SPATIAL AND TEMPORAL DISTRIBUTION OF THE ANNUAL PARASITE INCIDENCE OF MALARIA IN BRAZIL: A CASE STUDY OF ACRE BETWEEN 2003 AND 2017

DISTRIBUIÇÃO ESPACIAL E TEMPORAL DA INCIDÊNCIA PARASITÁRIA ANUAL DE MALÁRIA NO BRASIL: UM ESTUDO DE CASO DO ACRE ENTRE 2003 E 2017

DISTRIBUCIÓN ESPACIAL Y TEMPORAL DE LA INCIDENCIA PARASITARIA ANUAL DE LA MALARIA EN BRASIL: ESTUDIO DE CASO DE ACRE ENTRE 2003 Y 2017

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ABSTRACT

Malaria is a public health problem in Brazil. This study aims to analyze the number of cases and the Annual Parasite Incidence (API) of malaria in Brazil. For this purpose, the number of malaria infection cases was compiled and sorted out into three different categories according to their region of incidence: in the entire Brazil domain, in the States

belonging to the Brazilian Legal Amazon region, and in the municipalities of Acre. The API of malaria in the Brazilian municipalities was calculated dividing the number of malaria cases by the total population times 1000. Special attention was placed on Acre within the time interval between 2003 and 2017. A total of 4,647,102 malaria cases were registered in the Brazilian Legal Amazon between 2003 and 2017, which represents 99.99% of the total number of national cases. It was found that the API of malaria decreased in the Brazilian Legal Amazon over that period. Amazonas, Pará, Rondônia, and Acre were the States with the highest number of occurrences. Among them, only Acre showed an increasing trend in the number of cases in 2017 when compared to the infection cases reported in 2003. Three municipalities, namely Cruzeiro do Sul, Mâncio Lima and Rodrigues Alves displayed most of the total number of cases. Their number of cases also increased during the investigated period. The findings of this work also reveal that the transmission of malaria does not occur homogeneously inside the Brazilian Legal Amazon. This study provides a comprehensive and important analysis of the spatial and temporal evolution of the malaria occurrences in Acre.

Keywords: Malaria. Brazilian Legal Amazon. Annual Parasite Incidence. SIVEP-Malaria. Acre.

RESUMO

A malária é um grave problema de saúde no Brasil. Este estudo tem como objetivo analisar o número de casos e a Incidência Parasitária Anual (IPA) de malária no Brasil. Para isso, o número de infecções por malária foi compilado e dividido em três categorias diferentes de acordo com sua região de incidência: em todo o território brasileiro, nos Estados pertencentes à região da Amazônia Legal Brasileira e nos municípios do Acre. A IPA de malária nos municípios brasileiros foi calculada dividindo o número de casos de malária pela população total e multiplicada por 1000. Atenção especial foi dada ao Acre no intervalo de tempo entre 2003 e 2017. Um total de 4.647.102 casos de malária foi registrado na Amazônia Legal Brasileira entre 2003 e 2017, o que representa 99,99% do número nacional de casos. Foi constatado que a IPA de malária diminuiu na Amazônia Legal Brasileira durante esse período. Amazonas, Pará, Rondônia e Acre foram os Estados com maior número de ocorrências. Entre eles, somente o Acre mostrou uma tendência de aumento no número de casos em 2017 quando comparado com os casos de infecção reportados em 2003. Três municípios, especificamente Cruzeiro do Sul, Mâncio Lima e Rodrigues Alves, apresentaram a maior parte do número total de casos. O número de casos nestes municípios também aumentou no período analisado. As descobertas deste trabalho também revelam que a transmissão da malária não ocorre de forma homogênea na Amazônia Legal Brasileira. Este estudo fornece uma análise compreensiva e importante da evolução espacial e temporal das ocorrências de malária no Acre.

Palavras-chave: Malária. Amazônia Legal Brasileira. Incidência Parasitária Anual. SIVEP-Malária. Acre.

RESUMEN

La malaria es un problema de salud pública en Brasil. Este estudio tiene como objetivo analizar el número de casos y la Incidencia Parasitaria Anual (IPA) de malaria en Brasil.

Para este propósito, se compiló el número de casos de infección por malaria y se clasificaron en tres categorías diferentes según su región de incidencia: en todo el dominio de Brasil, en los Estados pertenecientes a la Amazonía Legal Brasileña y en los municipios de Acre. El IPA de malaria en los municipios brasileños se calculó dividiendo el número de casos de malaria por la población total y multiplicado por 1000. Se prestó especial atención a Acre en el intervalo de tiempo entre 2003 y 2017. Se registraron un total de 4.647.102 casos de malaria en la Amazonía Legal Brasileña entre 2003 y 2017, lo que representa el 99,99% del total de casos nacionales. Se constató que la IPA de la malaria disminuyó en la Amazonía Legal Brasileña en ese período. Amazonas, Pará, Rondônia y Acre fueron los estados con mayor número de ocurrencias. Entre ellos, solo Acre mostró una tendencia creciente en el número de casos en 2017 en comparación con los casos de infección notificados en 2003. Tres municipios, a saber, Cruzeiro do Sul, Mâncio Lima y Rodrigues Alves, presentaron la mayor parte del número total de casos. Su número de casos también aumentó durante el período investigado. Los hallazgos de este trabajo también revelan que la transmisión de la malaria no ocurre de manera homogénea dentro de la Amazonía Legal Brasileña. Este estudio proporciona un análisis completo e importante de la evolución espacial y temporal de los casos de malaria en Acre.

Palabras clave: Malaria. Amazonia Legal Brasileña. Incidencia Parasitaria Anual. SIVEP-Malaria. Acre.

INTRODUCTION

Malaria is an acute and potentially lethal infectious disease. It causes fever, chills, sweating and headache and occurs mainly in tropical and subtropical regions of the planet, causing social and economic losses to the vulnerable population (BRASIL, 2009; WHO, 2012). The World Health Organization (WHO) estimated that in 2017 there were 219 million cases of malaria in the world, most of which were registered in the African continent; 975,700 cases and 625 deaths were recorded in the Americas for the same period (WHO, 2018).

Brazil has approximately 50% of the cases in the American continent, which makes the disease a public health problem, due to not only the significant number of people infected annually but also to its high clinical severity (BRASIL, 2006). In the country, the cases occur mainly in the Amazon region, having the protozoa species *Plasmodium vivax*, *Plasmodium falciparum,* and *Plasmodium malariae* as the causative species. The main vector is the mosquito *Anopheles darling* (BRASIL, 2009; BRASIL, 2010a). The notification of the disease is compulsory in the entire country. When the cases occur inside the Amazon region, it should be made through the national online

platform called Malaria Epidemiological Surveillance Information System, also known as SIVEP-Malaria. For the infection cases observed in areas belonging to the region known as Extra-Amazon – composed of 17 States and Distrito Federal –, this notification is conducted using the Information System on Diseases of Compulsory Declaration (Sinan) (BRASIL, 2009; BRASIL, 2010b).

The number of malaria cases throughout Brazil fluctuates over the years without a consistent trend. In the 1940s decade, the number of cases was estimated as being approximately six million, and the corresponding area of occurrence covered a large extension of the national territory (BRASIL, 2010a). Through an eradication campaign, both, the number of cases and the area of occurrence decreased significantly, reaching the lowest values at the beginning of the 1960s (BARATA, 1995). However, as a result of the expansion of the agricultural frontier over the Amazon, the region started facing an intense settlement process which led to an increase in deforestation, cities and agro-industry growth, and the people migratory movement in search of job opportunities. These factors were responsible for the advent of a new scenario of intense transmission of malaria in Brazil (OLIVEIRA-FERREIRA et al., 2010).

In the 1990s decade, the fluctuation tendency for the number of cases and mortality associated with malaria persisted. In the beginning of the decade, a decrease in mortality occurred after improvements in diagnosis and treatments of the disease (LADISLAU et al., 2006). In the later 1990s, a new increase in the number of cases was registered, leading the Brazilian government to implement a systematic plan for controlling the disease within the Legal Amazon, the so-called Plan of Intensification of Malaria Control Actions (PIACM) (OLIVEIRA-FERREIRA et al., 2010).

The Amazon region has geographical, biological, and ecological characteristics that favor the occurrence of malaria. For example, one can cite high precipitation indexes and temperature, the presence of the vector (mosquito *Anopheles*), and deforestation. The interaction of these factors, associated with socioeconomic, political and cultural aspects (such as control actions, different land occupation forms, economic exploitation of natural resources, and working conditions), determine the transmission process and endemicity of the disease (BARATA, 1995; BRASIL, 2006; BRASIL, 2010a). Climatic and hydrological factors can also affect the spatial and temporal distribution of the disease, changing for example the distribution of the vector

and causing malaria transmission to be heterogeneously dispersed in the region (BRASIL, 2006; BRASIL, 2010a; COUTINHO et al., 2018).

Areas with high transmission rates are favored by the type of people occupation. Settlements or invasions expose people to risk, mainly due to the high density of mosquitoes, migrant populations with low immunity, precarious housing, difficult access and/or lack of health services, and low adherence to prevention measures (BRASIL, 2006).

The risk of contracting malaria can be measured using the Annual Parasite Incidence (API) of malaria parameter, which estimates the risk of the disease occurrence for every 1,000 inhabitants of a given population over a period of time. The results obtained classify the sites as high, medium, and low risk. It also reports the areas without transmission (BRASIL, 2009; BRASIL, 2010a).

The knowledge of the epidemiological dynamics of malaria is important for health agencies to promote appropriate strategies to combat the disease (SOUSA et al., 2015). Also, intending to reduce the risk of malaria, it is important to include in scientific studies the spatial variability of the disease (AYELE et al., 2013). In this context, this study aims to provide a descriptive analysis of the number of cases and the spatial variability of the malaria API index in Brazil. Considering that the cases of malaria occur mainly in the Brazilian Legal Amazon, Acre was chosen due to its significantly high number of cases and evolution over time, with special attention to the period from 2003 to 2017.

METHODS

Study area

State of Acre (AC) is located in the North region of Brazil, bordering Peru and Bolivia. Acre has an area of 164,123.74 km^2 with a population of 733,559 inhabitants according to the 2010 Census (IBGE, 2010). It was estimated that a total of 829,619 inhabitants were living in Acre in 2017 (IBGE, 2019). Acre integrates the Brazilian Legal Amazon together with the States of Amapá (AP), Amazonas (AM), Maranhão (MA), Mato Grosso (MT), Pará (PA), Rondônia (RO), Roraima (RR) and Tocantins (TO) (IPEA, 2008). The Extra-Amazon region is composed of all other Brazilian States, namely,

Alagoas (AL), Bahia (BA), Ceará (CE), Espírito Santo (ES), Goiás (GO), Mato Grosso do Sul (MS), Minas Gerais (MG), Paraíba (PB), Paraná (PR), Pernambuco (PE), Piauí (PI), Rio de Janeiro (RJ), Rio Grande do Norte (RN), Rio Grande do Sul (RS), Santa Catarina (SC), São Paulo (SP), Sergipe (SE), and Distrito Federal (DF).

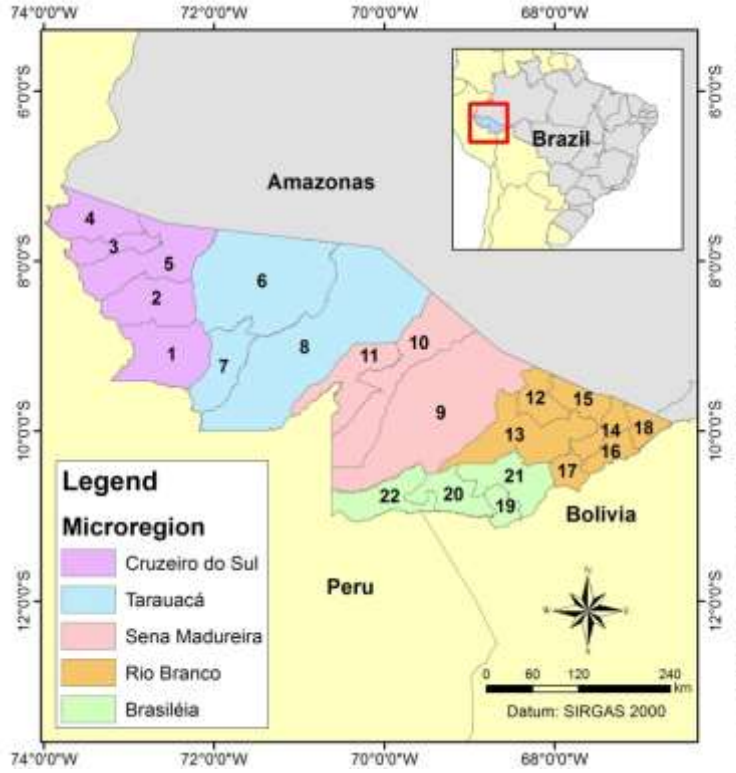
Acre is divided into 22 municipalities which are grouped into five microregions, as shown in Figure 1. The Cruzeiro do Sul Microregion includes the municipalities of Marechal Thaumaturgo, Porto Walter, Rodrigues Alves, Mâncio Lima, Cruzeiro do Sul. The Tarauacá Microregion includes Tarauacá, Jordão and Feijó municipalities. Sena Madureira Microregion is formed by the municipalities of Sena Madureira, Manoel Urbano and Santa Rosa do Purus. The Rio Branco Microregion contains the municipalities of Bujari, Rio Branco, Senador Guiomard, Porto Acre, Plácido de Castro, Capixaba, and Acrelândia. The Brasiléia Microregion includes the municipalities of Epitaciolândia, Brasiléia, Xapuri and Assis Brasil (IBGE, 2017).

The climate of Acre is equatorial hot and humid, with high precipitation levels, high relative humidity and high temperatures, whose annual average is approximately 24.5ºC. The rainfall pattern has a dry period characterized by reduced rainfall from June to August and a rainy period between September and May with high monthly rainfall. The predominant natural vegetation is tropical forests (ACRE, 2010).

Data analysis

This descriptive research used data of malaria cases registered by each probable municipality of infection occurrence between 2003 and 2017. The data were provided upon request to the Ministry of Health through the Electronic System of the Citizen Information Service (e-SIC, in Portuguese). The data is originally stored in the platform SIVEP-Malaria (SIVEP-Malária, 2018). The temporal period between 2003 and 2017 was chosen based on the fact that the beginning of the case records in the SIVEP-Malaria system started in 2003. Complete data without changes was only available in the beginning of this work until the year 2017.

Figure 1 - Map of the study area: Acre. The five microregions of the State are highlighted in this figure with different colors. The corresponding municipalities are indicated in the map by numbers and their names are shown in the right side table.



Municipalities	Number
Marechal Thaumaturgo	1
Porto Walter	2
Rodrigues Alves	3
Mâncio Lima	4
Cruzeiro do Sul	5
Tarauacá	6
Jordão	7
Feijó	8
Sena Madureira	9
Manoel Urbano	10
Santa Rosa do Purus	11
Bujari	12
Rio Branco	13
Senador Guiomard	14
Porto Acre	15
Plácido de Castro	16
Capixaba	17
Acrelândia	18
Epitaciolândia	19
Brasiléia	20
Xapuri	21
Assis Brasil	22

Source: created by the authors (2022).

Using the number of people infected with malaria, data was compiled and systematically characterized for the numbers of cases in Brazil, in the States of the Brazilian Legal Amazon, and in the municipalities of Acre. The entire area of Maranhão was considered as belonging to the Brazilian Legal Amazon. Besides that, using the number of cases and the data from the Population Count (IBGE, 2007), the Demographic Census (IBGE, 2010), and the Population Estimates (IBGE, 2019), the Annual Parasite Incidence (API) of malaria in the Brazilian municipalities was calculated using Equation (1) (BRASIL, 2010a).

$$API = \frac{number\ of\ positive\ malaria\ tests}{total\ population}\ x\ 1000 \qquad (1)$$

The analyzed regions were classified according to the following criteria: *No transmission*: API = 0; *low risk*: API between 0.01 and 9.99; *medium risk*: API between 10.00 and 49.99; and *high risk*: API ≥ 50.00 (BRASIL, 2006).

The API of malaria in the Brazilian States was calculated as the average of the API from the municipalities. API from Brazilian Legal Amazon was calculated as the average of the API from the States that belong to the Legal Amazon and the API from the Extra-Amazon Region as the average of the API from the States that do not belong to the Legal Amazon. A map of Acre was created using the geoprocessing software ArcGIS® 10.7 (ESRI, 2020) with the average of the API from each municipality for the period between 2003 and 2017.

RESULTS

Malaria in Brazil and in the Brazilian Legal Amazon

Table 1 shows the total number of malaria cases in Brazil and the corresponding infections that occurred in both, the Legal Amazon and Extra-Amazon regions. The total number of cases in the Brazilian Legal Amazon was 4,647,102 occurrences, which represents 99.99% of the total number of malaria cases in Brazil. Only 275 cases were registered in the Extra-Amazon region. The annual average of occurrences for this period was 309,825 cases. Table 1 also reveals that the highest record of cases occurred in 2005 with a total of 597,049 occurrences. From 2006 to 2016, the number of malaria cases gradually decreased to 141,204 cases. In 2017, there was an increase of 33.99% in the number of cases in relation to 2016.

The API of malaria for the Brazilian Legal Amazon displayed in Table 1 shows that the risk evolved from medium in 2003 to high between 2004 and 2006. In the period between 2007 and 2017, the risk returned to medium. The highest peak was found in 2005, whose API was 75.27 cases per thousand inhabitants. The average in this region was 34.86 cases per thousand inhabitants in the period between 2003 and 2017. The API of malaria showed a downward trend in the analyzed period. In the Extra-Amazon Region, the risk remained low throughout the period, with an average of 0.0003 cases per thousand inhabitants.

Table 1 - Number of malaria cases and API of malaria from Brazil, Brazilian Legal Amazon and Extra-Amazon region between 2003 and 2017.

Year	Brazilian Legal Amazon			Extra-Amazon Region			Brazil
	Number of cases	API	Risk	Number of cases	API	Risk	Number of cases
2003	401021	37.85	Medium	37	0.00083		**401058**
2004	453535	52.29		31	0.00043		**453566**
2005	597019	75.27	High	30	0.00048		**597049**
2006	539815	69.28		26	0.00034		**539841**
2007	448645	48.89		25	0.00018		**448670**
2008	308753	30.89		26	0.00033		**308779**
2009	301588	31.30		14	0.00026		**301602**
2010	325328	31.86		27	0.00035	Low	**325355**
2011	260453	24.93		18	0.00018		**260471**
2012	234500	21.90	Medium	16	0.00023		**234516**
2013	169196	19.90		9	0.00006		**169205**
2014	138925	18.71		7	0.00009		**138932**
2015	137931	19.72		3	0.000003		**137934**
2016	141202	19.30		2	0.00001		**141204**
2017	189191	20.81		4	0.0004		**189195**
Average	**309806.80**	**34.86**	**Medium**	**18.33**	**0.0003**	**Low**	**309825.13**
Total	**4647102**	**-**	**-**	**275**	**-**	**-**	**4647377**

Source: created by the authors and adapted from SIVEP-Malária (2018).

Table 2 shows the number of cases from the States of the Brazilian Legal Amazon. The highest number of cases was registered for the period between 2003 and 2017 in Amazonas, Pará, Rondônia, and Acre. The sum of the cases for these States corresponded to 4,112,657 occurrences, representing 88.49% of the total records of the disease in Brazil for the period.

Table 2 - Number of malaria cases and API of malaria registered in the Brazilian Legal Amazon States between 2003 and 2017.

Year	Brazilian Legal Amazon States																	
	AC		AP		AM		MA		MT		PA		RO		RR		TO	
	Number of cases	API	Number of cases	API	Number of cases	API	Number of cases	API	Number of cases	API	Number of cases	API	Number of cases	API	Number of cases	API	Number of cases	API
2003	11332	30.48	12182	73.51	143378	50.99	9497	2.69	6034	4.05	117367	27.17	89813	76.64	10871	74.31	547	0.8
2004	28627	60.69	14360	77.96	152538	69.7	12159	3.34	7054	4.33	111069	23.02	102463	77.97	24924	153.07	341	0.49
2005	54147	126.28	22806	130.1	232016	122.55	9234	2.25	9840	6.68	125075	27.66	112960	81.2	30688	180.34	253	0.4
2006	87961	183.6	24018	125.93	193620	112.27	7326	1.9	8143	5.27	102717	23.02	96144	69.33	19783	101.98	103	0.18
2007	48527	88.5	17067	88.32	202954	111.99	4951	1.28	7853	3.39	76520	15.25	76540	53.08	14176	78.1	57	0.08
2008	25516	43.26	12262	60	139229	77	3378	0.87	3715	1.3	68996	13.73	46272	30.63	9368	51.2	17	0.02
2009	25991	41	12690	56.03	102082	58.54	3991	1.11	3257	1.03	100413	20.9	39615	24.76	13529	78.3	20	0.03
2010	36231	52.8	12433	48.35	73927	34.94	2331	0.58	2165	0.75	136466	30.64	42703	22.54	19055	96.08	17	0.02
2011	22233	34.65	17097	66.45	59987	27.35	2291	0.6	1578	0.63	116117	24.31	29280	13.96	11864	56.42	6	0.002
2012	27005	39.83	13058	52.82	82975	46.89	971	0.22	1064	0.34	80305	16.97	23195	8.37	5923	31.66	4	0.003
2013	33755	48.31	13504	48.12	76114	45.19	546	0.12	1130	0.5	25497	4.86	13805	5.08	4829	26.9	16	0.01
2014	30982	46.09	12859	48.65	66787	37.29	598	0.18	979	0.28	11470	2.08	9534	3.38	5713	30.42	3	0.003
2015	26632	40.76	13068	60.22	74370	41.61	173	0.04	1189	0.31	9585	1.96	6738	2.63	6176	29.99	0	0
2016	37170	53.63	13279	52.62	56777	28.35	175	0.04	796	0.2	18302	3.51	8264	4.2	6430	31.17	9	0.01
2017	36009	49.74	14466	40.47	82723	43.1	339	0.07	596	0.15	37103	8.04	6734	3.62	11184	42.06	37	0.01
Total	**532118**	-	**225149**	-	**1739477**	-	**57960**	-	**55393**	-	**1137002**	-	**704060**	-	**194513**	-	**1430**	-
Average	**35474.53**	**62.64**	**15009.93**	**68.64**	**115965.13**	**60.52**	**3864.00**	**1.02**	**3692.87**	**1.95**	**75800.13**	**16.21**	**46937.33**	**31.83**	**12967.53**	**70.80**	**95.33**	**0.14**

AC = Acre, AP = Amapá, AM = Amazonas, MA = Maranhão, MT = Mato Grosso, PA = Pará, RO = Rondônia, RR = Roraima, TO = Tocantins.

Source: created by the authors and adapted from SIVEP-Malária (2018).

Most of the States pertaining to the Brazilian Legal Amazon had a downward trend in the number of cases during the analyzed period (2003-2017). Amazonas had a decrease of 42.30% in 2017 in relation to 2003. Pará had a decrease of 68.39%, whereas Maranhão presented the highest decrease, 96.43%. The other States, however, displayed a different trend. Acre, Amapá, and Roraima showed an increase in the number of occurrences in 2017 when compared to 2003. The highest increase was registered in Acre (217.76%), followed by Amapá (18.75%) and Roraima (2.88%).

The API of malaria from the Brazilian Legal Amazon shown in Table 2 indicated that the risk of contracting malaria decreased in all States, except in Acre. This state had an API of 30.48 cases per thousand inhabitants in 2003 and 49.74 cases per thousand inhabitants in 2017, corresponding to an increase of 63.19%. The corresponding API of malaria varied from medium to high. The highest risk in this State was registered in 2006, reaching 183.60 cases per thousand inhabitants. Acre showed a higher API of malaria in relation to the other States in the years of 2006, 2013, 2016 e 2017.

The States of Amazonas, Roraima, and Amapá, with Acre, had the highest API averages in the analyzed period (Table 2). The highest API for these States occurred in 2005, with values of 180.34 cases per thousand inhabitants for Roraima, 130.10 cases per thousand inhabitants for Amapá, and 122.55 cases per thousand inhabitants for Amazonas. All these three situations are found in the high risk of infection category.

Malaria in Acre

Acre is highlighted within the Brazilian Legal Amazon for being among the States with the highest number of disease cases in the period between 2003 and 2017 (Table 2). Another important fact about Acre is that both the cases of malaria and the risk of contracting the disease increased during this period.

Three municipalities represent the highest part of the total number of cases of malaria in the State: Cruzeiro do Sul, Mâncio Lima, and Rodrigues Alves, as shown in Table 3. The number of occurrences in these three municipalities was 464,588 cases and corresponded to 87.31% of the total registered in the State between 2003 and 2017. Cruzeiro do Sul corresponded individually to 53.77% of the records in this period with 286,104 cases. These three municipalities had an increase in the number of cases in the period. The highest increase occurred in Mâncio Lima (1,167.57%), followed by Cruzeiro

do Sul (437.22%) and Rodrigues Alves (187.10%). As occurred in the State, these three municipalities had the same evolution over time. Until 2006 was registered an increase in the number of occurrences, followed by a decrease with subsequent oscillations in the data.

Table 4 shows that the municipalities of Cruzeiro do Sul, Mâncio Lima and Rodrigues Alves had also the highest values of API of malaria, as occurred in the number of cases of the disease. These municipalities had high API during the analyzed period, with values, in general, considerably higher than other municipalities in the State. In 2003, five municipalities had high risk for malaria in the State, namely Acrelândia, Capixaba, Cruzeiro do Sul, Mâncio Lima and Rodrigues Alves. In 2017 only Cruzeiro do Sul, Mâncio Lima and Rodrigues Alves had high risk for malaria. Cruzeiro do Sul was the municipality with the highest number of cases. However, it is not the municipality with higher risk. Mâncio Lima and Rodrigues Alves are the municipalities with a higher risk for malaria in the State.

Using malaria API average for the municipalities of Acre, a map was created for the risk situation in each locality as reported in Figure 2. Based on this map, the microregions were identified according to their risk. Figure 2 shows that between 2003 and 2017 the Cruzeiro do Sul Microregion had three municipalities with a high risk of malaria: Rodrigues Alves (indicated as number 3 in Figure 2); Mâncio Lima (4); and Cruzeiro do Sul (5), while in the same microregion Marechal Thaumaturgo (1) and Porto Walter (2) had medium risk.

From the three municipalities of Tarauacá Microregion, two had a medium risk for malaria - Tarauacá (6) and Jordão (7) – and one had a low risk for the disease - Feijó (8). In the Rio Branco Microregion, six municipalities had medium risk for malaria: Bujari (12); Senador Guiomard (14); Porto Acre (15); Plácido de Castro (16); Capixaba (17); and Acrelândia (18). Rio Branco, the capital of Acre had low risk. All municipalities of Sena Madureira and Brasiléia Microregions had low risk for malaria.

The risk for these microregions shown in Figure 2 indicates that it is not homogeneously distributed in Acre and exist a microregion where the risk is higher.

Table 3 - Number of malaria cases per year in the municipalities of Acre between 2003 and 2017.

Municipalities of Acre	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total	%
Cruzeiro do Sul	3890	14672	25044	45432	26365	13465	14690	21621	12681	16053	19701	17179	13936	20477	20898	**286104**	**53.77**
Mâncio Lima	737	1868	11029	15524	6690	4444	5047	5729	4778	5205	7313	6076	5382	8191	9342	**97355**	**18.30**
Rodrigues Alves	1644	2719	10384	15871	7894	3103	2306	4441	3586	3701	3624	5175	5343	6618	4720	**81129**	**15.25**
Tarauacá	648	830	2248	2991	1934	2403	2454	2662	533	973	1771	1457	950	917	175	**22946**	**4.31**
Plácido de Castro	731	1857	826	2278	1314	395	246	479	169	47	125	51	48	37	70	**8673**	**1.63**
Acrelândia	801	1543	876	1156	859	262	70	132	56	60	543	120	32	34	92	**6636**	**1.25**
Rio Branco	1013	1582	980	732	517	223	148	201	125	151	95	70	97	135	125	**6194**	**1.16**
Senador Guiomard	558	885	482	1178	1073	446	98	148	31	99	82	70	153	236	161	**5700**	**1.07**
Porto Walter	61	125	786	692	563	153	359	379	72	371	289	347	522	364	288	**5371**	**1.01**
Porto Acre	263	588	227	399	326	126	86	70	106	150	55	30	38	17	19	**2500**	**0.47**
Capixaba	396	616	307	315	133	62	28	32	6	10	3	4	9	7	7	**1935**	**0.36**
Jordão	125	490	227	190	184	232	225	76	7	39	36	46	15	8	8	**1908**	**0.36**
Marechal Thaumaturgo	83	78	117	425	170	69	199	174	55	85	80	98	63	70	76	**1842**	**0.35**
Bujari	113	337	235	153	211	60	10	30	9	3	3	202	17	50	12	**1445**	**0.27**
Xapuri	165	196	92	226	156	35	3	7	0	9	3	1	5	0	6	**904**	**0.17**
Feijó	63	57	121	321	107	10	6	32	5	16	6	40	9	4	6	**803**	**0.15**
Sena Madureira	17	81	74	36	13	18	3	6	3	3	4	5	5	2	3	**273**	**0.05**
Brasiléia	11	87	86	14	7	3	0	5	5	3	1	0	3	0	0	**225**	**0.04**
Assis Brasil	8	4	0	3	2	3	0	4	4	23	15	2	2	2	1	**73**	**0.01**
Epitaciolândia	4	7	2	22	5	1	6	2	1	0	1	1	2	0	0	**54**	**0.01**
Manoel Urbano	1	4	3	0	4	2	7	0	1	2	5	5	0	0	0	**34**	**0.01**
Santa Rosa do Purus	0	1	1	3	0	1	0	1	0	2	0	3	1	1	0	**14**	**0.003**
Total	**11332**	**28627**	**54147**	**87961**	**48527**	**25516**	**25991**	**36231**	**22233**	**27005**	**33755**	**30982**	**26632**	**37170**	**36009**	**532118**	

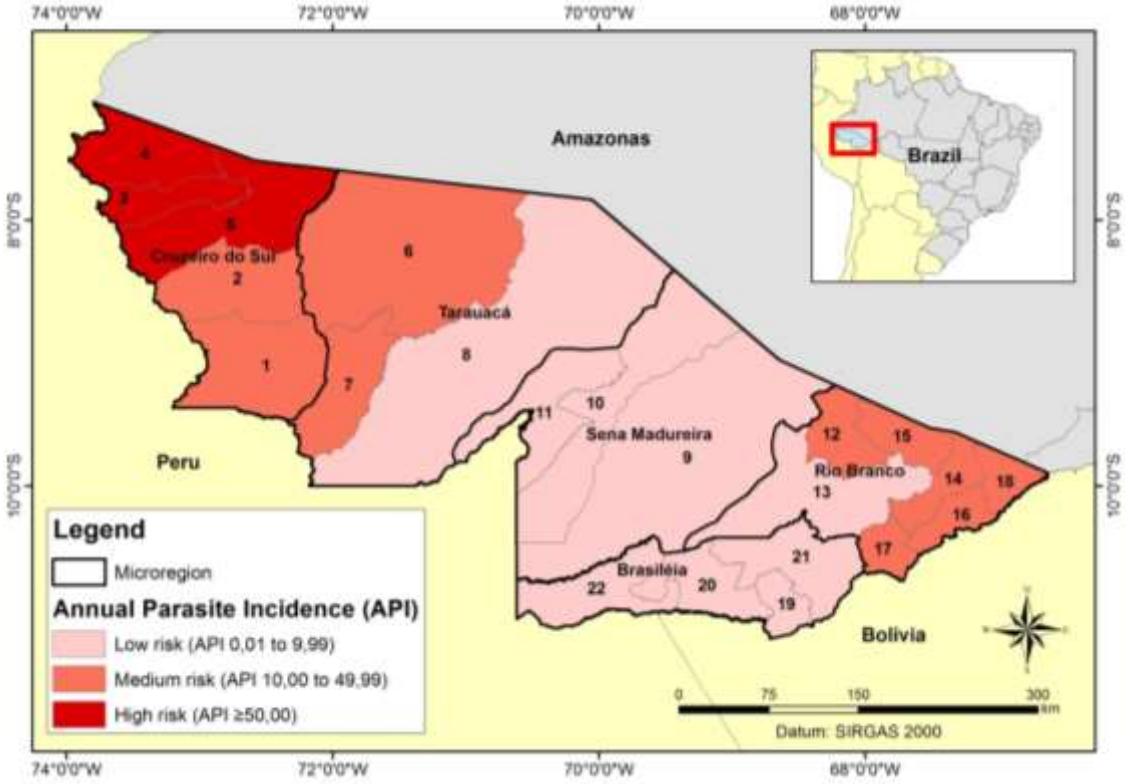
Source: created by the authors and adapted from SIVEP-Malária (2018).

Table 4 - API of malaria per year in the municipalities of Acre between 2003 and 2017.

Municipalities of Acre	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average	Risk
Mâncio Lima	60.92	157.2	865.22	1183.59	485.31	308.89	341.61	376.76	307.19	327.56	445.64	361.77	313.4	466.86	521.61	**434.90**	
Rodrigues Alves	192.51	290.9	1060.02	1588.85	635.18	238.33	171.32	308.64	241.77	242.53	226.95	314.11	314.78	378.95	263.03	**431.19**	**High**
Cruzeiro do Sul	52.93	186.23	296.96	523.86	356.53	176.26	190.77	275.4	160.17	201.12	245.11	212.21	170.95	249.49	252.94	**236.73**	
Porto Walter	11.76	23.95	158.4	142.65	68.91	17.87	40.54	41.3	7.62	38.2	28.49	33.2	48.52	32.91	25.37	**47.98**	
Tarauacá	24.15	28.15	74.11	97.39	60.12	72.02	72.43	74.8	14.73	26.47	47.14	38.14	24.47	23.26	4.37	**45.45**	
Acrelândia	92.12	144.64	76.5	98.08	74.57	21.86	5.72	10.53	4.38	4.61	40.67	8.82	2.31	2.41	6.4	**39.57**	
Plácido de Castro	45.6	116.57	49.49	133.89	76.14	22.04	13.49	27.83	9.71	2.67	7.02	2.84	2.64	2.02	3.78	**34.38**	
Jordão	27.6	107.36	49	40.76	30.37	36.63	34.51	11.56	1.04	5.65	5.04	6.28	2	1.04	1.02	**23.99**	
Senador Guiomard	26.35	45.75	23.51	56.1	56.88	22.86	4.98	7.33	1.52	4.81	3.94	3.33	7.22	11.04	7.47	**18.87**	**Medium**
Capixaba	64.96	97.98	43.44	42.55	15.75	6.97	3.01	3.64	0.66	1.07	0.31	0.39	0.86	0.65	0.63	**18.86**	
Porto Acre	21.71	51.14	18.78	32.35	23.77	8.81	5.86	4.7	6.97	9.66	3.43	1.83	2.27	0.99	1.09	**12.89**	
Bujari	17.02	44.03	27.9	17.48	32.25	8.9	1.48	3.54	1.04	0.34	0.33	22.02	1.82	5.26	1.24	**12.31**	
Marechal Thaumaturgo	9.93	9.29	13.84	50.11	13.02	5.03	13.94	12.23	3.75	5.62	5.05	5.98	3.73	4.02	4.25	**10.65**	
Xapuri	13.35	14.82	6.72	16.27	10.9	2.36	0.2	0.44	0	0.54	0.18	0.06	0.28	0	0.33	**4.43**	
Feijó	2.14	1.6	3.16	8.15	3.42	0.31	0.19	0.99	0.15	0.49	0.19	1.23	0.28	0.12	0.19	**1.51**	
Rio Branco	3.69	5.53	3.21	2.33	1.78	0.74	0.48	0.6	0.37	0.43	0.27	0.19	0.26	0.36	0.33	**1.37**	
Assis Brasil	2.18	0.82	0	0.58	0.37	0.54	0	0.66	0.65	3.65	2.31	0.3	0.3	0.29	0.14	**0.85**	
Brasiléia	0.61	5.14	4.85	0.78	0.37	0.15	0	0.23	0.23	0.13	0.04	0	0.13	0	0	**0.84**	**Low**
Sena Madureira	0.55	2.57	2.24	1.07	0.38	0.51	0.08	0.16	0.08	0.08	0.1	0.12	0.12	0.05	0.07	**0.55**	
Manoel Urbano	0.14	0.56	0.39	0	0.56	0.27	0.93	0	0.12	0.24	0.6	0.59	0	0	0	**0.29**	
Epitaciolândia	0.33	0.55	0.15	1.55	0.37	0.07	0.42	0.13	0.06	0	0.06	0.06	0.12	0	0	**0.26**	
Santa Rosa do Purus	0	0.34	0.29	0.84	0	0.24	0	0.21	0	0.4	0	0.54	0.17	0.17	0	**0.21**	
Average	**30.48**	**60.69**	**126.28**	**183.60**	**88.50**	**43.26**	**41.00**	**52.80**	**34.65**	**39.83**	**48.31**	**46.09**	**40.76**	**53.63**	**49.74**	**62.64**	**High**

Source: created by the authors and adapted from SIVEP-Malária (2018).

Figure 2 - Average API of malaria in the municipalities of Acre between 2003 and 2017*.



*Note: The numbers in the map indicate the municipalities that belong to the microregions pertaining to Acre. Cruzeiro do Sul Microregion: Marechal Thaumaturgo (1), Porto Walter (2), Rodrigues Alves (3), Mâncio Lima (4), Cruzeiro do Sul (5); Tarauacá Microregion: Tarauacá (6), Jordão (7), Feijó (8); Sena Madureira Microregion: Sena Madureira (9), Manoel Urbano (10), Santa Rosa do Purus (11); Rio Branco Microregion: Bujari (12), Rio Branco (13), Senador Guiomard (14), Porto Acre (15), Plácido de Castro (16), Capixaba (17), Acrelândia (18); and Brasiléia Microregion: Epitaciolândia (19), Brasiléia (20), Xapuri (21), and Assis Brasil (22).

Source: created by the authors (2021).

DISCUSSION

Malaria is a public health problem in Brazil (OLIVEIRA-FERREIRA et al., 2010). Its occurrence is mostly found in the Legal Amazon, representing 99.99% of the total cases in the country. This fact makes malaria to be an endemic disease in this region. Its transmission does not occur under equal intensity in such region but depends on the interaction among environmental, sociocultural, economic, and political factors. In this scenario one can expect different risks of contracting the disease (BRASIL, 2006).

The rise of the malaria incidence between 2003 and 2005 can be considered multifactorial. Climatic changes, deforestation, disorderly urban growth, and settlements

are some of the factors. Fishponds used for fish farming are also an important contributor to the increase of the mosquito population. The joint effort by the Ministry of Health, States, and municipalities in the Amazon region reduced the cases from 2006 onwards though (OLIVEIRA-FERREIRA et al., 2010).

In 2005 the southwest Amazon went through an intense drought, which led to a fall in precipitation and a fall in the level of rivers, and an increase in temperature (MARENGO et al., 2008). It is probable that the conditions of this drought were favorable for the increase in the number of cases and the risk of malaria in 2005 in this region (OLSON et al., 2010; WOLFARTH et al., 2013).

Acre is a Brazilian State that is highlighted in this scenario with a high risk API of malaria and with a high number of infected people. In this State, the Cruzeiro do Sul Microregion was highlighted, due to the permanent high risk of malaria in the analyzed period. According to Costa et al. (2010), some favorable conditions for the proliferation of infection cases in this region are the proximity of the communities to the forest, continuous transit of infected people, and difficulties in the local surveillance system. In this State, the presence of fishponds subsidized by the state government was also considered an important factor for the perpetuation and increase of malaria in this region of the state (COSTA et al., 2010).

The municipality of Cruzeiro do Sul had a higher number of cases and higher API in 2006, which occurred after the construction of fishponds in 2005. In the Northwest region of Acre, including Cruzeiro do Sul, high fishpond construction rates were also associated with high malaria incidence (REIS et al., 2015). The construction of fishponds can be associated with the high number of malaria cases, as they can become permanent breeding sites for mosquitoes. Many of them were abandoned due to scarcity of financial resources to maintain the activity (COSTA et al., 2010). The construction of these ponds was encouraged by a state program and was stimulated to increase economic development (COSTA et al., 2010; REIS et al., 2015).

Due to the high number of cases in Cruzeiro do Sul in 2005, a plan was elaborated to intensify the actions to control the disease, which contributed to the decrease in the number of cases from 2006 to 2008. The diagnosis and treatment network were improved through strategies such as hiring and qualifying professionals, purchasing equipment, and improving diagnostic stations (COSTA et al., 2010).

In 2006 the highest incidence of malaria occurred in Rodrigues Alves and Mâncio Lima. These municipalities are located on the border of Cruzeiro do Sul, which indicates that malaria transmission is not isolated in this municipality, but it is related to macroregional conditions (COSTA et al., 2010). These Acre municipalities are part of a wide cluster found in other study (BRAZ et al., 2014). The control of the disease must be regional and independent of geographical boundaries (COSTA et al., 2010). The analysis and detection of clusters are important indicators for integrated control actions, also contributing to the reduction in disease epidemics (BRAZ et al., 2014).

The control measures applied in Acre that decreased the number of cases indicate that the disease control is possible in the Legal Amazon based on the early treatment and diagnosis allied to partnerships between the different levels of government (COSTA et al., 2010). Among the strategies implemented in Acre can be included the free and early treatment and the distribution of impregnated bednets (REIS et al., 2015). However, despite that, the occurrence of malaria remains high in some municipalities (BRAZ et al., 2012).

The map created in this paper (Figure 2) shows that some regions of Acre have a higher risk than others. Cruzeiro do Sul Microregion is the region with municipalities that have high risk. Other studies have also identified this same area in the State of Acre as high risk and, therefore, a priority area for malaria control and prevention (REIS et al., 2015; VALLE and LIMA, 2014; MELCHIOR and NETO, 2016). Maps of disease risk are important to public health and helping decision-making, for example, deciding where to conduct interventions (VALLE and LIMA, 2014).

Although malaria is still a severe public health problem in the Legal Amazon, its incidence can be reduced through adequate health services. The joint action of the different levels of political management and the social and economic sectors can lead to disease control (LADISLAU et al., 2006). When treated immediately and appropriately, there is a reduction in mortality and prevention of severe forms of the disease. Therefore, public health policies are important to educate the population about malaria control, as the knowledge of the community helps in the protection and control of vectors (BRASIL, 2006).

CONCLUSIONS

Despite the reduction in the number of cases in Brazil in recent years, the disease is still significant in the country. Acre emerges as an important source of cases, as the State has a high number of infections and high API of malaria. Fishponds probably contributed to the increase in malaria notification in the municipalities where they were built. Cases are not homogeneously distributed in the State and Cruzeiro do Sul Microregion is an area of permanent high risk. These municipalities contribute to the high number of cases and the risk of the State. This work sheds light on the evolution over time from the occurrence and distribution of malaria in Acre, evidencing the areas that need more attention. Adequate health services can reduce the malaria incidence and studies in this field contribute to the knowledge about the disease and in decision making in public health.

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