THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Impact of Climatic Variables on the Temporal Patterns of Malaria in Oyigbo L.G.A, Rivers State, Nigeria

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Abstract:
The study used a retrospective design to examine the temporal patterns of malaria morbidity in Oyigbo LGA and investigate the relationship between temperature and rainfall on patterns of malaria morbidity in Oyigbo L.G.A. from 2007-2017. Malaria morbidity data from 2007 to 2017 were obtained from the Integrated Disease Surveillance and Response System of Rivers State Ministry of Health while temperature and rainfall records from year 2007 to 2017 were obtained from Nigeria Meteorological Agency (NIMET), Abuja. Data generated were analyzed using SPSS 22.0 and presented using descriptive and inferential statistics. A total of 43,662 malaria cases was recorded in the study area within during the study period with mean morbidity of 330.77. Mean temperature of 27.32°C and mean rainfall of 137.13mm were recorded. Temperature showed a negative relationship with malaria which was significant in the years 2012 and 2014. Rainfall and morbidity showed a positive relationship which was significant only in year 2012. Across the months, temperature and malaria morbidity showed a negative insignificant relationship. However, rainfall showed a positive and significant relationship with malaria morbidity in May. Malaria remains endemic among the local subjects in the study area. During the study period, overall study showed no significant relationship between malaria morbidity, temperature and rainfall. This is to say that climatic variables are not the major drivers of malaria morbidity in the study area. It is therefore recommended that more epidemiological studies be carried out to determine the drivers of malaria transmission to aid evidence-based interventions

Keywords: *Temporal patterns, temperature, rainfall, malaria morbidity, Oyigbo*

1. Introduction

It is widely acknowledged that the malaria transmission dynamics are closely related to socioeconomic, climatic and environmental factors (Mboera*et al.,* 2010). Malaria has, therefore, been defined as an environmental disease (Raso*et al*., 2012). The presence of malaria is strongly linked to environmental factors as they influence the abundance and survival of the mosquito vectors (Abiodun*et al*., 2016). Climate can influence malaria directly through transmission dynamics or indirectly through myriad pathways including the many socioeconomic factors that underpin malaria risk (Nissan *et al*., 2021). The indirect effects are largely unpredictable and so are not included in climate-drive disease models.

Two recent initiatives, the World Health Organization (WHO) Strategic Advisory Group on Malaria Eradication and the Lancet Commission on Malaria Eradication have assessed the feasibility of achieving global malaria eradication and proposed strategies to achieve it. Both reports rely on climate driven model of malaria transmission to conclude that long-term trends in climate will assist eradication efforts overall (Nissan *et al*., 2021). The impact of climate variability on malaria transmission cannot be over emphasized (Makinde and Abiodun., 2020). The role of climate change on global malaria is often highlighted in World Health Organization reports (Lubinda*et al*., 2021). Malaria transmission to humans involves the role of mosquitoes as vectors, parasites that cause malaria and humans as hosts and is greatly influenced by temperature and rainfall (Dabaro*et al*., 2021, Ladjumadil*et al*., 2021) and relative humidity (Dabaro*et al*., 2021).

Meteorological variables, such as rainfall, temperature and humidity could impact the bionomics of malaria vectors, which could eventually determine malaria transmission intensity (Darkoh*et al* 2017, Dabaro*et al*., 2021).

Although various interventions are now available to ensure that the burden of the disease is reduced, few studies have been conducted to identify the period of peak infection of the disease that would have improvement on the prioritization and allocation of resources. This task becomes necessary because there is a close relationship between malaria incidence and seasonality. Exploring trends of malaria infections and factors that may affect malaria transmission are needed to understand the progress towards elimination and the potential for rebound. Hence, a deeper understanding of these variables, conducive to mosquito vector life cycle, is crucial to target control interventions. Therefore, the study examined the temporal patterns of malaria parasitaemia in Oyigbo LGA and evaluated the impact of temperature and rainfall on the temporal patterns of malaria morbidity in Oyigbo.

2. Material and Methods

The study used retrospective design to investigate the relationship between temperature and rainfall on patterns of malaria morbidity in Oyigbo L.G.A. from 2007-2017. Malaria morbidity data from 2007 to 2017 were obtained from the Integrated Disease Surveillance and Response System of Rivers State Ministry of Health while temperature and rainfall records from year 2007 to 2017 were obtained from Nigeria Meteorological Agency (NIMET), Abuja. Data generated were analyzed using SPSS 22.0 and presented using descriptive and inferential statistics.

3. Results

Year	Total Morbidity	Mean Morbidity	Mean Temp(°C)	Mean Rainfall (mm)
2007	2587	215.5833	27.54	158.0
2008	3844	320.3333	27.45	124.2
2009	4985	415.4167	26.90	148.8
2010	6778	564.8333	27.77	131.5
2011	5356	446.3333	27.39	111.6
2012	3852	321	27.34	135.1
2013	6049	504.0833	26.99	134.4
2014	4308	359	27.32	145.7
2015	2050	170.8333	26.98	130.5
2016	976	81.33333	27.47	136.4
2017	2877	239.75	27.36	152.2
	43,662	330.7727	27.32	137.13

Table 1: Mean Morbidity, Temperature and Rainfall (2007-2017)

3.1. Annual Patterns of Malaria inOyigbo LGA

A total of 43,662 malaria cases was recorded in the study area within during the study period with mean morbidity of 330.77. Mean temperature of 27.32°C and mean rainfall of 137.13mm were recorded (Table 1). Figure 1 represents annual patterns of mean temperature and malaria morbidity (APMTMM) in Oyigbo LGA (2007-2017). Across the years, the mean highest malaria infection occurred in year 2010 with a mean value of 564.833 followed by year 2013 with a mean value of 504.0833.The least annual infection was recorded in 2016 with a mean value of 81.33. Mean temperature values across the years showed that 2010 (27.77°C) and March (28.63°C) had the highest degrees while 2007 (27.54°C) had the least. Highest mean rainfall was recorded in 2007 (158.0mm) whereas the least was recorded in2011 (111.6mm) (Fig. 1).

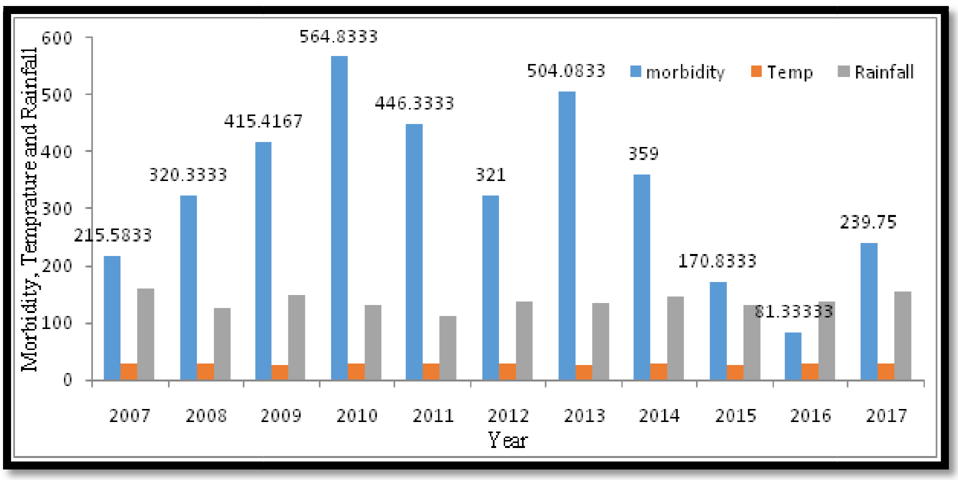

Figure 1: Annual Patterns of Mean Temperature and Malaria Morbidity (APMTMM) in Oyigbo LGA (2007-2017)

3.2. Annual Trends of Malaria in Oyigbo

Annual trend in malaria revealed a negative relationship between the infection and the years (y=-17.48x + 35501) with malaria decreasing at a rate of 1748% across the years. A coefficient of determination (R^2) = 0.1558 meant the years accounted for15.58% of the variation as shown in Fig. 2. Temperature had a negative trend with a regression equation of y = -0.0171x + 61.706, decreasing at a rate of 1.71%, and the years accounting for 4.6% of the variation (R^2 = 0. 0.046) (Fig. 2). However, rainfall showed a positive trend of occurrence (y = 3.7406x + 112.79) implying that rainfall increased at a rate of 14.64% across the years and the years accounting for 0.13% of the variations observed (R^2=0.0013).

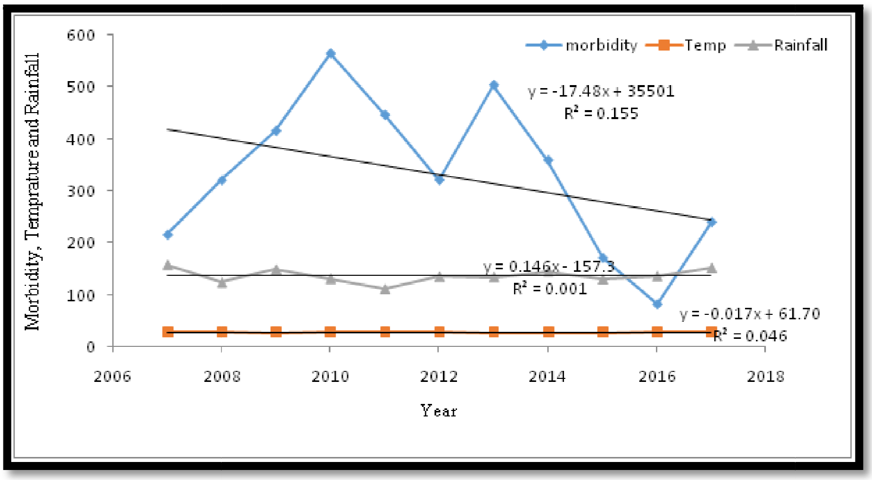

Figure 2: Annual Trends of Mean Temperature and Malaria Morbidity (APMTMM) in Oyigbo LGA (2007-2017

3.3. Seasonal Patterns of Malaria in Oyigbo LGA

Seasonally, the mean highest malaria infection month was June (395.63) followed by September (370.81) and December (365.63) while the least was in July (254.72). Mean temperature values across the months showed that February (28.69°C) and March (28.63°C) had the highest degrees while July (25.94°C) had the least. Mean rainfall had a parabolic-shaped distribution with January (41.85mm) having the least amount and ascending through February (69.78mm) to the highest, June (218.9mm) and descended gradually through July (209.6mm) and August (199.8mm) and deepened in December (48.78mm) (Fig. 3).

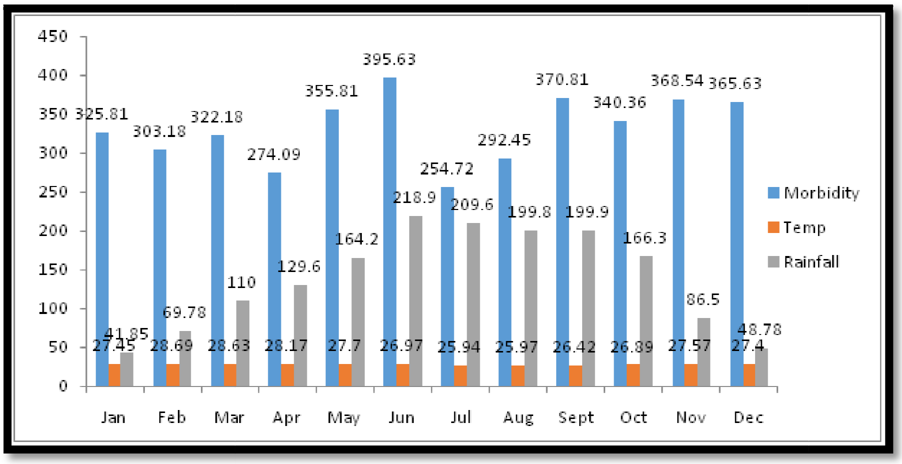

Figure 3: Seasonal Patterns of Mean Temperature, Rainfall and Malaria Morbidity (SPMTRMM) in Oyigbo LGA (2007-2017)

3.4. SeasonalTrends of Malaria in Oyigbo

Seasonal trend in malaria revealed a positive relationship between the infection and the months (y = 4.567x + 301.09) with the malaria increasing at a rate of 456.7% across the months. A coefficient of determination (R^2) = 0.1455 meant the months accounted for14.55% of the variation as shown in Fig. 4. Temperature had a negative trend with a regression equation of y = -0.1321x + 28.175, decreasing at a rate of 13.2%, and the months accounting for 26.57% of the variation (R^2 = 0.2657) (Fig. 4). However, rainfall showed a positive trend of occurrence (y = 3.7406x + 112.79) implying that rainfall increased at a rate of 374.06% across the months.

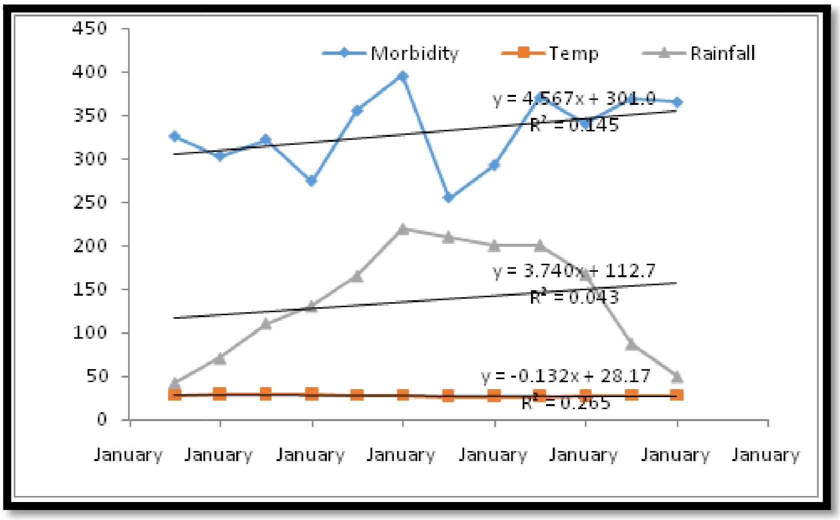

Figure 4: Trends of Seasonal Temperature and Seasonal Malaria Morbidity (2007-2017)

Across the years under surveillance, there was a negative and significant relationship between malaria and temperature in 2012 (r=0.795, p= 0.002) and 2014 (r=0.634, p=0.027). Other years had an insignificantly positive relationship (p>0.05). Although rainfall and morbidity showed a positive relationship, they were insignificant (p>0.05) except in 2012 (r=0.577, p=0.049) as shown in Table 2.

Climatic Factors		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Temp	r-value	0.005	0.302	0.093	0.065	0.305	0.795	0.415	0.634	0.435	0.374	0.212
	p-value	0.987	0.340	0.774	0.840	0.334	0.002*	0.179	0.027*	0.158	0.231	0.508
Rainfall	r-value	0.073	0.461	0.291	0.456	0.494	0.577	0.337	0.428	0.143	0.491	0.139
	p-value	0.821	0.132	0.359	0.136	0.103	0.049*	0.285	0.165	0.658	0.105	0.666

Table 2: Relationships between Malaria, Morbidity and Selected Climatic Elements within Individual Years
*NB: * Indicates Significant Difference at P < 0.05*

Although temperature and malaria morbidity showed a negative relationship across the months, they were insignificant (p>0.05). Across the months, there was a positive and significant relationship between malaria and rainfall in May (r=0.730, p = 0.011). Other months had an insignificantly positive relationship (p>0.05) as shown in Table 3.

Climatic Factors		Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Temp	r-value	0.140	0.382	0.247	0.117	0.392	0.346	0.110	0.176	0.227	0.470	0.340	0.290
	p-value	0.664	0.221	0.439	0.732	0.233	0.298	0.747	0.604	0.503	0.145	0.306	0.387
Rainfall	r-value	0.045	0.297	0.502	0.482	0.730	0.310	0.064	0.516	0.512	0.442	0.227	0.249
	p-value	0.890	0.348	0.097	0.133	**0.011***	0.354	0.853	0.104	0.107	0.174	0.504	0.460

Table 3: Relationships between Malaria, Morbidity and Selected Climatic Elements within Individual Months
*NB: * Indicates Significant Difference at P < 0.05*

4. Discussion

Malaria in Oyigbo LGA displayed a distinct temporal pattern, with unstable levels and showing biological relationships to climatic factors. Across the years and months, there was high malaria morbidity which was skewed and unevenly distributed. Year 2010 recorded both the highest annual mean morbidity and highest annual mean temperature. This shows that 2010 had the optimum temperature for malaria transmission. In 2012, morbidity decreased as rainfall increased. This may be as a result of low breeding sites for mosquito due to increased flooding and consequently washing away of larval habitats. This could also be attributed to population shift due to flooding and consequently, lower prevalence. Very low morbidity was recorded in the year 2016. This could be attributed to data insufficiency from 2014 to

2016 and consequently does not give a true representation of morbidity. However, among the years that had complete data, 2007 and 2017 recorded the least mean annual morbidity and the highest mean annual rainfall. It can be deduced from the study that temperature and rainfall greatly affect malaria transmission.

Temperature showed a positive relationship to malaria which was significant in the years 2012 and 2014. This is in line with the findings of Nanvyat*et al.,*(2017) in Plateau state and Segun*et al.,*(2020) in Abuja, Nigeria who recorded a positive significant relationship between temperature and malaria morbidity. The most favourable temperatures for mosquitoes range between 25^{o}C to 30^{o}C hence their abundance in Sub-Saharan Africa (CDC, 2012). Throughout the period of study, temperature data obtained fell within the favourable limits suitable for the survival and proliferation of *Anopheles sp,* the vector of *Plasmodium sp* and for *Plasmodium sp* development within its *Anopheles* mosquitoes. According to Nissan *et al*., (2021), within a moderate temperature range, warmer conditions facilitate malaria transmission by influencing both the rate of parasite development and vector population dynamics. This therefore explains why there is constant malaria infection in the study area. However, across the months, temperature showed a negative relationship with malaria morbidity which was not significant statistically.

In this study, rainfall showed a positive correlation with malaria morbidity in year2012 and month of May.This is in line with the studies by Abdullahi *et al*., (2013) in Kebbi state; Akinbobola&Omotosho (2013) in tropical rainforest and savannah regions of Nigeria; Badaru*et al*., (2014) in Abuja; Okoye and Nwachukwu (2014) in Enugu State; Sena*et al*., (2015) in Ethiopia; Chirebvu*et al*., (2016) in Botswana; Nanvyat*et al*., (2017) in Plateau state. The results of their study showed a significant relationship between rainfall and malaria cases. Rainfall is considered a predominant climatic factor for the distribution and transmission of malaria (Bomblies and Eltahir, 2009), having a huge influence on the completion of the life cycle of the malaria *Plasmodium sp* (Jusot and Alto, 2011) by modifying the effects of temperature and increasing the effects of humidity (Yang et al., 2010). However, the influence of rainfall on malaria transmission is multifaceted. In the current work, peak rainfall years (2007 and 2017) had the lowest morbidity. Heavy rainfall may destroy existing breeding places, interrupt the development of mosquito eggs or larvae, flush the eggs or larvae out of their aquatic habitats resulting in lower *Anopheles* density and thus reduced rate of malaria transmission (Imbahale*et al*., 2012; Tian *et al*., 2008).

5. Conclusion

Malaria remains endemic among the local subjects in the study area. During the study period, overall study showed no significant relationship between malaria morbidity, temperature and rainfall. However, in Year 2012 and 2014 and during the month of May, a significant relationship existed between malaria morbidity and the climatic variables. This is to say that climatic variables are not the major drivers of malaria morbidity in the study area.It is therefore recommended that more epidemiological studies be carried out to determine the drivers of malaria transmission to aid evidence-based interventions.

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