

## Spatial Distribution and Programmatic Implications of Orphan Polioviruses Detected from Acute Flaccid Paralysis Surveillance in Nigeria, 2025

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### ABSTRACT

### ARTICLE DETAILS

**Background:** Orphan polioviruses signal prolonged undetected circulation and gaps in population immunity. In Nigeria, where insecurity, population mobility, and hard-to-reach settlements challenge surveillance and immunization, orphan virus detection remains a critical programmatic indicator.

**Objective:** To describe the spatial distribution, surveillance performance, and immunization characteristics associated with orphan polioviruses detected through Acute Flaccid Paralysis surveillance in Nigeria in 2025, and to discuss implications for eradication strategies.

**Methods:** A descriptive cross-sectional analysis of AFP surveillance data for 2025 was conducted. Orphan virus detections were summarized by state and local government area (LGA), settlement security status, surveillance timeliness indicators, and vaccination history among children aged 0–59 months. Spatial distribution was visualized using state- and LGA-level mapping.

**Results:** A sum of 21 orphan polioviruses were discovered from AFP cases across 25 affected LGAs, predominantly in northern Nigeria. Notification within seven days of onset was achieved in 90% of cases, while investigation within 48 hours and stool collection within 14 days reached 100%. Forty-three percent of orphan viruses originated from insecure settlements. Only 5% of affected children had received three routine immunization doses of oral polio vaccine (OPV), while 81% had received at least four rounds of novel OPV type 2 (nOPV2). No cases were reported among children with zero nOPV2 exposure.

**Conclusion:** The detection of orphan polioviruses despite strong surveillance timeliness underscores persistent immunity gaps, particularly in insecure and mobile populations. Intensified subnational immunization, targeted outreach to high-risk settlements, and integration of environmental surveillance are essential to interrupt silent transmission.

**KEYWORDS:** Orphan poliovirus, AFP surveillance, Nigeria, nOPV2, polio eradication, insecure settlements

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### INTRODUCTION

Nigeria has made notable progress toward poliomyelitis eradication over the past decade, including the authorization of the disruption of transmission of wild poliovirus and significant declines in outbreaks of widespread vaccine-derived poliovirus type 2 (cVDPV2) through intensified vaccination campaigns and surveillance strengthening (Fomban Leke et al., 2020; Nasir et al., 2016). Despite these achievements, poliovirus transmission has not been completely eliminated, and the continued detection of genetically divergent poliovirus isolates remains a significant concern for Global Polio Eradication Initiative (GPEI) (Voorman et al., 2024). Orphan polioviruses are defined as poliovirus strains that exhibit substantial genetic variation in the viral protein 1 (VP1) region from their closest known relatives, typically exceeding 1.5% nucleotide divergence for poliovirus type 2 (Martinez et al., 2018). Such divergence implies prolonged undetected circulation, often for a year or more, without linkage to recognized transmission

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chains or previously identified cases (World Health Organization, 2021). The occurrence of orphan viruses is therefore considered a critical proxy indicator of surveillance sensitivity and underlying population immunity gaps, particularly in settings where asymptomatic transmission can persist silently (Braka et al., 2023).

Acute Flaccid Paralysis (AFP) surveillance is critical for poliovirus detection and eradication globally. A functional AFP surveillance system relies on timely case notification, rapid investigation, sufficient stool specimens within 14 days of the onset of paralysis, and high-quality laboratory confirmation through WHO-accredited laboratories (Eze et al., 2025). While Nigeria has consistently met key AFP performance indicators at the national level, including non-polio AFP rates and stool adequacy, subnational disparities persist, especially in areas affected by insecurity, and urban overcrowding (Hamisu et al., 2022; Nwaze et al., 2025). These contextual challenges can mask gaps in true surveillance sensitivity and allow poliovirus transmission to remain undetected for extended periods.

Northern Nigeria, in particular, continues to face complex humanitarian and security challenges that undermine both routine immunization and supplementary immunization activities (SIAs) (Wakabi, 2008). Inaccessible settlements, vaccine hesitancy, and population movements contribute to pockets of under-immunized children, creating conditions favorable for poliovirus emergence and sustained transmission (Taylor et al., 2017). The introduction and scale-up of novel oral poliovirus vaccine type 2 (nOPV2) since 2021 has significantly reduced the risk of outbreaks caused by vaccine-derived polioviruses; however, the detection of orphan viruses in areas with reported high nOPV2 campaign coverage raises important questions about campaign quality, reach, and immunity durability (Asekun et al., 2023).

In 2025, Nigeria detected multiple orphan polioviruses through AFP surveillance across several states, predominantly in the northern part of the country. These detections occurred despite generally strong surveillance timeliness indicators which reflects the need for a more nuanced understanding of where and why silent transmission persists. Examining the spatial distribution of orphan viruses alongside surveillance performance metrics, settlement security status, and immunization histories is essential for identifying high-risk geographies and refining eradication strategies (Effiong et al., 2021).

This work aims to describe the spatial distribution and programmatic characteristics of orphan polioviruses detected through AFP surveillance in Nigeria in 2025. Specifically, it analyzes geographic clustering at levels of state and local government area (LGA), evaluates key surveillance performance indicators, assesses the security context of affected settlements, and examines routine and supplementary immunization histories among affected children. This analysis seeks to inform targeted, risk-based interventions to interrupt silent poliovirus transmission by linking virologic, epidemiologic, and programmatic data.

## METHODS

### Study Design and Data Sources

This study used a descriptive cross-sectional design to characterize orphan polioviruses detected through Nigeria's AFP surveillance system between 1 January and 31 December 2025. Data were extracted from the National Polio Emergency Operations Centre (EOC) database, which consolidates epidemiologic, and immunization data reported through the national AFP surveillance network (Nwaze et al., 2025). The database captures standardized case investigation information collected using World Health Organization (WHO) AFP investigation forms and is routinely validated through national and subnational data quality review processes (Braka et al., 2023).

The analysis included all laboratory-confirmed poliovirus isolates classified as orphan viruses during the study period. Epidemiologic variables were linked with virologic and vaccination history data to enable integrated assessment of surveillance performance, and geographic distribution. Data completeness and internal consistency checks were conducted prior to analysis to minimize reporting errors and ensure analytical reliability (Shuaib et al., 2018).

### Case Definition and Laboratory Procedures

Orphan polioviruses were defined in accordance with WHO criteria as poliovirus isolates characterized by a nucleotide sequence identity of less than 98.5% within the VP1 genomic segment relative to their closest genetically related isolate for poliovirus type 2. This indicates prolonged undetected circulation typically exceeding 12 months (World Health Organization- Geneva, 2021). All stool specimens were processed at WHO-certified polio facilities within the Global Polio Laboratory Network (GPLN), following standardized protocols to ensure comparability and quality assurance.

Laboratory procedures included virus isolation using L20B (poliovirus receptor-expressing) and RD (human rhabdomyosarcoma) cell lines, followed by differentiation using real-time reverse transcription polymerase chain reaction (rRT-PCR) assays for the definitive determination of poliovirus serotypes, alongside vaccine-related origin (Martinez et al., 2018). VP1 sequencing was subsequently performed to assess genetic relatedness and quantify nucleotide divergence, enabling classification of isolates as orphan or non-orphan viruses (Hamisu et al., 2022). Laboratory results were subjected to routine external quality assurance and proficiency testing under GPLN standards (WHO, 2004).

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## Variables and Operational Definitions

Key epidemiologic variables extracted for analysis included age and sex of the AFP case, state and Local Government Area (LGA) of residence, and settlement type at the time of paralysis onset. Settlement security status was classified as either secure or insecure based on national polio program security risk stratification, which incorporates indicators such as active armed conflict, accessibility constraints, and limitations to routine health delivery (World Health Organization. Regional Office for Africa, 2024). This classification is routinely used by the Nigerian polio program to guide vaccination and surveillance strategies in high-risk areas. Surveillance performance indicators were assessed in line with WHO and GPEI standards, including timeliness of case notification, timeliness of investigation of case, and adequacy of stool specimen collection, defined as the acquisition of two stool samples, separated by a minimum 24-hour interval, within a 14-day window following the initiation of paralysis, ensuring delivery to the facility in optimal condition. These indicators were used to evaluate operational performance at the case level rather than aggregate surveillance sensitivity.

## Immunization Status Assessment

Immunization history was assessed using data recorded during AFP case investigations, based on caregiver recall and verification through immunization cards where available. Routine immunization status was evaluated by the reported number of oral polio vaccine (OPV) doses administered during outbreak response efforts, recognizing known limitations of recall accuracy in high-mobility and low-literacy settings (Taylor et al., 2017). Exposure to supplementary immunization activities (SIAs) was assessed by the reported number of novel oral polio vaccine type 2 (nOPV2) doses received during outbreak response and preventive campaigns. Vaccination status was categorized into programmatically relevant groups: zero nOPV2 doses, one to three doses, and four or more doses, consistent with GPEI risk stratification frameworks used to assess population immunity in outbreak settings (Voorman et al., 2024). These categories were selected to facilitate interpretation of immunity gaps in relation to observed orphan virus detections and campaign intensity.

## Data Analysis and Spatial Assessment

Descriptive statistical analyses were conducted to summarize the distribution of orphan polioviruses by demographic, geographic, surveillance, and immunization characteristics. Categorical variables were summarized using frequencies and proportions, and results were interpreted against established AFP surveillance performance benchmarks recommended by WHO. No inferential statistical testing was performed, as the analysis aimed to provide a comprehensive descriptive overview of all orphan virus detections within the study period.

Spatial analysis involved mapping orphan poliovirus detections at state and LGA levels to visualize geographic clustering and overlap with known high-risk and insecure areas. Spatial patterns were interpreted in the context of population movement, security constraints, and historical polio transmission risk to inform programmatic decision-making. Mapping outputs were used descriptively to support identification of priority geographies for intensified surveillance and immunization interventions.

## Ethical Considerations

This analysis was conducted as part of routine public health surveillance and polio eradication activities under the mandate of the Nigerian Federal Ministry of Health and the National Primary Health Care Development Agency. All data were anonymized prior to analysis, and no personally identifiable information was included. In accordance with national regulations and WHO guidelines, ethical approval was not required for secondary analysis of routinely collected surveillance data used for outbreak preparedness and programmatic evaluation (World Health Organization, 2024).

## RESULTS

### Geographic Distribution of Orphan Polioviruses

Consistent with the descriptive spatial analysis approach outlined in the Methods, a total of 21 orphan polioviruses were identified from AFP cases that were reported in Nigeria from January to December 2025. These detections were distributed across 25 Local Government Areas (LGAs), reflecting geographic dispersion with identifiable clustering patterns. Orphan virus detections were predominantly concentrated in northern Nigeria, with affected states including Sokoto State, Zamfara State, Katsina State, Kano State, Jigawa State, Yobe State, Borno State, Bauchi State., and Nasarawa State. Mapping at state and LGA levels demonstrated clustering along international borders and in areas historically characterized by population movement and security challenges.

### Surveillance Performance Indicators

As assessed using WHO-recommended AFP surveillance performance indicators described in the Methods, overall case-level surveillance timeliness was high. Of the 21 orphan virus-associated cases of AFP, 90% were received notification within seven days of onset of paralysis. All cases (100%) were investigated within 48 hours of notification, and each satisfied the criteria for

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adequate stool specimen collection, with two samples obtained at least 24 hours apart within 14 days of onset and delivered to the laboratory in good condition.

### **Settlement Security Status**

Applying the national polio program security risk stratification described in the Methods, 9 of the 21 orphan poliovirus detections (43%) originated from settlements classified as insecure, while the remaining 12 detections (57%) occurred in settlements classified as secure. Insecure settlements were characterized by active or recent armed conflict, banditry, restricted physical access, or significant disruption of routine health services. Orphan virus detections from insecure settlements were disproportionately represented in LGAs with documented access constraints and intermittent surveillance reach.

### **Immunization Characteristics**

Immunization histories of affected children aged 0–59 months were analyzed using AFP investigation data, as described in the Methods. Routine immunization coverage was low among cases associated with orphan virus detection: only one child (5%) had reportedly got three or more doses of OPV through routine immunization services. In contrast, reported exposure to other immunization responses using nOPV2 was substantially higher. Seventeen children (81%) had received four or more nOPV2 doses, while the remaining four children (19%) had received one to three doses. No orphan poliovirus detections were identified among children reported to have received zero doses of nOPV2 during supplementary immunization activities.

## **DISCUSSION**

This analysis of orphan polioviruses detected through AFP surveillance in Nigeria in 2025 provides important insights into the persistence of silent poliovirus transmission despite substantial progress toward eradication. In line with the study objectives, the findings demonstrate how spatial distribution, and immunization characteristics interact to sustain residual transmission risk. Orphan polioviruses, by definition, indicate prolonged undetected circulation and are widely recognized as sensitive markers of surveillance gaps and population immunity weaknesses (Fomban Leke et al., 2020).

Although AFP surveillance performance indicators met or exceeded WHO-recommended benchmarks for timeliness and stool adequacy, orphan virus detections were identified across multiple LGAs. This finding reinforces the distinction between operational surveillance performance *and* epidemiologic sensitivity (Raji et al., 2021). AFP surveillance depends on the occurrence and detection of paralytic disease, which represents fewer than 1% of all poliovirus infections, allowing asymptomatic or subclinical transmission to persist undetected in partially immune populations (Verma et al., 2018). Consequently, the presence of orphan viruses despite strong surveillance indicators should be interpreted as evidence of silent transmission rather than surveillance system failure (Ahmed et al., 2021).

The geographic concentration of orphan poliovirus detections in northern Nigeria aligns with historical and contemporary assessments of elevated poliovirus transmission risk in the region (Nasir et al., 2016). States in the North-West and North-East are characterized by high population mobility, nomadic pastoralist movements, and recurrent insecurity, all of which complicate consistent surveillance reach and immunization delivery (Forbi et al., 2023). The observed clustering of detections in border and high-mobility LGAs supports prior evidence that poliovirus transmission frequently follows population movement corridors rather than remaining confined within administrative boundaries (Kalkowska & Thompson, 2021).

The finding that 43% of orphan virus detections originated from insecure settlements further shows the relationship between access constraints and undetected transmission. Insecurity has been shown to reduce the frequency and quality of both surveillance and immunization activities, resulting in chronically under-immunized populations that can sustain poliovirus circulation (Nnadi et al., 2017). However, detection of orphan viruses in both secure and insecure settlements suggests that insecurity alone does not fully explain transmission dynamics. Instead, it likely interacts with other structural determinants, including health system fragility, population displacement, and community-level immunity gaps (Wiesen et al., 2022).

Immunization characteristics among affected children reveal persistent vulnerabilities in routine immunization systems. The very low proportion of children who had received three or more routine OPV doses is consistent with national and subnational estimates showing stagnation of routine immunization coverage in hard-to-reach and conflict-affected areas of Nigeria (Upfill-Brown et al., 2016). In contrast, high reported exposure to nOPV2 through supplementary immunization activities reflects the scale and intensity of outbreak response efforts since the introduction of nOPV2 (Asekun et al., 2023). Nonetheless, the occurrence of orphan virus detections among children with multiple nOPV2 exposures highlights that campaign reach alone does not guarantee uniformly protective immunity, particularly where campaign quality, timing relative to infection, or repeated missed children remain concerns (Voorman et al., 2024).

These findings reinforce the widely recognized limitation of relying predominantly on supplementary immunization activities in the absence of robust routine immunization systems. While SIAs are essential for outbreak control and rapid immunity boosting, sustained interruption of poliovirus transmission requires strong, and equitable routine immunization services integrated within primary health care systems (World Health Organization- Geneva, 2021). The absence of orphan virus detections among children

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with zero reported nOPV2 exposure should be interpreted cautiously, given potential recall bias and the limited sample size, but it does not diminish the broader evidence of immunity gaps (Deblina Datta et al., 2017).

From a programmatic perspective, the results emphasize the need for geographically targeted and risk-informed eradication strategies. These include intensified subnational immunization activities in high-risk LGAs, community-based surveillance approaches, and use of environmental surveillance to complement AFP surveillance in areas with known access challenges (Hamisu et al., 2016). The integration of real-time genomic sequencing with epidemiologic and spatial data is particularly critical for rapidly identifying silent transmission pathways and guiding timely corrective actions (Shakeel et al., 2019).

Overall, the detection of orphan polioviruses in Nigeria in 2025 should be viewed as a critical early warning signal rather than an indicator of programmatic failure. Such detections reflect the sensitivity of virologic surveillance systems and provide actionable intelligence for targeting immunity gaps before widespread outbreaks occur (Ahmed et al., 2021). Sustained investment in high-quality surveillance, equitable immunization delivery, and context-specific strategies for insecure and mobile populations will remain essential to achieving and maintaining poliovirus eradication in Nigeria.

### LIMITATIONS

This analysis relied on AFP data collected routinely, that are subject to reporting completeness and data quality constraints, particularly in insecure and hard-to-reach settings where underreporting of AFP cases may occur despite strong case-level performance indicators. As a result, the true extent of silent poliovirus transmission may be underestimated. Secondly, in this study, immunization histories were primarily based on caregiver recall, with limited availability of vaccination cards, introducing the potential for recall and misclassification bias, especially regarding the number and timing of nOPV2 doses received. This limitation may affect interpretation of the relationship between reported vaccination exposure and orphan virus detection. Despite these limitations, the findings provide valuable operational insights into silent poliovirus transmission and immunity gaps in high-risk settings and support the use of orphan virus detection as a sensitive indicator for targeted eradication interventions.

### CONCLUSION

The detection of orphan polioviruses through AFP surveillance in Nigeria in 2025 highlights the continued risk of silent poliovirus transmission despite strong surveillance timeliness and extensive use of supplementary immunization activities. The spatial concentration of detections in northern Nigeria reflects the persistence of localized immunity gaps that are not fully captured by routine surveillance indicators alone. While outbreak response campaigns using nOPV2 have achieved substantial reach, ongoing weaknesses in routine immunization systems and access-constrained populations continue to create conditions conducive to prolonged undetected transmission. Orphan poliovirus detection should therefore be interpreted as a critical early warning signal that enables targeted, risk-based corrective action rather than as an indicator of surveillance failure. Sustained interruption of poliovirus transmission in Nigeria will require continued investment in high-quality AFP and environmental surveillance, security-adapted and geographically targeted immunization strategies, and strengthened routine immunization services integrated within primary health care delivery.

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