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Spatiotemporal Mapping of Annual Malaria Incidence in Rivers State, Nigeria.

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Abstract

Rivers State is the centre of Nigeria's oil industry and has the presence of oil prospectors including expatriates who are at risk of malaria infection. Periodic analysis of epidemiological data will enable malaria control programmers to appraise the interventions carried out over the years and assist in the development of sustainable and adaptive strategies directed from an informed local level. This study, therefore, examined spatiotemporal variations in malaria incidence in the State using Annual Parasite Incidence (API) as an indicator. Monthly reported malaria cases from 2007-2017 at the local government area (LGA) level were retrieved from the Integrated Disease Surveillance Response (IDSR) system of Rivers State Ministry of Health while projected population data for the same period were obtained from the National Bureau of Statistics. API of the LGAs from 2007 to 2017 were computed, integrated into GIS, and subjected to weighted overlay analysis to delineate the risk zones. The eleven-year retrospective study of malaria in Rivers State displayed geographical variations which were statistically significant between the LGAs. Malaria incidence fluctuated throughout the study period. API values increased from 13.746 in 2007 to 34.067 in 2013 and dropped to 8.721 in 2017. All the LGAs recorded API values below 100, indicating a very low malaria burden in a controlled setting. However, none of the LGAs has reached the WHO standard level for the elimination of transmission. Ikwerre, Eleme, Ogu-Bolo and Opobo/Nkoro LGAs were assigned to the very high malaria risk stratum (362.615 to 490.005) whereas Abua-Odual, Akuku-Toru and Degema LGAs were assigned to very low-risk malaria stratum (103.281 to 113.897). The findings of this research will aid stakeholders in evaluating the impact of control strategies employed over the years and possibly, revisit malaria extant interventions for improved malaria control outcomes.

Keywords: Annual Parasite Incidence; Geographic Information System, Spatiotemporal; Weighted Overlay Analysis

Introduction

A quick reduction in the incidence and mortality from malaria in a cost-effective manner remains the major concern for all malaria control programmes. Malaria surveillance, both at local and national levels, makes malaria data easily available for evaluation of transmission trends [1]. Monitoring changes in malaria incidence has surpassed tracking variations in prevalence and is starting to get more attention as the worldwide effort to eradicate malaria continues [2]. All malaria control programs are concerned with reducing malaria incidence and death quickly and affordably. To successfully target regions in need and assess management practices, malaria data must be presented to show populations with the greatest

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incidence and fluctuations over time. This technique helps disease control professionals develop and operate surveillance systems. Malaria surveillance statistics are acquired from all or selected government health centres and include recorded malaria cases and fatalities [1]. These data might be supplemented with household survey data on malaria parasitaemia and main intervention tool coverage. Malaria cases, inpatients, and fatalities are reported monthly and may be used to assess malaria dispersion in space and time in various transmission contexts [1]. National Malaria Control Programmes (NMCPs) have relied heavily on the use of health management information systems (HMIS) to educate and guide control and eradication activities [2]. However, the use of HMIS data to track malaria trends has not been fully used in estimating risks in Africa. Integrated Disease Surveillance and Response (IDSR) system became operational in 2001 and continues to be the approach used in Nigeria's public health surveillance [3]. IDSR is a framework implemented to improve the usability of surveillance and laboratory data and improve detection and response to the primary causes of morbidity and mortality in African countries. The IDSR requires immediate notification of suspected outbreaks, weekly reporting of all the epidemic-prone diseases and those targeted for elimination and eradication including "zero" reporting and monthly reporting of all other priority diseases and conditions under surveillance. Health facilities are the basic operational units in the Local Government Area (LGA) and surveillance data are sourced from health facility registers [3]. Analyses of trends, therefore, depend on the use of reported cases and deaths, while intervention is carried out at the population level. Therefore, malaria incidence guides the distribution of resources. In a quest to make more meaning to stakeholders, the numbers of reported cases and deaths can be changed to indicators taking into consideration, certain indices like population size, malaria diagnostic tests etc [4].

There is a need to present malaria information to portray populations with the highest malaria incidence and the variations that occur over time to effectively give attention to areas in need and evaluate control. This approach is obtainable in surveillance systems and aids disease control experts in planning and implementation [4]. Lots of malaria cases exist in the early phase of control, making it impossible for health workers to examine each individual and treat accordingly. In other words, active case detection is not feasible. One of the indicators for assessing malaria burden is Annual parasite incidence (API). Annual parasite incidence (API) is for the stratification of areas and standard reporting to the World Health Organisation [5]. API is a direct reflection of all prevention and control efforts on humans but depends on active case detection which is often poor. The API analysis and its trends have informed the identification of priority areas and enabled control agencies to appraise past efforts and shape future trends. Accurate estimates of disease burden can be harnessed through an interplay of information on the spatial and temporal distribution of malaria with epidemiological models. A proper comprehension of the local disease dynamics through routine passive surveillance data is an indispensable step for the actualization of malaria elimination [6]. The geographic stratification of malaria risk is advocated by the WHO because disease patterns from one region to another depict the social and environmental factors influencing risk, susceptibility, social interaction, and behaviours and consequently, facilitate occurrence [7].

There is a heavy presence of expatriates in Rivers State due to oil exploration activities. These expatriates are therefore at risk of malaria attacks and if uncontrolled, could affect oil exploration and outputs leading to loss of revenue. Concerted efforts should therefore be geared towards malaria control in the State. One of the ways is to assess malaria trends for better-targeted control efforts to sustain the works of expatriates and locals in the various communities. This, therefore, makes the analyses of spatiotemporal trends of malaria cases in Rivers State important and will consequently steer local malaria control. This study is aimed at assessing the spatiotemporal variations in malaria burden in Rivers State and identifying malaria risk zones in Rivers State using annual parasite incidence (API) as an indicator.

Materials and Methods

Study Area

Rivers State is one of the 36 states of Nigeria and is located within latitude 4°18'58.294" N -5°43'51.652" N and longitude 6°24'7.883" E - 7°35'58.683" E (Figure 1). Its capital, Port Harcourt is the largest city and is economically significant as the centre of Nigeria's oil industry. The State occupies an area of about 10,363.98 km^2. It is bordered on the North, South, East and West by Imo and Abia States; Atlantic Ocean; Akwa Ibom and Bayelsa States and Delta State respectively; with its shores forming part

of the West African Coastline. Water occupies over one-third of the state. The lowland areas stretch from Andoni to Bonny in the Northern and Southern parts of the State, especially; with a network of creeks stretching through Bonny into the Atlantic Ocean [8]. Andoni, Asari Toru, Akuku Toru, Bonny, Degema, Ogu-Bolo, Okrika, and Opobo-Nkoro LGAs constitute the core riverine areas whereas Eleme, Emohua, Etche, Gokana, Ikwerre, Khana, Obio-Akpor, Omuma, Oyibo, Port Harcourt City and Tai LGAs constitute the upland LGAs. Abua–Odual, Ahoada East, Ahoada West and Ogba–Egbema-Ndoni are made up of mixed terrains.

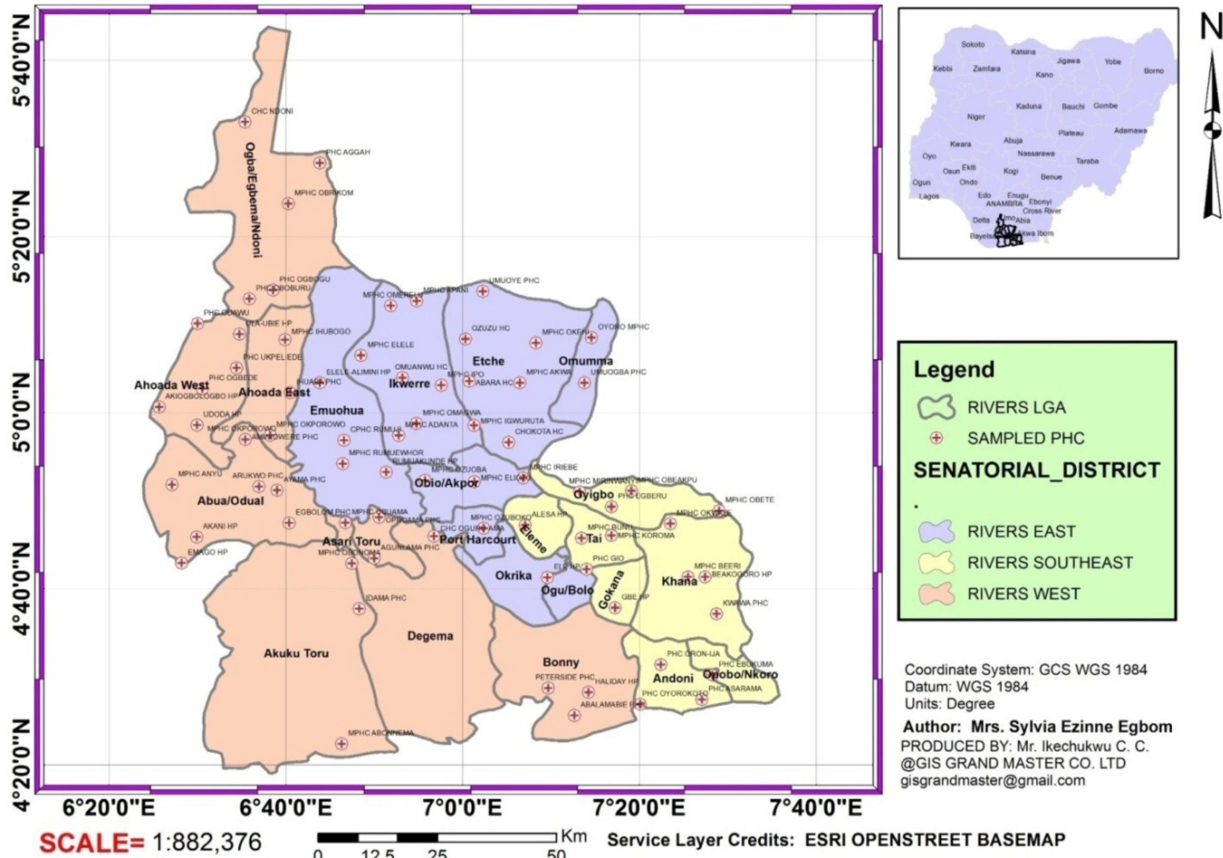

Figure 1: Map of the Study Area

Acquisition of Malaria Data

Monthly malaria cases reported from 2007-2017 at the LGA level were retrieved from the IDSR system of Rivers State Ministry of Health. Rivers State projected population data from 2007 to 2017 were obtained from the National Bureau of Statistics.

Determination of Annual Parasite Incidence (API)

To evaluate spatiotemporal patterns of malaria in the study area, surveillance data obtained were used to calculate the Annual Parasite Incidence (API) of the various LGAs in Rivers State from 2007 to 2017 [4]. API for each LGA was calculated thus:

$$\textbf{API} = \frac{\text{Number of confirmed malaria cases}}{\text{Population at risk of malaria}} \times 1000$$

Statistical Analysis

Data were analysed using Statistical Packages for Social Science (SPSS) version 23. Bivariate correlation was used to compare mean API values for the years and locations. A $p<0.05$ was considered significant.

GIS Analysis

Spatiotemporal API data (2007–2017) were integrated into ArcGIS 10.7 and weighted overlay analysis was carried out to define the malaria burden

in Rivers State [9]. Spatiotemporal maps of malaria incidence in Rivers State from 2007-2017 were thus generated. The LGAs were stratified based on API values. The malaria risk zones were identified by the weighted sum overlay method [9] in which the spatial API values were overlayed and summed up. The weighted sum of LGA level API was used to classify malaria risk as very high (362.615 – 490.005), high (264.038 – 362.614), moderate (195.793 – 264.037), low (113.898 – 195.792) and very low (103.281 – 113.897) risk.

Results

Annual Trend of Annual Parasitic Incidence from 2007 -2017

A total of 1,494, 243 cases of malaria were reported in Rivers State between the years 2007 – 2017) as seen in Table 1. The highest number of malaria cases was recorded in 2013 with a total case of 224,695 whereas the least was reported in the year 2015 with a total of 59,932 cases. A steady increase was observed from 2007 to 2009 with a decline in 2010. However, the figures dropped in 2010, 2012 and 2014. The highest value was recorded in the year 2013 whereas the least was recorded in 2016.

Table 1: Annual Trend of malaria cases and API

Year	Total malaria cases	Population	API
2007	73,935	5,378,514	13.746
2008	119,535	5,564,523	21.482
2009	158,404	5,756,971	27.515
2010	156,912	5,956,076	26.345
2011	168,231	6,162,061	27.301
2012	147,952	6,375,177	23.208
2013	224,695	6,595,660	34.067
2014	183,427	6,823,769	27.81
2015	59,932	7,059,766	8.489
2016	60,156	7,303,924	8.236
2017	141,064	7,535,206	8.721
Total	**1,494,243**		

Annual Parasite Incidence (API) values of the 23 LGAs in Rivers State between 2007 and 2017

Table 2 illustrates the API values of the 23 LGAs in Rivers State between 2007 and 2017. In 2007, the highest value was recorded in Etche LGA followed by Okrika and Emohua with values of 23.69 and 23.54 respectively. Degema recorded the least value of 5.03. In 2008, the highest and least records were recorded in Emohua and Degema LGAs respectively. In 2009, the highest and least values were recorded in Emohua and Abua-Odual. In 2010, Ikwerre and Abua-Odual recorded the least values. The highest and least values were recorded in Ikwerre and Ahoada-West in 2011, Ogu-Bolo and Port Harcourt in 2012, Eleme and Abua-Odual in 2013, Opobo-Nkoro and Asari-Toru in 2014, Obio-Akpor and Asari-Toru in 2015, Ikwerre and Ogu-Bolo in 2016 and Ikwerre and Ahoada-West in 2017. The variations across the years and LGAs were significant statistically ($p<0.05$).

Table 2: Annual Parasite Incidence (API) values of the 23 LGAs in Rivers State between 2007 and 2017

LGA	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Weighted Overlay Sum (2007 to 2017)
Abua/Odual	9.053	7.169	6.047	5.721	13.144	7.998	16.453	14.419	6.083	4.635	12.559	103.281
Ahoada East	17.562	12.577	9.822	7.693	9.095	24.220	46.110	36.168	12.414	10.082	11.415	197.159
Ahoada West	8.509	14.552	27.374	21.198	54.987	37.015	47.783	37.354	6.828	3.887	5.810	265.297
Akuku Toru	7.764	11.140	10.241	9.042	11.715	12.290	16.928	13.345	3.424	5.200	7.978	109.067
Andoni	8.347	24.218	19.434	34.794	22.779	30.257	36.205	28.391	4.765	8.806	18.036	236.032
Asari Toru	9.803	8.017	14.635	5.949	20.855	16.856	16.805	7.397	2.486	2.665	8.918	114.385
Bonny	15.556	17.187	15.151	17.068	14.771	22.361	26.878	13.002	2.853	7.688	16.473	168.531
Degema	5.025	3.228	12.383	11.788	13.883	14.706	17.099	9.718	4.079	2.668	10.542	105.121
Eleme	21.736	29.350	28.730	41.780	32.931	44.466	76.875	33.323	10.915	17.623	26.114	363.842
Emohua	23.542	62.220	58.909	57.852	17.750	16.775	32.923	25.543	10.530	3.898	8.709	318.651
Etche	29.608	38.389	32.954	32.799	37.940	27.279	27.925	31.576	6.499	12.305	32.746	310.021
Gokana	11.178	9.758	14.800	36.644	39.143	21.449	47.795	42.616	7.404	9.531	18.422	258.740
Ikwerre	14.192	34.229	48.351	64.009	71.613	58.627	57.777	37.191	13.548	31.970	58.497	490.005
Khana	16.551	24.064	33.476	35.781	30.990	20.406	48.351	45.520	4.296	1.856	24.985	286.278
Obio/Akpor	9.175	19.346	26.311	27.613	29.276	21.708	21.494	24.333	31.978	16.685	33.570	261.490
Ogba/Egbema/Ndoni	6.182	10.952	8.680	8.005	15.837	12.714	33.170	44.505	3.111	6.904	18.470	168.531
Ogu/Bolo	21.955	49.877	47.657	52.789	67.868	70.701	53.983	25.421	4.617	1.399	8.193	404.460
Okrika	23.690	33.796	48.067	39.027	20.514	26.927	31.647	16.835	3.584	4.300	10.764	259.153
Omumma	15.733	26.849	32.365	22.084	16.464	32.354	46.057	15.861	12.103	4.176	10.694	234.741
Opobo/Nkoro	20.870	28.841	43.877	72.331	68.870	39.815	59.113	54.953	4.120	7.074	20.910	420.773
Oyigbo	19.180	28.654	35.918	47.169	36.054	25.063	38.042	26.187	12.045	5.543	15.837	289.693
Port Harcourt	11.165	21.410	43.631	8.053	12.952	7.825	19.385	15.228	3.143	3.965	8.528	155.285
Tai	12.750	13.093	21.902	14.147	20.687	16.878	39.506	37.286	13.766	17.595	24.630	232.240

Spatiotemporal patterns of malaria incidence in Rivers State from 2007-2017

In 2007, Etche LGA had the highest incidence. In 2008, the highest API was recorded in Emohua and Ogu-Bolo. In 2009, five (5) LGAs namely Emohua, Ikwerre, Okrika, Ogu-Bolo, Opobo-Nkoro and Port Harcourt LGAs recorded higher API values. In 2010, Opobo-Nkoro, Ikwerre, Emuohua and Ogu-Bolo had a higher malaria burden. In 2011, a higher burden was recorded in Ikwerre, Opobo-Nkoro, Ogu-Bolo and Ahoada-West. Ogu-Bolo and Ikwerre had higher API values in 2012; Eleme, Opobo-Nkoro and Ikwerre in 2013, Ogba/Egbema/Ndoni in 2014; Obio-Akpor in 2015; Ikwerre, Eleme, Tai, Obio-Akpor and Ahoada-East in 2016 and Ikwerre LGA in 2017 (Figures2 to 12).

Figures 2-7: Spatiotemporal distribution of API in Rivers State for the year 2007 – 2012

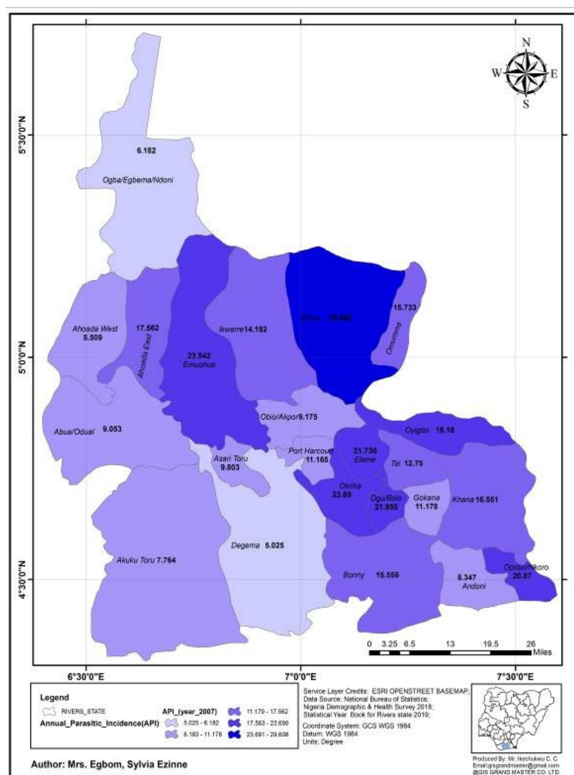

Fig 2: Spatiotemporal distribution of API in Rivers State for year 2007

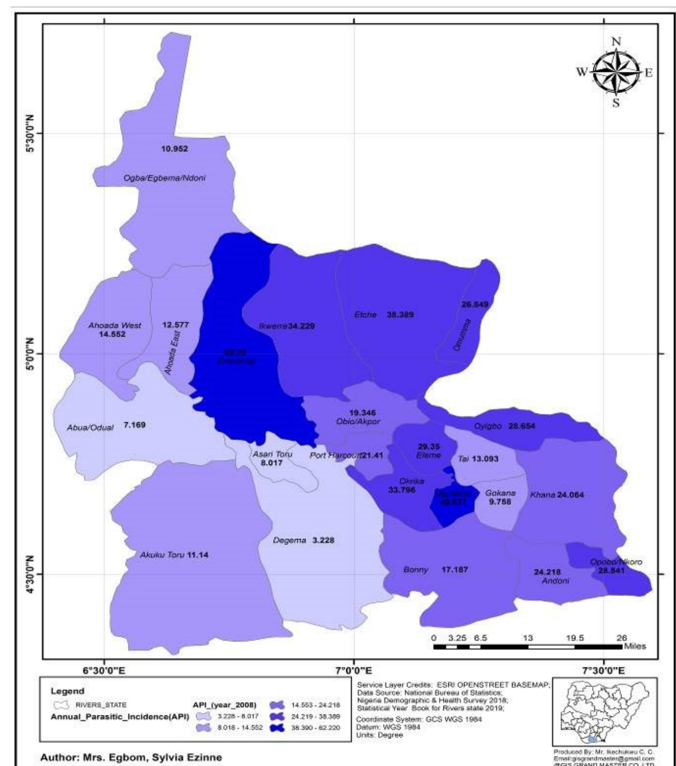

Fig 3: Spatiotemporal distribution of API in Rivers State for year 2008

Fig 4: Spatiotemporal distribution of API in Rivers State for year 2009

Fig 5: Spatiotemporal distribution of API in Rivers State for year 2010

Fig 6: Spatiotemporal distribution of API in Rivers State for year 2011

Fig 7: Spatiotemporal distribution of API in Rivers State for year 2012

Figures 8-12: Spatiotemporal distribution of API in Rivers State for the year 2013 - 2017

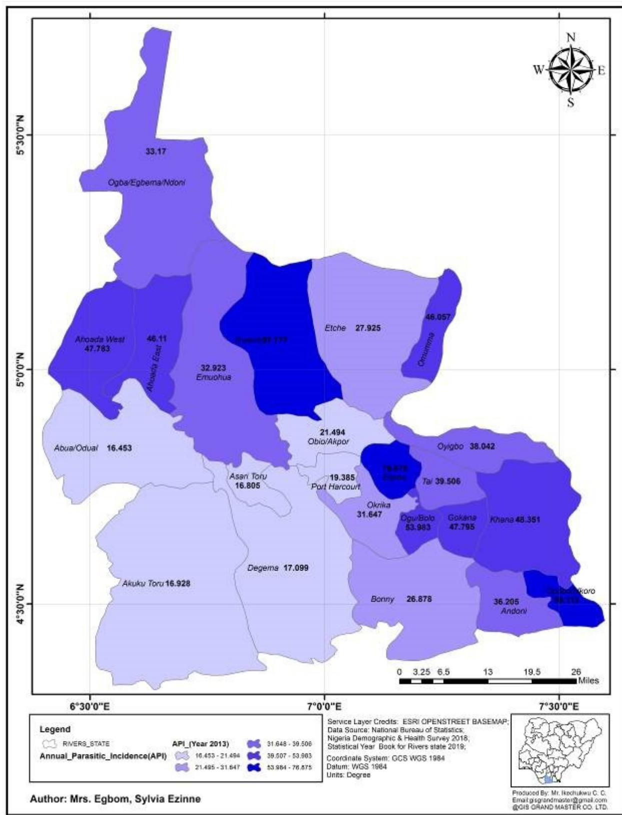

Fig 8: Spatiotemporal distribution of API in Rivers State for year 2013

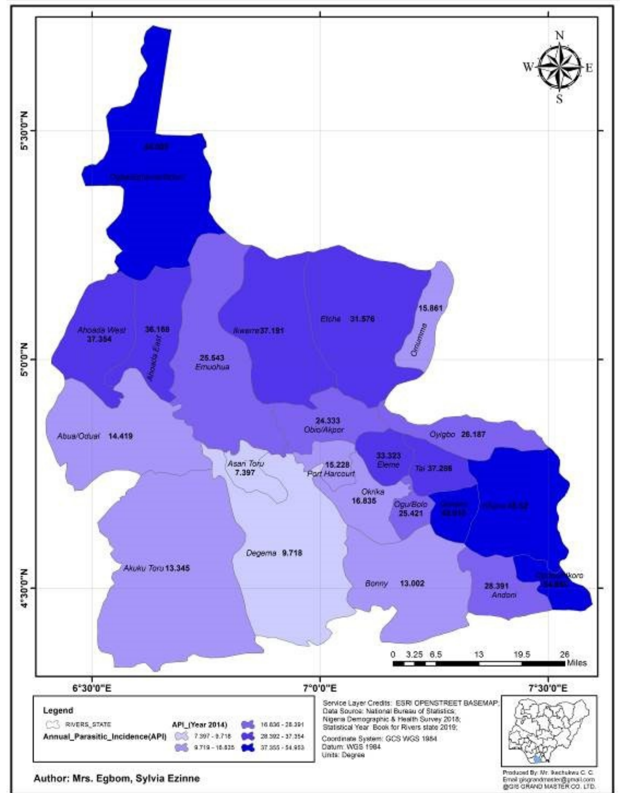

Fig 9: Spatiotemporal distribution of API in Rivers State for year 2014

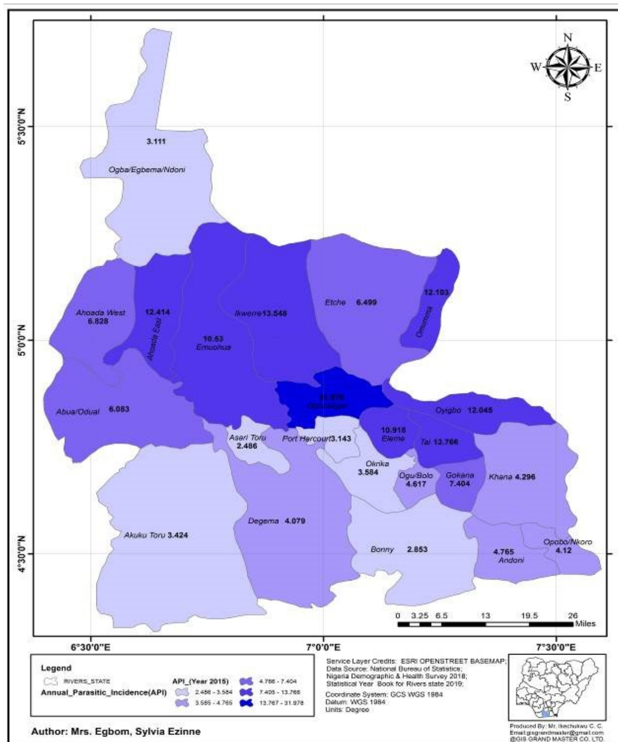

Fig 10: Spatiotemporal distribution of API in Rivers State for year 2015

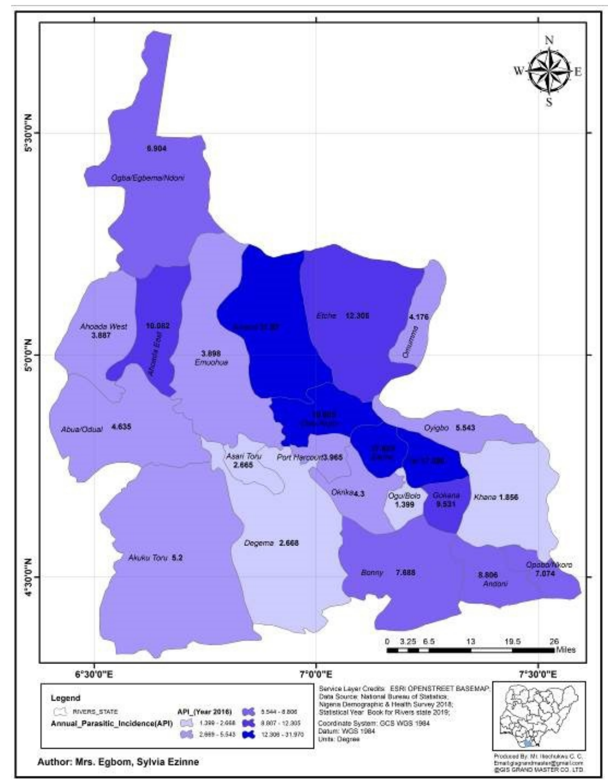

Fig 11: Spatiotemporal distribution of API in Rivers State for year 2016

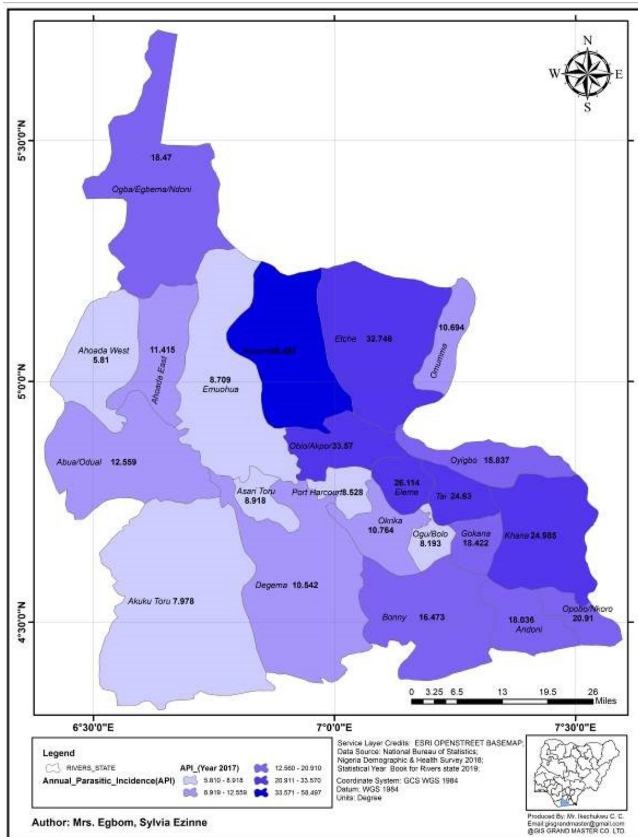

Fig 12: Spatiotemporal distribution of API in Rivers State for year 2017

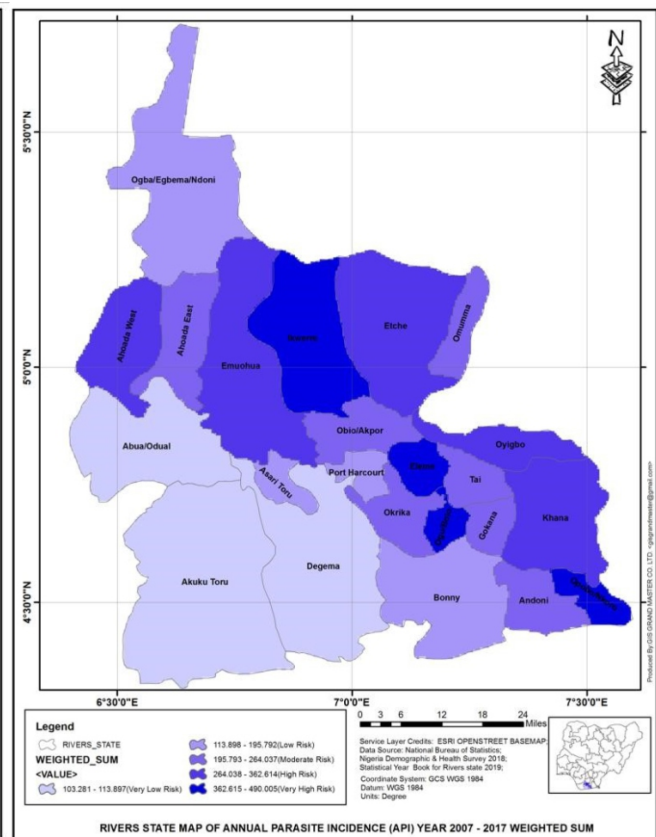

Figure 13: LGA level malaria risk stratification from 2007 to 2017

Malaria Risk Stratification Of Rivers State For The Study Period

Following the allocation of LGAs to the five malaria risk strata, four LGAs namely Ikwerre, Eleme, Ogu-Bolo and Opobo/Nkoro had very high risk. Five LGAs namely Ahoada-West, Emohua, Etche, Oyigbo and Khana had high malaria risk. Seven LGAs namely Andoni, Gokana, Tai, Okrika, Obio-Akpor, Omumma and Ahoada East had moderate risk; Asari-Toru, Ogba/Egbema/Ndoni, Port Harcourt city and Bonny had low risk while three LGAs namely Abua-Odual, kuku-Toru and Degema had very low risk (Figure 13).

Discussion

This study demonstrates the usefulness of API as a core surveillance indicator and elucidates the variations in annual trends of malaria incidence and risk across the various LGAs based on eleven years of retrospective surveillance data. Overall, malaria cases increased from 2007 to 2009 and declined in 2010 (Table 1). However, a decline was observed in 2012 and 2014. The lower number of cases recorded in 2012 could be attributed to the heavy rainfall experienced that year which resulted in excessive flooding across the State, thereby rendering the environment unconducive for malaria transmission. Between 2008 and 2014, more social infrastructure including ultramodern markets, schools and primary healthcare centres were built in the State [10], with 70 health centres commissioned in 2014 across the state [11]. The decline recorded in 2014 could be attributed to the impact of malaria interventions delivered through the Model Primary Healthcare Centres. The primary healthcare system is the entry point into the Nigerian health system and are the major channels through which health services are made available to the people [12]. It, therefore, suffices to say that the commissioning of these PHCs made more malaria intervention tools accessible to the people of Rivers State. Low API values were recorded in 2015 and 2016. This is attributed to the incompleteness of data due to industrial action by organized labour and as such, does not give a true representation of the malaria burden.

During the study period, all the LGAs in Rivers State recorded API values below 100 (Table 2), indicating a very low malaria burden in a controlled setting. However, for appropriate planning and implementation of evidence-based interventions, there is a need to further stratify API to identify locations and populations at higher risk. This stratification revealed that none of the LGAs has reached the WHO standard level for the elimination of transmission which is <1 person per 1000 population at risk indicating that Rivers State is very far from the target of malaria elimination.

The eleven-year (2007-2017) retrospective study of malaria in Rivers State displayed geographical variations. The incidence of malaria was found to vary significantly between the LGAs, and this is in line with the findings of [9] in Vadodara District, Gujarat, India and [13] in the Greater Accra Region and as such authenticates the actuality of a defined spatial heterogeneity of malaria transmission. Other studies authenticating the existence of spatiotemporal variations of malaria incidence include [2]; [14]; [15] and [16]. [2] assessed spatiotemporal trends of malaria incidence between 2015 and 2019 using HMIS data in Uganda. [14] used a surveillance dataset of 12 years (2005–2016) to review trends in 104 communes of PhuYen Province, Vietnam. Using data from the Global Burden of Disease Study 2019, [15] evaluated the regional and global malaria incidence of 204 countries between 1990 and 2019. A five-year trend of malaria incidence in Ethiopia was assessed by [16] using data obtained from the logbook of Bichena Primary Hospital. The difference in interactions of factors in the different settings could be responsible for the heterogeneity observed in all settings.

Spatiotemporal maps revealed heterogeneity in malaria incidence across the LGAs and have helped to identify areas that need to be prioritized for more targeted interventions (Figures 2 to 12). For example, Ikwerre LGA consistently recorded high API values over the years. Ikwerre is a rural community with farming as the predominant occupation. This makes the inhabitants more vulnerable to the bites of mosquitoes leading to continuous disease transmission. Other LGAs with high API values across the years include Ogu-Bolo, Oyigbo, Khana and Etche. Malaria risk stratification of Rivers State from 2007 to 2017 also showed that Ikwerre LGA recorded very high malaria risk (Figure 13) including Eleme, Ogu-Bolo and Opobo/Nkoro LGAs whereas Abua-Odual, Akuku-Toru and Degema had very low malaria risk. These LGAs with very low malaria risk are riverine communities and according to [17], the quality of water bodies could determine the presence and abundance of adult malaria vectors and consequently affect malaria transmission in the region. It is therefore highly probable that the water bodies are not conducive for malaria vector breeding and hence the very low risk recorded in the area. Identifying areas of consistently high or low malaria risk should ideally be the first step in the planning and implementation of control programmes. Locations with higher risk should therefore become targets for increased control efforts. When compared to previous approaches of blanket distribution of interventions across LGAs, a spatiotemporal analysis could lead to evidence-based distribution moving away from the dogma that one size fits all. It, therefore, becomes imperative to strengthen the capacity of the State Ministry of Health in routine data collection and analysis using Geographic Information Systems (GIS). Increased usage of maps will aid quick decision-making and ultimately increase the understanding and appraisal of the impact of malaria control efforts in the State.

Analysis of malaria spatiotemporal dynamics based on epidemiological surveillance systems is required to collect accurate local information and guide public health decision-making. This enables sustainable and adaptive modalities to be directed from an informed local level. The study reveals that API values fluctuated across the years which indicates the influence of unstable physical and biological factors as well as strategic interventions on malaria occurrence and control in the study area. The reason for variations in API across the State could be attributed to the failed implementation of malaria intervention strategies. The availability of efficacious interventions does not always translate to a positive impact at the population level. Certain factors such as the inability to penetrate health systems and low intervention coverage could hinder the implementation effectiveness of the healthcare systems. It is also possible that interventions are not implemented as prescribed. Failure to adhere to certain protocols regarding the use of these interventions will lead to implementation failure. Failure to reach at-risk populations and lack of sustainability of these malaria interventions over time could also cause implementation failure. There is, therefore, a need for Implementation Research to be carried out to evaluate access to and usage of

malaria interventions. This will aid the development of implementation strategies that will address identified bottlenecks in intervention delivery and uptake. A review of the existing malaria control strategies or the introduction of new ones to augment existing approaches can be done by stakeholders and policymakers to address deficiencies observed. This study made use of local malaria surveillance data and could be conducted in other States across the Federation. Although API values do not give a true picture of the malaria burden as it is limited by low-case reporting at healthcare facilities, such data are critical sources of information for programme management because they are usually the readily available source of data on malaria collected consistently over time from health facilities.

Conclusion

This study has revealed the spatiotemporal trend of malaria incidence in Rivers State over the past 11 years. The data obtained from the study helped to define and map malaria incidence to the derived API of the LGAs in the State. Findings from this study can aid in utilizing the available resources to substantially narrowed-down target areas. This will aid stakeholders to evaluate the effectiveness of previous and extant control strategies with the view to identifying their strengths and weaknesses as well as prospects in view. Rivers State Ministry of Health should therefore maximize the usefulness of routine surveillance data and turn malaria surveillance into a core intervention. This study serves as a baseline study which would require further studies to delineate malaria stratification into smaller units within the LGAs such as wards and villages.

Declarations

Authors' Contributions

SEE, FON, and SON conceptualized the study. SEE, FON, and SON designed the study. SEE collected data. SEE, FON, SON, and MUC performed the data analysis. SEE, FON, SON, and MUC interpreted the data. SEE prepared the first draft of the manuscript, reviewed by FON, SON, and MUC. All authors contributed to the development of the final manuscript and approved its submission

Ethical consideration and informed consent

The data used for this study are secondary data extracted from a public database. Therefore, ethical approval and informed consent are not applicable.

Conflict of interest

The authors have declared that no competing interests exist

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