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Temporal trends in leptospirosis incidence and association with climatic and environmental factors in the state of Santa Catarina, Brazil

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Abstract *Leptospirosis is a zoonosis with epidemic potential, especially after heavy rainfall causing river, urban and flash floods. Certain features of Santa Catarina's coastal region influence these processes. Using negative binomial regression, we investigated trends in the incidence of leptospirosis in the six municipalities with the highest epidemic peaks between 2000 and 2015 and the climatic and environmental variables associated with the occurrence of the disease. Incidence was highest in 2008 and 2011, and peaks occurred in the same month or month after disasters. Incidence showed a strong seasonal trend, being higher in summer months. There was a decrease trend in incidence across the six municipalities (3.21% per year). The climatic and environmental factors that showed the strongest associations were number of rainy days, maximum temperature, presence of flash floods, and river flooding. The impact of these variables varied across the municipalities. Significant interactions were found, indicating that the effect of river flooding on incidence is not the same across all municipalities and differences in incidence between municipalities depend on the occurrence of river flooding.*

Key words *Leptospira, Natural disasters, Regression analysis, Linear models*

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Introduction

Leptospirosis is a bacterial disease that affects humans and animals. It is the most widespread zoonosis, occurring worldwide, except in polar regions, and is more common in tropical and subtropical regions[1]. The disease is caused by bacteria of the genus Leptospira, found in the urine of infected animals. Excess rainfall and water-related natural disasters create conditions conducive to leptospirosis outbreaks and epidemics[1,2]. When heavy rains cause river, urban and flash floods, bacteria dispersed into the environment can cause infection when individuals come into contact with contaminated water. In these situations, the disease can reach epidemic proportions[3]. Humans can also acquire leptospirosis through direct contact with the urine of infected animals[4].

Transmission in humans occurs through cuts and abrasions in the skin or mucous membranes in the nose, mouth and eyes, and through waterlogged skin[4]. Leptospirosis may also occasionally be transmitted through drinking water or food contaminated with the urine of infected animals, notably rats. Human-to-human transmission is rare[1].

A systematic review of published and grey literature from January 1970 to October 2008 estimated that leptospirosis affects 1.03 million people and causes 58,900 deaths worldwide each year, with the majority of cases and deaths occurring in men aged between 20 and 49 years. In addition, morbidity and mortality are greatest in poor regions and areas where surveillance is not routinely performed, including tropical Latin America[5].

In high-income countries, the disease is linked mainly to occupational, sports and recreational activities[6], while in middle-income countries such as Brazil, leptospirosis occurs mainly in urban settings and is associated with land occupation and housing problems, lack of basic sanitation, high population density and water-related natural disasters[7-9]. In addition, climatic factors, such as rainfall and temperature, have also been associated with leptospirosis, mainly by studies using monthly or weekly temporal analysis[10,11].

According to data for the period 2001 to 2015 from the Ministry of Health's national notifiable diseases information system (SINAN), the South region has the highest cumulative incidence of leptospirosis in Brazil. Santa Catarina has the highest incidence among states in the South region and the third highest in Brazil, behind Acre and Amapá[12].

The unique geomorphic features of the state of Santa Catarina, particularly its coastal region, are conducive to natural disasters such as river and flash floods. *Climatic and* geological conditions and land use increase the risk of these events. Torrential rains and flooding are common. In November 2008, the region of Grande Florianópolis, Vale do Itajaí and the northern coast witnessed the biggest natural disaster in the state's history, when record rainfall caused widespread urban and river flooding and landslides[13]. In 2011, another disaster occurred, mainly affecting the east of the state, reaffirming the vulnerability of the population to these types of events. On both occasions, the state witnessed extremely high epidemic peaks of leptospirosis.

Few studies have described trends in leptospirosis in Brazil and around the world. The systematic review mentioned above did not identify significant temporal trends in disease morbidity or mortality[5]. Other studies reported upward trends in incidence in Croatia and Malaysia and decrease trends in Thailand and Denmark[14-17]. Studies in Brazil have investigated trends nationally[18] and in Belém do Pará. The latter reported a decrease in incidence between 2006 and 2013, despite the high number of deaths observed in this period[8,19]. Other studies have also shown a reduction in mortality in Fortaleza[20,21]. As in Brazil and the rest of the world, few previous studies have investigated temporal trends in leptospirosis in Santa Catarina[22,23].

The aim of this study was to investigate spatial trends in the incidence of leptospirosis in Santa Catarina between 2000 and 2015 and identify climatic and environmental factors associated with the occurrence of the disease.

Methods

Study area

Santa Catarina is located in Brazil's South region and has a total area of 95,730 sq km, divided into 295 municipalities[24]. For the purposes of this study, we selected the six municipalities with a population of over 50,000 inhabitants that showed the highest epidemic peaks during the study period: Blumenau (309,011 inhabitants), Camboriú (62,361 inhabitants), Gaspar (57,981 inhabitants), Itajaí (183,373 inhabitants), Jaraguá do Sul (143,123 inhabitants) and Navegantes (60,556 inhabitants)[25]. Smaller municipalities were not chosen because small changes in the number of cases in these areas are likely to cause major variations in incidence coefficients. Figure 1 shows the location of Santa Catarina, the six municipalities and their respective rivers.

Santa Catarina had a high Human Development Index (HDI) in 2017 (0.808), ranking third among Brazil's 27 states. In 2010, the indices in the municipalities selected for this study ranged from high (0.700 to 0.799) to very high (0.800 to 1), with Blumenau being the most developed (MHDI = 0.806, 25th place in Brazil), followed by Jaraguá do Sul (MHDI = 0.803, 34th place), Itajaí (MHDI = 0.795, 56th place), Gaspar (MHDI = 0.765, 289h place), Navegantes (MHDI = 0.736, 876th place) and Camboriú (MHDI = 0.726, 1,133th place)[26].

Case data

Data on leptospirosis cases during the period 2000 to 2015 were collected from the Leptospirosis Investigation Forms used in the SINAN provided by the Santa Catarina Department of Health. The confirmation of the leptospirosis cases included in this study was based on at least one of the criteria recommended by the Ministry of Health[27]. This information was used to calculate monthly case numbers in each municipality.

Population data

The annual number of inhabitants in each municipality was obtained from the 2000 and 2010 censuses and population estimates made by the Interagency Health Information Network (RIPSA)[12]. Since the analyses used monthly data, monthly population was assumed to be the same as the population in the respective year.

Climate data

Precipitation and air temperature data were obtained from the Climate Prediction Center (CPC) (www.cpc.ncep.noaa.gov), which belongs to the National Oceanic and Atmospheric Administration (NOAA). The data produced by the center is based on gauge-based daily precipitation analyses from 30,000 stations over global land areas using the optimal interpolation (OI) method at a 0.5-degree grid point for the entire globe and considering local relief[28]. We used monthly precipitation data collected from the points closest

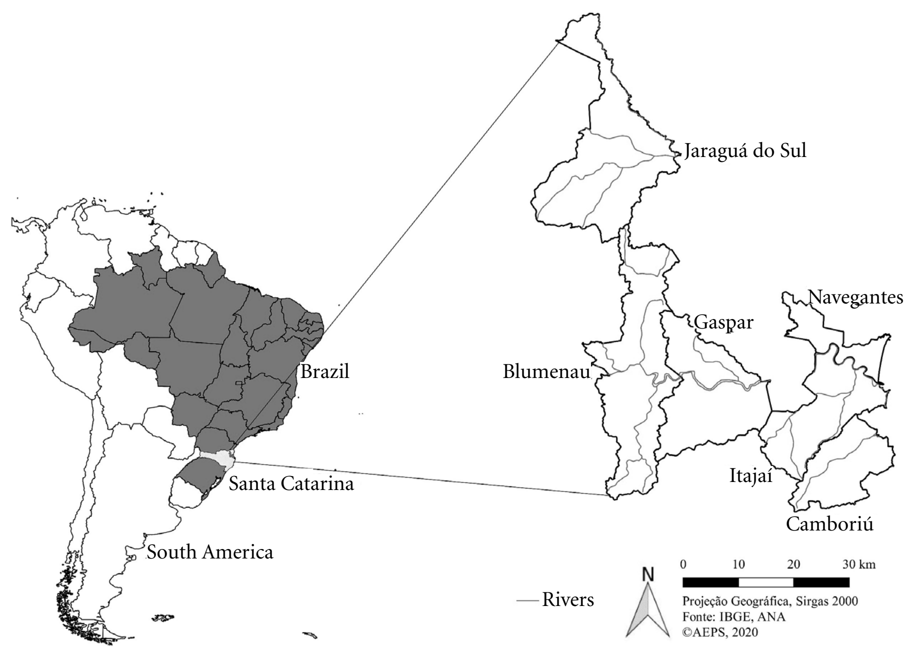

Figure 1. Location of the six municipalities in Santa Catarina. Brazil, South America.

Source: Authors.

to the administrative center of each selected municipality. Maximum and minimum daily land surface temperatures were interpolated from the same grid point as the precipitation data over the globe[29]. This data was used to obtain the monthly minimum, mean and maximum temperatures closest to the administrative center of each selected municipality.

Natural disaster data

Data on river, urban and flash floods in each of the six municipalities were obtained from the digital archives of the Integrated Disaster Information System (S2ID - https://s2id.mi.gov.br/). The number of events were recorded by type and month of occurrence.

Statistical analysis

Two types of generalized linear models (GLM) were run. The first was used to assess trends in incidence in the six municipalities during the study period, while the second was used to determine the climatic and environmental factors associated with leptospirosis. In both models, the response variable was the number of cases per month and the monthly population of each municipality was used as the offset.

In GLMs, the response variable can follow any of the distributions in the exponential family of distributions, including the normal, Poisson and negative binomial distributions. As the number of cases of the disease are count data, it is possible that distributions other than the normal distribution show a better fit to the data, such as the Poisson distribution or, in the presence of overdispersion, the negative binomial. We ran models considering each one of these distributions and the best fit (in this case the negative binomial distribution) was determined using residual analysis.

The explanatory variables in the first model were time (in years centered around zero), a dummy variable for each municipality, and terms for the interaction between time and municipalities. The model was run without the intercept. Using the coefficients of the dummy variables, it was possible to estimate and compare incidence in each municipality in the middle of the study period (2007.5). Using the coefficient of the time variable, we calculated the relative risk (RR) of the disease in a given year relative to the previous year and annual percent change (APC), expressed as (RR-1)*100. The coefficients of the interactions were used to assess whether the trend was the same across all municipalities, which is indicated by significant coefficients. Interactions that were not statistically significant were removed from the final model. To assess whether the trends observed in this model depended on time-dependent climatic and environmental factors, the model was rerun including the climatic and environmental variables as controls.

The second model was run using a forward stepwise procedure. The explanatory variables were climatic factors (monthly minimum, mean and maximum temperatures, precipitation, and number of rainy days), environmental factors (monthly indicators of natural disasters: river, urban and flash floods), and an indicator variable for each municipality. It is reasonable to assume that disease incidence in a specific month may be the consequence of temperature, precipitation and disasters not only in that month, but also in the previous month. To examine the contribution of these factors in both the respective and previous month, and determine the best way of characterizing their effects on disease incidence, we created variables with values observed in the respective and previous months and the two-month moving average (respective month and previous month) for each climatic factor. For each environmental factor, we created variables for the occurrence of the event in the respective month, previous month and either one of the months (respective or previous month). We then ran multiple models including number of leptospirosis cases and climatic and environmental factors as dependent and independent variables, respectively.

The only explanatory variable in the initial model was the municipalities. The remaining explanatory variables were added one after the other, going from the most important to the least important from a statistical point of view. The order of importance was defined using Spearman's correlation coefficient (highest to lowest). In each step of the procedure, a new variable was added to the model. We observed the following to determine whether a variable should remain in the model: the p-value from the t-test of its coefficient, the p-value from the likelihood ratio test (which compares the model with the variable to the model without the variable) and the influence of the variable on the variables already added to the model. The variables were kept in the model when the p-values were less than 0.05 and the variables already added remained statistically significant.

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After completing this procedure, we assessed whether the effects of the climatic and environmental variables that were added to the model were the same across the different municipalities. To this end, we tested the interactions between these variables and the municipalities. Only statistically significant interactions were maintained in the final model.

Results

Figure 2 shows monthly incidence of leptospirosis (in logarithmic scale) on the left and monthly precipitation (in millimeters) on the right in each municipality throughout the study period. The vertical lines represent the months in which there were natural disasters (river, urban and flash floods).

For most of the period, the highest incidences were found in Jaraguá do Sul and Gaspar, and the lowest were in Camboriú and Navegantes. In general, a small rise in incidence was observed after periods of higher temperature and greater rainfall. In November 2008, there were 500 mm of rain in the municipalities and December saw extremely high peaks in incidence. The same was observed in Jaraguá do Sul in January 2011. Particularly in these two years, epidemic peaks were preceded by natural disasters in the same or previous month.

Figure 3 shows the mean monthly incidence of leptospirosis in each municipality in the period 2000 to 2015. The incidence shows a strong seasonal trend, with peaks in the summer months.

Table 1 shows the estimates from the regression model used to identify trends in incidence of leptospirosis in the six municipalities. Incidence showed a decrease trend throughout the study period (RR = 0.97; $p < 0.01$), even after adjusting for climatic and environmental factors. The interactions between the municipalities and year were not statistically significant, showing that the drop in incidence was the same across all municipalities. APC was -3.21% (CI = -5.4%:-1.0%). Incidence was highest in Jaraguá do Sul (1.86, CI = 1.49:2.33) and Gaspar (1.66, CI = 1.29:2.14), irrespective of climatic and environmental conditions.

Spearman's correlation coefficients were statistically significant ($p < 0.01$) for all variables except occurrence of urban floods. Associations were strongest for the variables maximum temperature in the respective month, two-month moving average number of rainy days and precipitation, and occurrence of river flooding and flash floods in the respective and/or previous month. Only precipitation was removed from the final model, due to its strong correlation with number of rainy days (0.72). The results of the final model are shown in Table 2.

The results of this model show that for each additional day of rain in a specific month, the risk of disease increased on average by 6% ($p < 0.001$, RR = 1.06, CI = 1.03:1.09), irrespective of the other variables. Likewise, for every 1° C rise in temperature, the risk of disease increased on average by 12% ($p < 0.001$, RR = 1.12, CI = 1.08:1.16). In addition, the occurrence of flash floods led to a twofold increase in risk of disease ($p < 0.001$, RR = 2.05, CI = 1.53:2.76).

There were statistically significant interactions between the municipalities and occurrence of river flooding, suggesting that the effect of flooding on disease incidence is not the same across the municipalities. Likewise, differences in incidence across the municipalities depend on the occurrence of river flooding. The RR of river flooding is therefore presented for each municipality, based on the presence and absence of the event, allowing for the comparison of each municipality with the reference municipality (Camboriú).

In some municipalities, the occurrence of river flooding had a major impact on the risk of disease. In Itajaí, the presence of the event resulted in a 16-fold increase in risk (CI = 4.33:56.72), while in Camboriú, Navegantes and Blumenau, RR ranged between 9.41 and 4.18. In Gaspar and Jaraguá do Sul, river flooding did not have an impact on risk of disease ($p > 0.1$ in both cases).

During the periods in which there was no river flooding, RR was greater in all municipalities when compared to Camboriú. This difference was more pronounced in Gaspar and Jaraguá do Sul, where the risk was 8.17 (CI = 4.86:13.71) and 9.38 (CI = 5.72:15.37) times greater, respectively, than in Camboriú. However, in the periods in which there was river flooding, risk was similar to Camboriú in all municipalities, except Itajaí, where it was greater (RR = 4.10, CI = 1.32:12.74).

Discussion

Our findings reveal associations between incidence of leptospirosis and climatic and environmental factors, showing that the risk of disease increased with rising precipitation and temperature across the six municipalities. These

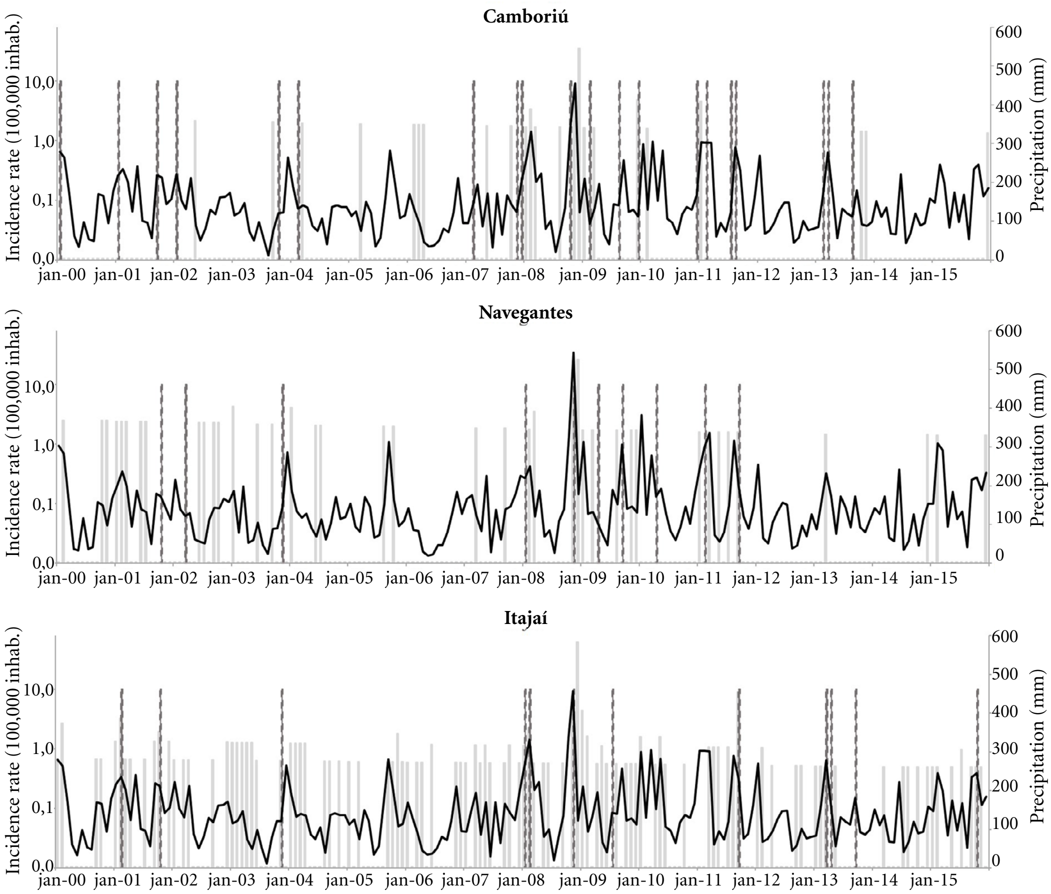

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Figure 2. Leptospirosis incidence rates in logarithmic scale, precipitation and occurrence of river, urban and flash floods by municipality.

findings are corroborated by other studies that show associations between disease incidence and minimum, mean[14,30,31], or maximum temperature[10] and precipitation, usually expressed in volume[10,14,30,32-34].

In the present study, incidence was associated with precipitation expressed both in terms of volume of rainfall and number of rainy days. Given the strong correlation between both variables, we included only number of rainy days in the final model, as the effect of this variable on incidence was greater than volume of rainfall. This may have occurred because this variable reflects not only volume, but also the daily frequency of rainfall. In this regard, prolonged periods of daily rainfall, even in low volumes, can lead to river flooding, flash floods and landslides[35].

We also observed associations between disease incidence and occurrence of natural disasters, with flash flooding leading to an increase in risk of disease in the six municipalities. However, the effect of river flooding varied across municipalities, being an important risk factor in Itajaí, Camboriú, Navegantes and Blumenau, but not in Gaspar and Jaraguá do Sul. The mouth of the River Itajaí-Açu, which receives all the water from the river basin, is located in Itajaí and Navegantes, while urban areas in Camboriú are close to the mouth of the River Camboriú in the neighboring municipality of Balneário Camboriú. The Itajaí River floods are differentiated due to the broad flat-floored valley between Blumenau and Itajaí. Blumenau also belongs to the middle stretch of the Itajaí River Valley, whose unique

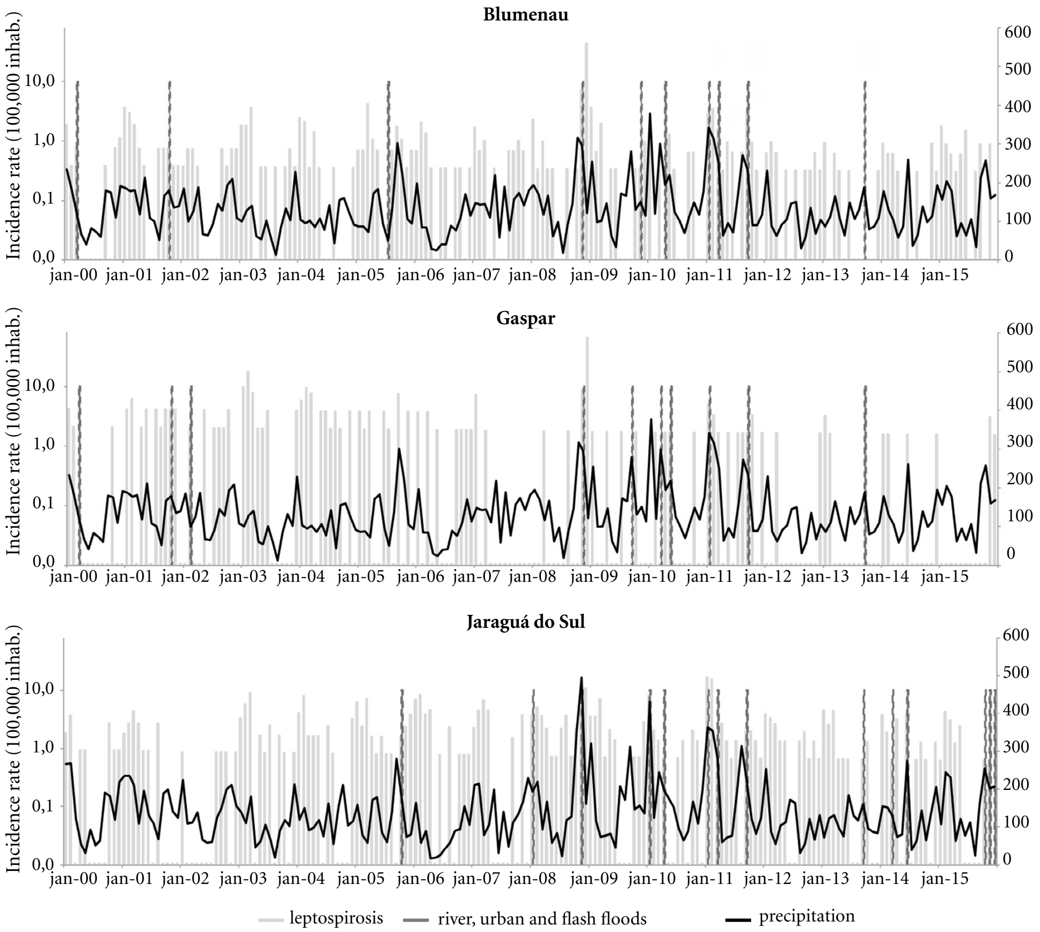

Figure 2. Leptospirosis incidence rates in logarithmic scale, precipitation and occurrence of river, urban and flash floods by municipality.

Source: Authors.

features are conducive to river flooding. According to Klein, cited by Mattedi et al.[36], upstream from Blumenau, the River Itajaí-Açu has rapids due to the local relief. However, when the river enters the urban boundary, it receives water from other tributaries and the terrain is flatter, reducing velocity and flow rate and causing a sudden rise in level and sprawling of the river across its old river bed, which has been narrowed by urban growth. River flooding did not have any impact on disease incidence in Gaspar and Jaraguá do Sul. Although Gaspar also belongs to the middle stretch of the Itajaí River Valley, it receives less water from the Itajaí-Açu River Basin than the municipalities located close to the mouth of the river. Jaraguá do Sul is located at the beginning of the Itapocu River Basin, which is a lot smaller in terms of area and length of main channel, and has a lower flow rate than the Itajaí-Açu River Basin[2].

All the types of disasters investigated by this study were associated with incidence of leptospirosis, except urban floods. Urban flooding is the accumulation of water due to drainage problems[37]. All the municipalities investigated by this study have rivers running through them, meaning that the overflowing of their normal confines constitutes a river flooding disaster, an event that is more frequent than urban floods in these municipalities.

Thus, the differences in disease incidence across the six municipalities partially reflect different levels of vulnerability to climatic and environmental factors. A study in Korea observed that

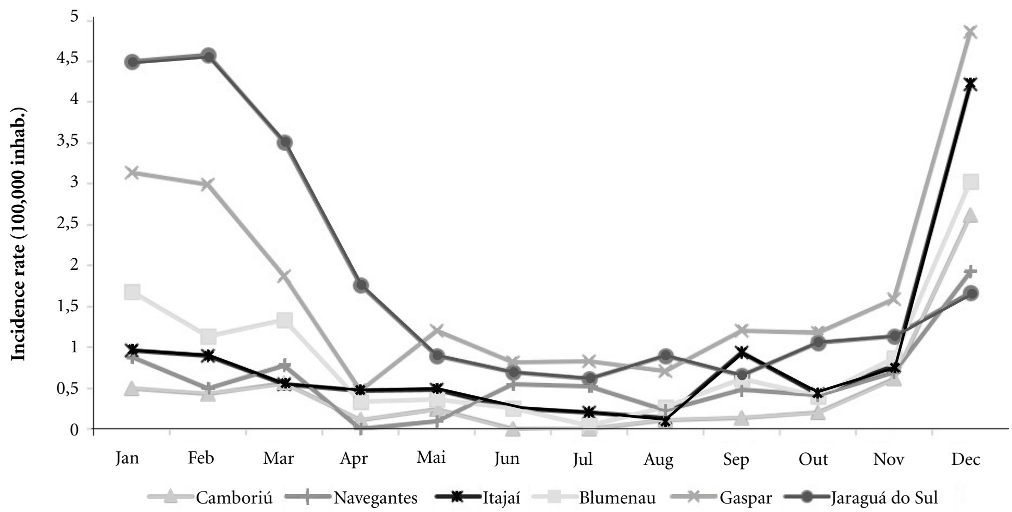

Figure 3. Mean monthly leptospirosis incidence rates in each municipality throughout the study period.

Source: Authors.

Table 1. Estimates from the regression model used to identify trends in incidence of leptospirosis in the six municipalities.

	No adjustment for climatic and environmental factors#		Adjustment for climatic and environmental factors#	
	Estimate	CI (95%)	Estimate	CI (95%)
Incidence (per 100,000) no ano 2007,5				
Camboriú	0.47*	(0.34:0.66)	0.01*	(0.002:0.013)
Navegantes	0.57*	(0.41:0.78)	0.01*	(0.004:0.021)
Itajaí	0.86*	(0.68:1.09)	0.01*	(0.006:0.028)
Blumenau	0.86*	(0.69:1.08)	0.02*	(0.007:0.032)
Gaspar	1.66*	(1.29:2.14)	0.03*	(0.015:0.071)
Jaraguá do Sul	1.86*	(1.49:2.33)	0.04*	(0.018:0.086)
Relative risk				
Time (years)	0.97*	(0.95:0.99)	0.97*	(0.95:0.99)

*P-value < 0,001; #climatic and environmental factors: number of rainy days, maximum temperature, occurrence of river flooding and flash floods.

Source: Authors.

a 1°C rise in minimum temperature at a lag of 11 weeks was associated with a 22.7% increase in leptospirosis cases[30]. In addition, as a result of global climate change, extreme climate events such as cyclones and river flooding are likely to occur with greater frequency and intensity, potentially resulting in an increase in disease incidence and the magnitude of leptospirosis outbreaks. Continuous monitoring in the post-disaster phase is essential to assess the long-term impacts of leptospirosis after river flooding[38]. Other factors also influence disease dynamics, such as basic san-

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Table 2. Estimates from the final regression model (relative risk and respective confidence interval) used to identify the climatic and environmental factors associated with leptospirosis in the six municipalities.

Explanatory Variables	RR	CI 95%
Number of rainy days	1.06**	(1.03;1.09)
Maximum temperature (°C)	1.12**	(1.08;1.16)
Occurrence of flash floods	2.05**	(1.53;2.76)
Occurrence of river flooding, for each municipality		
Camboriú	9.41**	(4.26;20.79)
Navegantes	4.75*	(1.15;19.71)
Itajaí	15.67**	(4.33;56.72)
Blumenau	4.18*	(1.20;14.58)
Gaspar	2.77	(0.77; 9.95)
Jaraguá do Sul	1.21	(0.34;4.37)
Municipality, in periods without river flooding		
Camboriú	1.00	
Navegantes	2.06*	(1.16; 3.65)
Itajaí	2.46**	(1.48; 4.10)
Blumenau	3.50**	(2.12; 5.77)
Gaspar	8.17**	(4.86;13.71)
Jaraguá do Sul	9.38**	(5.72;15.37)
Municipality, in periods with river flooding		
Camboriú	1.00	
Navegantes	1.04	(0.28;3.87)
Itajaí	4.10*	(1.32;12.74)
Blumenau	1.55	(0.52; 4.61)
Gaspar	2.40	(0.77;7.43)
Jaraguá do Sul	1.21	(0.39;3.71)

* $p < 0.050$; **$p < 0.010$.

Source: Authors

itation and environmental and social factors[39]. However, the available socioeconomic indicators show that there are no major disparities between the municipalities that could explain these differences in incidence[25].

Mean monthly incidence during the study period and the rate adjusted to July 2007 across the six municipalities (cases per 100,000 inhabitants per month) varied between 0.5 (in Camboriú) and 1.9 (in Jaraguá do Sul), which is equivalent to 6.0 to 22.8 cases per 100,000 inhabitants per year. These means are higher than those observed in the period 2001 to 2015 in SC (0.5 per 100,000 inhabitants per year) and Brazil (1.9 per 100,000 inhabitants per year)[12]. In 2008, the year in which the disaster occurred, incidence in the six municipalities was much higher than in SC as a whole (16 cases per 100,000 inhabitants per year), with Itajaí recording the highest rate among the group (72 cases per 100,000 inhabitants per year). Rates similar to that of Brazil were found in 2014 in Latin America (2.0) and some countries in the region, such as Colombia (2.6) and Cuba (2.1)[40].

Our findings showed a decrease trend in disease incidence across the six municipalities (3.21% per year). Other studies conducted in Brazil have also pointed to a drop in incidence. A study in SC showed an annual fall of 14.9% in the incidence of leptospirosis during the period 2008 to 2011[23], while a study of the period 2005-2015 showed a seasonal decrease between April and September[22]. A study in Belém also reported an annual fall of 1.33% between 2006 and 2011, possibly due to the underreporting of cases[19]. A national study of the period 2008 to 2012 did not find an upward trend in cases when the data were adjusted for seasonality[18].

A number of hypothesis may explain the decrease trend observed by the present study. One of these is improvements in basic sanitation. The proportion of households in SC with adequate sanitation increased from 61% in 2000 to 66.3% in 2010, while the proportion of households with inadequate sanitation fell from 10.5% to 4.1%, and there was a slight reduction in the proportion of households with partially adequate sanitation. In all six municipalities except Itajaí, there was an increase in the proportion of households with adequate sanitation and a reduction in the proportion with partially adequate and inadequate sanitation. In 2010, the proportion of households in these municipalities with adequate sanitation varied between 77% and 87%[25].

Better socioeconomic conditions in SC and the six municipalities investigated by this study may have contributed to a drop in leptospirosis incidence. Between 2000 and 2010, the illiteracy rate among the population aged 15 years and over fell across the state (6.3% to 4.1%), including the six municipalities[25]. During the same period, the state's and municipalities' HDI improved, with the latter achieving high and very high scores[26].

Increased public awareness of the risks of the disease, especially after flooding, may have contributed to the fall in incidence. In December 2011, the government created the National Center for Monitoring and Early Warning of Natural Disasters (Cemaden), which provides information on weather and geological conditions to the civil defense agency when there is an imminent threat of disaster. It is also possible that there has been improvements in government prevention actions and training of health professionals for epidemiological investigation, diagnosis and interventions.

However, the drop may also be related to a possible increase in underreporting of the disease amid increased incidence of other seasonal diseases such as dengue, whose initial symptoms can often be confused with leptospirosis. Like leptospirosis, dengue is more prevalent in the rainy season. Even in the dry season, when leptospirosis occurs regardless of rainfall through other means of transmission, cases may still be underreported as community health workers do not perform active screening for signs and symptoms of the disease during this period[18]. According to Soares et al.[7], in the driest months between 1998 and 2006 in the city of São Paulo, the incidence of leptospirosis was high in socioeconomically disadvantaged areas.

Leptospirosis incidence in the six municipalities showed seasonal trends, with higher prevalence in summer months, particularly December. In a study of leptospirosis incidence across SC between 2005 and 2015, Ghizzo Filho[41] observed higher incidence in October and March, when relative risk was more than double that of April to September. The Itajaí Valley, divided into the upper and middle stretches and mouth of the River Itajaí, showed a similar trend, with higher incidence between October and March. All of the six municipalities except Jaraguá do Sul belong to the middle stretch of the valley and mouth of the River Itajaí.

Despite the decrease trend in disease incidence, leptospirosis remains a public health problem in SC, whose magnitude is strongly influenced by climatic and environmental factors, especially extreme hydrological events. This study provides important information on leptospirosis in six municipalities in SC, which can make a valuable contribution the planning of disease prevention and control actions, particularly in the event of natural disasters.

Conclusions

Leptospirosis incidence in SC was highest in Gaspar, Itajaí, Blumenau, Camboriú, Navegantes and Jaraguá do Sul. Extremely high rates were found in these municipalities in 2008, and in Jaraguá do Sul in 2011. In general, incidence peaked in the same month or month immediately after natural disasters. Incidence showed strong seasonal trends, being higher in the summer months, particularly December, across the six municipalities. There was a decrease trend in disease incidence across the six municipalities (3.21% per year) during the study period. The climatic and environmental factors associated with incidence were number of rainy days, maximum temperature, and presence of river flooding and flash floods. The effect of river flooding varied across the municipalities. River flooding had an impact on risk of disease in Itajaí, Camboriú, Navegantes and Blumenau. The risk of disease in the presence of river flooding was highest in Itajaí, followed by Camboriú, Navegantes and Blumenau. River flooding did not have an impact on risk of disease in Gaspar and Jaraguá do Sul. In the periods in which there was no river flooding, RR was higher than in Camboriú in all the municipalities. In the periods in which there was river flooding, all municipalities showed similar risk to Camboriú, except Itajaí, where risk of disease was higher. Our findings can make an important contribution to improving leptospirosis surveillance and prevention actions in these and other municipalities with similar characteristics subject to extreme hydrological events.

Collaborations

AEP Silva worked on the conception, design, analysis, interpretation of data and paper writing. MRDO Latorre worked on the analysis, interpretation of data and paper critical review. F Chiaravalloti Neto worked on the design and paper critical review. GMS Conceição worked on the conception, design, analysis, interpretation of data, paper writing and its critical review. All authors approved the submitted version.

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