Waning Modeling Methods and Results

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Model and parameters

We used a simple, unstructured, susceptible-infectious-removed (=SIR) model to simulate the influenza transmission in a large population. The following parameters were chosen:

Parameter	Symbol	Value
Total Pop.	N	$2.0e+06$
Beginning vaccination uptake	p_v	0.47
vaccination uptake rate	ν	0
Removal rate	γ	0.25
Basic reprod. No.	R_0	1.6
Transmission coeff., unvacc.	$\beta = R_0\ \gamma$	0.4
Transmission coeff., vacc.	$\beta = R_0\ \gamma\ (1-\phi)$	0.2
VE	ϕ	$0.2, 0.3, 0.4, 0.5$
Pre-esisting immunity	ϵ	0

The following initial values were used:

Parameter	Symbol	Value
No. susceptible, vacc.	x_v	$9.4e+05$
No. susceptible, unvacc.	x_{nv}	$1.1e+06$
No. infectious, vacc.	$y_v = \frac{p_v\ \phi}{p_v\ \phi+1-\phi}$	$0.15, 0.21, 0.26, 0.31$
No. infectious, unvacc.	y_{nv}	0.69
No. removed, vacc.	z_v	0
No. removed, unvacc.	z_{nv}	0

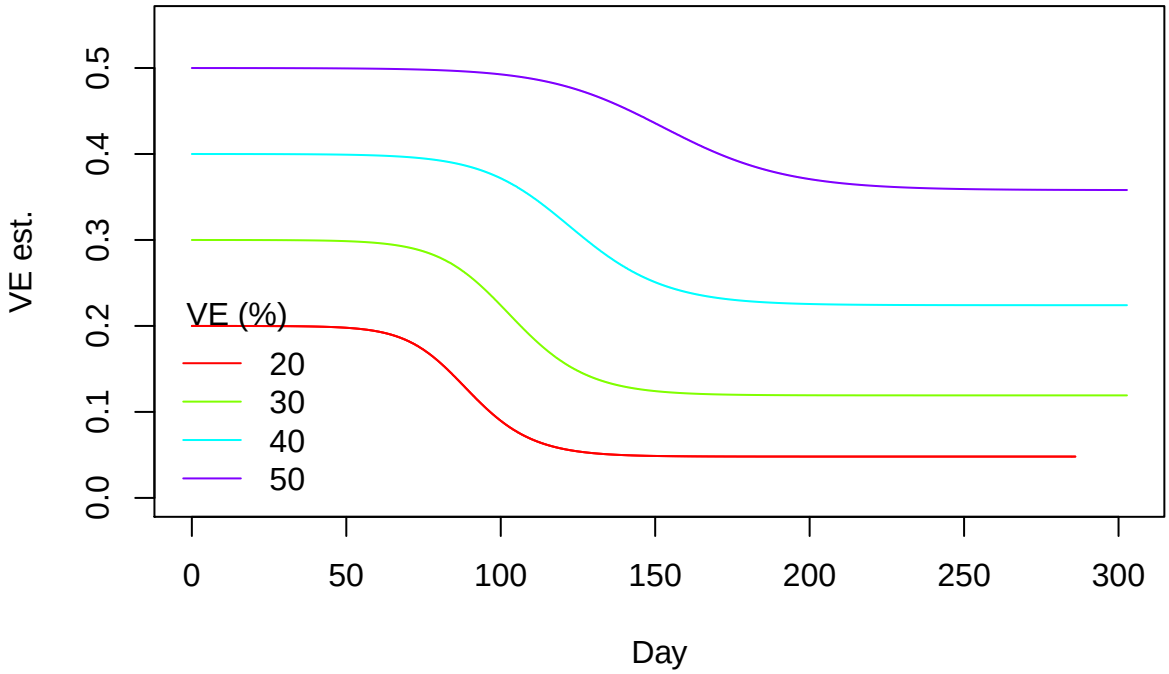
The model used is given by the following system or differential equations:

$$
\begin{aligned}
\frac{x_v}{dt} &= -\beta\ (1-\phi)\ x_v\ \frac{y_v + y_{nv}}{N} + \nu\ x_{nv} \\
\frac{x_{nv}}{dt} &= -\beta\ x_{nv}\ \frac{y_v + y_{nv}}{N} - \nu\ x_{nv} \\
\frac{y_v}{dt} &= \beta\ (1-\phi)\ x_v\ \frac{y_v + y_{nv}}{N} - y_v\ \gamma \\
\frac{y_{nv}}{dt} &= \beta\ x_{nv}\ - y_{nv}\ \gamma \\
\frac{z_v}{dt} &= y_v\ \gamma \\
\frac{z_{nv}}{dt} &= y_{nv}\ \gamma
\end{aligned}
$$

The system is numerically solved using the ode function from the deSolve R package. Test-negative design (TND) studies are simulated by keeping track of the incidence of vaccinated and unvaccinated "cases", i.e. new *infecteds*. The observed VE was calculated based on the ratio of the vaccination odds in the cases to the vaccination odds in the population.

Results

The trajectories are only shown for the periods of time when there was substantial transmission (more than 10 infectious) and aligned at their "start times".



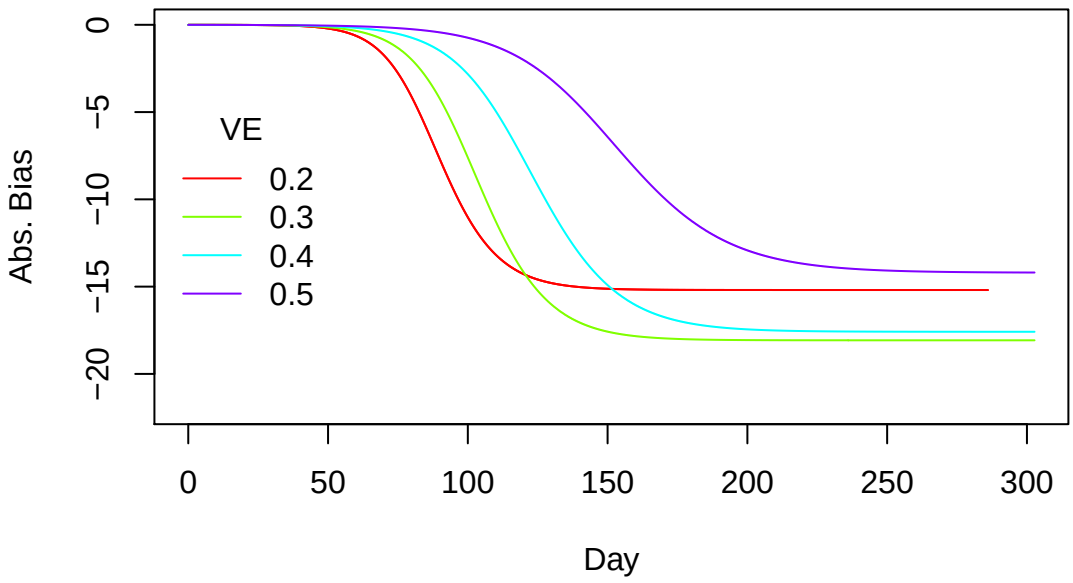


Figure 1: Expected Bias in VE estimates over time, by VE.

As Figure **??** shows, the observed VE always declined, The absulute decline was largest with intermediate VE (VE=30%), while the relative decline was most pronounced for low VE (VE=20%)

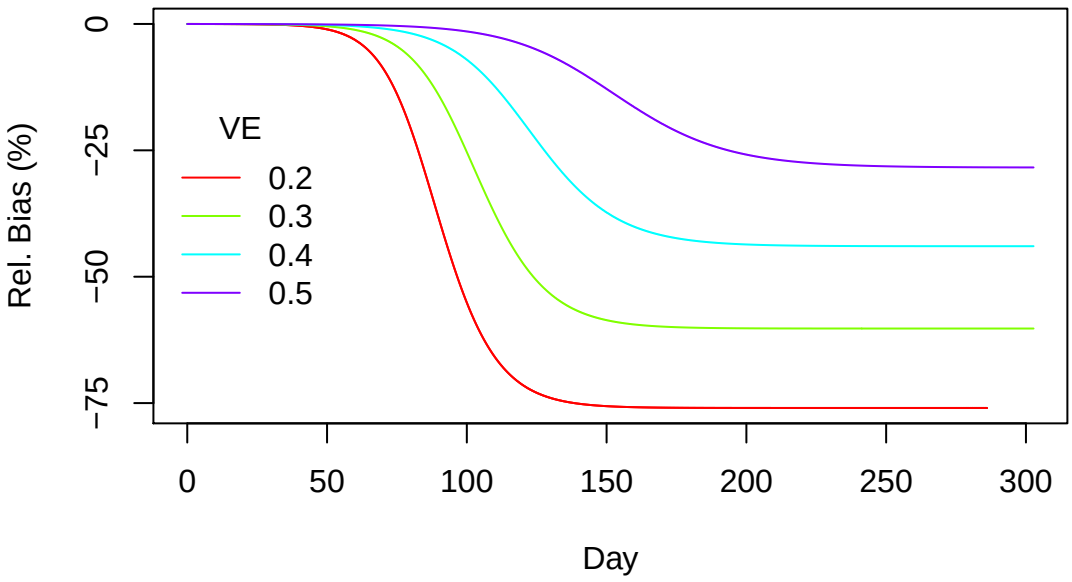


Figure 2: Expected Bias in VE estimates over time, by VE.

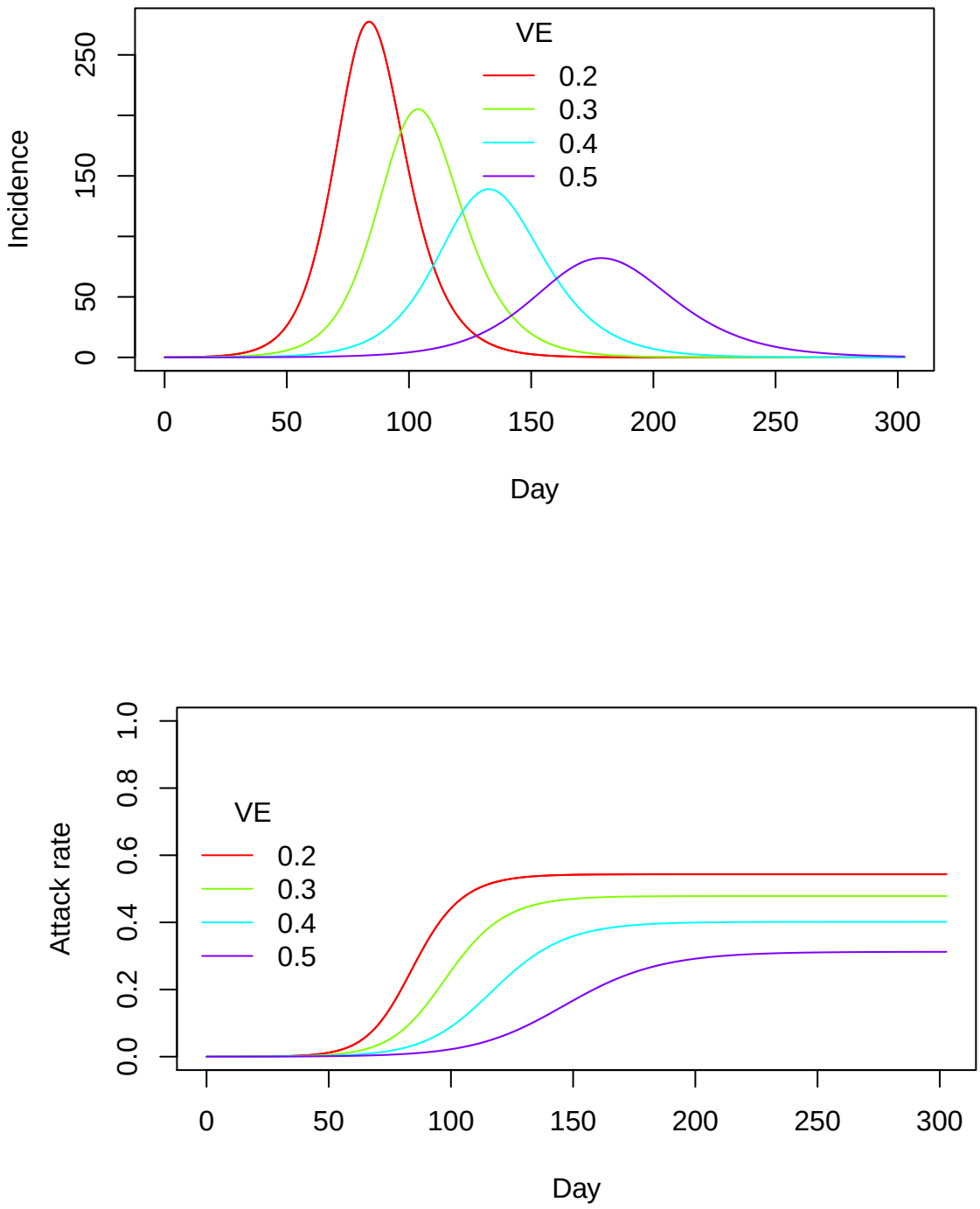


Figure 3: Epi curve (top) and cummulative attack rates (bottom) over time, by VE.