THE UNIVERSITY OF MELBOURNE

Modelling Workflows For Rapid Outbreak Appraisal, Decision- And Policy-support in Australia

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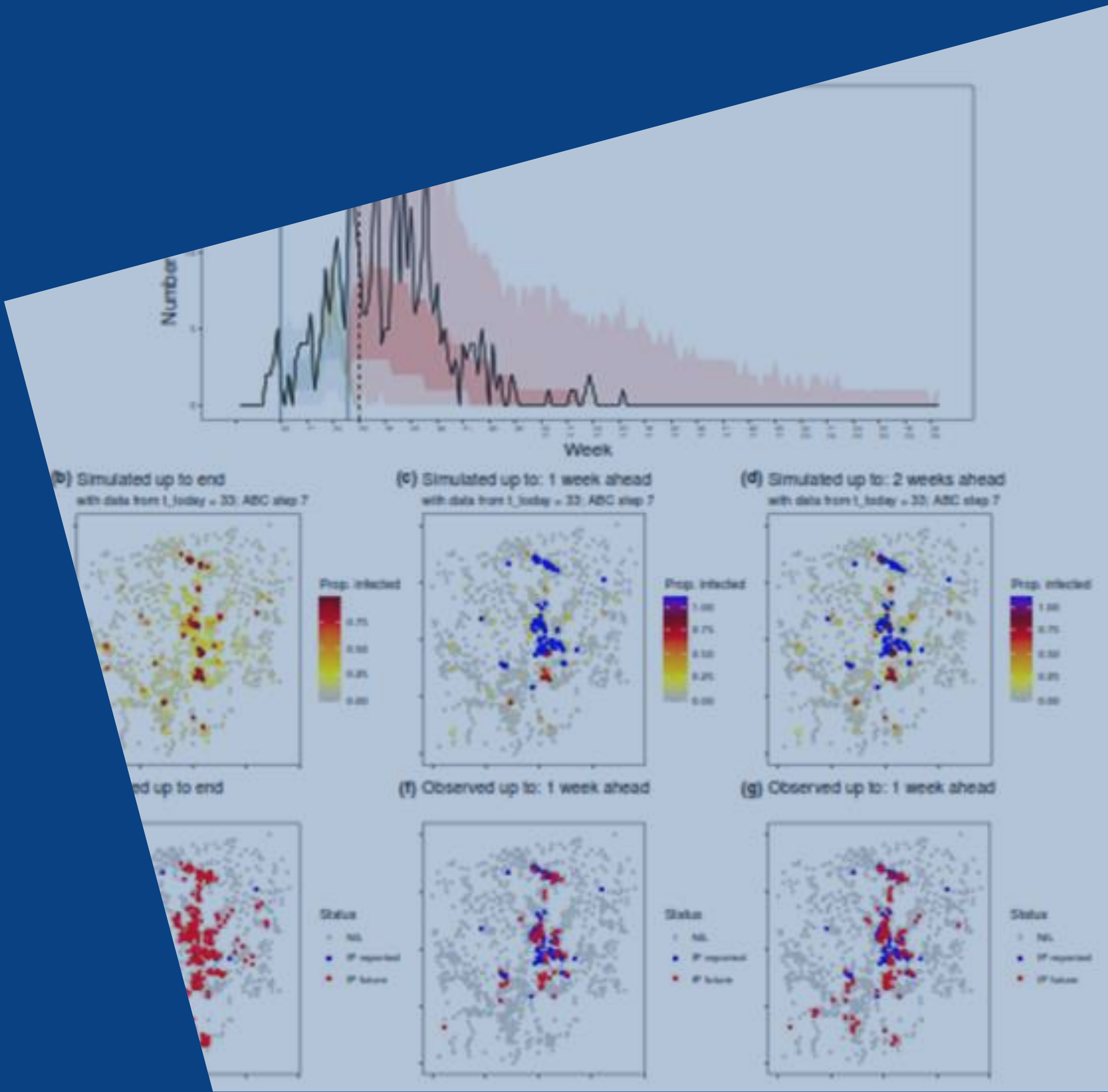
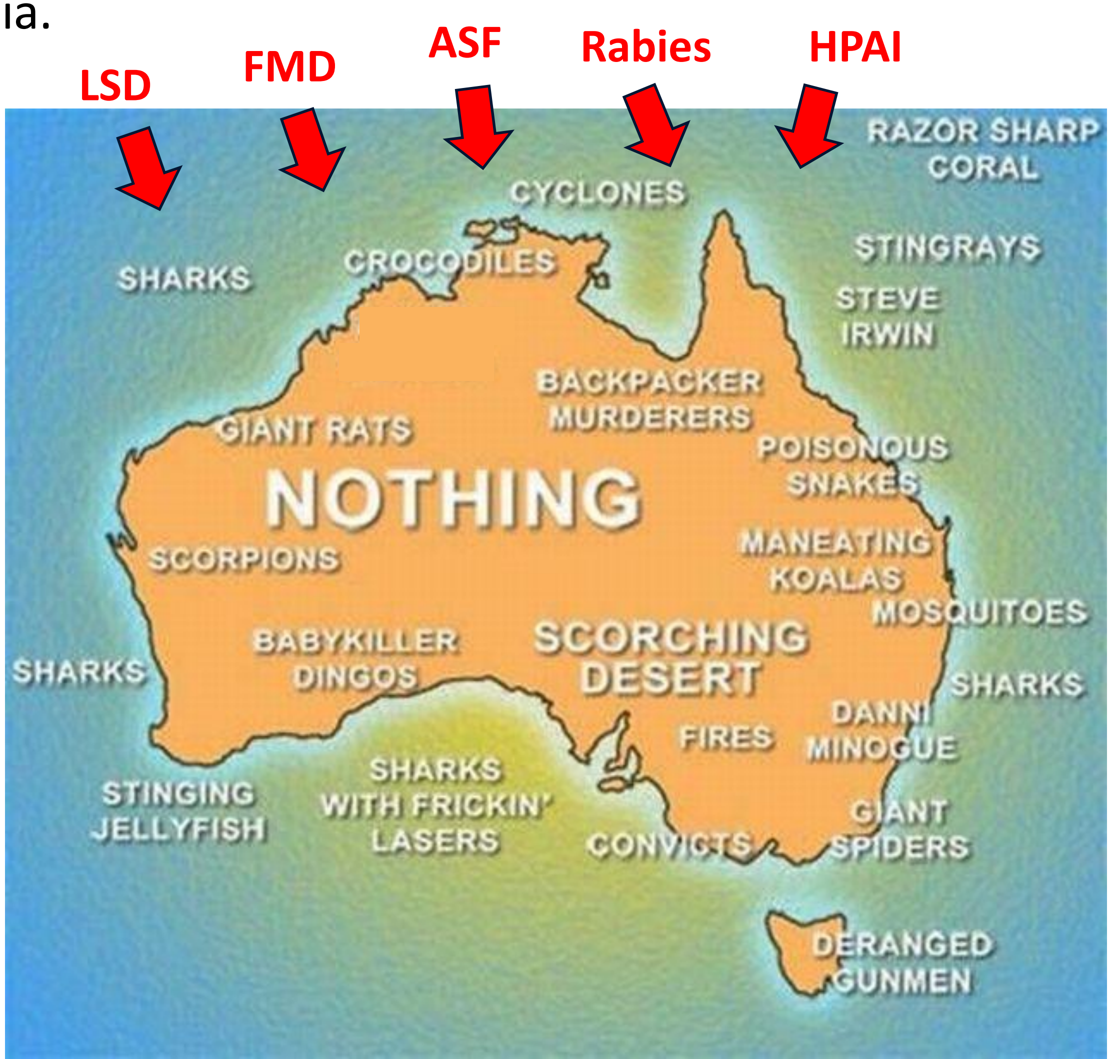


Current transboundary animal disease threats to Australian livestock

PROJECT AIM: To develop decision-support tools including epidemiological models for use during animal disease outbreaks in Australia.



Rapid outbreak appraisal/modelling project activities

- National workshop and subsequent gap analysis of modelling needs
- A systematic review of modelling undertaken in response to the first occurrence of LSD in a country
- Consultative development of a **workplan for addressing critical animal disease modelling gaps**
- **The development of modelling and decision-support tools for addressing the identified gaps**
- Demonstration of use cases of decision-support tools to government partners and handover/integration, and
- Continued activity to address modelling gaps (ongoing consortium development, consultations and exercising)

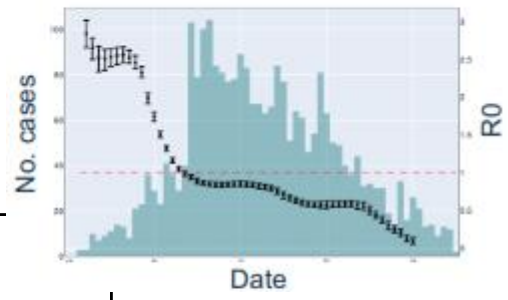
Rapid outbreak appraisal workplan and tool development

Quick visualisations of outbreak data, and rapid estimation of key epidemiological metrics.

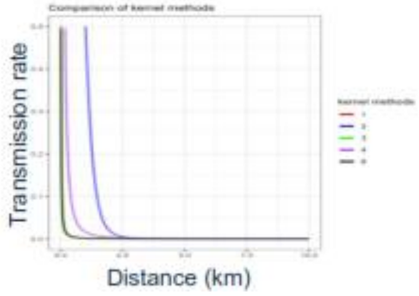
Modules proposed (**bolded prioritised** by Federal government):

Core tools (enhancements)	• **Situational awareness** Temporal/spatial descriptive epi Tracing, population@risk, risk assessment
Extending the core	• **Spatiotemporal epi** Measures of spread: R_0/R_{eff}, kernel fitting/projection Measures of efficiency: key time periods
Specialised tools/approaches	• **Dynamic transmission model/projections** • Ecological niche modelling • Phylogenetic modelling (with CSIRO's ACDP) • Windborne dispersal (with CSIRO's ACDP)
Interoperability	• **Dashboard development**

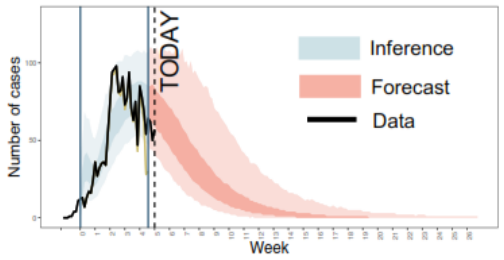
Daily epidemic curve and R0



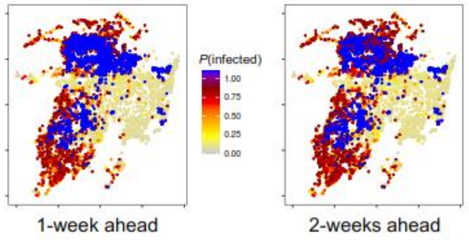
Spatial kernel estimation



Daily case counts

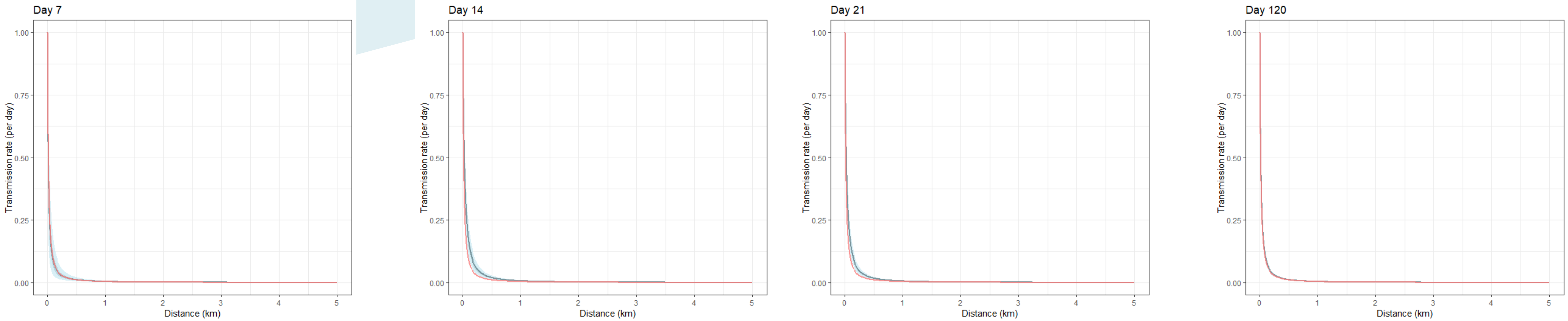


Spatial risk maps

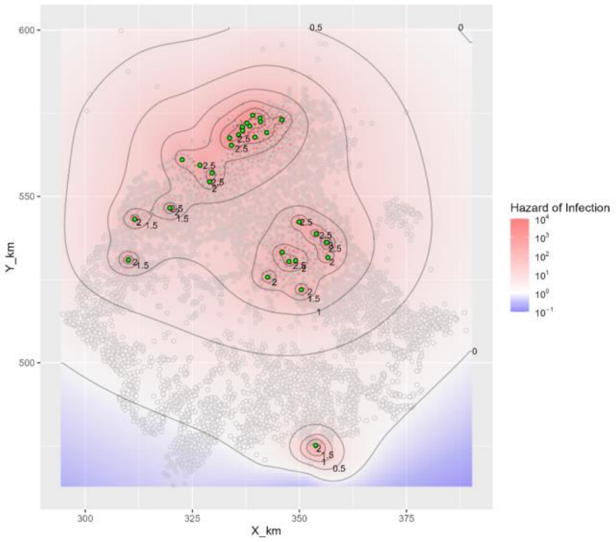


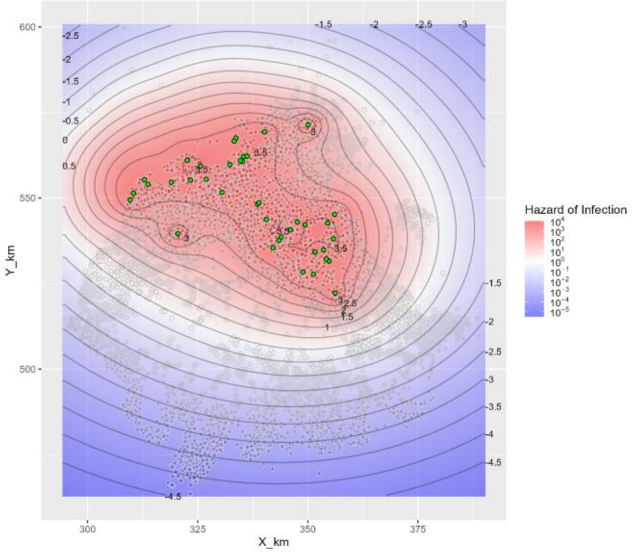
Spatiotemporal module outputs FMD 2001 & EI 2007: spatial kernels very stable

Cumbria, kernels estimated with data available at early timepoints versus whole outbreak



Spatial risk projections 1- and 2-weeks ahead
7 days post outbreak detection in the cluster.





Temporal and spatial projections based on data available at different time slices

Base model built on equine influenza outbreak data from Australian outbreak in 2007 (AUS EI 2007)

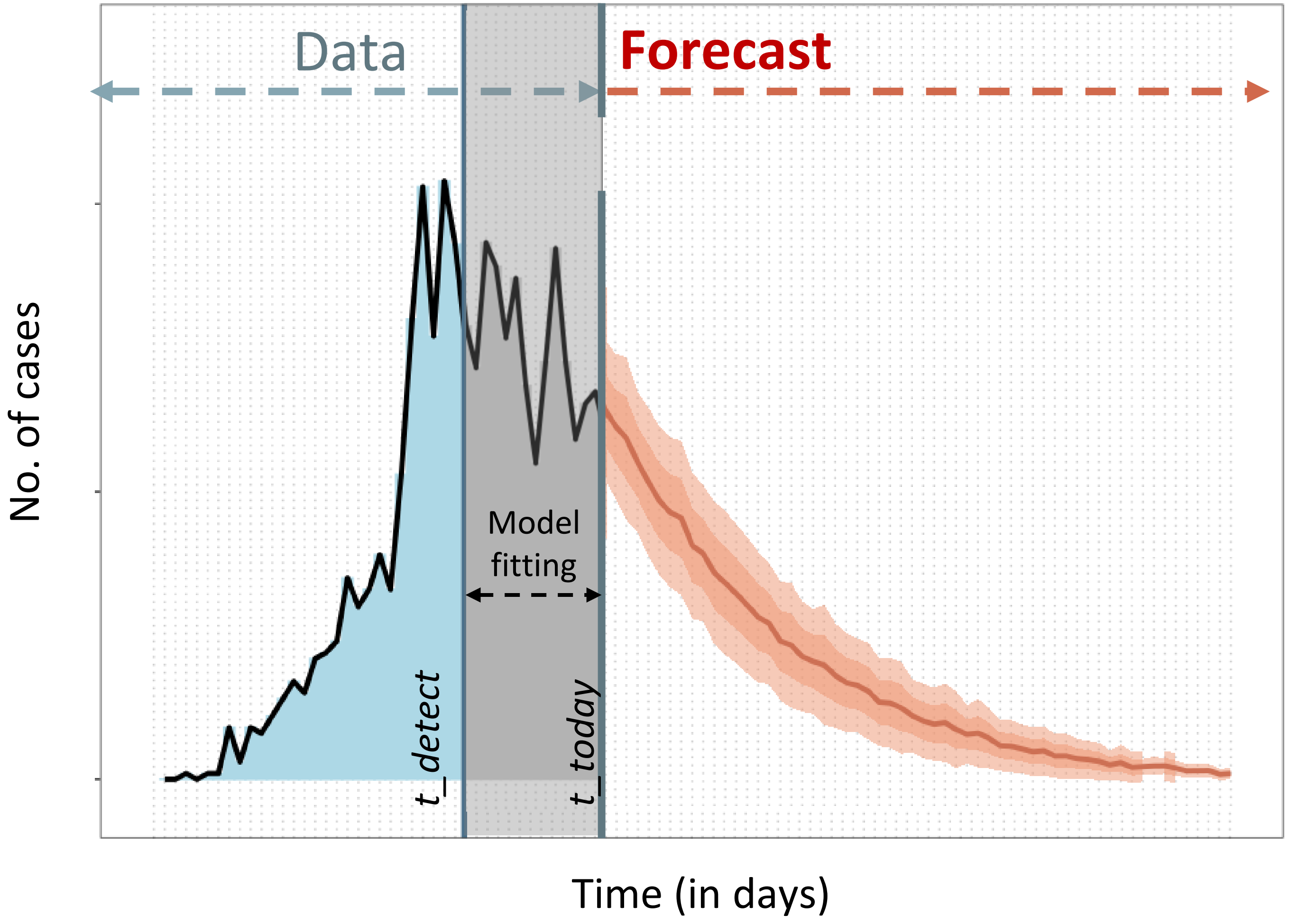
Model adapted to FMD 2001 UK

Other datasets in preparation for modelling:

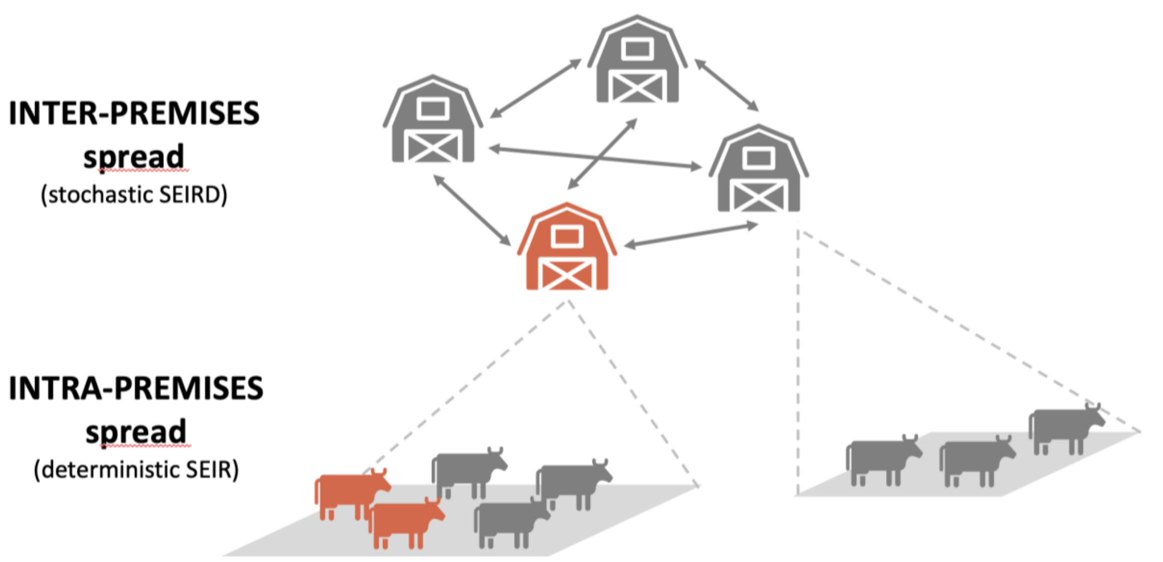
- Simulated LSD and ASF in Australia

What are predictions like at:

3 weeks, 5 weeks, 7 weeks after detection?



Model formulation



INTRA-PREMISES
(deterministic)

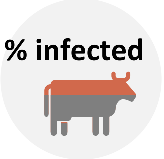
S $$\frac{ds}{dt} = -\left(\frac{\beta_{intra} \times s \times i}{n}\right)$$

E $$\frac{de}{dt} = +\left(\frac{\beta_{intra} \times s \times i}{n}\right) - (\sigma_{intra} \times e)$$

I $$\frac{di}{dt} = +(\sigma_{intra} \times e) - (\gamma_{intra} \times i)$$

R $$\frac{dr}{dt} = +(\gamma_{intra} \times i)$$

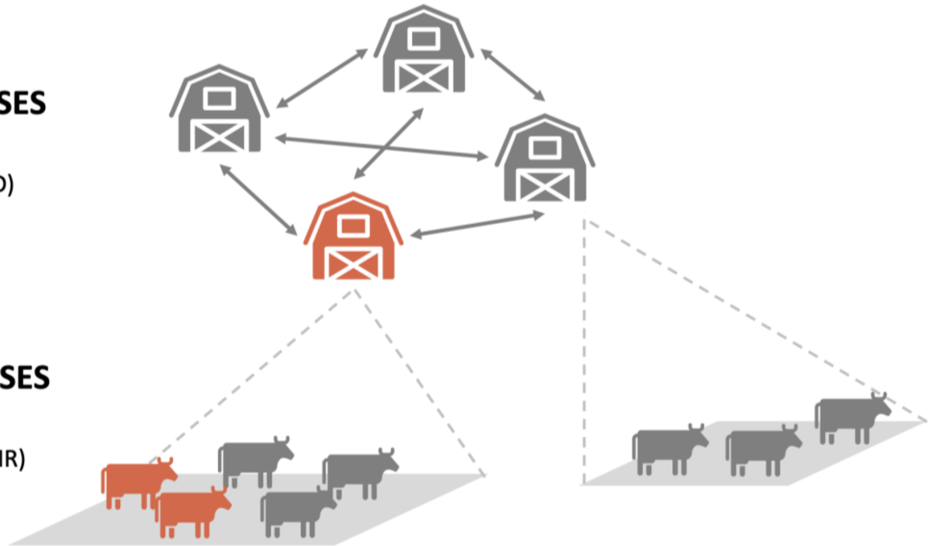
- Prevalence of infective individuals,
  $$\boldsymbol{h(t)_{[i]}} = e_{[i]}/n_{[i]}$$



- Time of recovery, $t_{i[j]}$

Model formulation

INTER-PREMISES spread
(stochastic SEIRD)



INTRA-PREMISES spread
(deterministic SEIR)

vaccine effectiveness

$$\hat{\theta}_{[j]} \begin{cases} t \le t_{v[j]}, & \hat{\theta}_{[j]} = 0 \\ t_{v[j]} < t < \left(t_{v[j]} + 14\right), & \hat{\theta}_{[j]} = \theta \left(\frac{t - t_{v[j]}}{14}\right) \\ t \ge \left(t_{v[j]} + 14\right), & \hat{\theta}_{[j]} = \theta \end{cases}$$

INTER-PREMISES (EI)

(stochastic)

Total infection pressure,

$$\tau_t = \alpha + \sum_{i \in I_t, j \in S_t} \beta_{[i,j]}$$

Pairwise infection pressure $\beta_{[i,j]}$,

$$\beta_{[i,j]} = \beta_0 \times q\_inf_{[i]} \times s\_susc_{[j]} \times K\_xy_{[i,j]}$$

distance kernel

$$q\_inf_{[i]} = \boldsymbol{h(t)}_{[i]} \times \left(n_{animals[i]}/area_{[i]}\right)^{\zeta}$$

infective prevalence

$$s\_susc_{[j]} = \left(1 - \hat{\theta}_{[j]}\right)\left(n_{animals[j]}/area_{[j]}\right)^{\xi}$$

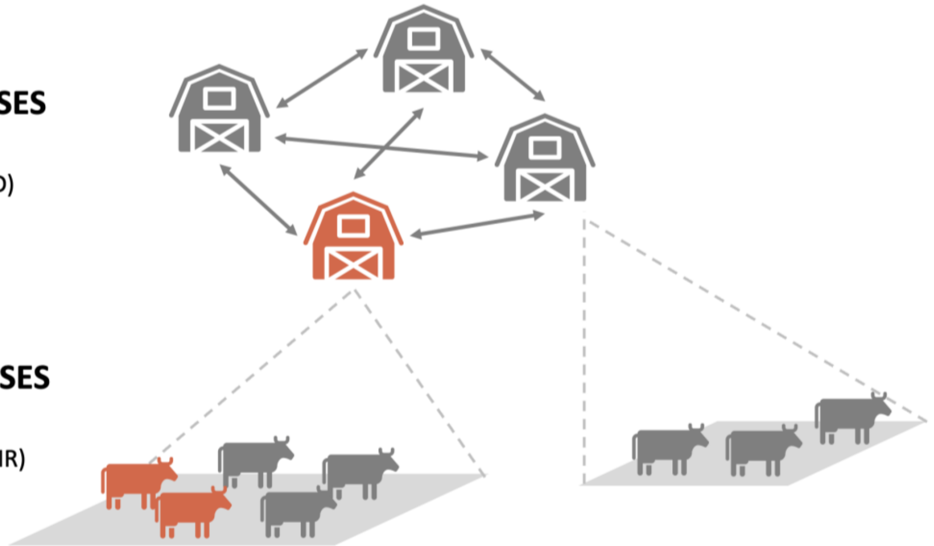
vaccine effectiveness

$$K\_xy_{[i,j]} = \frac{\psi}{\rho_{[i,j]}{}^2 + \psi^2}$$

Cauchy kernel

Firestone, S. M. (2012). Epidemiological investigations into the 2007 outbreak of equine influenza in Australia. Ph.D. thesis.

Model formulation



INTER-PREMISES (FMD)

(stochastic)

Total infection pressure,

$$\tau_t = \alpha + \sum_{i \in I_t, j \in S_t} \beta_{[i,j]}$$

Pairwise infection pressure $\beta_{[i,j]}$,

$$\beta_{[i,j]} = \beta_0 \times q\_inf_{[i]} \times s\_susc_{[j]} \times K\_xy_{[i,j]}$$

distance kernel

$$q\_inf_{[i]} = \boldsymbol{h(t)}_{[i]} \times q\_inf_{[i]} = h(t)_{[i]} \times \left(n_{sheep[i]}{}^{\chi} + \zeta_1 \cdot n_{cattle[i]}{}^{\chi} + \zeta_2 \cdot n_{pigs[i]}{}^{\chi} + \zeta_3 \cdot n_{others[i]}{}^{\chi}\right)$$

infective prevalence

$$s\_susc_{[j]} = \left(1 - \hat{\theta}_{[j]}\right) \times \left(n_{sheep[j]}{}^{\chi} + \xi_1 \cdot n_{cattle[j]}{}^{\chi} + \xi_2 \cdot n_{pigs[j]}{}^{\chi} + \xi_3 \cdot n_{others[j]}{}^{\chi}\right)$$

$$K\_xy_{[i,j]} = \left(1 + \frac{\rho_{[i,j]}}{\rho_0}\right)^{-\psi}$$

Power law, type 2

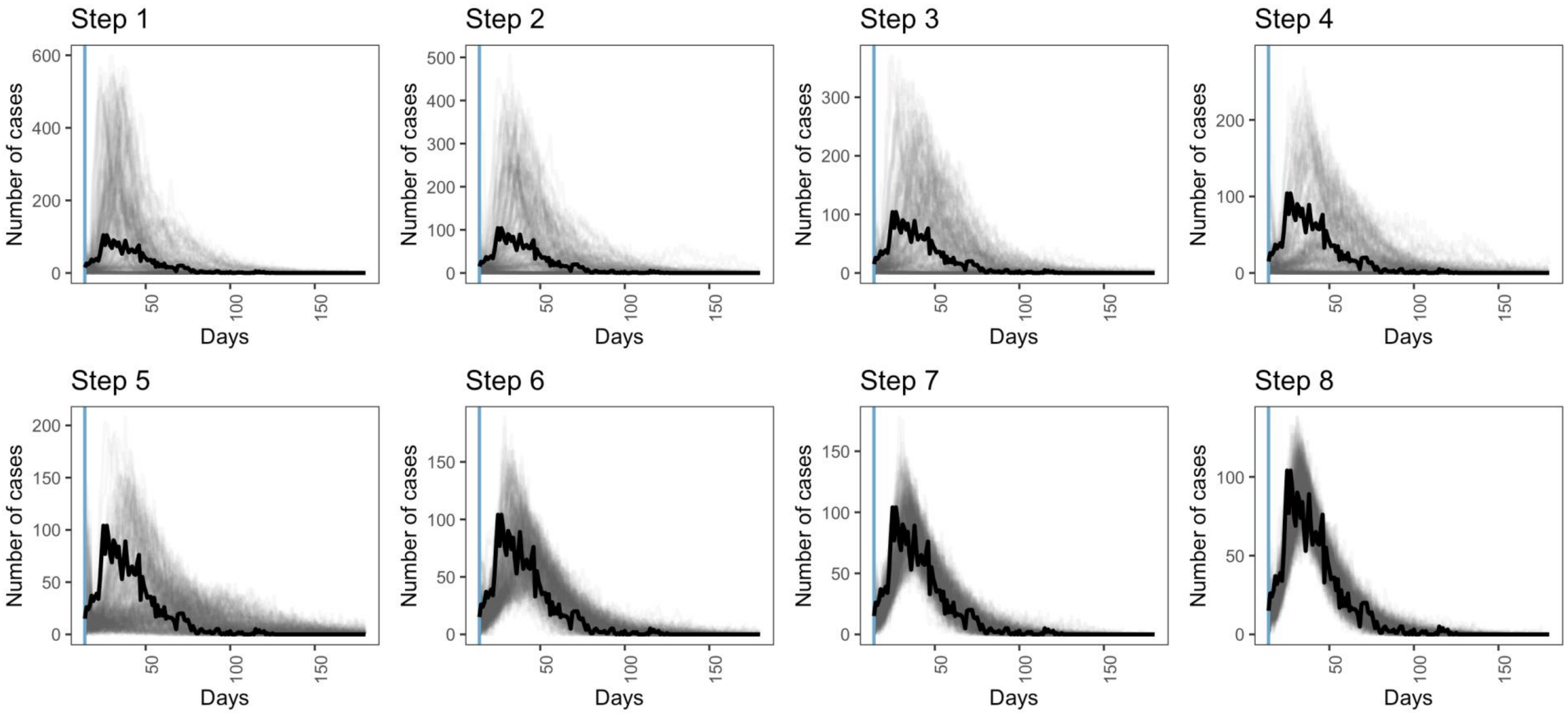
Jewell, C. P., et al. (2009). "Bayesian Analysis for Emerging Infectious Diseases." Bayesian Analysis 4(3): 465.

FMD 2001 Cumbria: ABC-SMC fitting step plot

Temporal tolerance criterion: i.e. ±10 cases per day

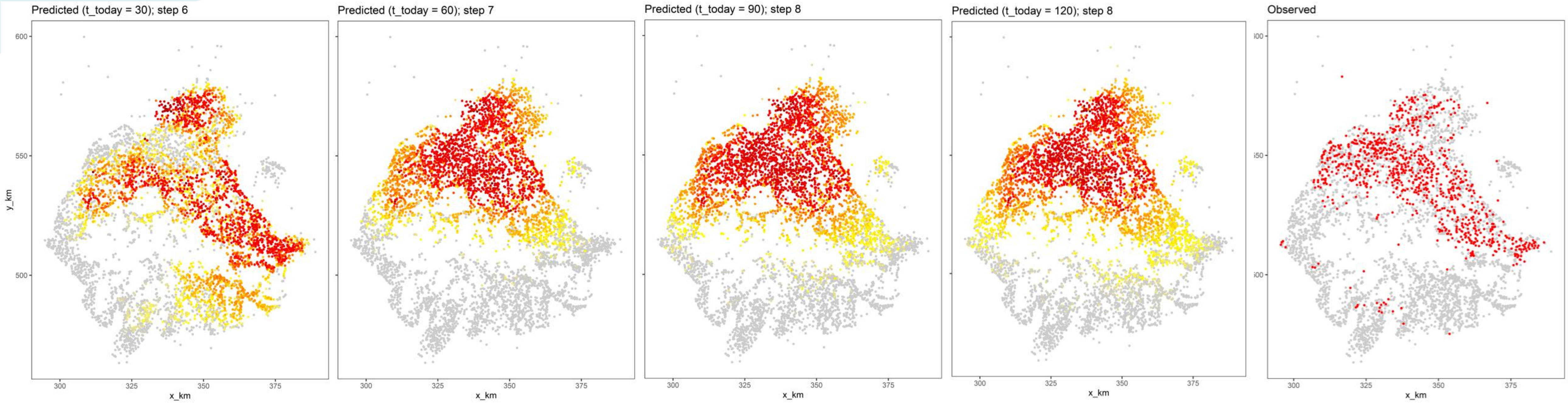
Spatial tolerance criterion: Spearman's ρ > 0.6 (observed to predicted) on small grid

Tolerance progressively narrowed to 75th percentile of the distance from the observed data of the retained particles from the previous step



FMD 2001 Cumbria: spatial forecasts

Day 30 | Day 60 | Day 90 | Day 120 | Observed



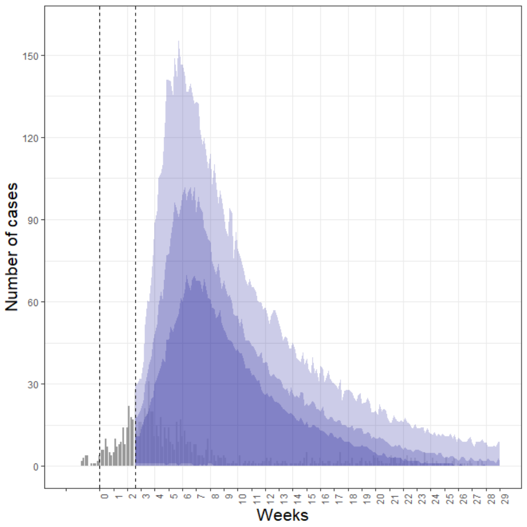
status
- IP
- NIL

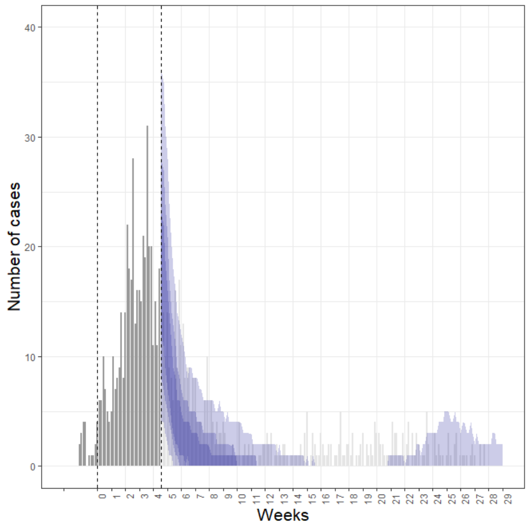
Quantiles of number of posterior samples premises infected
- 99%
- 80%
- 60%
- 40%
- 20%

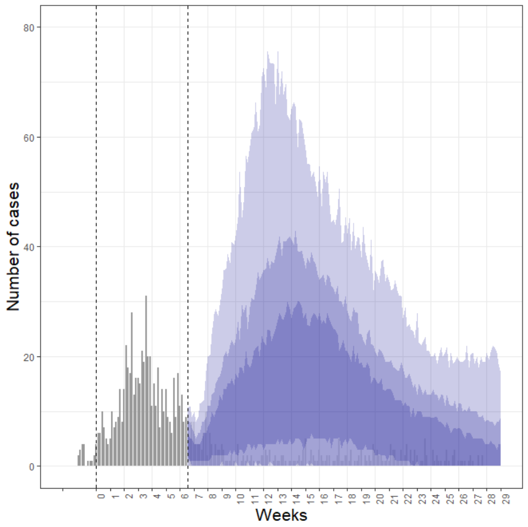
FMD 2001 temporal forecasts

Day 21 | **Day 35** | **Day 63**

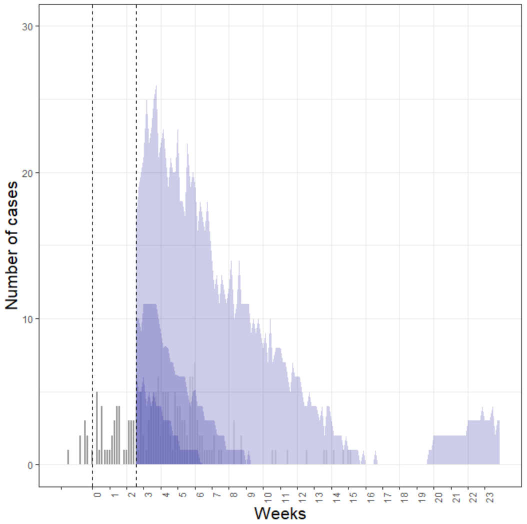
Cumbria

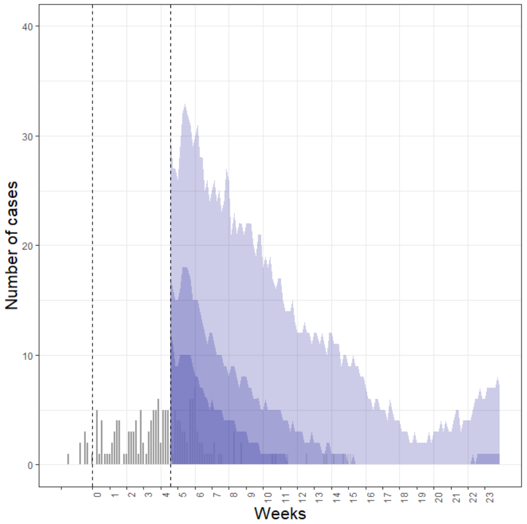


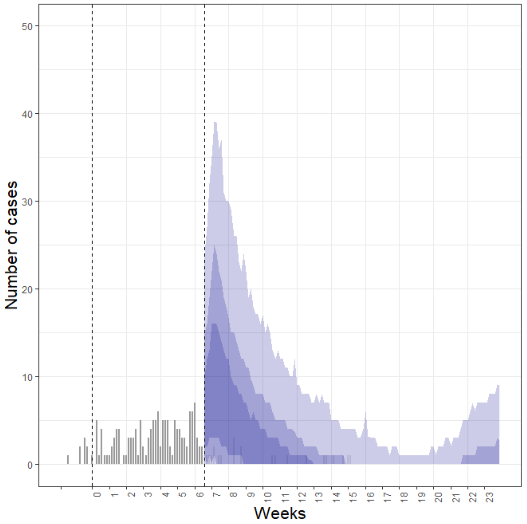




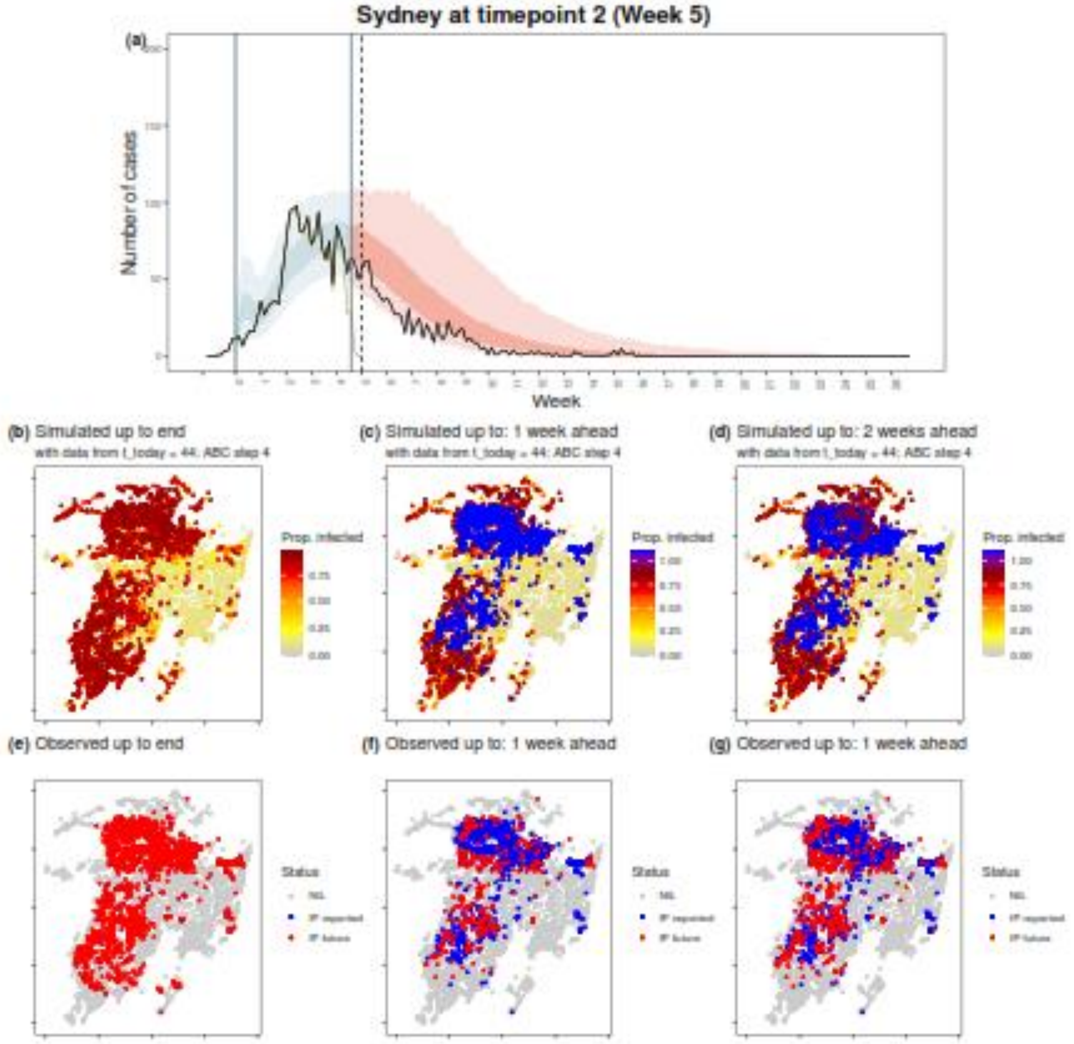
Devon

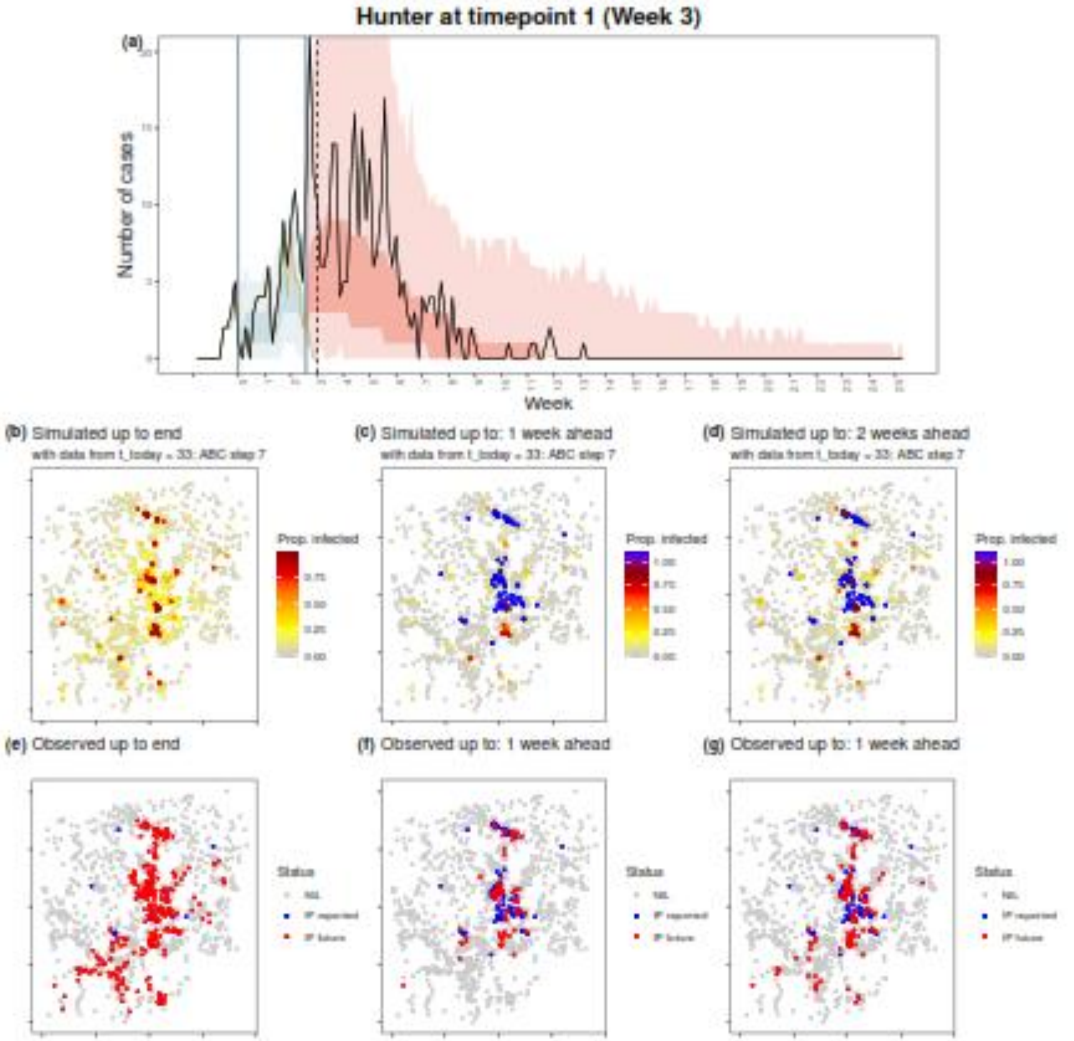




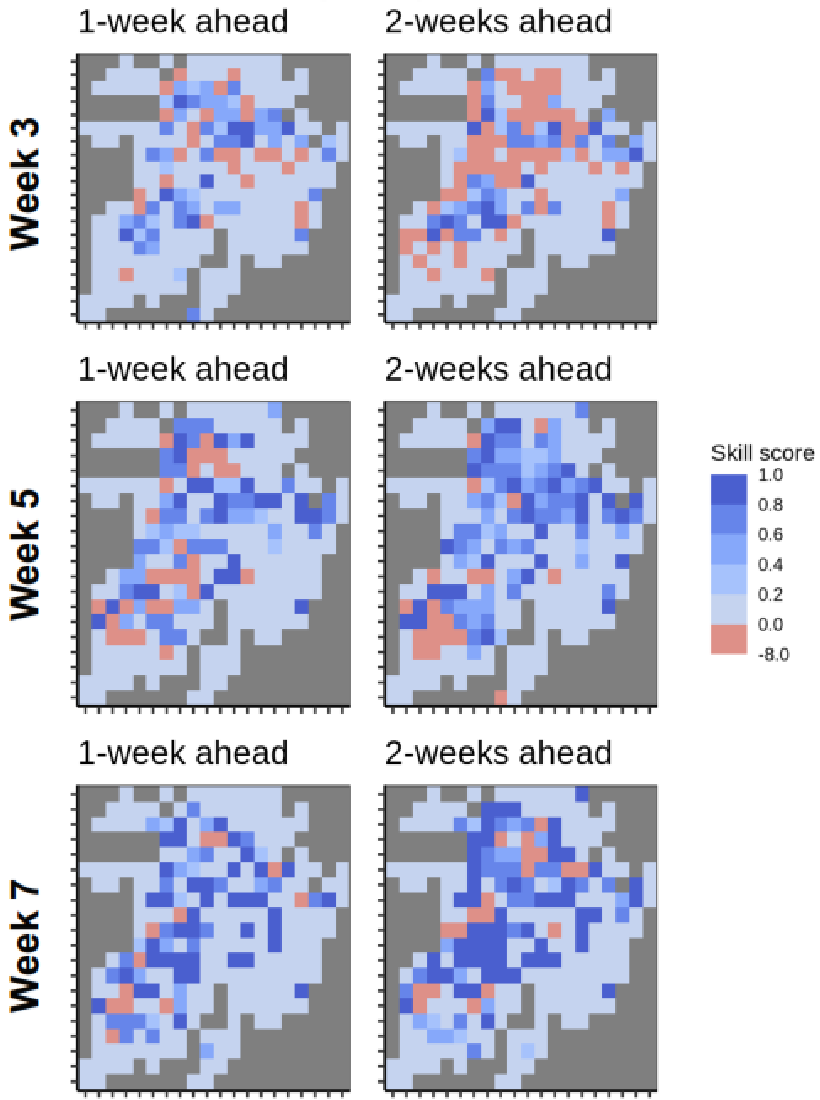


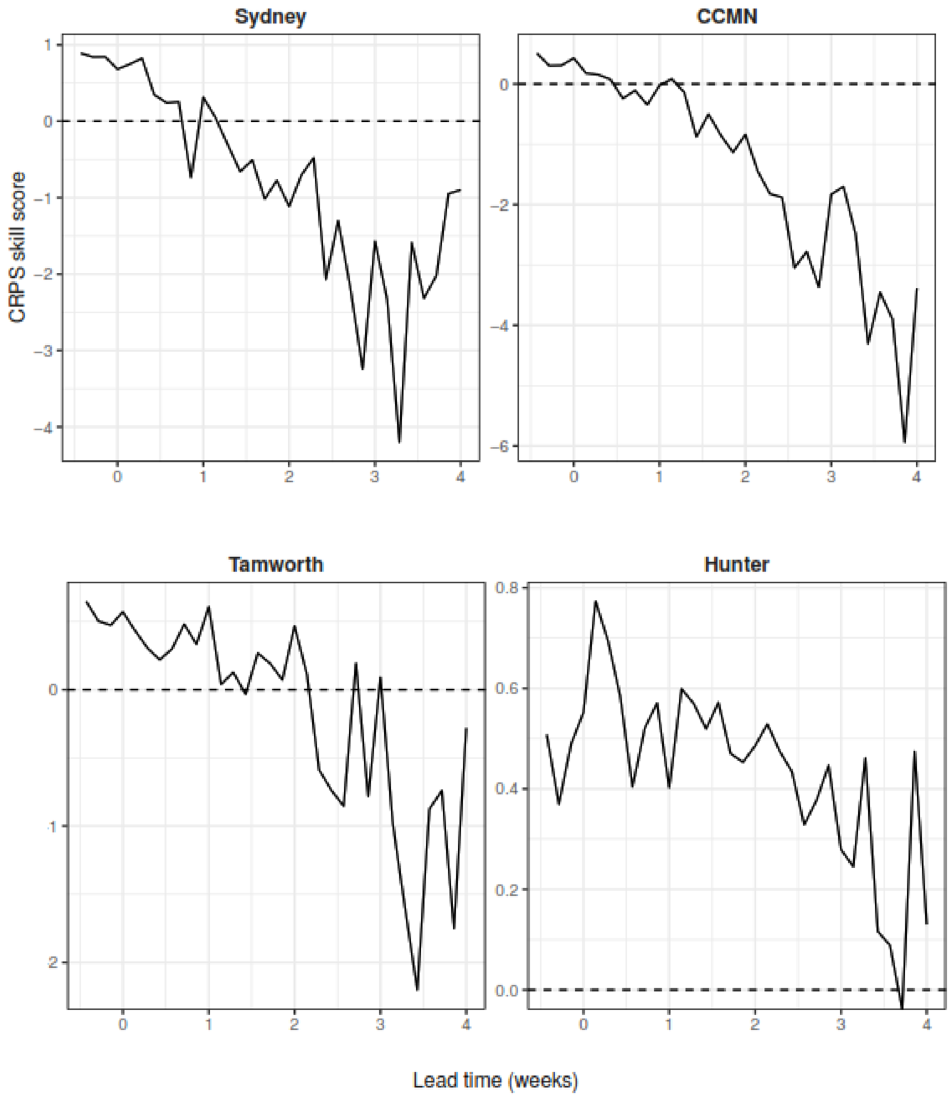
EI Australia 2007: spatial & temporal forecasts



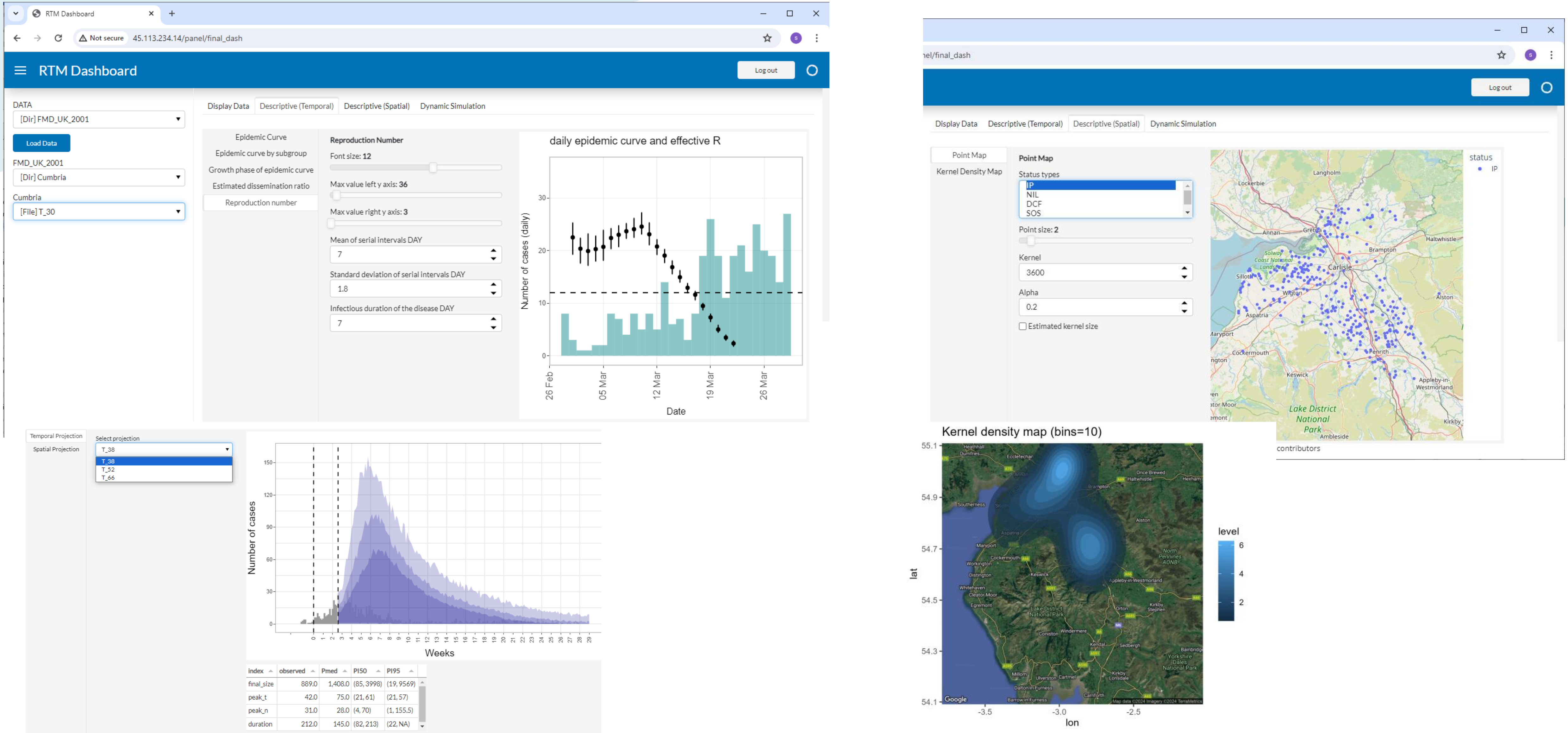


Spatial and temporal skill scoring

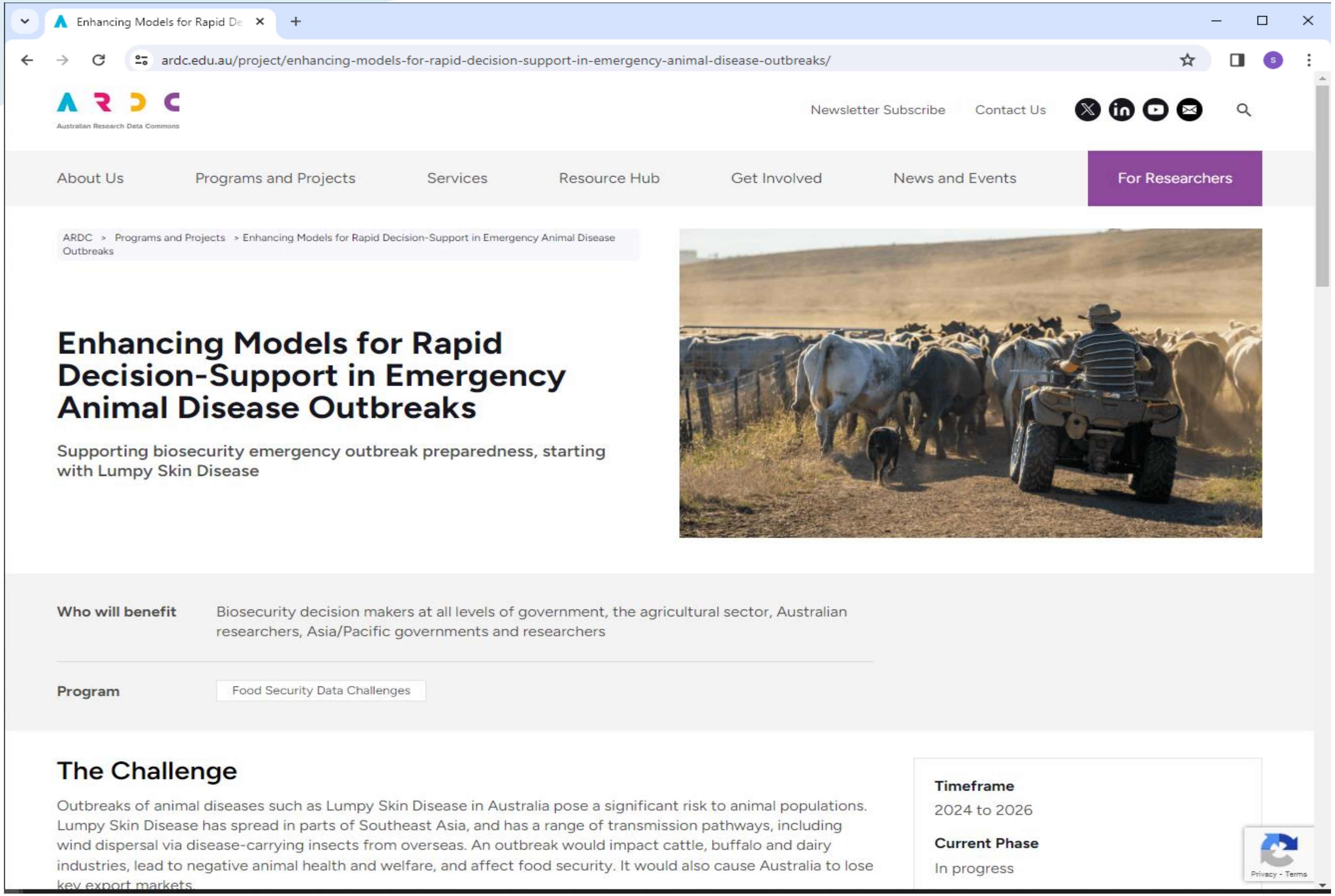




RTM dashboard prototype



Next steps


Enhancing Models for Rapid De
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ARDC > Programs and Projects > Enhancing Models for Rapid Decision-Support in Emergency Animal Disease Outbreaks
Enhancing Models for Rapid Decision-Support in Emergency Animal Disease Outbreaks
Supporting biosecurity emergency outbreak preparedness, starting with Lumpy Skin Disease
Who will benefit
Biosecurity decision makers at all levels of government, the agricultural sector, Australian researchers, Asia/Pacific governments and researchers
Program
Food Security Data Challenges
The Challenge
Outbreaks of animal diseases such as Lumpy Skin Disease in Australia pose a significant risk to animal populations. Lumpy Skin Disease has spread in parts of Southeast Asia, and has a range of transmission pathways, including wind dispersal via disease-carrying insects from overseas. An outbreak would impact cattle, buffalo and dairy industries, lead to negative animal health and welfare, and affect food security. It would also cause Australia to lose key export markets.
Timeframe
2024 to 2026
Current Phase
In progress
Privacy - Terms

Thanks, Funding and Questions?

- DAFF (Biosecurity2030 Project C09530)
- Australian Research Council's Discovery Projects funding scheme (project DP210103239).
- Australian Research Data Commons and project partners: CEBRA, DAFF/CSIRO Catalysing Australia's Biosecurity/Biosecurity Commons
- Agriculture Victoria / Livestock Biosecurity Grants Program: VIC Cattle, Sheep & Goats compensation funds
- The University of Melbourne Research Higher Degree Scholarship Program (supporting Simin Lee)