International Journal of **Health Science**

SEASONALITY IN DENGUE CASE NOTIFICATIONS IN STATE AMAZONAS: A NEW PERSPECTIVE THROUGH ECOLOGICAL STUDY

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Abstract: Dengue is an acute febrile infectious disease, whose vector is the Aedes aegypti mosquito. It can range from asymptomatic to severe symptoms with a risk of shock and death, and is classified as a major public health problem in Brazil. Considering the northern region, specifically the state of Amazonas, it is important to study the relationship between seasonality in the reporting of cases of the disease. OBJECTIVE: To analyze the seasonality of dengue case notifications in the state of Amazonas. METHODOLOGY**:** The study used data from the Epidemiological Epidemiological Monitoring of urban arboviruses - epidemiological weeks 1 to 35 of 2023 of the Secretariat of Health and Environmental Surveillance of the Ministry of Health, database of the Department of Information and Informatics of the Unified Health System (DataSUS), emphasizing SINAN and SIM, National Institute of Meteorology (INMET), administered by the Ministry of Agriculture and Livestock, and the Brazilian Institute of Health. Institute of Geography e Statistics (IBGE). The a cross--sectional ecological methodological approach was adopted, covering the North of Brazil, the state of Amazonas, and four of its main municipalities, from January 2023 to February 2024. Information was analyzed such as sex race/color, schooling, number of cases reported per month in Amazonas and monthly averages for temperature, rainfall, number of cases reported per month and data on sewage disposal services in the four cities. RESULTS AND DISCUSSION: In the period analyzed, Brazil recorded 1,530,940 probable cases of dengue, with the North and Northeast regions being the least affected. However, in the North, especially in the state of Amazonas, the majority of cases are registered among men, of brown race/color and with completed high school. This indicates that the mosquito has no preference for gender, race or educational level. As the focus of this study is the state of Amazonas, in particular the cities of Manaus, Humaitá, Manicoré and Itacoatiara, it can be seen that from November to May there is a significant increase in reported cases, coinciding with the Amazonian winter. This phenomenon is associated with high temperatures, increased humidity, higher rainfall and an increase in flooded areas. In addition, the El Niño climate phenomenon has contributed to the proliferation of Aedes aegypti and the increase in cases. Thus, the seasonality of notifications highlights a serious public health problem in the region. CONCLUSION: It is essential to increase monitoring climate fluctuations and variations order to effectively predict and respond to dengue epidemics. Control and prevention strategies must consider not only epidemiological factors, but also climatic conditions, as these affect virus replication rates. An integrated approach is essential to mitigating the impacts of dengue, protecting public health and reducing the social and economic costs related to epidemics. **Keywords:** Dengue; Aedes aegypti; Seasonality; Brazil; Amazonas.

INTRODUCTION

Dengue is a significant threat to public health worldwide, with an estimated 100-400 million new infections every year, showing a sharp increase in its incidence. In Brazil, around 1,530,940 probable cases were compiled in 2023 alone, showing an endemic-epidemic profile. It is an acute febrile infectious disease whose main vector in the Americas is the *Aedes* mosquito *aegypti*, transmitting the virus through its bite, with infected female being responsible. There is another species called *Aedes albopictus*, but to a lesser extent. It belongs to the *Flavivirus* family, is classified as an arbovirus, has four serotypes (DENV 1, DENV 2, DENV 3, DENV 4), and is a hyperendemic disease in subtropical and tropical climates, especially in urban and suburban areas (1) (2) (3).

This arthropod capable of spreading the virus for the rest of its life after going through the incubation period, which around 4 to 10 days, and can generate the benign or severe form of the disease in humans. This pathology can be asymptomatic, or show clinical signs of high fever, with a sudden onset lasting 2-7 days, headache, myalgia, asthenia, prostration, retro-orbicular pain and skin rashes, or show signs of severity such as severe abdominal pain, bleeding from the mucous membranes, severe dehydration accompanied by hepatomegaly, thrombocytopenia and a lowered level of consciousness. In this situation, the patient should be monitored in hospital due to the risk of shock and may die (4) (5).

Dengue's seasonality is often linked to climate fluctuations and changes, such as rising temperatures, variations in rainfall and relative humidity. These factors create more convenient places for the vector to reproduce, thus boosting its development, dissemination and persistence. In the Brazilian Amazon region, Dengue emerges as the most common arbovirus, imposing a significant burden in terms of public health, social impact and economic challenges for the area. This location is characterized by the seasonal factors mentioned above, thus intensifying the risk of transmission of the disease (6) (7).

It is worth noting that the Amazonian climate is influenced by oceanic and atmospheric processes in the nearby tropical oceans, with the El Niño-Southern Oscillation (ENOS) standing out as one of the most significant over the tropical Pacific. This phenomenon has two well-defined phases, marked by the persistence of abnormally warm (El Niño) and cold (La Niña) sea surface temperature patterns for more than five months in the tropical Pacific (8).

The aim of this study is to concisely demonstrate a correlation of data on the seasonality of dengue case notifications in the state of Amazonas, from January 2023 to February 2024, with the aim of highlighting the importance of a broader study on the region's climate and suspected cases of the arbovirus. In this way, future studies are encouraged to examine any gaps, highlighting ways to effectively address this national public health problem, which is dengue, especially in the northern region of the country.

METHOD

The method adopted was a cross-sectional ecological approach, with a regional scope, highlighting the North of Brazil, emphasizing the state of Amazonas, using secondary data obtained from the "Epidemiological Bulletin - Monitoring of urban arboviruses: epidemiological weeks 1 to 35 of 2023", carried out by the Secretariat of Health and Environmental Surveillance, administered by the Ministry of Health. In addition, by searching the database of the Department of Information and Informatics of the Unified Health System (DataSUS), focusing on SINAN and SIM, the National Institute of Meteorology (INMET), administered by the Ministry of Agriculture and Livestock, and the Brazilian Institute of Geography and Statistics (IBGE). The period used was one year and two months, from January 2023 to February 2024.

The study covered the state of Amazonas, located in the northern region of the country, and four of its main municipalities, listed in an Excel spreadsheet, where some indicators obtained from DataSUS (SINAM and SIM), INMET and IBGE were added: Female and male gender, race/color (white, black, yellow, brown and indigenous), different levels of education, from illiterate to those with higher education, including cases of complete and incomplete education at each level (pri-

mary, secondary and higher education) and the number of cases notified per month in the region. Also taken into account were the number of dengue cases reported per month, the average monthly temperature, rainfall and data on the sewage service sanitation by network collective (network private or public and administration) of the four selected cities in the state of Amazonas (Manaus, Humaitá, Manicoré, Itacoatiara).

RESULTS

Of the 1,530,940 probable dengue cases recorded in 2023, with an incidence coefficient of 753.9 cases per 100,000 inhabitants, in the 5 regions of Brazil, the highest incidence coefficient was found in the South with 1,269.8 cases per 100,000 inhabitants, followed by the Southeast with 1,028.6 cases, and the Midwest with 935.9 cases. The North had 173.8 cases per thousand inhabitants and the Northeast 174.7 cases, considering the results obtained in the "Epidemiological Bulletin - Monitoring urban arboviruses: epidemiological weeks 1 to 35 of 2023", conducted by the Health and Environment Surveillance Secretariat through the Notifiable Diseases Information System, managed by the Ministry of Health. In summary, the South, Southeast and Midwest regions are the most affected by dengue in the country. In 2024, there were a total of 1,501,498 probable cases of dengue reported in the months of January and February. The most affected regions were the Southeast, Midwest and South, while the Northeast and North recorded fewer incidences of the disease, considering the results obtained from the database of the Information and Informatics Department of the Unified Health System - DataSUS (SINAN).

Region	2023	2023
	Cases (n)	Incidence rate
Brazil	1.530.940	753, 9
North	30.153	173,8
North East	95.491	174,7
South East	872.756	1.028, 6
South	380.098	1.269, 8
Midwest	152.442	935,9

Table 1 - Number of probable cases and incidence rate (cases per 100,000 inhabitants) of dengue according to geographical region - Brazil, 2023

Source: Epidemiological Bulletin - Monitoring urban arboviruses, 2023.

Region	2024
	Cases (n)
Brazil	1.501.498
North	21.205
North East	56.717
South East	983.041
South	188.868
Midwest	251.667

Table 2- Number of probable dengue cases by geographic region - Brazil, January to February 2024

Source: SINAN/DATASUS, 2024.

When it comes to the Northern Region, more specifically the state of Amazonas, analyzing the reported cases of dengue fever from January 2023 to February 2024, according to the characteristics of the population, it was shown that the largest number of cases were in males (2,766), brown race/color (4,556) and those with completed high school education (1,446). However, this last piece of information has an addendum as 2,232 cases were left blank, reducing the assertiveness of the survey.
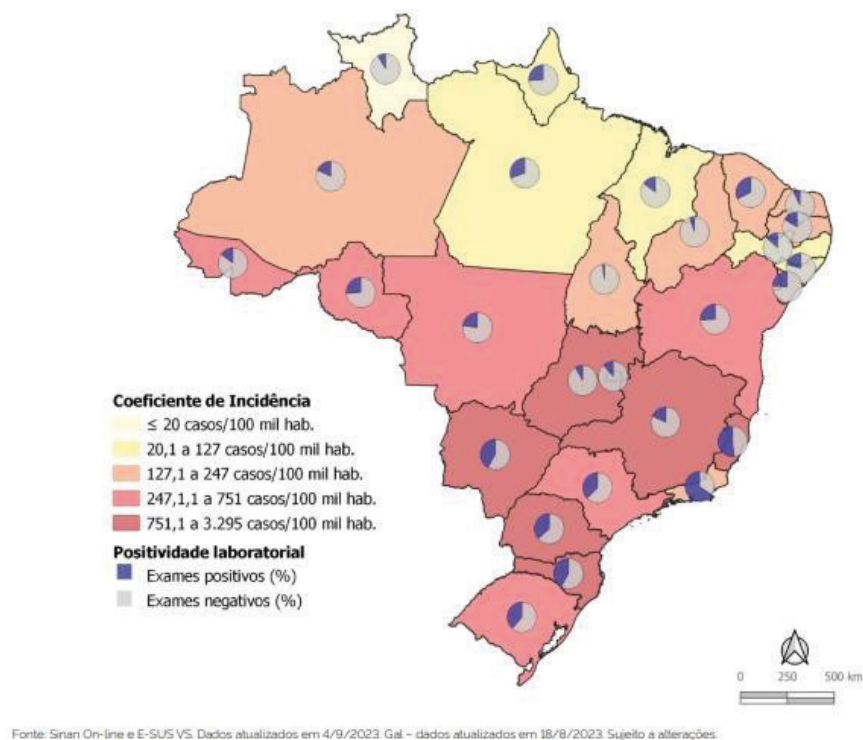
Figure 1- Dengue incidence rate (cases per 100,000 inhabitants) by geographic region - Brazil, 2023

Source: Epidemiological Bulletin - Monitoring urban arboviruses, 2023.
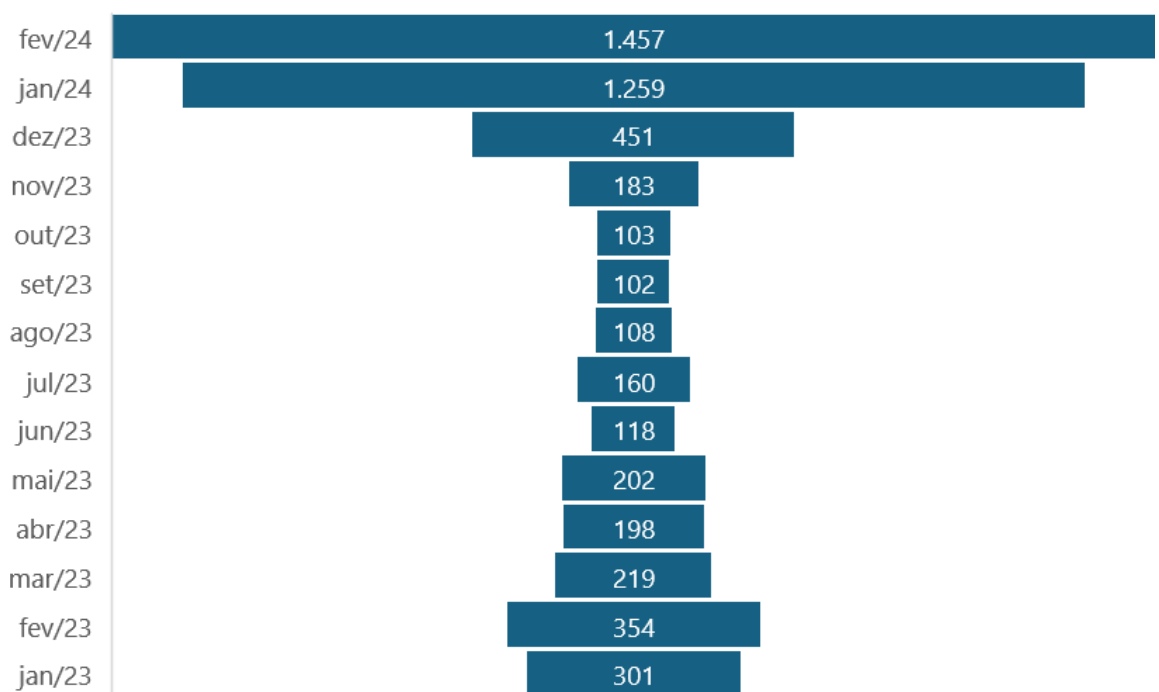

Figure 2- Number of dengue cases reported per month from January 2023 to February 2024 in the state of Amazonas, Brazil.

Source: SINAN/DATASUS, 2024.

Sex	2023	2024	Total
Female	1.144	1.296	2.240
Male	1.352	1.414	2.766
Ignored/ White	3	6	9
Education			
Illiterate	7	15	22
Elementary school incomplete	304	327	631
Complete elementary school	134	90	224
High school incomplete	188	154	342
Complete high school	690	776	1.446
Higher education incomplete	32	59	91
Complete university degree	87	120	207
Ignored/ White	1.057	1.175	2.232
Race/Color			
White	88	138	226
Black	31	48	79
Yellow	17	35	52
Brown	2.238	2.318	4.556
Indigenous	78	136	214
Ignored/ White	47	41	88

Table 3- Number of reported dengue cases according to sex, race/color, schooling in the period 2023 to 2024 in the state of Amazonas - Brazil.

Source: SINAN/DATASUS, 2024.

It is important to quantify the number of dengue case notifications on a monthly basis, given the research carried out in the period from January 2023 to February 2024, considering the fluctuations and climatic variations in the state of Amazonas and, consequently, in the 4 cities listed in the body of the text. It can be seen that in the first two months of 2023, there was an allusive stability in the number of cases, albeit significant. Sequentially, there was a considerable drop until the month of May. The number of cases then stabilized, with few cases until October, and then increased again in November until February 2024, which was the last month of the study. It can be concluded that during the months of November to May, the number of cases increased abruptly, this period being represented by the Amazon winter, showing a link between the phenomena, due to high temperatures, higher relative humidity, excessive rainfall and flooded regions.

Month/Notification	2023	2024
January	301	1.259
February	354	1.457
March	219	-
April	198	-
May	202	-
June	118	-
July	160	-
August	108	-
September	102	-
October	103	-
November	183	-
December	451	-
Total:	2.499	5.215

Table 4- Number of dengue cases notified per month from January 2023 to February 2024 in the state of Amazonas, Brazil.

Source: SINAN/ DATASUS, 2024.

Also taken into account were the average monthly temperature in degrees Celsius in the four main municipalities highlighted in this work, namely Manaus, Humaitá, Manicoré and Itacoatiara, the rainfall and the number of cases reported per month in each of these places, over 14 months. It can be seen that the months with the highest temperatures recorded for the 4 municipalities were August, September, October and November, with Manaus reaching a maximum of 30°C for 3 consecutive months, Itacoatiara reaching a maximum of 30°C during October and Manicoré and Humaitá reaching a maximum of 28°C for 3 consecutive months, but different from each other. An analysis of the data shows that Manaus registered 449 cases, Manicoré 91 cases and Humaitá 102 cases, with peaks of notifications in February 2023. On the other hand, Itacoatiara had only 2 cases over the entire period examined.

Month	Manaus	Manicoré	Itacoatiara	Humaitá
January/ 23	25,9	25,4	25,6	-
February/ 23	26	25,6	26	-
March/ 23	26,6	25,9	26,6	-
April/ 23	27	26,3	26,6	-
May/ 23	27,9	26,8	27,4	-
June/ 23	28,1	26,3	27,1	25,4
July/ 23	29,4	27,6	28	26,4
August/ 23	30,5	28,2	29,2	27,6
September/ 23	30,8	28,4	29,7	28,3
October/ 23	30,8	28,7	30,1	28,6
November/ 23	29,9	27,7	29,5	28,1
December/ 23	27,6	27	27,3	27,5
January/ 24	28,1	26,9	27,2	27
February/ 24	28,4	27	27,9	27,1

Table 5- Average monthly temperature from January 2023 to February 2024 in the regions of Manaus, Manicoré, Itacoatiara and Humaitá - Brazil.

Source: INMET, 2024

Month / Measurement date	Precipitation	Tem. M. M.
January / 31.01.23	276,6	25,9
February/ 28.02.23	-	26
March/ 31.03.23	366,6	26,6
April/ 30.04.23	242	27
May/ 31.05.23	132,4	27,9
June/ 30.06.23	48,4	28,1
July/ 31.07.23	69,8	29,4
August/ 31.08.23	18	30,5
September/ 30.09.23	42,8	30,8
October/ 31.10.23	90,2	30,8
November/ 30.11.23	134,8	29,9
December/ 31.12.23	307,8	27,6
January/ 31.01.24	137	28,1
February/ 29.02.24	301	28,4

Table 6- Average monthly temperature and rainfall for the period from January 1, 2023 to February 29, 2024, in the Manaus region

Source: INMET, 2024

Month / Measurement date	Precipitation	Tem. M. M.
January / 31.01.23	450,2	25,4
February/ 28.02.23	400,6	25,6
March/ 31.03.23	312,6	25,9
April/ 30.04.23	315	26,3
May/ 31.05.23	162	26,8
June/ 30.06.23	92,2	26,3
July/ 31.07.23	3,8	27,6
August/ 31.08.23	85,6	28,2
September/ 30.09.23	113,6	28,4
October/ 31.10.23	219,2	28,7
November/ 30.11.23	170,4	27,7
December/ 31.12.23	333,6	27
January/ 31.01.24	-	26,9
February/ 29.02.24	-	27

Table 7- Average monthly temperature and rainfall for the period from January 1, 2023 to February 29, 2024, in the Manicoré region

Source: INMET, 2024

Month / Measurement date	Precipitation	Tem. M. M.
January / 31.01.23	-	25,6
February/ 28.02.23	-	26
March/ 31.03.23	-	26,6
April/ 30.04.23	-	26,6
May/ 31.05.23	-	27,4
June/ 30.06.23	-	27,1
July/ 31.07.23	-	28
August/ 31.08.23	-	29,2
September/ 30.09.23	-	29,7
October/ 31.10.23	-	30,1
November/ 30.11.23	-	29,5
December/ 31.12.23	-	27,3
January/ 31.01.24	-	27,2
February/ 29.02.24	-	27,9

Table 8- Average monthly temperature and rainfall for the period from January 1, 2023 to February 29, 2024, in the Itacoatiara region:

Source: INMET, 2024

Month / Measurement date	Precipitation	Tem. M. M.
January / 31.01.23	-	-
February/ 28.02.23	-	-
March/ 31.03.23	-	-
April/ 30.04.23	-	-
May/ 31.05.23	-	-
June/ 30.06.23	103,6	25,4
July/ 31.07.23	1	26,4
August/ 31.08.23	32,8	27,6
September/ 30.09.23	88	28,3
October/ 31.10.23	34,4	28,6
November/ 30.11.23	105,2	28,1
December/ 31.12.23	80,8	27,5
January/ 31.01.24	289	27
February/ 29.02.24	305	27,1

Table 9- Average monthly temperature and rainfall for the period from January 1, 2023 to February 29, 2024 in the Humaitá region

Source: INMET, 2024

With regard to the sanitation sewage service through a collective network in operation, it was noted that all four cities have basic sanitation, i.e. sanitation infrastructure, with only their administration changing, showing that Manaus is a private network, Manicoré is managed by the public authorities and is represented by the municipality, and Humaitá and Itacoatiara are municipal authorities.

In relation to climate fluctuations and variations and the continental equatorial air mass, it is evident that during the months of November to May, cases gradually increase, coinciding with the Amazon winter period (milder temperatures, even high temperatures, higher relative humidity, high rainfall, places with flooding), favoring proliferation in the state of Amazonas. With the addition of El Niño, even with the increase in temperature, regions of drought and intermittent rainfall, these factors aligned with the specific period, helped to increase cases in the state of Amazonas and in the four cities listed.

DISCUSSION

Given the results, in both years surveyed, the South, Southeast and Midwest regions were the most affected, while the Northeast and North regions were the least affected, with the lowest incidence of the disease. When considering the North region, with emphasis on the state of Amazonas, during the period from January 2023 to February 2024, an analysis of the reported cases of dengue revealed that the highest number of occurrences was among males (2,766), brown people (4,556) and those with completed high school education (1,446). However, it is important to note that there were 2,232 cases in which the information on schooling was not filled in, which reduces the accuracy of the survey data.

As for the location, Manaus recorded a maximum temperature of 30°C for three consecutive months, while Itacoatiara only reached this milestone in October. As for Manicoré and Humaitá, both reached a maximum of 28°C in three consecutive months, but in different periods. It can be seen that over the months of August, September, October and November, which are the periods with the highest temperatures in the 4 municipalities evaluated, 449 cases were recorded in Manaus, 91 cases in Manicoré and 102 cases in Humaitá, reaching their peak notifications in February 2023. In contrast, Itacoatiara had only 2 cases during the period analyzed. We also obtained data from the IBGE on sanitation sewage service by collective network in operation in the 4 cities listed, in which they all have sanitation infrastructure, but the form of administration changes, with Manaus being a private network, Manicoré by the public authorities, represented by the municipality, and Humaitá and Itacoatiara by the municipal authorities. Therefore, this information did not influence the reporting of cases.

Municipalities	Months													
	01	02	03	04	05	06	07	08	09	10	11	12	01	02
Manaus	11	15	38	37	34	32	24	19	35	7	4	150	19	24
Manicoré	10	15	8	3	2	-	-	-	-	-	-	1	23	29
Itacoatiara	-	-	-	-	1	-	-	-	-	-	-	-	1	-
Humaitá	34	44	2	2	5	-	1	-	2	3	2	-	3	4

Table 10- Number of cases notified monthly from January 2023 to February 2024 in the regions of Manaus, Manicoré, Itacoatiara and Humaitá - Brazil.

Source: SINAN/DATASUS, 2024.

This epidemiological scenario is justified by the fact that climate fluctuations and variations play an important role in the incidence of dengue. Climatic conditions such as temperature influence viral replication and therefore the spread of the disease. However, humidity and precipitation are also factors that must be taken into account, due to their total participation. High temperatures can accelerate the mosquito's life cycle, expanding its reproduction rate due to the increase in its temperature.

activity. Humidity provides ideal conditions for proliferation, just as precipitation can lead to the accumulation of water in places and containers, favoring ideal environments for reproduction.

There is also the influence of the Continental Equatorial Air Mass, which is responsible for more intense rainfall in the months January to July. It can be seen that the above information causes the incubation period of the virus to decrease, the mosquito population to expand and the risk of transmission to increase. It is worth noting that due to the effects of natural climate change, there is an expansion of tropical and subtropical areas due rising temperatures, which can lead to a greater spread of the mosquito and the disease to previously unaffected regions, with repercussions on the influence of the geographical distribution of the mosquito vector and thus the transmission of dengue.

Regarding the number of monthly dengue case notifications in the state of Amazonas from January 2023 to February 2024, it is clear that in the first two months of 2023 there was relative stability in the number of cases, albeit with significant numbers. Then, in the following months, there was a considerable and constant reduction until the month of May. After that, the number of cases stabilized, with small numbers until October.

Subsequently, there was an increase in cases in November until the last month surveyed, February 2024. Therefore, it stands out that during the months November to May, cases grow exponentially and precisely during this period the Amazon winter occurs, a time with milder but higher temperatures, higher relative humidity, lots of rain and flooded regions, concluding that all the factors listed contribute to a greater endemic proliferation in the state of Amazonas, and consequently in the four cities listed. However, it is worth noting that the winter was the warmest, with below-average rainfall and the lowest river volumes on record in the region, due to the El Niño climate phenomenon, characterized by anomalous and continuous warming of the surface of the Pacific Ocean. The Amazonian winter in itself would already have factors such as relative humidity, rainfall and mild but high temperatures influencing the progressive increase in dengue cases, but with the addition of El Niño, evident since June 2023, there has been a greater increase in temperatures, humidity,

and even with the drought, there have been intermittent rains contributing to situations and places conducive, aligned with the other factors, to the ideal proliferation of the mosquito, increasing the cases in the state of Amazonas and consequently, in the cities listed.

CONCLUSION

In view of the information presented in this article, it can be seen that there is a seasonality in notifications, allowing it to be framed as a relevant public health problem in the region. Therefore, greater monitoring of climate fluctuations and variations is crucial in order to effectively predict and respond to dengue epidemics. Disease control and prevention strategies must take into account not only epidemiological factors, but also global and local climatic conditions, as these influence replication rates. This integrated approach is essential to mitigate the impacts of dengue and protect public health, reducing the social impact, the economic challenges of dealing with epidemics and unnecessary costs with avoidable patients. This demonstrates the need for a new look at the disease and especially at the profile of the region, which is necessary for better health promotion and quality of life, reducing the concentration of patients in the UBS, reducing laboratory tests, possible hospitalizations and deaths.

CONTRIBUTIONS

Marjorie Correia de Andrade participated in data analysis and critical review with intellectual contribution. Alexandra Weber Lamela, Larissa de Sá Santos, Mariana Bonfim Lopes de Oliveira, Nadine Claude Nagate participated in the conception, writing, collection, analysis and/or interpretation of data and critical revision with intellectual contribution. All the authors approved the final version to be published.

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