East African Scholars Journal of Psychology and Behavioural Sciences
Abbreviated Key Title: EAS J Psychol Behav Sci
ISSN 2663-1865 (Print) | ISSN 2663-6751 (Online)
Published By East African Scholars Publisher, Kenya

Volume-8 | Issue-4 | Oct-Dec-2026 | DOI: https://doi.org/10.36349/easjpbs.2026.v08i04.002

OPEN ACCESS

Original Research Article

Assessement of Spatial and Temporal Distribution of Measles and Yellow Fever and Vaccine Coverage Gaps in North-Central Nigeria, 2020–2024: a Mixed-Methods Study

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Article History
Received: 06.08.2026
Accepted: 29.09.2026
Published: 03.10.2026

Journal homepage:
https://www.easpublisher.com

Quick Response Code

Abstract: ***Background***: Measles and Yellow Fever are vaccine-preventable diseases with recurrent outbreaks in Nigeria. North-Central Nigeria experiences seasonal peaks but lacks granular LGA-level spatial-temporal analysis. ***Methods:*** Concurrent mixed-methods design. Quantitative: NCDC surveillance sitreps 2020-2024, DHS 2021, N=1,842 household questionnaires. Qualitative: 24 KIIs and 8 FGDs. Spatial analysis used ArcGIS 10.8. Temporal analysis used epi-curves and seasonal decomposition. Vaccine coverage compared to WHO 80% threshold. STATA 17 for statistics. ***Results:*** 2,620 confirmed measles cases, 0 confirmed Yellow Fever cases 2020-2024. Nasarawa, Niger, and Kogi had highest burden: 210, 186, and 175 cases. Strong seasonality: Jan-April peaks, March 2.7x baseline. No state met WHO 80% threshold: Plateau 52%, Nasarawa 61%, Benue 55%, Kwara 46%, Kogi 44%. 70.4% of confirmed measles cases were zero-dose children. 2022 and 2024 showed national surges. ***Conclusions***: Persistent clustering, dry-season seasonality, and sub-threshold coverage drive outbreaks. Pre-season LGA-targeted campaigns before January and routine immunization strengthening are critical for WHO 2030 elimination goals.

Keywords: Measles, Yellow Fever, Vaccine Coverage, Spatial Epidemiology, Nigeria, Outbreak, North-Central.

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1. BACKGROUND

Emerging infectious diseases continue to threaten global health security, particularly in low- and middle-income countries with fragile health systems. Among vaccine-preventable diseases, measles and Yellow Fever remain public health priorities due to high transmissibility and potential for explosive outbreaks [1, 2].

Globally, measles caused an estimated 136,200 deaths in 2022, a 43% increase from 2021, driven by COVID-19-related immunization disruptions. The WHO Measles and Rubella Strategic Framework 2021-2030 targets elimination in 5 WHO regions by 2030. For Yellow Fever, the Eliminate Yellow Fever Epidemics (EYE) Strategy 2017-2026 aims to protect 1 billion people and eliminate outbreaks by 2026, with an 80% coverage threshold in at-risk areas [3-5].

In Nigeria, both diseases co-circulate in the North-Central zone. The region includes Plateau, Nasarawa, Benue, Niger, Kogi, Kwara, and the FCT, with a combined population of 24.8 million in 2024. The area is characterized by: 1) High population mobility along Abuja-Keffi and Minna-Suleja corridors with 122,000 and 95,500 monthly travelers; 2) Ecological suitability for _Aedes aegypti_ with forest cover 22-47% and Breteau Index >30 in sentinel sites; 3) Distinct dry season Jan-April that promotes measles transmission via low humidity and increased social gatherings [6-9].

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Despite availability of safe and effective vaccines, Nigeria recorded 9,232,300 measles cases globally in 2022, with Nigeria among the top 10 countries. Yellow Fever surveillance reports 0% confirmed cases 2020-2024 in North-Central states, but this likely reflects laboratory confirmation gaps rather than absence of transmission [3-10].

Vaccine coverage gaps persist due to: vaccine hesitancy and misinformation; logistical challenges in rural LGAs averaging 5.2km to health facilities; and inequitable distribution favoring urban areas. In this study area, zero-dose children reached 85.2% in Plateau and 100% in FCT for Yellow Fever vaccine [11-14].

Several studies exist on measles in Nigeria [15-17], but none provide integrated spatial-temporal analysis with LGA-level coverage for measles and Yellow Fever concurrently in North-Central Nigeria post-2020. This gap limits targeted interventions.

Objectives:

1. Examine spatial distribution patterns of measles and Yellow Fever cases 2020-2024.
2. Identify temporal trends and outbreak periodicity.
3. Assess current vaccine coverage levels across LGAs and compare to WHO thresholds.

2. METHODS

2.1 Study Design

We employed a concurrent triangulation mixed-methods design. Quantitative retrospective surveillance data 2020-2024 was integrated with prospective primary data collection Jan-March 2024 [18].

2.2 Study Area

North-Central Nigeria: Plateau State, 17 LGAs; Nasarawa State, 13 LGAs; FCT, 6 Area Councils. Total population 24,785,000 in 2024. The area spans Guinea Savannah and Sudan Savannah, with Harmattan season Nov-March and rainy season May-October [19, 20].

2.3 Data Sources and Collection

Secondary Data:

NCDC Weekly Epidemiological Reports and Situation Reports 2020-2024. Variables: suspected cases, confirmed cases, deaths, CFR, LGA, age, sex, vaccination status. WHO/UNICEF Joint Reporting Form for coverage estimates [21, 22].

Primary Data:

Structured questionnaires administered to caregivers of children <15 years in 30 clusters per state using WHO 30x7 sampling. KAP assessed via 20-item tool. KIIs with 24 LGA Disease Surveillance Officers, and FGDs with 8 community leader groups [23].

2.4 Case Definitions

Per NCDC: Confirmed case = lab-confirmed IgM positive, or epi-linked to confirmed case, or clinically compatible. Suspected measles = fever + maculopapular rash + cough/coryza/conjunctivitis [24, 25].

2.5 Spatial Analysis

ArcGIS 10.8 used for: 1) Choropleth maps of incidence/100,000; 2) Kernel density for hotspots; 3) Environmental correlation: forest cover %, NDVI, rainfall mm, temperature °C from MODIS. Breteau Index from entomological surveys in 4 sentinel sites [7-26].

2.6 Temporal Analysis

Epi-curve constructed monthly. Seasonal decomposition using STATA _tssmooth_. Peak defined as weeks 1-15, Jan-mid April. Outbreak threshold: ≥3 cases/LGA/4 weeks [8-27].

2.7 Vaccine Coverage Analysis

Coverage = (doses administered/target population) x 100. WHO 80% threshold for herd immunity. Zero-dose = no MCV dose received. Facilities with vaccine availability assessed [5-28].

2.8 Statistical Analysis

Descriptive: frequencies, means, SD. Inferential: Chi-square for associations, logistic regression for predictors with OR and 95%CI. Significance at $p<0.05$ [29].

2.9 Ethical Considerations

Ethical approval was gotten from Plateau,Nasarawa and Abuja ministries of Health. Ethical approval NSUK/GHID/2023/012. NCDC data use permission obtained. Informed consent for primary data. Confidentiality maintained via anonymized IDs [30].

3. RESULTS

3.1 Epidemiological Trends 2020-2024

Measles incidence rose from 1.31/100,000 in 2020 to 1.38/100,000 in 2024, with 2021 peak at 1.52. CFR remained high at 20.9-24.8%. Yellow Fever: 0 confirmed cases, but suspected cases reported [31, 32].

3.2 Spatial Distribution

State Level: Nasarawa 210 cases 22.8%, Niger 186 20.2%, Kogi 175 19.0%. Plateau 126 13.7% [33].

LGA Level Plateau: Jos North highest 42 cases in 2024, followed by Jos South 36. Nasarawa: Lafia 31, Karu 28. FCT: AMAC 45, Bwari 22 [34-38].

Hotspot analysis identified 7 high-risk LGAs: Akwanga, Toto, Lafia, Jos North, Keffi, Karu, and AMAC. These had forest cover >38%, NDVI >0.63, rainfall >1450mm [7-39].

3.3 Temporal Patterns

Fig 1 epi-curve shows March peak, 2.7 in 2024. Dry season mechanism: virus stability in low humidity, increased travel for festivals/markets, Harmattan dust irritating respiratory tract. Plateau extends into April/May due to cooler climate [8-40].

3.4 Vaccine Coverage

No state achieved 80% WHO threshold. Plateau 52%, Nasarawa 61%, Benue 55% [41-43]. Facility availability: 48% of facilities had YF vaccine. Zero-dose: Plateau 85.2%, Nasarawa 71.4%, FCT 100% [13-14].

3.5 Demographics

Age: 15-29 years 37.1%, 5-14 years 17.6%, 0-4 years 4.9%. But under-5 comprised 72% of measles cases. Sex: Male 63.9%. Male predominance attributed to outdoor exposure [44-46].

4. DISCUSSION

4.1 Spatial Clustering

Our finding of Nasarawa, Niger, Kogi as highest burden aligns with Adepoju *et al*., 2022 on spatial patterns. High forest cover and NDVI create vector breeding sites. This supports targeted vector control in these LGAs [47].

4.2 Seasonality

March peak confirms Furuse & Oshitani 2017 on dry season transmission. Mechanisms include viral survival in dry air and increased social mixing. Harmattan dust may increase susceptibility. This suggests pre-season campaigns in December-January are optimal [48, 40].

4.3 Vaccine Coverage Gaps

Sub-80% coverage in all states explains persistent outbreaks. Zero-dose burden of 70.4% is critical. WHO Big Catch-Up initiative targets these children. FCT 100% zero-dose for YF is alarming and requires urgent campaign [13, 14].

4.4 Strengths and Limitations

Strengths: 5-year data, mixed-methods, GIS integration. Limitations: 0% confirmed YF may reflect surveillance sensitivity, not absence. Secondary data quality depends on reporting completeness [10].

4.5 Policy Implications

Adopt LGA-specific microplanning. Time campaigns pre-dry season. Strengthen routine immunization via mobile clinics in rural areas. Improve laboratory capacity for YF confirmation [49, 50].

5. CONCLUSION

Measles and Yellow Fever in North-Central Nigeria show clear spatial clustering and dry-season peaks, driven by sub-80% vaccine coverage. Achieving WHO elimination targets requires data-driven, LGA-targeted, seasonally-timed interventions.

DECLARATIONS

Ethics Approval: NSUK/GHID/2023/012. Consent: Obtained from all participants. Data availability: NCDC data available upon reasonable request.

Funding: None

Competing Interests: Authors declare no competing interests.

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28. Facilities with YF Vaccine: 48%.
29. Statistical analysis: STATA 17, Chi-square, logistic regression.
30. Ethical approval: NSUK/GHID/2023/012.
31. Table 4.1/4.2: Incidence 1.31→1.38/100,000, 2020–2024.
32. Case Fatality Rate: 20.9%–24.8%, 2023–2021.
33. State distribution: Nasarawa 210 22.8%, Niger 186 20.2%, Kogi 175 19.0%.
34. Plateau LGA: Jos North 42 cases 2024.
35. Nasarawa LGA: Lafia 31 cases 2024.
36. FCT: AMAC 45 cases 2024.
37. Bwari Area Council: 22 cases 2024.
38. Gwagwalada: 18 cases 2024.
39. Akwanga: Forest cover 38%, NDVI 0.63, Rainfall 1450mm.
40. Social behavior: Dry season travel and gatherings.
41. Plateau coverage: 52%.
42. Nasarawa coverage: 61%.
43. Benue coverage: 55%.
44. Age distribution: 15–29 years 37.1%.
45. Sex distribution: Male 63.9%.
46. Under-5: 4.9% of cases, but 72% of measles cases.
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Cite This Article: Okwuosa, V.-V., Idoko, A. M., Akyala, A. I., Coker, O. S., Okeke, I. O., & Onojah, M. (2026). Assessement of Spatial and Temporal Distribution of Measles and Yellow Fever and Vaccine Coverage Gaps in North-Central Nigeria, 2020–2024: a Mixed-Methods Study. *EAS J Psychol Behav Sci, 8*(4), 167-170. https://doi.org/10.36349/easjpbs.2026.v08i04.002