



Malaria in the borders between Brazil and French Guiana: social and environmental health determinants and their influence on the permanence of the disease

Malária na fronteira do Brasil com a Guiana Francesa: a influência dos determinantes sociais e ambientais da saúde na permanência da doença


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Abstract

This study analyzes the influence of socio-environmental health determinants on the maintenance of *Plasmodium vivax* malaria at the borders between French Guiana and Brazil. This study was carried out between 2011 and 2015 in the city of Oiapoque, Amapá, situated in the Brazilian Amazon region. The sample included 253 individuals of both sexes aged between 10 and 60 years. The disease was predominant in 63.64% (161/253) adult males. The most affected age group was 20 to 29 years old, with 30% (76/253). About 84.6% did not complete high school, while 29.6% (75/253) of the cases had not finished the first degree. Concerning the environmental aspect, negative correlation was observed between rainfall and the incidence of *P. vivax* malaria ($p=0.0026$). In terms of mobility, there was a considerable influx of migrants from the states of Pará and Maranhão, with 55.73% (141/253). Lastly, the data indicated that 31.23% (79/253) of malaria cases were imported from French Guiana. In summary, the transmission of malaria in these particular borders involved ecological, environmental, biological and social factors, which are expressed in the high social vulnerability of the population living and circulating in the border zone, favoring the occurrence of outbreaks and the maintenance of the disease.

Keywords: Socio-Environmental Determinants of Health; Malaria; Border; Migration; *Plasmodium vivax*.

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Resumo

O objetivo deste artigo é analisar a influência dos determinantes socioambientais da saúde na incidência de malária por *Plasmodium vivax* na fronteira franco-brasileira. O estudo foi realizado entre 2011 e 2015, no município de Oiapoque (AP), na Amazônia brasileira. Foram incluídos na amostra 253 indivíduos de ambos os sexos, de 10 a 60 anos de idade. Houve predominância de 63,64% (161/253) de casos de malária em adultos do sexo masculino. A faixa etária mais acometida foi de 20 a 29 anos, com 30% (76/253); 84,6% (214/253) dos pacientes não concluíram o ensino médio, e 29,6% (75/253) não concluíram o ensino primário. No aspecto ambiental, houve correlação negativa entre as precipitações pluviométricas e a incidência da malária por *P. vivax* ($p=0,0026$). Em termos de mobilidade, constatou-se considerável proporção de migrantes provenientes dos estados do Pará e do Maranhão (55,73%; 141/253). Por fim, os dados apontaram que 31,23% (79/253) dos casos de malária foram importados da Guiana Francesa. Em síntese, a transmissão da malária na fronteira franco-brasileira envolve fatores ecológico-ambientais, biológicos e sociais que se expressam na elevada vulnerabilidade social da população que vive e circula na zona fronteira, favorecendo a ocorrência de surtos e a permanência da enfermidade.

Palavras-chave: Determinantes Socioambientais da Saúde; Malária; Fronteira; Migração; *Plasmodium vivax*.

Introduction

Malaria is a parasitic infectious disease caused by single-celled protozoa of the genus *Plasmodium*. Its characteristic symptoms are high fever with chills, intense sweating and headache occurring in cyclical patterns, depending on the type of infectious plasmodium. Its transmission occurs through the bite of the female mosquito of the genus *Anopheles*, for maturation of its eggs (Jain et al., 2010). Annually, between 250 and 500 million cases of malaria are reported worldwide, especially in the poorest regions and with the highest social exclusion (Piñeros, 2010). In Brazil, the disease has a high incidence in the Amazon region, where about 99% of cases in the country are recorded (Griffing et al., 2015).

Despite efforts to reduce the incidence of malaria through national and state control programs, health differences between human groups result from living and working conditions, socially constructed habits and behaviors that influence the health-disease process, notably in the production of health inequalities (Silva, 2013; Souza; Silva; Silva, 2013). These facts contribute to the heterogeneous distribution of the disease, affecting most population groups living in unsatisfactory housing and working conditions, in new logging and agricultural settlements, in the artisanal gold mining area, settlement projects and agrarian colonization, and intense human mobility (Silveira; Rezende, 2001).

Malaria is an important public health problem in Brazil and on the French Guiana's border. The city of Oiapoque (AP), on the Brazilian side of the border, is an important hotspot. Located in an equatorial climate, with rainfall throughout the year, the city has an annual parasitemia index that normally varies from medium to high risk of transmission (Gomes et al., 2015). The spread of diseases in border areas is related to the high cross-border flow population, constituting one of the main social determinants of malaria (Buss; Pellegrini Filho, 2007).

The social determinants of health (SDH) reveals the relations between living and working conditions with the health situation, both individually and collectively (Buss; Pellegrini Filho, 2007;

Pellegrini Filho, 2011). According to the National Commission on Social Determinants of Health (CNDSS), SDH are composed of social, economic, cultural, ethnic/racial, psychological and behavioral factors that influence the occurrence of health problems and their risk factors (Lima; Guimarães, 2007).

SDH are intrinsically related to tropical diseases such as malaria and negligible diseases such as Chagas disease, visceral leishmaniasis, lymphatic filariasis, dengue and schistosomiasis, among others. Malaria does not manifest itself at random; its transmission is highly influenced by socioeconomic, geographic and environmental aspects, that is, its intensity and distribution are modulated by these aspects (Lima; Guimarães, 2007). In addition, certain patterns of disease incidence can be observed, according to particular characteristics of the populations (Almeida-Filho et al., 2003). Migration, for example, influences the occurrence of diseases in space and time, and are related to broader economic and social processes, which determine the circulation of hosts (mainly men) in areas of greater or lesser receptivity to malaria, favoring or hindering the disease transmission (Costa, 1982; Souza; Dourado; Noronha, 1986).

The city of Oiapoque, located in the extreme north of the state of Amapá, in the northern region of Brazil, has about 27 thousand inhabitants (Instituto Brasileiro de Geografia e Estatística, 2019) and is bordered by French Guiana. In 2010 this city resented high risk for malaria as it registered 5,378 cases of malaria, with an annual parasite index (API) of 259.8, (API > 50 cases/1 thousand inhabitants). In 2015, with the number of malaria cases dropped to 1,482, and the risk to medium, with an API of 45.1. *Plasmodium vivax* was responsible for almost 85% of the cases notified in the Epidemiological Surveillance Information System (Sivep-Malaria) (Brasil, 2010), which justified the choice of this species of plasmodium for our study.

As a city on the international frontier, Oiapoque has significant cross-border movement of people and goods, from one side to the other of the river of the same name, where several small boats (catraias) navigated, connects the twin cities of Oiapoque, in Amapá, and Saint-Georges in French Guiana. The main reasons for crossing the border are work, social

activities and trade, among others, forming legal and illegal flows between the two countries (Silva, 2017; Silva; Granger, 2016).

This study deals with health at the border from a holistic, dynamic and complex approach, considering the biological, social and environmental dimensions as major determinants of the health-disease process. The main objective of this article is to analyze the influences of social and environmental determinants of malaria by *Plasmodium vivax* in the border city of Oiapoque, a key place to understand determinants of disease transmission on the Brazilian border with French Guiana.

Methods

This is a mixed methods epidemiological study, with a sociodemographic basis and exploratory-descriptive design, carried out in the city of Oiapoque. Secondary data were collected in health, demography and environment information systems, together with fieldwork where semi-structured interviews with city dwellers were applied.

Study area

Our study area is the city of Oiapoque, located on the northern Brazilian border, about 600 kilometers from Macapá, capital of the state of Amapá. Oiapoque interacts with two communes in French Guiana, Saint-Georges-de-l'Oyapock, with which it has strong commercial and social relations (twin city), and Camopi, located on the other side of the Oiapoque River, in front of the small Brazilian village called Vila Brasil (Silva, 2013).

Oiapoque has about 22 thousand km² of territorial area and an estimated population of 27 thousand inhabitants (Instituto Brasileiro de Geografia e Estatística, 2019), besides a floating population estimated between 12 thousand and 15 thousand individuals. The city has two districts: Vila Velha do Cassiporé and Clevelândia do Norte, in addition to Oiapoque's city district. Also part of the municipal territory are the environmental reserves of the Parque do Cabo Orange and Parque das Montanhas do Tumucumaque along with three indigenous lands, Uaçá, Galibi and Juminã

(Silva, 2013; Vidal, 2009). The peripheral condition in relation to the country core areas and the daily cross-border exchanges with French Guiana are key elements to characterize this Brazilian border (Almeida; Rauber, 2017).

French Guiana is located 15 minutes downstream of the Oiapoque river at its left bank, forming the border zone with Brazil. This overseas department of France, was an ancient colonial territory of the French State. The Guianas Region is one of the oldest and richest mineral deposits in the world, a geological formation called Guiana Shield (Musset et al., 2014).

Furthermore, French Guiana is part of the European Union - EU, adding another political layer to this international border, the border between Mercosur and EU. French Guiana's main economic activity is linked to the most advanced industrial sector aerospace industry, namely rockets and satellites assembly and launching. The construction industry is also important in French Guiana, as well as various public services and research centers related to environmental sciences and tropical medicine. The mining sector is also important attracting people all over the region, specially Brazilian artisanal gold miners, which penetrate the French territory illegally, and it is estimated that (Hammond et al., 2007; Musset et al., 2014) two-thirds of the exported gold comes from illegal mining. It is estimated that around 10,000 people (90% of whom are illegal migrants) are involved in this activity (Granjer, 2013). Gold mining is responsible for a constant and significant flow of illegal immigrants to Guiana, mainly Brazilians, who develop mining activities in tropical forest areas (de Theije, 2009).

Casuistry and inclusion criteria

A total of 253 participants formed the study population, from 2011 to 2015. The selection of subjects was by spontaneous demand, among individuals seen at the following locations: Oiapoque Border Laboratory, Oiapoque Hospital, and municipal health local units (Nova Esperança, Paraíso, Planalto and Infraero). The included participants met the following criteria: (1) having

been diagnosed with malaria by *P. vivax*; (2) Age between 10 and 60 years; and (3) having signed the informed consent form.

Social determinants of health

This study adopted the SDH approach (Buss; Pellegrini Filho, 2007), collecting information contained in the epidemiological forms and complementing it with individual interviews. The variables analyzed were sex, age, education, main activity and probable site of infection, associated with the incidence of malaria. The data were subsequently grouped, forming a database created according to the research goals. In parallel, in order to complement and compare the data, information from the Sivep-Malaria Notification Form was used. Regarding the occupation variable, the activity declared on the probable date of infection, that is, 15 days before the onset of symptoms was considered. To survey the education level of the research subjects, the Sivep-Malaria Notification Form was also used.

Statistical analysis

To analyze the age of the research subjects, descriptive statistics were used: amplitude, mean and standard deviation. The proportion between males and females, the origin per unit of the federation (state) and the probable places of infection were analyzed using the Chi-square test (χ^2). The distribution of individuals according to sex in different age groups was compared using the Mann-Whitney test (U). The predominance of sex in different age groups, the activities performed by individuals and the autochthonous cases in the neighborhoods were compared using the Williams' G-test. The correlation of Pearson was used to analyze the association between the incidence of *P. vivax* malaria and rainfall indexes using the monthly averages of accumulated rainfall between 2011 and 2015, from January to December, versus the disease incidence rate in the same period. These statistical analyses were performed using the BioEstat 5.0 program, with a 5% confidence interval, with $\alpha = 0.05$.

Ethical aspects

This study was carried out respecting the precepts established by Resolution No. 466/2012, in compliance with national and international standards of ethics in researches involving human beings. The instruments applied were validated and authorized by the Research Ethics Committee of the Federal University of Amapá, according to the principles adopted by the National Research Ethics Commission. All respondents or their guardians consented to participate in the study, registering their agreement in the informed consent form with signature or digital visa, when they could not write.

Results and discussion

The United Nations (UN) has established the 17 Sustainable Development Goals in its 2030 Agenda, and the first goal, “ending poverty in all its forms and in all places,” as well as the third, “ensuring a healthy living and promoting well-being for all, at all ages,” clearly dialogue with the SDH approach. In this sense, there is a growing interest in the study of SDH, given the repeated evidence that health disparities have increased in recent years and are real obstacles to sustainable development. Therefore, it is necessary to prioritize interventions aimed at reducing health disparities in each country, and in Brazil in particular. For this to happen, Almeida-Filho et. al (2003) point out that it is necessary to build territorialized public policies, namely, adapted to the particular situations of each territory, deepening knowledge and research on the determinants of health in these territories, with updated and consistent data.

The lack of information is higher in the least developed regions of the world. In Brazil, inequality in the distribution of economic and social resources impacts health status and access to services, causing deleterious effects on the health of the poorest populations (Almeida-Filho et al., 2003). It is known that the context of high inequity influences the

transmission pattern of vector diseases such as malaria, leading to differential exposure to sources of infectious agents (hosts) and exposure to disease-transmitting vectors. These patterns are conditioned by population dynamics, by the living conditions of different groups, by class and work relations, by access to health services and by gender, ethnic and cultural relations. All of these elements result in different patterns of exposure and transmission of diseases (Almeida-Filho et al., 2003; Piñeros, 2010).

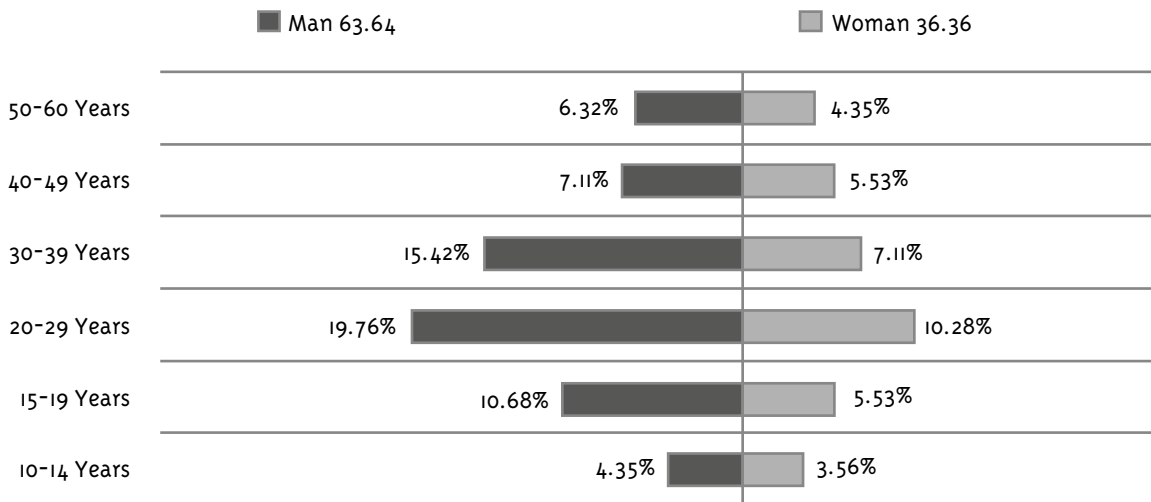
In addition, socioeconomic and cultural characteristics and environmental degradation by human activities influence vector exposure and malaria transmission (Marques; Pinheiro, 1982). Therefore, in order to understand the dynamics of malaria, it is essential to define the sociodemographic characteristics of the study area and its relationship with the maintenance of the disease, considering the border situation in a region of high endemicity.

Population profile

The study population was predominantly male ($\chi^2=18.818$; $p<0.0001$), corresponding to 63.64% of the sample (161/253), in the proportion of approximately two to one in relation to female. The sample's mean age was 30 years (12 standard deviations), and it ranged from 10 to 60 years. The age group most affected was 20 to 29 years, followed by 30 to 39 years. The lowest age group was 10 to 14 years old, in both sexes. Regarding sex, the different age groups had similar profiles of malaria occurrence (Mann-Whitney test, $\alpha = 0.05$; bilateral p-value = 0.1093), with a predominance of males in all age groups [(Williams' G-test), $\alpha = 0.05$; $p < 0.0001$], as shown in Figure 1.

Although *P. vivax* malaria affects both sexes, there is a predominance of cases in adult males. These results corroborate with studies carried out in other states of the Brazilian Amazon, which showed a higher incidence of the disease among men in the age group corresponding to the main segment of the economically active population (Barbosa et al., 2006; Marques; Pinheiro, 1982; Teixeira, 2011).

Figure 1 – Distribution by sex and age group of patients infected with vivax malaria in the study population, Oiapoque, from 2011 to 2015



The dynamic of social relations and work relations influences community daily activities in order to achieve its biological and social reproduction, in the different territorial contexts (Castellanos, 1997; Piñeros, 2010). These elements are the key to understand the differential patterns of exposure and vulnerability of groups and social subjects, highlighting, in the case of malaria, the SDH involved in the distribution of exposure and risk. The fact that malaria mainly affects men of working age reveals the situation experienced by this population group in illegal gold mines in the region. Pannings (*garimpos*) are in areas of high receptivity for malaria and gather susceptible populations in constant renewal, given their high mobility, which produces a situation of high risk for the disease.

Schooling and occupation

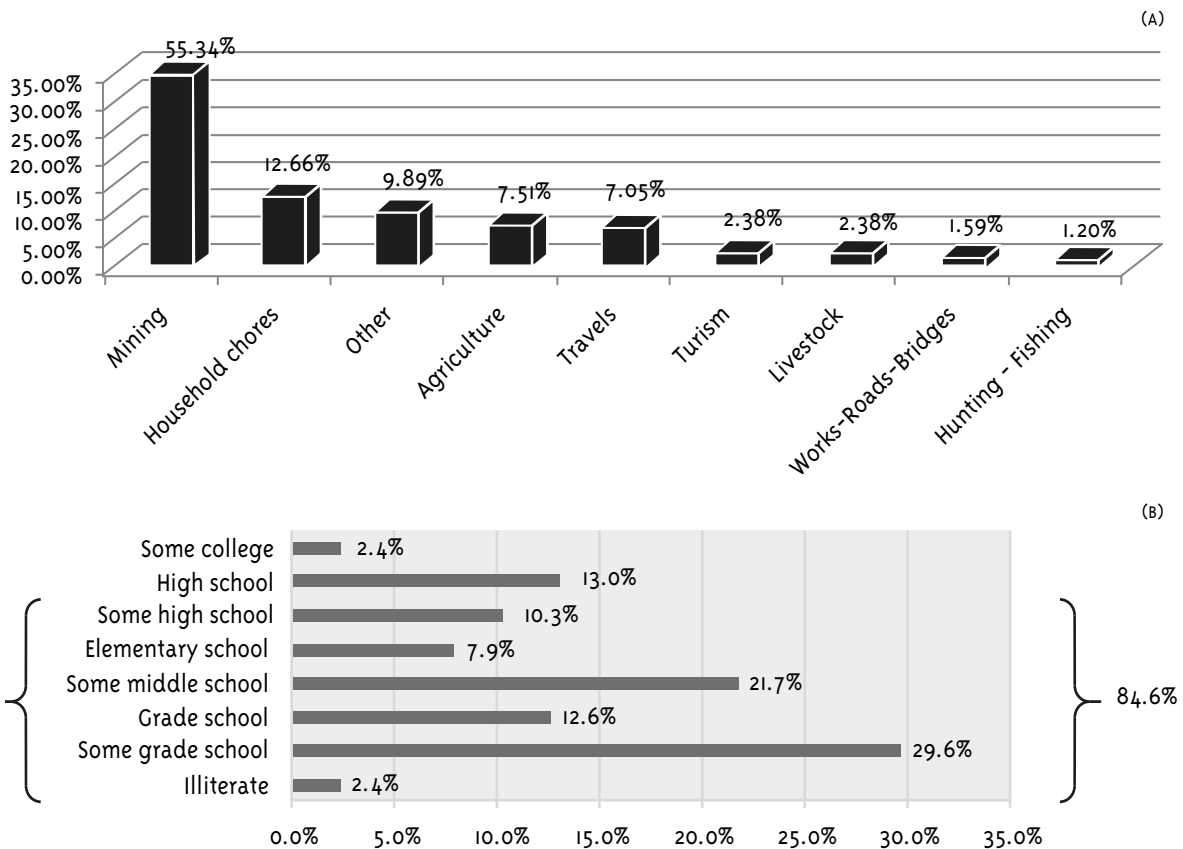
It is important to consider the level of education in SDH analysis, as well as in the health promotion approach (Fonseca; Corbo, 2007). The distribution by level of education of the sample indicates only 7.9% who completed elementary school, 13% who completed high school and only 2.4% who attended higher education, but did not complete it.

Here, a significant percentage of 84.6% of individuals who have not completed high school stands out. Therefore, the level of formal education in the city pushes the economically active population to work in low qualification jobs, generally manual labor, agriculture, mineral extraction (notably gold mining) or domestic services. In this perspective, the low level of education of individuals represents a strong social indicator in the region (Figure 2).

Data referring to the activities performed by individuals in the 15 days prior to the onset of symptoms show artisanal mining as the most reported activity, comprising 55.34% (140/253) of the cases (G-test = 140.2330; $p < 0.0001$). Artisanal mining is followed by domestic activities: “other” (unspecified activities, according to the Sivep form), agriculture, travelers, tourism, livestock, construction (roads and bridges) and, to a lesser extent, hunting or fishing (1.2%) (3/253). Legal mining and plant exploitation have not been reported (Figure 2).

It is estimated that around 10,000 Brazilians work in clandestine mines on the French side of the border. This group moves both ways, but seeks treatment for malaria infections in Brazil (Andrade, 2005; Granjer, 2013).

Figure 2 – (A) activities performed by patients with malaria in Oiapoque in the last 15 days; (B) percentage distribution of the education level of patients with vivax malaria, Oiapoque, from 2011 to 2015



In this study, the most mentioned occupational activity was panning. Based on this information, it is necessary to further investigate the working conditions of illegal gold mines in French Guiana, which in general are in places of difficult access, inside the forest, with precarious housing conditions, basic sanitation and food. All of this increases, exposure to the malaria vector (the anopheles mosquito), increasing the incidence of this disease and other endemic ones in the Amazon region (such as leishmaniasis, dengue and chikungunya) among gold prospectors (Peiter, Machado & Rojas, 2008).

Added to this situation is the fear or difficulty in accessing health services, preventive measures and the control or treatment of malaria and other diseases. In this perspective, illegal mining determines the disease transmission in this region.

Rainfall variation and incidence of malaria by *P. vivax*

Oiapoque's climate is equatorial, according to the Köppen classification, with an annual relative humidity of 82%. The highest temperatures coincide with the driest months of the year. The average temperature is 27°C, oscillating between 26°C and 33°C (Agência Nacional de Águas, 2015). Among the four seasons, two stand out: winter, with an average rainfall of 1,800 mm, and summer, generally dry, with an average precipitation of 500 mm. When considering the average monthly rainfall in the years of study, it is clear that the months of March, April and May had the highest rainfall (385 mm, 449 mm and 429 mm, respectively), reduced in the subsequent months until reaching the lowest

monthly averages (49 mm, 58 mm and 75 mm), corresponding to September, October and November, and starting to increase again from December (Figure 3). The factors are inversely associated with rainfall, indicating that the occurrence of malaria has multifactorial conditions. Precipitation data were obtained from the Institute of Scientific and Technological Research of the State of Amapá – Nucleus of Hydrometeorology and Renewable Energies and the National Institute of Meteorology (Agência Nacional de Águas, 2015; Nhmet, 2011).

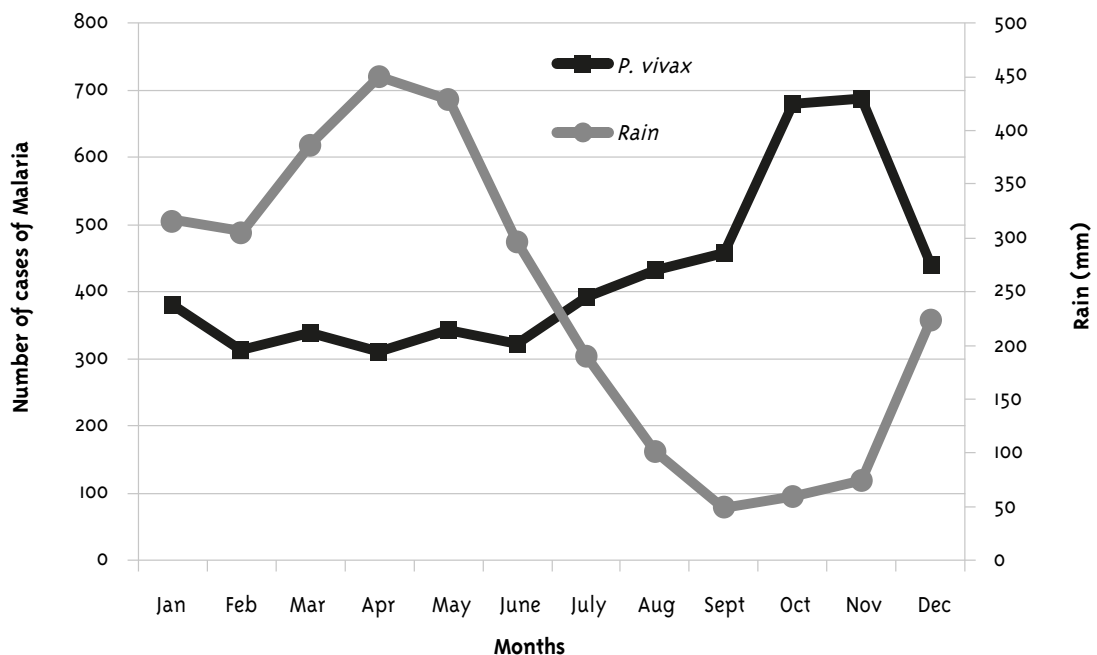
When comparing the intra-annual variability of monthly precipitation with the incidence of malaria in the study period, a plateau was observed for *P. vivax* in October and November (driest months). Therefore, a strong negative correlation (Pearson $r = -0.7819$; $p = 0.0024$) is observed between the monthly averages of accumulated rainfall between January and December with the incidence rate of *P. vivax* malaria ($p = 0.0026$). However, it was observed by Pearson's correlation coefficient that only part of the malaria incidence, that is, 78% (198/253), is inversely associated with rainfall.

In Oiapoque, the increase in the incidence rate of malaria is due to the higher previous monthly accumulated rainfall (two to three months before the growth of cases). The subsequent plateau of occurrence suggests that the increase in incidence, after a period of intense rain, increases the transmission of the parasite, probably due to the appearance of breeding sites during this period, favoring an increase in the density of mosquitoes that carry the disease.

Studies in the state of Amapá and other Amazonian borders have investigated the relationship between precipitation and the incidence of malaria, corroborating the results of this research. Amanajás et al. (2011), for example, in a study in the municipalities of Mazagão (AP) and Oiapoque, showed the association between cases of malaria and rainfall.

However, the association between meteorological variables and malaria is not enough to explain the occurrence of the disease, as this is not its only determining factor, as pointed out by Andrade-Filho and Marinho (2008) and Omena et al. (2011).

Figure 3 – Intra-annual malaria incidence rates and accumulated monthly precipitation, Oiapoque, from 2011 to 2015 (incidence rates were calculated monthly for *P. vivax*)



Source: Adapted from Nhmet (2011); Agência Nacional de Águas (2015)

Stefani et al. (2001) when studying a commune on the French Guiana border called Camopi (92.5 km from the city of Oiapoque, on the Oiapoque River channel), occupied by traditional populations, found a significant association between environmental, entomological, socioeconomic and behavioral factors and malaria in Amerindian children. The survey also pointed out that the peak incidence of malaria occurs between the beginning of the rainy season (January) and its end (June). The disease rate was significantly higher during the rainy season, compared to the dry season ($p < 0.001$), differing from the results of this study, since in this case the malaria incidence was higher during the drier period, in September and October (Pearson= $p = 0.0026$).

Further studies should be carried out to elucidate the reason for the differences in malaria behavior in two geographically close regions (92.5 km distant). Camopi is a cluster of indigenous villages whose main occupations are subsistence agriculture, hunting, fishing and collection of wild fruits. The city of Oiapoque, on the other hand, has a larger and more consolidated urban area, with about 15 thousand inhabitants, and which receives significant contingents of highly mobile populations, such as prospectors and border tourists. In this area, the problems of basic sanitation, urban drainage, waste management and disposal are serious. Historically, the main economic activity in the city is artisanal mining in addition to trade, and more recently, there has been the development of other sectors, such as services (higher education, health, and hotel management, among others).

However, it is not possible to make a direct comparison between the two studies in focus, since the age composition of the research groups was different, and it is known that age influences the behavior of malaria. In the study in Camopi, there were only children under 7 years old, in a different cultural context. In this study, only people who were 10 or older were selected, and more than 93% of the individuals in the sample reported being over 15 years old.

Health effects of population mobility

Regarding the place of birth of the patients in the study, three states were mentioned, with Amapá (44.27%; 112/253) being the most common place of origin ($\chi^2 = 5.91$; $p = 0.0521$). Amapá-born people were subdivided into those born in the city of Oiapoque (23.72%; 60/253) and in other municipalities in the state (20.55%, 52/253). The other participants came from the state of Pará (30.83%; 78/253) and Maranhão (24.90%; 63/253), totaling 55.73% (141/253) of the patients who migrated to this border (Figure 4).

The results show a considerable migratory flow to this border area, constituted by a significant portion of the floating population (76.24%; 193/253), in constant displacement, coming from other municipalities in the state of Amapá and other Brazilian states.

Regarding the autochthonous cases of malaria caused by *P. vivax* reported by the patients, according to the probable site of infection, it was observed that the Paraíso neighborhood had the highest percentage of cases (23.56%; 41/174) ($G = 37.4090$; $p < 0.0001$), followed by Infraero (18.97%; 33/174), BR-156 (13.79%; 24/174), Nova Esperança (13.22%; 23/174), Nova União (10.92%; 19/174), Planalto (8.62%; 15/174), indigenous villages (4.02%; 7/174), Universidade (4.02%; 7 / 174) and Clevelândia (2.87%; 5/174), the latter being the neighborhood with the lowest percentage of cases (Figure 4).

As for the probable site of infection in the border region, 68.77% (174/253) of indigenous cases of *P. vivax* malaria were identified as originating in Oiapoque, and 31.23% (79/253) were imported cases from French Guiana (Figure 5), extrapolating the ratio of two to one ($\chi^2 = 38.739$; $p < 0.0001$). Of the imported cases, several illegal mines were reported as a probable infection sites, with the highest percentage coming from the Sikini mines, with 48.1% of the cases (38/79) ($G = 87.111$; $p < 0.0001$), followed by the Sapucaia, Corrêia, Iporsen, Regina, Ouanary, D21 and Varal mines (Figure 5).

Figure 4 – (A) proportion of patients with *P. vivax* malaria in Oiapoque by place of origin; (B) distribution of *P. vivax* malaria cases in the city of Oiapoque by likely infection site

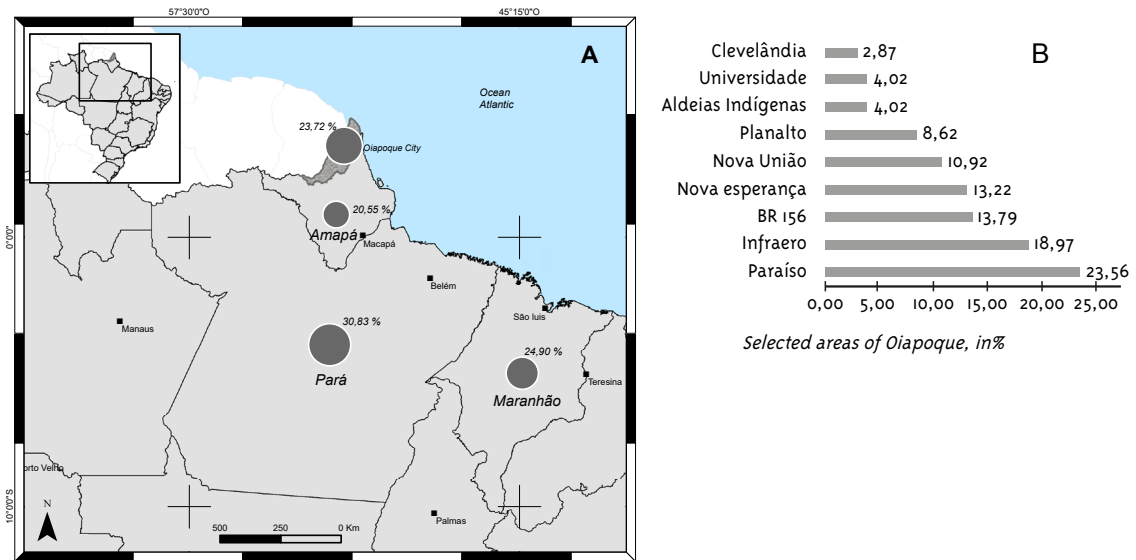
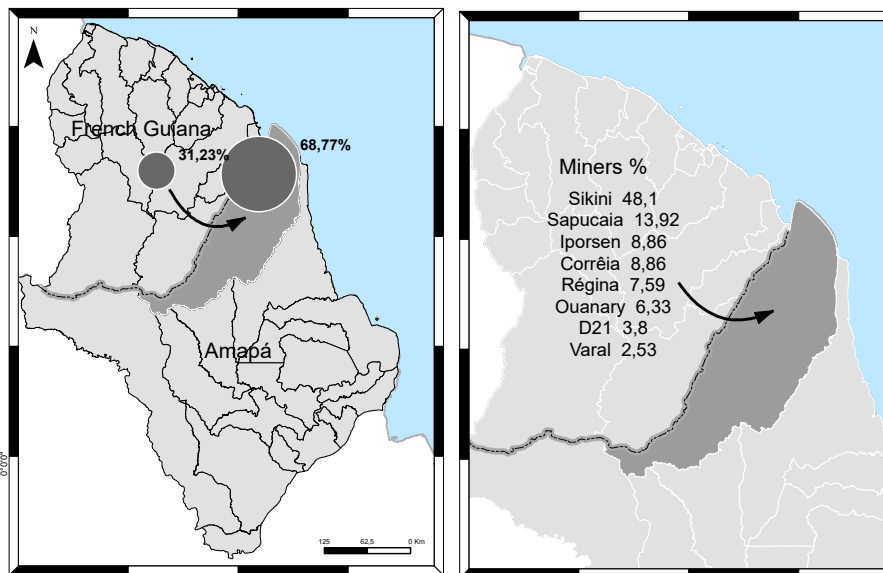


Figure 5 – Cases of malaria by *P. vivax* according to the probable infection site and distribution of malaria imported from the mines of French Guiana to Oiapoque



Another aspect to be highlighted is the cases of malaria imported from French Guiana, which corresponded to 31.23% (79/253) of the sample and corroborate the data reported by the Ministry of Health's Sivep-Malária (Brasil, 2010), according to which, 5,329 cases of malaria occurred in 2010,

1,414 of which (26.53%) were imported from another country (French Guiana), which reveals the role of cross-border mobility in the transmission and permanence of the disease. This constant population displacement, and especially the return to Brazil in search of health treatment, gives rise to the

phenomenon known as “imported malaria.” This mobility pattern was observed from the route established by the prospectors infected with malaria acquired in the mines located in French Guiana (Andrade, 2005).

The population mobility resulting from the search for economic alternatives has a significant impact on the health-disease process in this region. This occurs due to the precarious living conditions of these high mobility groups, which normally settle in places with high malaria endemicity to perform their extractive activities. These groups in illegal situation work in places of difficult access, they can be banned for such activity, which hinders or prevents the implementation of measures for the prevention, control and treatment of the disease. This fact occurs particularly in the illegal mines of French Guiana, located in dense forests, highly receptive to the vector, with high transmission of the disease and distant from health services. This context leads miners, when they become ill, to return to Oiapoque for diagnosis and treatment.

Another consequence of this situation is the potential for outbreaks of urban malaria, as infected miners return to the city from time to time, staying for a variable period for shopping, leisure, health treatment, etc., which may imply an increased risk of transmission of urban malaria. Suggesting a recurrent malaria transmission process in this region (Sawyer, 1982; Schrijvers et al., 1998), the findings of this study corroborate Andrade (2005) and Peiter, Machado and Rojas (2008), who pointed out the effects of migration on the distribution and incidence of malaria on the Franco-Brazilian border.

Final considerations

Artisanal illegal gold mining was the main occupational activity declared by the interviewed subjects. The illegal mines of French Guiana draw poor Brazilian workers to a high-risk activity, motivated by the dream of economic independence that an eventual discovery of a golden vein would definitively take them out of poverty. These pannings are located in places of difficult access, within the Amazon rainforest, close to breeding grounds for mosquitoes.

Furthermore, low education of the study population proved to be a key social variable to understand the risk of malaria in the region. It limited the search for formal employment, leading workers and unemployed people to seek usual or traditional economic alternatives in this border region, such as artisanal mining, which contributes to the permanence of the disease.

The predominance of males occurred in all age groups, and most patients, of both sexes, were between 20 and 29 years old. However, the incidence in men was approximately twice that in women, corresponding to the economically active population segment.

Another social determinant was interstate and transboundary population mobility, which influences population dynamics in the region and favors contact with the parasite and transmission of the disease. The results demonstrate a considerable migratory flow to the border area, constituted by a floating population, in constant displacement, coming from other municipalities of Amapá and other Brazilian states. Another important aspect to highlight are the cases of malaria imported from French Guiana, revealing several illegal mining sites as probable infection sites, with emphasis on the Sikini mining. Thus, it is worth highlighting the role of cross-border migration in the transmission of the disease, leading people with signs and symptoms of malaria to return to Oiapoque in search of treatment. This transmission dynamics gives clues about the exposure and vulnerability patterns of the resident population and that circulates on the border.

In addition, the malaria incidence in the city of Oiapoque presents semiannual seasonality, related to rainfall, with low incidence in the first semester and high incidence in the second semester, being inversely associated with rainfall, which confirms the influence of the climate in this disease.

The mechanisms of diffusion and permanence of malaria on the Franco-Brazilian frontier are related to aspects of the climate and environment, the presence of the vector, of the etiological agent and of humans. The social determinants and vulnerability of border populations contribute to the persistence of malaria in the region, despite the prevention and

control measures adopted by the disease control programs.

Population migration, low level of education of affected individuals, the predominance of cases in male adults in the economically productive age group and, especially, illegal mining as the main occupation, are social health determinants that influence the permanence of malaria on the border of Brazil with French Guiana and contribute as sociodemographic predictors in the incidence of the disease. These results on malaria on the northern border of the Amazon help to understand the health-disease process and provide information for disease prevention and control measures.

References

- AGÊNCIA NACIONAL DE ÁGUAS. Rede Hidrometeorológica Nacional. *Sistema HIDRO - Telemetria*. Brasília, DF, 2015. Disponível em: <<https://bit.ly/33uVrny>>. Acesso em: 23 maio 2015.
- ALMEIDA, C. S.; RAUBER, A. L. Oiapoque, aqui começa o Brasil: a fronteira em construção e os desafios do Desenvolvimento Regional. *Redes*, Santa Cruz do Sul, v. 22, n. 1, p. 474-493, 2017.
- ALMEIDA-FILHO, N. et al. Research on health inequalities in Latin America and the Caribbean: bibliometric analysis (1971-2000) and descriptive content analysis (1971-1995). *American Journal of Public Health*, Nova York, v. 93, n. 12, p. 2037-2043, 2003.
- AMANAJÁS, J. C. et al. Associação entre incidência de malária autóctone e precipitação no estado do Amapá. In: SIMPÓSIO INTERNACIONAL DE CLIMATOLOGIA, 4., 2011, João Pessoa. *Anais...* São José dos Campos: Sociedade Brasileira de Meteorologia, 2011.
- ANDRADE, R. F. *Malária e migração no Amapá: projeção espacial num contexto de crescimento populacional*. 2005. 403 f. Tese (Doutorado em Desenvolvimento Sustentável do Trópico Úmido) - Universidade Federal do Pará, Belém, 2005.
- ANDRADE-FILHO, V. S.; MARINHO, R. R. Casos de malária e variabilidade pluviométrica em Manaus, AM: considerações preliminares do estudo no período de 2003 a 2007. In: REUNIÃO NACIONAL DE PESQUISA EM MALÁRIA, 11., 2008, Manaus. *Anais...* São Paulo: Sociedade Brasileira de Infectologia, 2008. p. 54-55.
- BARBOSA, H. H. M. M. et al. Epidemiologia dos pacientes atendidos no programa de malária na unidade de saúde da pedreira, em Belém. *Revista Paraense de Medicina*, Belém, v. 20, n. 1, p. 58, 2006.
- BRASIL. Ministério da Saúde. *Sistema de Informação de Vigilância Epidemiológica, Sivep-Malária*. Brasília, DF, 2010.
- BUSS, P. M.; PELLEGRINI FILHO, A. A saúde e seus determinantes sociais. *Physis*, Rio de Janeiro, v. 17, n. 1, p. 77-93, 2007.
- CARBALLO, M. The challenge of migration and health. *World Hospital and Health Services*, Londres, v. 42, n. 4, p. 18-19, 2006.
- CASTELLANOS, P. L. Epidemiologia, saúde pública, situação de saúde e condições de vida: considerações conceituais. In: BARATA, R. B. (Org.). *Condições de vida e situação de saúde*. Rio de Janeiro: Abrasco, 1997. p. 31-75.
- COSTA, E. A. Movimentos migratórios e controle de doenças: por uma epidemiologia social. In: SEMINÁRIO SOBRE TRANSMISSÃO E CONTROLE DE DOENÇAS TROPICAIS NO PROCESSO DE IMIGRAÇÃO HUMANA, 1981, Brasília, DF. *Anais...* Brasília, DF: Centro de Documentação do Ministério da Saúde, 1982. p. 147-155.
- DE THEIJE, M. E. M. Moving frontiers in the Amazon: Brazilian small-scale gold miners in Suriname. *European Review of Latin American and Caribbean Studies*, Amsterdã, v. 87, p. 5-25, 2009.
- FONSECA, A. F.; CORBO, A. M. D. (Org.). *O território e o processo saúde-doença*. Rio de Janeiro: Escola Politécnica de Saúde Joaquim Venâncio, 2007.
- GOMES, M. S. M. et al. Efficacy in the treatment of malaria by *Plasmodium vivax* in Oiapoque, Brazil, on the border with French Guiana: the importance

of control over external factors. *Malaria Journal*, Londres, v. 12, n. 402, 2015.

GRANJER, S. La Guyane et le Brésil, ou la quête d'intégration continentale d'un département française d'Amérique. 2012. 858 f. Tese (Doutorado) - Université Sorbonne Nouvelle Paris 3, Paris, 2013.

GRIFFING, S. M. et al. A historical perspective on malaria control in Brazil. *Memórias do Instituto Oswaldo Cruz*, Rio de Janeiro, v. 110, n. 5, p. 1-18, 2015.

HAMMOND, D. S. et al. Causes and consequences of a tropical forest gold rush in the Guiana Shield, South America. *Ambio*, Oslo, v. 36, n. 8, p. 661-670, 2007.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Estimativas da população residente para os municípios e para as unidades da federação brasileiros com data de referência em 1º de julho de 2017. Rio de Janeiro, 2017. Disponível em: <<https://bit.ly/2IUqdwH>> Acesso em: 30 nov. 2017.

JAIN, V. et al. A preliminary study on pro- and anti-inflammatory cytokine profiles in Plasmodium vivax malaria patients from central zone of India. *Acta Tropica*, Basel, v. 113, n. 3, p. 263-268, 2010.

LIMA, S. C.; GUIMARÃES, R. B. Determinação social no complexo tecno-patogênico informacional da malária. *Hygeia*, Uberlândia, v. 3, n. 5, p. 58-77, 2007.

MARQUES, A. C.; PINHEIRO, E. A. Fluxos de casos de malária no Brasil em 1980. *Revista Brasileira de Malariologia e Doenças Tropicais*, Rio de Janeiro, v. 34, p. 1-3, 1982.

MUSSET, L. et al. Malaria on the Guiana Shield: a review of the situation in French Guiana. *Memórias do Instituto Oswaldo Cruz*, Rio de Janeiro, v. 109, n. 5, p. 525-533, 2014.

NHMET/IEPA - Núcleo de Hidrometeorologia e Energias Renováveis do Instituto de Pesquisas Científicas e Tecnológicas do Amapá. *Boletins Semanais de Previsão do Tempo/ Boletins Climáticos Mensais*. Macapá, 2011.

Disponível: <<https://bit.ly/3dUpYAO>>. Acesso em: 10 mar. 2018.

OMENA, J. C. R. et al. Correlação entre casos de malária e a variabilidade pluviométrica na cidade de Macapá-AP (2003 a 2010). In: SIMPÓSIO INTERNACIONAL DE CLIMATOLOGIA, 4., 2011, João Pessoa. *Anais...* São José dos Campos: Sociedade Brasileira de Meteorologia, 2011.

PEITER, P. C.; MACHADO, L. O.; ROJAS, L. I. Doenças transmissíveis na faixa de fronteira Amazônica: o caso da malária. In: MIRANDA, A. C. *Território, ambiente e saúde*. Rio de Janeiro: Editora Fiocruz, 2008. p. 257-272.

PELLEGRINI FILHO, A. Determinantes sociais da saúde e determinantes sociais das iniquidades em saúde: a mesma coisa? *Determinantes Sociais da Saúde*, Rio de Janeiro, 2011. Disponível em: <<https://bit.ly/2xaKI5C>>. Acesso em: 10 mar. 2018.

PIÑEROS, J. G. Malaria y determinantes sociales de la salud: un nuevo marco heurístico desde la medicina social latinoamericana. *Biomédica*, Bogotá, DC, v. 30, n. 2, p. 178-187, 2010.

SAWYER, D. R. Migrações humanas e doenças tropicais: fatores sociais. In: SEMINÁRIO SOBRE TRANSMISSÃO E CONTROLE DE DOENÇAS TROPICAIS NO PROCESSO DE IMIGRAÇÃO HUMANA, 1981, Brasília, DF. *Anais...* Brasília, DF: Centro de Documentação do Ministério da Saúde, 1982. p. 121-133.

SCHRIJVERS, C. T. et al. Socioeconomic inequalities in health in the working population: the contribution of working conditions. *International Journal of Epidemiology*, Oxônia, v. 27, n. 6, p. 1011-1018, 1998.

SILVA, G. V. Desenvolvimento econômico em cidades da fronteira amazônica: ações, escalas e recursos para Oiapoque-AP. *Confinis*, [S.l.], n. 17, 2013.

SILVA, G. V. France-Brazil cross-border cooperation strategies: experiences and perspectives on migration and trade. *Journal of Borderlands Studies*, Las Cruces, v. 32, n. 3, p. 325-343, 2017.

SILVA, G. V.; GRANGER, S. Desafios multidimensionais para a cooperação transfronteiriça entre França e Brasil 20 anos depois (1996-2016). *Geographia*, Niterói, v. 18, n. 38, p. 27-50, 2016.

SILVEIRA, A. C.; REZENDE, D. F. *Avaliação da estratégia global de controle integrado da malária no Brasil*. Brasília, DF: Organização Pan-Americana da Saúde, 2001.

SOUZA, D. O.; SILVA, S. E. V.; SILVA, N. O. Determinantes sociais de saúde: reflexões a partir das raízes da “questão social”. *Saúde e Sociedade*, São Paulo, v. 22, n. 1, p. 44-56, 2013.

SOUZA, S. L.; DOURADO, M. I. C.; NORONHA, C. V. Migrações internas e malária urbana - Bahia,

Brasil. *Revista de Saúde Pública*, São Paulo, v. 20, n. 5, p. 347-351, 1986.

STEFANI, A. et al. Environmental, entomological, socioeconomic and behavioural risk factors for malaria attacks in Amerindian children of Camopi, French Guiana. *Malaria Journal*, Londres, v. 10, p. 246, 2011.

TEIXEIRA, J. R. M. Avaliação da terapêutica da malária por *Plasmodium vivax*: perfil cinético da cloroquina e primaquina. 2011. 95 f. Tese (Doutorado em Biologia de Agentes Infecciosos e Parasitários) - Universidade Federal do Pará, Belém, 2011.

VIDAL, L. B. *Povos indígenas do Baixo Oiapoque: o encontro das águas, o encruzo dos saberes e a arte do viver*. Rio de Janeiro: Museu do Índio, 2009.

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MSMG, RAOM, JLFV, AMM, GVS, PCP, MCSM and VCF contributed to the drafting and critical review of the content, participating in all project stages. MSMG, RAOM, AARDC and RLDM conceived and participated in all aspects of the study and manuscript preparation. All authors read and approved the final manuscript. MSMG and RAOM are guarantors of the paper.

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