

Field Performance of Mass PCR Screening and Targeted Treatment in an Amazonian Low Malaria Transmission Setting

Emilie Mosnier (✉ emilie.mosnier@gmail.com)

Centre Hospitalier Andrée Rosemon

Yassamine Lazrek

Centre National de Référence du Paludisme, Institut Pasteur de la Guyane

Aurel Carbunar

Centre Hospitalier Andrée Rosemon

Rodolphe Priam

Centre d'Investigation Clinique Antilles Guyane – Inserm 1424

Jordi Landier

Aix Marseille Univ, APHM, INSERM, IRD, SESSTIM, Hop Timone, BioSTIC, Biostatistic & ICT

Mélanie Gaillet

Centre Hospitalier Andrée Rosemon

Céline Michaud

Centre Hospitalier Andrée Rosemon

Luana Mathieu

Centre National de Référence du Paludisme, Institut Pasteur de la Guyane

Emmanuel Roux

ESPACE-DEV (IRD, Univ. de Montpellier, Univ. de La Réunion, Univ. de la Guyane, Univ. des Antilles),
Institut de Recherche pour le Développement (IRD)

Stéphane Pelleau

Centre National de Référence du Paludisme, Institut Pasteur de la Guyane

Jean Gaudart

Aix Marseille Univ, APHM, INSERM, IRD, SESSTIM, Hop Timone, BioSTIC, Biostatistic & ICT

Mathieu Nacher

Centre d'Investigation Clinique Antilles Guyane – Inserm 1424

Magalie Demar

Centre Hospitalier Andrée Rosemon

Loïc Epelboin

Centre Hospitalier Andrée Rosemon

Maylis Douine

Centre d'Investigation Clinique Antilles Guyane – Inserm 1424

Félix Djossou

Centre Hospitalier Andrée Rosemon

Lise Musset

Centre National de Référence du Paludisme, Institut Pasteur de la Guyane

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Abstract

The three main obstacles to the elimination of malaria in French Guiana are asymptomatic carriers of *Plasmodium vivax*, relapses and, to a lesser extent, *Plasmodium falciparum*. This study aims to assess the impact of PCR-based mass screening and treatment (MSAT) interventions in this malaria-endemic area.

Two MSAT interventions were conducted twelve months apart in inhabitants of Saint Georges de l'Oyapock village, which has the highest malaria burden in French Guiana. Symptomatic malaria incidence was also passively monitored through the local health center from 12 months before the first intervention until the end of the second intervention.

At the time of the first intervention, malaria prevalence was 6.7% [CI₉₅ 5.4-7.9%], including 90% of *Plasmodium vivax* cases and 10% *Plasmodium falciparum* (n=1,501 participants). Twelve months later, it had decreased by 53.7% to a value of 2.5% [CI₉₅ 2.0-3.9%] ($p < 0.05$; n=1,271 inhabitants), of which 83% and 17% of cases showed *Plasmodium vivax* and *Plasmodium falciparum* carriage, respectively. Similarly, the passive malaria detection carried out by the health center during the 12-month surveillance period that followed the first MSAT noted a decrease in symptomatic *Plasmodium spp.*

This study suggests that the implementation of mass PCR testing and the subsequent malaria treatment of positive cases could reduce the prevalence of both symptomatic and asymptomatic malaria infections in the Amazonian context.

Introduction

Global efforts to scale-up malaria control interventions are essential in the fight against this disease. Despite the deployment of means such as the test-treat-track strategy, Long-Lasting Insecticide Nets (LLIN) and Indoor Residual Spraying, malaria incidence around the world has increased since 2016, particularly in Amazonia¹. Although climatic, economic and political factors could partially explain this increase in transmission, a significant role is played by asymptomatic parasite carriers who generally fall outside the scope of control interventions.

French Guiana is a malaria-endemic French overseas territory in Amazonia, bordering Brazil. This area is committed to a regional program for malaria control². Over the last ten years, there has been a steady decline in *Plasmodium falciparum* (*P. falciparum*) transmission. However, the region now faces an increase in the proportion of *Plasmodium vivax* (*P. vivax*) infections³. *P. vivax* biology could explain this situation, namely through the occurrence of dormant liver stages (hypnozoites) in humans and the consequent relapses and early circulation of gametocytes in the blood during the infection. A radical primaquine treatment is required to clear hypnozoites, but this drug is associated with a risk of haemolysis in individuals with glucose-6 phosphate-dehydrogenase (G6PD) deficiency. The administration of primaquine to such patients could lead to severe side effects. G6PD testing in French

Guiana is therefore crucial but also difficult to obtain ⁴, meaning that primaquine treatment coverage is globally insufficient in French Guiana, and particularly in remote areas where malaria is endemic.

The use of mass drug administration (MDA) to eliminate malaria has been widely evaluated over recent years ^{5,6}. Although these campaigns generally reduce the initial risk of malaria carriage, few studies describe a sustained impact beyond six months post-treatment. MDAs also show more success in reducing the transmission of *P. falciparum* than in decreasing *P. vivax* infection ⁷. Mass-Screen-and-Treat (MSAT) approaches have also been evaluated, most of which were associated with rapid diagnostic testing (RDT) due to its ease of use in the field ⁸. MSAT had a limited impact in high transmission settings, but this may be explained by the low capacities of RDTs to detect asymptomatic carriers ⁹.

For this study, we hypothesized that MSAT could reduce *P. vivax* transmission and thus the prevalence of both symptomatic and asymptomatic parasitaemia in our low transmission setting in South America. The MSAT study was based on Polymerase Chain Reaction (PCR) testing and was implemented in two phases, twelve months apart.

Materials And Methods

This pre-post study, named “Palustop”, occurred in the Amazonian context of the Guiana Shield and involved two cross-sectional interventions occurring one year apart and a passive monitoring of all malaria cases in the village population by the local health centre. The first campaign was implemented from October to December 2017, and the second took place one year later from October to December 2018. The methodology, prevalence and spatial distribution of malaria cases characterized during this first MSAT campaign have already been reported ¹⁰.

Study Area

The Saint-Georges de l’Oyapock (STG) municipality is located beside the Oyapock River, the natural border with the Brazilian State of Amapá (Fig. 1). The neighbourhoods of STG were selected for this study due to their history of high incidence of malaria cases, as recorded by the regional surveillance system in 2015 and 2016.

In this part of Amazonia, the equatorial climate involves four annual seasons: a long rainy season from April to June, a dry season from July to December, a short rainy season from January to February and a short dry season in March. In this village, *Anopheles darlingi* is the predominant *Anopheles* species ¹¹. However, its density is heterogeneous and varies according to the proximity to dense forest ¹². This vector density increases following every dry season and is followed by an increase in malaria cases a few weeks later ^{11,13}. Two peaks in malaria cases are generally observed in this area, the first occurring in June and the second in November ¹⁴.

Population

STG village has ~ 4,033 inhabitants (STG health centre data 2017) of autochthonous origin such as Amerindians (mainly Palikur), French Guianese Creoles but also migrants originating mostly from neighbouring Brazil. The single health centre located in the area is the frontline provider of malaria diagnosis and treatment, and distributes LLINs to all pregnant women and positive malaria cases.

Sample size

The entire population size of the targeted neighbourhoods was ~ 2,727 inhabitants (67.7% of the total population), all ages and nationalities included. Based on previous data, and assuming an expected PCR-prevalence of 4%, an error-margin and an alpha risk of 0.05, the required sample size was estimated at 1,200¹⁵. Given the mobility and expected participation of the population in this area, we targeted a sample size of 1,500 participants for the first intervention, expecting that 1,200 of these individuals would be monitored one year later.

Outcomes

The primary outcome was a reduction in the *Plasmodium spp.* prevalence values determined by PCR in the second MSAT intervention compared to the first. The secondary outcomes were the incidence of clinical malaria episodes in participants and non-participants, an increase in the time before the first recurrence occurred, and the observation of severe adverse events over 30 days after initiation of the antimalarial drug treatment.

Community engagement

Community awareness interventions were conducted during the MSAT intervention to secure the commitment and participation of a majority of the inhabitants. Community engagement started in meetings with the community leaders such as the Amerindian community and the village mayor, as well as healthcare workers and the members of local associations. Stakeholders were sensitized to the study objectives, interventions and expected role of the community. Community engagement meetings were held in neighbourhoods in local languages with trained cultural mediators¹⁶. Health participants were informed about malaria and the rationale of mass testing to limit and prevent malaria infections. Positive malaria cases were treated and followed at home by a mobile team composed of an infectious diseases specialist, a nurse and a cultural mediator who informed patients on how to take their treatment sought to improve medication adherence and reported any side effects. Additional mobilization strategies included media campaigns and WhatsApp messages. At the end of the study, each neighbourhood received feedback about the results.

Biological analysis

Rapid Diagnostic Testing (RDT) for malaria was performed, and any participant with a positive result was immediately treated. The test used was the SD BIOLINE® Malaria Ag Pf/Pan test (pfHRP2/pLDH-based, Standard Diagnostics), commonly used in French Guiana. Malaria diagnosis was performed using a real-time PCR derived from Shokoples et al. and accredited according to the medical biology norm ISO NF EN 15189¹⁷. Detection and identification of the four major *Plasmodium* species (*P. falciparum*, *P. vivax*, *P.*

ovale and *P. malariae*) were performed using a Taqman probe strategy with a sensitivity of 1 parasite/ μ l of blood. Blood counts including reticulocyte were performed, and glucose-6-phosphate dehydrogenase (G6PD) activity testing was also carried out.

Interviews and medical care

During each MSAT phase, participants were interviewed by trained cultural community health workers in the language of participants (Creole, Palikur, Portuguese, French) and using a questionnaire¹⁰. The homes of participants were georeferenced. The temperature of each patient was measured. All participants had a medical examination. If RDT or PCR results were positive, participants were treated according to the regional treatment guidelines². *P. falciparum* infections were treated by artemether-lumefantrine and *P. vivax* by chloroquine for 3 days followed by 14 days of primaquine (0.5mg/kg) in the absence of medical contraindications (pregnancy, G6PD deficiency or breastfeeding an infant below the age of 6 months)¹⁸.

Passive follow-up of cohort

The health centre of STG is the only place where malaria diagnosis and treatment could be carried out in this municipality. Data from the health centre provided exhaustive records for medical consultations in this population. *P. vivax* relapse was defined as a patient with a medical history of malaria diagnosed within a period of 7 to 90 days of the last malaria diagnosis. A *P. vivax* malaria case was considered to be new if it was diagnosed more than 90 days after a previous malaria infection, as defined in a previous local epidemiological study¹⁹. This interval was considered adequate to distinguish between recurrences or relapse and a new infection.

Data analysis

Symptomatic cases were defined as individuals presenting with a positive RDT or PCR result and fever ($\geq 38^{\circ}\text{C}$) or a history of fever in the 48 hours preceding or including the diagnosis test. Conversely, *Plasmodium spp.* asymptomatic cases were defined as *Plasmodium*-PCR positive individuals presenting without fever or any history of fever in the last 48 hours.

Survival analysis was used to analyse the cumulative incidence of *Plasmodium spp.* infection over 12 months after the first MSAT intervention. The difference between the two survival curves was assessed at month 12 through a Kaplan-Meier estimate using log-rank test.

Ethical approval

The study was approved by the *Comité de Protection des Personnes du Sud-Ouest et Outre-Mer 4* N° AM-36/1/CPP15-024. The database of the Palustop prospective study was anonymized and declared to the French regulatory commission (Commission Nationale Informatique et Libertés, CNIL, n°917186). The passive follow-up database was anonymized and declared to the *Commission Nationale Informatique et*

Libertés (CNIL) (authorization N°2135463). Samples collected by the National Reference Centre were registered by the French Ministry for Research (declaration number DC-2010-1223; collection Nu2).

Results

Enumeration of study participants and MSAT coverage

More than half of the targeted inhabitants (1,566/2,727, 57.4%) were included in the study and participated in MSAT1. PCR screening involved 1,501 of these participants (Fig. 2).

Of the 1,566 initial participants, 1,276 (81.5%) were included in the second MSAT campaign (Fig. 2, Table 1). Overall, 1,232 individuals had PCR results for both campaigns. The study participants were mainly female (53.4%, n = 836) and 34.9% (n = 546) were children under 10 years. Thirty seven women were pregnant at the 1st MSAT intervention (n = 37/836). Households had an average occupancy of 6.5 persons [6.3–6.6] per house.

Before the MSAT intervention, around 33.7% of the population of STG had a medical history of malaria, mainly involving *P. vivax* (Table 1).

Table 1

History of malaria among MSAT participants and non-participants, Saint Georges de l'Oyapock, 2017.

	Non participants	MSAT Participants	Total
	n (%)	n (%)	n (%)
Cumulative number of individuals	2,467 (61.2%)	1,566 (38.8%)	4,033
1st MSAT with PCR results	-	1,501	
2nd MSAT, one year apart with PCR results	-	1,232	
History of malaria (2007–2017)	917 (37.2%)	442 (28.2%)	1,359 (33.7%)
<i>Plasmodium vivax</i>	675 (27.4%)	346(22.1%)	1,021 (25.3%)
<i>Plasmodium falciparum</i>	242 (9.8%)	96 (6.1%)	338 (8.4%)
Total individuals with history of malaria	1,550 (62.8%)	1,124 (71.8%)	2,674 (66.3%)
MSAT: mass screen and treat.			

MSAT efficiency

During the 1st MSAT campaign, the PCR positivity rate was 6.7% [5.4–7.9] (6.0% *P. vivax*, 0.7% *P. falciparum* with 73.0% of asymptomatic carriage), compared to 2.9% [2.0-3.9] (2.4% *P. vivax*, 0.5% *P.*

falciparum with 88.8% of asymptomatic carriage) during the 2nd campaign ($p < 0.005$) (Fig. 2). All participants with positive PCR tests received treatment during the two interventions if there was no contraindication. Any severe side-effect was reported. Of 90 *P. vivax* cases, five concerned pregnant women and seven concerned participants with a G6PD deficiency. These patients did not receive primaquine treatment ($n = 12$, 13.3%).

Participants carrying *P. vivax* at the 1st MSAT were more likely to have a *P. vivax* recurrence before and after the MSAT campaign ($p < 0.005$, Table 2).

Table 2

Monitoring of participants, carrying or free of *Plasmodium vivax*, in the year preceding the 1st MSAT campaign and the year following it.

	No <i>Plasmodium vivax</i> carriage n = 1,411	Carriers of <i>Plasmodium vivax</i> n = 90	p value
During the year preceding MSAT1			
Participants with ≥ 1 <i>vivax</i> infection	79 (5.6%)	25 (27.7%)	$p < 0.005$
Participants with ≥ 1 <i>vivax</i> relapse	15 (1.1%)	5 (5.6%)	$p < 0.005$
During the year following MSAT1			
Number of <i>vivax</i> infections	26 (1.8%)	13 (14.4%)	$p < 0.005$
Time before the 1st <i>vivax</i> infection (median in days)	193.5 [154.0-233.0]	68.2 [43.1–93.2]	$p < 0.005$
Number of participants with <i>vivax</i> relapses	14 (1.0%)	13 (14.4%)	$p < 0.005$
Time before the 1st <i>vivax</i> relapse (median in days)	37.3[33.7–42.0]	42.2 [31.2–53.2]	$p = 0.756$

MSAT efficacy to prevent new infection

A major seasonal malaria epidemic occurred during the first campaign¹⁴. To evaluate its impact on the results of this study, we compared malaria incidence between the two MSAT interventions through the passive monitoring of study participants and non-participants (supplementary Fig. 1). A significant decrease in malaria incidence was observed in the study participant group (95 to 43/1,566 person-years, $p < 0.005$) between the two MSAT campaigns but not in the non-participant group (38 to 59/2,467 person-years $p = 0.24$) (Fig. 3).

The passive monitoring of symptomatic cases in the municipality of STG recorded 235 malaria cases (212 *P. vivax*, 8 *P. falciparum* and 15 *Plasmodium spp.* cases) (Supplement file Fig. 1). Between October 2017 and December 2018, the variations of malaria incidences over time were similar among MSAT participants and non-MSAT participants living in the study area and even outside these neighbourhoods (Supplement file Fig. 1). However, variation was higher in the targeted neighbourhoods, as expected.

Analysis of Kaplan-Meier curves revealed also a significantly greater decrease in *P. vivax* infections in MSAT participants than in non-participants (log-rank $p < 0.05$) after the campaign (Figure 4). During the same period, there was no significant difference in the Kaplan-Meier survival curve of *P. vivax* relapse between participants and non-participants of the first MSAT intervention (log-rank $p = 0.99$) (supplementary fig 2).

Only four cases of *P. falciparum* infection were reported during the follow-up period, namely three MSAT participants and one non-participant.

During the 2018-study, 266 participants (20.8% $n = 1,277$) reported a history of fever during the last 12 months. Of these, only 117 (44.0%) sought a diagnostic test, with an average of 1.7 [1.4-2.0] tests by participant. A minority of these fevers (36 participants; 22 males and 14 females) were due to malaria, with 28 *P. vivax* infections, one *P. falciparum* and seven *Plasmodium spp.* More than half of the 36 participants reported a case of malaria infection within their household ($n = 22$, 61.1%), with an average of two cases per household [1.45-2.55]. The 8 falciparum-infected participants were treated with artemether-lumefantrine and the 28 *vivax*-infected participants with chloroquine. Among them, 26 received by primaquine because two individuals presented contraindication. Among the 26 patients treated with primaquine, 34.6% ($n = 9/26$) did not complete their treatment.

G6PD deficiency and contraindication

All *P. vivax* or *P. falciparum* carriers received treatment and were monitored. Following the WHO definition, 9.2% of the participants presented a severe G6PD deficiency ($n = 13/136$ below 30% of the normal G6PD activity²⁰, Table 3) and were treated with chloroquine alone. No severe side effects were reported.

No significant differences in the number of malaria infections were observed between MSAT participants with G6PD deficiency, meaning without primaquine treatment, and participants without G6PD deficiency in the number of malaria infection recorded between the two MSAT interventions (Table 3).

Table 3

Socio-demographic characteristics and results of malaria carriage, infection or relapse of participants with or without G6PD deficiency

	No G6PD deficiency n = 1,339	G6PD deficiency* n = 136	<i>p</i> value
G6PD activity < 30%	90.78 [89.3–92.3]	9.22 [7.7–10.7]	
Age	23.4 [22.4–24.4]	29.5 [26.0–32.9]	<i>p</i> < 0.005
Male	622 (46.5%)	64 (47.1%)	<i>p</i> = 0.893
Female	717 (53.5%)	72 (53.0%)	
History of vivax malaria before MSAT	130 (9.7%)	6 (4.4%)	<i>p</i> = 0.477
Number of vivax reinfections between MSAT1 and MSAT2 interventions	36 (2.7%)	3 (2.2%)	<i>p</i> = 0.738
Number of vivax relapses	23 (1.7%)	4 (2.2%)	<i>p</i> = 0.311
Number of PCR vivax carriages in 1st MSAT	83 (6.2%)	7 (5.0%)	<i>p</i> = 0.625
Number of PCR vivax carriages in 2nd MSAT	26 (1.9%)	4 (2.9%)	<i>p</i> = 0.431
* Severe deficiency (< 30%) according to the WHO threshold ²⁰ , MSAT: Mass screening and Treatment			

Discussion

This study provided evidence of a sustained decrease in the prevalence of *Plasmodium spp.* carriage over at least one year following an MSAT campaign. The MSAT also noticeably reduced the incidence of symptomatic *P. vivax* infections in participants for more than 12 months. Relapses, and to a lesser degree reinfections, are the most likely source of *P. vivax* infections, and are a source of ongoing transmission. In French Guiana, *P. vivax* infections generally relapse after a short interval (up to 90 days, and generally around 28 days) ¹⁹. Therefore, the MSAT campaign including a radical cure of chloroquine and 14 days of primaquine will block transmission by clearing *P. vivax* gametocytes and also hypnozoites. Nearly half of the *P. vivax* cases in the studied area were previously reported to be caused by latent hypnozoites in patients who had not benefited from primaquine as a radical cure ⁴. The obstacles to primaquine administration were mainly logistical (samples for G6PD testing were shipped by canoe and drugs delivery followed a complex pharmaceutical approval process) ^{4,10}. In addition, patients feel better after chloroquine treatment, and do not usually return to the health centre for G6PD testing and primaquine treatment. For these reasons, this MSAT campaign with dedicated teams including cultural health mediators increased primaquine delivery to 100% of *P. vivax* carriers who had no contraindication for its

use. This approach was rapid and suitable for local populations, including a personalized follow-up. Despite this, only 60.7% of the primaquine-treated cases reported adherence to the complete 14-day course. This is a long period of treatment and follow-up did not include a daily visit to supervise primaquine intake. This poor adherence could explain why relapses were observed in MSAT participants. Single-dose tafenoquine, which was successfully evaluated in neighbouring Brazil, could be a solution to increase medication adherence²¹. However, tafenoquine involves stronger side-effects in case of G6PD deficiency than for primaquine, and this treatment is not yet available in French Guiana.

Several Mass Drug Administration (MDAs) including mass primaquine administrations have been used to eliminate *P. vivax* throughout the world²². When MDA achieved high coverage and was associated with vector control measures, it was described as an effective means to decrease incidence²². However, data are scarce about its efficiency on asymptomatic carriage and therefore on the reservoir^{9,23}. MDA of primaquine showed a good tolerability, despite high levels of G6PD deficiency in some regions of the world²². In our study, participants with severe G6PD deficiency and pregnant women were only prescribed chloroquine treatment in cases of *P. vivax* carriage. However, these populations did not reveal significantly more relapses or carriage in our study. The difficulty to detect such a difference could be explained by the lack of statistical power, given the low number of patients with G6PD deficiency in the study samples. This study not only allowed a reduction of *Plasmodium spp.* carriage, but also enabled us to determine the G6PD status of a large part of this population living in a high malaria-risk area. These values have been recorded carefully in the health centre. This will enable participants to benefit from a faster primaquine treatment administration in the future.

This is the first Amazonia-based study to evaluate the efficiency of a MSAT campaign involving PCR diagnosis followed by a treatment of all *Plasmodium spp.* carriers. Contrary to the studies of Phommasone et al. in Myanmar and Garfield et al. in Nicaragua, we did not observe any resurgence of *P. vivax* infections during the 12-month follow-up^{24,25}. This may be due to the radical cure with 14 days (30mg/day) of primaquine treatment. Indeed, participants of Phommasone et al. MDA study participants received three-day courses of dihydroartemisinin-piperaquine and only a single dose of primaquine used as gametocytocide that does not target *P. vivax* hypnozoites²⁵. The treatment in the study by Garfield et al. was also shorter than that prescribed in our study, with a three-day course of chloroquine and a five-day course of primaquine (15mg/day)²⁴. However, *P. vivax* carriers in our study had a higher risk for *P. vivax* infection and a shorter median time before the next infection compared to participants without *P. vivax* carriage. This could be due to a higher global risk for malaria when living in specific areas such as a remote neighbourhood, or socio-demographic parameters such as high malaria-risk activities (hunting, fishing or farming in the forest), as previously described¹⁰. It is also important to note that although primaquine coverage was 100% at the first MSAT intervention, medication adherence to 14 days of primaquine was low (around 60%); this figure should be taken with caution due to a possible memory bias (patients were asked about primaquine adherence one year after treatment). Similarly, data regarding behaviours in cases of fever during the 2nd MSAT identified a lack of medical consultation for malaria testing (56% of patients with fever presented for malaria testing), and this despite health

education provided by dedicated teams during the 1st MSAT. In routine care, primaquine coverage was also low

In our transborder context, this kind of intervention must be repeated and coordinated with our Brazilian neighbour in order to be effective over the long term, and avoid new infections in this territory. It is also important to target mobile populations. In this respect, the ongoing MALAKIT project seeks to provide a kit for auto-testing and auto-treatment, and aims to control malaria in mobile gold miner populations ²⁶. Efforts are also being made to develop and maintain a cross-border observatory on vector-borne disease (notably by the French-Brazilian Joint International Laboratory “Sentinela”) and a political commitment to eliminating this disease, with regular meetings and the implementation of specific measures in the field ²⁷.

The efforts made to engage the empowerment and participation of the communities at all levels led the local population to accept and willingly participate in the MSAT campaigns. Communication via cultural community mediators who know local culture, languages and community mobilization made it possible to build confidence about MSAT and increased adherence ²⁸. Door-to-door distribution of medication and the follow-up of carriers were effective in targeting all positive cases and improved the care of malaria patients. It was also easier for cultural mediators to explain directly to patients that the drugs had to be taken regularly, even by those who were asymptomatic and did not feel sick, in order to protect their household and community and eventually defeat malaria transmission. Being close to the inhabitants was also a logical approach given the logistical difficulties and the high cost of transport from houses to the health centre in this area. However, primaquine treatment adherence remains particularly challenging.

Although MSAT implementation was a success, it has a number of limitations. MSAT activities were conducted during the day, making it difficult to reach adult men who were at work, hunting or fishing. In addition, these communities move around a vast border territory for family purposes (ex: Amerindians moving between Brazil and French Guiana) or for subsistence. Finally, during the first intervention, a major seasonal malaria epidemic was reported. This outbreak may have resulted in an overestimation of MSAT efficiency. However, results of passive monitoring of non-participants of the study were a good indication of the impact on the number on symptomatic cases of MSAT strategy.

Conclusion

In a border and remote area context, MSAT intervention was feasible, safe, and effective for not only *Plasmodium spp.* carriage prevalence but also *P. vivax* infections, with a follow-up of more than 12 months. The elimination of malaria caused by *P. falciparum* or *P. vivax* could be accelerated by interventions in the general population, targeting malaria transmission with sensitive diagnostic tools and adapted treatments.

Abbreviations

AME: Aide Médicale d'Etat; CNIL: Commission Nationale Informatique et Libertés; G6PD: Glucose-6-phosphate dehydrogenase; ITN: insecticide-treated net; NGO: Non-Governmental Organization; PCR: Polymerase Chain Reaction; *Pf*: *Plasmodium falciparum*; *Pv*: *Plasmodium vivax*; STG: Saint Georges de l'Oyapock; RDT: Rapid Diagnostic Test; WHO: World Health Organization

Declarations

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Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available due to special CNIL authorization to transfer databases. Upon reasonable request and following specific authorization by the CNIL, the dataset may be obtained from the corresponding author.

Author Contributions

Wrote the first draft of the manuscript: EM. Contributed to the writing of the manuscript: LM, RP, JL, LM, ER, JG, MD and LE. EM, AC, MG, CM and LE collected the data and samples. YL, LM, MD and SP performed biological analysis. Analyzed the data: EM, RP. Conceived the study: EM, FD, LM. All authors contributed to the subsequent draft and have reviewed and agreed with the content of the final manuscript.

Ethics approval and consent to participate

The study was approved by the *Comité de Protection des Personnes du Sud-Ouest et Outre-Mer 4* N° AM-36/1/CPP15-024 (French ethics committee). The database was anonymized and declared to the French regulatory commission (Commission Nationale Informatique et Libertés, CNIL, n°917186). Samples collected by the National Reference Center were registered by the French Ministry for Research (declaration number DC-2010-1223; collection Nu2). Duly signed informed consent was obtained from all participants involved in the study after explanations about the study in their local languages. Treatments and medical follow-up of malaria infection were provided to the participants free of charge.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

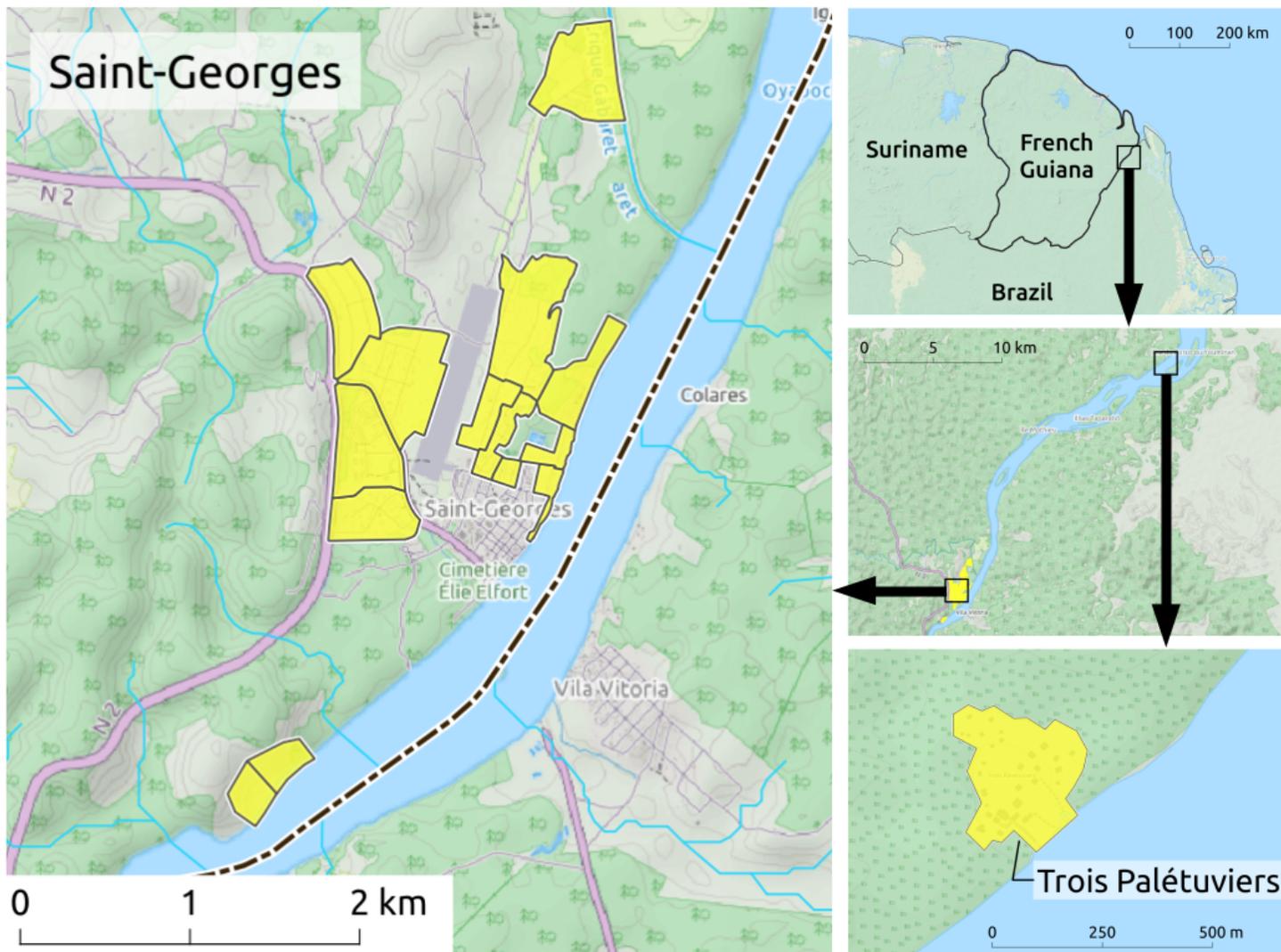


Figure 1

Study area: Neighbourhoods of Saint Georges de l'Oyapock municipality selected for the MSAT campaigns (in yellow). The map was created using data from OpenStreetMap and QGIS Geographic Information System (Open Source Geospatial Foundation Project <http://qgis.osgeo.org>)

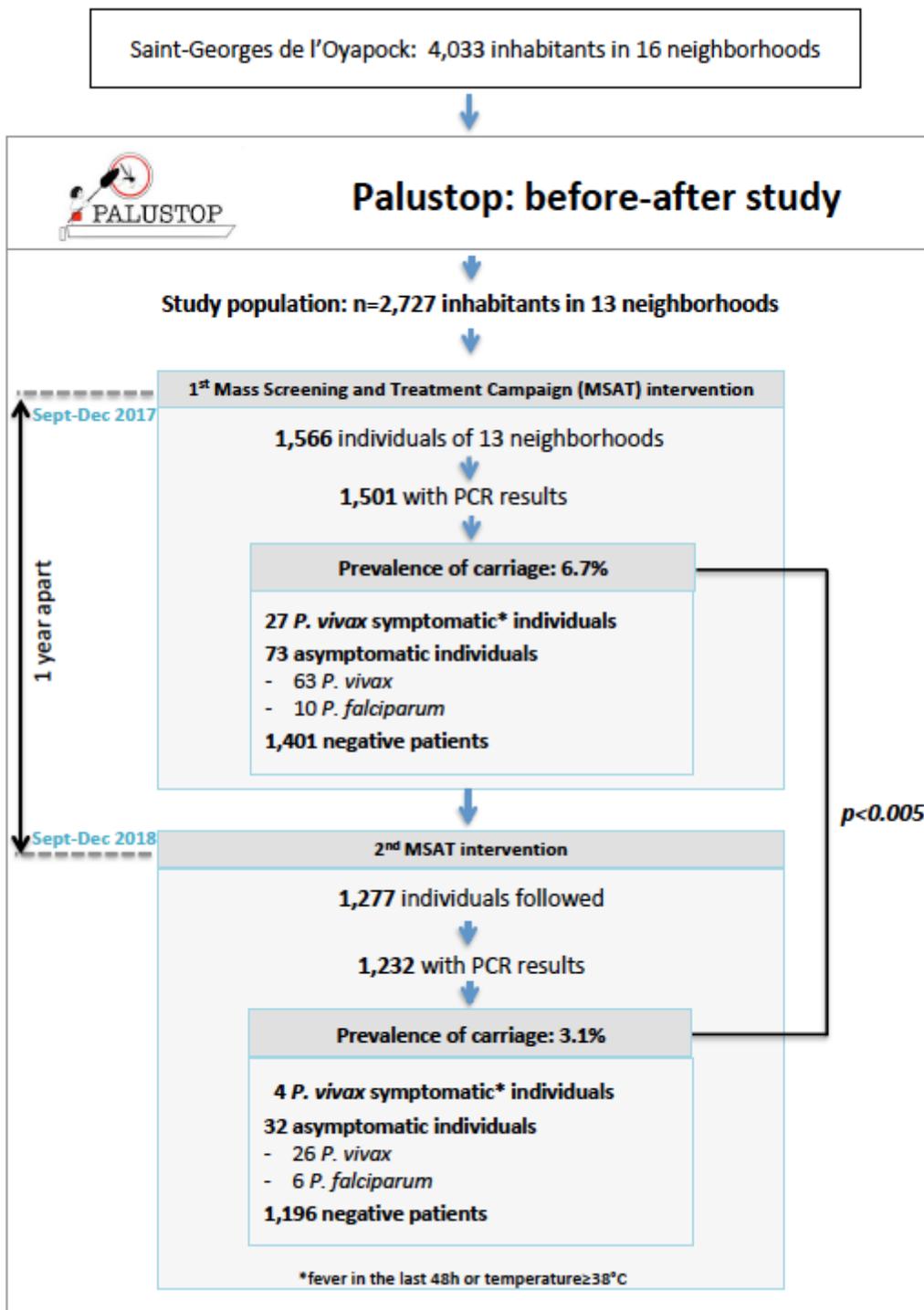


Figure 2

Consort flow chart of recruitment and main PCR results of Mass Screen and Treat (MSAT) interventions

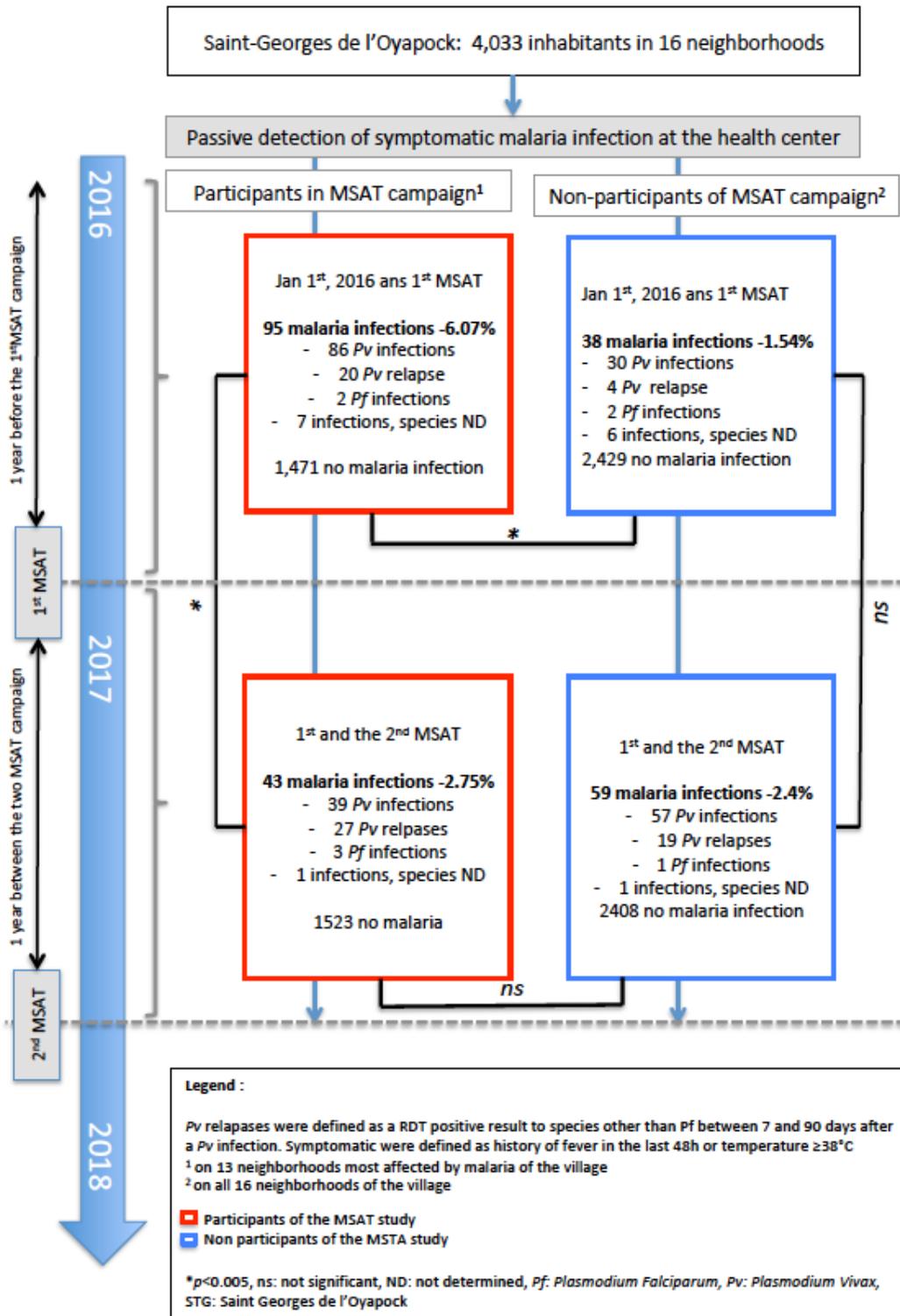


Figure 3

Results of the passive monitoring of symptomatic cases by rapid diagnosis test (RDT) at the Saint Georges de l'Oyapock (STG) health centre, 2016-2018.

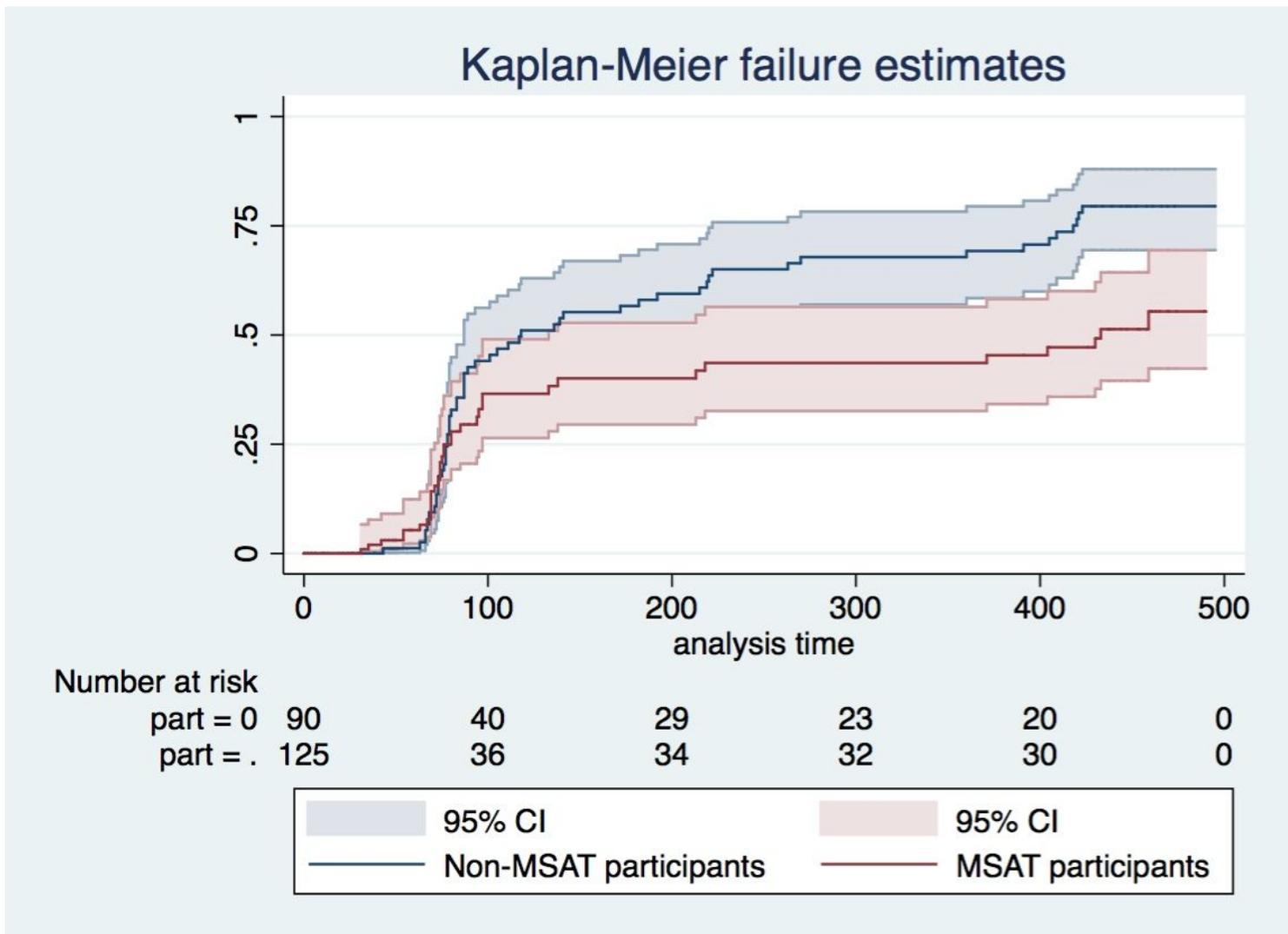


Figure 4

Kaplan-Meier curves with log rank test of *Plasmodium vivax* infections comparing Mass Screen and Treatment (MSAT) participants and non-participants.

Supplementary Files

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