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Special Feature: The other 1%: Showcasing science and scientists from the Global South and indigenous communities. Guest edited by Sarah Brosnan, Stephanie Meirmans, Maurine Neiman, Guadalupe Peralta and Shalene Singh-Shepherd.

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# When science remembers what is neglected: addressing the risks of rodent-borne diseases in urban Latin America

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Latin American cities face deep socio-economic inequalities that impact health, education and the environment. These disparities influence zoonotic disease dynamics through complex host–pathogen–environment–human interactions. This study explores zoonotic risks associated with rodent communities across diverse social and environmental settings in the Matanza-Riachuelo River Basin, one of the most polluted urban areas in Buenos Aires, Argentina. Between 2022 and 2023, rodent community composition and health status were assessed at 22 sites, ranging from low-income neighbourhoods to green areas along an urbanization gradient. A total of 366 rodents—comprising three synanthropic and four native species—were captured and tested for leptospirosis, Orthohantavirus, SARS-CoV-2 and zoonotic helminths. Rodent community structure reflected local environmental conditions: wild species dominated low-disturbance areas, while synanthropic species, especially *Rattus norvegicus*, prevailed in densely populated sites lacking basic urban services and hosted the highest pathogen richness. Pathogen presence was spatially heterogeneous and strongly linked to infrastructural deficiencies, underscoring the role of poor urban planning in the emergence of rodent-borne diseases. Findings informed the development of educational and training programmes to prevent zoonoses. Grounded in the One Health framework, this study emphasizes the interconnectedness of human, animal and environmental health, and the need for transdisciplinary strategies in neglected urban areas.

## 1. Introduction

Urbanization is a complex, irreversible process influenced by demographic, economic, social, political and geographical factors [1]. Latin America is the most urbanized developing region, with almost 80% of its population living in urban areas. This proportion is higher than in more developed countries [2], and, further, the proportion of the population that resides in megacities (>1 million inhabitants) in Latin America (39%) surpasses Europe (16%) and even Asia (23%) [3]. However, unplanned urban growth has caused poverty, social inequality and environmental harm, endangering public health [4].

Urbanization differs between developed and developing nations. In the former, it was gradual, aligned with industrial, economic growth and social progress, fostering liveable and resilient cities [5]. In contrast, Latin America's rapid urban shift, driven by modest economic growth and high rural-to-urban migration, led to an urban crisis in the 1980s and 1990s [5]. This crisis was manifested through the expansion of precarious settlements, unregulated land

use, poor sanitary conditions, environmental problems and an increase in poverty. Although such issues have been reduced over the last decade, they remain a global concern due to their impact on health and urban planning [6]. According to UN-HABITAT datasets [7], 70 of the 120 developing-world cities lack resources to track urbanization processes, limiting them from understanding the relationship between urban growth, informal settlements and low-income neighbourhoods (LINs). This lack of information can be attributed both to the absence of measurement tools and to the unawareness and reluctance of local authorities to address the problems of urban poverty.

Neglected diseases, often of zoonotic origin, are linked to rapid, disordered urbanization [8]. Conditions like poverty, overcrowding and poor sanitation promote synanthropic rodents [9]—*Rattus norvegicus* (Norway rat), *R. rattus* (black rat) and *Mus musculus* (house mouse)—and synurbic wild rodents [10], increasing zoonotic transmission risk [11,12]. Low-income urban peripheries face greater outbreak impacts due to complex spatial and household vulnerabilities [13–15]. In this sense, Gandy [13] advocates rethinking the urban peripheries epidemiologically. Thus, integrated studies focused on humans, animals, pathogens and environments are key for the development of policies and strategies for the prevention and control of zoonotic diseases in unplanned urban contexts [16].

The Matanza-Riachuelo River Basin (MRRB) in Buenos Aires (Argentina) exemplifies these challenges. It holds 10% of Argentina's population in 2047 km<sup>2</sup> (4 703 058 inhabitants [17]), and its urbanization began in the late nineteenth century, driven by industrial expansion and population growth. Over 5000 industries [18] settled along the riverbanks, unregulated industrial and sewage waste disposal and unchecked urban sprawl led to severe pollution and environmental degradation. The rapid influx of migrants, attracted by employment opportunities, contributed to the establishment of densely populated LINs, often lacking in basic infrastructure. Over the decades, the basin has become synonymous with environmental neglect, and despite ongoing efforts to clean and restore the area, its complex socio-environmental landscape remains a public health concern, particularly for zoonotic neglected diseases.

Previous studies conducted within the northern margin of the MRRB, part of the area covered by our study, have demonstrated a relationship between rodent assemblages and landscape unit types—such as green spaces, LINs and residential areas [19]. This relationship, in turn, influences the presence of various pathogens and parasites, including zoonotic ones [20–22]. Examples of these pathogens carried by synanthropic species are *Leptospira* spp. [23], Seoul virus (SEOV) [20] and helminths such as *Hymenolepis diminuta* and *Hymenolepis nana* [24]. Moreover, the circulation of virus Andes (Orthohantaviridae) was confirmed in the synurbic wild rodent species *Oligoryzomys flavescens* [25]. Currently, there is also some evidence that would demonstrate that rodents could be reservoirs of SARS-CoV-2 virus [26].

*Leptospira* spp. is a major zoonotic threat with a significant public health impact. Annually, 500 000 to 1.03 million cases occur worldwide, with a mortality rate exceeding 10% [27,28], and Latin America reports some of the highest numbers [29,30]. True prevalence is probably underestimated due to symptoms resembling dengue or malaria, frequent misdiagnosis and weak reporting systems [27,28,31]. Argentina is one of the leading countries in alerts of cases in the region [30], but underdiagnosis persists despite mandatory reporting [32], due to the diversity of clinical presentations and limited access to laboratory diagnostics in vulnerable communities [33–35].

Underdiagnosis also affects zoonotic diseases like haemorrhagic fever with renal syndrome (HFRS) and hantavirus pulmonary syndrome (HPS), caused by Orthohantavirus species such as SEOV and Andes virus (ANDV) [36,37]. HFRS cases are mostly in Asia [38], with few in America [39], likely due to low medical awareness [37]. In contrast, HPS is one of the deadliest yet least-studied tropical diseases in America [40], with low incidence but over 35% mortality rates [41].

Many helminths are WHO-listed neglected zoonotic diseases, sustained by animal reservoirs that complicate control efforts [42]. Various zoonotic parasites have been found in rodents from LIN areas of Latin American cities [43,44], reflecting community exposure to these pathogens [24]. In the MRRB, surveys conducted among residents in several LINs reported about 13% parasite prevalence (<https://www.acumar.gob.ar/salud-ambiental/informes> [45], accessed: 14 July 2025).

In Argentina and Latin America, the absence of a consistent public health policy for neglected zoonoses results in a reactive and fragmented response. Efforts rely on unstable factors such as researchers, media, funding and political will, causing discontinuous and ineffective interventions. This inequity mainly affects low-income communities, highlighting a social justice issue that demands both disease control and structural change.

Considering the previously described socio-environmental complexity of the MRRB and the current knowledge about the role of rodents as reservoirs of different pathogens, we aim to uncover the extent of zoonotic risks posed by rodent communities across diverse social and environmental gradients in this basin. Our study is framed within the One Health approach, recognizing the importance of the interrelation between human, animal and environmental health, and transdisciplinary efforts as fundamental bases to propose targeted interventions in neglected urban spaces. Through this approach, we attempt to enhance disease prevention strategies and public awareness, contributing to a safer and healthier urban future in Latin America.

## 2. Material and methods

### (a) Study area

The MRRB is situated primarily in Buenos Aires Province (90%), with a smaller portion within the city of Buenos Aires (10%), Argentina. The climate is temperate, characterized by warm to hot summers, cold winters and an average annual temperature of 17.4°C [46]. Annual precipitation averages 1146 mm, displaying a seasonal pattern with lower levels in winter (June–August) and higher levels in autumn (March–April) and spring (October–November) [47]. The river basin covers a drainage area of 2047 km<sup>2</sup> and comprises numerous tributary streams that converge into a main channel, referred to as the Matanza in its upper

course and as the Riachuelo in its final 15 km stretch before flowing into the Río de la Plata (<https://www.acumar.gob.ar/caracteristicas-cuenca-matanza-riachuelo> [48]; accessed: 1 November 2024). This is a short-length (80 km) lowland river (0–50 m above sea level), with an average flow of  $8 \text{ m}^3 \text{ s}^{-1}$  and a gentle slope of 0.35% [46,49,50].

The MRRB is topographically divided into three sub-areas: the upper, middle and lower basins. The upper basin is primarily surrounded by agricultural and livestock areas [51], and water is supplied by numerous streams, though only three are considered main tributaries. The middle basin is less urbanized and industrialized than the lower basin [51], and the streams converge to form the primary watercourse [49]. The lower basin shows the highest population and industrial densities [46] and is characterized by a matrix of LINs and industries, interspersed with parks and green spaces. Major industries here include tanneries, cold storage warehouses and metallurgical and chemical facilities [52]. Most residents in the MRRB are exposed to heightened health risks as a result of living in homes located along the riverbanks, often with precarious and inadequate access to basic urban services [53,54].

The study was conducted in 22 sites belonging to two landscape units from the MRRB, 10 green areas (GAs) and 12 LINs. Site selection was based on accessibility, participation of residents and prior evidence of rodent presence. GAs included large, uninhabited, vegetated spaces ranging from urban parks to natural reserves with varying degrees of management. They are not agricultural areas, but in some cases (located in the upper basin), they may be close to a rural matrix. The size of these areas ranged from 5 (site 22) to 1000 ha (site 20). In contrast, LIN sites had population densities between 4928 inhabitants  $\text{km}^{-2}$  (site 12) and 47 787 inhabitants  $\text{km}^{-2}$  (site 4). The distance between contiguous GAs ranged from 1.7 (sites 16 and 17) to 25 km (sites 21 and 22). For LIN sites, the distance between adjacent neighbourhoods varied from 3 (sites 5 and 6) to 30 km (sites 10 and 12). All LINs are in low-lying, flood-prone areas, near water bodies within the basin and are therefore adjacent to GAs. These green spaces predominantly consist of wetlands and river or stream banks, some of which have been designated as nature reserves or parks. The composition of the plant community varies according to the management regime applied. GAs with formal or mixed management is primarily dominated by native grassland and shrub species characteristic of the region, whereas unmanaged areas are typically colonized by plant communities in early successional stages, dominated by exotic herbs and forbs. In contrast, LIN sites do not contain cultivated gardens; instead, they feature areas of unmanaged, spontaneously growing vegetation.

## (b) Landscape and demographic characterization

Each study site was characterized at two spatial scales: the site level and a 1 km buffer zone around each site centroid. At the site level, the following variables were measured: total area, total vegetated area, total water surface area and total urbanized area. In addition, sites were classified in four categories according to their primary use and management type (residential, recreational, conservation with formal management and conservation with mixed or absent management) and the presence of breeding animals for subsistence (pigs, cows, horses, sheep and chickens). Formal management refers to sites with strict control of human access, including fenced perimeters and the continuous presence of security personnel or park rangers who enforce regulations such as bans on fires, littering or hunting. In contrast, unmanaged sites lack these controls, while sites under mixed management show partial or inconsistent controls, such as incomplete fencing or sporadic security presence, conditions that often facilitate human-driven disturbances like illegal dumping, the presence of stray animals or intentional fires.

To capture the landscape features surrounding each site, a 1 km buffer zone was delineated from the centroid of each sampling location. Within this buffer, the same land cover classification was applied, distinguishing between vegetation, urban infrastructure and water bodies. Vegetation was defined as any area containing herbaceous, shrubby or arboreal cover with public access, such as parks, natural reserves, squares, railway embankments and streambanks. Urban infrastructure comprised built structures such as houses, buildings, avenues, streets and highways, while water bodies encompassed rivers, streams, lagoons and ponds. Based on this classification, the following variables were calculated within each buffer: % of vegetated surface, % of urbanized surface, % of water surface and a vegetation-to-urban area ratio (total vegetated area divided by total urbanized area). Population density (inhabitants  $\text{km}^{-2}$ ) was also estimated for each buffer using data from the 2022 National Census [55]. All land cover data were obtained from high-resolution satellite imagery and processed using QGIS v. 3.40.6 [56].

## (c) Rodent capture

A total of 47 trapping sessions were carried out between February 2022 and December 2023. Rodent trappings were carried out in 12 LIN sites and 10 GA sites from the MRRB, using Sherman ( $8 \times 9 \times 23 \text{ cm}$ ) and cage ( $15 \times 16 \times 31 \text{ cm}$ ) live traps. In GAs, Sherman and cage traps, which were distanced by 5 m, were placed in transects. Both the number and extension of the transects at each site depended on its size and the amount of different vegetal communities. On some occasions, when the vegetation was not dense and tall enough to camouflage the presence of cage traps, it was decided to place only Sherman traps to prevent them from being stolen. In LINs, a fixed number of traps (one Sherman and one cage trap) were set in each house whose owners volunteered for the research project, except in houses inhabited by more than one family or with very large yards where additional traps (up to 6) were placed. Although most of the sites were sampled only once, there were some that were part of other ongoing research and were sampled in different seasons of the year. Traps were baited with a mixture of peanut butter and cow fat (Sherman traps), and with carrot and raw meat (cage traps). They were active during four consecutive nights and checked every morning. Animals were assigned to species according to external characteristics [57]. All animals were sacrificed except those from site 13, which are part of an ongoing population dynamics study. Rodents were handled following the recommendations of the American Society of Mammalogists [58].

## (d) Household living condition survey

To gather updated and accurate information on the living conditions of the households participating in the study, a survey to neighbours ( $n = 293$ ) was conducted alongside rodent trapping sessions in LINs. We asked about access to running water supply, the presence of sanitary sewerage system or blind well since these are factors that can impact the quality of life of people, especially in terms of well-being. We also inquired about the presence and the number of domestic and/or breeding animals in their houses, given their potential role as reservoirs or vectors of zoonosis, and materials from the street (pavement or natural soil) and the house were recorded (see details in electronic supplementary material, S1). In addition, this information was used to characterize each household where rodent traps were placed, particularly those where rodents were captured ( $n = 69$ ), to determine their impact on the presence of pathogens.

## (e) Zoonotic pathogens

### (i) Analyses of *Leptospira* spp.

Leptospirosis is a zoonotic disease caused by *Leptospira* spirochetes, which colonize the renal tubules of mammalian hosts such as rodents, dogs and cattle [59] and can survive in the environment for several weeks or even months. Transmission to humans mainly occurs through contact with infected animal urine or contaminated soil/water sources [59].

DNA was prepared from 30 mg of previously frozen ( $-80^{\circ}\text{C}$ ) kidney samples from 145 synanthropic rodents using the PURO Genomic DNA kit (PB-L, Argentina) according to the manufacturer's instructions. The extracted DNA was quantified using Qubit (Invitrogen). An endpoint PCR targeting a 423 bp fragment of lipL32, a gene that is exclusively present in pathogenic *Leptospira* [60], was used to detect DNA from pathogenic leptospires. The amplification reaction was carried out according to [61].

### (ii) Analyses of Seoul and Andes orthohantaviruses

Seoul and Andes orthohantaviruses, which cause (HFRS) and (HPS), respectively, are transmitted by rodent species of the subfamilies Arvicolinae and Murinae in Europe and Asia (HFRS) and Neotominae and Sigmodontinae in the Americas (HPS) [36]. Humans typically become infected through the inhalation of aerosolized excreta of chronically infected reservoir rodents.

Blood samples of captured sigmodontine rodents and rats were screened for ANDV and SEOV-specific immunoglobulin G (IgG) antibodies, respectively. An enzyme-linked immunosorbent assay, with the recombinant nucleoprotein of the virus (ANDV or SEOV) as antigen, was used as previously described by Padula *et al.* [62].

### (iii) Analyses of SARS-CoV-2

In sigmodontine and synanthropic rodents, molecular and serologic techniques were performed to detect the presence of SARS-CoV-2 viral genome and IgG antibodies against SARS-CoV-2. RNA extraction and RT-qPCR assays were performed under BSL-2 conditions. RNA was extracted from oropharyngeal and rectal swabs, urine and serum samples of 47 sigmodontine and 64 synanthropic rodents using the QIAamp Viral RNA Mini Kit (Qiagen), according to the manufacturer's instructions. RT-qPCR analysis targeted the N, E and ORF1ab genes to detect the presence of the SARS-CoV-2 viral genome, with  $\beta$ -actin as the housekeeping gene. Serum samples with volumes less than 100  $\mu\text{l}$  were reserved exclusively for serological testing.

Moreover, indirect immunofluorescence serology was performed to assess rodent exposure to SARS-CoV-2. Imprints were prepared using a culture of the ancestral Wuhan variant under BSL-3 laboratory conditions. To detect IgG antibodies, a dilution of 1 : 100 of the available serum samples of 73 synanthropic and 9 sigmodontine rodents was applied and incubated at  $37^{\circ}\text{C}$  for 30 min. Following this, a 1 : 300 dilution of an anti-rat or anti-mouse IgG antibody labelled with FITC was applied and incubated again at  $37^{\circ}\text{C}$  for 30 min. The imprints were observed under a fluorescence microscope. Sera with two or more fluorescent cells in a  $40\times$  field were considered positive.

### (iv) Parasitological screening

The entire alimentary tract of 111 synanthropic rodents was removed and scrutinized for helminth parasites. In addition, the heart and lungs were examined for the presence of adult *Angiostrongylus cantonensis*. Parasitological screening was concentrated in synanthropic rodents since these species are more likely to harbour parasites of zoonotic relevance [63]. The organs of the digestive system were removed from the rodents and transferred to individual Petri dishes. The liver was examined, the entire alimentary tract was slit lengthwise and the gut content was observed. When found, helminths were removed carefully, identified and preserved in 70% ethanol. Samples of faeces were also taken to obtain helminth eggs. Identification of helminth species was carried out based on morphometric characteristics of the worms, larvae and eggs, as appropriate.

## (f) Statistical analyses

Statistical analyses using joint species distribution modelling [64] within the hierarchical modelling of species communities (HMSC) [65] Bayesian multivariate framework were conducted through the R package 'Hmsc' v. 3.0-11 [66,67].

Three models were fitted. First, the presence/absence of rodent species in each site of both landscape units ( $n = 22$ ), including synanthropic and wild species, was modelled as a function of local environmental characteristics (at each site and within a 1 km buffer) previously described in §2b. On the other hand, the same HMSC approach was applied to separately evaluate how the presence of pathogens detected in *Rattus* spp. and *M. musculus* in LIN sites was associated with the household environmental covariates previously described in §2d and LIN population density (inhabitants km<sup>-2</sup>). These analyses were focused on the subset of houses where rodents were captured ( $n = 69$ ). All response matrices were binary (presence/absence), and thus models were fitted with a probit link function. For parasite models, we accounted for spatial structure by including a random effect of sampling site, reflecting the hierarchical design of parasite sampling across households within LINs. For the rodent model, no random effect was included.

Models were fitted using the default prior distributions as outlined in the supporting information of [65]. Posterior distributions were estimated using Markov chain Monte Carlo sampling, with four chains of 1000 iterations, thinning = 10 and a burn-in of 500 iterations. The convergence was assessed using the potential scale reduction factor, as described by Gelman & Rubin [68], with values below 1.05 indicating adequate convergence, following the criteria in [65]. Predictive accuracy was quantified using the area under the receiver operating characteristic curve (AUC), Tjur's  $R^2$  and root mean square error (RMSE) for each species. Model inference was based on a posterior support level of 95% of environmental effects (beta coefficients) for each species. A variable was considered to have a strong effect if  $\geq 95\%$  of posterior samples were either above or below zero.

In all cases, prior to model fitting, collinearity among explanatory variables was evaluated and excluded those with Pearson's correlation coefficients  $|r| > 0.7$ . We then performed model selection based on explanatory performance, removing variables that consistently yielded poor model fit across species, as assessed using Tjur's  $R^2$ , AUC and RMSE. All analyses were conducted in R software, v. 4.4.2 [69].

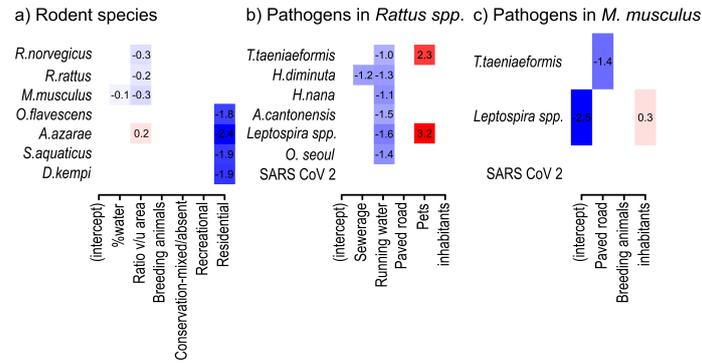
## 3. Results

Three hundred sixty-six rodents belonging to seven species were captured from a total capture effort of 12 384 Sherman traps and 6937 cage traps per night each (see electronic supplementary material, table S1 for details of location, time, trap effort, trap success and parasitological screening of each trapping session). Of these, 55.5% were synanthropic rodents (58 *R. norvegicus*, 31 *R. rattus* and 114 *M. musculus*) and 44.5% were synurbic wild species (89 *O. flavescens*, 60 *Akodon azarae*, 7 *Deltamys kempi* and 7 *Scapteromys aquaticus*). In the set of GAs, the seven rodent species were recorded, while in LINs, only the three synanthropic species were detected. All synurbic wild species were negatively associated (support level  $>95\%$ ) with habitational land use at the site level. In particular, the presence of *A. azarae* was positively influenced by the vegetation-to-urban area ratio within a 1 km buffer. In contrast, all synanthropic species were negatively affected by this ratio (figure 1a).

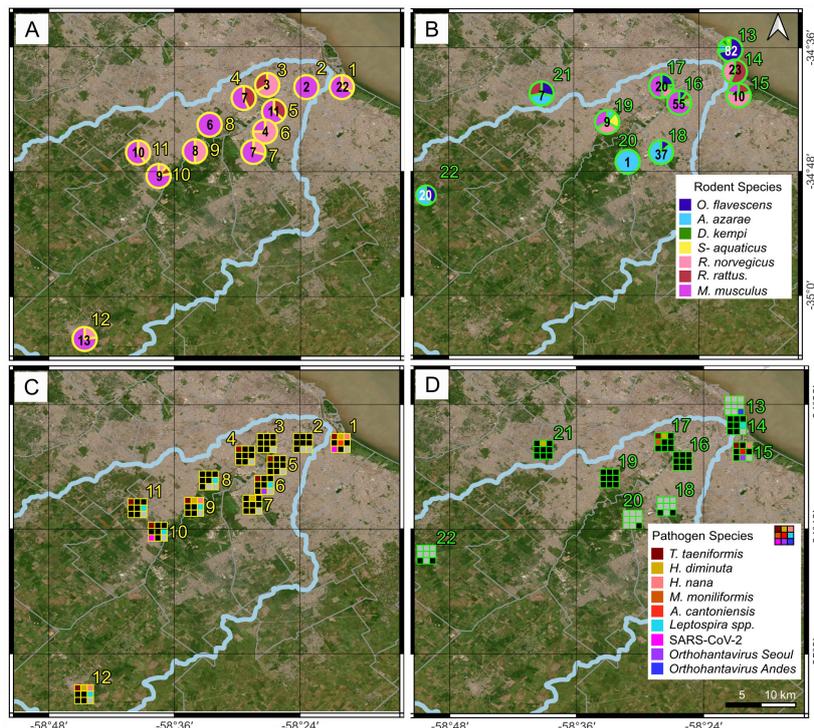
Among the 10 GAs surveyed, it was possible to differentiate sites where only wild species were captured (sites 13, 18, 20, 22), only synanthropic species (sites 14, 15) and both (sites 16, 17, 19, 21; figures 2B and 3C,H). Within the first group, the sites were characterized by low levels of human disturbance and were primarily nature reserves, exhibiting varying degrees of environmental conservation. Except for site 13, where *O. flavescens* was numerically prevalent, all other sites were dominated by *A. azarae*. On the other hand, in those sites that had higher anthropic inputs or uses, synanthropic species were captured, mainly *M. musculus*, with sites 14 and 15 being at the extreme of this case and dominated by *R. norvegicus* and *R. rattus*. Regarding LINs, *M. musculus* and *R. norvegicus* were the numerically dominant species, although *R. rattus* was captured in sites with more paving and building construction (figures 2A and 3A–F).

We detected nine different types of pathogens in the captured rodents that have a negative sanitary and/or veterinary impact (electronic supplementary material, figure S5 for details). Positive serology against ANDV was detected in two synurbic wild species, *O. flavescens* and *A. azarae*. The synanthropic species harboured the other pathogens, with *R. norvegicus* being the host with the greatest total richness since it presented all of them. The spatial distribution of the pathogens in the GAs was not homogeneous. The ANDV was only detected at a single site (13) while SEOV, the bacteria *Leptospira* spp. and the helminths *Taenia taeniaeformis*, *H. diminuta*, *H. nana*, *Moniliformis moniliformis* and *A. cantonensis* were recorded in four GAs where synanthropic rodents were precisely captured (figure 2D).

Regarding the pathogens detected in LINs (figure 2D), we highlight the detection of specimens of *R. norvegicus* and *M. musculus* with antibodies against SARS-CoV-2 in two sites. Furthermore, we highlight three sites (1, 9 and 12) with higher richness of parasites, noting that these hot spots are not geographically clustered but are distributed across the upper, middle and lower areas of the basin (figure 2C). By analysing which variables revealed by surveys of the rodent-infested housing affect the presence of pathogens, we were able to determine that the lack of connection to a drinking water network is associated with the presence of most of the rat-borne pathogen species (figure 1b). In addition, the lack of sewers is associated with the presence of *T. taeniaeformis* and *H. diminuta*, while the number of pets (dogs and cats) is positively linked with *T. taeniaeformis* and *Leptospira* spp. (figure 1b). In *M. musculus*, the presence of *T. taeniaeformis* and *Leptospira* spp. was associated intradomiciliary with the lack of paving in the streets and with the increase in the number of inhabitants of the houses (figure 1c). All these variables (lack of running water and sewers, unpaved streets, overcrowding and high number of domestic animals) were



**Figure 1.** Estimated beta coefficients indicating positive (red), negative (blue) or no relationships (blank) of species responses to the set of environmental covariates included (with at least a posterior support level of 95%). (a) Rodent species in green areas (GAs) and low-income neighbourhoods (LINs). (b,c) Pathogens detected in LINs in (b) *Rattus* spp. and (c) *M. musculus*. V/U area = vegetation-to-urban area ratio. % water = percentage of water surface. Conservation-mixed/absent = sites whose primary use is conservation with mixed or no management.



**Figure 2.** (A,B) Composition of the rodent community of (A) each low-income neighbourhood (LIN) and (B) each green area (GA) sampled in the MRRB, Buenos Aires, Argentina. The yellow and green numbers represent the site identification, while the numbers inside the circles indicate the number of individuals captured in each site. (C,D) Pathogens detected in (C) LINs and (D) GAs. Black squares indicate that the rodents sampled were negative for the corresponding pathogen, while grey squares indicate that the samples were not tested for that pathogen.

correlated with a support level greater than 95% and are indicators of the lack of urban planning that characterizes the neighbourhoods we studied.

## 4. Discussion

Zoonotic spillover in urban areas, where humans closely interact with wildlife and vectors, underscores the need for effective monitoring to prevent future outbreaks [70]. These diseases arise from complex social-ecological dynamics, requiring diverse, sometimes conflicting, perspectives to build sustainable One Health strategies [71]. Rodent-borne diseases involve intricate human-rodent-pathogen interactions, demanding coordinated efforts in public health, urban planning, education and environmental management, often hard to implement. While high-income nations invest in research and development to address socio-economic challenges, low-income ones fall behind [72]. The Matanza-Riachuelo Basin reflects the socio-environmental complexity of a Latin American metropolis like Buenos Aires undergoes. This study offers a first approach to how urbanization influences rodent-borne disease risks, providing baseline data on host and pathogen presence to support future multisectoral strategies.



**Figure 3.** (A–F) General aspects of some low-income neighbourhoods: (A) site 3, (B, E, F) site 1, (C) site 4, (D) site 11. (G,H) Two contrasting green areas: (G) site 22, (H) site 17.

### (a) Rodent and pathogen communities in green areas

Wild rodents are common components of urban landscapes [73–75]. To survive in cities, they must adapt to the new environmental conditions and exploit the new resources and habitats generated by urbanization [76,77]. However, the specific composition of rodent communities in a given location can vary depending on landscape structure, which is influenced by the diversity of environments and the proportion of space they occupy [19,73]. In this study, the presence of wild species in the rodent community was negatively associated with a variable indicative of intense anthropogenic use. Moreover, greater vegetation cover in the surrounding urban matrix favoured the presence of a dominant wild rodent species while limiting synanthropic species. In GAs, communities exclusively composed of wild species were found in natural urban reserves, while mixed communities of synanthropic and synurbic species were observed in urban parks and poorly managed reserves. These findings underscore the importance of parklands and natural reserves within urban landscapes for the conservation of biodiversity [78–80]. However, it also carries significant epidemiological implications due to the high abundance of wild rodents—particularly *O. flavescens* and *A. azarae*—in certain GAs, and the constant circulation of ANDV in at least one natural urban reserve (site 13; see also [25]). HPS was first identified in the USA in 1993 [81], is among the deadliest yet understudied tropical diseases [40], with consistently low incidence but high mortality rates, 35% in the USA [41] to up to 50% in Bolivia [82]. In Argentina, ANDV is the main cause of HPS [83], representing a serious concern not due to case number, but because most require hospitalization and have a high mortality rate (13–39%) [84]. To date, no treatment, vaccine or drug exists to prevent or combat HPS [85].

Particularly at site 13, *O. flavescens* showed atypical numerical dominance within the wild rodent assemblage. This old coastal natural reserve (350 ha) under formal management is located near the city centre and occupied by riparian thickets, freshwater marshes and flooded grasslands, which provide optimal habitat for *O. flavescens* [19]. Its dominance may reflect the site's strong isolation from surrounding natural and rural environments [86], which likely limits immigration of competitively superior species, such as *A. azarae* and *Oxymycterus rufus* [87–89]. Combined with the site's high visitor numbers, this context may elevate zoonotic disease risk, underscoring the need for preventive measures.

In most GA samples, where *A. azarae* dominated the wild rodent assemblage, the risk of ANDV transmission seems lower, as this species is linked to the Pergamino genotype not yet associated with human disease [90]. Nevertheless, potential human risk cannot be discarded. Several factors require consideration: some sites were sampled only once, *O. flavescens* populations in urban areas show marked seasonal fluctuations [25], and virus prevalence often rises with reservoir abundance [25,91–93]. Moreover, RNA viruses such as orthohantaviruses exhibit high mutation rates and genotype diversity, allowing adaptation, host-switching and spillover [94]. Thus, pathogenic orthohantaviruses circulation cannot be ruled out, even in GAs with only seronegative *O. flavescens* or without this species.

The detection of mixed synanthropic–synurbic rodent communities in GAs with high levels of anthropogenic disturbance—or in reserves with deficient management—adds complexity to the epidemiological scenario. These areas, often surrounded by LINs, exhibit environmental degradation and rodent species sympatry, which could facilitate pathogen exchange between introduced and native rodents [95]. Generalist species like *R. norvegicus*, *R. rattus* and *M. musculus* may significantly impact disease dynamics by spreading parasites across habitats, increasing the risk of host-switching and spillover to other rodents or humans [96]. Although pathogen-associated variables could not be modelled at the landscape level due to the limited

number of sampling sites (whereas modelling at the household level made it feasible in LINs), we highlight the potential risk of transmission of bacteria (*Leptospira* spp.), viruses (e.g. SEOV and SARS-CoV-2) and helminth parasites in such GAs where synanthropic rodents were captured. These findings underscore the urgent need for proactive measures in these areas of high epidemiological concern. Further parasitological studies should target synurbic rodents to assess novel parasites transferred from introduced synanthropic hosts. Finally, we emphasize the need for seasonal epidemiological surveillance to identify infection hotspots, providing policymakers and green space managers with guidance on priority areas and optimal times for preventive measures to reduce infections and protect vulnerable populations.

## (b) Rodent and pathogen communities in low-income neighbourhoods

LINs of Latin American cities have already been described as areas conducive to supporting rodent populations that harbour different zoonotic parasite species [43,44]. In accordance with previous studies in the city of Buenos Aires (see [19]), the main rodent species in the LINs surveyed were *R. norvegicus* and *M. musculus*, although *R. rattus* was detected in sites with a higher degree of urbanization and infrastructure. Just as with the composition and abundance of rodents, the communities of their parasites respond to the characteristics of the environment due to changes in host density and the biotic and abiotic features of the microhabitat, which can affect the life cycles of the parasites. We have previously detected that rats in LINs have greater parasite richness than other residential neighbourhoods in the city of Buenos Aires, reflecting high environmental contamination of helminth infectious stages here [24].

The results obtained in this study show us the link between social precariousness, rodent proliferation and exposure to neglected zoonotic diseases. Despite having a single sampling session at most sites, we detected associations between the presence of different rodent-borne pathogens and indicators reflecting deficiencies in basic urban services like access to drinking water, sewage or paving. While it is important to note that the number of captures was low in some sites, we cannot conclude the absence of pathogens that were not detected there, but the results suggest that there could be greater circulation and prevalence where they were detected. This increases the probability of detectability on our part and a higher probability of exposure for the population residing there.

We detected *Leptospira* spp. in all three murid rodent species across six of twelve LINs, indicating widespread bacterial presence in the basin. Although leptospirosis is a global public health concern, Latin America reports some of the highest case numbers worldwide [29,33]. Argentina ranks among the leading countries in regional case alerts [29], mainly from low-income settlements in flood-prone areas [30]. In our study, infection in synanthropic rodents was associated with households lacking running water and housing many people and pets. Many sampling sites included stagnant streams, ponds or flood-prone areas after storms—conditions that favour bacterial persistence. Infected rodents, along with dogs—also common hosts—may facilitate pathogen transmission within neighbourhoods. Additionally, limited access to clean water and sanitation likely increases human infection risk. Our findings align with previous research identifying a high prevalence of waterborne protozoa such as *Giardia* and *Cryptosporidium* in *R. norvegicus* from the Riachuelo River [22], though not assessed here. These results highlight the need to integrate responsible water use education into environmental health programmes, especially in underserved communities. Such strategies could enhance disease prevention by addressing both zoonotic risks and underlying infrastructural vulnerabilities.

We analysed two viral pathogens. On one hand, SEOV was detected in *R. norvegicus* in both a LIN and a GA. This virus causes 150 000–200 000 HFRS cases annually, mostly in Asia [38]. In the Americas, human cases are rare, likely due to low medical awareness and limited diagnostic capacity [37,39]. In Argentina, SEOV-positive rats have been reported since the 1980s, mainly in low-income areas of Buenos Aires and surrounding cities [20,97,98]. However, no human HFRS cases linked to SEOV have been confirmed in the country to date [20].

On the other hand, we detected specimens of *R. norvegicus* and *M. musculus* with antibodies against SARS-CoV-2 in two LINs. The samplings were conducted in the post-pandemic years, and residents of LINs were at a significantly higher risk compared to the rest of the community since the spread of the epidemic was influenced by social factors [99]. A large body of scientific evidence suggests that human-to-animal reverse transmission of the SARS-CoV-2 virus poses a risk for the emergence of new reservoirs and the evolution of new variants [100–102]. Rodents living near humans may act as viral reservoirs, facilitating the circulation and mutation of the virus [26]. Monitoring SARS-CoV-2 in these rodents is essential to prevent the emergence of variants with greater potential to infect humans.

Regarding intestinal parasites, four species of sanitary interest were recorded. The parasitological diversity of synanthropic rodents can indicate environmental contamination and human exposure to these pathogens. Firstly, larvae of *T. taeniaeformis* (called *Strobilocercus fasciolaris*) were frequently detected in all murine species in different sites throughout the basin. This cestode uses carnivores as definitive hosts, mainly cats in urban environments, while the larval forms parasitise mainly rodents. Its widespread presence suggests a high prevalence in pets, especially in LINs. We determined that the presence of infected rodents within households is associated with domestic animals, posing a potential risk of infection to inhabitants from eggs of this species (a disease called cysticercosis).

The two *Hymenolepis* species identified have a global distribution, with *H. nana* commonly infecting humans, especially children in developing countries [42,103]. Though often overlooked, chronic infections can cause significant health impacts. We detected infected rats in four distant LINs, all sharing poor socio-economic conditions. Parasite presence was statistically linked to households without access to potable water or sewage systems, which favour transmission via the faecal–oral route. These findings underscore the importance of promoting hygiene practices in environmental health education, particularly in communities lacking essential urban services.

Finally, we would like to point out the finding of *A. cantonensis* in this study. Although it was already reported in [104], we would like to note that the introduction of this zoonotic parasite that causes eosinophilic meningitis mainly in the Southeast Asian area occurs due to the confluence of a series of situations that provide the appropriate ecological conditions for its arrival and establishment. As occurs in basins that flow into coastal cities around the world, the presence of ports where international ships arrive allows the introduction of all types of species. Also, the precarious socio-environmental conditions of the areas surrounding the port support great populations of murine rodents, such as the site where we detected the parasite, and the presence of floodable areas where populations of potential intermediate hosts for this parasite, such as snails, live. This situation is allowing the geographical expansion of *A. cantonensis*, which is why this species should be included in the health agenda in coastal cities worldwide.

### (c) The role and challenges of environmental health education in marginalized communities

Our findings led to the development of educational materials to support awareness campaigns on sanitation and rodent-borne disease prevention, implemented in 2022–2023 with health departments, ACUMAR promoters, local governments and recycling cooperatives (electronic supplementary material, figure S4). Activities included workshops, training and household visits in LINs, where practical advice was given to reduce food sources and rodent shelter. Although well-received, the programme ended abruptly after political changes in late 2023, preventing post-intervention assessments and revealing the vulnerability of health initiatives dependent on shifting national priorities.

Environmental health education should be continuous, participatory and interdisciplinary to address rodent-borne diseases, in line with Freire's vision [105] of empowering disadvantaged communities. Similar efforts in urban contexts have demonstrated the value of community-based approaches in fostering behavioural change and stewardship [106,107]. However, long-term success requires sustained funding and institutional commitment. We argue that such programmes must be state policies rather than contingent government actions to ensure their continuity and impact.

## 5. Conclusions

This first study on rodent communities and their pathogens in the MRRB—one of the world's most polluted basins due to prolonged industrialization—revealed clear links between social vulnerability, rodent proliferation and exposure to neglected zoonoses. Despite limitations such as few sampling sessions at some sites and the lack of epidemiological data, the diversity of LINs and GAs surveyed offered initial insight into pathogen presence and rodent communities, enabling assessment of disease transmission risk in the urban periphery. A next step, if feasible, is to investigate associations between pathogen richness/prevalence in rodents and in humans sharing the same environments.

Under the One Health paradigm, we aim to strengthen collaboration with health promoters, educational institutions, the scientific community and decision-makers to adopt a holistic approach to addressing zoonotic diseases in major Latin American cities.

**Ethics.** Rodents were handled strictly following biosafety norms and according to the Argentine law for the protection of animal welfare (Penal Code, law no. 14.346), in accordance with the ethical standards of the Institutional Commission for the Care and Use of Laboratory Animals (CICUAL) of the Faculty of Exact and Natural Sciences, University of Buenos Aires (experimental protocol no. 156 'Ecology of Urban Rodents') and the recommendations of the American Society of Mammalogists.

**Data accessibility.** The datasets generated during and/or analysed during the current study are available in Dryad [108].

Supplementary material is available online [109].

**Declaration of AI use.** We have not used AI-assisted technologies in creating this article.

**Authors' contributions.** E.M.: conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, supervision, writing—original draft, writing—review and editing; D.H.: conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, supervision, writing—original draft, writing—review and editing; M.A.T.: conceptualization, data curation, formal analysis, investigation, methodology, software, visualization, writing—review and editing; T.J.B.D.: data curation, methodology, visualization; M.E.D.: data curation, methodology; L.M.P.-C.: data curation, methodology, visualization; C.B.G.: data curation, methodology, visualization; E.B.: data curation, methodology, resources; O.V.S.: conceptualization, funding acquisition, investigation, methodology, project administration, resources, supervision, writing—original draft, writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

**Conflict of interests.** We declare we have no competing interests.

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