Appendix: Force of infection for New World Arenaviruses (NWA) in South America

# Deriving the model for Force of infection

The impact of climate change on the transmission risks for humans was studied by deriving the estimated rate of successful contact between susceptible humans and infectious rodents that resulted in transmission. This was termed as density dependent Force Of Infection (FOI). The exact mechanistic model for deriving the FOI for each of the geospatial coordinates and its connection with Species Distribution Models (SDMs) of rodent reservoirs of NWA is given by Equation S1:

Eq. S1

Where, is the force of infection defined as the contact between susceptible humans and infectious rodents resulting in successful transmission of infection, is the population of susceptible humans set at 0.95 times that of total human population in the same geospatial coordinates of SDMs (author’s expertise and from study performed on Lassa Fever in Nigeria 1) and is the proportion of infectious rodent population based on the binomial sampling between 1 and 15 rodents per grid cell adjusted with the probability of presence of rodents in the given geospatial coordinates based of the SDMs. The denominator represents the total density of the interacting populations of human hosts and rodent reservoirs. is the transmission rate parameter derived from review of analogous viral transmission dynamics studies as seen in Table S1. Two extreme average value of or contact rate per week were tested, namely and . Of these two, since the FOI scaled linearly due to density dependence ( with change in , the highest value of 2% () was selected for deriving the hotspots for potential outbreaks. was the proportion of infectious rodents which was taken to be 0.645, adapted from study on Argentine Hemorrhagic Fever (AHF) caused by Junin virus from reservoir *Calomys musculinus* which estimated a prevalence rate of seropositive rodents between 0.2% to 10.9% 2. Same infectious rate of rodents was applied to Guanarito virus and Machupo virus and their respective rodent reservoirs as well as to the other two reservoirs of Junin virus since no studies were found estimating the prevalence to date. Given these assumed inputs, the number of susceptible humans and infectious rodents in each geospatial coordinate grid cell was given by Equations S2 and S3:

Eq. S2

Eq. S3

Where, is the human population in each geospatial grid cell of the SDM map, is the proportion of susceptible humans from , is the estimated number of rodents in grid cell sampled from binomial distribution with average number of rodents assumed to be 15 modulated by the probability of presence of rodents () and was the proportion of rodents that were assumed to be infectious.

Table S1. Source literature used to determine the transmission rate parameter for Force Of Infection (FOI) estimation

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Value [95% CI]** | **Subcategory** | **Transmission Route (unit)** | **Virus** | **Region** | **Estimated or Derived** | **Year** | **Value Description** |
| 0.0024 3 | Peridomestic areas | Deer mouse (*Peromyscus maniculatus*) to deer mouse (per month) | Hantavirus | Montana, United States | Derived | 2009 | Direct transmission rate from an infected mouse to a susceptible one. Derived from the direct transmission rates that produced a prevalence of 15% based on the study's model. Rates were different between peridomestic and sylvan areas studied. |
| 0.0052 3 | Sylvan areas |
| 0.43 [.38-.48] 4 | -- | Rat (*Mastomys natalensis*) to rat (per month) | Lassa virus | Guinea and Mali | Derived | 2014 | Infection rate. LASV RNA and antibody prevalences among captured rodents were combined to estimate the overall infection rate. |
| 0.8 5 | -- | Rat (*Mastomys natalensis)* to human (per day) | Lassa virus | -- | Estimated | 2015 | Infection rate of humans from contact with rat excreta. |
| 0.6 6 | -- | Rat (*Mastomys natalensis*) to human (no unit described) | Lassa virus | -- | Estimated | 2017 | Effective transmission rate in susceptible humans by infected rodents. |
| 0.43 4,7 | -- | Rat (*Mastomys natalensis*) to human (no unit described) | Lassa virus | -- | Estimated | 2018 | Transmission rate from infected rodents to susceptible humans. |
| Estimated |
| 0.0024 3,8 | -- | Deer mouse (*Peromyscus maniculatus*) to deer mouse (per month) | Hantavirus | -- | Estimated | 2019 | Direct transmission rate from an infected mouse to a susceptible one. |
| Estimated |
| 1.0 [0.1-2.6] 9 | January to April (low-density, no-breeding period) | Rat (*Mastomys natalensis*) to rat (per day) | Mongoro virus | Tanzania | Derived | 2019 | Transmission coefficent. Derived from the best fit model assuming no horizontal transmission with 1% chronic carriers. Seasonality influenced the value. |
| 4.7 [2.8-7.2] 9 | April to July (low-density, breeding period) |
| 2.7 [1.4-3.9] 9 | August to December (high-density, no-breeding period) |
| 0.024 to 0.048 10,11 | -- | Rat (*Mastomys natalensis*) to human (no unit described) | Lassa virus | -- | Estimated | 2020 | Transmission rate from an infected rat to a susceptible human. Value taken from a study looking at the probability of transmission of *P. falciparum* from recovered humans to susceptible mosquitoes in areas of low and high transmission. |
| Estimated |
| 0.075 12 | Baseline | Rat (*Mastomys natalensis*) to human (per day) | Lassa virus | Nigeria | Estimated | 2020 | Transmission rate from rats to humans. |
| 0.03 to 0.2 12 | Range |
| 0.00001 6,13 | -- | Rat (*Mastomys natalensis*) to human (per day) | Lassa virus | Nigeria | Estimated | 2020 | Contact rate between susceptible humans and infected rats. |
| [(Obabiyi and Onifade, 2017)](https://www.researchgate.net/profile/Akindele-Onifade/publication/320840225_MATHEMATICAL_MODEL_FOR_LASSA_FEVER_TRANSMISSION_DYNAMICS_WITH_VARIABLE_HUMAN_AND_RESERVOIR_POPULATION/links/59fcd54aaca272347a22c52b/MATHEMATICAL-MODEL-FOR-LASSA-FEVER-TRANSMISSION-DYNAMICS-WITH-VARIABLE-HUMAN-AND-RESERVOIR-POPULATION.pdf) |
| 0.0182 14,15 | -- | Rat (*Mastomys natalensis*) to human (per day) | Lassa virus | Nigeria | Estimated | 2020 | Probability of transmission per contact by an infectious rat. Value taken from a study looking at Typhoid fever transmission dynamics among humans. |
| Estimated |
| 1.9 to 2.9 16 | -- | Rat (*Mastomys natalensis*) to human (per day per susceptible human) | Lassa virus | West Africa | Derived | 2021 | Rate of new infections. Describes the force-of-infection multiplied by the number of susceptible people. The range of rates covers the individual country rates derived in the study. |
| 0.0296 17 | Baseline | Rat (*Mastomys natalensis*) to human (per day) | Lassa virus | Nigeria | Derived | 2021 | Transmission rate from rodent to human. Derived from model-fitting to confirmed cases of Lassa fever in Nigeria from 2017 to 2020 . |
| 0.1 to 0.8 17 | Range |
| 0.216 12,17 | Rate associated with disease extinction | Estimated |
| 0.373 12,17 | Rate associated with disease persistence |
| 0.0179 18 | 2018 | Rat (*Mastomys natalensis*) to human or rat (per week) | Lassa virus | Nigeria | Derived | 2021 | Transmission probability from rodents to humans and rodents. Derived from model-fitting to weekly reported cases of Lassa fever in Nigeria from 2018 to 2020. |
| 0.0627 18 | 2019 |
| 0.0553 18 | 2020 |
| 0.0372 18 | Estimated mean |
| 0.43 7,19 | -- | Rat (*Mastomys natalensis*) to human (per day) | Lassa virus | Nigeria | Estimated | 2021 | Contact rate of infectious rats to humans. |
| 0.5 20 | -- | Human to human (per day) | Lassa virus | -- | Estimated | 2021 | Transmission rate resulting from interaction between a susceptible human and an active virus reservoir. |
| 0.0372 [18,21](https://doi.org/10.1016/j.physa.2022.127259) | -- | Rat (*Mastomys natalensis*) to human (per day) | Lassa virus | -- | Estimated | 2022 | Rat-to-human effective transmission rate. |
| 1.765x10^-11 21 | Female | Rat (*Mastomys natalensis*) to human (per week) | Lassa virus | Nigeria | Derived | 2024 | Rate of infection in female or male humans via rodents. Derived by fitting a model to data on female and male Lassa fever cases collected from the Nigeria Centre for Disease Control and Prevention database beginning in January 2020 and spanning 65 weeks. |
| 2x10^-11 21 | Male |

# Hotspots for potential outbreak

Figure S1. Guanarito Virus

Figure S2. Machupo Virus

Figure S3. Junin Virus

Figure S4. Delta FOI

# Effect of climate change on changes in risk profile

Table S2. Logistic model for Z.brevicauda

Table S3. Logistic model for S.alstoni

Table S4. Logistic Model for C. callosus

Table S5. Logistic Model for C. musculinus

Table S6. Logistic Model for C. laucha

Table S7. Logistic model for O.flavescens

Table S8. Feature importance ML model Z.brevicauda and S.alstoni

Table S9. Feature importance ML model C. callosus

Table S10. Feature importance ML model C. musculinus, C.laucha, O.flavescens

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