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Research Article

Dynamics in Malaria Transmission in the Cross-Border Areas of Mozambique, South Africa and Eswatini (Mosaswa), from March 2017 to March 2019

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Abstract

Introduction: malaria is considered a public health threat for the humankind worldwide, estimations indicate that more than 1/3 of the population is in equal risk of acquiring it. Shared borders between countries with different malaria prevalence and preventive strategies delays elimination goals. Aim: to analyze malaria transmission dynamics in the cross border areas of Mozambique, South Africa and ESwatini from March 2017 to March 2019. Methodology: a secondary malaria database was used. Ratio comparison tests and logistic regression model estimation were done. The sample consisted of 250563 migrants and residents in MOSASWA cross-border areas tested for malaria, between March 2017 to March 2019. Data were analyzed using SPSS 22.0. Results: 250563 people were tested, out of which, 93035 (37.13%) were migrant populations and 157528 (62.87%) were residents of the surrounding areas. Regarding gender and occupation, 50.1% were male and 76% had informal occupation. The positivity rate was 2.1% (5253), out of which, 33.3% (1751) were mobile and migrant populations, 45.9% of the total cases were asymptomatic carriers. 39.18% (686) and 28.44% (498) of the positive migrants were using the Macuacua and Ressano Garcia borders on their way to South Africa respectively. 66.7% of the positives cases were surrounding populations, out of which 20.5% and 20.6% crossed the borders three to four times a week. The predictive power of having malaria increased 5.090 and 3.540 times more if the migrant had been tested in Mozambique and if he/she was a resident in the neighbouring borders, crossing into the borders of the same country respectively. Conclusions: A large number of the moving cases were diagnosed in Mozambique on their way to South Africa through Macuacua border.

Keywords

Malaria Elimination, Cross-Border Malaria Transmission, MOSASWA Malaria Initiative

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1. Introduction

Mentioned for the first time by Chinese doctors 2700 Before Christ (BC), attributing its symptoms to supernatural forces. A theory later, rejected by Hippocrates. It was Laveran, who first observed parasites in the blood of patients with malaria in 1907, demystifying all demoniac theories [1]. Malaria is considered one of the main public health problems for mankind, where 1/3 of the world's population is at risk of contracting it, it has been affecting humanity for over 5000 years, with West and Central Africa cited as the birthplace of the Plasmodium falciparum and Plasmodium vivax etiological agents respectively [2].

Efforts to control the Anopheles gambiae vector date back to the early 20th century, however it was during the First World War, that the first synthetic antimalarials were developed [3]. However, it was from 1955 onwards that the World Health Organization (WHO) launched the World Malaria Eradication Campaign with the aim of extinguishing the disease, which saw a decrease in the disease by the end of the 1970s and freed around 53% of the population in endemic areas from the risk of malaria [4].

Though, the campaign had freed about 53% of the population from Malaria, a deterioration of malaria control programme in poor countries, lead to an increase in malaria, the rising cost of insecticides and anopheles resistance [4]. For this reason, a global reorientation of the malaria eradication programme was undertaken in Amsterdam, Holland in 1992 by the health ministers of all countries, with a special focus on Africa [5].

Despite so many historical advances aimed at controlling and combating the spread of malaria, the disease is still endemic in many countries. In 2016, around 216 million cases were reported in 91 countries, with an increase of 5 million cases compared to 2015, causing 445,000 deaths and 90% of them occurring in Africa, with 80% of all deaths attributed to fifteen countries in sub-Saharan Africa [6]. The incidence of malaria cases and deaths reported in 2016, questions the achievement of the intermediate objectives, which include: global reductions in the malaria burden by at least 40% compared to 2015 levels by 2020 and 75% by 2025, and elimination in at least 10 to 20 countries by 2020 and 2025, respectively [7].

Thus, to accelerate the 2020 targets (malaria elimination), Southern African Development Community (SADC) member states with shared borders, namely: Mozambique, South Africa and Eswatini, (MOSASWA), have been collaborating to eliminate malaria, as they recognise that the dynamics of malaria transmission between their countries are intrinsically linked to the population and ecological movement of malaria [6, 8].

Prior to MOSASWA malaria elimination initiative, South Africa, had pledged to a goal of malaria elimination, with zero local transmission by 2018, however, recognizing the risk posed by Mozambique as one of the neighboring countries with high malaria prevalence, appealed a focused intervention on the mobility patterns of humans, particularly where the majority of infections are imported from [20]. A substantial growing movement of people across borders poses obstacles to elimination, creating a constant potential for malaria importation [10, 11].

The incidence rates recorded in 2014 of the three countries, were: 2.64 cases per 1000 population at risk in South Africa, 2.34 in Eswatini and 219 in Mozambique. The difference in incidence rates, places Eswatini and South Africa on the right track for elimination, however, if malaria interventions are not optimized at their borders with Mozambique, to contain the transmission, a new transmission pattern and incidence will occur in these countries [8].

The MOSASWA collaboration aligns with the World Health Organisation's Global Technical Strategy (GTS) 2016-2030 and the Malaria Action and Investment Strategy (MIA) 2016-2020, which advocates cross-border collaboration to achieve successful control of malaria elimination [9].

From this perspective and in view of the data from the MOSASWA cross-border region, there is a need to analyse the dynamics of malaria transmission in the cross-border areas of Mozambique, South Africa and ESwatini in the last two years of the ‘elimination 8’ initiative, which is why this research was carried out with the main aim of analysing the dynamics of malaria transmission in the cross-border areas of Mozambique, South Africa and ESwatini from March 2017 to March 2019.

2. Material and Methods

This is a retrospective cross-sectional study covering the period from March 2017 to March 2019, with a quantitative approach that analyses the dynamics of malaria transmission in the cross-border areas of Mozambique, South Africa and Eswatini using regional data from the (E8) malaria elimination programme in SADC.

The study was carried out using an excel malaria secondary database, hosted by the ministry of health of Mozambique. It contains the following variables: Name of border crossed, sex, age, country of departure, country of destination, province of departure, province of destination, district of departure, district of destination, presence of symptoms at the time of testing (yes or no), occupation (formal/informal), test result and type of post where testing took place (Border or Neighbouring Community) with the aim of monitoring regional cross-border results.

To have access of the database, these steps were followed:

a) A letter of request for permission to access and use the database was submitted to the Ministry of Health of Mozambique.
b) Cleaning and exportation of the data from the excel data base to SPSS software version:
c) The total number of people tested was 250563, which was then considered as the sample size of the study.
d) The total positives cases in the database was 5253, out of the total. All analysis were done using only the positive

cases.

e) The cross-border areas used were: Ressano Garcia, Macuacua, Goba and Ponta de Ouro, located in the province of Maputo, in the districts of Moamba, Namaacha and Matutuine respectively.

f) The statistical analyses in this study were carried out using a significance level of $p \leq 0.05$.

g) Binomial test was used for the variables type of symptoms (symptomatic and asymptomatic) and gender to analyse the proportions of diagnosed cases. The Chi-Square test was applied to check the association between the proportions of positive cases at each post. Logistic regression was applied to estimate the probability of an individual tested positive for malaria. A significance test was also carried out on the coefficients of the logistic regression model as a whole, in order to ascertain the degree of significance of each coefficient in the logistic equation, including the constant.

3. Results

The total number of individuals tested (analysed) in the three countries (Mozambique, South Africa and ESwatini) was 250,563, comprising migrants and people living in the surrounding the borders regions of Ressano Garcia, Macuacua, Goba and Ponta de Ouro. The testing by country was: 193,586 people in Mozambique, 6,145 and 50,832 in Africa in the kingdom of ESwatini respectively. Breakingdown by sex, there were tested 125,647 (50.1%) male and 124,916 (49.9%) female. In regard to occupation, 190,571 (76%) had informal occupation and 59,992 (24%) were formal workers. In relation to education, 46,852 (18.7%) were illiterate, 107,311 (42.8%) had primary school, 57,458 (22.9%) had secondary school and 38,942 (15.5%) had higher education school. In terms of testing by age groups, per country, 91.5% of the people tested were aged 5 or more (age ≥ 5 years.

3.1. Testing Trend by Month

The Figure 1 below highlights the tendency of people tested by year and month. For year one (2017), the peak in testing occurred in the months of September (14,927) and October (22,480). For year two (2018), testing peaked in January (16,601), March (14,115) and April (14,217). For 2019, there was a substantial rise in the number of people tested from January to March, followed by a rapid decrease in the number of people tested in subsequent months.

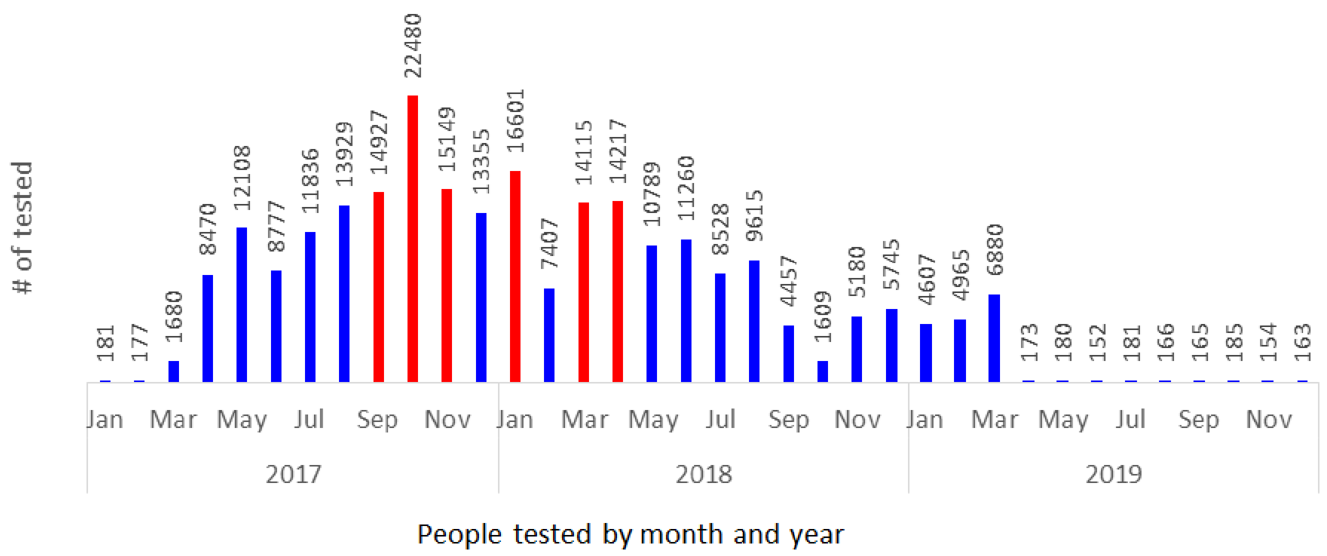

Figure 1. *Testing trends by month.*

3.2. Malaria - Related Characteristics

Out of the total (250563) people tested, 5,253 (2.1%) tested positive for malaria. There were more positive male 3,228 (61.5%) than female 2,025 (38.5%). More positive cases were 93.07%) diagnosed in Mozambique, followed by the kingdom of Eswatini with 4.84% and South Africa with 2.09%. details on the Table 1.

Table 1. *Absolute values and percentages of individuals who tested positive for malaria.*

		Country		
	N	**Mozambique**	**South Africa**	**ESwatini**
Tested	250563	193586	6145	50832
Positive	5253	4889	110	254
% Positive	2.09	30.5	1.8	0.5
% compared to the positive	100	93.07	2.09	4.84

Table 2 shows the proportions of individuals who tested positive for malaria in the three countries according to demographic situation: Migrant population or neighbouring Community. 3502 (66.67%) of the positive cases were neighbouring communities and 1751 (33.33%) were people in transit (migrant populations). Mozambique registered the most cases in transit 1613 (30.71%), and South Africa had the lowest number of cases in transit 30 (0.57%).

Table 2. *Number of migrants tested versus populations around the borders.*

Demograph Situation	**Country of Origin Tested**	**Result**			
		Positive	**N**	**p-value**	**X^2**
Migrants	Mozambique	1613 (30.71%)	65332 (26.07%)		
	South Africa	30 (0.57%)	2.552 (1.02%)	0.000	416.149[b]
	ESwatini	108 (2.06%)	25.151 (10.04%)		
	Total	1751 (33.33%)	93035 (37.13%)		
Neighbouring Community	Mozambique	3276 (62.36%)	128.254 (51.19%)		
	South Africa	80 (1.52%)	3.593 (1.43%)	0.000	388.167[c]
	ESwatini	146 (2.78%)	25.681 (10.25%)		
	Total	3502 (66.67%)	157528 (62.87%)		
Totals	Mozambique	4.889 (93.07%)	193.586 (77.26%)		
	South Africa	110 (2.09%)	6.145 (2.45%)	0.000	807.862[a]
	ESwatini	254 (4.84%)	50.832 (20.29%)		
	Total	5253 (100%)	250563 (100%)		

Table 3 shows the proportions of people in transit in relation to the country of departure and the country of destination. The total number of migrants (in transit) diagnosed with malaria in the three countries was 1751 (100%), out of which, 1613 (92%) cases were found at the Mozambican borders, 1511 (86.28%) of the cases found in Mozambique were in transit to South Africa as their destination country, and 102 (5.83%) for Eswatini.

On the other hand, 108 (6.17%) of the migrants diagnosed with malaria were found in the kingdom of Eswatini. 26 (1.48%) were in transit tor South Africa and 82 (4.68%) were in transit to Mozambique. Overall, of the total cases in transit (1,751), the majority of them 1,537 (87.78%) were going to South Africa.

Table 3. *Country of departure and destination.*

Destination country					
		Mozambique	**South Africa**	**ESwatini**	**Total**
Departure Country	Mozambique	NA	1,511 (86.29%)	102 (5.83%)	1,613 (92%)
	South Africa	23 (1.31%)	NA	7 (0.4%)	30 (1.71%)
	ESwatini	82 (4.68%)	26 (1.48%)	NA	108 (6.17%)
Total		105 (6.00%)	1,537 (87.78%)	109 (6.23%)	1751 (100%)
	Chi-square Test	$X^2 = 1330.815^a$; p-value = 0.000			

Table 4 shows the proportions of people diagnosed with malaria in transit through the borders of the three countries. Four borders were used by mobile and migrant populations, namely: Goba, Macuacua, Ponta de Ouro and Ressano Garcia. 1,613 (92%) of the cases in transit, diagnosed in Mozambique, 686 (39.18%) of them were in transit to South Africa through Macuacua border, 498 (28.44%) were using Ressano Garcia border and 330 (18,8%) were using the Ponta de Ouro border to travel to the same destination. The results show that the most used borders of the four was Macuacua one, which illegal border.

Table 4. *Movement of cases between countries versus borders used.*

Departure country					
		Mozambique	**South Africa**	**ESwatini**	**Total**
Borders	Goba	99 (5.65%)	NA	35 (2.00%)	134 (7.65%)
	Macuacua	686 (39.18%)	0 (0%)	NA	686 (39.20%)
	Ponta D'Ouro	330 (18.80%)	0 (0%)	NA	330 (18.85%)
	Ressano Garcia	498 (28.44%)	30 (1.71%)	73 (4.20%)	601 (34.30%)
Total		1,613 (92.10%)	30 (1.70%)	108 (6.20%)	1,751 (100%)
	Chi-square Test	$X^2 = 258.658^a$; p-value = 0.000			

3.3. Diagnosed with Malaria Versus Malaria Symptoms

Out of the total positive cases 5253 (100%) diagnosed with malaria, 2,844 (54.1%) of them, were symptomatic cases, while the remaining 2,409 (45.9%) were asymptomatic carriers.

Figure 2 shows the evolution of cases by month over the study period. In 2017, there were peaks in May (217), August (209) and October (254). In 2018, there were peaks in January (644), May (359) and August (437) and in 2019 there was an upward trend in cases from January to March.

Table 5, shows a comparative analysis of positive cases diagnosed in the neighbouring areas versus migrant populations. More cases were diagnosed in the neighbouring regions in all countries: Mozambique 3,276 (67.0%), South Africa 80 (72.7%) and Eswatini 146 (57.5%). Although Eswatini is the smallest of the three countries, there is a uniform pattern in terms of the potential for malaria transmission to neighbouring countries. And the differences observed are statistically significant at the 5% significance level. These results call into question the theory that Mozambique is the sole transmitter of malaria among the three countries.

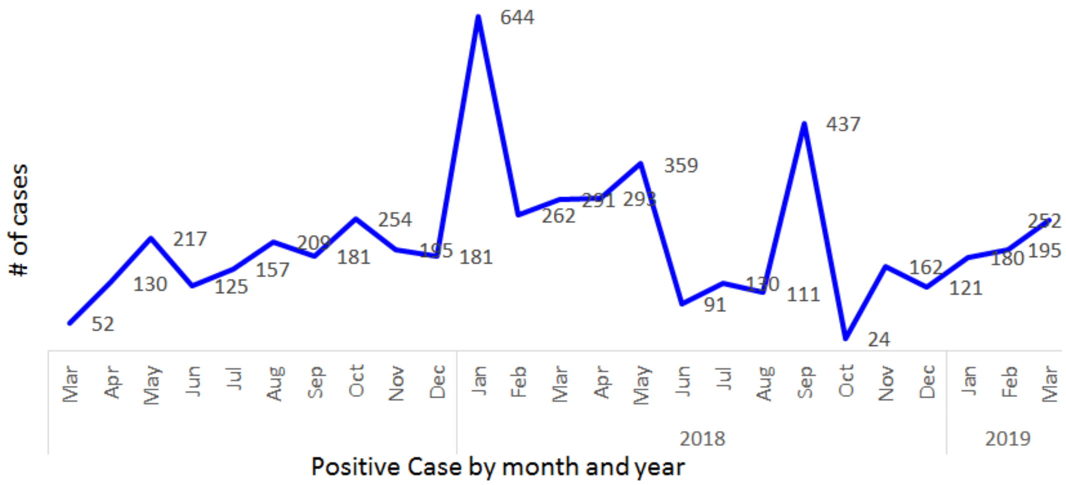

Figure 2. *Monthly evolution in cases over the three years.*

Table 5. *Comparing neighbouring moving cases.*

Testing Country	Positive Case confirmed		Total
	Migrants	**Neibghbour Community**	
Mozambique	1,613 (33.0%)	3,276 (67.0%)	4889 (100.0%)
South Africa	30 (27.3%)	80 (72.7%)	110 (100.0%)
ESwatini	108 (42.5%)	146 (57.5%)	254 (100.0%)
Total	1,751 (33.3%)	3,502 (66.7%)	5253 (100.0%)
Chi-square Test	$X^2 = 11.720$; p-value = 0.003		

Table 6 shows the probability of a person being positive, considering their country of testing, compared to other countries. It shows also the probability of a person tested turning positive, given that they are: neighbouring communities or migrants and including sex.

a) The probability of a person tested for malaria in the Mozambican borders becoming positive is 5.090 higher (95%, CI 4,485-5,778, p=0.000), if compared to other country borders.
b) The probability of a person tested for malaria in the borders of South Africa is 3,780 higher (95%, CI, 3,780-4,736, p=0.000), if compared to those tested within borders of Eswatini.
c) The probability of a person tested for malaria within the borders of Eswatini 3,670 lower (95%, CI 0,883-0,993, p=0.000), if compared to those tested within other borders.
d) The probability of a person tested for malaria, turning positive, given that they are border neighbouring communities residents is 3,540 higher (95%, CI 3,230-3,989, p=0.000).

Table 6. *Chance of being positive in relation to the border crossed, country, gender.*

					95% C.I for Exp (Chances)	
	Coefi	**Df**	**Odd ratios (OR)**	**P-value**	**Lower**	**Upper**
Tested in Mozambique	1.627	1	5.090	0.000	4.485	5.778
Tested in South Africa	1.330	1	3.780	0.000	3.780	4.736

	Coefi	Df	Odd ratios (OR)	P-value	95% C.I for Exp (Chances)	
					Lower	Upper
Tested in ESwatini	1.230	1	3.670	0.000	0.883	0.993
Community						
Neighbouring	1.211	1	3.540	0.000	3.230	3.989
Migrants	0.066	1	0.936	0.027	0.883	0.993
Gender	0.470	1	1.600	0.000	1.543	1.656
Const	0.522	1	1	0.004		

4. Discussion

For the author's recognition, no studies of this nature were found in the areas studied that sought to analyse the dynamics of malaria transmission in the cross-border areas of Mozambique, South Africa and Eswatini.

The results of the study reveal that 76% of the migrants tested at the borders and in the surrounding regions had an informal occupation, 42.8% had primary education and 50.1% of them were male, whose ages were mostly above 5 years. These results are consistent with the study by [11] conducted in Iran, which showed that 18.6% and 43.3% of migrants from Afghanistan and Pakistan to Iran tested for malaria had informal occupations (hairdresser) and primary education respectively, and 98.6% of them were male, whose ages ranged from 31-40 years. Similar patterns were observed in the studies by [12] and [13], where more than 70% of the migrants were male, with an average age of 37. And more than 50% of the participants declared an informal profession (miners). This pattern of male tendencies may be associated with the search for jobs in the mines. Regarding the dynamics of the cases between the three countries, the study showed that 92% of the positive cases in transit were diagnosed in Mozambique, with 86.28% of them going to South Africa and 5.83% to Eswatini. These findings were corroborated by [14] in the study High genetic diversity of Plasmodium falciparum in low transmission sites of the Kingdom of Eswatini, indicating that most of the imported cases diagnosed in Eswatini that had a travel history, 93% had reported travelling to Mozambique. The same patterns of malaria transmission in this area were reported by [15] in the kingdom of Eswatini as an important factor in the resurgence of malaria through the migration of labourers to the cane fields of Eswatini from Mozambique in the 60s and 70s. Similarly, the findings of the study by [16] suggested in the 1990s that malaria elimination in South Africa in the priority areas would be hampered by the fact that the country borders Mozambique, which is extremely endemic for malaria, requiring joint efforts. [17], pointed to the substantial and increasing movement of people across borders as obstacles to achieving elimination, creating a constant potential for malaria importation and drug resistance.

From 2017 to 2019, the study showed that the Macuacua border was the most used of the four analysed in this period, with around 39.18% of the cases passing through it. This finding is new in this type of study in the region. In the authors' opinion, the people who pass through these illegal points the most may often come from places where malaria prevention may be deficient. However, the use of illegal borders was discussed by the [18] at the meeting of the advisory committee on malaria policy, where it was concluded that the population often favoured unofficial crossing points because they were local residents, and their movements were short-term, cyclical and anchored by ethnic, family and cultural ties between cross-border peoples.

The dynamics of cases across borders indicated that 45.9% of cases were asymptomatic reservoirs, although this finding was not the subject of the study, it raises an additional concern regarding elimination due to the constant risk of perpetuating infections. This finding corroborates the retrospective study by [19] which revealed that asymptomatic malaria contributed around 20-50% of future infections, posing greater challenges for malaria elimination. In The Gambia, [20], pointed to asymptomatic cases as a disruptive factor to elimination as asymptomatic reservoirs were not adherent to malaria treatment due to the absence of symptoms.

In relation to malaria in cross-border regions, the study revealed that there were more positive cases in these surrounding areas compared to migrants from distant areas, this finding is consistent with the study by [21], which revealed that the prevalence of malaria was higher in cross-border areas than in other areas, due to less access to health services, difficulties in implementing prevention programmes in communities, difficult-to-access terrain and the constant movement of people across porous national borders.

Despite the consistency of this result with [21], there is a paradox with the areas studied, as they have health centres close to their populations.

In addition, the study revealed that individuals living around the borders caught with malaria crossed the borders around three to four times, a fact revealed in the study by [21], where they pointed out the following as possible reasons for multiple crossings: migration for work opportunities, visits to friends and family, tourism, business trips or cross-border trade, social relationships, cultural exchanges.

With regard to the epidemiological graph, research has revealed peaks in malaria cases crossing MOSASWA borders in the months of May and October, patterns corroborated by [21] in his research, where he reported that most malaria transmission occurred during the summer rainy season between October and May. The evolution of cases suggests that more attention should be paid to mass protection of populations in January, May and August.

Regarding the chance of an individual being positive for malaria, the study revealed that the predictive factor for malaria increases by around 5,090 and 3,540 times more if the person tested on the move comes from Mozambique and/or is a resident of the regions surrounding the borders respectively. This fact was not verified in the studies consulted, perhaps because they used a different methodology and logistic regression was not the focus of the studies consulted.

It was found that adding at least one of the variables not included in the model only with the constant improves its predictive or estimation power, indicating the importance of including these variables in the model to estimate the chances or probabilities of a person having malaria.

5. Conclusion

In this study, the theory indicating that elimination of malaria in South Africa and Eswatini is impossible because of Mozambique, which is their bordering country with the highest (among the three) movement of people carrying malaria to South Africa and Eswatini was demonstrated.

A need to deploy malaria strategies/ interventions, such as: vector control, Testing and treatment of cases and indoor spraying, for the local border surrounding communities is key to malaria elimination, because, the local surrounding residents were found with higher malaria prevalence, if compared to migrants.

For the purpose of cross-border malaria elimination, countries must create a single masterplan for malaria containment at their borders. Challenges of malaria country program, should be jointly addressed.

Abbreviations

BC	Before Christ
GTS	Global Technical Strategy
MIA	Malaria Action and Investment Strategy
MOSASWA	Mozambique, South Africa and Eswatini
SADC	Southern African Development Countries
WHO	World Health Organization

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Author Contributions

Nelson Raul Uate: Conceptualization, Methodology, Validation, Writing - Original Draft Preparation, Writing - Review & Editing

Nivaldo António Tomo Chirindza: Methodology, Validation, Writing - Review & Editing

Acácio Mugunhe: Methodology, Validation

Atanásio Serafim Vidane: Methodology, Validation

Gerito Augusto: Conceptualization, Methodology, Validation, Writing - Review & Editing, Supervision

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Data Availability Statement

Data are available upon request from the corresponding author or in the Ministry of Health of Mozambique.

Conflicts of Interest

The authors declare no conflicts of interest.

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