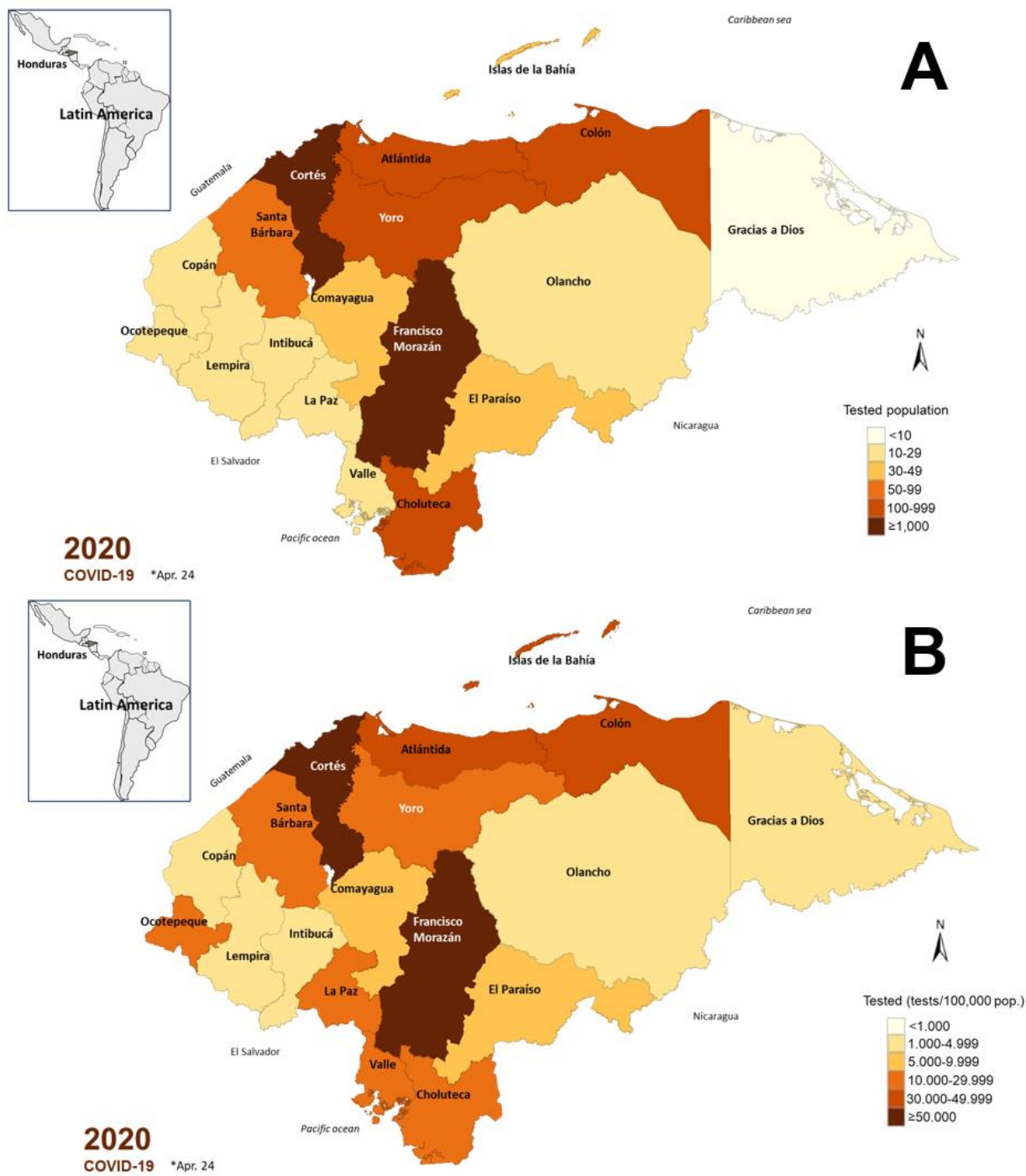
COPD, chronic obstructive pulmonary disease.



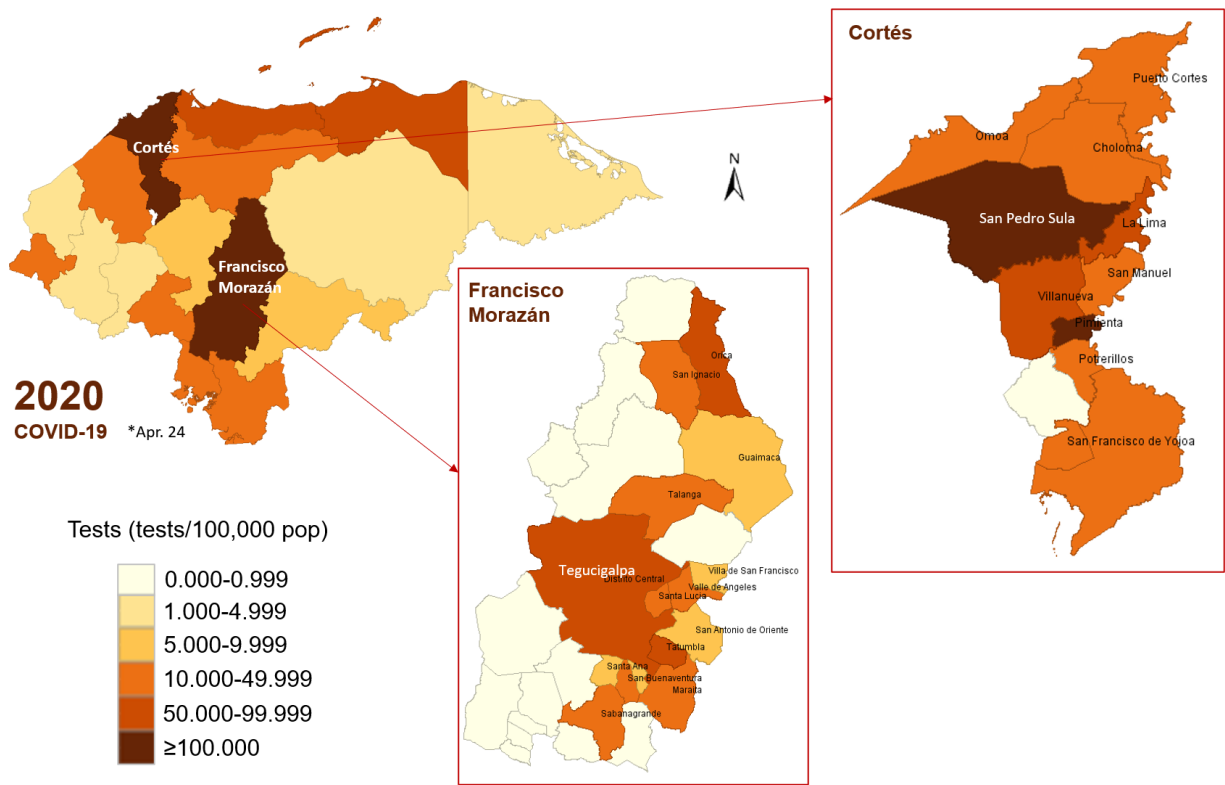
**Figure 1.** COVID-19 in Honduras, March 12-May 25, 2020. A. Number of confirmed cases and deaths per day. B. Cumulated number of confirmed cases and deaths per day.



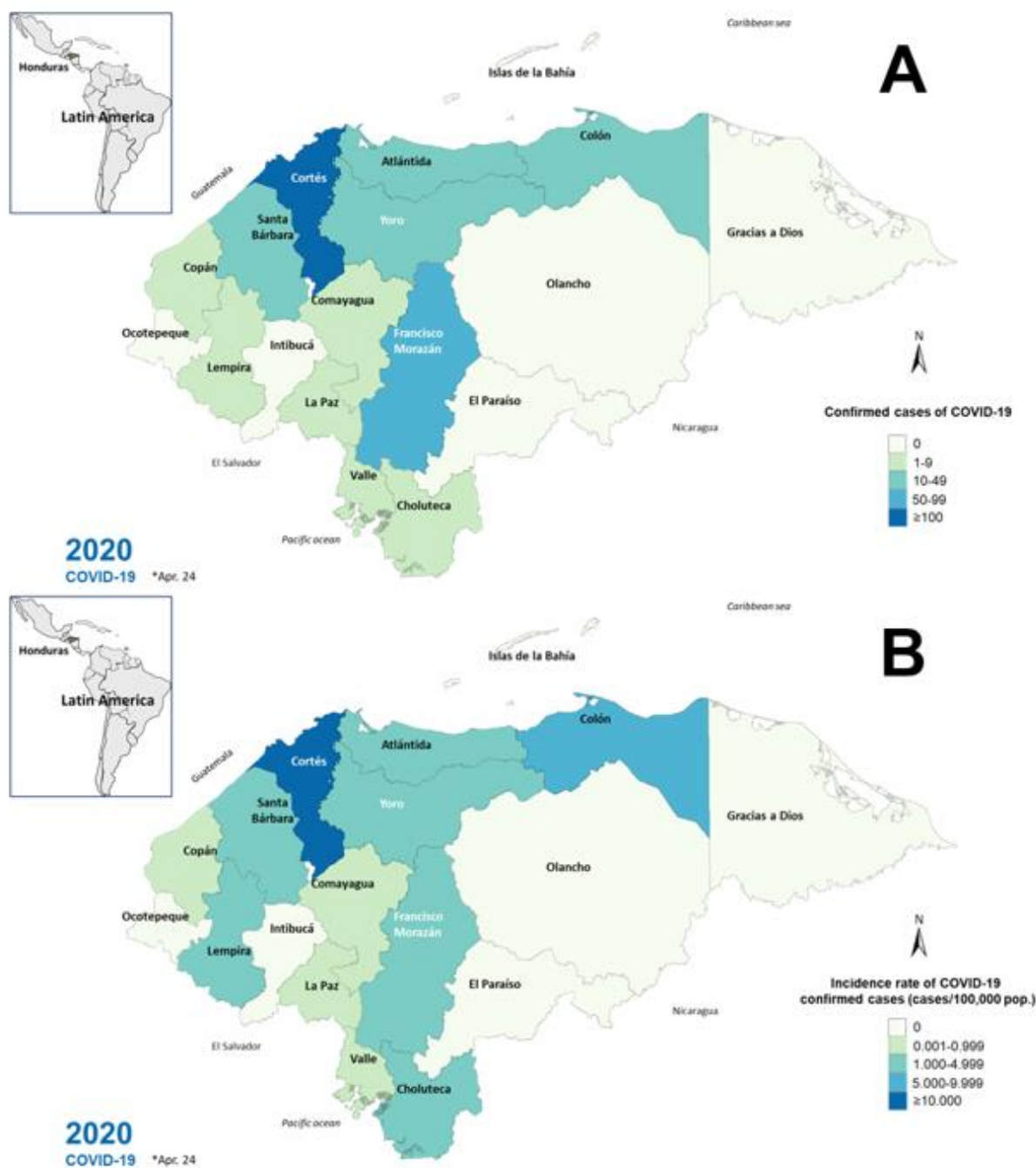
**Figure 2.** Tested applied to the population by departments. A. Total number of tests. B. Tests per 100,000 population.



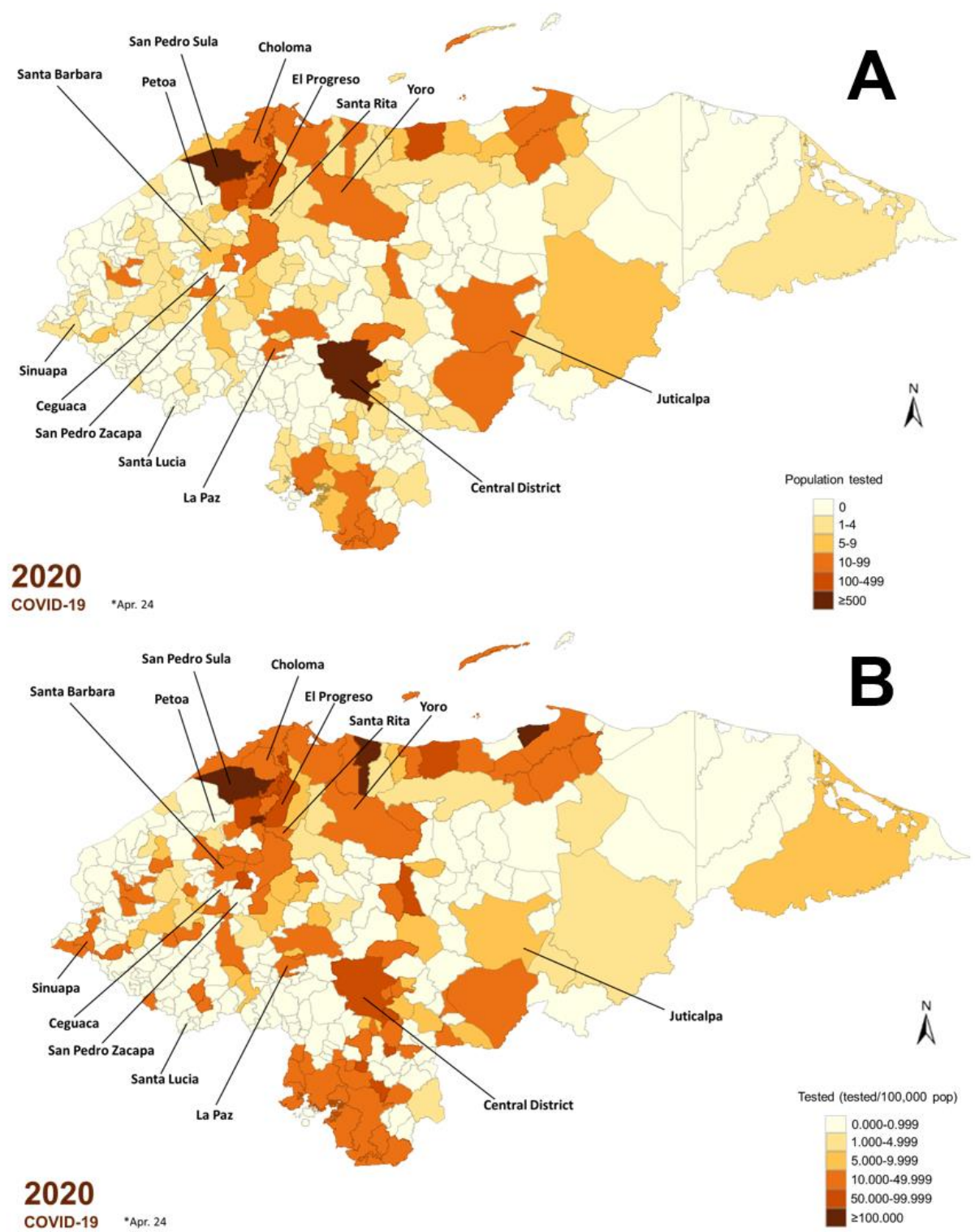
**Figure 3.** Tested applied per 100,000 population in the departments of Cortés and Francisco Morazan.



**Figure 4.** COVID-19 confirmed cases in Honduras by departments. A. Total number of cases. B. Incidence rates (cases/100,000 pop.).



**Figure 5.** Tested applied to the population by municipalities. A. Total number of tests. B. Tests per 100,000 population.





**Figure 6.** COVID-19 confirmed cases in Honduras by municipalities. A. Total number of cases. B. Incidence rates (cases/100,000 pop.).

