MATH 572

Monkeypox Transmission & Prevention

Project Proposal

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3-2-2023

Description

To model the transmission and prevention of the monkeypox virus, we propose a compartmental mathematical model evaluated at different levels of intervention. The project will aim to construct a model specific to a local outbreak of monkeypox in Alberta. The intended audience are government officials wanting a description of the threat the virus poses to Albertans and if a public education intervention might be effective in reducing transmission.

Background

The monkeypox virus was first discovered in humans in 1970 and has since become endemic in the Democratic Republic of Congo and has spread to other nearby countries in central and west Africa (Parker & Buller, 2013).The disease has garnered more attention recently due to numerous outbreaks around the world and its similarity to smallpox, a disease that killed an estimated 300 million since the year 1900 (Mohr, n.d.).

Monkeypox can be transmitted from contact between humans and infected rodents; however, the most recent outbreaks have occurred primarily due to human-to-human contact. Transmission usually occurs from direct contact with infected rashes, scabs, and bodily fluid, but can also be transmitted by respiratory secretions. Once transmitted, infection results in flu-like symptoms and the characteristic rash, turning into painful blisters. Typically, illness is moderate and resolves within 2-4 weeks, with those who are immune compromised having more severe symptoms, with the possibility of death (Peter, et al., 2022).

There is currently no vaccine or treatment specific to monkeypox. There are however vaccines and treatments developed for smallpox that are effective (Peter, et al., 2022).

Research Objectives

The objective of this research is to understand the transmission dynamics of local outbreaks of monkeypox and to investigate the effect of public education about the virus on specific disease attributes, such as:

- Peak infections,
- final size, and
- endemic & disease-free equilibria

The research will be conducted for the purposes of public policy making and would include answers to questions such as:

- How many infections could we expect at one time during the peak of the outbreak?
- Will the pandemic end or become endemic?
- How many Albertans could be affected by the disease before the pandemic ends?
- Will public education have a significant effect on the impact the disease outbreak has on Albertans?

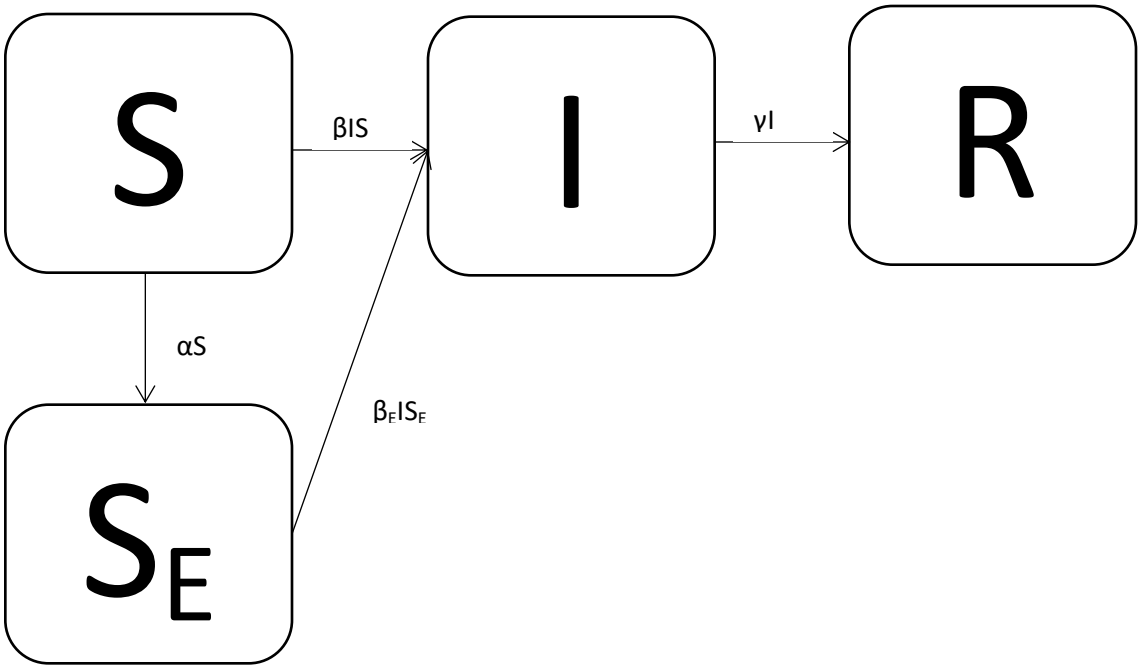
Method

To achieve the research objectives set out in this proposal, a compartmental model of monkeypox is proposed. The model will be constructed using Matlab and results will be presented in a report and presentation aimed at public health policy decision-makers. The research questions will be answered by mathematical analysis of model results. This analysis will include peak infections, final size, and equilibria that will be evaluated at various levels of intervention and input levels.

Preliminary Model

The preliminary model proposed is a simplified version of previous monkey pox modelling (Peter, et al., 2021). The purpose of the proposed model is to describe local outbreak dynamics in Alberta; therefore, compartment for rodent transmission is removed, as it is assumed that a local spread would likely be human to human.

To study the dynamic effects of a realistic intervention during a local outbreak, a compartment for educated susceptible population is added. Once the simplified model is run and calibrated, other compartments may be added or removed; such as age groups, birth and death rates, high risk susceptible population, quarantined population, or infected population yet to be contagious.



System of Equations:

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dS_E}{dt} = \alpha S - \beta_E I S_E$$

$$\frac{dI}{dt} = I(\beta S + \beta_E S_E) - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

Variables and Parameters:

S – Number of uneducated susceptible population

S_E – Number of educated susceptible population

β – infectious rate for uneducated population

β_E – infectious rate for educated population

I – number of infected population

R – number of recovered population

α – education rate

γ – recovery rate

Sensitivity Analysis

A global sensitivity analysis will be performed to discern the impact on outputs relating to uncertainties of model inputs.

Data Sources

To date, no suitable data sources for model fitting have been found.

Mathematical Analysis

Mathematical analysis will include a final size estimate, finding the total people infected from the number of initial susceptible minus the susceptible at the end of the pandemic ($S_0 - S_\infty$). This will be determined mostly by the basic reproduction number.

Peak infections will be analyzed given different levels of intervention, and inputs.

Local stability analysis will be performed to determine which equilibrium points are stable or unstable. This will include a phase-line analysis, bi-furcation diagram, and the basic reproduction number level that results in either a disease-free or endemic equilibrium.

Group Contributions

Hedieh Kalachahi (1467616): Initial project idea, sensitivity analysis research, final draft review, and data source research.

Saira Faiz (1775398): First proposal draft, initial research, final draft review, and project planning

Colby Jamieson (1714722): Proposal review and drafting, research objectives, initial model, and mathematical analysis.

References

Mohr, J. (n.d.). *Smallpox*. Retrieved from American Museum of Natural History: https://www.amnh.org/explore/science-topics/disease-eradication/countdown-to-zero/smallpox#:~:text=One%20of%20history's%20deadliest%20diseases,the%20first%20disease%20ever%20eradicated.

Parker, S., & Buller, R. M. (2013). A review of experimental and natural infections of animals with monkeypox virus between 1958 and 2012. *Future Virol*, 129-157.

Peter, O. J., Oguntolu, F. A., Ojo, M. M., Oyeniyi, A. O., Jan, R., & Khan, I. (2022). Historically, outbreaks of monkeypox have been linked to animal-to-human transmission, where wild animals like African rats and monkeys transmit the virus to people which could occur as a result of bites or scratches the processing of bush meat, direct co. *Physica Scripta*.