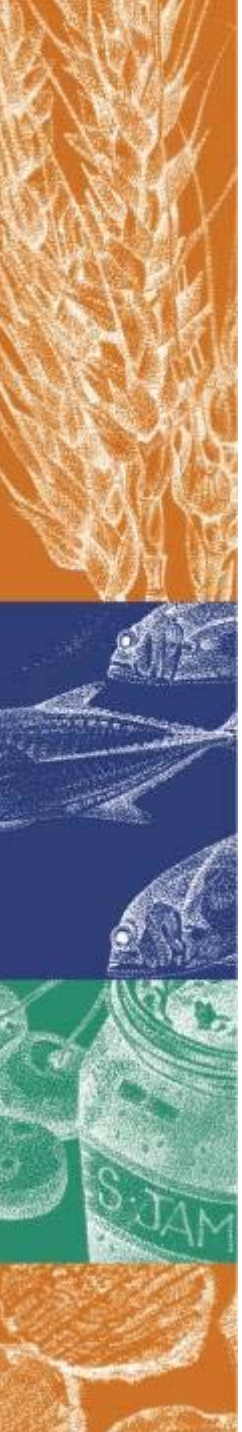

Australian Government
Department of Agriculture, Fisheries and Forestry

Representing Disease Spread in Spatial Simulation Models

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Summary

- Transmission of FMD virus
- Common approaches to modelling disease spread
  - Pathway approach
  - Spread rate approach
  - Hybrid approach
- Our study design

Transmission of FMD Virus

- FMD virus can be transmitted by direct or indirect contact
  - Direct contact includes physical contact or contact with secretions or excretions
  - Indirect contact requires the movement of virus by way of biological or mechanical vectors, including
    - Spread by farm workers, veterinarians, etc
    - Spread by motorised vehicles, etc

Transmission of FMD Virus

- FMD virus can also be transmitted by respiratory droplets or by windborne droplet nuclei
  - Respiratory droplets are transferred over short distances, and, thus, are considered a form of direct contact
  - Windborne droplet nuclei can be transferred over longer distances and are generally considered a discrete form of disease transmission, or a subset of indirect contact

Modelling Transmission

- Putting this together?
  - Most modellers agree that the important pathways to include are
    - Direct contact between infectious and susceptible animals
    - Indirect contact by way of vehicles, people, etc
  - Windborne spread is less definitive
    - Virus strain
    - Environmental conditions

Modelling Disease Spread

- In modelling the spread of FMD, address the fundamental disease spread relationship

$$C = \frac{SR}{P}$$

- Where
  - C is the rate of contact
  - SR is the spread rate
  - P is the probability that contact will result in disease transmission

$$C = \frac{SR}{P}$$

Modelling Disease Spread

- Pathway approach
  - Estimate rate of contact (C)
  - Estimate the probability that contact will lead to transmission (P)
- Spread rate approach
  - Estimate spread rate (SR)
  - Estimate P
  - Calculate C

$C = \frac{SR}{P}$

Modelling Disease Spread

- Hybrid approach
  - Specify key pathways
    - Estimate rate of contact (C)
    - Estimate the probability that contact will lead to transmission (P)
  - Use a catchall spread rate (SR) rate for the balance
    - Estimate SR
    - Estimate P
    - Calculate C

Pathway approach

- Typical pathways
  - Direct contact
  - Indirect contact
  - Windborne spread
- Each will require C and P
- Each C and P will be specific to
  - Combinations of herd or flock types
  - Stage of outbreak
  - Stage of disease in source herd or flock
  - etc …

Pathway Approach

- Advantages?
  - Estimation of contact rate (C) is intuitive
  - Approach is transparent
- Constraints?
  - Very large number of contact rate estimates
    - Complex producer behaviour
    - Heterogenous populations
    - Spatial distribution of farms
    - Changes in behaviour with detection of the disease, etc

Pathway Approach

- Example
  - 5 herd or flock types
  - Direct and indirect contact only
  - Before and after detection differs
    = 100 or so parameter estimates
- Solution?
  - Generally aggregate pathways to minimise the number of parameter estimates
- Drawback?
  - Lose intuitiveness and transparency

Spread Rate Approach

- Spread rate parameter
  - Expected number of cases generated by an infected case per unit of time
  - No differentiation on how a new farm becomes infected
- A synthetic parameter
  - Doesn't try to capture particular transmission 'pathways'
  - Does capture a more general trend in the rate of movement of contagion from infectious farms

Spread Rate Approach

- Advantages?
  - SR parameter can be estimated from data collected from past or ongoing outbreaks
    - Know where new cases occur, and when they became infected, even if how they became infected is not known
  - Miller (1979) approximation for SR termed estimated dissemination rate (EDR)
    - Calculated for each period of an outbreak
    - Ratio of cumulative incidence (CI) in that period to CI in previous period

Spread Rate Approach

- Constraints?
  - Does not differentiate amongst pathways for infection
    - Less intuitive
  - Does not consider interactions between farms of different types, stages of infection, locations, etc
    - Cannot test the effectiveness of control strategies targeted at particular pathways or farm types

Spread Rate Approach

- Solutions?
  - Identify pathways and interactions of interest
  - Apportion spread rate amongst them
- Drawbacks?
  - Further loss of intuitiveness / transparency
  - Increased number of parameter estimates, as each combination will require
    - Spread rate (SR)
    - Probability that contact results in transmission (P)

Hybrid Approach

- Identify pathways that can be parameterised
  - Easily and intuitively
  - With some reliability in data
    - Model such pathways using the pathway approach
- Model the balance of spread using a ‘catchall’ spread rate parameter
  - Room for some disaggregation based on herd type combinations, etc

Hybrid Approach

- Example?
  - Discrete pathways
    - Saleyard spread
    - Spread by way of the movement of animals within integrated production systems
    - Windborne spread
  - Balance of spread modelled with a catchall spread rate parameter

Hybrid Approach

- Advantages?
  - Pathways are modelled where parameters can be estimated
    - Transparent and intuitive
    - Easily updated
  - Spread rate retained for pathways that cannot easily be parameterised
    - Minimise the number of ‘rubbery’ estimates
    - Allow ‘real’ outbreak data to be used if available

Hybrid Approach

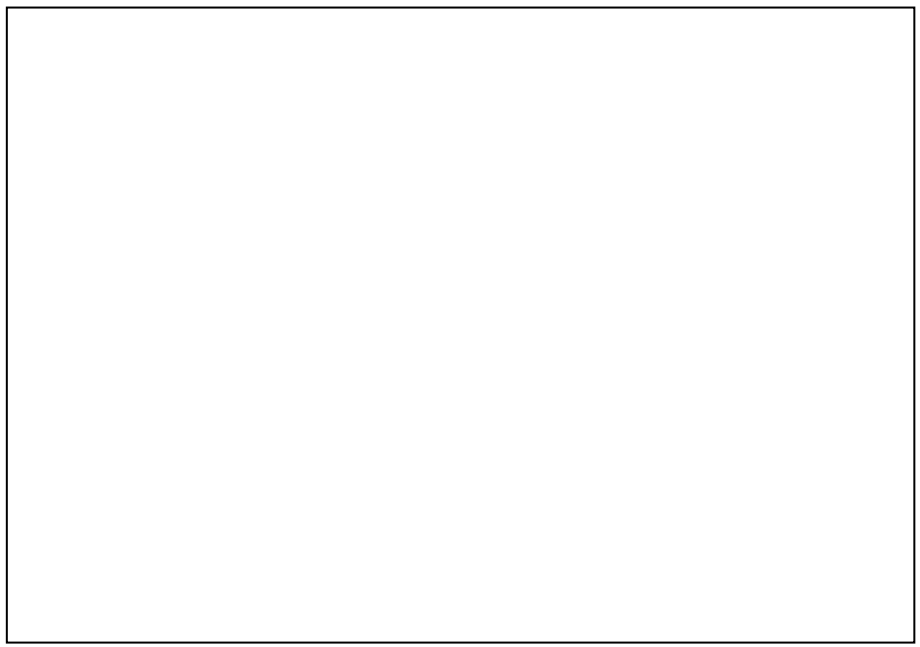
- Constraints?
  - Requires an adaptive modelling framework
  - Model discussion has some additional complexity
- Solutions?
  - Develop in an environment that allows for rapid prototyping and redevelopment

The Study

- AusSpread 1.0 customised to give three variants
  - Pathway model
  - Spread Rate Model
  - Hybrid Model
- Assessment
  - Ease of parameterisation, to be evaluated by a panel of within-government epidemiologists
  - Variance in model outputs, to be evaluated statistically

The Study

- Progress … ?
  - Watch this …



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