Using Network Models to Simulate Disease Spread in Equestrian Centers

Introduction

- In equine populations, Streptococcus equi is a bacteria known to cause the upper respiratory infection, colloquially known as "strangles."
- Our goal was to create a mathematical model of the spread of strangles to test the effectiveness of different mitigation strategies.
- We started by building an understanding of strangles- researching topics like infection rates, methods of mitigation, and lasting effects. Then, we used data collected by the biology department and literature from other institutes to model the network structure of the infection spread.
- The models provided show each technique's effectiveness, which determines which strategy is most effective in reducing the spread.

Choice of Network

- To model the spread of strangles. We need to first model how the equine contact network.
- The most basic model we can use is a random graph where edges are formed between nodes with probability p.
- We also can use a planted partition model which allows us to account for the fact that equid typically have higher contact within stables than with outside equids.
- For this project, we use a stochastic block model that roughly approximates the equine community of a subregion of Kentucky.

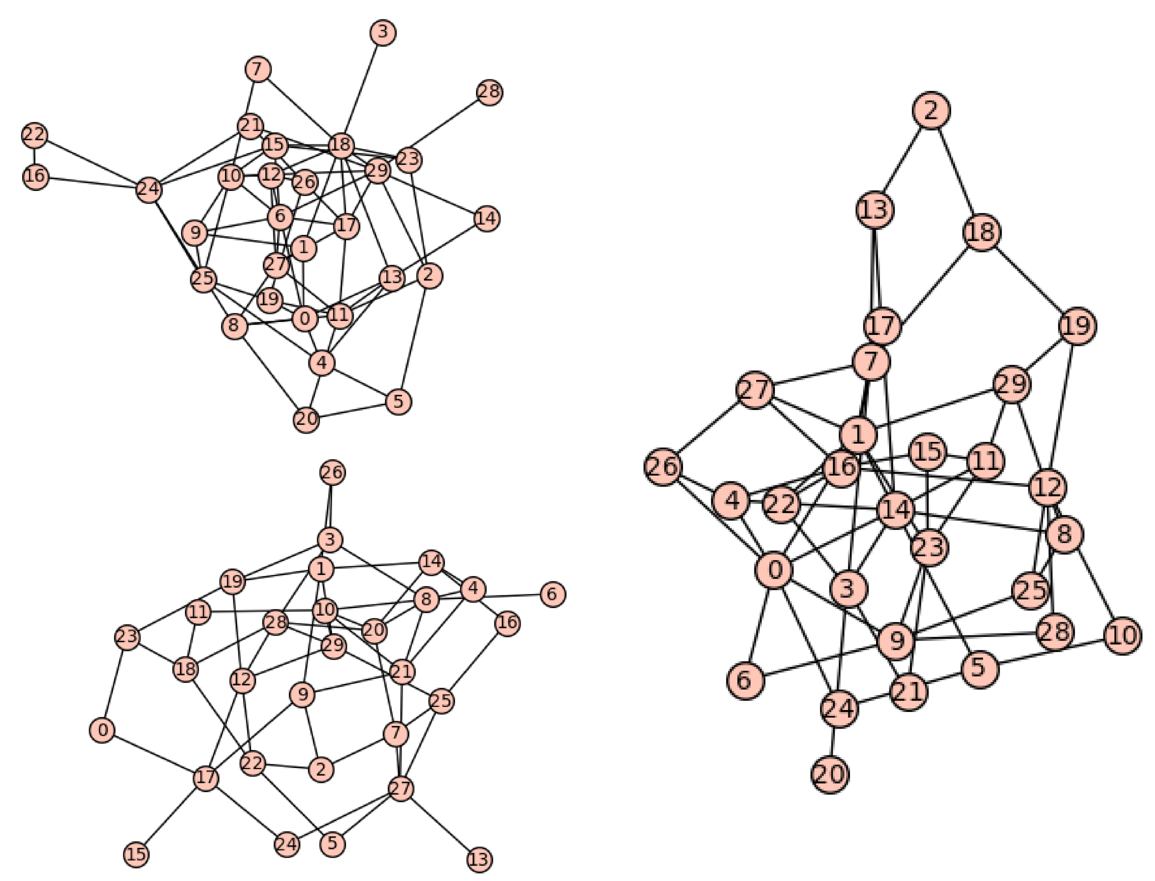

Figure 1: Example random networks on 30 vertices.

Sick Quarantine

- In this model, we are examining the effects of a sick quarantine on equids infected with strangles.
- Start with a standard SIRS model with an immune state
- Then, add a quarantine state, which in this case represents sick quarantine
- This model assumes that every infected horse that is showing symptoms of strangles is being put into sick quarantine, to prevent the spread of the bacteria to other equids.
- We also assume that the equids come out of quarantine only when they are fully recovered.
- It has been estimated that 90% of infected equids are symptomatic, so for the simulations, we allow 90% of equids at the infected node to move to the quarantine node.
- A flowchart describing the model and the data from an example simulation are shown in Fig. 3

Simulation of the Models

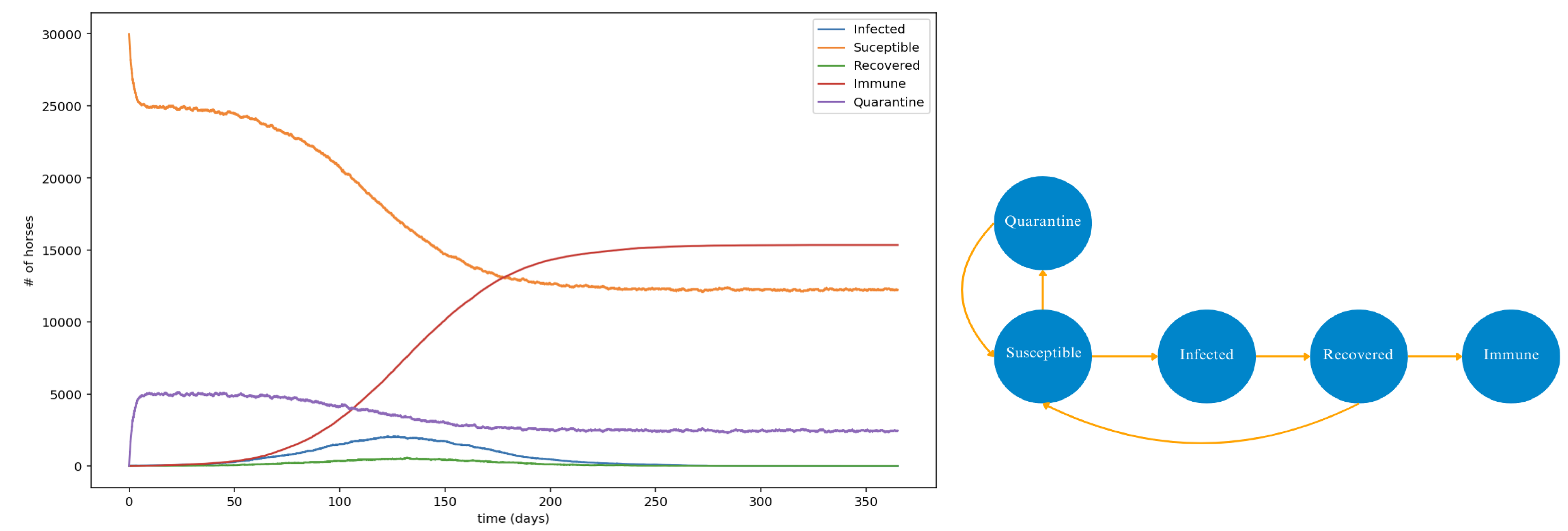

Figure 2: Simulation data (left) and flowchart (right) for the Preventative Quarantine model

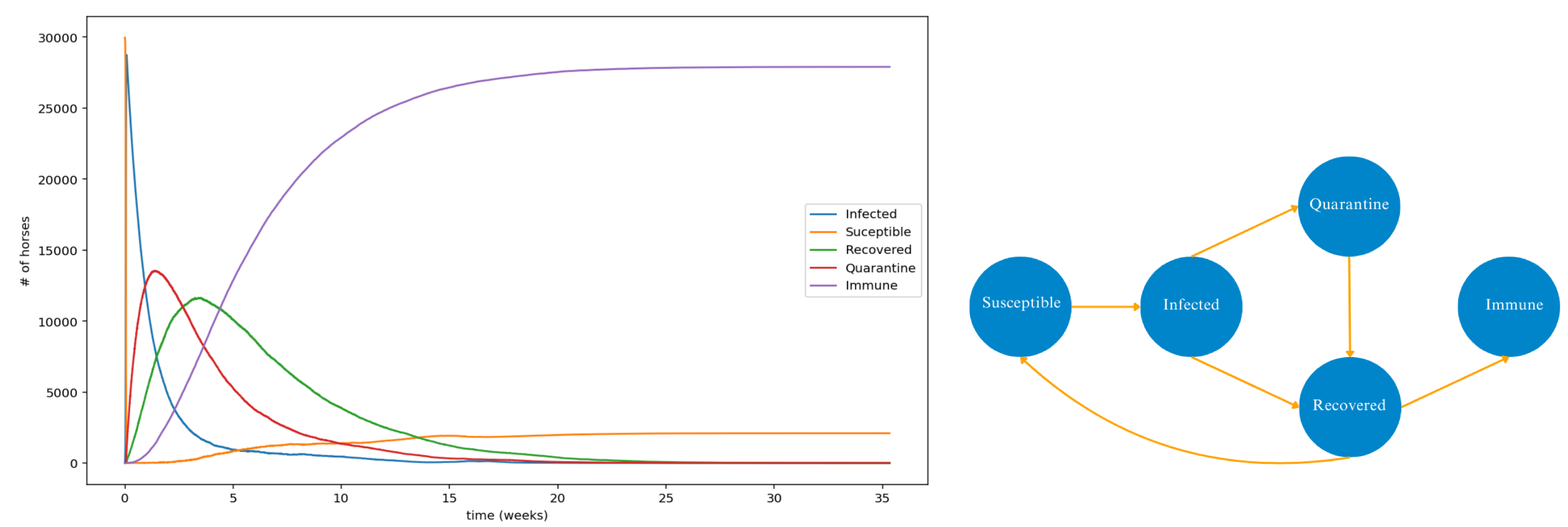

Figure 3: Simulation data (left) and flowchart (right) for the Sick Quarantine model

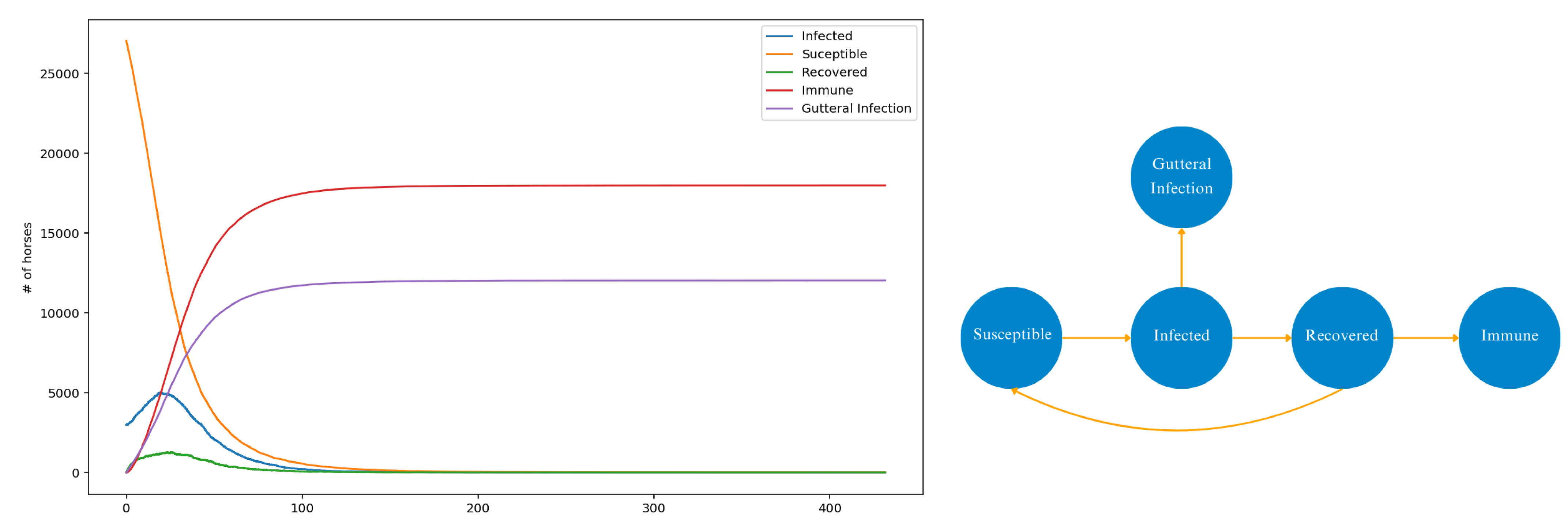

Figure 4: Simulation data (left) and flowchart (right) for the Guttural Infection model

Preventative Quarantine

- In this model we attempt to observe the impact of preventative quarantine protocol
- In this model, random susceptible equids are placed in quarantine for a period of two weeks
- We aimed to compare this quarantine strategy with the sick quarantine strategy
- A flowchart summarizing the model along with the data from a sample simulation are shown in Fig. 2

Guttural Pouch Infection

- In this model we aimed to account for case where equids infected with strangles develop guttural pouch chondroids.
- When an equid develops guttural pouch chondroids, they can appear completely healthy but continue to infect surrounding equids.
- To model this, we start with a standard SIRS model with an immune state.
- We then added a Guttural Pouch Infection state that causes nearby nodes to switch to an infected state with probability g.
- The model diagram and results from a sample simulation are shown in Fig. 4.

Next Steps

- One consideration is to build a model with a "vaccinated" state, which could account for vaccination implementation and its effectiveness
- Observing the effects of combined models
- Finding which parameters are the most impactful on reducing the spread of infection
- Testing the model's sensitivity to variation in known parameters
- Applying this model to more realistic contact networks
- Modeling other disease mitigation techniques and observing the differences to find the most effective technique

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