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Paraguay's Resilience in Malaria Elimination: 24 Years of Malaria Indicators (2000-2024) and Post-Certification Challenges

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Abstract

This study aimed to analyze the evolution of malaria epidemiological indicators in Paraguay (2000-2024), focusing on the elimination of autochthonous transmission and the monitoring of imported cases. The methodology employed an observational, descriptive, retrospective, ecological and longitudinal study design, utilizing secondary data from scientific literature and SENEPA official records. Malariometric indicators such as Annual Parasitic Incidence (API), autochthonous and imported cases and blood examinations were analyzed. Results revealed a three-phase epidemiological transition: a drastic reduction in autochthonous cases (2000-2011), culminating in the last recorded case in 2011; and a consolidation phase (2012-2024) without local transmission, but with persistent imported cases. Success was attributed to comprehensive vector control, active surveillance and sustained financial commitment. The initial increase in imported cases was interpreted as an indicator of effective surveillance. However, the decline in the Annual Blood Examination Index (% IEA) highlights the dilemma between efficiency and sensitivity in post-elimination surveillance, making active case finding for asymptomatic infections crucial for validation. In conclusion, Paraguay's experience demonstrates that malaria elimination is achievable through political commitment, continuous funding, adaptive surveillance and integrated strategies, serving as a replicable model for other regions. Maintaining malaria-free status will depend on continuous surveillance of imported cases and rapid response capabilities to any reintroduction.

Keywords: Malaria; Paraguay; Epidemiological surveillance; Malaria indicators; Public health

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Introduction

Malaria remains a disease of significant global relevance, being endemic in more than 100 countries located predominantly in tropical and subtropical zones. It is an infection caused by protozoa of the genus *Plasmodium*, whose primary route of transmission to humans occurs through the bite of infected female *Anopheles* mosquitoes [1]. The disease represents a severe public health problem characterized by high morbidity and mortality rates, which impose a disproportionate burden on populations in low-income countries.

Despite significant advances in diagnosis, treatment and vector control, the eradication of malaria remains a complex challenge. Successful elimination strategies demand not only technical interventions but also economic development, the strengthening of healthcare systems, robust epidemiological surveillance and the implementation of sustainable control measures. It is crucial that these strategies be adapted to local contexts considering their specific epidemiological, social and environmental characteristics and integrated into multisectoral actions that include active community engagement [2]. Some optimistic prospective models, based on the acceleration



of scientific breakthroughs, the application of innovative tools and the guarantee of sustainable funding, allow us to envision the possibility of global eradication by the middle of the century [3].

Despite global progress, the geographical distribution of malaria remains deeply unequal, with a disproportionately higher epidemiological burden on vulnerable populations. This is evident when analyzing 2022 data: 247 million cases and 619,000 deaths were recorded worldwide, with Africa accounting for 95% of total deaths, while the Americas, in contrast, accounted for only 0.2%. Specifically observing the Americas region, Brazil, Colombia and Venezuela jointly account for 73% of cases [4]. However, this reality coexists with notable success stories. Paraguay, for instance, became a milestone by completely eliminating local transmission in 2018, proving that eradication is possible even in endemic regions [5].

This achievement, however, is the pinnacle of a long history of confrontation. In the 1940s, the country faced a severe malaria epidemic with more than 80,000 recorded cases. The disease spread through approximately 90% of the national territory, establishing itself as one of the most serious public health problems of the time [6]. Cases were concentrated mainly in poor regions of the Alto Paraná, Caaguazú and Canindeyú departments areas affected by significant ecological changes resulting from population growth and the construction of the Itaipu hydroelectric power plant [7]. In response, an anti-malaria agency now known as National Malaria Eradication Service (SENEPA, Spanish acronym) was created in 1957 and public policies aimed at controlling and eliminating the disease were implemented [8]. These actions resulted in a continuous and progressive reduction in the number of cases, laying the foundations that, decades later, would culminate in the country's elimination certification.

This milestone is the result of a historical effort that culminated in the registration of the last autochthonous case of *Plasmodium falciparum* in 1995 and *P. vivax* in 2011. That same year, a five-year plan was launched to consolidate progress and prepare the country for elimination certification. The strategy was based on three pillars: strengthened epidemiological surveillance with early detection; systematic management with free treatment; and community education actions for prevention (5). Success was evident starting in 2012, when all detected cases began to be classified as imported [6].

In recognition of this effort, Paraguay established itself as a regional example, becoming the first country in the Americas since Cuba in 1973 to receive malaria-free certification from the WHO in 2018 (9). Of the 21 countries in the Americas, only four hold this certificate: Paraguay (2018), Argentina (2019), El Salvador (2021) and Belize (2023) [10]. The program's sustainability is guaranteed by national legislation that ensures stable funding, allocating 1.5% of social security revenue to vector control [5].

The Paraguayan experience demonstrates that the elimination of endemic diseases requires firm political commitment, continuous funding and constant epidemiological surveillance. The lessons learned have been applied to tackling other arboviruses, solidifying the country as a relevant model for regional public health [5]. In this context, it becomes essential to understand how malariometric indicators such as incidence, parasitemia, *Plasmodium* species and the origin of imported cases reflect this trajectory of success. Analyzing these data is fundamental for monitoring transmission, formulating public policies and understanding the critical factors that sustained elimination.

Given the above, this study aims to analyze the evolution of malaria epidemiological indicators in Paraguay between 2000 and 2024, taking as a reference the process of eliminating autochthonous transmission and the monitoring of imported cases. The Paraguayan experience, marked by effective strategies and concrete results, represents a valuable success case. Therefore, the present analysis seeks to identify the determining factors for this success and generate evidence that can support replicable strategies in other endemic regions aiming for disease elimination.

Methodology

This observational, descriptive, retrospective, ecological and longitudinal study is based on time series of population indicators. These series were constructed using mixed secondary data obtained from scientific literature (2000-2011) and official records from the National Malaria Eradication Service (SENEPA, Spanish acronym) covering the period 2008-2024, accessed through Paraguay's Unified Public Information Access Portal.

The following malariometric indicators were analyzed: estimated population; population at risk for malaria; total number of blood samples examined; annual blood examination rate (ABER, per 100 inhabitants); number of positive malaria samples; annual parasite incidence (API, per 1,000 inhabitants); number and proportion of imported and autochthonous cases; identified parasite species (*Plasmodium falciparum*, *P. vivax* and *P. ovale*); geographic origin of imported cases; hospitalization rate; and case fatality rate.

Data were systematized into electronic spreadsheets with annual stratification, enabling the construction of time series. The presentation of results included comparative chart and tables, accompanied by descriptive analyses of trends and historical milestones in the national health response.

In accordance with the study design, no inferential statistical tests were applied. Since the study utilized aggregated, secondary, public-domain data without individual identification, submission to a research ethics



committee was not required. All information sources were duly cited, ensuring the traceability and reliability of the data used.

Results and Discussion

Malaria in Paraguay: Two Decades of Evolution and Epidemiological Trajectory (2000–2024)

The analysis of **Figure 1** corroborates and quantifies the historical narrative of Paraguay's success, revealing a transition in the epidemiological profile that can be divided into three phases:

- An initial period of drastic and sustained reduction in autochthonous cases, which dropped from thousands to just one between 2000 and 2011;
- A pivotal transition year (2011), marking the last recorded case of local transmission and;
- A prolonged consolidation stage (2012-2024), characterized by the absence of autochthonous transmission and the detection of a residual, yet constant, number of imported cases. This final phase highlights the new frontier of the challenge: permanent surveillance against the reintroduction of the parasite.

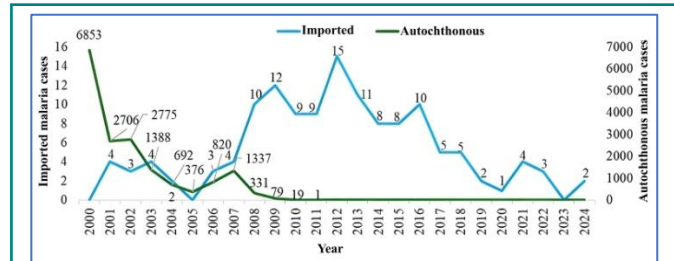


Figure 1: Annual distribution of autochthonous and imported malaria cases in Paraguay, 2000-2024. Data for imported and autochthonous cases, 2000-2011, Viveros et al. (2017) [7]. Period 2008-2024, SENEPA (2025).

The year 2008 represented a crucial inflection point, with 341 recorded cases. According to the literature, this was the lowest number of cases in a decade (1999-2008) (7,11). Of this total, five cases were *Plasmodium falciparum* (**Table 1**) and ten were classified as imported (**figure 1**), an early sign of the shifting epidemiological profile that would eventually consolidate. **Table 1** complements and deepens the temporal analysis of **Figure 1** by detailing the operational indicators that sustained the elimination trajectory. A longitudinal analysis of the data allows for an understanding of the core strategy behind the successful cessation of local transmission: Vector control combined with active and adaptive surveillance.

Table 1: Malariometric indices of Paraguay, 2008–2024: (A) estimated population by sex and age; (B) population at risk zone (malarial zone); (C) number of blood samples examined; (D) Annual Blood Examination Rate (ABER) per 100 inhabitants; (E) number of positive samples; (F) Annual Parasite Incidence (API), per 1,000 inhabitants; (G) Number of samples diagnosed with *Plasmodium falciparum*; (H) *Plasmodium falciparum* incidence per 1,000 inhabitants.

Year	Population (A)	Population at risk zone (B)	Blood samples (C)	%ABER (D)	Positive samples (E)	API (F)	<i>P. falciparum</i> (G)	<i>Pf</i> incidence (H)
2008	6.071.781	722.697	80.61	1,33	341	0,47	5	0,0001
2009	6.340.639	722.697	64.66	1,05	91	0,13	9	0
2010	6.451.122	707.41	62.178	0,99	27	0,04	5	0
2011	6.561.765	578.322	48.611	0,76	10	0,02	6	0
2012	6.461.041	578.32	31.499	0,49	15 (#)	0	11	0
2013	6.559.027	578.32	24.86	0,38	11 (#)	0	7	0
2014	6.657.232	578.32	24.832	0,37	8 (#)	0	7	0
2015	6.755.756	578.32	9.157	0,14	8 (#)	0	6	0
2016	6.854.53	578.32	3.191	0,14	10 (#)	0	7	0
2017	6.953.646	6.953.65	8.046	0,12	5 (#)	0	2	0
2018	7.052.983	7.052.98	11.068	0,16	5 (#)	0	2	0
2019	7.152.703	7.152.70	10.967	0,15	2 (#)	0	1	0
2020	7.252.672	7.252.67	11.122	0,15	1 (#)	0	1	0
2021	7.353.038	7.353.04	10.792	0,15	4 (#)	0	1	0
2022	7.453.694	7.453.694	10.95	0	3 (#)	0	0	0
2023	7.656.215	7.656.215	9.265	0	0	0	0	0
2024	6.372.623	6.372.623	10.387	0	2 (#)	0	0	0
Values	6.819.121 ^a	3.459.094 ^a	432.195	-	543 (74 #) 6 ^a	-	-	-

Note: (#) Since 2012, positive cases have been exclusively imported cases. ^a Average.

Studies indicate that the nationwide use of Indoor Residual Spraying (IRS) was fundamental for vector

control during the 2001-2014 period, protecting as many as 500,000 people from local transmission in 2003. This,



associated with other government investments in surveillance, contributed to the consistent decline of the Annual Parasite Incidence (API) until it reached zero after 2011 [11]. Furthermore, the data show that the commitment to malaria control was maintained beyond the elimination phase of autochthonous transmission, as evidenced by the number of blood samples examined over time and the notable expansion of the population at risk starting in 2017 (**Table 1**). This shift from focused to universal surveillance may have been a strategic move to address the new challenge: Preventing the reintroduction of the parasite *via* imported cases.

This consistent downward trajectory placed Paraguay in a prominent regional position as early as the 2000s. In 2008, the country's Annual Parasite Incidence (API) was only 0.47 per 1,000 inhabitants (**Table 1**), already classifying it at that time as a low-risk transmission area [12]. This value was not only low but also placed Paraguay at the forefront of malaria control in the Americas. Historically, the country has been among those with the lowest APIs in Latin America and the Caribbean (LAC), alongside nations such as Argentina, the Dominican Republic, El Salvador, Mexico and Panama. The magnitude of this achievement becomes clear when contrasting its API with the regional average: While Paraguay recorded 0.47/1,000, the average for LAC countries was approximately ten times higher, hovering around 5.0/1,000 inhabitants in the same year [13].

A crucial epidemiological pattern emerges during the transition phases toward elimination: While autochthonous cases exhibited a sharp decline with a reduction of approximately 73% in 2009 compared to 2008 imported cases showed an upward trend. This increasing detection of imported cases, which had been intensifying since 2005, reached its peak in 2012 with 15 records, the highest value in 24 years (**Figure 1**).

This apparent paradox the increase in imported cases at a time of progress toward the elimination of autochthonous cases may, in fact, be an indicator of the surveillance system's effectiveness. The peak in notifications in 2012 coincides precisely with the confirmation of the first full year without any autochthonous transmission in the country demonstrating that the health network had become sensitive enough to detect and report even infections acquired abroad. Following this milestone, imported cases began to show a consistent downward trend, reaching a reduction of approximately 87% by 2024 relative to the 2012 peak (**Table 1 and Figure 1**).

Discussion

Reflections on surveillance, post-elimination and sustainability

In relative terms, Paraguayan surveillance

demonstrated significant capacity, with 432,195 blood samples examined between 2008 and 2024 for an average population of 6,819,121 inhabitants, of which 543 were positive for malaria. However, an analysis of the Annual Blood Examination Rate (ABER per 100 inhabitants) reveals a constant downward trend, systematically remaining below 1% after 2009 (**Table 1**). The interpretation of this trend is ambivalent and reflects a central dilemma of the post-elimination phase. On one hand from an operational efficiency perspective, the progressive reduction in the ABER can be seen as a rational adaptation to the new epidemiological reality. Given the drastic reduction in local transmission, surveillance necessarily became more targeted and focused on suspected cases and priority areas, optimizing resource allocation. On the other hand, as advocated by the Pan American Health Organization (PAHO), higher examination rates are an indicator of active, robust and more sensitive surveillance [14]. In this sense, the sustained drop in the ABER raises a critical reflection: to what extent could the pursuit of efficiency compromise the ability to detect asymptomatic cases or discrete outbreaks in areas of residual risk?

Precisely to mitigate this risk and validate the system's sensitivity, specific strategies for case detection of asymptomatic individuals can be implemented, as illustrated by Puerto's study [15]. The research was conducted in an indigenous community in the Caaguazú department, an area with a history of high endemicity where 30% of the population was infected in 2007. The result of the active search was decisive: no *Plasmodium* species were detected in the blood samples analyzed after 2011. This negative finding is, in fact, a deeply positive and robust result. It serves as an *in loco* validation of the effectiveness of control measures and the sustained interruption of transmission, even in one of the country's formerly most vulnerable locations. Studies of this nature are essential to offset potential reductions in the sensitivity of routine surveillance and to provide robust evidence that malaria elimination is being sustained, even in micro-areas of residual risk.

The interruption of local malaria transmission in Paraguay is the result of the successful implementation of an integrated set of strategies, including vector control, timely diagnosis and treatment and intensified epidemiological surveillance. Financial sustainability was a crucial pillar of this achievement, with the Paraguayan government investing millions of dollars in prevention and control programs between 2000 and 2014, with additional support from the global fund [1,6,11,16].

The final milestone of autochthonous transmission was reached in 2011, with the last case recorded in the Alto Paraná department [16]. After a six-year consolidation period of intensive surveillance without any local recurrence, the World Health Organization (WHO) officially granted Paraguay malaria-free certification in



2018, crowning one of the most successful public health journeys in the Americas in recent decades [17].

Imported cases and residual risk: Post-elimination challenges

The epidemiology of malaria in Paraguay was historically dominated by *Plasmodium vivax*, which accounted for 99.49% of autochthonous cases between 1990 and 2008 and was generally associated with milder clinical forms of the disease. *P. falciparum* and *P. malariae* represented only 0.47% and 0.01% of cases, respectively, during the same period [13].

However, it is the *P. falciparum* species that represents the greatest residual risk, being associated with severe and potentially fatal conditions. Although the autochthonous transmission of *P. falciparum* was interrupted in 1996 (7), this parasite remains a public health threat due to the continuous occurrence of imported cases, which continue to be reported and are occasionally fatal.

Between 2012 and 2024, 74 imported cases were reported, corresponding to an average of approximately six infections per year (**Table 1**). An analysis of these imported cases (16, 18) reveals a high-risk pattern: i) the vast majority (82%) originated from countries on the African continent, 17% from the Americas and 1% from Asia; ii) despite the external origin, 74% of the diagnosed individuals were of Paraguayan nationality, suggesting infection during international travel; iii) *P. falciparum* was responsible for 61% of imported cases, followed by *P. vivax* (33%) and *P. ovale* (6%); iv) the severity profile is alarming: nearly half of the patients (47%) required hospitalization and the case fatality rate reached 7%.

Paraguay remains vigilant against the reintroduction of malaria, despite the persistence of competent vectors in several regions. The primary vector for *P. falciparum*, *Anopheles darlingi*, remains present in areas of Canindeyú, Caaguazú and Alto Paraná. Vectors for *P. vivax* and *P. ovale* are found in departments such as Presidente Hayes, Central and Amambay. Crucially, imported cases were detected in all these regions, creating a permanent risk of parasite reintroduction in receptive environments [16]. This combination of factors constitutes the main challenge for the sustainability of the elimination status. To mitigate this risk, it is imperative to maintain an uninterrupted and robust surveillance system, along with efficient diagnostic capacity [19].

The institutional architecture to address this challenge is coordinated by the Ministry of Public Health and Social Welfare (MSPBS), through its General Directorate of Surveillance and Health (DGVS), the National Service for Malaria Eradication (SENEPA), the Central Public Health Laboratory (LCSP) and the General Directorate for the Development of Health Services and Networks (DGDSyRS), in coordination with various governmental and non-

governmental entities [20].

Ongoing actions for the prevention of reintroduction and management of residual risk

To preserve its malaria-free status, achieved in 2018 as a result of sustained efforts over the years by the State, cooperating agencies and society, Paraguayan health authorities have maintained and progressively intensified epidemiological surveillance. These efforts focus primarily on border areas and migratory flows originating from regions where malaria remains endemic [5,9].

An early detection and rapid response system was established, underpinned by the mandatory notification of suspected cases [6,15]. The importance of this system was reinforced following outbreaks, such as the one in Pirá Verá (2007), which highlighted specific vulnerabilities and the constant threat of reintroduction in border regions [12]. Additionally, an active monitoring program was implemented in historically endemic regions, such as Canindeyú and Alto Paraná, aiming for the prompt identification of any imported case that could trigger local transmission [7,16].

Malaria elimination in the country was sustained by a set of key measures, with an emphasis on vector control and prevention. These strategies included the distribution of Insecticide-Treated Nets (ITNs), Indoor Residual Spraying (IRS) in high-risk areas and the systematic identification and elimination of breeding sites for *Anopheles darlingi*, the primary malaria vector in the region [8,11,18].

Regarding diagnosis and treatment, Paraguay guaranteed universal access to Rapid Diagnostic Tests (RDTs) and microscopy, ensuring that treatment with Artemisinin-based Combination Therapies (ACTs) was initiated within 24 hours of case detection [1,8]. To support this approach, the country invested in continuous training for healthcare professionals in standardized protocols, which was fundamental to ensuring an effective and timely clinical response [17].

Community engagement and health education were strategic pillars for the success of malaria elimination in Paraguay. Awareness campaigns targeted at populations at risk were implemented, with a special focus on indigenous communities and rural areas [12]. Simultaneously, collaboration with local leaders was fostered to ensure early reporting of suspected cases, a measure that decisively strengthened community-based surveillance and rapid response capacity [6].

To ensure the sustainability of these achievements, international cooperation proved to be an indispensable component. The country formally aligned itself with the PAHO malaria elimination action plan 2021-2025 and



benefits from continuous technical and financial support, which has been fundamental to maintaining its malaria-free certification [2,5,10].

Beyond attesting to the success of the elimination process, the data consolidated in **Table 2** can assist in the strategic orientation of future surveillance actions and

guide the allocation of resources for the management of residual risk, particularly where it appears most significant and imminent. Maintaining the status of a country free of autochthonous malaria is intrinsically linked to a detailed understanding of the current epidemiological landscape.

Table 2: Epidemiological map of malaria in Paraguay (2000-2024).

Aspect	Data (2000-2024)	Source
Date of the last reported autochthonous malaria case in Paraguay and its certification	Last case in 2011	[1-3]
	Certified malaria-free by the WHO in 2018	
Number of reported imported cases	2000-2011 ^a : Scattered and non-comparable records	[4-6,16]
	2012-2023: 72 cases (average of 6-7/year) with an 80% reduction.	
Geographic origins of imported malaria cases in Paraguay	Africa (82%): Mostly Equatorial Guinea; Angola, Republic of the Congo, Mozambique, Central Africa, Ivory Coast, Cameroon, Benin	[4,5,11,16]
	Americas (17%): Primarily the Brazilian Amazon, Venezuela and Peru	
	Asia (1%): Indonesia	
Epidemiological profile of the patients	Sex: 83% Male	[4,16]
	Age: 85% between 20 and 49 years old	
	Occupations: 36% construction, 22% administrative, 10% teacher/student, 7% military, 7% office, 4% agricultural activities, 4% commerce, 3% religious, 7% others	
Main recorded symptoms	Fever, headache, myalgia, arthralgia, retro-orbital pain, sweating, abdominal pain, pallor, hepatomegaly, vomiting	[16,24]
Proportion of reinfection among imported cases	77% had a previous history of infection; 23% were primary infections	[16]
Nationality of imported cases	74% Paraguayan; 15% foreigners; 11% unspecified	[16]
Contribution of <i>Plasmodium</i> species to malaria	<i>Plasmodium falciparum</i> : 61%; <i>Plasmodium vivax</i> : 33%; <i>Plasmodium ovale</i> : 6%	[4,7,16]
Main departments affected by imported malaria	Central: 28%; Asunción: 15%; Misiones: 15%; Canindeyú: 13%; Cordillera: 7%; Caaguazú: 13%; Caazapá: 4%; Alto Paraná: 4%; Others: 6%	[16]
Hospitalizations and Case Fatality Rates for Malaria in Paraguay	47% hospitalization rate; 7% case fatality rate	[4,5,16]
Primary vector and occurrence sites	<i>Anopheles darlingi</i> present in 60% of cases; 4 molecular confirmations. Occurrence in: Caaguazú, Alto Paraná and Canindeyú	[4,8,16]
Distribution of malaria vectors in Paraguayan departments according to <i>Plasmodium</i> species	<i>P. falciparum</i> : Presidente Hayes, Asunción, Central, Cordillera, Paraguari, Caazapá, Misiones, Itapúa, San Pedro and Canindeyú <i>P. ovale</i> : Central, Asunción and Misiones <i>P. vivax</i> : Misiones, Central, Asunción, Cordillera, Caazapá, Alto Paraná, Canindeyú, Amambay, Concepción. Prior to the elimination of autochthonous cases, this was the predominant parasite among indigenous tribes	[16,22]
Paraguayan departments with no recorded malaria vectors	Boquerón, Ñeembucú and Alto Paraguay	[16]
Relevant pre-2011 events	2007: Localized outbreaks, such as in Pirá Verá and in indigenous communities located in Santa Teresa (Caaguazú), primarily among the Mbyá Guaraní ethnic group	[9,10,15, 22]
Relevant post-2011 events	2013-2015: PCR and microscopy studies of blood samples from residents of historically endemic areas (Alto Paraná, Canindeyú and Caaguazú) demonstrated the absence of <i>Plasmodium</i> spp. 2014: PCR and microscopy studies confirmed that the indigenous tribes of Santa Teresa were no longer contaminated 2016-2017: PCR and microscopy studies in <i>Anopheles</i> spp. vectors demonstrated the absence of <i>Plasmodium</i> spp.	[22,23]
Malaria vector species collected across Paraguay	<i>Anopheles albitarsis</i> , <i>Anopheles evansae</i> , <i>Anopheles fluminensis</i> , <i>Anopheles galvaoi</i> , <i>Anopheles noroestensis</i> , <i>Anopheles nuneztovari</i> , <i>Anopheles oswaldoi</i> , <i>Nyssorhynchela parvus</i> , <i>Anopheles rondoni</i> , <i>Anopheles shannoni</i> , <i>Anopheles strodei</i> , <i>Anopheles triannulatus</i> , <i>Albitarsis complex</i> , <i>Nyssorhynchela lutzi</i>	[23]



Note: The absence of data prior to 2011 in centralized records is due to the fact that malaria epidemiological surveillance in Paraguay before that date had limitations in geographical coverage, diagnostic standardization and information digitalization, which hinders comparison with subsequent data [4,9,11]. Records prior to 2011 originate from printed reports and timely outbreak reports, without a continuous notification system with laboratory parasitological confirmation [9-11]. Extending the period to 2000–2024 allows the analysis to align with regional PAHO/WHO frameworks for malaria elimination, but data prior to 2011 should be interpreted with caution due to these methodological differences [1,2,6].

Conclusions

Paraguay's trajectory in eliminating malaria between 2000 and 2024 represents a significant milestone in global public health, demonstrating the feasibility of disease eradication even in historically endemic regions. The results of this study corroborate that Paraguayan success was driven by a strategic combination of comprehensive vector control, robust and adaptive epidemiological surveillance, timely diagnosis and treatment and sustained financial commitment.

The drastic reduction in autochthonous cases, culminating in the last record in 2011 and subsequent WHO certification in 2018, highlights the effectiveness of the interventions. The analysis of the Annual Parasite Incidence (API) and its comparison with the regional average for the Americas reinforce Paraguay's leadership position in malaria control. The apparent paradox of the initial increase in imported cases, followed by a consistent decline, served as a crucial indicator of the surveillance system's growing sensitivity, capable of detecting infections acquired abroad and preventing the reintroduction of the parasite.

However, the Paraguayan experience also underscores the dilemma inherent in the post-elimination phase: the need to balance operational efficiency with the maintenance of sensitive epidemiological surveillance. The drop in the Annual Blood Examination Rate (ABER) highlights the importance of complementary strategies, such as active case detection of asymptomatic individuals, to ensure that the absence of local transmission is continuously validated, even in micro-areas of residual risk. This study demonstrates that the sustained interruption of transmission was confirmed through field investigations, requiring ongoing constancy.

In summary, Paraguay's experience offers a replicable model for other nations aiming for malaria elimination. The determining factors for this success include continuous investment in prevention and control programs, the ability to adapt surveillance strategies to new epidemiological realities and the integration of multisectoral actions. Maintaining the status of a malaria-free country will depend on the continuous surveillance of imported cases and the capacity for rapid response to any sign of reintroduction, solidifying the legacy of a successful and lasting effort.

Authors' Contributions

The authors declare no conflict of interest.

PSSS: Contributed to the study's conceptualization original project design, data collection and organization, preparation of tables and figures, literature review, critical analysis of preliminary versions, results analysis and manuscript drafting. **ALRGL** Contributed to data collection and organization, preparation of tables, literature review, critical analysis of preliminary versions, results analysis and manuscript drafting.

LKMC: Contributed to the literature review, results analysis and manuscript drafting.

LCR: Contributed to the literature review, critical analysis of preliminary versions, results analysis and manuscript drafting.

FAMO: Contributed to the critical analysis of preliminary versions, results analysis and manuscript drafting.

All authors contributed to and approved the final version of the manuscript.

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