Infectious Disease Models

Professor Naomi Cogger

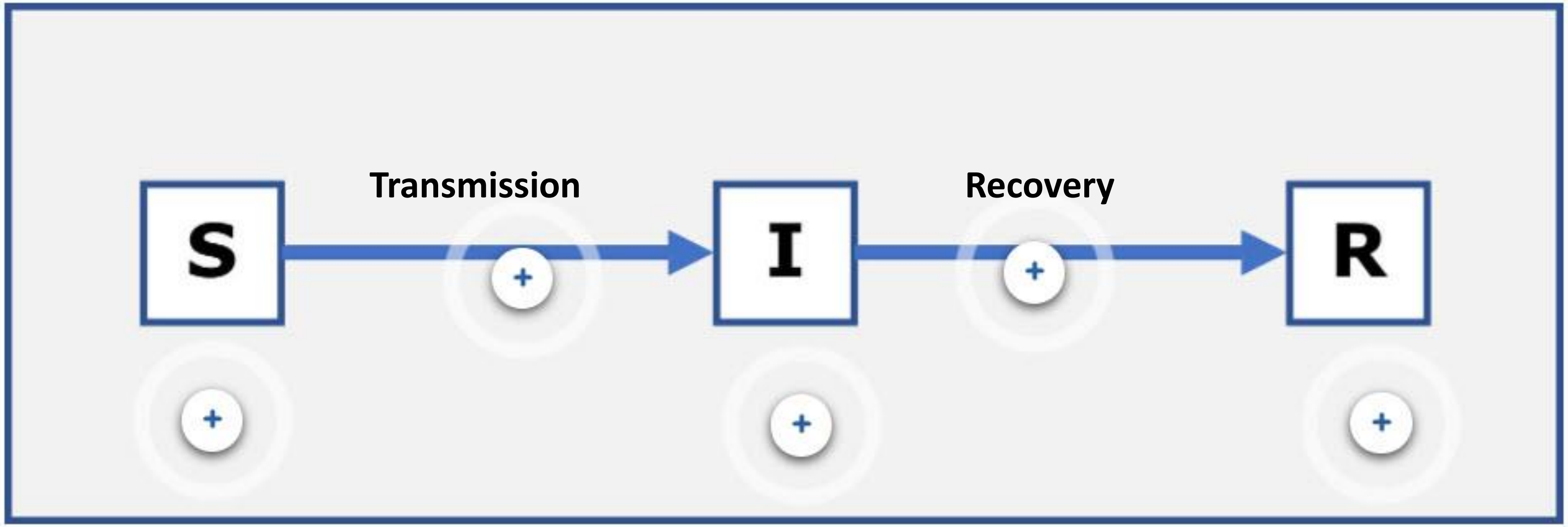
EpiCentre, School of Veterinary Science

Massey University

Infectious disease models provide information that can be used to understand transmission and compare controls options.

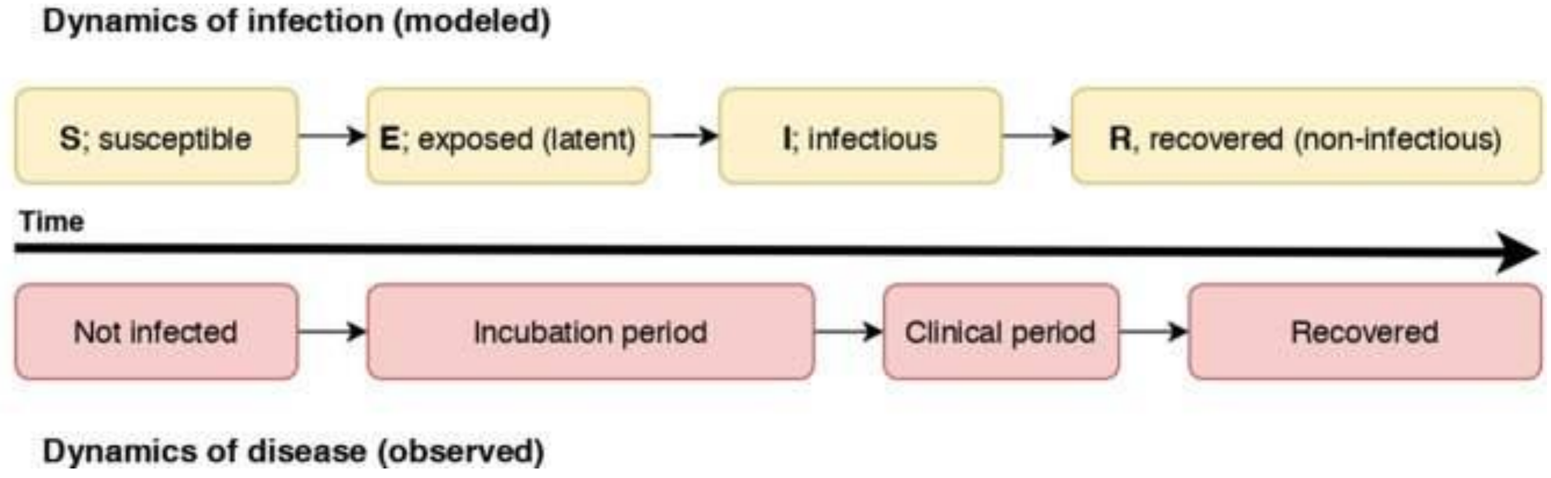
Infectious Disease Models

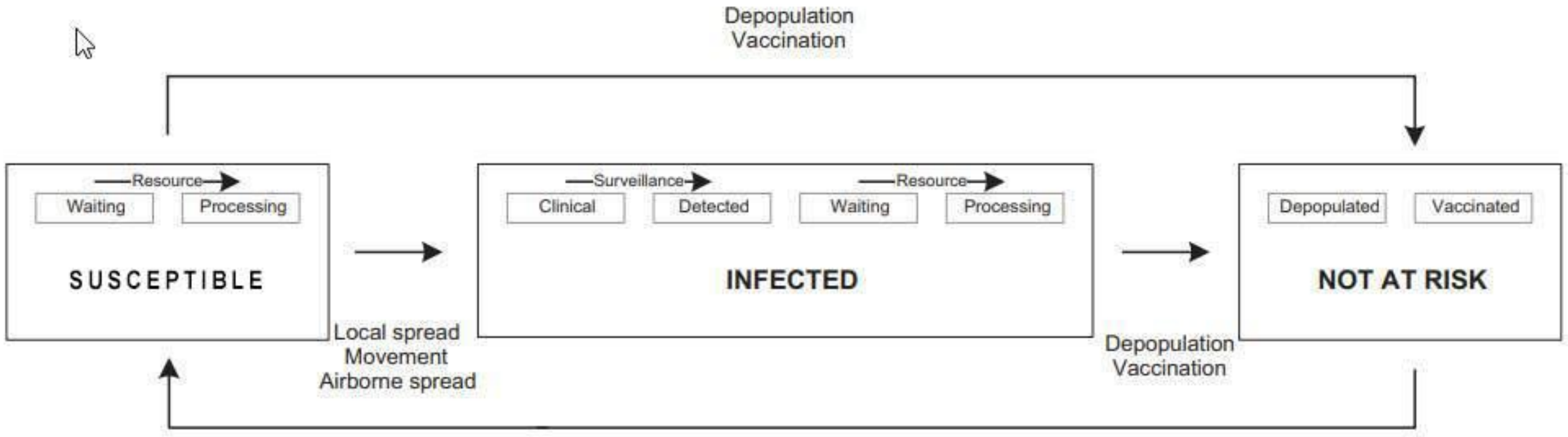
- Disease spread models represent the progression of the units of interest through different disease states.
- Use mathematics to describe transmission and evaluate controls
- Basic model is Susceptible-Infectious- Recovered



Infectious Disease Models

- Not limited to SIR





Infectious Disease Model

- To sum up:
  - Infectious Disease Models classify animals according to their current status (e.g. susceptible, infectious and recovered)
  - We use mathematical formulas to determine how many animals will be susceptible, infectious, and recovered each day.
  - SIR models have parameters that are fixed for a given scenario but can vary among scenarios.
  - We can include chance and when we do it is called a stochastic model

What to do before you start to build a model?

1. Define the purpose:

    Involves identifying the question or questions to be answered, the system to be modelled, and the outputs to track

2. Identify the unit of interest

    When modelling spread of an outbreak in a country or region we then to focus on the farm

3. Identify what is known about the disease and population to be modelled.

4. Determine the model type

Type of model

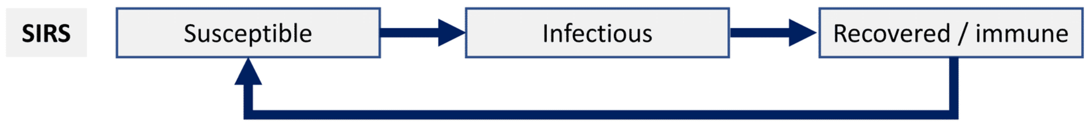
Comprises of two parts:

- How do you want to conceptualise the model?
- Will you create a deterministic or stochastic model?

Conceptualising the model

Susceptible-Infectious-Susceptible

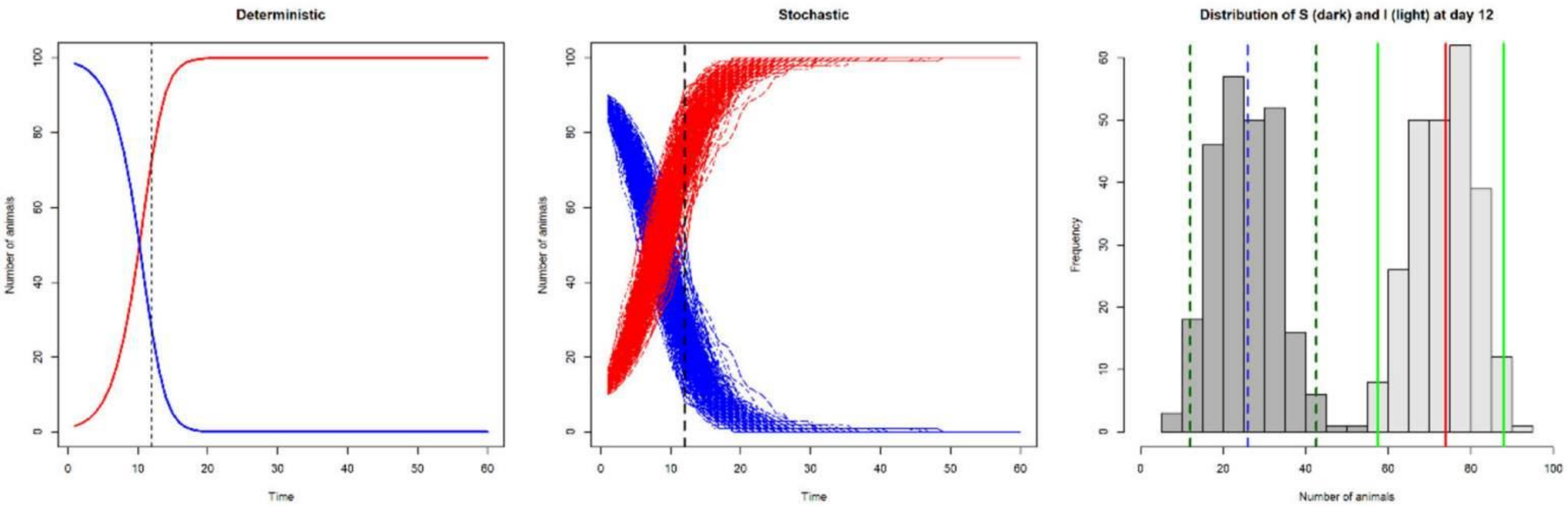
Susceptible-Infectious-Recovered/Immune-Susceptible



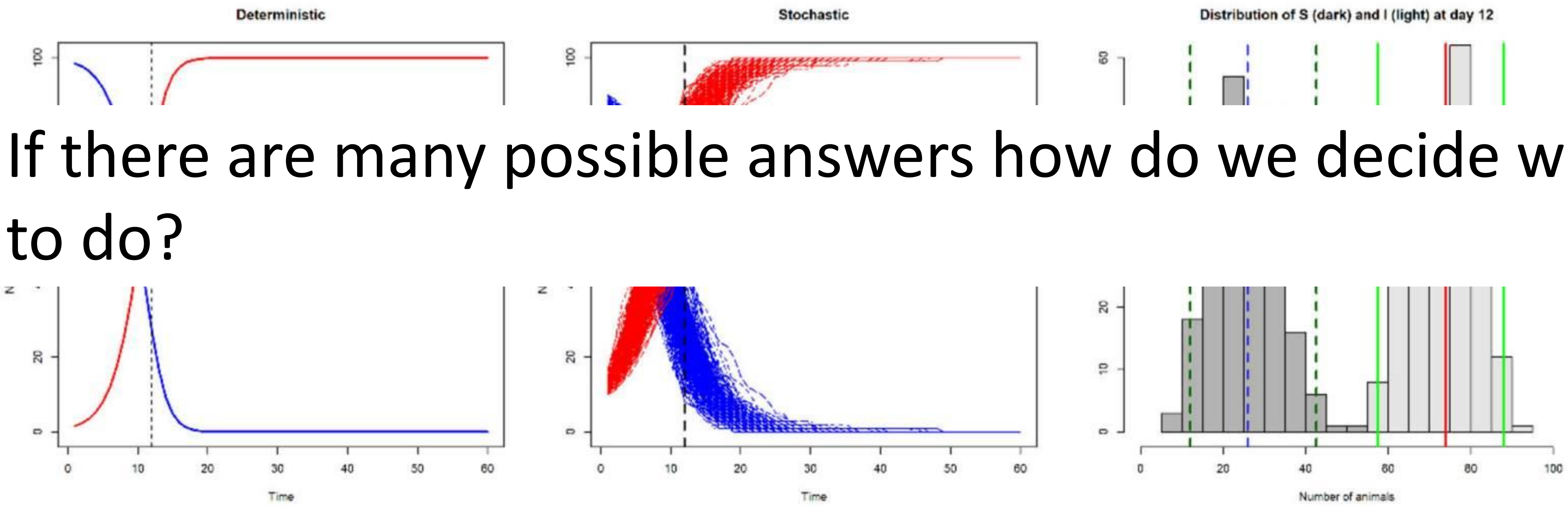
Conceptualising the model

Susceptible-Exposed-Infectious-Recovered-Susceptible

Deterministic V Stochastic



Key difference is that for each day we have multiple possible values.



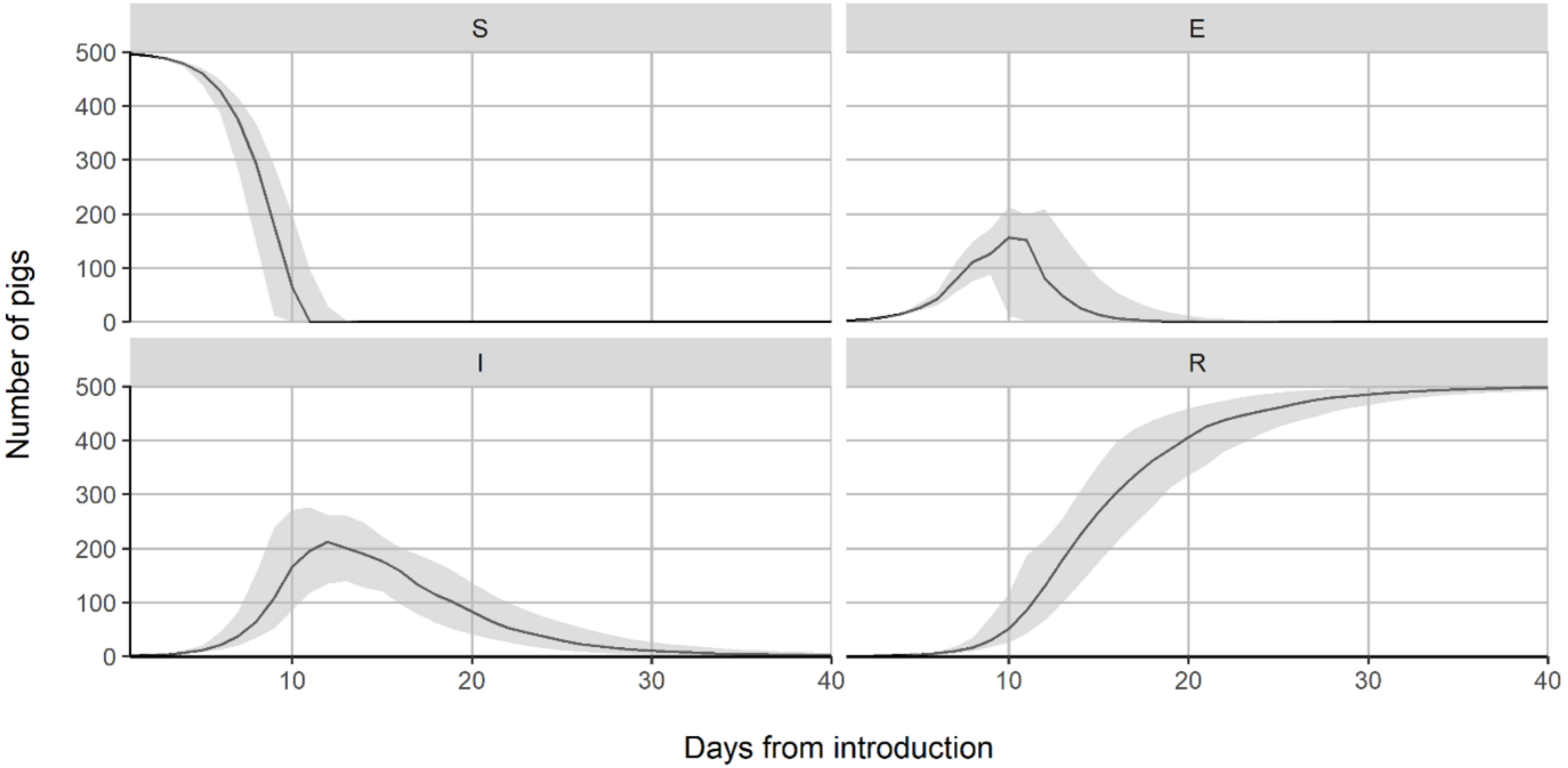
If there are many possible answers how do we decide what to do?

Key difference is that for each day we have multiple possible values.

FMD on a farm

- To prepare for the possible introduction of foot-and-mouth disease (FMD) virus to a pig farm with 500 animals, we developed a stochastic susceptible-exposed-infected-recovered (SEIR model). Our model assumptions were:
    1. The latent period could range from 0 to six days
    2. The infection period could range from one to ten days.
    3. Infected pigs were assumed to recover and are fully immune to the infected FMD virus strain
    4. The latent period was equal to the incubation period)
    5. The farm owner would recognise an FMD outbreak when more than 100 pigs show clinical signs of FMD.

FMD on a farm - Model Outputs

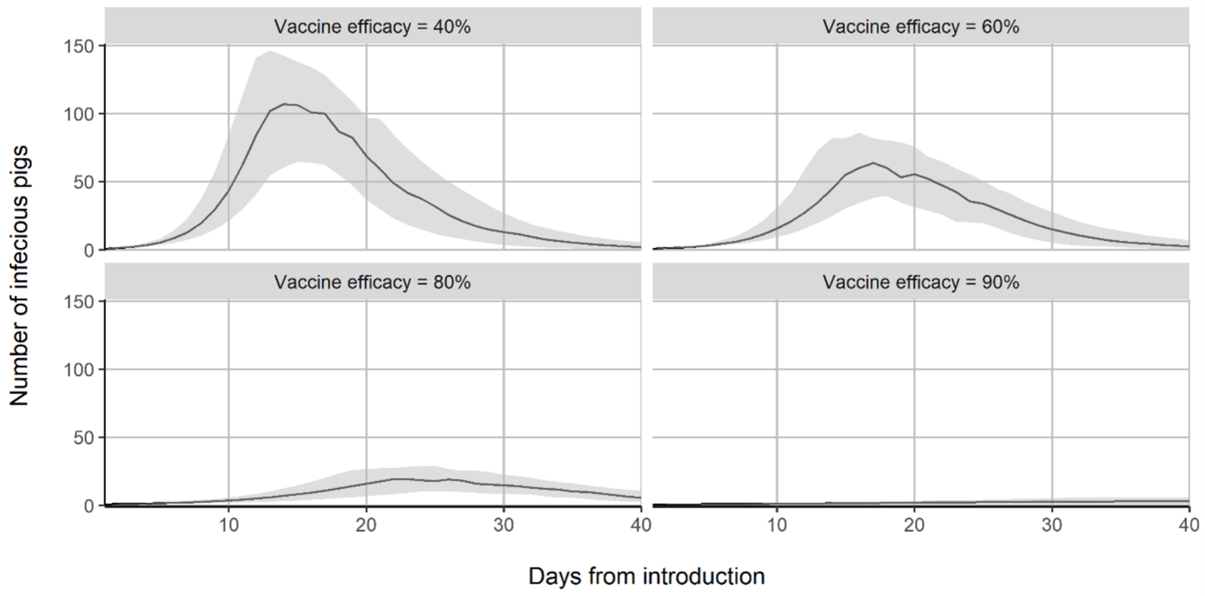


A result of FMD model simulation for 40 days. S, E, I, and R respectively indicate susceptible, exposed, infections, and recovered pigs. Blackline and grey area represent the median and probable range (= range from first to the third quartile) of the simulation result.

FMD on a farm

- The owner decided to vaccinate the pigs based on the model result above. There is only one commercially available FMD vaccine that the owner can purchase. Unfortunately, it is uncertain how effective the commercial vaccine will be against the current FMD field strain. We ran different simulations to investigate the effect of vaccination efficacy on outbreak size.

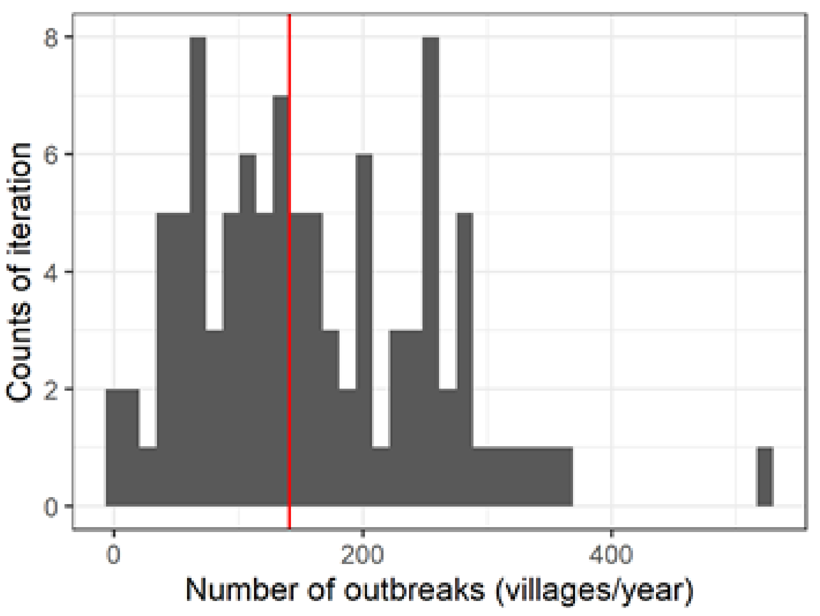
FMD on a farm – Model Outputs with vaccination

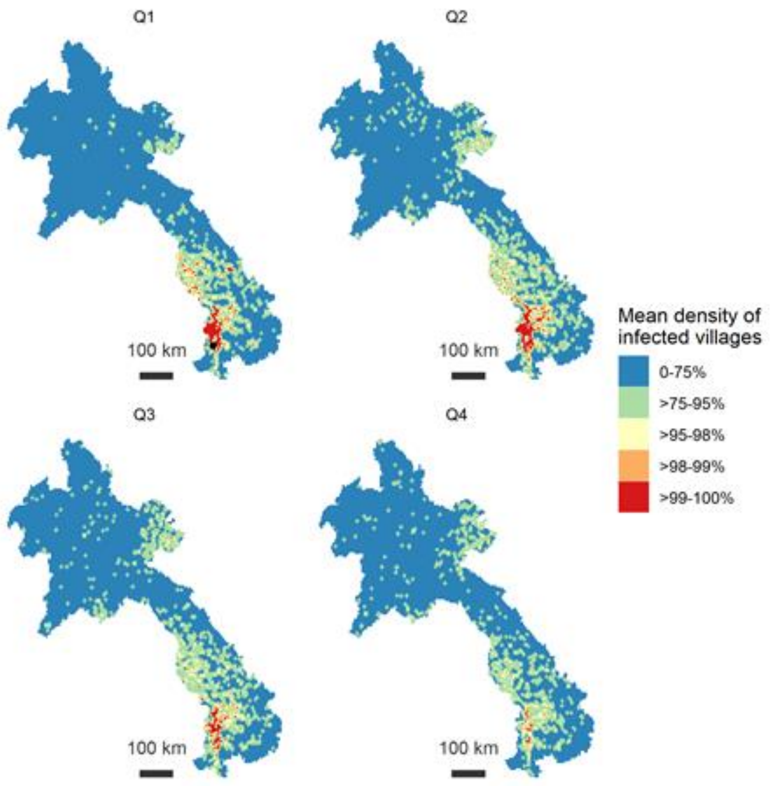


FMD in Laos

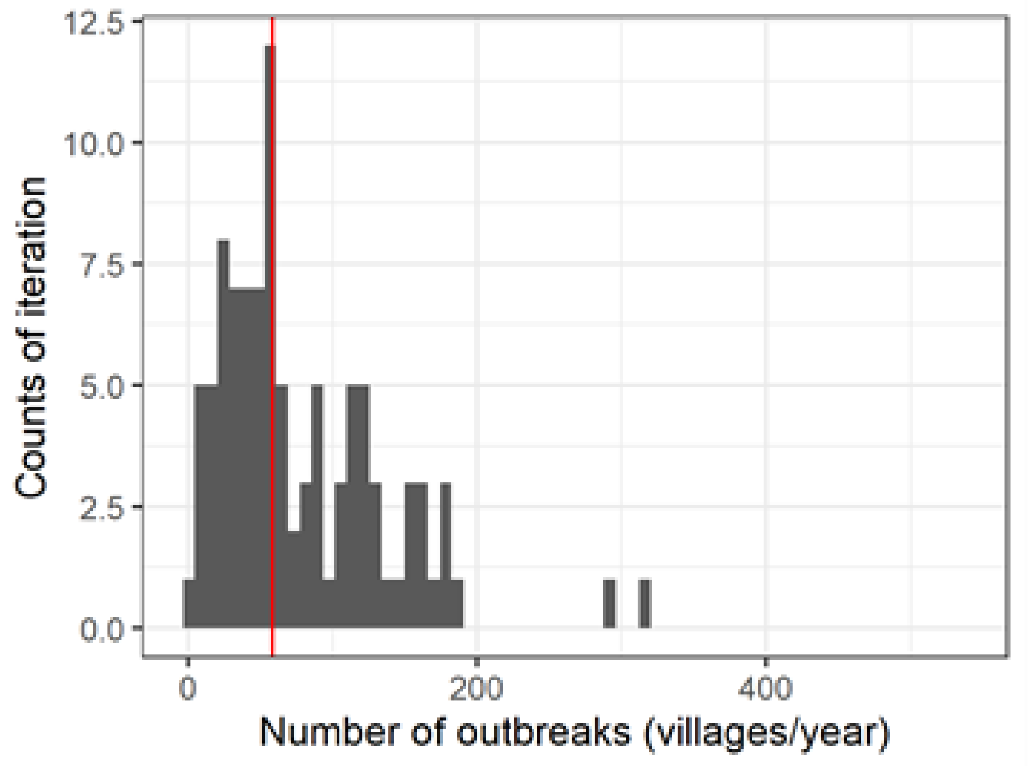
- FMD is endemic in Lao PDR
- We have enough vaccination to cover 500 villages but there are 10,000 villages in Lao PDR.
- We developed a model to predict FMD spread in the country, using villages as the unit of interest. The idea is to understand were to target vaccination.
- The model assumed:
    1. FMD virus was introduced in the southern province bordering Thailand.
    2. We predicted the spread of the virus over a year with two strategies:
        A. No intervention; and
        B. Vaccination campaign of 60% of animals in the 500 villages are vaccinated.
- We ran 25 iterations and will now look at the outputs.

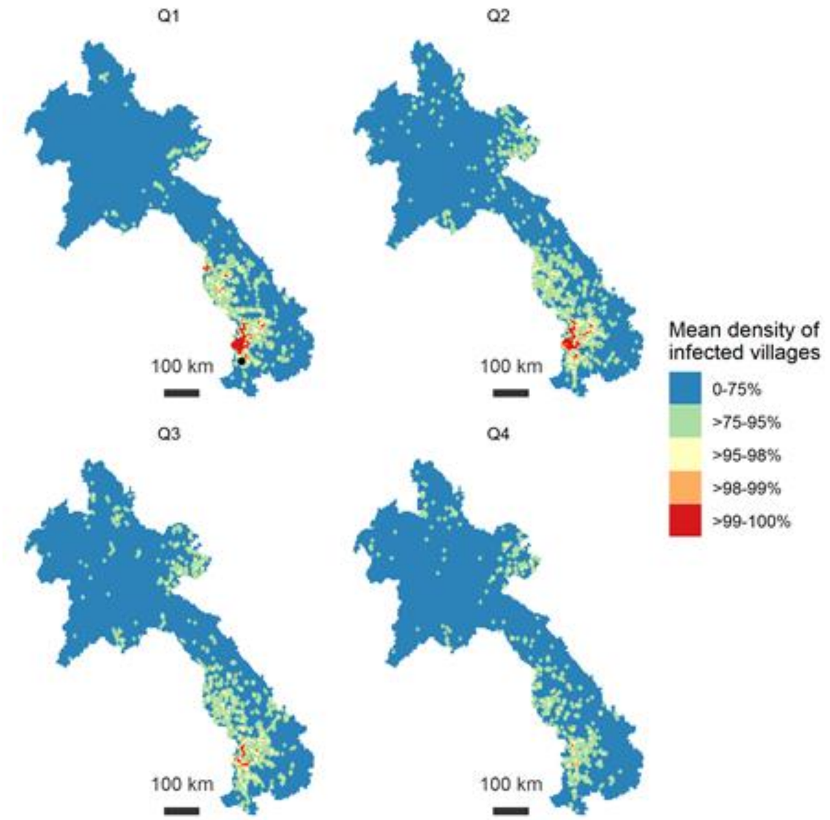
FMD in Laos – No intervention





FMD in Laos – Vaccination





Breakout rooms

Naomi’s Breakout Rooms

Mentimeter link:
https://www.menti.com/i8zqo8o36x

Feedback from breakout rooms

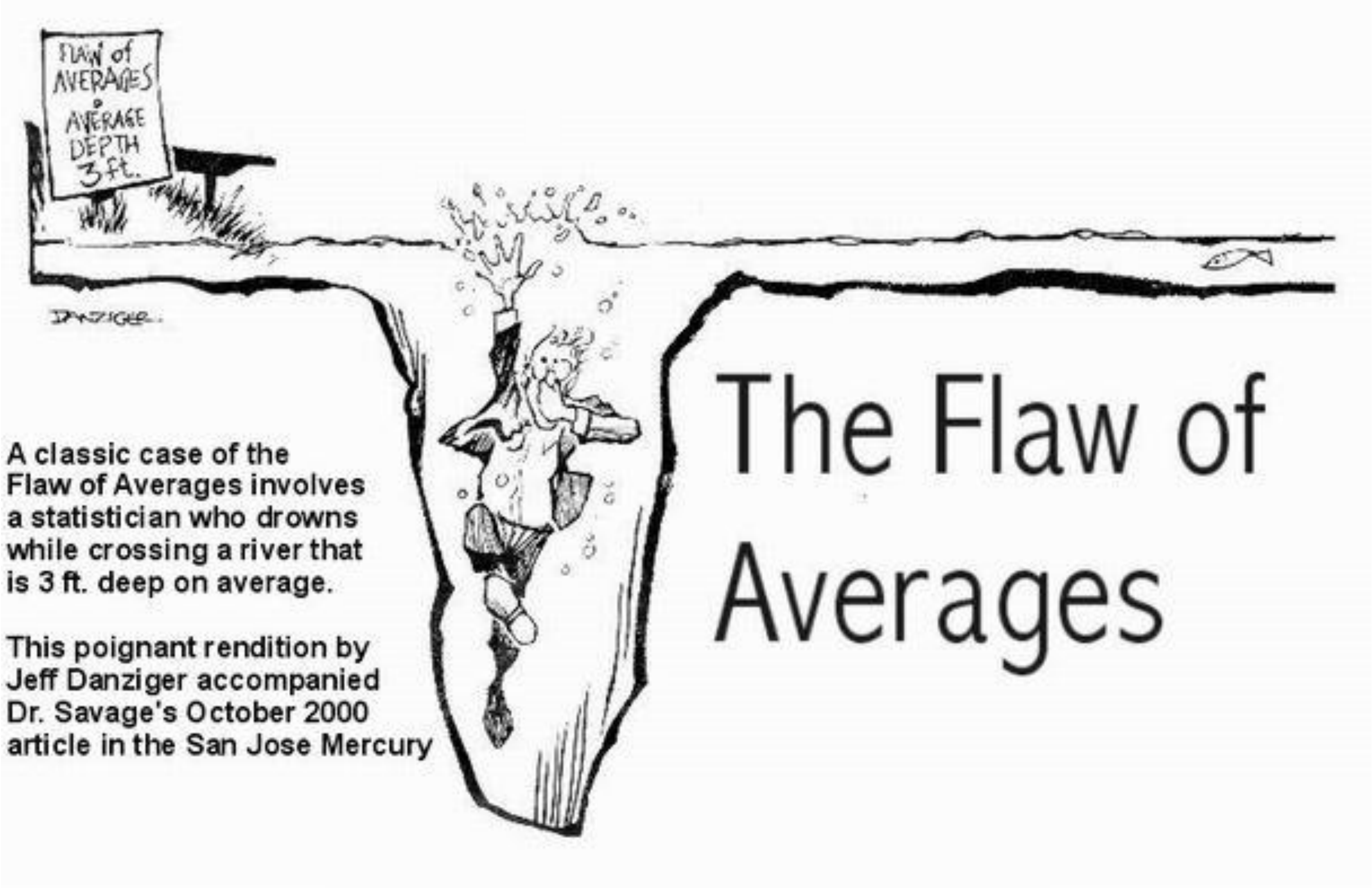
I am not certain of anything now?

Help I am uncertain about what to do with models now

What would we NOT say

The model prediction mean we will have 27.3 outbreak

Why we should not focus on average

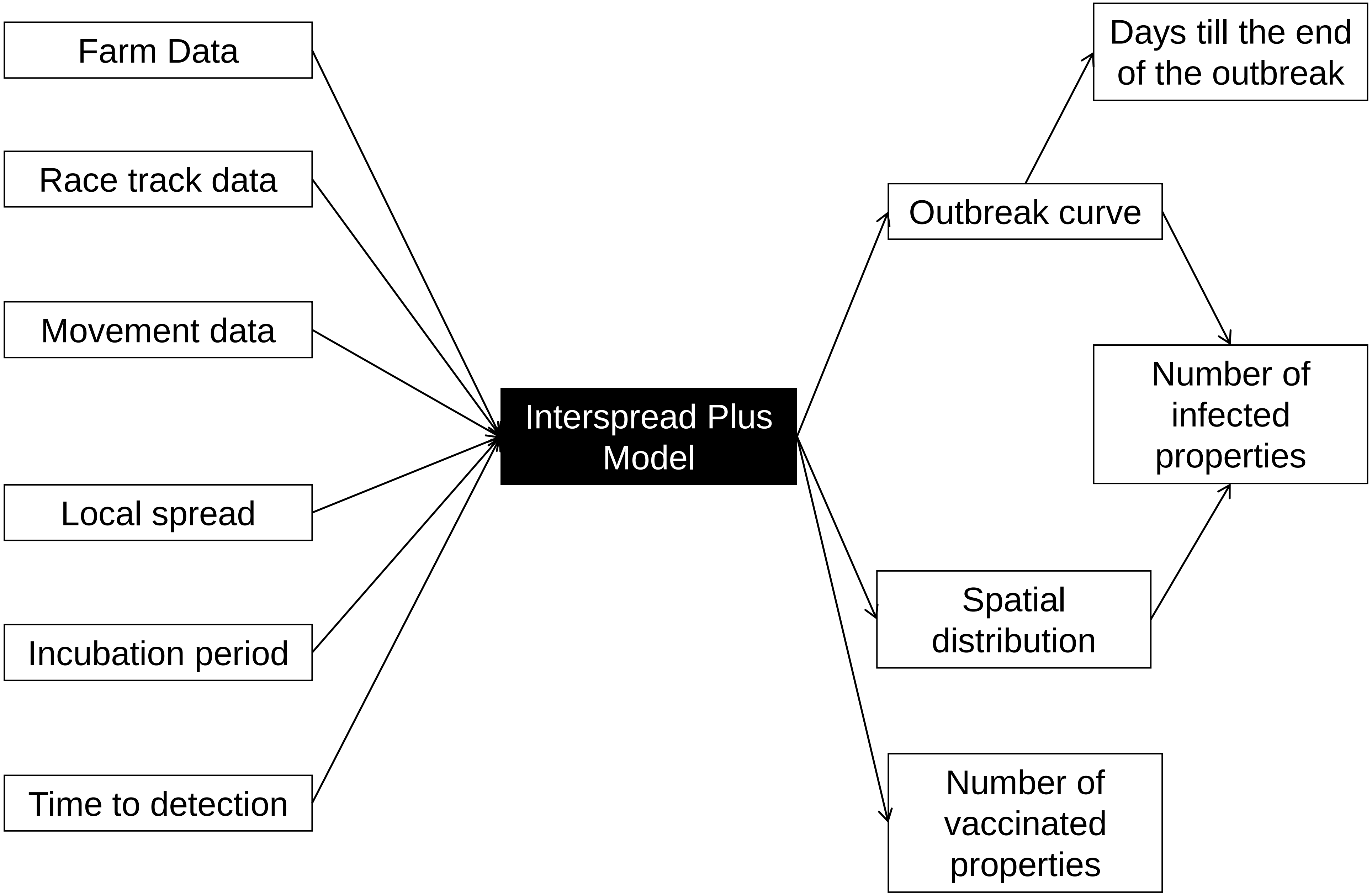


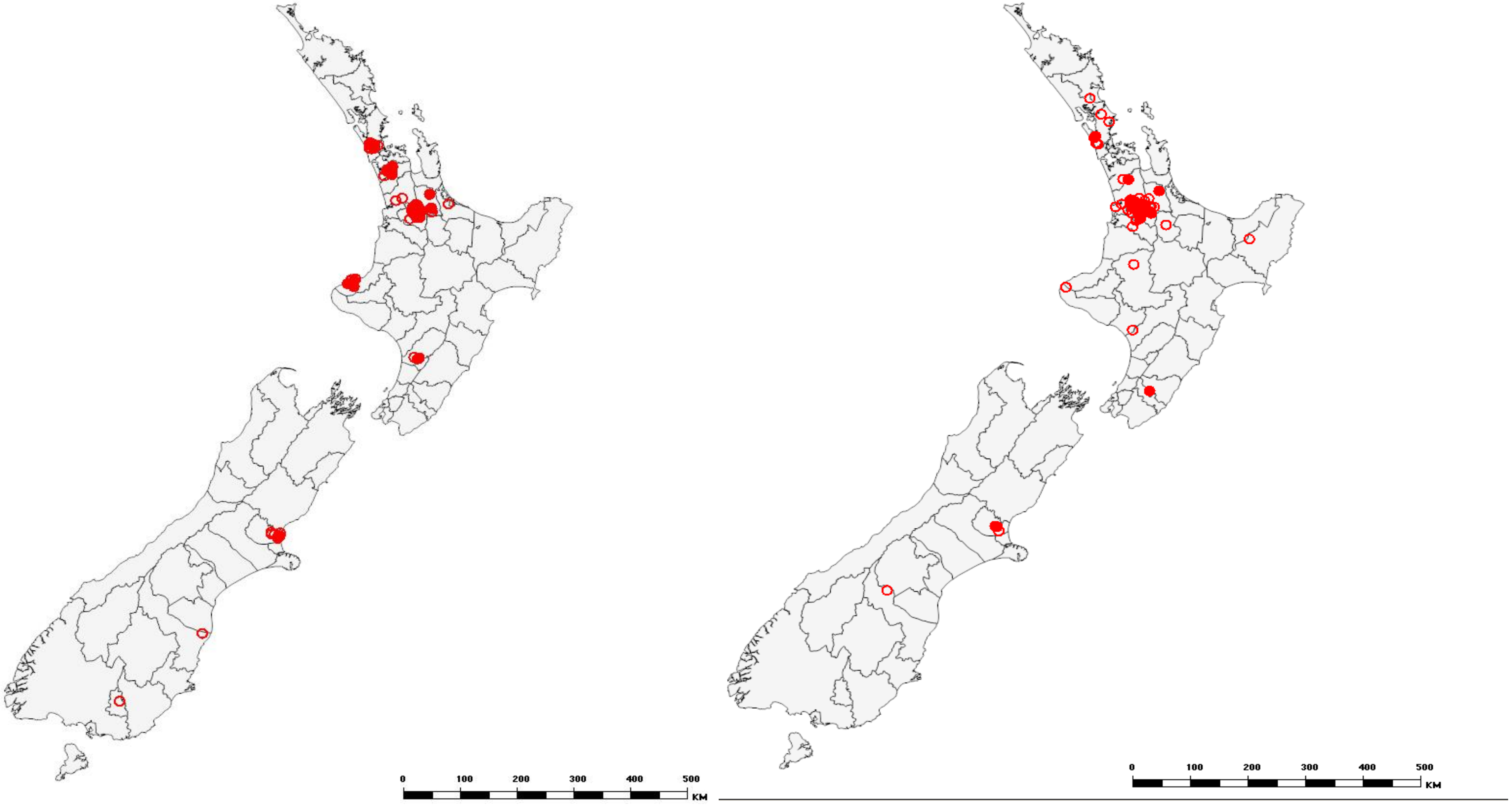
For more of Jeff Danziger’s cartoons, visit www.danzigercartoons.com

Addressing variability & uncertainty

- <u>Uncertainty Analysis</u>
  - Describes the entire set of possible outcomes with their probability
- <u>Sensitivity Analysis</u>
  - Describes the impact of specific model inputs on the model output

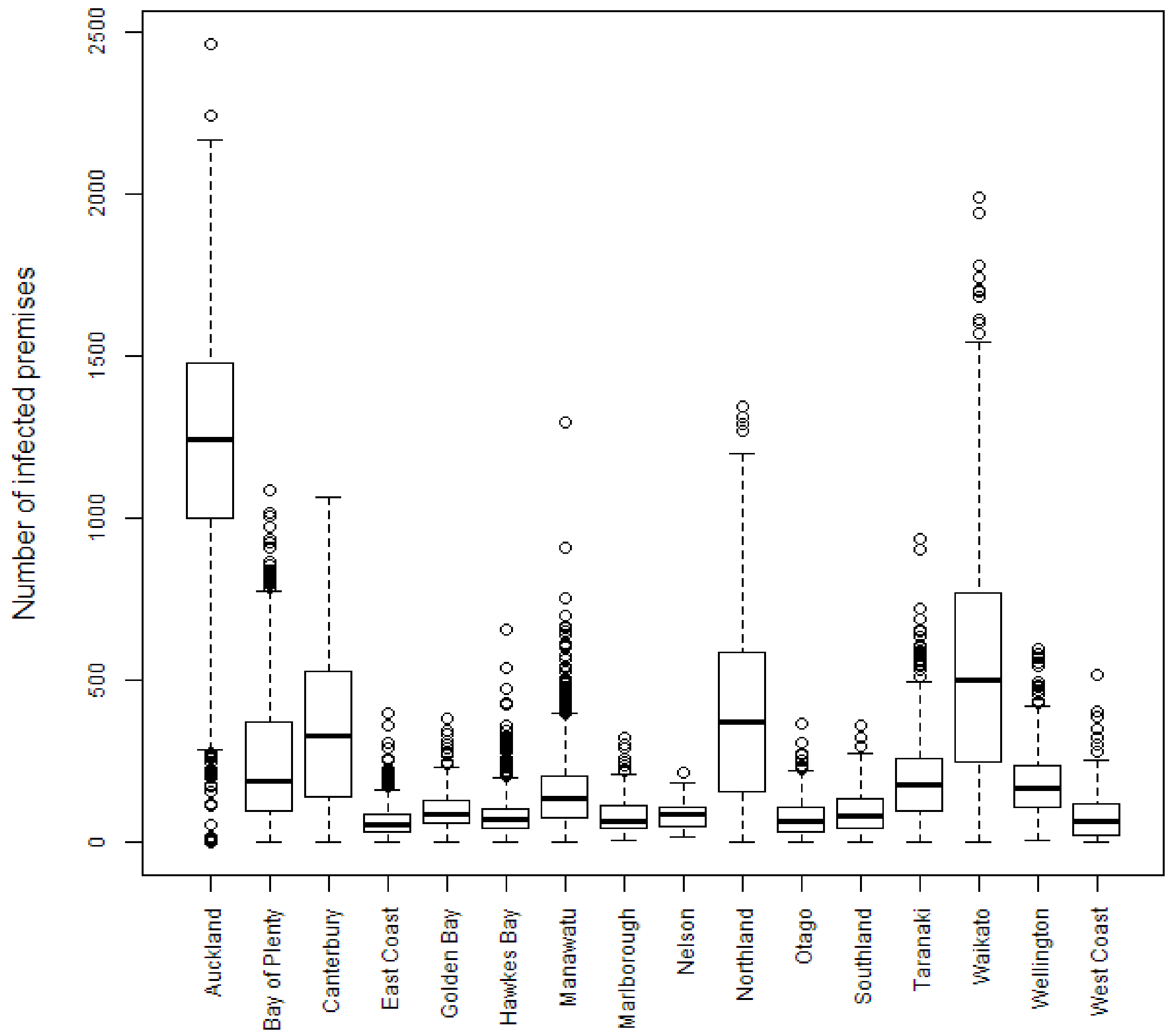
Possible spread patterns for Equine Influenza in NZ





Distribution of infected properties on day 15 of an outbreak in January (Left) and August (Right).

Disease was seeded in a Thoroughbred breeding operation in the Waikato.



Sensitivity analysis exploring the impact of location of first property infected in New Zealand on the number of properties that would have horses infected by equine influenza 15 days after the incursion.

What next

- If you are interested in building an infectious disease model then please contact us directly.
- Models depend on data availability a key step to preparedness is determining what data is available
  - We will circulate a checklist of data sets required to construct individual-based-models
- Want to practice your interpretation further then. Complete the third activity and submit written answers for feedback

- Finally, we value feedback it is the only way we improve. Please take a few minutes to let us know how you found this course