Deciphering the seasonality of lassa fever in Nigeria from 2019 to 2023 and mathematical modelling analysis of the impact of rapid point of care diagnostic tests: Rapid diagnosis, rapid response, rapid control

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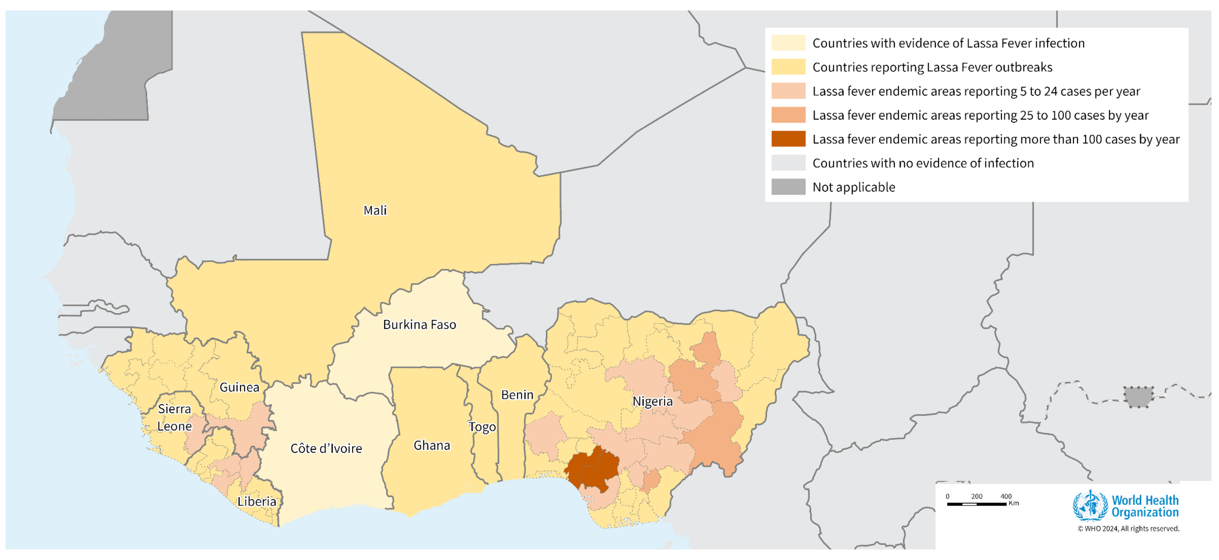
Background

- According to WHO, Nigeria accounts for the majority of Lassa fever (LF) cases and deaths globally, with case fatality rates ranging from 1% to 50%
- Understanding the seasonality and trend is crucial for effective control

- Rapid point-of-care diagnostic tests (RPOCT) can potentially reduce transmission and improve response
- Recent advances in diagnostic technologies have led to the development of RPOCT for Lassa fever

- However, the impact of these RPOCT on Lassa fever control in Nigeria has not been rigorously evaluated
- We investigated the seasonality in Nigeria from 2019 to 2023 and evaluated the potential impact of RPOCT on the control of outbreaks, using mathematical modeling analysis



Geographical distribution of Lassa fever in West African affected countries

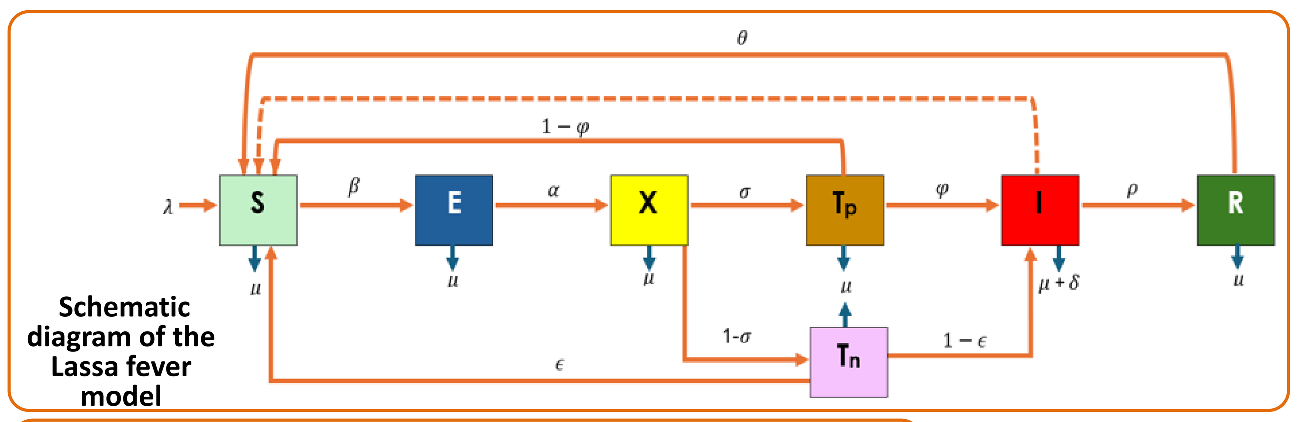
Methods

Monthly Lassa fever data was obtained from the NCDC

- Compartmental SEIR model, slightly modified to include the tested population, and the outcomes of RPOCT
- Implemented in R using the deSolve package

Simulations over a period of 30 years to observe the dynamics of the different compartments under various diagnostic scenarios.

One-at-a-time (OAT) sensitivity analysis was conducted by varying each parameter with 20% increase and 20% decrease while keeping others constant



Schematic diagram of the Lassa fever model

S-Susceptible population
E-Exposed population
X-Tested population
T_p -RDT positive humans
T_n -RDT negative humans
I- Infectious humans
R- Recovered humans
λ–Recruitment rate
β-Transmission rate
μ-Natural death rate
α-Testing rate
σ-Positivity rate
φ-Predictive value positive
ϵ-Predictive value negative
δ-Lassa fever death rate
ρ-Recovery rate
θ-Immunity waning rate

$$\frac{dS}{dt} = \lambda + \theta R + (1-\varphi)T_p + \epsilon T_n - \frac{\beta IS}{N} - \mu S \quad (1)$$
$$\frac{dE}{dt} = \frac{\beta IS}{N} - \mu E - \alpha E \quad (2)$$
$$\frac{dX}{dt} = \alpha E - \mu X - \sigma X - (1-\sigma)X \quad (3)$$
$$\frac{dT_p}{dt} = \sigma X - (1-\varphi)T_p - \mu T_p - \varphi T_p \quad (4)$$
$$\frac{dT_n}{dt} = (1-\sigma)X - \mu T_n - \epsilon T_n - (1-\epsilon)T_n \quad (5)$$
$$\frac{dI}{dt} = \varphi T_p + (1-\epsilon)T_n - (\mu+\delta)I - \rho I \quad (6)$$
$$\frac{dR}{dt} = \rho I - \mu R - \theta R \quad (7)$$

Model equations

The force of infection was defined as: $\frac{\beta IS}{N}$

These equations were subjected to the following initial conditions:

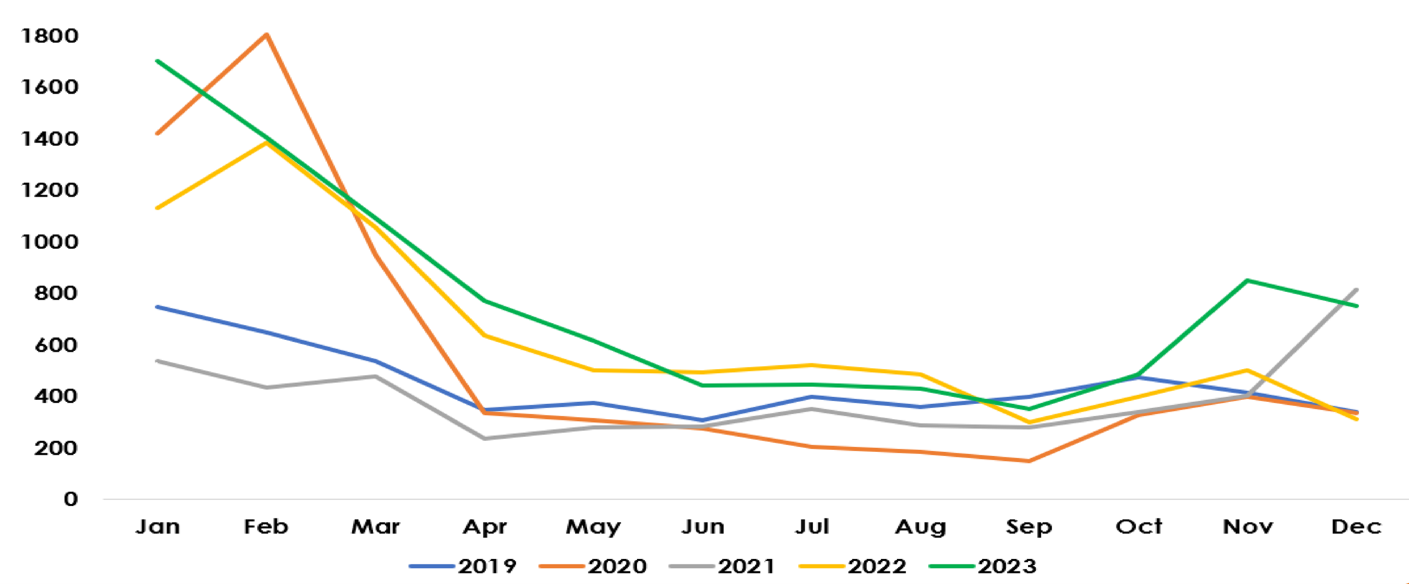
$S>0,\ E\geq 0,\ X\geq 0,\ T_p\geq 0,\ T_n\geq 0,\ I\geq 0,\ R\geq 0$

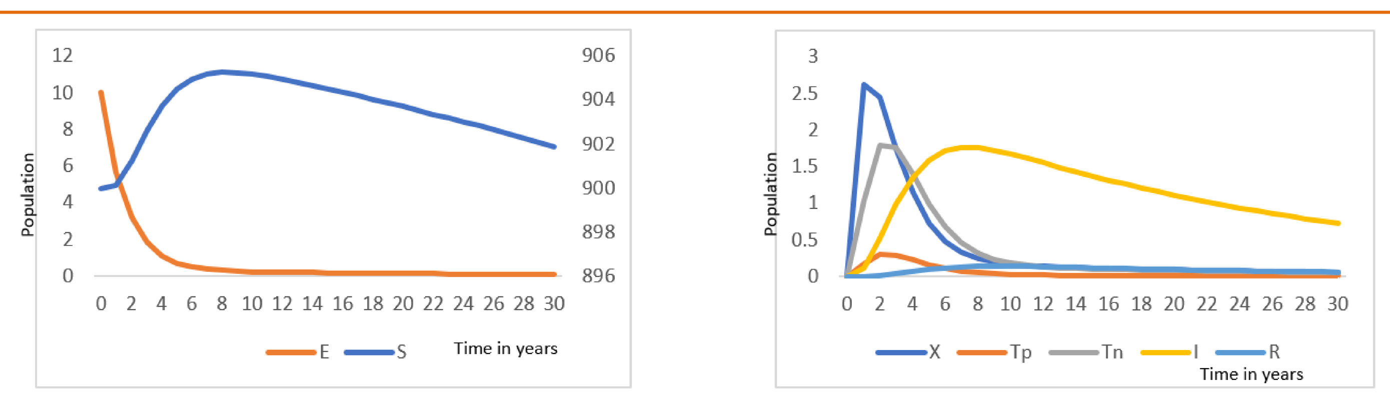
Assumptions

- The immunity conferred by the infection wane off after a period.
- Individuals in all the compartments die at the same natural rate except for the class of infectious humans which has an additional disease-induced death rate.
- There are some false positive and false negative RPOCDT

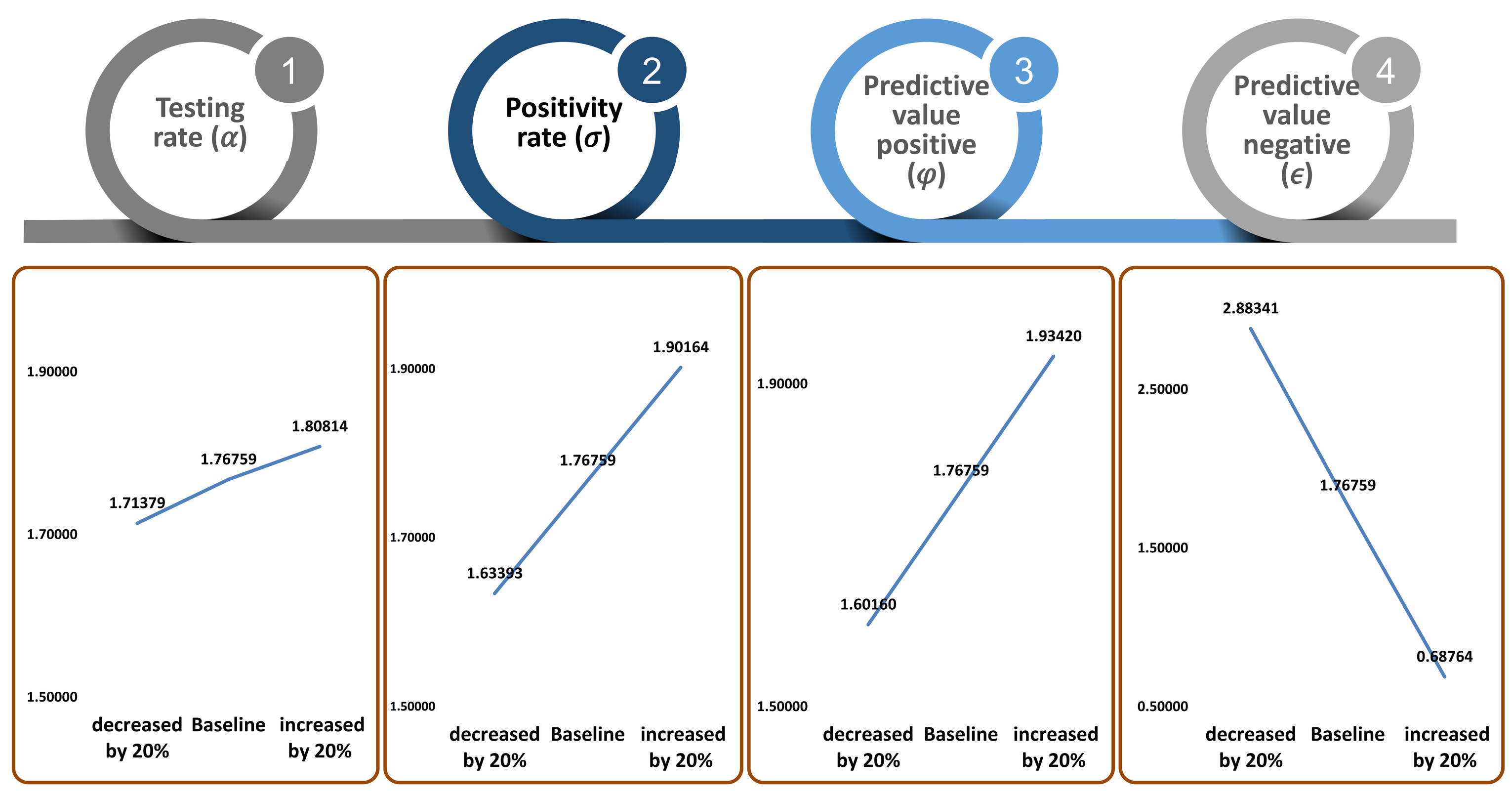
Results

Seasonality of Lassa fever in Nigeria from Jan 2019 to Dec 2023





The population dynamics of Lassa fever transmission in Nigeria



OAT sensitivity analysis of the number of cases detectable at baseline and ±20% parameter variation

Conclusions and Recommendations

Increasing Trend

LF cases in Nigeria steadily increased from 2019 to 2023, reflecting a growing public health threat

Strengthen national and state-level surveillance and allocate additional resources for sustained prevention and control efforts

Seasonal Pattern

Most cases occurred between November and March, showing a predictable seasonal surge in transmission

Establish seasonal preparedness strategies (Nov–Mar), including early community sensitization, pre-positioning of supplies, and enhanced case detection

Propagated Pattern

Indicates that human-to-human transmission contributes significantly to outbreaks

Intensify infection prevention and control (IPC) in health facilities

Rapid Diagnostic Tests

Rapid point-of-care diagnostic tests with high predictive values can accelerate detection and improve outbreak control.
Scale up the deployment of rapid tests, alongside training for healthcare workers and robust supply chain support.

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