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Dynamics of the Monkeypox Virus - Impacts from Environment Factors:

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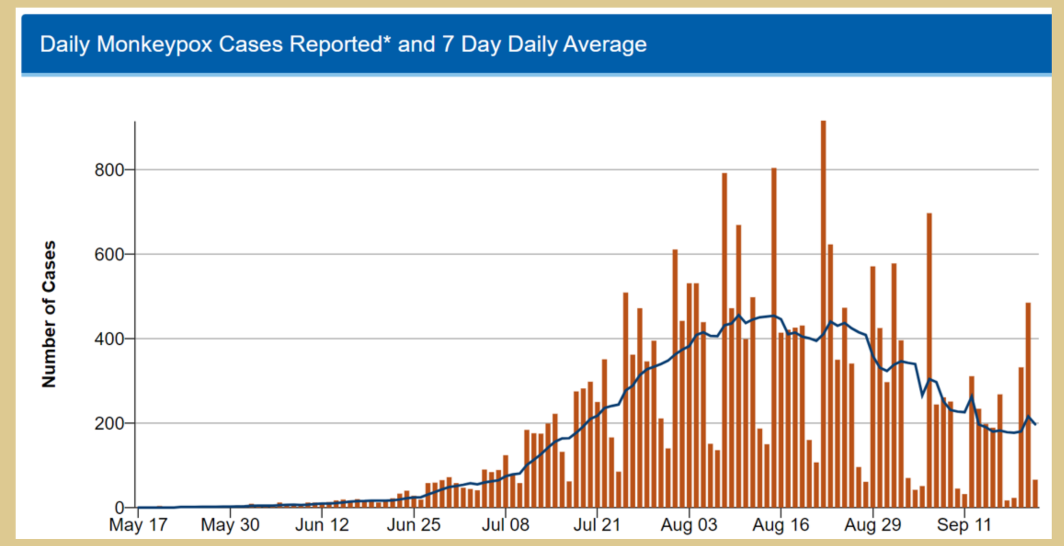


Introduction and Objectives

Infections diseases have major consequences on all aspects of human life. COVID-19 highlights how aspects of modern society can be affected by a disease. Misunderstanding the dynamics of infectious diseases puts at-risk populations in danger and strain on global economies infrastructures. The recent international spread of the Monkeypox Virus (MPV), despite its initial discovery in the 1950s (1)(2), raises concerns how future viruses might impact communities, and the world, at large.

Mathematical modeling allows many factors, including the environment, to be accurately forecasted over time, shedding insight into viral dynamics and variable interactions over time (3). Understanding how MVP is influenced by both human & environmental factors is crucial to begin understanding how to mitigate its impact and future viral impacts on society.

Research Questions and Hypotheses:

- How can environmental factors be incorporated to model MVP virus?
- If so, how do those environmental factors affect the disease dynamics?

SIRS Model for COVID-19

Using SIRS Models for COVID-19 accounts for nuanced variables

SIRS COVID-19 Model can account for diminishing vaccination efficacy, symptomatic and asymptomatic viral spread, and limited mobility among others (3)(4):

$$S' = \lambda - \boldsymbol{\beta}(\boldsymbol{S}[\mathbf{1} - \boldsymbol{\psi}][(\mathbf{1} - \boldsymbol{\rho})\boldsymbol{I} + \boldsymbol{c}(\boldsymbol{\rho I})]) - \mu S - \psi S + \phi R$$

$$I' = \boldsymbol{\beta}([\mathbf{1} - \boldsymbol{\psi}]\boldsymbol{S}[(\mathbf{1} - \boldsymbol{\rho})\boldsymbol{I} + \boldsymbol{c}(\boldsymbol{\rho I})]) - rI - (\mu + \delta)I$$

$$R' = rI + \psi S - \mu R - \phi R$$

For all simulations we keep the following parameter values the same
λ=1, μ=0.01, β=.1, δ=0.003, r=1/20,ϕ=.1, ρ=.85,c=.2,

Extend SIRS to SIRPS Model for Moneybox

SIRS COVID model Extended to MPV SIRPS Model to account for how infections and dynamics from the environment also affect at-risk populations:

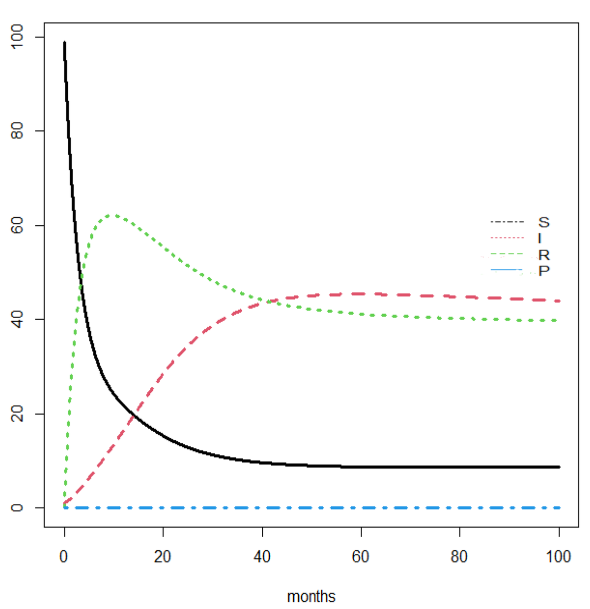
$$S' = \lambda - \boldsymbol{\beta}(\boldsymbol{S}[\mathbf{1} - \boldsymbol{\psi}][(\mathbf{1} - \boldsymbol{\rho})\boldsymbol{I} + \boldsymbol{c}(\boldsymbol{\rho I})]) - \mu S - \psi S + \phi R - \beta_2 PS$$
$$I' = \boldsymbol{\beta}([\mathbf{1} - \boldsymbol{\psi}]\boldsymbol{S}[(\mathbf{1} - \boldsymbol{\rho})\boldsymbol{I} + \boldsymbol{c}(\boldsymbol{\rho I})]) - rI - (\mu + \delta)I + \beta_2 PS$$
$$R' = rI + \psi S - \mu R - \phi R$$
$$P' = kI - dpP$$

Glossary: β = *Avg contact rate sufficient for transmission*, $\boldsymbol{\beta_2}$ = *Avg contact ratefrom environment sufficient for transmission*, ψ = *Avg num of population vavvinated*, S = *Susceptible population*, ρ = *Avg num of pop showing symptoms*, I = *Infected population*, c = *Reduced mobility of infected pop*, ϕ = *Avg time of immunity after recovery from disease*, R = *Recovered population*, P = *Environmental pop. dynamics* r = *Avg recovery rate*, λ = *Birthrate into pop*, μ = *Mortality rate*, δ = *Natural dealth rate of population*, $\boldsymbol{dp}$ = *dilution of virus into environment*, $\boldsymbol{k}$ = *environment factors*

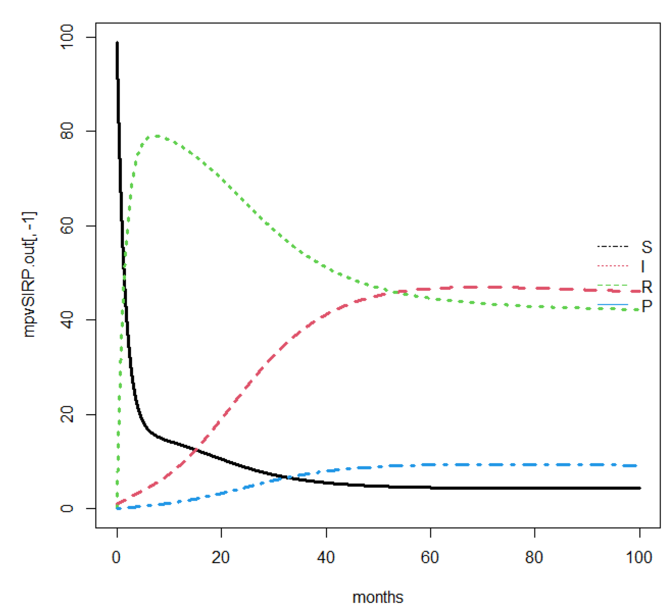
Results I – Environmental Effects

Question: How do environmental factors affect SIRPS model dynamics?
k=0.0/0.1/0.2, β_2=0.05/0.1, dp=0.5/0.75, ψ=0.25
(a) No Envirom.k=0 (b) LOW k/β_2/dp (c) HIGH k/β_2/dp

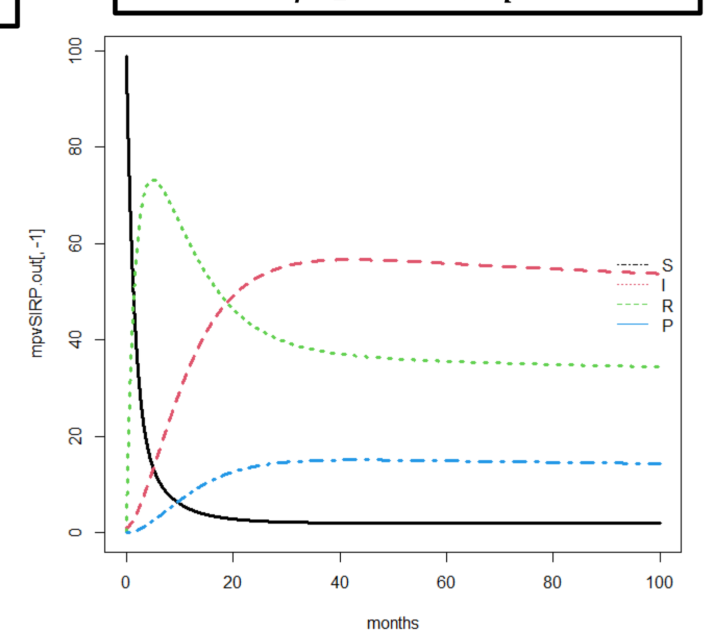
$k = 0.0, \beta_2 = 0.05, dp = 0.50$



$k = 0.1, \beta_2 = 0.05, dp = 0.50$

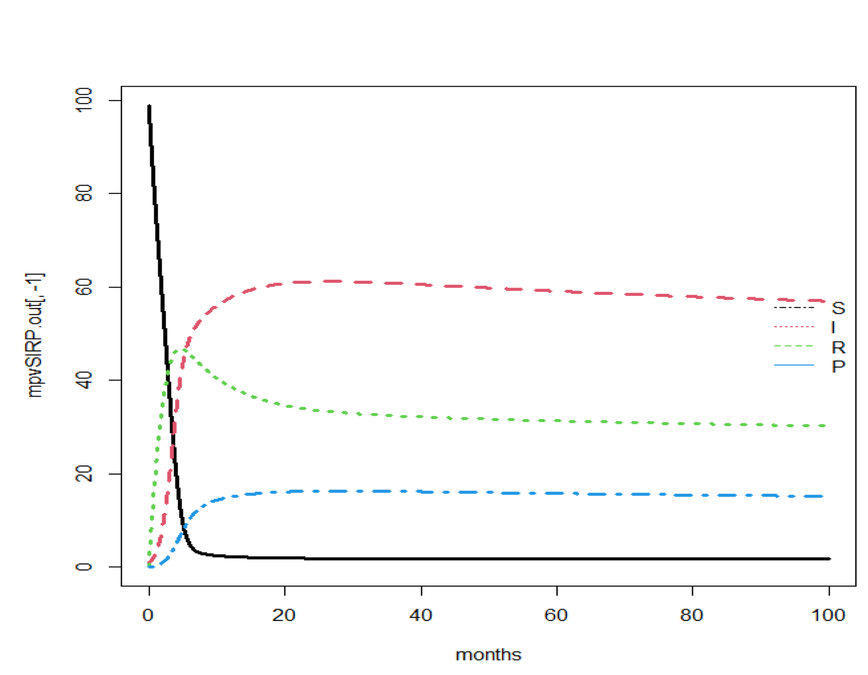


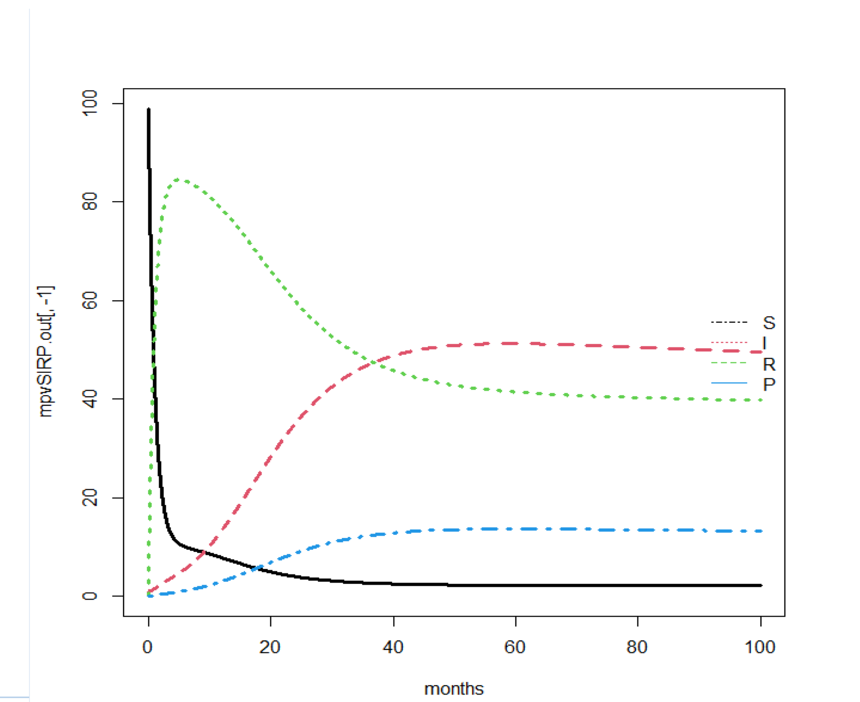
$k = 0.2, \beta_2 = 0.1, dp = 0.75$



Results – Impact of Vaccination

Question: How vaccination affect SIRPS model?
λ=1, μ=0.01, β=.1, δ=0.003, r=1/20,ϕ=.1,
ψ=0.25/0.85,ρ=.85,c=.2, β_2=0.1,k=0.2,dp=0.75
(a) Low vac: ψ=0.25 VS (b) High Vac: ψ=0.85





Conclusions

Slight variations in environmental parametric values greatly affected the MVP SIRP model. β_2 appears to have greater influence at affecting model sensitivity than other environmental parametric values. Like COVID SIRS model, vaccinations also affected the ODE positively, noticeably affecting I, R, & P populations.

However, more research is needed to accurately account for the model dynamics of the P population. Moreover, more research is needed to show causation of how new SIRP values affected model performance.

Literature Cited & Acknowledgements

1. CDC. 2022. U.S. “Monkeypox Case Trends Reported…”
2. CDC. 2022. “About Monkeypox”.
3. Olumuyiwa, J.P., et. all. 2022. “Transmission dynamics of MVP: a mathematical modelling approach”.
4. Ding, Cheg, et all. 2021. “The Value of Infectious Disease Modeling…”. Vol 9: 1135-1145.