Original article

Leptospirosis incidence in a state capital in the Western Brazilian Amazon and its relationship with climate and environmental variability, 2008-2013*

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Abstract

Objective: to analyze association between environmental variables and leptospirosis incidence in the municipality of Rio Branco, Acre, Brazil, 2008-2013. **Methods:** this was an ecological study of association between monthly average environmental variables and monthly leptospirosis incidence, according to generalized autoregressive score models and moving averages. **Results:** increases in the monthly average levels of the River Acre and days of precipitation per month were associated with a 7% increase (incidence rate ratio [RR] 1.07 – 95%CI 1.02;1.14) and a 4% increase (RR 1.04 – 95%CI 1,00;1,07) in the monthly incidence of leptospirosis, respectively; in 2013 leptospirosis incidence in the municipality was 8 times higher than in 2008 (RR 8.00 – 95%CI 4.07;15.71). **Conclusion:** this study showed a strong increase in leptospirosis incidence, over the years studied, and positive associations with environmental variables.

Keywords: Leptospirosis; Climate; Environmental Health; Floods; Climate Change.

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Introduction

Leptospirosis is an acute febrile illness caused by bacteria of the Leptospira SP genus. In particular it affects the liver and the kidneys, causing symptoms such as fever, headache, muscle pain, nausea and vomiting. These symptoms are common to a variety of other infectious diseases, but in the case of leptospirosis, they can progress to more serious forms and lead to multiple organ failure.[1,2] Leptospirosis lethality can reach 20% and occurs principally when the disease is not duly diagnosed and treated. It is one of the most geographically widespread zoonoses worldwide, although it is more frequent in developing countries and countries with tropical climates. A large variety of wild and domestic animals can act as reservoir hosts, but rodents, in particular the brown rat (Rattus norvegicus), have been more frequently related to this disease.[1,2]

In Brazil leptospirosis is an endemic disease which can take on epidemic proportions during rainy periods, particularly in state capitals and their metropolitan areas, owing to the combination of floods, large pockets of low-income inhabitants, improper sanitation and high infected rodent infestation.[3,4] The Western Brazilian Amazon has an ecological structure and tropical climate that are very favorable to the spread of leptospirosis.[5] In this large region, municipalities such as Rio Branco, Acre, for example, undergo periods of flooding practically every year, leaving thousands of people homeless or constantly exposed to floodwater.[6-9]

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Studies relating climatic and environmental variables to leptospirosis incidence in the Amazon are quite scarce and there is a lack of quantitative evidence regarding climatic and environmental risks of leptospirosis transmission in the region.[10,11] As such, in view of the differentiated pattern of urban flooding and regional climatic variations, the objective of this study was to analyze the association between environmental variables and leptospirosis incidence in the municipality of Rio Branco, Acre, Brazil, from 2008 to 2013.

Methods

This was an ecological study analyzing the monthly incidence of leptospirosis in the population living in the municipality of Rio Branco, capital of the state of Acre (AC), between 2008 and 2013. In 2017 Rio Branco had a population of 383,443 inhabitants, approximately 92.0% of whom lived in urban areas.[6] The region's climate is equatorial, with annual temperatures varying between 25°C and 35°C. The region has two seasons: a dry season (from May to September) and a rainy season (from October to April). Rio Branco is located on the banks of the River Acre, one of the main rivers of the Northern Brazilian region. Almost every year during the rainy season there are floods resulting from the increased level of this river which affect most of the city.[7-9]

The period of time covered by the study was selected because of the availability of information on the database used, namely the Notifiable Diseases Information System (SINAN). Leptospirosis incidence was analyzed as to its evolution over time, distribution between different age groups, its relationship with average regional monthly climatic variations and monthly oscillations in the level of the River Acre, considering the climatic conditions peculiar to the region and also a differentiated pattern of urban flooding and exposure of vulnerable populations.

Our study used data relating to the monthly number of confirmed leptospirosis cases among individuals resident in the municipality of Rio Branco, AC. Cases were recorded according to the month in which the first symptoms of the disease appeared. Data recorded on SINAN was categorized into ten age groups in relation to the period from January 1st 2008 to December 31st 2013. The SINAN system is available on the webpage of the Brazilian National Health System's Information Technology Department (DATASUS) and is maintained by the Brazilian Ministry of Health.[12] For the purpose of analysis, we calculated monthly leptospirosis incidence per 100,000 inhabitants, stratified by year, month and age group.

We obtained estimates of population size from the Brazilian Institute of Geography and Statistics (IBGE).[6] We used the annual estimates to calculate monthly incidence. We took the denominator to be the population estimated for the year in question, since there are no monthly estimates. For this same reason, we used the annual estimates for each of the age groups.

We used the following climatic variables: number of days with precipitation per month; average monthly precipitation (in mm); monthly average maximum, compensated medium and minimum temperatures (in °C); and average compensated relative humidity (in %). This data was retrieved from the information database available on the National Meteorology Institute (INMET) website.[13] The environmental variable used was the average monthly level of the River Acre (in meters), retrieved from the hydrological information system available on the National Water Agency (ANA) website.[14]

In order to analyze association between variables, we used generalized autoregressive score models and moving averages, also referred to as GARMA (Generalized Autoregressive Moving Average) models, with negative binomial (NB) distribution and logarithm link function.[15] These models are being increasingly used in the literature, especially in time series studies, and enable serial correlation between data to be modeled.[16,17] In order to assess what would be the best order for the GARMA model, we compared diverse models using different orders according to the Akaike Information Criterion (AIC).[18] This is based on choosing the model providing information least distant from the true model and which therefore has the lowest AIC.[18] We selected the variables using the backward method, i.e. removing one by one variables with the highest p-value. This procedure was repeated until only significant variables remained in the model.[19] We used a 5% significance level for this method. These analyses were performed using R statistical software version 3.0.1 (year 2013).

All data used in this study were retrieved from open-access secondary sources and as such there was no need for approval by the University of São Paulo Faculty of Public Health Research Ethics Committee.[20]

Results

During the six-year period covered by the study, 779 leptospirosis cases were reported in the municipality of Rio Branco. Annual leptospirosis incidence showed a strong upward trend with effect from 2010, when it was 13.4 cases/100,000 inhab., reaching 122.3 cases in 2013, with incidence between 10 and 60 times higher than that for Brazil as a whole. Moreover, a geometric increase in incidence rates was found in the municipality with effect from 2011: annual leptospirosis incidence increased from 30.6 cases/100,000 inhab. in 2011, to 71.6 in 2012 and 122.3 in 2013 (Figure 1).

Average monthly leptospirosis incidence measured between 2008 and 2013 showed a strong increase precisely in those months corresponding to the rainy season in the region (October-April): from an average of 3.9 cases/100,000 inhab. in October to 8.1 cases/100,000 inhab. in March, when the highest average leptospirosis incidence rate was found in the municipality. In the dry season (May-September), the highest average was found in May (2.3 leptospirosis cases per 100,000 inhab.), while the lowest average was found in July (1.4 case/100,000 inhab.) (Figure 2).

Figure 3 shows that the highest average monthly leptospirosis rates were found in individuals aged 20 to 39 years during the time period studied: 49.8 cases/100,000 inhab. Children aged under one year old and children in the 1 to 4 age group had the lowest average monthly leptospirosis rates, with 2.6/100,000 inhab. and 2.0 cases/100,000 inhab., respectively. The elderly, mainly those aged over 80 years, comprised the age group with the third lowest leptospirosis incidence rates, with approximately 10.5 monthly cases per 100,000 inhab.

After analyzing association, in order to select the best model, we adjusted eight GARMA models with different orders, using AIC as the selection criteria. We chose the model with the lowest value. After applying the backward method, we selected the following variables: year; average monthly level of the River Acre; number of days per month with precipitation; total average monthly precipitation; monthly average compensated humidity; and monthly average minimum, compensated and maximum temperatures (Table 1).

In relation to the time interval studied, we found significant increase in leptospirosis incidence with effect from 2011: 2.16 times higher in 2011 compared to 2008 (RR 2.16 – 95%CI 1.06;4.42); 4.22 times higher in 2012 compared to 2008 (RR 4.22 – 95%CI 2.11;8.45); and 8.00 times higher in 2013 compared to 2008 (RR 8.00 – 95%CI 4.07;15.71) (Table 1).

The level of the River Acre significantly influenced the occurrence of leptospirosis (RR 1.07 – 95%CI 1.02;1.14): each additional meter in the average monthly level of the river was associated with a 7% increase in monthly leptospirosis incidence. The number of days

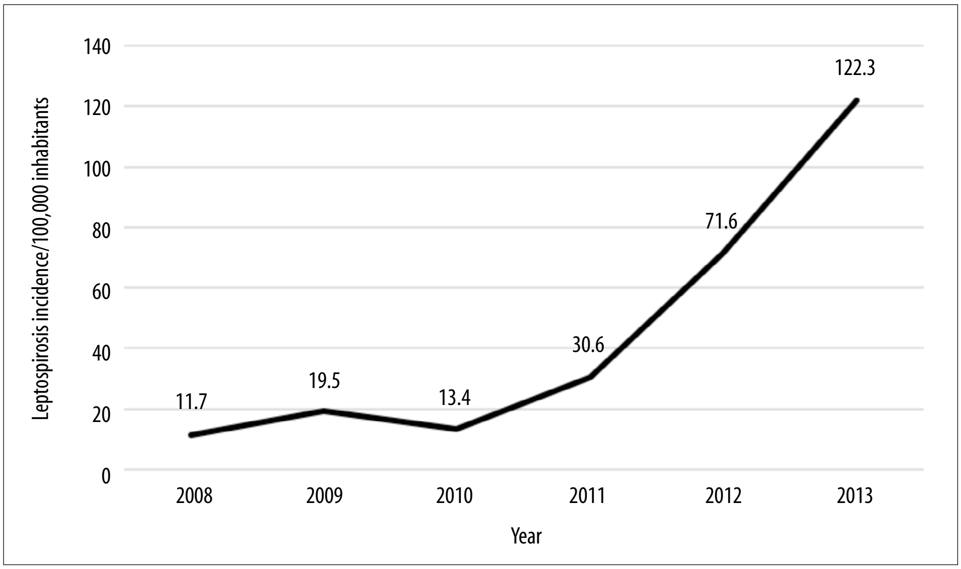

Figure 1 – Annual leptospirosis incidence (per 100,000 inhabitants) in the municipality of Rio Branco, Acre, 2008-2013

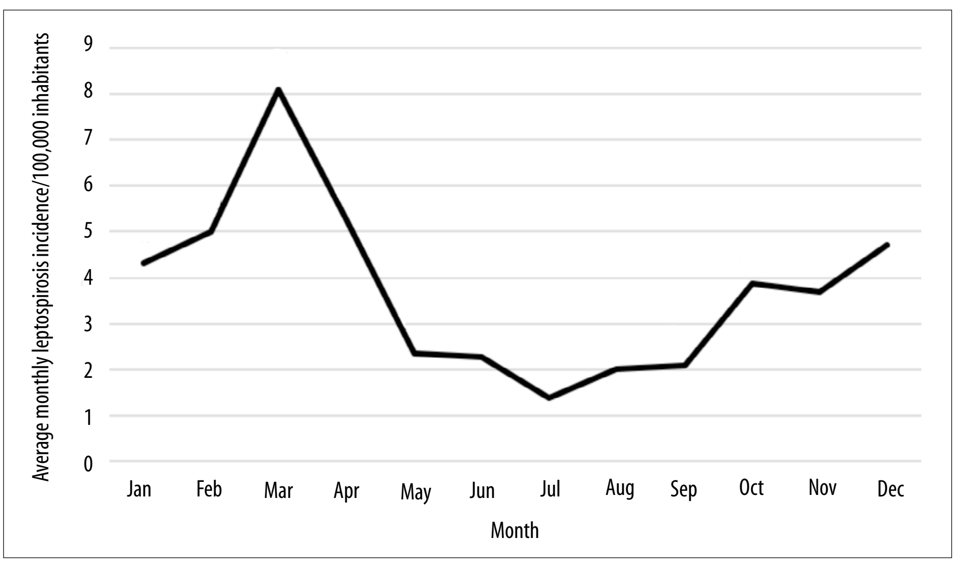

Figure 2 – Average monthly leptospirosis incidence (per 100,000 inhabitants) in the municipality of Rio Branco, Acre, 2008-2013

with precipitation in the month also showed significant influence on leptospirosis occurrence: each additional day of precipitation in the month was associated with a 4% increase in monthly leptospirosis incidence (RR 1.04 – 95%CI 1.00;1.07) (Table 1).

The average moving parameter (Θ) showed a significant value which was also different from zero ($p=0.050$), thus confirming the choice of order in the GARMA model. The dispersion parameter (σ) was also different from zero and was significant ($p=0.002$), thus confirming that the negative binomial model was the most correct for this analysis (Table 1).

Discussion

The results found through these analyses show that in the municipality of Rio Branco, the amount of days per month with precipitation and the average monthly level

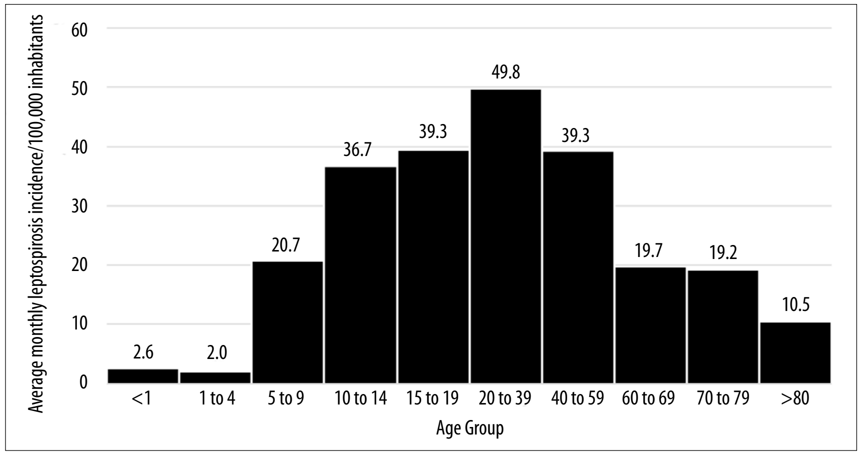

Figure 3 – Average monthly leptospirosis incidence (per 100,000 inhabitants) by age group in the municipality of Rio Branco, Acre, 2008-2013

of the river can influence the occurrence of leptospirosis, causing increases of 4.0% and 7.0% in the incidence of the disease, respectively. These variables can represent indicators for forecasting trends in the occurrence of leptospirosis in this and the other municipalities in the Amazon Region, given that these municipalities have very similar environments and climates.

It is known that heavy rain and flooding are indeed mainly responsible for epidemic outbreaks of leptospirosis in tropical and underdeveloped countries, especially when combined with environmental pollution and the presence of rodents.[4,20,21] Notwithstanding, the extent to which these factors could contribute to such outbreaks, especially in this region of Brazil, was not known prior to our study. Brazil is a country of continental dimensions and, consequently, its different regions are climatically and environmentally diverse.

In Rio Branco this situation is of special concern because the River Acre floods almost every year.[7,8] During these floods leptospirosis, which is concentrated in the ground during dry periods, spreads to more distant areas and affects population groups exposed to floodwater. Individuals living in areas close to breeding grounds generally have contact with the infectious agent more quickly and more frequently, thus resulting in the outbreaks that typically occur 3 to 5 weeks following flooding, as the incubation period is usually 7 to 12 days.[1,4,22,23]

Our study also shows that monthly leptospirosis incidence has increased considerably in the region. Between 2011 and 2013, for instance, the increase was geometrical, revealing an emergency situation and reinforcing the need for greater attention to be paid to prevention and infection control measures. Leptospirosis is currently considered to be an emerging infectious disease worldwide, owing to the substantial increase in its incidence and in its geographic distribution.[23,24] A factor contributing to its growth may be that leptospirosis has been a neglected disease in recent decades owing to its low impact on society.[24]

It is also important to highlight that our study associates aspects of climatic and environmental variability with leptospirosis incidence in a context within the Amazon, where the perspective of global climate change may result in exacerbated vulnerability and epidemiological scenarios of considerable concern. As these climatic changes are already underway, the frequency of extreme climatic and environmental events worldwide is expected to increase and become more intense.[25] The climatic models projected for the Amazon Region indicate large increases in the temperature, thus contributing to possible increases in the survival time of bacteria in the environment, habitat expansion and increase in the number of species acting as bacteria reservoirs.[24-26] This increase in the temperature may also influence the pattern of rainfall and occurrence of flooding in the region owing to the warming of the surface of the Southern Tropical Atlantic Ocean,[27] leading to greater distribution and exacerbation of leptospirosis and other waterborne diseases, especially in vulnerable urban contexts.[22,27]

Table 1 – Monthly average values of climatic and environmental variables associated with monthly leptospirosis incidence rates in the municipality of Rio Branco, Acre, 2008-2013

Variable	Bivariate model	Multiple variable model
	RR[a] (95%CI[b]), p-value[c]	RR[a] (95%CI[b]), p-value[c]
Year		
2008	Intercept	Intercept
2009	1.21 (0.57;2.58), 0.624	1.26 (0.60;2.65), 0.540
2010	0.97 (0.41;2.30), 0.948	0.97 (0.45;2.09), 0.929
2011	1.88 (0.86;4.12), 0.116	2.16 (1.06;4.42), 0.035
2012	4.36 (1.87;10.17), <0.001	4.22 (2.11;8.45), <0.001
2013	7.39 (3.11;17.55), <0.001	8.00 (4.07;15.71), <0.001
River level (in meters)	1.10 (1.03;1.17), 0.003	1.07 (1.02;1.14), 0.012
Number of days of precipitation per month	1.07 (1.00;1.15), 0.049	1.04 (1.00;1.07), 0.026
Total precipitation	0.76 (0.58;1.00), 0.047	–
Compensated humidity	0.98 (0.86;1.12), 0.757	–
Minimum temperature	1.25 (0.54;2.92), 0.604	–
Compensated temperature	0.73 (0.20;2.64), 0.628	–
Maximum temperature	1.10 (0.68;1.79), 0.689	–
Θ [d]	0.19 (p=0.050)	0.19 (p=0.022)
σ [e]	0.16 (p=0.002)	0.18 (p=0.001)
AIC[f]		399.50

a) RR: incidence rate ratio.
b) 95%CI: 95% confidence interval.
c) Significance probability.
d) Moving average parameter.
e) Dispersion parameter.
f) AIC: Akaike Information Criterion.

It is equally important to consider the way in which urbanization of the Brazilian Amazon has taken place and its role in generating conditions favorable to leptospirosis transmission.[4,28] Increased migration from rural to urban areas in recent decades has resulted in a process of urbanization lacking in planning, an increase in populations occupying land next to rivers and seasonal streams, abnormal agglomerations with precarious infrastructure and sanitation and, as a consequence, the establishment of a context of vulnerability that reflects the socioeconomic dimension of leptospirosis.[3,11,29]

The results of our study corroborate those found in the literature, by demonstrating that leptospirosis incidence is usually greater among adults and lower among children and the elderly.[2,30] Children have limited contact with contaminated earth and water, principally during extreme environmental events when outbreaks commonly occur. Moreover, children aged under 10 years old usually have less serious reactions to leptospirosis.[30] Lower incidence among the elderly is probably due to lower exposure to contaminated environments and to the development of a certain level of immunity resulting from prior exposure in endemic areas.[30] However, data found in the literature reveal greater leptospirosis lethality among the elderly.[30] Adults are more exposed to leptospirosis because of their working activities and, because they comprise the economically active workforce, their becoming ill and/or dying results in a loss both for labor and social production.

Studies involving secondary data, despite providing very valuable information for ecological studies, are known to be subject to a variety of limitations. One of the most important limitations for studies analyzing time series are variations in data collection and recording over time, leading to incorrect analysis and difficulty in obtaining more reliable results. In our study we used a statistical method that enables biases to be modeled, such as serial correlation between data and errors related to the choice of model order and variable selection.

Our analyses were not based on socioeconomic data and geographical characteristics, so that population groups in situations of socio-environmental vulnerability to leptospirosis were not characterized. Nor did we evaluate progress made by health and surveillance services with regard to access to and increased availability of diagnostic tests, which may have contributed to the remarkable growth in basal leptospirosis incidence found in the period in question.

Notwithstanding, our study was able to present for the first time in the Amazon Region climatic and environmental variables truly associated with increased leptospirosis incidence and its intensity. This increased knowledge of case distribution over time, its relationship with the regional climate and environment, together with the detection of the high potential for leptospirosis transmission in Rio Branco, can contribute to planning and decision-making aimed at preventing and mitigating climatic and environmental impacts on the health of people living in the capital of the state of Acre.

Authors' contributions

Duarte JL contributed to the conception and design of the study, result analysis and interpretation, writing and critical revision of the contents of the manuscript. Giatti LL contributed to the interpretation of the results, writing and critical revision of the contents of the manuscript. Both authors approved the final version of the manuscript and are responsible for all its aspects, including ensuring its precision and integrity.

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