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Spatial and seasonal analysis on leptospirosis in the municipality of São Paulo, Southeastern Brazil, 1998 to 2006

ABSTRACT

OBJECTIVE: To analyze the spatial and seasonal distribution of leptospirosis and identify possible ecological and social components of its transmission.

METHODS: A total of 2,490 cases registered in each district of the municipality of São Paulo, Southeastern Brazil, between 1998 and 2006, were georeferenced. The data were obtained from the Notifiable Diseases Information System. Thematic maps were made, showing the variables of incidence rate, lethality rate, literacy rate, average monthly income, number of residents per household, water supply and sewage system. To identify spatial patterns (dispersed, clustered or random), these variables were analyzed using the global and local Moran indices. Spearman's correlation coefficient was used to test associations between variables with clustered spatial patterns.

RESULTS: Clustered spatial patterns were observed for the variables of leptospirosis incidence, literacy rate, average monthly income, number of residents per household, water supply and sewage system. There were 773 notified cases in the dry season and 1,717 cases in the rainy season. The incidence and lethality rates correlated with the population's socioeconomic conditions, independently of the period.

CONCLUSIONS: Leptospirosis is spread throughout the municipality of São Paulo, and its incidence increases during the rainy season. In the dry season, the localities where cases appear coincide with the areas of poorest housing conditions. In the rainy season, it also increases in other districts, probably due to the proximity of rivers and streams.

DESCRIPTORS: Leptospirosis, epidemiology. Temporal Distribution. Residence Characteristics. Risk Factors. Socioeconomic Factors. Geographic Information Systems, utilization.

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INTRODUCTION

Leptospirosis is a zoonosis of great public health importance. It can be acquired through contact with animal reservoirs or environments contaminated with these animals' urine.[6,8,14] According to the *Centers for Disease Control and Prevention (CDC),*[6] it is the most widely distributed type of zoonosis in the world.

Spatial distribution is important in analyzing and evaluating risks to health, particularly those relating to the environment and the socioeconomic profile of the population.[3] Since such spaces are constructed socially, they may indicate relationships between health and social structuring, and stratify the population according to living conditions.[7]

In Brazil, a few studies analyzing leptospirosis from the viewpoint of spatial distribution have been produced. In the city of Salvador, state of Bahia, northeastern region, Costa et al[9] concluded that this disease was associated with low socioeconomic level and that the numbers of cases increased when there were higher levels of rainfall. In the city of Belo Horizonte, state of Minas Gerais, southeastern region, Figueiredo et al[10] observed that cases were registered predominantly in regions without adequate sanitary infrastructure, urban development conditions and garbage collection. In a study in the state of Rio Grande do Sul, southern region, Barcellos et al[4] noted that the highest incidence rates were in humid coastal areas at low altitude (subject to flooding) with land used for agricultural purposes. In the city of Rio de Janeiro, southeastern region, Tassinari et al[18] reported on the occurrence of an epidemic following heavy storms. However, none of these studies compared the incidence and lethality of leptospirosis between rainy (wet) periods and drought (dry) periods. The factors triggering the disease might be different or of different magnitudes during these periods.

Taking into consideration the risk factors needed for leptospirosis to develop and the living conditions of inhabitants of the municipality of São Paulo, the present study had the aims of analyzing the spatial and seasonal distribution of this disease and identifying possible ecological and social components of its transmission.

METHODS

This was a descriptive study carried out in the municipality of São Paulo, State of São Paulo, between 1998 and 2006, a period during which there were no epidemics of this disease. It was decided to start the investigation using data from 1998 due to the implementation of the Notifiable Diseases Information System (*Sistema de Informação de Agravos de Notificação* – SINAN) in the same year.

According to the Brazilian Institute for Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* – IBGE), São Paulo is the largest city anywhere in the southern hemisphere, with around 11 million inhabitants. It is located in the southeastern region of Brazil and covers an area of 1,530 km² divided into 96 districts. It has large socioeconomic disparities: while the central region is rich and well-developed, the more peripheral areas generally suffer from lack of infrastructure and social facilities, with poverty and precarious urban and housing development. These characteristics are expressed through irregular building plot division and shantytown development.[11,16]

According to the World Health Organization,[20] confirmation of leptospirosis cases depends on certain laboratory criteria (ELISA test, microagglutination reaction and blood or urine cultures) and on certain clinical-epidemiological criteria (signs and symptoms characterizing risk and/or epidemiological antecedents presenting risk). SINAN uses both types of criterion for defining confirmed cases.

All of the 2,624 confirmed cases of leptospirosis among people living in the municipality between 1998 and 2006 whose residential address was located were included in the study. After eliminating duplicated records and unknown addresses, the final total was 2,490 cases of leptospirosis.

The following variables were used: data on the home, data on the first symptoms and the date of death, if this occurred. These data were collected from the leptospirosis epidemiological investigation files of the Zoonosis Division, Health Department of the State of São Paulo. These files were filled out by municipal surveillance services or by healthcare units capacitated for performing epidemiological investigations. They were forwarded to the State Health Department and then to the Ministry of Health, for inclusion in the SINAN database.

The following variables were taken to be indicators of socioeconomic level in the municipality of São Paulo (Akerman et al[2]): mean family income, literacy (population aged five years or over), sewage system, water supply and number of people living in each household. These indicators were obtained from the IBGE's demographic census of 2000. Data relating to the numbers and density of residents and households in shantytowns were also used.[13]

The street addresses were located using the Geomapas Electronic Guide version 3.0 (on CD-ROM) and the Guia Mais search website.[a] These software packages

indicated the district in which each patient lived, using the street name that appeared in the investigation file.

The digital cartographic base for the municipality (Geolog 2.1.2) was obtained from the Municipal Planning Department. This is composed of different layers and it can thus be used in conjunction with geographical information system (GIS) software.

The 2,490 cases were georeferenced according to the districts in which these individuals lived. They were divided between dry season cases (April to September) and wet season cases (October to March), according to the date when symptoms began. The incidence rate (number of cases/population living in the district X 10,000) and lethality rate (number of deaths/number cases X 100) were calculated for each period.

To create the thematic maps, the data on incidence, lethality, mean monthly family income, literacy rate among the population, number of people living in each household, water supply, sewage system and the density and proportion of households and residents in shantytowns were transferred to the Mapinfo® 6.0 software and superimposed on the municipal districts.

The maps showed that there was no distribution pattern for the shantytowns: they were randomly distributed and located both on the periphery and in prime districts of the city. Hence, the shantytowns were withdrawn from the analysis.

All the variables were transferred to the ArcGis® 9.2 software to calculate the autocorrelation according to the global Moran index and to analyze the spatial distribution pattern (clustered, random or dispersed) of these variables according to district. For the variables with clustered spatial distribution, the local Moran index was used to map out the intensity of the clusters in Mapinfo® 6.0. There was no limit for the values of the local Moran index, and the result depended on the intensity of the cluster, i.e. the correlation of the variable with distance.

The global Moran index ranges from –1 to 1. Values close to zero indicate lack of spatial autocorrelation, while positive values indicate positive spatial autocorrelation and negative values indicate negative autocorrelation.

On the thematic maps, the intensity of the grey shading is directly related to the intensity of the coefficients of incidence and lethality. In other words, the darker the shading was, the greater the incidence or lethality was. The coefficients on the maps were divided into quartiles.

To test the hypothesis that the clusters would be correlated, Spearman's correlation coefficient was calculated between incidence and lethality (dry and wet seasons) and the variables of mean income, literacy, number of people living in each household, water supply and sewage system.

RESULTS

Table 1 presents the numbers and proportions of leptospirosis cases according to demographic and clinical characteristics. Out of the 2,490 cases, 80.4% were men, 45.4% were in the age group from 20 to 39 years, 65.1% presented jaundice and 49.3% probably became infected at home.

From the analysis on the global Moran index (Table 2), it was seen that the variables of literacy rate, mean income, number of people living in each household, water supply, sewage system and incidence during the wet and dry seasons presented cluster patterns. Lethality presented random distribution during both periods. The highest index (0.81) was in relation to the number of people living in each household, while the lowest index was for lethality during the wet season (0.02).

Figure 1 represents the local Moran index for the variable of incidence rate during the wet and dry seasons. The highest correlations were in districts with high and low incidence, i.e. the peripheral and central regions, respectively. Lethality was not represented in this index because of its random pattern.

In relation to the social need variables (Figure 2), clusters were observed in the central and peripheral regions. While the central cluster presented a concentration of good social conditions, the peripheral regions showed the contrary. The regions located in the transition zones between the center and periphery presented low or no correlation.

Figure 3 presents the thematic maps of incidence and lethality, divided into quartiles in order to view the spatial patterns. On the incidence map for the wet season, the highest rates were located in the districts close to the Guarapiranga reservoir and Pinheiros river. The central region presented low incidence of the disease, except in the Sé and Brás districts. During the dry period, districts in the south and east of the municipality presented high incidence, correlating with the areas of worst socioeconomic level. The Sé and Brás districts also presented high incidence during the dry period.

Lethality was concentrated in regions with worse living conditions, but without any formation of clusters during either period.

Among the deaths registered, 80.5% were men, 45.3% were in the age group from 30 to 49 years, 85.3%

Table 1. Numbers and proportions of leptospirosis cases according to demographic and clinical characteristics. Municipality of São Paulo, Southeastern Brazil, 1998-2006.

Variable	n	%
Sex		
Male	2001	80.4
Female	489	19.6
Age group		
0 to 9	100	4.0
10 to 19	382	15.3
20 to 29	539	21.6
30 to 39	592	23.8
40 to 49	452	18.2
50 to 59	251	10.1
> 60	174	7.0
Clinical form		
Jaundiced	1622	65.1
Non-jaundiced	703	28.2
Unknown	165	6.6
Infection setting		
Home	1227	49.3
Work	374	15.0
Leisure	124	5.0
Other	130	5.2
Unknown	635	25.5
Total	2490	100.0

presented jaundice (and remained hospitalized for a mean of eight days), 49.0% acquired the infection at home and 56.7% had had contact with a rodent.

Spearman's correlation coefficient indicated that the incidence of cases during the dry period presented negative correlations with the literacy rate ($r = -0.61$, $p < 0.001$); mean monthly income ($r = -0.48$; $p < 0.001$); water supply ($r = -0.44$, $p < 0.001$) and sewage system ($r = -0.56$, $p < 0,001$). It presented positive correlations with the number of people living in each household ($r = 0.54$, $p < 0.001$). There were correlations with the same variables during the wet season ($r = -0.57$, $p < 0.001$; $r = -0.41$, $p < 0.001$; $r = -0.48$; $p < 0.001$; $r = -0.59$, $p < 0.001$; and $r = 0.50$, $p < 0.001$, respectively). Lethality during the dry period presented a negative correlation with literacy ($r = -0.28$, $p = 0.002$), mean income ($r = -0.34$, $p < 0.001$) and sewage system ($r = -0.30$, $p = 0.002$), and a positive correlation with the number of people living in each home ($r = 0.34$, $p < 0.001$). During the wet season, lethality presented a negative correlation with the literacy rate ($r = -0.42$, $p < 0.001$), mean income ($r = -0.37$, $p < 0.001$), water supply ($r = -0.25$,

$p = 0.007$) and sewage system ($r = -0.35$, $p < 0.001$) and a positive correlation with the number of people living in each home ($r = 0.35$, $p < 0.001$).

DISCUSSION

The results from the present study showed that almost half of the cases became infected in the home, thus indicating the precariousness of some housing locations in the municipality. Young male adults were the group most contaminated by the disease, as also seen in other studies.[5,9,10,12,15] This was perhaps because they were the ones responsible for rescuing possible victims in cases of flooding and landslides caused by rain.

During the dry period, the locations where cases appeared coincided with the areas of worst housing conditions. This showed that even outside of the period of flooding, the people living in these regions continued to present risk factors for the disease to appear. During the wet season, the incidence of leptospirosis increased in the regions close to riverbank highways and reservoirs, probably because of flooding in these locations. During the period of least rainfall, the highest incidence was 2.49 cases per 10,000 inhabitants in Sé, while during the rainy season, the highest incidence was 5.4 cases per 10,000 inhabitants in Barra Funda. Data from the Health Surveillance Department of the Ministry of Health showed that between 1985 and 2005, the greatest proportion of confirmed cases in the southeastern region was in the state of São Paulo (54.1%).[a]

Between 1998 and 2005, the variation in the incidence of the disease in the state of São Paulo followed the variation in the municipality of São Paulo, but always with smaller numbers.[5]

Lethality presented random patterns with practically the same rate for the two periods (14.1% during the dry season and 14.2% during the wet season. Its occurrence in the more needy areas may have been due to failure to seek healthcare services, lack of medical attendance or diagnostic errors caused by lack of clinical suspicion. The rate was higher than the mean for the state (10%) and the country (12%), over the same period. The CDC has reported a lethality rate of 1 to 5% and occurrences of 100 to 200 cases per year in the United States.

Between 1998 and 2005, the municipality presented higher lethality rates than those of the state in six of these years.[5]

Taking into consideration that the non-jaundiced form of the disease is often not diagnosed, the 2,490 cases that occurred over the study period do not reflect the real incidence of the disease in the municipality of São

[a] Secretaria de Vigilância em Saúde, Ministério da Saúde. Distribuição de Casos Confirmados, por Unidade Federada. Brasil, 1980-2003. [Cited 2006, Oct 19]. Available at: http://portal.saude.gov.br/portal/arquivos/pdf/leptospirose_2006.pdf

Table 2. Calculation of global Moran index from socioeconomic variables and incidence and lethality rates. Municipality of São Paulo, Southeastern Brazil, 1998-2006.

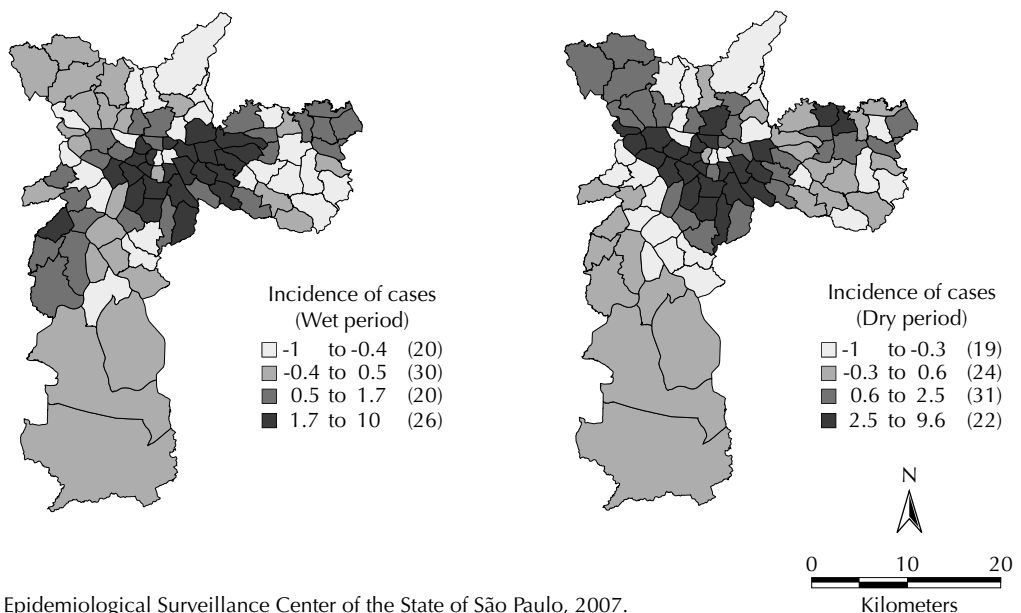| Variable	Global Moran index (Z-score)	Spatial distribution pattern
Literacy[a]	0,61 (9,72)	Clustered
Mean monthly income[a]	0,73 (11,85)	Clustered
Number of people per household[a]	0,81 (12,91)	Clustered
Water supply[a]	0,02 (4,04)	Clustered
Sewage system[a]	0,10 (9,85)	Clustered
Incidence		
Dry[a]	0,26 (4,32)	Clustered
Wet[a]	0,19 (3,19)	Clustered
Lethality		
Dry[b]	-0,09 (-1,32)	Random
Wet[c]	0,02 (0,45)	Random

[a] Probability greater than 99%
[b] Slight pattern, but randomly
[c] No pattern

Paulo. The incidence of leptospirosis may be underestimated because of cases with nonspecific symptoms, lack of laboratory availability for diagnostic tests, lack of clinical suspicion, non-confirmation of suspected cases and lack of medical attendance in some regions. In the study by Ko et al,[12] 42% of the leptospirosis cases were erroneously diagnosed as dengue cases. This is a disease with similar geographical distribution and symptoms. Sarkar et al[17] conducted a case-control study and found that 7% of the controls presented anti-*Leptosp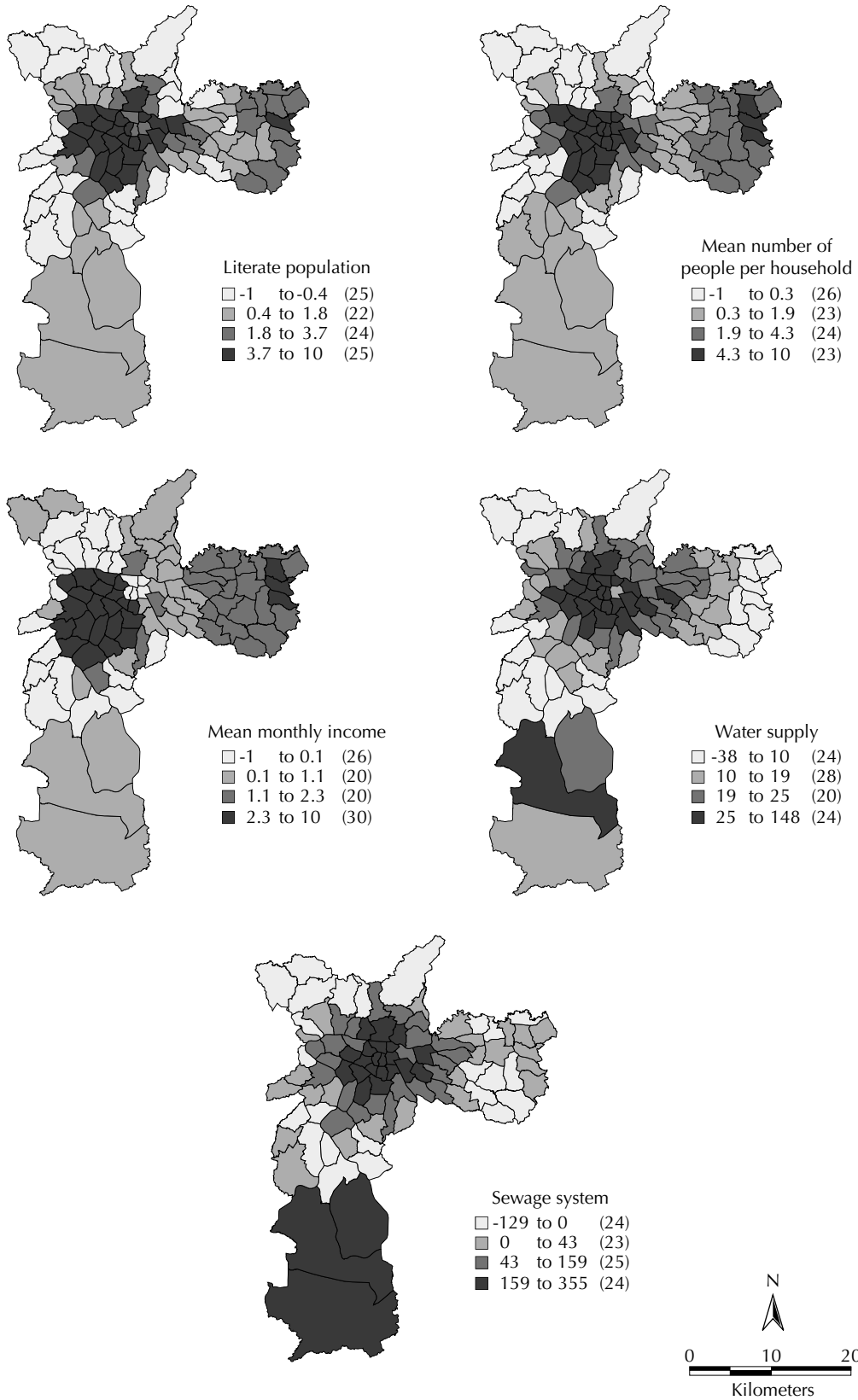ira* IgM antibodies, thus indicating that a significant proportion of the population living in high-risk areas was exposed to the disease and might develop subclinical or asymptomatic infection. Correct diagnosis would enable rapid intervention, thereby diminishing the lethality of the disease.

The results from the present study were concordant with data from other investigations, such as the studies by Costa et al[9] and Romero et al.[15] These authors concluded that the disease was associated with low socioeconomic level, with increases in the numbers of cases with increasing rainfall. Figueiredo et al[10] observed that the

Incidence of cases
(Wet period)
☐ -1   to -0.4   (20)
▨ -0.4 to 0.5   (30)
▨ 0.5 to 1.7   (20)
■ 1.7 to 10   (26)

Incidence of cases
(Dry period)
☐ -1   to -0.3   (19)
▨ -0.3 to 0.6   (24)
▨ 0.6 to 2.5   (31)
■ 2.5 to 9.6   (22)
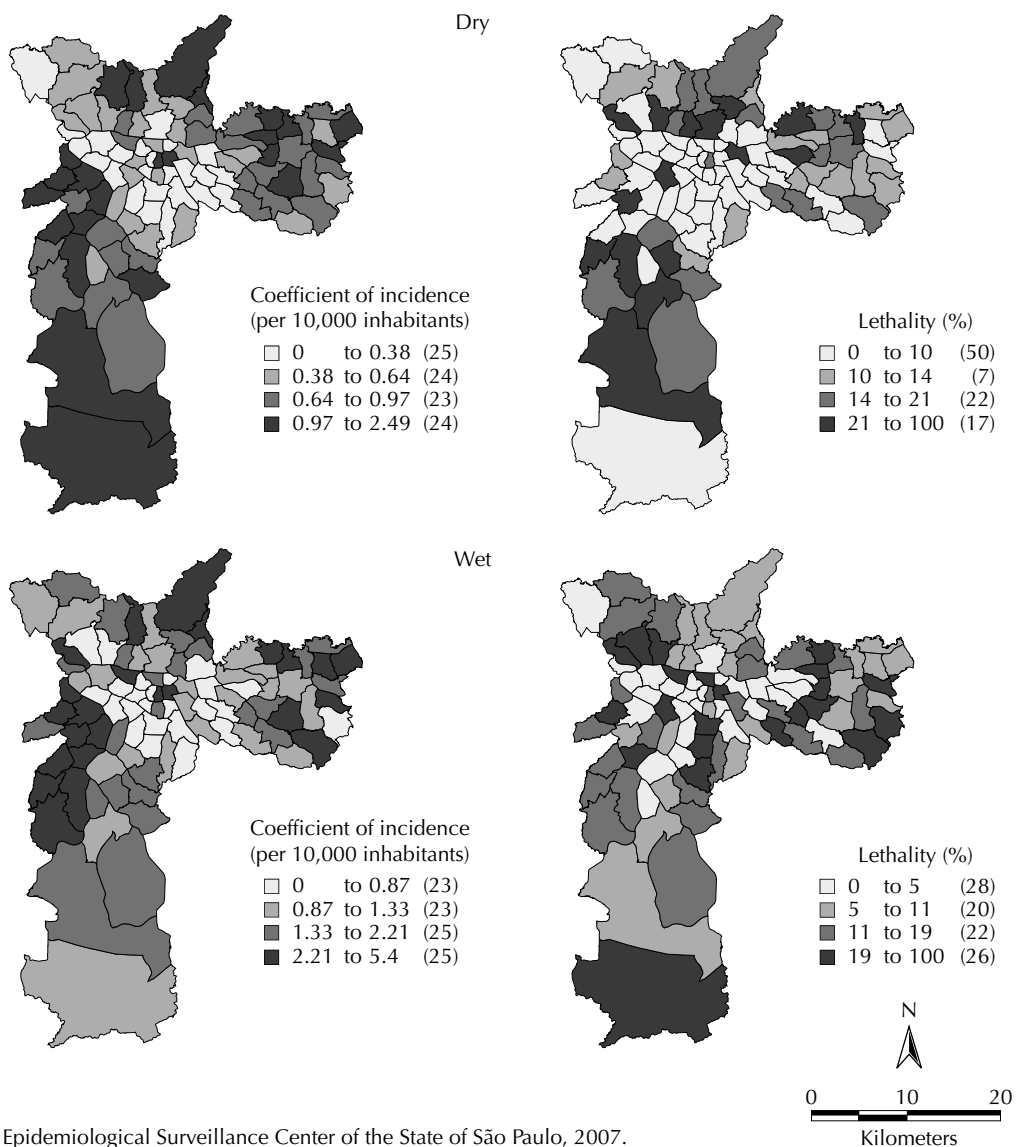
N

0   10   20

Kilometers

Source: Epidemiological Surveillance Center of the State of São Paulo, 2007.

Figure 1. Local Moran index from the leptospirosis incidence rate. Municipality of São Paulo, Southeastern Brazil, 1998-2006.

Source: Demographic Census (Brazilian Institute for Geography and Statistics / Instituto Brasileiro de Geografia e Estatística), 2000.

Figure 2. Local Moran index from socioeconomic variables. Municipality of São Paulo, Southeastern Brazil, 2000.

Figure 3. Incidence and lethality rates (%) for leptospirosis during the wet and dry periods. Municipality of São Paulo, Southeastern Brazil, 1998-2006.

cases were predominantly registered in regions without adequate sanitary infrastructure, urban development condition and garbage collection, and that populations without sewage treatment, living beside rivers that were liable to flood, were more exposed to infection by *Leptospira*.

Other authors have found other types of association. Barcellos et al[4] noted that the highest incidence rates were in humid coastal areas at low altitude (subject to flooding), with land predominantly used for agriculture. Tassinari et al[18] did not find any repetition of localities with greater concentrations of cases, or any spatial relationship between disease incidence and the distribution of shantytowns and areas subject to flooding.

The variables that presented clustered patterns according to the global Moran index indicated that nearby regions had similarities with each other. In fact, some regions of the municipality of São Paulo are characterized by a lack of adequate infrastructure, while others present better socioeconomic levels. The maps of the local Moran index showed where these regions with social similarities were located, for example: the center with good conditions, the periphery with poor conditions and a cluster around the center, without any pattern.

The shantytowns have a random distribution pattern because they are scattered throughout the city. Marques et al[13] conducted a study in which the growth rate of the population living in shantytowns between 1999 and 2000 was found to be 3% per year, i.e. well above the

growth rate for the population of the whole municipality over the same period (0.9%). The number of people living in precarious housing in São Paulo is similar to the total number of inhabitants of the largest Brazilian cities, exceeding one million inhabitants.[16]

The number of people living in each household presented a positive correlation, probably because more individuals were exposed the same source of infection. At times of flooding, rainwater would invade houses close to rivers and streams and expose the whole family to contact with water contaminated with rodent urine.

Variation in the numbers of leptospirosis cases was determined not only by rainfall, but also by a multiplicity of environmental and social factors. According to Alves,[1] social groups with greater levels of poverty and social deprivation live in areas with higher exposure to risk and to environmental degradation, thus constituting situations of high socioenvironmental vulnerability.

According to data from the demographic census of 2000,[a] 13.3% of the households in the municipality of São Paulo had a family income lower than two minimum monthly salaries, without access to housing in the peripheral zones. Thus, these individuals were obliged to live in urban areas of greater precariousness, generally presenting environmental risks, with very poor social and sanitary indicators,[16,19] and generally close to watercourses. The most likely explanation for this is that these are the only areas accessible to the poorest segment of the population, since they are publicly owned and/or preserved areas that have been invaded. Nevertheless, these areas are much devalued because they are unsuitable for occupation.[1]

Leptospirosis has been reported to be an occupational or recreational disease in developed countries.[6] However, in Brazil and in the municipality of São Paulo, it is mainly acquired through contact with contaminated water during rainy periods. Its epidemiological characteristics correlate with socioeconomic factors. This characteristic makes it possible to suggest that the incidence of this disease may be a social indicator.

Leptospirosis is found more frequently in areas where addresses are irregular, thus resulting in great loss of information. The treatment given to addresses in shantytowns, camps and invaded areas is a problem that deserves special study, considering that 5% of the cases in the present study could not be georeferenced for this reason.

In conclusion, the results from the present investigation made it possible to identify geographical areas in which the residents shared similar socioeconomic, environmental and living conditions. Identification of these homogenous areas enables decisions regarding specific strategies and interventions for the needs of people living in these areas. It also allows prioritization of resources for groups with greater vulnerability, thereby contributing towards diminishing healthcare inequalities. Since there are limitations on resources within public administration, breaking down the statistics in this manner may contribute towards prioritizing the investments in the most problematic areas.

The periphery of the city requires appropriate urban development and improvement in its sanitary conditions. The actions needed go from simple manipulation and monitoring of the environment, such as cleaning of drainpipes and adequate disposal of urban garbage, to urban development of shantytowns, with drainage and canalization of rivers and streams, thereby preventing occurrences of flooding. In addition, a rodent control program should be implemented in areas around homes and within work environments, even during drought periods.

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