

Review Article

Spatiotemporal Patterns of Measles Outbreaks in Rivers State, Nigeria (2020-2022)

Ifeoma Nwadiuto , Ositadinma Pius Mberekpe* , Christie Tobin Briggs ,
Pauline Aruoture Green , Nnanna Victor Onyekwere , Golden Owghonda ,
Felix Wekere 

Department of Community Medicine, Rivers State University, Port Harcourt, Nigeria

Abstract

Background: Measles remains a leading cause of child mortality globally despite an effective vaccine. Nigeria has persistent measles transmission due to suboptimal immunization coverage (around 54% for first dose)]. The study analyzed measles surveillance data of Rivers State from 2020-2022 to identify spatiotemporal clusters and outbreak characteristics by Local Government Area (LGA) and age group. **Methods:** A retrospective cross-sectional study conducted on measles case-based surveillance data for Rivers State from January 2020 to December 2022. Cases were aggregated by month, LGA, and age. Measles outbreak was defined as the number of laboratory-confirmed cases ≥ 3 in an LGA within 4 weeks. Descriptive statistics summarized case counts by time, place, and age. Chi-square tests assessed associations between categorical variables (e.g. age group versus LGA, year versus age distribution). An epidemic curve and bar charts were used to visualize temporal trends and the distribution of cases by LGA and age group. **Results:** A total of 761 measles cases were reported in Rivers State from 2020-2022 (200 in 2020; 229 in 2021; 332 in 2022). The epidemic curve showed a peak of 70 cases in February 2020, a decline, a resurgence in mid-2021, and a larger outbreak in early 2022 (peak 61 cases in February 2022). Transmission persisted year-round at lower levels between these outbreaks. Spatial distribution of Cases occurred in all 23 LGAs, but 10 LGAs (led by Obio/Akpor and Port Harcourt) accounted for ~60% of cases. The age distribution of Cases ranged from infants to 79 years (median ~6 years, IQR 2-16). Children <5 years comprised 41% of cases, and 25% were aged ≥ 15 years. children (1-4 years) and adults also contributed substantial proportions, indicating gaps in historical vaccination coverage. **Conclusion:** Rivers State experienced recurrent measles outbreaks in 2020-2022 with clear spatiotemporal clustering. The pattern suggests a two-year cycle of major outbreaks, with an early 2020 peak, a smaller mid-2021 wave, and a large 2022 outbreak. All LGAs were affected, but the burden was more in certain urban centers and varied over time. Gaps in immunity were evident in both young children and older age groups, reflecting inadequate vaccination coverage.

Keywords

Spatiotemporal, Patterns, Measles, Outbreak, Rivers State

*Corresponding author: ositadinma.pius@ust.edu.ng (Ositadinma Pius Mberekpe)

Received: 7 July 2025; **Accepted:** 18 August 2025; **Published:** 9 September 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Measles is one of the most contagious viral diseases and continues to be a significant cause of vaccine-preventable morbidity and mortality worldwide despite the availability of an effective vaccine [1]. Globally, an estimated 134,200 measles-related deaths occurred in 2015, mostly among children under five years [2]. Sub-Saharan Africa contributes disproportionately to the global measles burden, and despite the introduction of measles-containing vaccines (MCVs), coverage has remained suboptimal in many countries [3, 4]. The WHO African Region missed its 2020 elimination target, and by 2021, no African country had achieved measles elimination [5].

In Nigeria, measles is endemic and continues to cause recurrent outbreaks. Immunization coverage remains below the 95% threshold required for herd immunity [6]. According to WHO and UNICEF estimates, only about 54% of children in Nigeria received the first dose of measles-containing vaccine (MCV1) in 2020, while coverage for the second dose (MCV2, introduced in 2019) is significantly lower [7]. As a result, large pools of susceptible children persist, leading to periodic outbreaks. Between January and August 2021, Nigeria reported over 67,000 suspected measles cases, a substantial increase compared to the 9,300 cases reported in 2020 [8]. These outbreaks were exacerbated by disruptions to routine health services during the COVID-19 pandemic, which further reduced immunization uptake and strained surveillance systems [9].

Rivers State, located in southern Nigeria with a population of over seven million and 23 Local Government Areas (LGAs), continues to experience recurrent measles outbreaks despite periodic supplementary immunization activities [10, 11]. Outbreaks have been reported in both urban and rural LGAs, with clusters often linked to low routine vaccination coverage, high population density, and inadequate outbreak response measures [12, 13]. Prior studies have demonstrated that measles outbreaks in Nigeria frequently occur in areas with low immunization uptake and can spread rapidly due to weak surveillance and delayed response [14-16].

The epidemiology of measles is also changing. While children under five years remain the most affected group, outbreaks increasingly involve older children and even adults, reflecting historical immunity gaps and low MCV2 coverage [17, 18]. Inadequate Vitamin A supplementation, high rates of malnutrition, and poor health-seeking behavior further exacerbate morbidity and mortality [19, 20]. Furthermore, seasonal patterns, population mobility, and urban-rural disparities influence measles transmission dynamics [21, 22].

Given these realities, characterizing the spatiotemporal distribution of measles outbreaks at subnational levels is crucial. Few studies have specifically examined outbreak patterns in Rivers State using surveillance data across multiple years. This study aimed to analyze measles outbreaks in Rivers State from 2020 to 2022, highlighting temporal trends,

geographic clustering by LGA, and age distribution of cases. Findings are expected to guide targeted interventions, strengthen immunization programs, and improve surveillance and outbreak preparedness in the state and beyond.

2. Methods

2.1. Study Design and Data Source

The study was a retrospective cross-sectional analysis of measles surveillance data in Rivers State for the period January 2020 to December 2022. Data were obtained from the Rivers State Ministry of Health measles case-based surveillance system, which compiles information on all suspected measles cases investigated in the state. Each case record included variables such as date of symptom onset, LGA of residence, age or date of birth, sex, and laboratory results (measles IgM serology). Laboratory-confirmed and epidemiologically linked measles cases were included in the analysis; cases later discarded as non-measles were excluded. The dataset was filtered to include only cases with dates of onset from 1 January 2020 through 31 December 2022.

2.1.1. Case Definitions

A suspected measles case is defined by Nigeria's Integrated Disease Surveillance and Response (IDSR) guidelines as any person with fever and maculopapular rash (with cough, coryza or conjunctivitis) or any patient in whom a clinician suspects measles. Laboratory confirmation is via detection of measles-specific IgM antibodies. For identifying outbreak clusters, the study adopted the Nigeria Centre for Disease Control (NCDC) measles outbreak definition which defined measles outbreak as any LGA with at least three laboratory-confirmed cases within a 4-week period

2.1.2. Variables and Categorization

Date of onset was used to derive the month and year of each case. Monthly case counts were aggregated to generate time-series trends. Cases were assigned to their LGA of residence for spatial analysis. Age was initially recorded in years (with decimals for months); validated and computed in years using the date of birth (when available) and date of onset. For analysis, age was categorized into five groups: <1 year, 1-4 years, 5-9 years, 10-14 years, and ≥15 years. These categories reflect key epidemiologic and immunization-relevant cohorts (infants, preschool, school-age children, adolescents, and adults). A small number of cases with missing age data were labeled as "Unknown" in age-group analyses. Sex (male/female) was recorded, but since the data showed an almost equal gender distribution, sex-specific analysis is not presented in detail.

2.2. Data Analysis

Descriptive statistics used to summarize measles occurrence by time, place, and person. Temporal patterns were examined by plotting an epidemic curve of monthly cases for the 3-year period. Annual totals were calculated and peak outbreak months identified. Spatial distribution was assessed by tabulating cases per LGA per year and the total. “Hotspot” LGAs with the highest case counts were highlighted and LGAs that crossed the outbreak threshold of ≥ 3 cases in a month noted. For person characteristics, the age distribution, median age, and proportion of cases in each age category per year were computed. The Pearson chi-square (χ^2) test was used for associations: (1) between outbreak year and LGA distribution of cases, (2) between year and age group of cases, and (3) between LGA and age group. These assess whether measles cases were evenly distributed or whether certain years had disproportionate cases in certain LGAs or age groups. Expected frequencies in contingency tables were checked to ensure chi-square test validity; when cell counts were low, categories were combined or Yates’ correction applied as needed. A p-value < 0.05 was considered statistically significant.

Graphical illustrations were made to support the analysis. A monthly epidemic curve (line graph) was plotted to depict trends and outbreak peaks over time. For spatial distribution, bar charts were plotted to compare LGA case totals. One bar chart ranked LGAs by total cases from 2020-2022, highlighting the highest-burden areas. Another bar chart showed the number of cases by age group, to visualize the age distribution of cases. Data cleaning and analysis were performed using Microsoft Excel and Python (Pandas), and charts were generated with Python’s Matplotlib library.

2.3. Ethical Considerations

This analysis was conducted on de-identified surveillance data collected for public health purposes. Individual patient consent was not required as no personal identifiers were used and the study posed minimal risk. Permission to use the measles surveillance dataset was obtained from the Rivers State Ministry of Health. The study complies with confidentiality and ethical standards for the use of surveillance data, and findings were presented in aggregate without any personally identifiable information.

3. Results

3.1. Temporal Trends

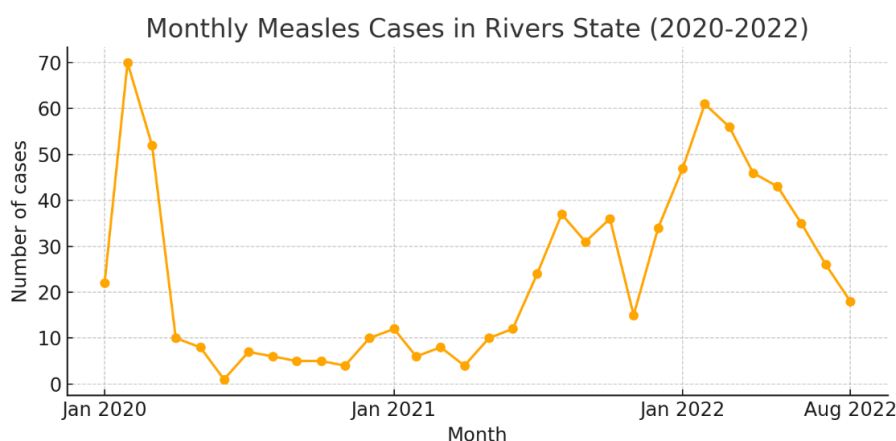


Figure 1. Illustrates the monthly epidemic curve of reported cases.

A total of 761 measles cases were reported in Rivers State during the 3-year period (2020-2022). Annual case counts showed an increasing trend: 200 cases in 2020, 229 in 2021, and 332 in 2022.

Three distinct outbreak periods can be seen:

- 1) **Early 2020 Outbreak:** Cases surged in the first quarter of 2020, peaking in February 2020 with 70 cases, followed by 52 cases in March. This was the largest spike in 2020. After March 2020, cases declined sharply; by June 2020,

only 1 case was recorded, indicating the outbreak was largely contained by late second quarter of 2020. Sporadic cases (fewer than 10 per month) continued through the second half of 2020.

- 2) **Late 2021 Resurgence:** Compared to 2020, 2021 had a more protracted low-level transmission for the first half of the year, with a slight uptick mid-year. A noticeable increase began in July 2021 (24 cases), rising to a peak of 37 cases in August 2021. Cases remained relatively

elevated through October 2021 (36 cases), then fluctuated, with a secondary peak of 34 in December 2021. This suggests that instead of one sharply defined outbreak, 2021 experienced an extended period of measles transmission from mid-year into the end of the year. The sustained nature of this wave may indicate multiple localized outbreaks or continuous spread in different communities.

- 3) **Major 2022 Outbreak:** The year 2022 saw the highest measles activity. Cases spiked dramatically in January 2022 to 47, climbing to 61 in February - surpassing the 2020 peak. A total of 56 cases occurred in March 2022 and 46 in April, indicating a widespread outbreak in early 2022. After April, there was a steady decline: by August 2022 cases fell to 18. (Data after August were not available in the dataset, so it's unclear if further waves occurred later in 2022.) The early-2022 outbreak was the largest observed in the study period, both in peak magnitude and in the number of consecutive high-incidence months.

These patterns suggest a 2-year cycle of major measles outbreaks (early 2020 and early 2022) in Rivers State, with an intervening smaller wave in late 2021. The timing corresponds to accumulation of susceptible individuals after the 2020 outbreak, leading to another outbreak by late 2021-2022. Notably, the 2020 outbreak occurred mainly in the dry season (late winter), whereas the 2021 wave peaked in the rainy season (August) and the 2022 outbreak again in the dry season, though interpretation of seasonality is limited by the multi-year cycle.

3.2. Geographic Distribution

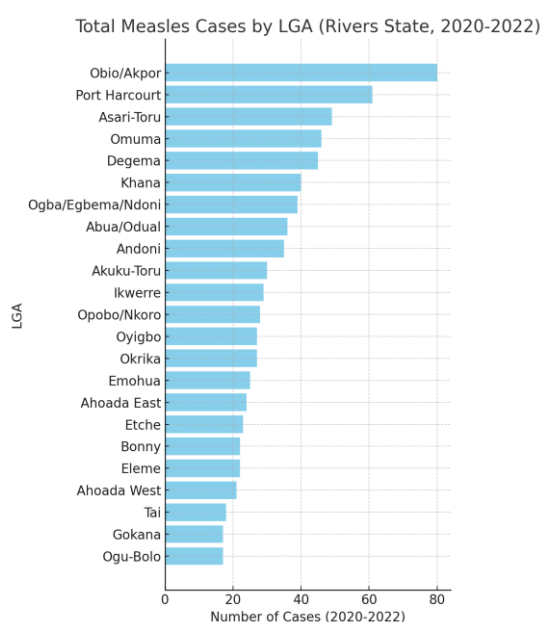


Figure 2. Illustrates measles cases distribution by local Government Areas.

Measles cases during 2020-2022 were reported from *all* 23 LGAs in Rivers State, reflecting wide geographic spread of the virus. However, the case burden was uneven, with certain LGAs experiencing substantially more cases and more frequent outbreaks.

The top 5 LGAs by total case count were:

- 1) **Obio/Akpor (80 cases):** This LGA (which is part of the Port Harcourt metropolis) had the highest number of cases overall. It contributed 10.5% of the state's cases. Obio/Akpor reported 30 cases in 2020, 21 in 2021, and 29 in 2022, indicating high incidence in the 2020 outbreak and again in 2022. It exceeded the outbreak threshold multiple times (e.g., February-March 2020 and in early 2022). Obio/Akpor's consistently high numbers make it a persistent hotspot.
- 2) **Port Harcourt (61 cases):** This LGA had the second highest number of measles cases (8.0% of cases). Notably, Port Harcourt City recorded relatively fewer cases in 2020 (17) and 2021 (10), but a major spike in 2022 (34 cases). It was a focus of the 2022 outbreak, with monthly counts reaching 8 in January and 8 in May 2022. This suggests that while the city was less affected in 2020-21, it became a significant transmission epicenter in 2022.
- 3) **Asari-Toru (49 cases):** This riverine LGA experienced a large outbreak in 2020 (27 cases, one of the highest LGA totals that year). In subsequent years, Asari-Toru's cases dropped (11 each in 2021 and 2022). This pattern implies a major 2020 cluster centered in Asari-Toru (likely affecting communities there and possibly neighboring LGAs) that did not recur as strongly later. It highlights the spatiotemporal clustering nature - an outbreak hit Asari-Toru in 2020 and subsided by 2021 after presumably imparting immunity to many locals.
- 4) **Omuma (46 cases):** Omuma LGA had low cases in 2020 (8) but saw increased activity in 2021 (16) and 2022 (22). Especially in 2022, Omuma crossed the outbreak threshold in consecutive months (e.g., 5 cases in February 2022, 3 in March, 3 in April). This indicates that Omuma was part of the widespread outbreak in early 2022, despite being a more rural LGA. Its rising case count over the years suggests growing susceptibility or improved reporting in that area.
- 5) **Degema (45 cases):** Degema LGA reported 18 cases in 2020 and a significant 22 cases in 2021, but only 5 in 2022. Degema had an outbreak in mid-2021 (notably 6 cases in July 2021), which was one of the larger LGA-specific outbreaks of that year. By 2022, Degema had relatively few cases, possibly due to immunity gained from the prior year's outbreak. Degema's spike in 2021, contrasted with its quiet 2022, exemplifies how some LGAs had off-cycle outbreaks.

Other LGAs with notable measles cases include *Khana* (40 cases) - mostly driven by a large jump to 26 cases in 2022 (versus 7 each in 2020 and 2021), *Ogba/Egbema/Ndoni* (39

cases) - which had outbreaks in both 2021 (18 cases) and 2022 (19 cases), and *Abua/Odual* (36 cases) - with a notable outbreak in 2021 (17 cases). In fact, in late 2021, an outbreak in *Abua/Odual* communities was reported to have caused significant morbidity and even multiple child deaths (per local media), underscoring the severity of measles in that area. Many of the smaller LGAs (e.g., *Gokana*, *Ogu-Bolo*, *Tai*, *Ahoada West*, each with <20 cases total) saw sporadic cases or small clusters, but no major sustained outbreaks during this period.

Outbreak clustering in space and time: The geographic pattern shifted over time, as reflected by the significant chi-square test for year vs LGA distribution ($p < 0.001$). For instance, the 2020 outbreak was concentrated in *Obio/Akpor*, *Asari-Toru*, *Degema* and some spread to neighboring LGAs. The late 2021 wave involved clusters in *Degema*, *Ogba/Egbema/Ndoni*, *Abua/Odual*, and parts of the state's northwest. The big 2022 outbreak was more widespread: urban centers (*Obio/Akpor*, *Port Harcourt*) and multiple rural LGAs (*Khana* in the southeast, *Emohua* and *Etche* in the north, *Bonny* in the south, etc.) all reported concurrent surges, suggesting a state-wide epidemic. In March 2022 alone, at least 9 different LGAs each had ≥ 3 cases in that single month, indicating multiple simultaneous transmission foci. By contrast, at the nadir in mid-2020, most LGAs had zero cases for several months.

Overall, *urban LGAs (Obio/Akpor, Port Harcourt)* bore a consistently high measles burden. This likely relates to their larger population density (hence more susceptibles) and possibly better reporting. *Rural LGAs* experienced more episodic outbreaks - intense but isolated in time - which may reflect accumulations of susceptible children over years until an outbreak occurs. It is noteworthy that measles cases were indeed widespread and not confined to one part of the state: control efforts therefore must maintain broad coverage while also targeting the worst-affected areas.

3.3. Age Group Characteristics

Distribution of Measles Cases by Age Group (Rivers 2020-2022)

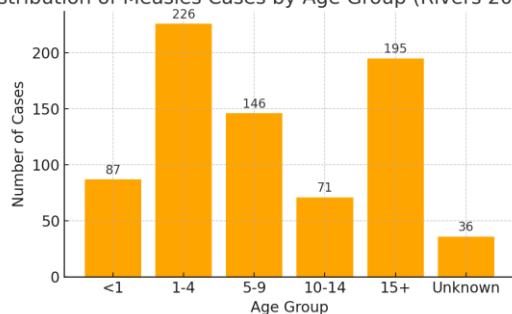


Figure 3. Shows the overall distribution of cases by age group.

A striking feature of the Rivers State measles data is the wide age range of cases. Ages ranged from 2 months to 80

years old. The median age of cases was 6.4 years (interquartile range 2.1 - 16.2 years), indicating that half of cases were young children, but a substantial minority were adolescents or adults.

Key observations include:

- 1) **Children <5 years:** Young children (under 5) accounted for the largest share of cases when combined. Infants <1 year represented 87 cases (11.4% of total), and children 1-4 years old accounted for 226 cases (29.7%). Altogether, the under-5 age group made up ~41% of all cases. This aligns with the expectation that measles primarily affects young children in high-transmission settings. Notably, infants under 9 months (who are generally too young for routine measles vaccination in Nigeria) comprised a significant number of cases, underscoring the risk in unvaccinated infants and the importance of herd immunity to protect this group.
- 2) **Children 5-9 years:** There were 146 cases (19.2%) in the 5-9 years age group. Many of these children would have been eligible for at least one dose of measles vaccine, suggesting that either they missed vaccination or did not develop immunity. The sizable number of school-age children getting measles points to gaps in immunization coverage or potential secondary vaccine failures.
- 3) **Adolescents 10-14 years:** 71 cases (9.3%) fell in the 10-14 age bracket. By this age, most would have long passed the routine vaccination schedule, implying these were likely individuals who missed childhood vaccination. The presence of cases in older children indicates measles susceptibility extending into early adolescence for some cohorts, possibly due to historically low vaccination rates in certain areas (a child who was 10 in 2022 would have been due for vaccination around 2012, when national MCV1 coverage was around 42%^{aeji.journals.ekb.eg} in some regions, reflecting those missed).
- 4) **Adults ≥ 15 years:** A total of 195 cases (25.6%) occurred in individuals 15 years and older, including young adults and some middle-aged or older adults. This is a substantial proportion. Many of these adult cases were in their late teens and twenties, but a few were much older (over 50 or 60 years). The occurrence of measles in adults suggests long-term gaps in immunity - either people who never received vaccine nor had the disease in childhood, or waning immunity in the absence of re-exposure. In Nigeria, routine measles vaccination began in the late 1970s/1980s; thus, older adults may have been unvaccinated but often had natural infection in childhood. The fact that some older adults in Rivers State were still susceptible enough to contract measles (e.g., the 79-year-old case) is unusual and might indicate an atypical situation or error in reporting age. However, the bulk of "adult" cases were likely young adults who missed vaccination in childhood due to low coverage in the 1990s-2000s.

5) *Unknown age*: 36 cases (4.7%) had unknown age data. These were excluded from age-specific percentage calculations but are shown in [Figure 3](#) for completeness.

Age distribution by year: The proportion of cases in each age group shifted somewhat from year to year (refer to [Table 1](#)). In 2020, the median age was about 5 years; the 2020 outbreak heavily impacted under-5 children (46% of 2020 cases) with relatively fewer adults (~19% ≥15yrs). In 2021, the median age increased to ~9 years; only ~35% were under 5, while adult cases rose to 34.5% of 2021 cases. This suggests the 2021 outbreaks involved older cohorts - possibly because the areas affected in 2021 had lower historical vaccination, leaving older children and adults susceptible. By 2022, the pattern shifted back: under-five formed ~45% of cases in the large 2022 outbreak, and adults 23.8%. This could indicate that the widespread 2022 epidemic swept through many unvaccinated young children across the state, while a portion of older individuals had gained immunity (some via the 2020-21 outbreaks or vaccination). The chi-square test confirmed a significant association between year and age group ($p \approx 0.002$). In practical terms, *2021's outbreaks had an older age profile* compared to the *2020 and 2022 outbreaks*, which were more concentrated in young children.

LGA vs Age profile: We also observed differences in age profiles between urban and rural LGAs. In high-density urban LGAs (Obio/Akpor, Port Harcourt, Eleme, Oyigbo), a larger

fraction of cases were under 5. For example, in Obio/Akpor 43% of cases were <5, and in Port Harcourt 38% were <5. This suggests that in urban areas, measles tends to infect children early in life (likely due to higher transmission force of infection, so most susceptible children get exposed while young). By contrast, some rural LGAs saw more older cases: in *Tai LGA*, 37.5% of cases were adults ≥15, and similarly over 28% of cases in Asari-Toru, Opobo/Nkoro, Gokana were adults. These are areas with historically lower routine immunization coverage; many children there might escape measles in early childhood only to remain susceptible into adolescence and adulthood. This pattern resulted in the strong statistical association between LGA and age group ($p < 0.001$). It highlights that *immunity gaps in certain communities extend across a broad age range*, whereas in better-immunized communities, measles is largely confined to younger unvaccinated children.

In summary, the age distribution of measles cases in Rivers State indicates that while young children are the most affected group, measles is *not solely a pediatric disease* in this setting - a considerable proportion of cases occurred in older children and adults, reflecting past failures to vaccinate those cohorts. This has implications for outbreak control, as cases in school-age children and adults can fuel transmission (and adults may have more contacts, potentially spreading to other areas).

Table 1. Distribution of measles cases by age group and year, Rivers State (2020-2022).

Age Group	2020 Cases (n=200)	2021 Cases (n=229)	2022 Cases (n=332)	Total 2020-22 (n=761)
< 1 year	22 (11.0%)	30 (13.1%)	35 (10.5%)	87 (11.4%)
1-4 years	61 (30.5%)	51 (22.3%)	114 (34.3%)	226 (29.7%)
5-9 years	44 (22.0%)	33 (14.4%)	69 (20.8%)	146 (19.2%)
10-14 years	15 (7.5%)	30 (13.1%)	26 (7.8%)	71 (9.3%)
≥15 years	39 (19.5%)	77 (33.6%)	79 (23.8%)	195 (25.6%)
Unknown	19 (9.5%)	8 (3.5%)	9 (2.7%)	36 (4.7%)
Total	200 (100%)	229 (100%)	332 (100%)	761 (100%)

Note: “Unknown” refers to cases with missing age data. Percentages for age groups are out of total cases each year (and overall). Due to rounding, percentages may not sum exactly to 100%.

The above table reinforces the earlier descriptions: e.g., ≥15-year-olds constituted one-third of 2021’s cases (the highest proportion among the three years), whereas the <5 group was largest in 2022. Public health efforts should particularly ensure measles vaccination in children under 5 (who consistently make up a large portion of cases) but also consider catch-up campaigns for older children and adults in communities with known immunity gaps.

3.4. Inferential Statistics Summary

To summarize the analytical test findings:

- 1) *Year vs LGA distribution*: There was a statistically significant association between outbreak year and which LGAs were affected (χ^2 test, $p < 0.0001$). This means the pattern of LGAs with high case counts was not the same each year. For example, some LGAs like Asari-Toru had many cases in 2020 but not in later years, whereas others

like Khana had major outbreaks only in 2022. The spatial focal points of measles shifted over time.

- 2) *Year vs Age distribution*: The age profile of cases changed significantly across the 3 years (χ^2 test, $p=0.002$). Specifically, 2021's outbreaks involved relatively older individuals than the more child-focused outbreaks of 2020 and 2022. This could reflect differing local immunity profiles or the effect of prior outbreaks on different age cohorts.
- 3) *LGA vs Age group*: There was a significant association between LGA and age group of cases (χ^2 test, $p<0.001$). Certain LGAs had a disproportionate share of adult cases whereas others had mostly young children, as discussed. This likely results from variation in historical vaccination coverage - where coverage is good, measles is confined to the very young, but where coverage is poor, measles affects older ages as well.

These findings collectively underscore that *measles epidemiology in Rivers State is heterogeneous across time and place*. Outbreaks do not uniformly affect all areas or age groups, which has important implications for tailoring interventions.

3. Discussion

This study revealed persistent measles transmission and recurrent outbreaks in Rivers State between 2020 and 2022. The findings demonstrate a cyclical outbreak pattern, significant immunity gaps across age groups, and spatiotemporal clustering across different LGAs.

Recurring outbreaks and cyclic patterns

The study identified two major outbreaks in early 2020 and early 2022, with an intermediate resurgence in late 2021. Such cyclical patterns have been described elsewhere in Nigeria and the African region, often reflecting the accumulation of susceptible individuals following incomplete immunization coverage [23, 24]. The resurgence of measles after the COVID-19 pandemic aligns with reports of increased outbreaks in Africa due to pandemic-related service disruptions [25].

Age distribution and immunity gaps

A key observation is the significant proportion of cases among older children and adults (≥ 15 years), who constituted about a quarter of all cases. In well-immunized populations, measles predominantly affects unvaccinated infants; hence, the presence of cases among older cohorts indicates long-standing immunity gaps [26, 27]. Nigeria's historically low routine immunization coverage during the 1990s and 2000s likely contributed to this vulnerability [28]. Recent evidence also suggests waning immunity in populations with incomplete two-dose coverage [29]. These findings underscore the importance of catch-up vaccination campaigns targeting not only children under five but also older children and adolescents.

Vaccination coverage and outbreak drivers

Measles outbreaks in Rivers State reflect broader national challenges, including low MCV2 uptake (around 38% in 2023), vaccine hesitancy, and gaps in outreach to marginalized populations [30-32]. Studies have shown that strengthening both routine immunization and supplementary immunization activities (SIAs) is essential to interrupt transmission [33, 34]. The clustering of outbreaks in certain LGAs, especially urban centers such as Obio/Akpor and Port Harcourt, highlights the influence of high population density and rapid transmission in urban settings [35]. Conversely, outbreaks in rural LGAs reflect challenges of access, logistics, and surveillance weaknesses [36].

Mortality and complications

Although this study did not include mortality data, measles is known to cause severe complications, including pneumonia, diarrhea, encephalitis, and death, particularly in malnourished children [37, 38]. Nigeria's reported case fatality rate for measles ranges between 0.5% and 1% in recent years [39]. Local reports of unrecorded deaths during outbreaks in Rivers State suggest underestimation of the mortality burden [40]. Strengthening case management, ensuring Vitamin A supplementation, and improving reporting systems are critical to reducing measles-related deaths.

Surveillance and public health implications

The detection of measles cases in all 23 LGAs indicates relatively strong surveillance performance, consistent with previous evaluations of Rivers State's IDSR system [41]. However, gaps remain, including underreporting and incomplete laboratory confirmation. Enhanced community-based surveillance, rapid outbreak response immunization (ORI), and timely data sharing are needed to prevent large-scale outbreaks [42, 43].

Implications for elimination goals

The African Region has now shifted its measles elimination target from 2020 to 2030 following setbacks from the COVID-19 pandemic [44]. Achieving this goal in Rivers State will require intensifying MCV1 and MCV2 coverage, ensuring effective SIAs, and implementing mop-up campaigns in identified hotspots [45, 46]. Strengthening health system resilience, addressing vaccine hesitancy, and engaging communities will be critical for success [47, 48].

4. Conclusion

The study highlighted the need for a multi-faceted approach: improving routine vaccination, conducting timely ORIs, strengthening surveillance, and engaging communities. Measles outbreaks often reveal health system weaknesses - by addressing these (immunization coverage and outbreak response capacity), Rivers State can advance towards measles control. It is worth noting that the African Region has now shifted the measles elimination target to 2030, recognizing setbacks from the 2020 goal. Without intensified efforts (especially improved two-dose coverage and surveillance), achieving this renewed goal will be challenging.

Abbreviations

IDSR	Integrated Disease Surveillance and Response.
LGA	Local Government Area
MCV	Measles Containing Vaccine
MCV1	First Dose of Measles Containing Vaccine
MCV2	Second Dose of Measles Containing Vaccine
NCDC	Nigeria Centre for Disease Control
ORI	Outbreak Response Immunization
SIA	Supplementary Immunization Activity
UNICEF	United Nations Children's Fund
WHO	World Health Organization

Funding

The research received no external financial support.

Acknowledgments

The authors do acknowledge the Rivers State Ministry of Health for providing the measles surveillance dataset.

Conflict of Interest

The authors declare no conflict of interest.

References

- [1] WHO. Measles - Key facts. Geneva: World Health Organization; 2019. Available from: <https://www.who.int/news-room/fact-sheets/detail/measles>
- [2] WHO. Global measles deaths fell by 73% between 2000 and 2018. Geneva: World Health Organization; 2019.
- [3] Masresha BG, Hatcher C, Lebo E, et al. Progress Toward Measles Elimination — African Region, 2017-2021. *MMWR Morb Mortal Wkly Rep*. 2023; 72(36): 985-991. <https://doi.org/10.15585/mmwr.mm7236a3>
- [4] Dabbagh A, Laws RL, Steulet C, et al. Progress toward regional measles elimination — worldwide, 2000-2020. *MMWR Morb Mortal Wkly Rep*. 2021; 70(45): 1563-1569. <https://doi.org/10.15585/mmwr.mm7045a1>
- [5] WHO Regional Office for Africa. Measles outbreaks in Africa. Brazzaville: WHO AFRO; 2021.
- [6] Nnaji CA, et al. Vaccine hesitancy and challenges of measles elimination in sub-Saharan Africa. *Vaccine*. 2022; 40(35): 5162-5168. <https://doi.org/10.1016/j.vaccine.2022.07.020>
- [7] UNICEF/WHO Estimates of National Immunization Coverage (WUENIC). Geneva; 2021.
- [8] Nigeria Centre for Disease Control. Weekly epidemiological report, 2021. Abuja: NCDC.
- [9] Gavi, the Vaccine Alliance. COVID-19 pandemic threatens measles elimination. Gavi; 2022.
- [10] Utulu R, Urang J, Usman A, et al. Performance of measles case-based surveillance system in Rivers State, Nigeria 2011-2018. *J Immunol Sci*. 2020; 4(1): 10-18. <https://doi.org/10.29245/2578-3009/2020/1.1183>
- [11] Enitan SS, Iduh MU, Itodo GE, et al. Combating measles in Nigeria: Epidemiological trends and interventions. *Afro-Egypt J Infect Endem Dis*. 2024; 14(4): 375-95. <https://doi.org/10.21608/aej.2024.308038.1402>
- [12] Naku D. Measles: 50 children feared dead in Rivers communities. *Punch Nigeria*. 2022 Aug 8.
- [13] News Agency of Nigeria. Measles outbreak spreads to eight states. *Peoples Gazette*. 2022 Mar 4.
- [14] Okonko IO, et al. An overview of measles resurgence in Nigeria. *Int J Trop Dis Health*. 2019; 36(4): 1-10.
- [15] Goodson JL, et al. Measles outbreaks and progress toward elimination in Africa, 2016-2018. *J Infect Dis*. 2020;222(Suppl 5): S652-60. <https://doi.org/10.1093/infdis/jiaa146>
- [16] Fatiregun AA, et al. Outbreak response to measles in Nigeria: lessons from the field. *Pan Afr Med J*. 2021; 38: 123. <https://doi.org/10.11604/pamj.2021.38.123.28472>
- [17] Orenstein WA, Cairns L, Hinman A, et al. Measles and rubella global strategic plan 2012-2020 midterm review. *Vaccine*. 2018; 36 Suppl 1: A1-34. <https://doi.org/10.1016/j.vaccine.2017.09.026>
- [18] Moss WJ. Measles. *Lancet*. 2017; 390(10111): 2490-502. [https://doi.org/10.1016/S0140-6736\(17\)31463-0](https://doi.org/10.1016/S0140-6736(17)31463-0)
- [19] Aaby P, Martins CL, Garly ML, Rodrigues A, Benn CS, Whittle H. Non-specific effects of measles vaccine on child survival: review. *Trop Med Int Health*. 2010; 15(9): 1079-87.
- [20] WHO. Vitamin A supplementation in measles control. Geneva: WHO; 2020.
- [21] Pomeroy LW, et al. Seasonality of measles in Africa: a systematic review. *BMC Infect Dis*. 2019; 19: 297. <https://doi.org/10.1186/s12879-019-3916-1>
- [22] Ferrari MJ, et al. Influence of demographic and seasonal patterns on measles epidemics in Africa. *Proc Biol Sci*. 2010; 277(1692): 2775-82.
- [23] Nsubuga P, et al. Measles outbreak cycles in Africa. *J Infect Dis*. 2020; 222(Suppl 5): S640-51. <https://doi.org/10.1093/infdis/jiaa157>
- [24] Grais RF, et al. Uncertainty and spatiotemporal heterogeneity in measles epidemics in West Africa. *Epidemiol Infect*. 2006; 134(5): 1009-19.
- [25] Gavi. 24 million Nigerian kids to be vaccinated against measles in major campaign. 2024 Nov 7.
- [26] Patel MK, et al. Progress toward regional measles elimination — worldwide, 2000-2019. *MMWR*. 2020; 69(45): 1700-5.

- [27] Goodson JL, et al. Challenges in achieving measles elimination in Africa. *J Infect Dis*. 2017; 216(Suppl 1): S293-9.
- [28] WHO/UNICEF. Nigeria immunization coverage trends. Geneva; 2023.
- [29] Leuridan E, Sabbe M, Van Damme P. Measles outbreak in Europe: susceptibility of infants too young to be immunized. *Vaccine*. 2012; 30(9): 5905-13.
- [30] Oyo-Ita A, et al. Barriers to routine immunization in Nigeria: a systematic review. *Vaccine*. 2016; 34(34): 4144-52.
- [31] Abegunde D, et al. Vaccine hesitancy in Nigeria: drivers and interventions. *Vaccine*. 2023; 41(13): 2090-98.
- [32] Nnaji CA, et al. Bridging immunization gaps in LMICs. *Trop Med Int Health*. 2023; 28(6): 765-73.
- [33] Patel MK, et al. Progress toward measles elimination in the WHO African Region, 2013-2016. *MMWR*. 2017; 66(17): 436-43.
- [34] Gidding HF, et al. The impact of supplementary immunization on measles elimination. *Vaccine*. 2018; 36(41): 6065-72.
- [35] Ogbuanu IU, et al. Urban measles outbreaks in sub-Saharan Africa. *Vaccine*. 2019; 37(24): 3257-63.
- [36] Brownwright TK, et al. Equity in measles vaccination coverage. *Int J Equity Health*. 2017; 16: 134.
- [37] Moss WJ, Griffin DE. Measles. *Lancet*. 2012; 379: 153-64.
- [38] Perry RT, Halsey NA. The clinical significance of measles: a review. *J Infect Dis*. 2004; 189 Suppl 1: S4-16.
- [39] NCDC. Integrated disease surveillance and response report. Abuja; 2022.
- [40] Punch Newspaper. Measles outbreak fatalities in Rivers State. 2022.
- [41] Utulu R, et al. Performance of measles surveillance, Rivers State. *J Immunol Sci*. 2020.
- [42] WHO. Strengthening surveillance for vaccine-preventable diseases. Geneva: WHO; 2022.
- [43] Balogun MS, et al. Evaluation of IDSR performance in Nigeria. *BMC Public Health*. 2019; 19: 123.
- [44] WHO AFRO. New measles elimination target 2030. Geneva; 2023.
- [45] Gavi. Supporting measles elimination in Africa. Geneva; 2024.
- [46] Goodson JL, et al. Ensuring equity in SIAs for measles control. *J Infect Dis*. 2017; 216 Suppl 1: S293-301.
- [47] Nnaji CA, et al. Role of community engagement in vaccination. *Vaccine*. 2023; 41(22): 3052-60.
- [48] UNICEF. Building trust for vaccines in Nigeria. New York; 2022.