FULL ARTICLE

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Feline sporotrichosis: social vulnerability and prioritization of geographic areas in Guarulhos, SP, Brazil

Esporotricose felina: vulnerabilidade social e priorização de áreas geográficas em Guarulhos, SP, Brasil

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ABSTRACT
Over the past two decades, many Brazilian cities have been reporting an increasing incidence and spread of feline sporotrichosis. The disease is neglected, and little is known about the causal processes underlying its epidemic occurrence. This study characterized the spatiotemporal dynamics of feline sporotrichosis in Guarulhos. Moreover, we proposed and tested a causal explanation for its occurrence and zoonotic transmission, giving a key role to social vulnerability. A direct acyclic graph represented the causal explanation, while Bayesian spatial models supported its test as well as the attribution of a risk-based priority index to the census tracts of the city. Between 2011 and 2017, the disease grew exponentially and the spatial spread increased. The model findings showed a dose-response pattern between an index of social vulnerability and the incidence of feline sporotrichosis. This pattern was not strictly monotonic, so some census tracts received a higher priority index than others with higher vulnerability. According to our causal explanation, there will not be effective prevention of feline and zoonotic sporotrichosis as long as social inequities continue imposing precarious livelihoods.
Keywords: Zoonoses. Bayesian models. Epidemiological surveillance. Neglected diseases. One Health of Peripheries.

RESUMO
Nas últimas duas décadas, diversas cidades brasileiras têm relatado um aumento na incidência esporotricose felina e sua disseminação. A doença é negligenciada e pouco se sabe sobre os processos causais que estão envolvidos na sua ocorrência epidêmica. Neste estudo, foi caracterizada a dinâmica espaço-temporal da esporotricose felina em Guarulhos. Além disso, é proposta e testada uma explicação causal para sua ocorrência e transmissão zoonótica, atribuindo um papel fundamental à vulnerabilidade social. Um grafo acíclico direcionado representou a explicação causal, enquanto modelos espaciais Bayesianos foram usados para testá-la e para atribuir um índice de prioridade baseado em risco aos setores censitários da cidade. Entre 2011 e 2017, a doença cresceu exponencialmente e a sua disseminação espacial aumentou. Os resultados do modelo mostraram um padrão de dose-resposta entre um índice de vulnerabilidade social e a incidência de esporotricose felina. Esse padrão não foi estritamente monotônico, já que alguns setores censitários receberam um índice de prioridade mais alto do que outros com maior vulnerabilidade. Segundo nossa explicação causal, não haverá prevenção efetiva da esporotricose felina e zoonótica enquanto as iniquidades sociais continuarem impondo condições de vida precárias.
Palavras-chave: Zoonoses. Modelos Bayesianos. Vigilância epidemiológica. Doenças negligenciadas. Saúde Única em Periferias.

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Introduction

Sporotrichosis is a mycosis caused by thermally dimorphic fungi of the genus *Sporothrix* (Orofino-Costa et al., 2017), composed of 53 species, distributed worldwide, predominantly in tropical and subtropical regions (Rodrigues et al., 2020). However, most *Sporothrix* species behave as non-pathogenic environmental saprobes. The few associated with human and animal sporotrichosis belong to the pathogenic clade: *Sporothrix schenckii sensu stricto*, *Sporothrix brasiliensis*, *Sporothrix globosa*, and *Sporothrix luriei* (Rodrigues et al., 2020).

Infections that are driven by *Sporothrix* spp. classically occur through contact with soil, plants, and organic materials contaminated by propagules of the pathogen, representing an occupational risk for people who work in contact with vegetation. The alternative route is associated with bites and scratches from infected cats, which can transmit the disease to others cats and humans (Gutierrez-Galhardo et al., 2015; Rodrigues et al., 2020). In Brazil, the zoonotic transmission reached epidemic levels (Schubach et al., 2008), mainly involving *S. ssis*, the most virulent species among pathogenic species (Rodrigues et al., 2013; Sanchotene et al., 2015).

The first outbreak of sporotrichosis reported in Brazil occurred in the late 1990s, in Rio de Janeiro, whose urban region is currently considered hyperendemic for the disease (Barros et al., 2008; Silva et al., 2012). Over the past two decades, there was a geographical expansion of the disease (Gremião et al., 2020), and nowadays sporotrichosis represents an important public health problem (Brandolt et al., 2019; Falcão et al., 2019; Rodrigues et al., 2013; Sanchotene et al., 2015).

States in the Southern and Southeastern regions are the most affected by the disease (Gremião et al., 2017). Feline cases, which are usually a precedent of human cases, were reported in Rio Grande do Sul (Poester et al., 2018), Santa Catarina (Colodel et al., 2009), Paraná (Rüncos et al., 2017), São Paulo (Montenegro et al., 2014), Rio de Janeiro (Pereira et al., 2014), Minas Gerais (Barros et al., 2012), and Espírito Santo (Falqueto et al., 2012). Animal cases have also been reported in other regions of the country, such as Central West, in Mato Grosso (Fernandes et al., 2004), and Federal District (Cordeiro et al., 2011). Recently, there has been an expansion of feline sporotrichosis to the Northeastern region, as described in the states of Paraíba (Nunes et al., 2011), Pernambuco (Silva et al., 2018), Alagoas (Marques-Melo et al., 2014), and Rio Grande do Norte (Figueira & Nunes, 2010).

It is believed that complex interactions between pathogen, host, and environment underlie epidemics of *S. brasiliensis* (Montenegro et al., 2014). Some environmental characteristics seem to favor the maintenance of the pathogen in the environment, such as high humid soil and the presence of rubbish in the streets (Barros et al., 2010; Ramírez-Soto et al., 2018). Both factors are often found together in Brazilian favelas. Also, delayed diagnosis and treatment of infected cats, as well as discontinuing the treatment earlier than recommended, contribute to the dispersion of *S. brasiliensis* (Chaves et al., 2013), and constitute obstacles to the control of sporotrichosis.

In the city of Guarulhos (SP), Brazil, the first case of feline sporotrichosis confirmed by the municipal health surveillance service occurred in November of 2011 in a favela, and since then, the number of infected cats has been increasing (Fernando C. Pereira, personal communication). With concerns of zoonotic transmission growing, an ordinance issued in 2016 made mandatory the notification of human cases (Guarulhos, 2016).

In Guarulhos, Gonsales (2018) found that 100% of the cat samples analyzed were positive for *S. brasiliensis*, in agreement with the results of Montenegro et al., (2014), who detected 17 samples positive for *S. brasiliensis* in cats from the same region. This seems to be the predominant species in the city. In Brazil, cats represent the main source of cat and human *S. brasiliensis* infections, so preventive and control measures for cats are strategic against the disease in humans. These animals have a high potential for spreading sporotrichosis due to their behavioral habits and mobility, while dispersal through soil and vegetation (predominant for other species of *Sporothrix* spp.) remains less effective (Rodrigues et al., 2013).

Despite the recognition of this public health problem, there are still no epidemiological studies of the spatiotemporal distribution of the disease and its risk factors in Guarulhos. Previous studies mention the occurrence of feline sporotrichosis in Guarulhos, however addressing clinical only aspects, diagnosis, or molecular characterization (Galati et al., 2017; Gonsales et al., 2019; Gonsales, 2018). As governmental agencies in Guarulhos and other municipalities face many challenges to contain the increasing number of cases, it is necessary to understand why the disease continues spreading and how to improve the efficiency of control strategies.

Therefore, the present study described the spatiotemporal dynamics of feline sporotrichosis in Guarulhos. It also tested a causal hypothesis regarding the effect of social vulnerability on feline sporotrichosis incidence and attributed a risk-based priority index to census tracts to guide surveillance actions and resource allocation.

Material and Methods

This section is divided into seven subsections. The first four refer to the study area, the surveillance service, the data, and the preparation of these data, respectively. Subsections five and six present the causal hypothesis and the corresponding Bayesian models. The last subsection describes the software used and points to a public repository with codes and datasets to reproduce the results.

Study area

The present study was carried out in the city of Guarulhos, located in the Metropolitan Region of the state of São Paulo, Brazil. The largest airport in Latin America is located in Guarulhos and it is at the convergence of the roads that connect São Paulo to Rio de Janeiro. The municipality has an estimated population of 1,379,182 people, the second most populated in the state, only behind the population of São Paulo, and the thirteenth in the country. The territorial area covers 318,675 km^2 and the demographic density is 3,834.51 inhabitants/km^2, being the 26th densest city of Brazil (Instituto Brasileiro de Geografia e Estatística, 2020).

Surveillance service

The surveillance service for feline sporotrichosis started to be developed after the first case occurred in 2011. Since then, there have been adjustments over time guided by the accumulation of epidemiological knowledge of the disease in the municipality. However, there have been variations in the availability of surveillance resources over the years, and the challenge of meeting the needs of human and physical resources represents a chronic and critical situation.

Investigation and detection of cases of feline sporotrichosis by the GZCC occur through spontaneous demand, active search, and referrals by veterinary establishments. Spontaneous demand happens by face-to-face assistance or, in cases of impossibility of bringing the animal to the GZCC for veterinary evaluation, home care is provided. Spontaneous face-to-face demand attended at the GZCC occurs in a specific veterinary assessment room where anamnesis procedures, physical examination, and collection of material from the lesion are performed. An active search is frequently carried out in combination with home care when there is an opportunity to investigate new cases in the neighborhood. The forwarding of suspected cases by autonomous veterinarians occurs in two ways: the person in charge of the animal receives guidance from the professional to contact the GZCC or the veterinarian sends the sample of the collected material to the GZCC.

GZCC distributes swabs free of charge to veterinary clinics and hospitals, in addition to delivering free medicines for the treatment of feline sporotrichosis to cat tutors. Receiving the collected sample and sending it for the examination of fungal culture are also executed at no cost.

The drug of choice is Itraconazole, administered orally at a dose of 25 mg (animals with less than 1 kg); 50 mg (animals with 1 to 2.5 kg), or 100 mg (animals with more than 2.5 kg), in a single dose every 24 h. Or, in very rare cases, half the dose every 12 h. Treatment time varies. When the animal has only dermatological wounds, the treatment lasts at least six months and ends after two months without macroscopic lesions. When there is impairment of the respiratory system, the treatment is done by approximately 12 months, with an association of Itraconazole with Potassium Iodide, at a dose of 2.5 to 10 mg/kg.

Information about sporotrichosis is disclosed by the Guarulhos city website, specific actions in Health Units, forums, visits and distribution of pamphlets in veterinary establishments, presentation in Management Councils, and promulgation of the ordinance that determines compulsory notification of suspected and confirmed cases of human sporotrichosis (Guarulhos, 2016).

Data

The study used all positive cases of feline sporotrichosis detected by professionals of Guarulhos Zoonoses Control Center (GZCC), between 2011 and 2017. Samples were collected from cats with apparent clinical signs compatible with the disease, as skin lesions, wet or dry, across the cephalic region and body. For wet lesions, a sterile swab was used for collection, while dry lesions were scraped and collected in sterile receptacles. After this procedure, samples were refrigerated at 4°C and transported in Stuart Media to the Laboratory of Zoonoses and Vector-Transmitted Diseases (LabZoo) of the São Paulo Zoonoses Control Center (SPZCC), where they were analyzed.

Cases were classified as positive when *Sporothrix* spp. was cultured and isolated. Samples were stored in polypropylene plastic tubes containing sterile Stuart medium and processed according to the standard operating procedures using the selective Mycosel Agar (Becton Dickinson & Co.) culture medium in duplicates and incubated at 25 °C ± 2°C for 30 days. Colonies with uncertain identification were replicated on plates with Sabouraud Agar Dextrose (Oxoid Ltda.). After isolating the fungus by culture, microscopic and macroscopic analyzes were performed. The samples we analyzed were processed in the same laboratory and following the procedures described in detail by Montenegro et al. (2014).

Data preparation and descriptive analysis

Positive cases were geocoded using the Google Maps® API and aggregated by census tract (CT). Then, spatiotemporal dynamics were characterized by a yearly time series at the city level and yearly maps at the census tract level.

Causal model

The causal model of zoonotic sporotrichosis is represented by a directed acyclic graph (DAG), whose relationships are described as follows. Inefficient coverage of basic sanitation benefits the proliferation of rats (Figure 1a), and increase the carrying capacity of the stray cats population because organic waste and rats are sources of food for them (Figure 1b, c). The lack of basic sanitation worsens social vulnerability (Figure 1d) that, in turn, contributes to increasing stray cat population densities due to difficulties to control the reproduction and movement (households without physical barriers to avoid free access to the streets) of these animals (Figure 1e). Infected cats and high population densities increase contact rates between susceptible and infected individuals; consequently, the incidence of feline sporotrichosis also increases (Figure 1f). Social vulnerability restricts access to veterinary services (Figure 1g), so the infectious period of affected cats become longer, creating more opportunities for cat-cat and cat-human transmission (Figure 1h). Therefore, a higher prevalence of feline sporotrichosis increases the likelihood of zoonotic transmission (Figure 1i). Similarly, social vulnerability reduces access to medical services (Figure 1j) and decreases recovery rates from human sporotrichosis (Figure 1k). It is important to note that in this study we did not address the causes of social vulnerability, and as long as they continue operating, there will be favorable conditions for the maintenance of sporotrichosis.

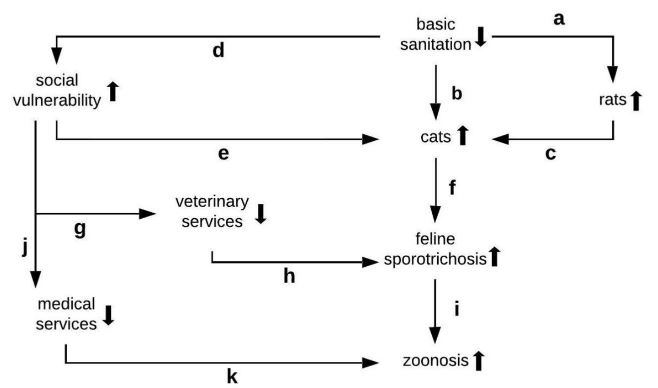

Figure 1 – Directed acyclic graph representing the causal hypothesis of zoonotic sporotrichosis. Guarulhos, 2011-2017.

We used a social vulnerability index as a proxy of the DAG described above, assuming that the higher the index, the greater the incidence of feline sporotrichosis because the index changes according to modifications in the state of the DAG. The index, known as IPVS for its Portuguese initials, ranges from 1: extremely very low, 2: very low, 3: low, 4: medium, 5: high (urban location), 6: very high (subnormal, urban location), 7: high (rural location). In Guarulhos, it ranged between 1 and 6. The "subnormal" of the sixth category refers to urban census tracts that are favelas with at least 51 households. Further details on the IPVS are described by the Statistical Bureau of the State of São Paulo (Fundação Sistema Estadual de Análise de Dados, 2013) and reviewed in English by Baquero et al. (2018).

Statistical model

The model was given by

$$\eta_i = \alpha + \varsigma_i + \beta IPVS \quad (1)$$

where $i\ (1,\ldots,n)$ is the spatial index, $\eta_i = log(E(y_i))$ is the mean of an additive linear predictor, y_i is the number of observed cases, α is the fixed intercept, β is the IPVS effect, and ς_i is the combination of spatial effects, one structured υ_i, and other unstructured ν_i. We assumed that $y_i \sim Poisson(\theta_i E_i)$, where θ_i is the case density (CD) in CT_i and E_i is the area of the CT_i (the density of cases per area was the measure of incidence). IPVS 1 and 2 were the reference category for estimating β and were aggregated because there was only one case in CT with IPVS 1. The exponentiated β corresponded to the relative case density (RCD). The model previously described was compared with a model without IPVS, in terms of their *Deviance Information Criteria* (DIC).

The definition of the spatial effect was given by:

$$\varsigma_i = \frac{1}{\sqrt{\tau}}\left(\sqrt{1-\varphi}\nu + \sqrt{\varphi}\upsilon\right) \tag{2}$$

where τ is the marginal precision, ν_i follows a normal distribution, and υ_i is a scaled and conditional autoregressive model:

$$\nu_i \sim N\left(0, \frac{1}{\tau(1-\varphi)}\right) \tag{3}$$

$$\upsilon_i \mid \upsilon_{-i}, \tau\varphi \sim N\left(\frac{1}{\eta_{\delta i}}\sum_{j\in\delta i}\upsilon_j, \frac{1}{\eta_{\delta i}\tau\varphi}\right) \tag{4}$$

In the previous equations, $\eta_{\delta i}$ is the number of neighbors of *i*, and φ is the proportion of the marginal spatial variance explained by υ.

With the model described, we estimated CD_i, the Excess Risk probability ER_i = Prob (CD_i > $RCD_{\text{IPVS} = 4}$), and a Priority Index (PI):

$$PI = \frac{RCD_i RE_i}{max\left(RCD_i RE_i\right)}100 \tag{5}$$

This PI indicates the priority that must be assigned to each CT and the CT with the highest priority receives a PI = 100. The other PIs are relative to that 100. Thus, if CT A has a PI = 100 and CT B has a PI = 50, the priority to be given to CT B is equivalent to 50% of the priority to be given to CT A.

Following the principle of parsimony, we used penalizing complexity (PC) priors (Simpson et al., 2014). PC Priors favor models with spatial variation equal to zero (τ = ∞) and φ = 0 (without structured spatial effect). The penalty was based on a constant decay rate, specified in terms of a type-2 Gumbel distribution. For τ, the specification was through the probabilistic statement $Prob\left(\left(\frac{1}{\sqrt{\tau}}\right) > U\right) = \alpha$, equivalent to a constant decay rate defined as -log(α)/U (Riebler et al., 2016; Simpson et al., 2014). In the case of φ, the statement was $Prob(\varphi < U) = \alpha$. The statements were instantiated as $Prob\left(\left(\frac{1}{\sqrt{\tau}}\right) > \frac{0,3}{0,31}\right) = 0,01$ and $Prob(\varphi < 0.5) = 0.7$, respectively. Consequently, we assumed that with a probability equal to 0.99, the residual RCD (τ) was less than 2; and ν explained most of the spatial variation.

Software, code, and dataset

The study used the R packages cowplot 1.0.0 (Claus, 2019), lwgeom 0.2-4 (Pebesma, 2020), gridExtra 2.3 (Auguie, 2017), units 0.6-6 (Pebesma et al., 2016), ggsn 0.5.0 (Baquero, 2019), spdep 1.1-3 (Bivand & Wong, 2018), lubridate 1.7.8 (Grolemund & Wickham, 2011), INLAOutputs 1.4.11 (Baquero, 2018), INLA 20.03.17 (Rue et al., 2009), sf 0.9-3 (Pebesma, 2018), and tidyverse 1.3.0 (Wickham et al., 2019). The code and the dataset to reproduce the analyzes are available in a public repository (Baquero, 2021a).

Results

The two cases detected in 2011 occurred in favelas close to each other. However, in subsequent years, cases were reported in CTs with varying degrees of social vulnerability (Figure 2), and the number of detected cases increased,

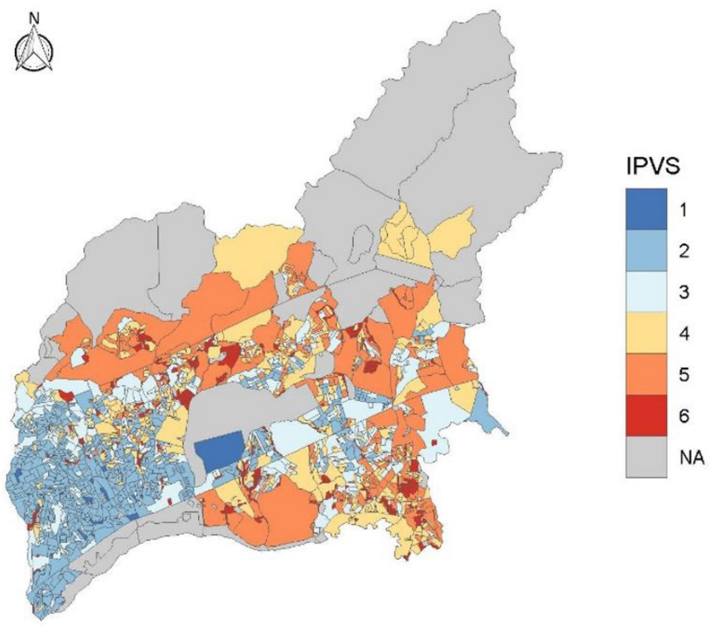

Figure 2 – IPVS of the census tracts in Guarulhos city that had cases of feline sporotrichosis reported between 2011 and 2017. NA corresponds to the census tract where there was no case reported. IPVS: Paulista Social Vulnerability Index. Geographical division: census tracts. Guarulhos, 2011-2017.

reaching a total of 711 in 2017 and an accumulated of 1371 between 2011 and 2017 (Figure 3). The spread of cases also increased during this period (Figure 4). The relationship between RCD and IPVS showed a dose-response pattern (the higher the social vulnerability, the higher the incidence). It was monotonic in the median (except for IPVS 4) and mean, and there was overlap among the distribution of the RCD of different IPVS categories (Figure 5A and 5B). The CT with IPVS 6 represented 2.3% of the municipality's area and concentrated 22% of the cases. The CTs with at least one case represented 22.2% of the municipality's area.

All lower limits of credibility were higher than one (Table 1) and the IPVS model reduced the CID from 2305 to 2274. The spatially structured component explained 96% of the estimated variability, and the 0.95 quantile of PIs was 13.2, resulting in a few high-priority CT). Table 2 shows the ten CT with the highest PI values, in decreasing order; 8 (0.5%) PIs were greater than 50, and the first three CTs with the highest PI had a high level of social vulnerability.

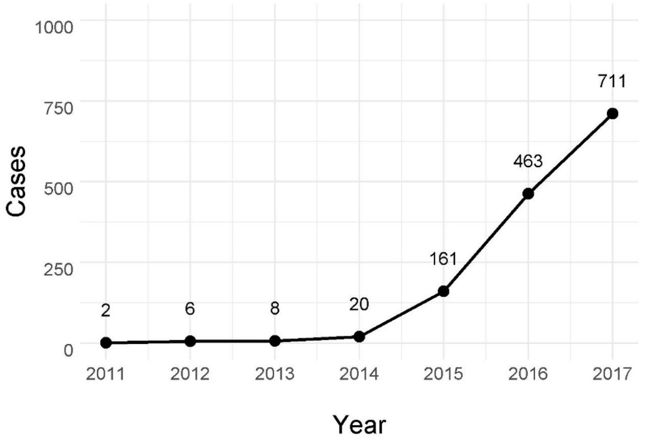

Figure 3 – Time series of cases of feline sporotrichosis notified between 2011 and 2017 by the zoonosis surveillance service in Guarulhos city. Guarulhos, 2011-2017.

Discussion

The approximately exponential growth and geographic dispersion confirmed the ongoing feline sporotrichosis epidemic in Guarulhos. Although the disease had widespread distribution, it was highly concentrated in a few areas that should be prioritized by prevention and control actions. As we hypothesized, social vulnerability was positively associated with the incidence of feline sporotrichosis. This association has been suggested by previous studies but not tested and causally explained (Alzuguir et al., 2020; Silva, 2010).

The studies above showed that feline sporotrichosis is endemic or epidemic in socially vulnerable areas, but not

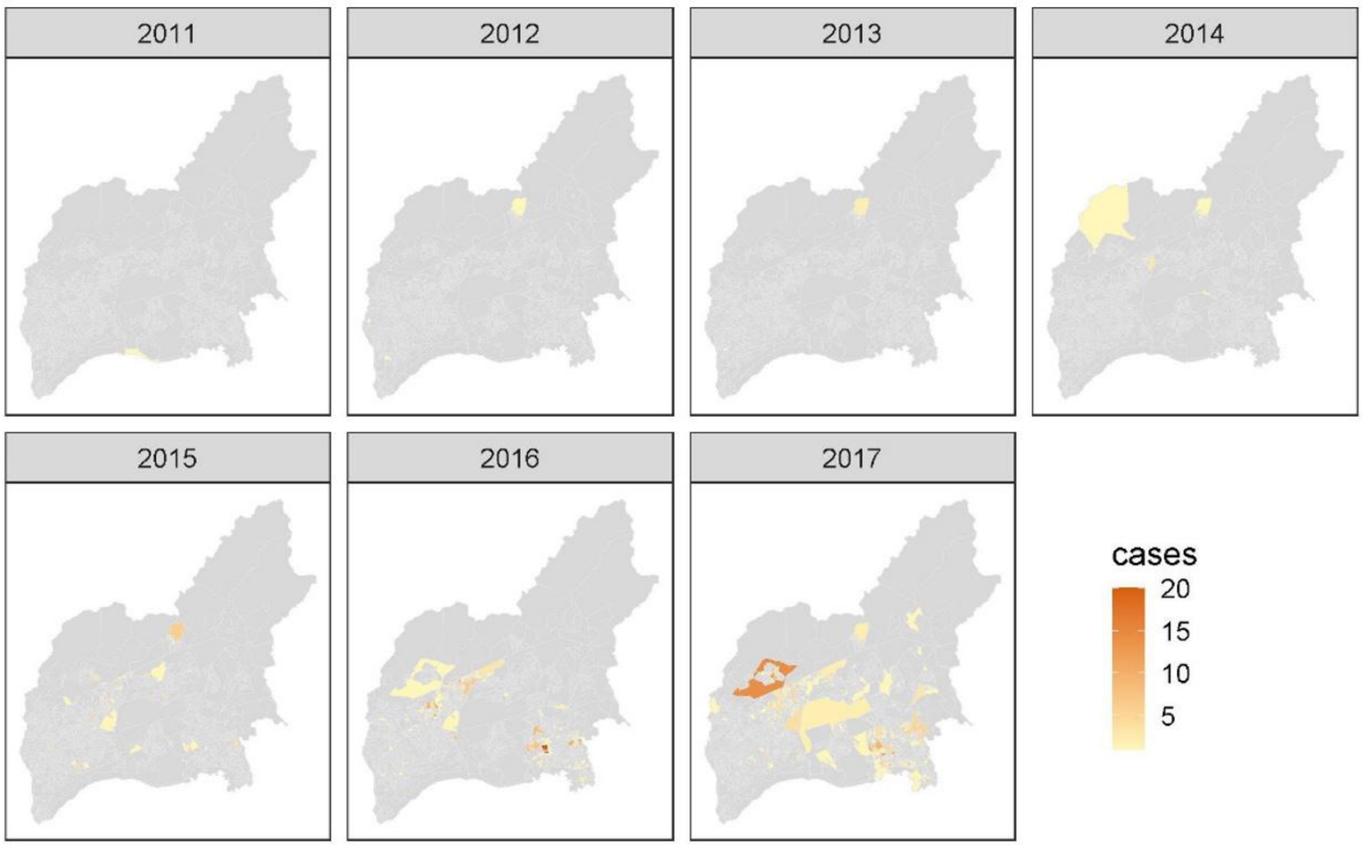

Figure 4 – Spatiotemporal distribution of cases of feline sporotrichosis notified between 2011 and 2017 by the zoonosis surveillance service in Guarulhos city. Geographical division: census tracts. Guarulhos, 2011-2017.

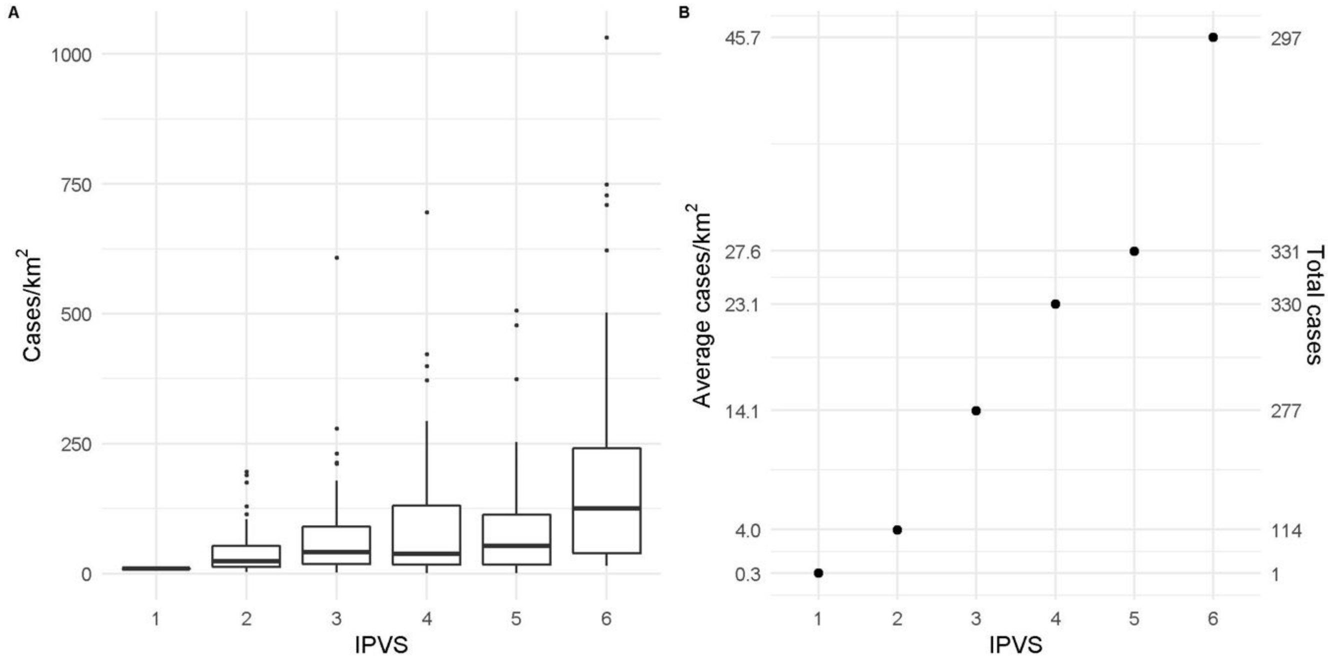

Figure 5 – (A) Distribution of case density of feline sporotrichosis cases notified between 2011 and 2017 by the zoonosis surveillance service in Guarulhos city; (B) The average and total density of feline sporotrichosis cases were notified between 2011 and 2017 by the zoonosis surveillance service in Guarulhos city. IPVS: Paulista Social Vulnerability Index. Analysis unit: census tracts. Guarulhos, 2011-2017. Data Availability Statement.

Table 1 – The posterior probability of the relative density case of feline sporotrichosis was notified between 2011 and 2017 by the zoonosis surveillance service in Guarulhos city

IPVS	RCD	CI
3	1.76	1.01-2.87
4	2.30	1.31-3.76
5	2.57	1.40-4.36
6	3.50	1.74-6.29

IPVS: Paulista Social Vulnerability Index; RCD: relative case density; CI: 95% credible interval. Guarulhos, 2011-2017

Table 2 – Top ten census tracts with the highest priority index value, and their respective social vulnerability indexes

Census Tract	PI	IPVS
1	100.00	6
2	73.3	6
3	70.9	6
4	70.8	4
5	70.7	6
6	60.00	3
7	59.8	6
8	52.6	2
9	49.3	6
10	48.5	5

PI: Priority Index; IPVS: Paulista Social Vulnerability Index. Guarulhos, 2011-2017.

that the incidence is higher in these areas compared to others. Both events are not equivalent and the existence of epidemics in vulnerable areas does not rule out the occurrence of major epidemics in socially favored areas. To relate social vulnerability to feline sporotrichosis, it is necessary to have a measure of vulnerability, identify areas with different degrees of it, and analyze its variation in terms of the incidence of feline sporotrichosis.

In Guarulhos, there was a positive relationship between IPVS and the incidence of feline sporotrichosis. The dose-response gradient suggests a causal relationship and the relevance of social determinants in the epidemiology of feline sporotrichosis. The connection between disease and poor socioeconomic conditions was already described for other Brazilian neglected zoonoses, such as visceral leishmaniasis (Marcondes & Day, 2019), leptospirosis (Karpagam & Ganesh, 2020), and rabies (Wilde et al., 2017). According to the Institute of Applied Economic Research (Instituto de Pesquisa Econômica Aplicada, 2010), 35.6% of Brazilian municipalities were in the range of very high or high social vulnerability. With more than one-third of the human population in a condition in which many zoonoses impose a higher burden of disease for it and its multispecies collective, public health policies must target social vulnerability. Otherwise, unhealthy processes will continue overwhelming preventive and control efforts.

As long as houses do not have an adequate structure to restrict the free access of cats to public spaces while providing enriched internal environments, recommendations to apply such restrictions will be ineffectual. As long as the carrying capacity on streets remains high, the effects of sterilization campaigns will be diluted. Thus, cat population densities and the ensuing contact rates will remain high, facilitating disease transmission.

GZCC provides medications for free and guides the treatment of infected cats detected by its surveillance service. Nevertheless, in many situations, the treatment is not applied as intended. Cats or tutors are not always present at the time of medication, and the misunderstanding of treatment guidelines, a GZCC' staff complaint, compromises schedule and dose administration. Moreover, untreated stray cats maintain a large *Sporothrix* spp. reservoir. According to our causal hypothesis, the higher the social vulnerability, the worst this situation and the incidence of feline and zoonotic sporotrichosis.

We used a DAG (Figure 1) to explain the causal relationship between the IPVS and feline sporotrichosis. The causal networks specified as DAG are useful to differentiate causal and non-causal associations as well as to identify the variables that must be controlled to estimate hypothesized effects (Greenland et al. 1999). In other words, DAGs identify the statistical models necessary to test the different components of an explicit causal hypothesis. Although we did not instantiate each DAG element with a variable, we worked with it because a DAG allows experts to assess the plausibility of our causal explanation and sets a background for more research on the social determinants and social determination (Baquero, 2021b) of sporotrichosis.

Social vulnerability in Guarulhos is spatially segregated and this was reflected in the pattern of the incidence of feline sporotrichosis. This finding has a strategic value from an epidemiological point of view, as it identifies areas to be prioritized. However, the IPVS did not fully explain the spatial pattern. The incidence of the disease varied between the categories of IPVS and some CT with IPVS = x had a lower incidence than other CT with IPVS < x. A high social vulnerability does not necessarily imply a high incidence of sporotrichosis, as shown by the epidemic outbreaks in areas of low vulnerability (outliers in CT with IPVS 2 and 3 - Figure 5A). Therefore, the PI also took into account the spatial pattern of cases. Despite the widespread occurrence of the disease, this index showed that the excess risk was concentrated in a few high-priority CT that should be targeted by surveillance actions.

Surveillance efforts affected all our results, and we do not have evidence to identify the contribution of underreporting or its change over the studied period. However, some indirect information helps to speculate about surveillance coverage. Despite the challenges of surveilling favelas, the highest densities of reported cases occurred in them, so underreporting did not affect the most vulnerable areas to the extent of compromising our causal hypothesis. The lowest densities in more favored CT reinforce our hypothesis but might have partially resulted from underreporting if cases are consistently treated by private veterinarians. Moreover, there were silent areas (CT without cases), including favelas, and some were contiguous neighbors of positive areas. We assume that overall, CT borders do not significantly limit cat movements and interactions, while surveillance is not perfect. Thus, it seems that some silent areas have undetected cases, and perhaps, undetected epidemics. Future works can predict cases in silent areas without assuming that there are no cases in them, and verify through active surveillance if there is a positive association between observed and predicted densities.

As the population at risk was unknown (cat population size in Guarulhos), we used the number of cases per area or case density instead of the cumulative incidence or incidence density. Although case density is not a measure of risk, it is related to it because the greater the density of the cat population, the greater the likelihood of contact between infected and susceptible individuals. From a surveillance perspective, case density allows prioritization of areas based on the spatial concentration of cases.

Conclusion

Social vulnerability is a structural cause of sporotrichosis that limits the effectiveness of preventive, control, and treatment efforts. Structural changes are not easy to achieve and require great efforts over time, especially in Brazil, rated as one of the top ten unequal countries in the world (Victora, 2016). Nevertheless, social vulnerability cannot continue naturalized. With it, sporotrichosis will continue out of control. Addressing the social determination of One Health of Peripheries and its strategies of promotion (Baquero et al., 2021; Baquero, 2021b) is necessary to face the challenges brought by sporotrichosis.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethics Statements

This research was approved by the Ethics Committee on the Use of Animals (CEUA) of the Faculty of Veterinary Medicine and Animal Science at the University of São Paulo, through process number 8471110417. No human studies are presented in this manuscript. No potentially identifiable human images or data are presented in this study.

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