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Sociodemographic and environmental analysis for the occurrence of anti-Leptospira antibodies in dogs of Teresina, Piauí, Brazil

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Abstract *Leptospirosis is a worldwide zoonosis whose transmission is interlinked by multiple factors in the man-animal-ecosystem interface. This study aimed to evaluate the risk factors for the occurrence of anti-Leptospira antibodies in dogs in the capital Teresina (PI), and to determine their spatial distribution. Five hundred fifty-eight dog blood samples were submitted to the Microscopic Serum Agglutination (MSA) test. We applied semi-structured questionnaires to dog owners and obtained the area of residence for projection in geographical maps. Serum prevalence was 13.8%, in which the most common serovar was icterohaemorrhagiae, with 49.2%. Dogs with street access, failure to collect food bowl and low income of owners were risk factors. There was a higher number of seropositive dogs in the rainy season, with 87.1%, which is a probable risk factor for the occurrence of cases. The distribution of seropositive dogs was widely spread in the city, with predominance of cases in anthropized areas. These risk factors favor the occurrence of anti-Leptospira antibodies in dogs that are agent maintenance sources in the city and reinforce the need for epidemiological and environmental surveillance to prevent leptospirosis.*

Key words *Epidemiology, Leptospira, Dogs, Risk factors*

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Introduction

Leptospirosis is a global zoonosis, whose transmission is interlinked by multiple factors at the human-animal-ecosystem interface[1]. It can affect humans and wild and domestic animals alike. Thus, it is important both for public health and for animal production[2]. Domestic and wild synanthropic animals are the essential reservoirs for persistent infection outbreaks. Humans are only accidental and terminal hosts within the transmission chain[3].

Leptospirosis is a serious public health problem in dogs, since the animals can become subclinical carriers, assuming the condition of reservoirs. In addition, dogs have close contact with humans in their conviviality, thus playing an important role in the epidemiology of human leptospirosis and are a link in disease transmission[4,5].

The main risk factors for dogs observed in other studies were the habit of hunting rodents, floodplains close to homes and street access[6]. The animal owner's schooling, age, income, population density and housing characteristics in the areas where dogs reside are considered risk factors[7] as well. In addition to the socioeconomic conditionants, the geographic distribution of leptospirosis is also favored by the environmental conditions of tropical and subtropical regions, where high temperature and high rainfall periods favor the emergence of epidemic outbreaks[8].

Analyzing the Health Map database, which uses different online sources for real-time surveillance of emerging public health threats, more than half of leptospirosis alerts were located in the Americas between 2010 and 2012, and Brazil had the highest number of alerts[9]. In developing countries, such as Brazil, leptospirosis is related to the abrupt and disorderly urban expansion process, in which a large part of the population began to inhabit suburban areas without the minimum infrastructure and sanitation conditions, facilitating the maintenance of pathogens that are harmful to animal and human health[10].

The spatial analysis used to characterize the main transmission points of leptospirosis has been widely used, mainly in large urban centers[11]. The geographic distribution in some Brazilian regions has not yet been fully established. It is necessary to elucidate the situation of canine leptospirosis in the country in order to characterize the epidemiology in each region so that preventive measures are taken to address the agent's transmission. Therefore, this study aimed to evaluate the occurrence of anti-Leptospira antibodies in dogs in the capital Teresina (PI) and to establish the spatial distribution and identify the risk factors.

Methods

Study area

Teresina is the capital of the state of Piauí and is located at 05°05'12" South and 42°48'42" West. The average urban area altitude is 72m and the municipality stands at 100-150m. It has a surface of around 1,392 km², with a population of 814,230 inhabitants and a density of 585 inhabitants/km² [12]. According to Köppen's classification, Teresina has a megathermal tropical weather (AW), with annual thermal amplitude lower than 5°C. The region receives strong solar radiation throughout the year, due to the proximity of the Equator. Low altitude is another factor that is associated to low latitude and causes high temperatures in the region throughout the year. It is characterized by a tropical continental climate, with two well-defined seasons: a rainy season from January to May and a dry season from July to November[13].

Sampling

The sample was calculated by simple casual or random sampling $n = z^2 . p . q / e^2$, where z (1.96) refers to the abscissa of the standard normal distribution considering a level of confidence interval of 95%, p (0.154) as an estimate of the true proportion of dogs based on a pilot study carried out in the city of Teresina (PI)[14], where *q* (0.846) is the complement of *p*, and (0.03) refers to the sample error of 3%, obtaining *n* (sample size) of 556 dogs. The total population of dogs was estimated at 84,070 animals. The North had around 31,246 dogs, the South, 24,284 dogs and the East/Southeast, 28,540 dogs based on the Annual Rabies Vaccination Campaign held in 2012, coordinated by the Management of Zoonoses of Teresina (GEZOON). Based on this city canine population estimate, the studied population comprised 208 (37.17%) dogs from the North; 161 (28.88%) from the South and 189 (33.95%) from the East/Southeast totaling a sample of 558 dogs.

Map distribution

The choice of the unit of analysis of the region occurred in three stages. The first stage se-

lected 20% of districts by area. In Teresina, the northern area has 30 districts, the south has 35 and the east/southeast has 43. However, 6, 7 and 9 districts were chosen respectively. So the distribution of collection was as follows: of the 208 dogs from the north, 35 blood samples were collected in each four districts and 34 samples in two districts; of the 161 dogs from the south, 23 samples were collected in each seven districts; and of the 189 dogs from the east/southeast, 21 samples were collected from each nine districts. Sampling districts were chosen within each area, whenever possible, adopting the criterion of districts with the lowest territorial limit in common, aiming to cover a well distributed analysis of the city covering all its extension. The second stage consisted in the random selection of the blocks of each selected district (1 dog/block). The third stage consisted of a draw of dogs in the household, if it had more than one animal. The geographical location of each property visited was obtained through the Global Positioning System (GPS).

Meteorological data

The Agrometeorological Station of the National Meteorological Institute (INMET) provided monthly data on rainfall, humidity and mean maximum temperatures recorded in the study region, located in the experimental area of the Brazilian Agricultural Research Corporation - EMBRAPA Meio-Norte, located in Teresina-PI.

Questionnaire

A semi-structured questionnaire was applied to dog owners in order to collect data on demographic characteristics as well as environmental factors. First, it collected the identification data and the sample collection period. The demographic characteristics section included questions on the dog regarding age, gender, race, management, feeding, leptospirosis vaccination, collecting food bowl at night, hunting habits and contact with other animals, as well as questions about the property-related environmental factors, including sewage network, garbage collection, flooding, number of dogs and humans per residence, presence of rodents and accumulation of debris in the residence. The final section included demographic questions to homeowners as to whether they had knowledge about leptospirosis, their occupation, schooling level and family income.

Sample collection

Following the application of the questionnaire, blood samples were collected and the serum of GEZOON dogs, males and females, from approximately 3 months to 13 years, were collected from January to December 2014, totaling 558 samples in this study. Dog blood samples were collected from the jugular or cephalic vein via syringes, centrifuged at 2500 rpm for 10 minutes to obtain serum, which was filled into 2.0mL plastic microvial and kept in a freezer at -20 ° C until the Microscopic Serum Agglutination (MSA) test was performed. Dogs vaccinated against leptospirosis within a period shorter than 12 months were excluded from the study.

Geographic map

A Geographic Information System was adopted using the ArcGis® 10 program to prepare the maps indicating the recorded cases of the survey with the use of GPS. The mapping of land use and occupation thematic classes was obtained by photointerpretation of satellite imagery Landsat-7/ETM+ false-color colored composition 5R4G3B, with distorted images for the mosaic assembly of images and clipping in the area of interest. It is true that the aforementioned images are hardly the best option in an urban case study; however, they allow easy and free access in terms of remote sensing images. Land was classified into categories relative to the study of leptospirosis, which were water density, pasture, exposed soil, anthropized area and vegetation.

Determination of anti-Leptospira agglutinin levels

The MSA test was performed at the Laboratory of Reproductive Bacterial Diseases of the Biological Institute of São Paulo. The technique was performed according to Galton et al.[15] and Cole et al.[16] using live cultures of Leptospira spp. of serovars Icterohaemorrhagiae, Canicola, Pomona, Grippotyphosa, Wolffi, Hardjo, Australis, Autumnalis, Bataviae, Bratislava, Butembo, Castellonis, Copenhageni, Cynopteri, Hebdomadis, Javanica, Panama, Pyrogenes, Shermani, Tarassovi, Whitcombi, Sentot as antigens. Cultures had 4-14 days of growth and were diluted in a 1:3 proportion in buffered saline, pH 7.2. Sera were screened at a 1:100 dilution and those with 50% agglutination or more were titrated by examination of a series of geometric two-fold dilutions.

The serum titer was the reciprocal of the highest dilution that showed a positive result. Prior to the tests, antigens were examined under a dark field microscope to check mobility and self-agglutination or contaminants. The criterion adopted for the probable reactive serovar was the one that showed the highest titer, and animals with two or more serovars with identical titers were considered positive, but not considered for the calculation of the most frequent serovar.

Statistical analysis

Seroprevalence and seasonality were obtained and described percentage wise. Risk factors were studied in two stages. In the first stage, a univariate analysis was performed using the chi-square test or Fischer's exact test. The Monte Carlo Test was applied when it was not possible to calculate the exact value of P through these tests. In the second stage, a multivariate analysis was performed using the logistic regression technique[17], with variables that showed P value lower than 20% ($P < 0.20$) in the first stage. In the final logistic regression model, variables with $P < 0.05$, with respective Odds Ratio (OR) and 95% confidence interval (CI) were classified as risk factors.

The Goodman test was used in the association of dogs submitted to the MSA test with Teresina's districts, in which lowercase letters were used to indicate differences between event proportions, with a 5% significance level. The reading of the letters should be interpreted as follows: two proportions followed by at least one letter do not differ at 5% significance level. The analyses were performed using SPSS Statistics 22.0 for Windows.

Ethics and animal experimentation

This study was conducted under the ethical terms and conditions and was approved by the Animal Experiments Ethics Committee of the Federal University of Piauí, under protocol 002/14, and by the Research Ethics Committee (CEP) of the Plataforma Brasil.

Results

Of the 558 serum samples, 77 (13.8%) were positive for leptospirosis in the MSA test, with 33 (49.2%) reagents for serovar Icterohaemorrhagiae, in addition to positive samples for serovars Canicola (25.4%), Bratislava (14.9%), Pyrogenes (6.0%), Australis (1.5%), Sentot (1.5%) and Tarassovi (1.5%).

The highest number of positive samples was observed in tests carried out in the rainy season, with 87.1% (64/77) of the cases, with a rainfall index between 308.6mm and 124.3mm in the period; in the non-rainy period (June to December), with rainfall between 37.8 mm and 1.0 mm, only 12.9% (13/77) of the cases were positive (Figure 1).

In the univariate analysis, the characteristics of the dogs and the environment of the property were evaluated along with the blood collection period, and the following variables were selected for the logistic regression: collection period, gender, management, feeding, food bowl's collection at night, type of sanitary sewage and accumulation of debris in the property. The final logistic regression model indicated rainfall (OR = 5.10, 95% CI: 2.745-9.486, P = 0.000), street access (OR = 1.99, 95% CI: 1.124-3.523; P = 0.018) and not collecting the food bowl at night (OR = 1.81, 95% CI: 1.047-3.140, P = 0.034) as risk factors. The analyses of these variables are shown in Table 1.

The mean number of dogs and people per household were, respectively, two dogs and four humans. Animal species living with seropositive dogs were cat (24), snake (1), pig (2), fox (1), rooster (10), birds (1), duck (1) and red-footed tortoise (2). There were also dogs raised loose in the streets and had contact with unspecified animals (19).

In the analysis of variables regarding the sociodemographic characteristics of dog owners, shown in Table 2, variables knowing about leptospirosis and household income in the univariate analysis were significant. Household income of less than a minimum wage was the only significant variable in the logistic regression (OR = 3.42, 95% CI: 1.036-11.289, P = 0.044).

The distribution of cases in the city was widely scattered, with no clusters in the central or peripheral area. The mapping of soil use and occupation defined that seropositive dogs lived predominantly in an anthropized area, and others, in anthropized area interspersed with the others (exposed soil, vegetation, water and pasture). Collections in areas near Poti and Parnaíba rivers did not evidence seropositive animals, as well as in regions near the lagoons, except for the Alto Alegre district, with seropositive dogs near the lagoon (Figure 2).

Table 3 shows a differentiated distribution of positivity among districts, although no district

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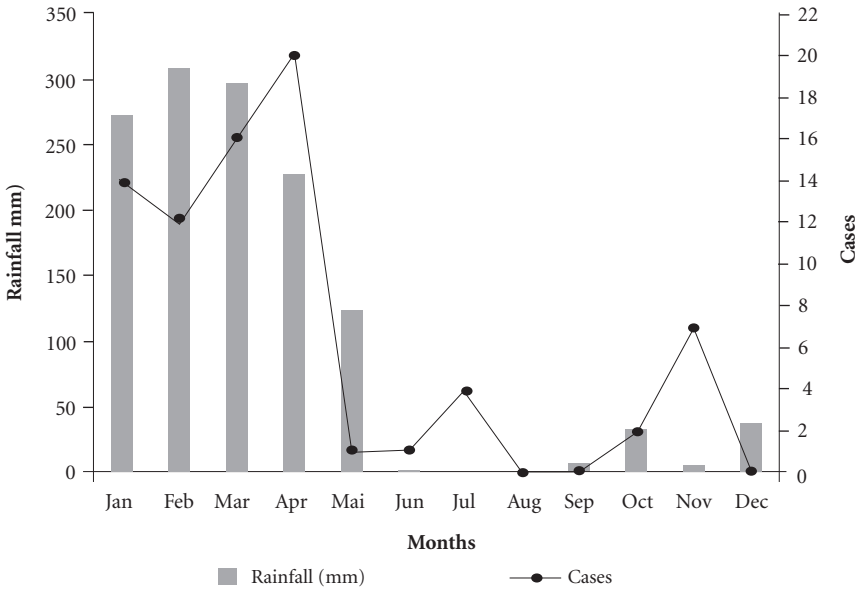

Figure 1. Relationship between monthly rainfall and occurrences of seropositive dogs for anti-Leptospira antibodies in the municipality of Teresina (PI), Brazil, during 2014.

was positive isolated from the others in a significant way. Districts B1 and B2 (33.33%) were the ones with the highest seroprevalence and seropositivity was statistically equivalent to B14 value (9.52%); B3 (30.43%) was associated with B15 (5.88%), whereas B6 (21.74%) shows similarity up to B18 (4.35%), and B10 (14.29%) to B22 (0.00%) had the lowest prevalence, whose results did not differ significantly ($P > 0.05$).

Discussion

The seroprevalence of 13.8% obtained in this study was considered low, since canine leptospirosis is endemic in practically all Brazilian regions, with an average of 26% of dogs reacting to the MSA[18] test. In Brazil, seroprevalence values for canine leptospirosis vary from 6.6% to 85% and, in particular, in the Northeast, 7% and 85% rates have been reported[19,20]. Factors related to the epidemiology of infection, such as animal density, rainfall, cropping system, soil type, occurrence of other animal species and access to water explain the gaps between prevalence rates[21].

As in the entire Northeast, annual average temperature fluctuations are minimal throughout the year in Teresina[22]. In the study period, mean annual maximum temperature ranged from 32.1 to 37.8°C, which hinders the survival of leptospires in the environment. Lower ambient temperatures of 7-10°C or higher, 34-36°C impair the survival of this microorganism, as well as direct exposure to solar radiation, large pH variations, soil salinity or high waters and dry environments, and the agent requires 15.2 to 31.4% humidity[21,23]. We observed relative humidity between 52.2 and 84.2%, favorable throughout the year for *Leptospira spp.*, rainfall in the rainy season (January-May) of 308.6-124.3 mm and 37.8-1.0 mm in the non-rainy season (July-December), with a higher proportion of seropositive cases (87.1%) in the rainy season, directly proportional to increased rainfall.

The logistic regression showed a statistically higher number of cases of seropositive dogs for *Leptospira spp.* in the rainy season in this study. About 60% of the rainfall volume is concentrated in the rainy season and mitigates temperature. Temperature is amenable in the non-rainy period from June to August, and the September-December period has low humidity and high temperatures[24]. These weather conditions interfere with agent's continuity in the environment, which justifies the low prevalence observed in this study, since Teresina has two well-defined seasons: a

Table 1. Analysis of demographic characteristics of dogs examined and seropositive for anti-Leptospira antibodies in the city of Teresina (PI), Brazil.

Variable	Nº of dogs			Univariate		Multivariate		
	Examined	Positive	%	χ^2	P	OR	P	CI (95%)
Collection period								
Dry	275	14	5.09	34.569	0.000	1	0.000	2.745-9.486
Rainy	283	63	22.26			5.10		
Gender								
Female	271	29	10.70	4.252	0.039	1	0.060	0.979-2.780
Male	287	48	16.72			1.65		
Age (years)								
< 1	72	5	6.94	3.479	0.323	-	-	-
≥ 1---|3	162	23	14.20					
≥ 3---|7	211	33	15.64					
≥ 7	113	16	14.16					
Race								
Undefined	493	70	14.20	0.568	0.451	-	-	-
Specific race	65	7	10.77					
Management								
Domiciled	260	21	8.08	13.402	0.000	1	0.006	1.255-3.827
Access to streets	298	56	18.79			2.19		
Food								
Homemade food and pet food	190	25	13.16	4.612	0.100	1	0.466	1.047-3.140
Pet food	101	8	7.92			1		
Homemade food	267	44	16.48					
Collects food bowl at night								
Yes	274	26	9.49	8.408	0.004	1	0.015	1.139-3.304
No	284	51	17.96			1.94		
Hunting habit								
Yes	260	32	12.31	0.911	0.340	-	-	-
No	298	45	15.10					
Contact with other animal species								
Yes	321	49	15.26	1.365	0.243	-	-	-
No	237	28	11.81					
Vaccinated against leptospirosis								
Yes	50	5	10.00	0.666	0.414	-	-	-
No	508	72	14.17					
Rats in the household								
Yes	286	37	12.94	0.367	0.545	-	-	-
No	272	40	14.71					
Type of sewage								
Network	25	-	-	4.190	0.041	-	0.998	-
Pit	533	77	14.45					
Garbage collection								
Yes	504	67	13.29	1.119	0.290	-		-
No	54	10	18.52					
Flood								
Yes	149	23	15.44	0.458	0.499	-		-
No	409	54	13.20					
Accumulation of debris in the residence								
No	301	31	10.30	6.731	0.009	1	0.190	1.141-3.143
Yes	257	46	17.90			1.89		

$\chi 2$ = Chi-square, P = probability, OR = Odds Ratio.

Table 2. Analysis of possible risk factors of the demographic characteristics of owners of dogs examined and seropositive for anti-Leptospira antibodies in the city of Teresina (PI), Brazil.

Variable	Nº of people			Univariada		Multivariada		
	Examined	Positive	%	χ^2	P	OR	P	CI (95%;)
Do you know Leptospirosis?								
Yes	213	24	11.27	1.856	0.173	1	0.420	0.732-2.113
No	345	53	15.36			1.24		
Schooling								
Illiterate and incomplete elementary school	222	34	15.31					
Complete elementary school and incomplete secondary school	112	12	10.71	1.488	0.685	-	-	-
Complete secondary school and incomplete higher education	182	26	14.28					
Complete higher education	42	5	11.90					
Occupation								
Agriculture, livestock, forestry, fishing and aquaculture	7	2	22.2					
Unpaid (housewife, student, unemployed)	158	34	17.9					
General service and trade workers	183	28	13.3					
Professional, scientific and technical activities	23	3	11.5	7.930[a]	0.322[a]	-	-	-
Others (retired, pensioners)	72	9	11.1					
Human health and social services	23	1	4.2					
Arts, culture, sport and recreation	11	0	0					
Members of the armed forces, police and military firefighters	4	0	0					
Household income (minimum wage)								
<1	355	66	15.68			1		
≥1---|5	113	10	8.85	5.294	0.071	1	0.044	1.036-11.289
≥5	22	1	4.35			3.42		

[a] Monte Carlo test, χ^2 = Chi-square, P = probability, OR = Odds Ratio.

rainy season with amenable temperatures and humidity favorable to the maintenance and the proliferation of leptospires, thus, known for their seasonal nature, which causing urban outbreaks in rainy periods[25], and a non-rainy season with low rainfall, high temperatures and relatively low humidity, providing a dry environment that interferes with the survival of this bacterium.

The most frequent serovar was Icterohaemorrhagiae, followed by Canicola, which is to be expected since canine leptospirosis is caused mainly by Canicola and Icterohaemorrhagiae serovars, for which the main hosts are, respectively, dogs and rodents[26]. The presence of rats at home reported by the owners was not significant ($p < 0.05$). However, almost half of the samples (49.2%) were reactive for Icterohaemorrhagiae, a serovar whose reservoirs are mostly found in rodents, and dogs are frequently accidental hosts of this agent[27]. Such a circumstance may be a possible bias of prevarication or false response, since homeowners may feel constrained in affirmatively answering the question about the presence of rodents in their household[28]. The increased prevalence of Canicola and Icterohaemorrhagiae serovars may indicate that the lack of vaccination against leptospirosis in the general canine population influences the prevalence of these serovars[29].

Several recent studies have examined the de-

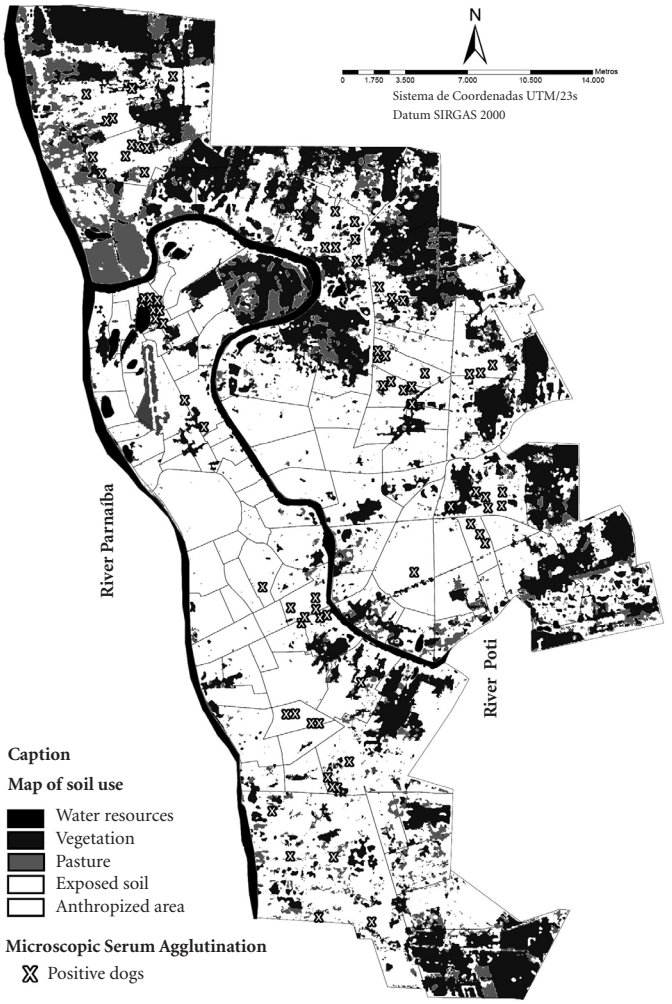

Figure 2. Spatial distribution of seropositive dogs for anti-Leptospira antibodies in the microscopic serum agglutination test and soil use classes of the urban perimeter of Teresina (PI), Brazil, during 2014.

mographic profile of seropositive dogs for Leptospira spp., but results are ambiguous[29]. Dogs with street access were more likely to be exposed to the agent than those domiciled, similar to studies by Martins et al.[20], whereas in other studies there was no difference in the management[30,31]. Similar to stray dogs, dogs with street access are exposed to several environments, with the habit of drinking sewage and ponds water, bathe in these waters in order to mitigate the heat and rummage the garbage, as was observed during the research. Failure to collect the animal's food bowl was considered another risk factor, a result different from a study by Bier et al.[10]. Usually, animal owners do not have this habit of collecting and sometimes even think it is necessary to leave the food at night for animals to eat; however, such a habit attracts rats seeking food, exposing dogs to probable reservoirs.

While contact with other animal species does not show a significant risk factor ($p < 0.05$) for the occurrence of seropositive dogs in this study, it is important to report that these dogs, even living in urban areas, had contact with other domestic (cat, pig, rooster and duck) and wild animals (snake, birds, fox and red-footed tortoise). Thus, other animals may transmit leptospires since serovars Australis, Pyrogenes, Sentot and Tarassovi, with reagent sera in the samples of this study, are accidental for dogs and this linkage has

Table 3. Distribution of dogs submitted to microscopic serum agglutination test in the districts of Teresina (PI), Brazil.

District	Microscopic Serum Agglutination				
	Total	Positive		Negative	
	Nº	Nº	%	Nº	%
Gurupi (B1)	21	7	(33.33) d	14	66.67
Pedra Mole (B2)	21	7	(33.33) d	14	66.67
Três Andares (B3)	23	7	(30.43) cd	16	69.57
Samapi (B4)	21	6	(28.57) cd	15	71.43
Alto Alegre (B5)	35	9	(25.71) cd	26	74.29
Angelim (B6)	23	5	(21.74) bcd	18	78.26
Cidade Industrial(B7)	35	7	(20.00) bcd	28	80.00
Parque Piauí (B8)	23	4	(17.39) bcd	19	82.61
Santo Antônio (B9)	23	4	(17.39) bcd	19	82.61
Santa Maria (B10)	35	5	(14.29) abcd	30	85.71
Piçarreira (B11)	21	3	(14.29) abcd	18	85.71
Morros (B12)	21	3	(14.29) abcd	18	85.71
Vale Quem Tem (B13)	21	3	(14.29) abcd	18	85.71
Renascença (B14)	21	2	(9.52) abcd	19	90.48
Primavera (B15)	34	2	(5.88) abc	32	94.12
Itararé (B16)	21	1	(4.76) ab	20	95.24
Bela Vista (B17)	23	1	(4.35) ab	22	95.65
Monte Castelo (B18)	23	1	(4.35) ab	22	95.65
Novo Horizonte (B22)	21	0	(0.00) a	21	100.00
São Pedro (B21)	23	0	(0.00) a	23	100.00
Matadouro (B20)	34	0	(0.00) a	34	100.00
Mocambinho (B19)	35	0	(0.00) a	35	100.00

been reported over the years in the studies on canine leptospirosis[4,27,30,31].

Traditionally, leptospirosis is described in medical literature as an endemic disease for low-income countries in temperate and tropical regions[32]. Rapid urbanization and urban poverty have led to the dramatic growth of favelas in all countries with low- and middle-income people. Because of a lack of sanitation in communities, slum dwellers are increasingly exposed and at risk of acquiring waterborne diseases and those transmitted by animals[33]. In addition, the socioeconomic status of the study population reveals the likely low education and financial condition of owners to provide health conditions for their animals and for the prevention of diseases, among which is leptospirosis, evidenced by the low number of people in the study who vaccinate their dogs.

According to data from the Municipal Secretariat for Planning and Coordination (SEMPLAN)[34], the basic service sectors (health facilities, educational establishments, transportation, security, water supply, housing type, garbage collection, sanitary sewage) of the districts selected for collection and analysis of information have in their territory clusters of similar social groups (favelas and noble areas), in which the pattern of urban infrastructure is homogeneously distributed in each district. These conditions allowed districts to be equivalent to each other, there being no isolated district neighborhood with an exclusive public service item and, consequently, no district with prevalence very different from the others. This information consolidates with the type of distribution of cases occurring in the city and can be visualized in Figure 1, which showed that it was scattered. While the choice of the district was not random, which may be a limitation of this study, it was possible to observe the lack of case clusters only in suburban districts or in the city's downtown area.

Among the districts with the largest seroprevalence (Gurupi and Pedra Mole) against those with lower seroprevalence (Matadouro, Mocambinho, São Pedro e Novo Horizonte), there were no basic service sectors that differed, except for sewage networks, in which those with the highest

frequencies did not have a sewage network, and those of lower frequencies (except Mocambinho) had more than 10% of the sewage network in the district.

Leptospires may be involved with all soil occupations (water density, pasture, exposed soil, anthropized area and vegetation); however, it can be seen that they adapt well in the anthropized area. Such evidence is similar to the study by Ward et al.[35], which mentions that urbanized areas were considered a risk factor for leptospirosis.

Rainfall and number of cases of leptospirosis are directly related to soil saturation and urbanization[25]. Urbanization can potentially increase flood intensity by tenfold. Large cities are particularly prone to flooding due to the combination of large paved, compacted or covered areas, which are less permeable than vegetated land and generate stiller waters[36].

In large urban centers, intense and disorderly urbanization process caused by rapid growth, lack of basic sanitation and inadequate garbage production and collection provide favorable environmental conditions for the reproduction of the rodent population, the main reservoirs of leptospirosis[25]. The city of Teresina was founded in 1852 and was the first planned Brazilian city[37]. However, based on data from the IBGE Demographic Census, it can be observed that Teresina witnessed an intense population increase. In 1980, the population did not reach 400,000 inhabitants and, in 2010, it topped 814,230 inhabitants. This increase in population and its concentration in the urban area, among other factors, lead to a greater difficulty in providing suitable housing planning conditions for collective services and an insufficient action of public policies to meet this demand. Therefore, soil occupation not preceded by the planning of rainwater drainage systems leads to an insufficient network for drainage needs, especially during periods of heavy precipitation, favoring dog contact with water contaminated with *Leptospira spp*.

The occurrence of floods was not considered a risk factor in this study ($p>0.05$), and may be a possible information bias, since the occurrence of cases in dogs was concentrated in the period of high rainfall, and presence of dogs in anthropized area suggests that flooding and inundations are determinant risk factors for the occurrence of canine leptospirosis in Teresina. The anthropized areas close to the banks of rivers and ponds did not show seropositive dogs' cases, which reinforces that floodwaters in anthropized area are the main water source of occurrences in this study.

Conclusions

In the urban perimeter of Teresina, capital of the state of Piauí, dogs' seropositivity for leptospirosis has a low frequency (13.8%) compared to other Brazilian regions, and dogs with street access, failure to collect the food bowl at night and low household income are risk factors for the occurrence of seropositive dogs for *Leptospira spp*. Although not statistically evidenced, floods and the presence of rodents may be important risk factors, since there was a higher frequency of seropositive for serovar Icterohaemorrhagiae, most of the cases observed in the rainy season and predominantly in the anthropized area.

The scattered distribution of seropositive animals for *Leptospira spp.* in the city emphasizes the importance of planning specific actions directed at the area of basic sanitation and urban infrastructure, reinforcing the context of epidemiological and environmental surveillance in disease prevention.

Collaborations

ALBB Mineiro worked on theoretical conception, critical review and final writing; V Castro worked on research, laboratory analysis and methodology; GHC Martins worked on research, data collection and methodology; MV Santana worked on research, data collection and methodology; LM Brito worked on the draft, design and data analysis and interpretation; MG Prianti worked in the writing of the paper, critical review and final writing of the text and SMMS Silva worked in the theoretical conception and elaboration and final writing of the text. ERDFS Silva worked on research, methodology, data collection, design and writing of the article.

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