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(RESEARCH ARTICLE)

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Epidemiology and Spatio-Temporal Dynamics of Plague in Ecuador (1908–2008)

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Abstract

Background: Plague is an infectious disease caused by the virulent Gram-negative bacillus *Yersinia pestis*, is a zoonotic infection that has caused three devastating global pandemics. While historically known for the "Black Death," the pathogen remains a contemporary public health concern, persisting in endemic foci across Asia, the Americas, and Africa. In Ecuador, the disease has evolved from a coastal epidemic into a complex Andean endemic since its introduction in 1908.

Methods: This study reviews the epidemiological trajectory of plague in Ecuador, which spans five distinct phases. Transmission dynamics were facilitated by maritime trade at the Port of Guayaquil and the national railway network, which served as a mechanical vector for infected rodents and fleas (*Xenopsylla cheopis, Polygenis litragus*) into the Inter-Andean heartland.

Results: The disease heavily impacted provinces such as Chimborazo, Tungurahua, and Loja. While coastal incidence declined by 1930, persistent foci remained in the highlands, sustained by favorable ecology and socioeconomic factors. Despite the establishment of the National Anti-Plague Service in 1960, a significant re-emergence occurred in 1998 in Galte Laime (Chimborazo), potentially triggered by climatic shifts from the 1996 El Niño phenomenon.

Conclusion: Plague management in Ecuador has transitioned toward rigorous epidemiological surveillance. Current strategies emphasize the active monitoring of rodent and flea reservoirs to prevent the fatal transition from bubonic to pneumonic plague. Continued vigilance remains essential in endemic zones to mitigate the risks posed by environmental and infrastructure-driven transmission.

Keywords: *Yersinia pestis*; Ecuador; Epidemiology; Zoonosis; Public Health Surveillance; Chimborazo

1. Introduction

Plague is a zoonotic infection that has burdened human populations for millennia. The disease is caused by the Gram-negative bacillus *Yersinia pestis*, widely considered one of the most virulent pathogens in history.

It has been responsible for three documented pandemics, most notably the "Black Death" of 14th-century Europe-which decimated approximately 30% of the population-and the most recent pandemic, which emerged in the late 19th century in Asia and India. While the latter persists in parts of Africa, the bacterium remains endemic across regions of the Americas and Asia (Barbieri *et al*., 2020; Organización Mundial de la Salud, 2022).

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The life cycle of *Y. pestis* typically alternates between an insect vector (primarily fleas) and mammalian hosts, such as rodents or other small mammals; humans generally serve as incidental hosts. Clinical manifestation primarily occurs through three major syndromes: bubonic, septicemic, and pneumonic plague (Vallès *et al.,* 2020; Hinnebusch *et al.,* 2017). Additionally, rarer forms, including cutaneous and gastrointestinal plague, have been documented. Diagnostic protocols involve the isolation of the bacterium via culture, alongside the detection of specific antigens, antibodies, or nucleic acids. According to World Health Organization (WHO) guidelines, cases are classified as suspected, presumptive, or confirmed based on the strength of clinical and laboratory evidence. Standard therapeutic intervention relies on aminoglycoside antibiotics, typically streptomycin or gentamicin (Yang R., 2017; World Health Organization, 2000).

2. Methods

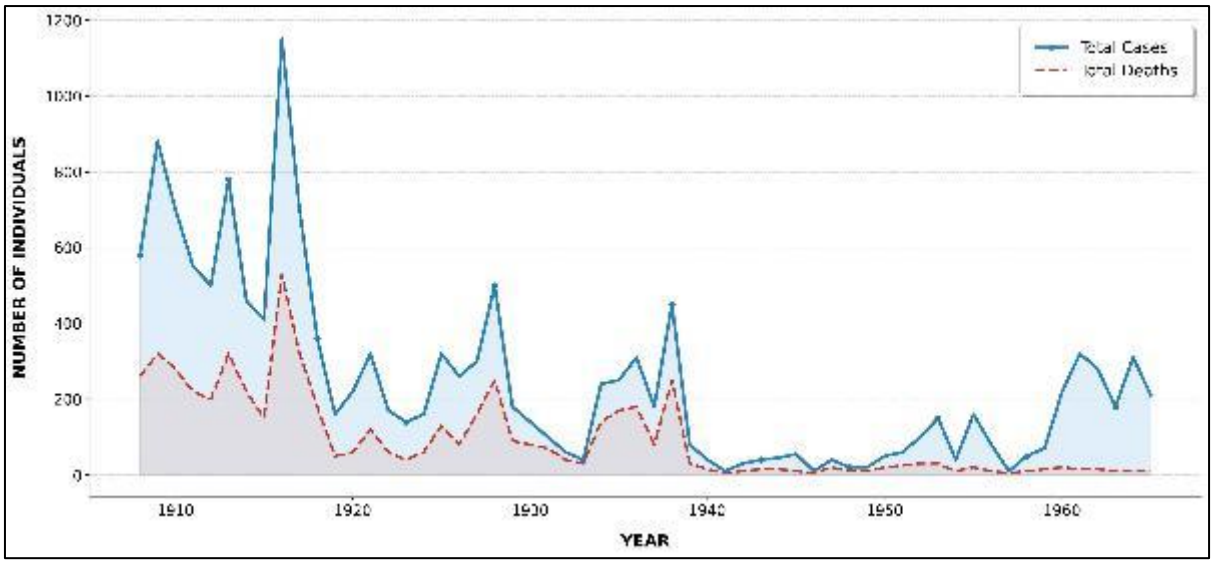
This study was conducted through a comprehensive bibliographic review of historical records, technical reports, and epidemiological archives to analyze plague cases and deaths in Ecuador between 1908 and 2008. The research integrated data on incidence and mortality with ecological variables, including the distribution of vectors. For the spatial analysis, geographic data were processed using Python (utilizing libraries for spatial visualization) to create and modify maps from previous studies, updating them with current historical data. These maps illustrate the disease's transition from maritime ports to the Inter-Andean heartland.

2.1. Epidemiology and Spatio-Temporal Dynamics of Plague in Ecuador

The plague first breached Ecuador's borders on March 7, 1908, arriving at the bustling port of Guayaquil. Likely hitching a ride on maritime trade routes from India or Peru, the disease quickly adapted to the local landscape. What began as a coastal epidemic eventually transformed into a persistent Andean endemic, following the veins of the country's growing infrastructure and unique ecological niches (Jervis, 1967; Iturralde, 1909).

During the initial epidemic period (1908–1939), the spread was aggressive. Guayaquil bore the brunt of the crisis with over 7,800 cases and 3,100 deaths, but the bacteria didn't stay confined to the coast. The Guayaquil-Quito railway acted as a mechanical vector, carrying infected rats and fleas into the Inter-Andean heartland. This inland invasion heavily impacted provinces like Chimborazo and Tungurahua, while cross-border trade further south introduced the disease to Loja by the late 1910s (Jervis, 1967; Saenz, C. D.,1908).

The epidemiology of the plague in Ecuador is defined by five distinct phases. After the initial rapid spread, the disease entered an Andean endemic period (1949–1959), followed by a coastal re-infestation in the 60s and 70s. By the late 20th century, the disease had settled into localized pockets, primarily in Chimborazo, occasionally re-emerging during significant climatic shifts (Fig 1 & 2).



Adapted from Jervis (1967), showing plague trends in Ecuador (1908–1965).

Figure 1 Temporal trends in plague cases and mortality in Ecuador, 1908–1965

This figure illustrates the number of reported plague cases and deaths in Ecuador between 1908 and 1965. During the early period, a high burden of disease is observed, characterized by multiple peaks of incidence and elevated mortality. Secondary peaks occur between 1920–1930 and 1930–1940, followed by a marked decline in both cases and deaths during 1940–1950. In the subsequent years, intermittent increases in case numbers are observed; however, mortality continues to decrease. The graph is represented by two lines: a solid blue line indicating reported cases and a dashed red line representing deaths.

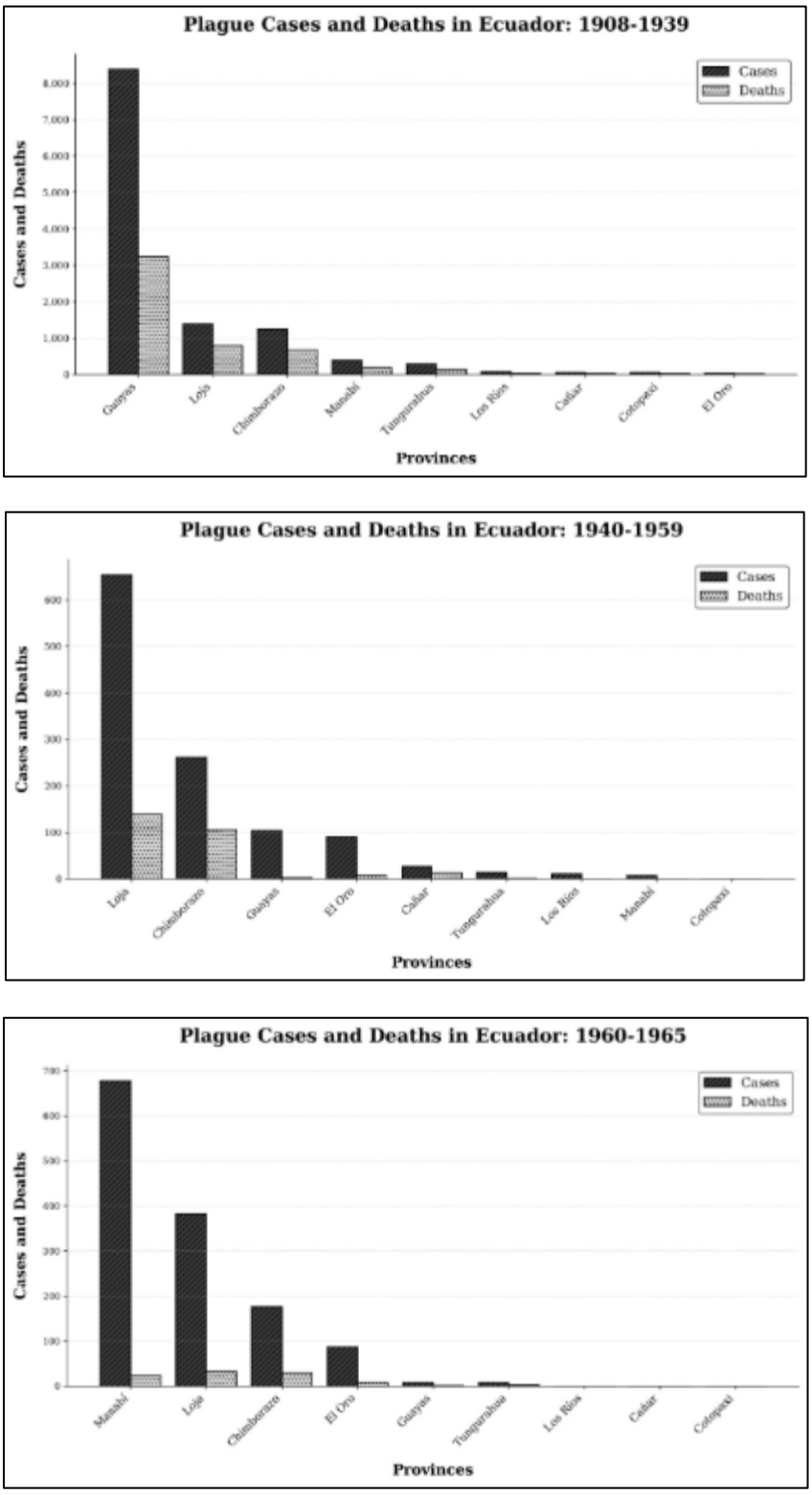


Figure 2 Temporal geographic distribution of plague cases and mortality in Ecuador, 1908–1965

Three bar graphs illustrate the number of reported cases and deaths across the same time periods. The highest incidence and mortality occur between 1908 and 1939, followed by a geographic shift and concentration of cases in Loja during 1940–1959. A marked decline in overall cases is observed from 1960 to 1965, although mortality remains comparatively elevated in Andean provinces, particularly Loja and Chimborazo Adapted from Jervis (1967), showing plague trends in Ecuador (1908–1965).

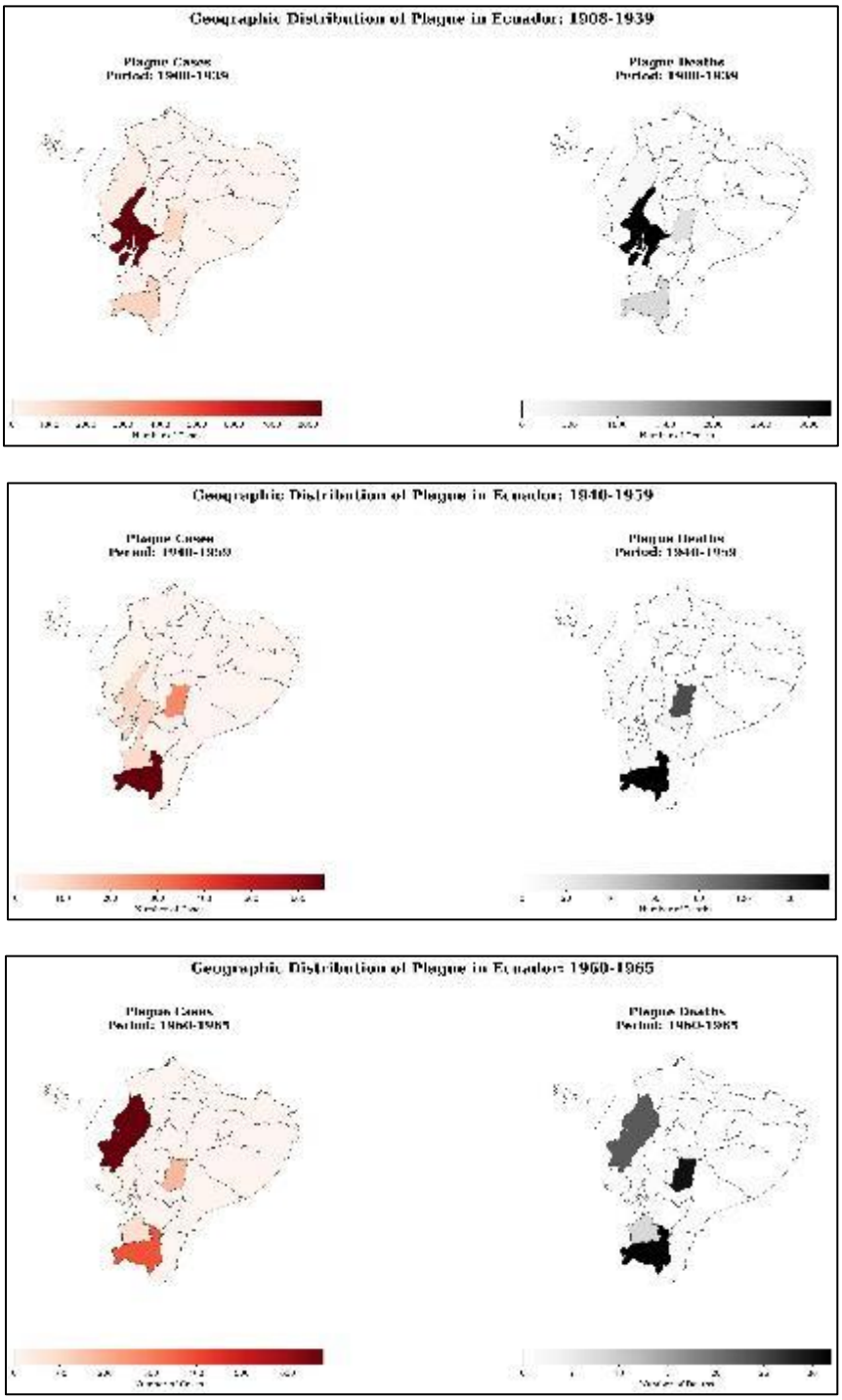


Figure 3 Spatiotemporal Dynamics of Plague Distribution: Cases and Mortality (1908–1965)

Three maps depict the spatial distribution of reported plague cases and associated mortality across three time periods (1908–1939, 1940–1959, and 1960–1965). During the first period, a high concentration of cases and deaths is observed in coastal regions, particularly in Guayas, consistent with the introduction of plague through maritime ports. In the second period, the disease spreads andean provinces, with a marked burden in Loja and a lower but notable presence

in Chimborazo. In the final period, a reduction in cases is observed; however, persistent transmission remains in Manabí, Loja, and Chimborazo, with relatively higher mortality in Andean regions Adapted from Jervis (1967), showing plague trends in Ecuador (1908–1965).

In light of these dynamics, a historical division can be established: an epidemic period (1908–1939), an endemic period in the Sierra (1949–1959), a reinfestation period on the Coast (1960–1976), a period of localized endemicity (1977–1983), and a new endemic phase (1998–2008). Two persistent foci remained in Chimborazo and Loja, sustained by poor socioeconomic conditions, favorable ecology, and the presence of indigenous populations. In response to this, the National Anti-Plague Service was established in 1960 (Fig. 3), organizing the country into three epidemiological departments: Central, Austral, and Litoral (Pezantes *et al., 2008; Schneider et al., 2014*).

The transmission of the disease was driven by specific vectors and reservoirs. Ectoparasites involved included *Xenopsylla cheopis* in both the Litoral and the Sierra, alongside *Polygenis litragus, Nosopsyllus londiniensis,* and *Cediopsylla inquinalis* in the highlands (Fig. 4). These parasites were carried by rodent reservoirs, specifically *Mus musculus, Cavia cobaya, Akodon mollis,* and *Oryzomys xanthaeolus* (Macchiavello, 1943).

Several hypotheses pointed to the human flea (*P. irritans*) for the spread of Andean rural plague; however, it is argued instead that the disease primarily follows the classic rat-to-flea-to-human cycle, though it is significantly modified by altitude and climate. In this dynamic, guinea pigs serve as accidental intermediaries rather than primary reservoirs; they attract infected fleas from rat burrows and, upon dying, release these vectors into human living spaces. Furthermore, the fleas themselves may act as the long-term reservoir by surviving between seasons and reinfecting susceptible rat populations that return to dwellings after harvests—a process further complicated by social factors such as the holding of wakes and the distribution of the deceased's clothing (Macchiavello, 1943; Ministerio de Salud Pública, 2012).

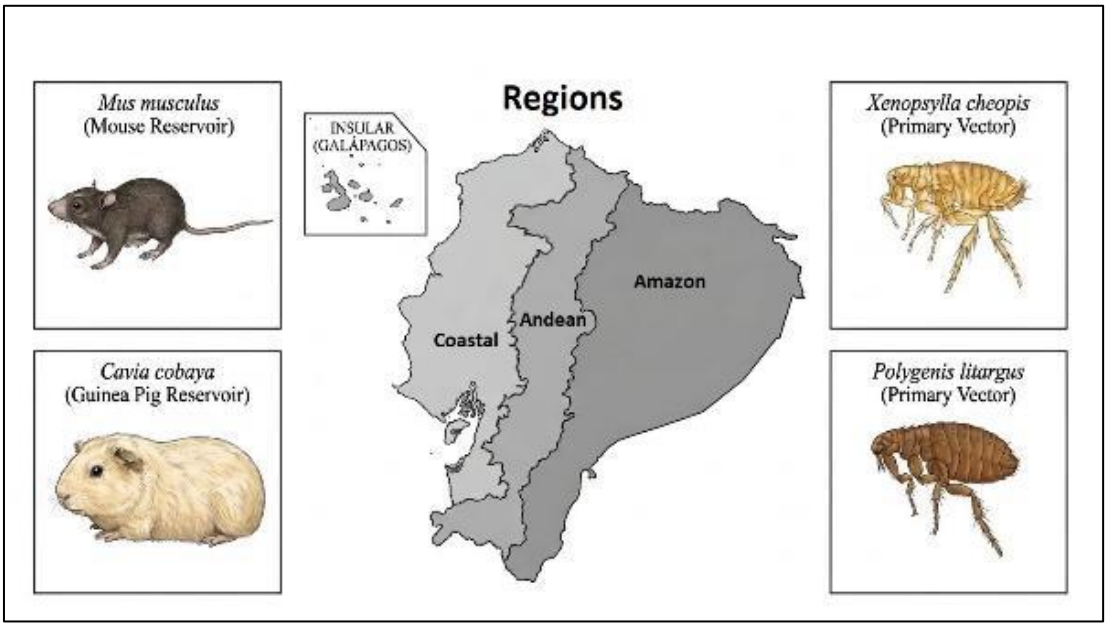


Figure 4 Vectors and reservoirs of plague in Ecuador

This figure illustrates the principal flea vectors and mammalian reservoirs associated with plague transmission in Ecuador. The main vectors include Polygenis litargus and Xenopsylla cheopis, predominantly found in coastal regions, while Xenopsylla species are also distributed in both coastal and Andean regions. Polygenis litargus is particularly associated with the highland (Andean) areas. The primary reservoirs include rodents of the genus mice but also have been reported guinea pigs, which play a key role in maintaining the enzootic cycle of Y. pestis.

By 1972, the plague was almost exclusively reported in the province of Chimborazo, with Nizag serving as the primary natural focus, supplemented by temporary foci such as Zunag, Guasuntos, and Quilliquin. Bubonic plague remained prevalent in these areas until 1983. However, new concerns emerged in 1998, when 30 cases and 12 deaths were reported in Galte Laime, just 35 km from Nizag (Pezantes *et al.,* 2008). Experts hypothesized that the 1996 El Niño

phenomenon triggered the migration of infected rodents, a situation complicated by the failure to diagnose cases of pneumonic plague (Table 1).

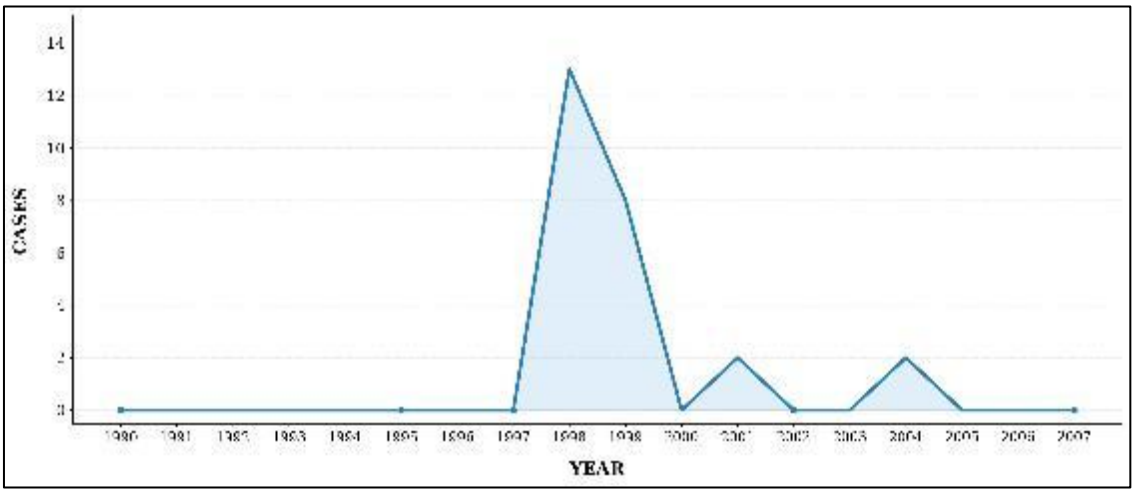
Furthermore, in the 21st century, both cases and deaths would have decreased, being restricted to sporadic outbreaks, especially located in the inter-Andean region. Of Chimborazo (Fig. 5)

To address these challenges, the country implemented rigorous epidemiological surveillance, utilizing diagnostic protocols from the CDC in Fort Collins. Current measures include the active monitoring of rodent populations, fleas, and guinea pigs, as well as immediate interventions for suspected cases. A probable case is defined as any person of any age who presents fever and adenitis while residing in an endemic zone. Furthermore, protocols mandate that for any death caused by fulminant pneumonia (with an evolution of 24 to 48 hours), diagnostic samples must be taken for further investigation (Pezantes *et al.,* 2008; OPS, 2020).

Table 1 Plague Cases and Deaths in Ecuador during the 20th Century

Year	Number of Cases	Number of Deaths	Location
1919–1970	11,828	5,135	1,265 locations
1971–1976	1,702	120	Not specified
1981	9	0	Nizag
1983	65	3	Nizag
1984	10	0	Nizag
1985	3	0	Zabiango
1998	30	12	Galte Laime
1998	8	4	Pul Chico
1999	1	1	Sta Lucia Bravo
1999	1*	1	Cubijies
2000	8*	0	Licto
2000	21*	1	Riobamba

This table illustrates the epidemiological transition of the disease between 1919 and 2000, showing a shift from widespread endemicity (11,828 cases) to localized, sporadic outbreaks. Note. * Indicates specific locations from Chimborazo



Adapted from: Aguilar J. E. Casos y tasa de peste, Ecuador 1990-2007 Epidemiology, Ministerio de Salud Pública del Ecuador; 2007.

Figure 5 Temporal trends in plague cases in Ecuador, 1990–2007.

This figure illustrates the number of reported plague cases in Ecuador between 1990 and 2007. The early part of this period is characterized by sporadic outbreaks represented by three distinct incidence peaks. Notably, the significant surge in cases observed in the late 1990s is closely correlated with the 1997–1998 El Niño phenomenon, which could have triggered the migration of infected rodent reservoirs and led to the re-emergence of the disease in the Andean highlands. The graph is represented by a solid blue line indicating the total reported cases

3. Discussion

Following the initial outbreak that devastated Ecuador with a high volume of cases and fatalities—spreading first through its ports before reaching the Andean region—the plague eventually abated. While Bolivia, Brazil, Peru, and Ecuador are all considered plague-endemic, the disease has lost epidemiological visibility over the last decade due to a low frequency of reports. Despite this apparent latency, a persistent risk of resurgence remains (Donaires et *al.,* 2010). Among these nations, Peru has recorded the highest volume of sporadic cases, while Ecuador and Bolivia have reported only a small number of incidents (Carcauzon *et al.,* 2026). A critical example of this underlying threat occurred in La Libertad, Peru, in 2010, where two cases of nosocomial transmission of pneumonic plague were linked to a single index case (Donaires *et al.,* 2010). On the other hand, in 1998, a remote Andean community in Ecuador; a sudden cluster of 13 fatalities was reported in the region, primarily involving a single family with a history of close contact with infected guinea pigs. Epidemiological investigations identified *Yersinia pestis* as the etiological agent, with diagnostic confirmation achieved by detecting the F1 structural antigen through passive hemagglutination, PCR, and monoclonal antibody-based immunohistochemical staining. The findings indicated that the victims succumbed to pneumonic plague, while serological surveillance of close contacts revealed positive antibody titers in four individuals, confirming further human exposure. Furthermore, the presence of plague antibodies in 5 of 14 local dogs provided definitive evidence of a recent epizootic event, underscoring the significant zoonotic risk associated with infected domestic rodents in these communities (Gabastou *et al.,* 2000).

Currently, epidemiological studies have found the presence of *Yersinia spp.* in animals. A study identified a 4% prevalence of this Gram-negative enterobacterium in the livers of guinea pigs from the Chuquiribamba, Loja, revealing a significant sanitary issue due to the ability of these animals to act as asymptomatic reservoirs. The findings highlight that the presence of *Yersinia pseudotuberculosis*, is closely linked to deficiencies in the technical management of family production systems, such as a lack of biosecurity, absence of quarantine protocols, high population density, and direct contact with other species, particularly sheep. These conditions, combined with the consumption of contaminated forage and water, promote stress and bacterial dissemination, leading to pathological lesions such as multifocal necrotic hepatitis. Given the non-specific nature of clinical signs and the risk of antibiotic resistance caused by empirical treatments, these findings underscore the urgent need to implement molecular diagnostic programs and technical improvements in breeding to mitigate economic impact and protect public health against this potentially zoonotic disease (Puglla Remache, 2025).

4. Conclusions

The epidemiological trajectory of *Yersinia pestis* in Ecuador from 1908 to 2008 reveals a complex transition from a maritime-driven coastal epidemic to a persistent Andean endemic. This shift was facilitated by national infrastructure, specifically the railroad system, and sustained by unique ecological niches where diverse flea vectors (such as *Polygenis litargus* and *Xenopsylla cheopis*) and rodent reservoirs allowed the pathogen to remain entrenched. While the frequency of reported cases has declined significantly since the mid-20th century, the 1998 re-emergence in Chimborazo, potentially linked to the El Niño climatic phenomenon, serves as a critical reminder that the plague is not a disease of the past. The documented risk of domestic transmission via guinea pigs and the threat of fatal pneumonic outbreaks underscore the need for continued vigilance.

Compliance with ethical standards

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Disclosure of conflict of interest

There are no conflicts of interest.

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