

Supplementary Material

Modelling and Analyzing Virus Mutation Dynamics of Chikungunya Outbreaks

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In order to fit the 2007 chikungunya fever outbreak in Italy, we do not consider the human demographic effects, that is, we assume that $\lambda_H = 0, \mu_H = 0$ in model (2.1). Further, since the outbreak happened mainly in two small villages we assume the human population being a constant value N_H . Now model (2.1) is simplified as follows:

$$\begin{aligned}\frac{dS_M}{dt} &= \lambda_M - b\beta_{H1M} \frac{S_M(I_{H1}^N + I_{H1})}{N_H} - b\beta_{H2M} \frac{S_M(I_{H2}^N + I_{H2})}{N_H} - \mu_M S_M, \\ \frac{dE_{M1}}{dt} &= b\beta_{H1M} \frac{S_M(I_{H1}^N + I_{H1})}{N_H} - \gamma_{M1} E_{M1} - \mu_M E_{M1} - \delta E_{M1}, \\ \frac{dI_{M1}}{dt} &= \gamma_{M1} E_{M1} - \mu_M I_{M1} - \delta I_{M1}, \\ \frac{dE_{M2}}{dt} &= b\beta_{H2M} \frac{S_M(I_{H2}^N + I_{H2})}{N_H} - \gamma_{M2} E_{M2} - \mu_M E_{M2} + \delta E_{M1}, \\ \frac{dI_{M2}}{dt} &= \gamma_{M2} E_{M2} - \mu_M I_{M2} + \delta I_{M1}, \\ \frac{dS_H}{dt} &= -\frac{b\beta_{M1H} S_H I_{M1}}{N_H} - \frac{b\beta_{M2H} S_H I_{M2}}{N_H}, \\ \frac{dE_{H1}}{dt} &= \frac{b\beta_{M1H} S_H I_{M1}}{N_H} - \gamma_H E_{H1}, \\ \frac{dI_{H1}^N}{dt} &= (1 - \phi)\gamma_H E_{H1} - qI_{H1}^N, \\ \frac{dI_{H1}}{dt} &= \phi\gamma_H E_{H1} - qI_{H1}, \\ \frac{dE_{H2}}{dt} &= \frac{b\beta_{M2H} S_H I_{M2}}{N_H} - \gamma_H E_{H2}, \\ \frac{dI_{H2}^N}{dt} &= (1 - \phi)\gamma_H E_{H2} - qI_{H2}^N, \\ \frac{dI_{H2}}{dt} &= \phi\gamma_H E_{H2} - qI_{H2}, \\ \frac{dR_{H2}}{dt} &= q(I_{H2}^N + I_{H2}),\end{aligned}\tag{S1}$$

To further simplify the model by considering only nonmutant CHIKV without the mutation possibilities, we assume that $\delta = 0$ and reduce model (S1) to the following model which was used

to understand the 2006 Réunion Island outbreak:

$$\begin{aligned}
\frac{dS_M}{dt} &= \lambda_M - b\beta_{H1M} \frac{S_M(I_{H1}^N + I_{H1})}{N_H} - \mu_M S_M, \\
\frac{dE_{M1}}{dt} &= b\beta_{H1M} \frac{S_M(I_{H1}^N + I_{H1})}{N_H} - \gamma_{M1} E_{M1} - \mu_M E_{M1}, \\
\frac{dI_{M1}}{dt} &= \gamma_{M1} E_{M1} - \mu_M I_{M1}, \\
\frac{dS_H}{dt} &= -b\beta_{M1H} \frac{S_H I_{M1}}{N_H}, \\
\frac{dE_{H1}}{dt} &= b\beta_{M1H} \frac{S_H I_{M1}}{N_H} - \gamma_H E_{H1}, \\
\frac{dI_{H1}^N}{dt} &= (1 - \phi)\gamma_H E_{H1} - qI_{H1}^N, \\
\frac{dI_{H1}}{dt} &= \phi\gamma_H E_{H1} - qI_{H1},
\end{aligned} \tag{S2}$$

with the basic reproduction number $\mathcal{R}_1 = \sqrt{\frac{b^2 \beta_{H1M} \beta_{M1H} \gamma_H \gamma_{M1} \lambda_M}{N_H \mu_M q \gamma_H (\delta + \mu_M) (\delta + \gamma_{M1} + \mu_M)}}$.