Modelling management strategies for vaccinated animals after an outbreak of FMD and the impact on return-to-trade

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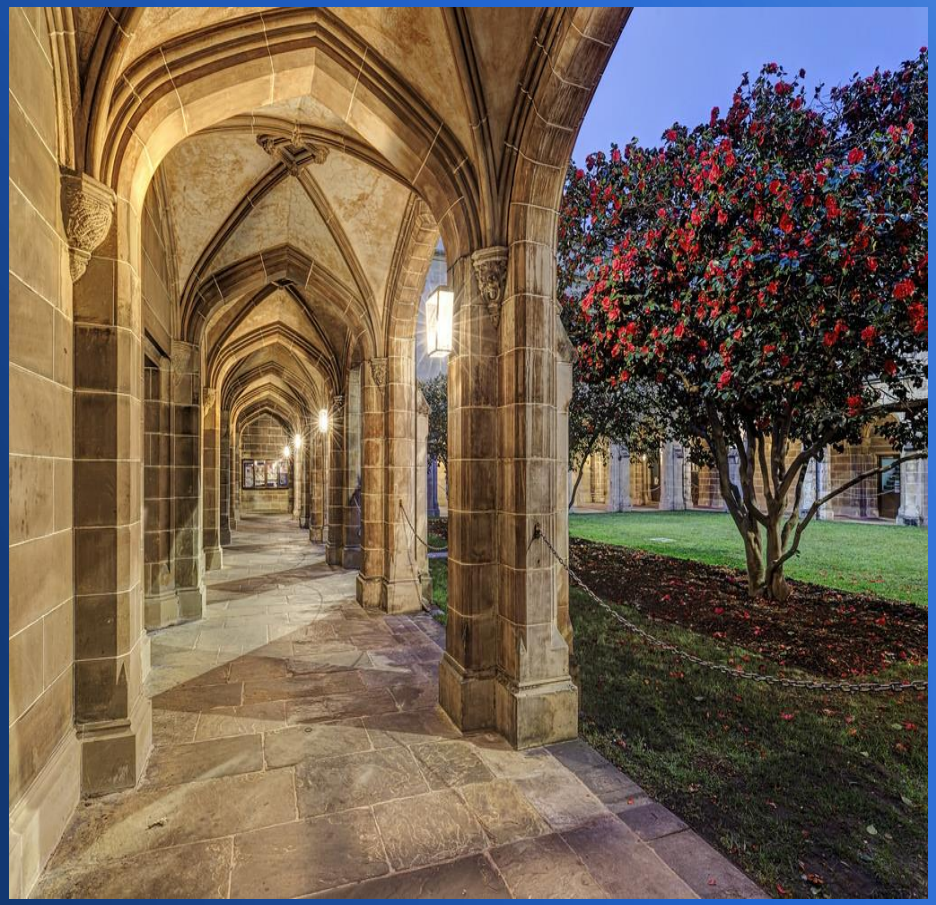
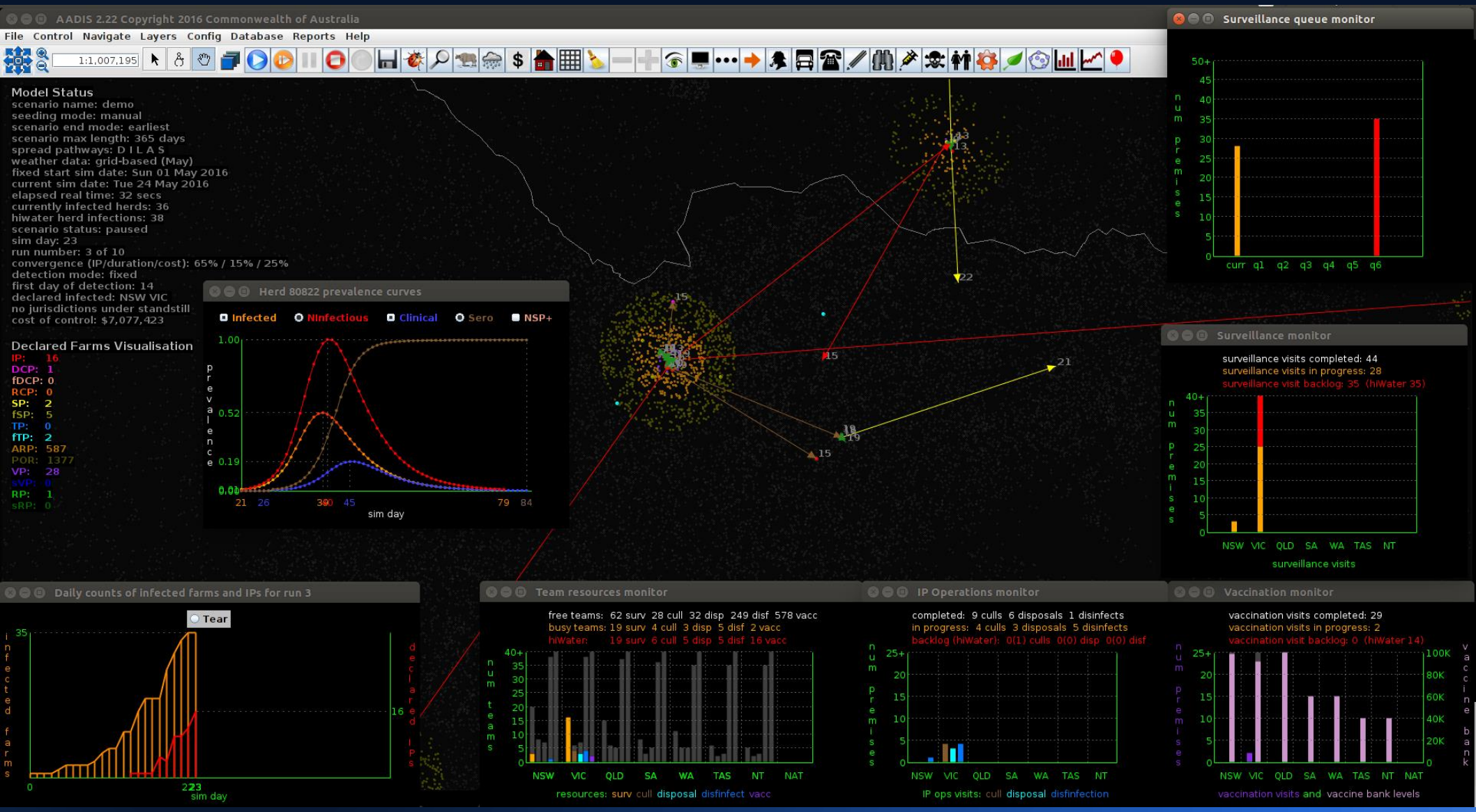


Overview

The AADIS epidemiological model
Post-outbreak surveillance
Post-outbreak management of vaccinated animals
Case study
Acknowledgements
Future work

The AADIS epidemiological model



Bradhurst et al (2015). A hybrid modelling approach to simulating foot-and-mouth disease outbreaks in Australian livestock. Frontiers in Environmental Science, 3(17).

The AADIS epidemiological model

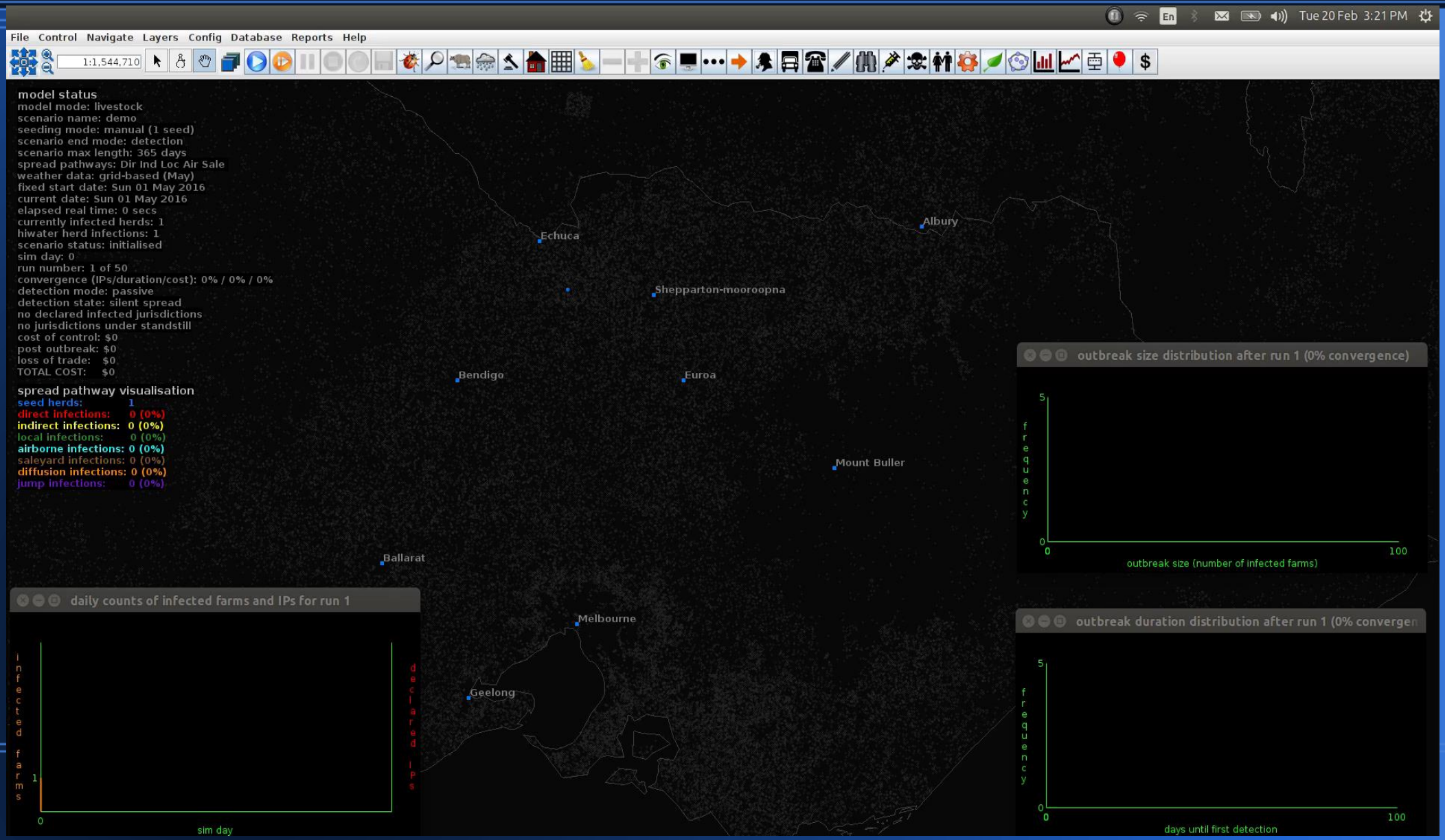
- Australian Animal DISease Model (AADIS).
- Project commenced in 2012 under funding from the Australian Department of Agriculture & Water Resources.
- National-scale model of EAD with FMD as the test case.
- Hybrid model architecture – blends equation-based, agent-based and cellular automata modelling approaches.
- Flexible agent based modelling framework with polymorphic agents and plug-in spread pathways - now extended to vector-borne disease, plant pests and human disease.
- Disaggregated spatially-explicit simulation – lot's of model dials for the user to experiment with.

The AADIS epidemiological model

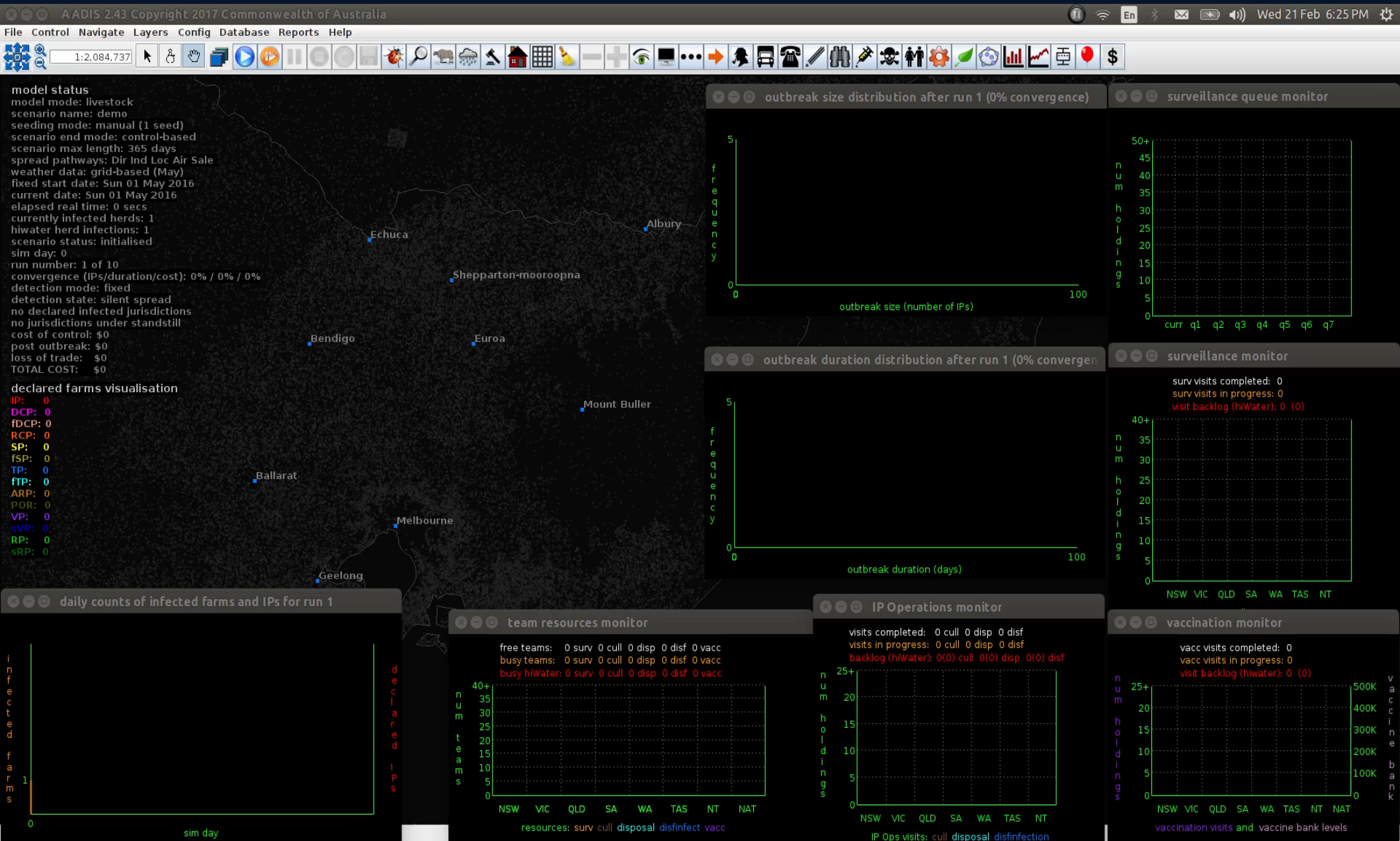
Examples of questions that AADIS can help address:

- how soon might we detect disease?
- what are the benefits of early detection?
- what are the consequences of late detection?
- will increasing surveillance at assembly centres help?
- will our control and eradication strategies work?
- what are the advantages of larger control zones?
- what are the consequences of illegal movements?
- do we have sufficient teams to control disease?
- will we run out of vaccine?
- should we only vaccinate cattle?
- what is the potential economic impact of an outbreak?

Video: FMD silent spread



Video: FMD spread and control



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Project 1604D

Australian Government
Department of Agriculture and Water Resources

- Australia would suffer economic damages up of to $52B AUD from a large FMD outbreak. Over 90% of this would arise from loss of FMD-sensitive markets.
- Key elements of regaining FMD-free status and recovering markets: (i) post-outbreak surveillance to support proof-of-freedom, and (ii) post-outbreak management of vaccinated animals (should vaccination be deployed during the control program), and the impact on return to trade.
- Project 1604D called for modifications to AADIS to simulate beyond the end of the control program to allow comparisons of different post-outbreak strategies in terms of effectiveness and cost.

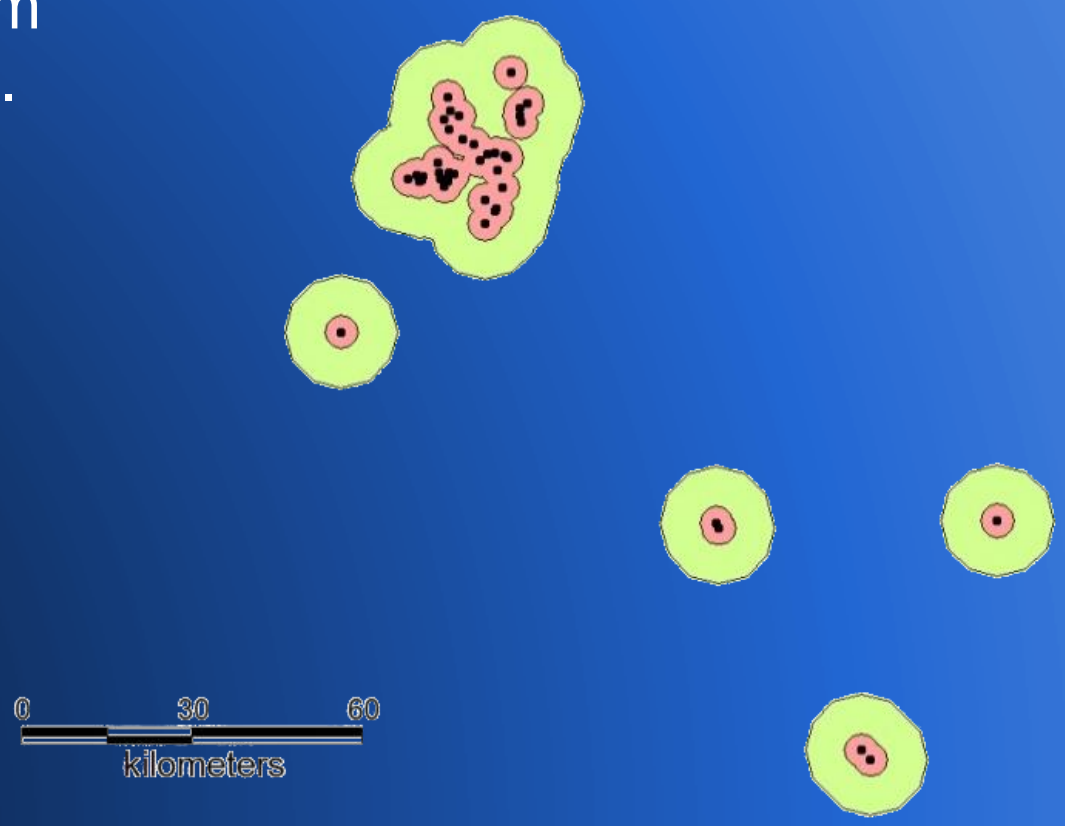
Post-outbreak surveillance – sampling regime

- Surveillance is conducted in terms of 'clusters' of infection (formed from overlapping Surveillance Zones).
- The sampling regime defines:

  (i) the number of herds to test within a cluster, and

  (ii) the number of animals to test within a herd,

  in order to achieve a specified confidence that infection at a specified prevalence would be detected, e.g. 95:5.



Post-outbreak surveillance – sampling regime

- The sampling regime is user configurable with respect to zone, species, clinical inspections and design prevalence, for example:

Protection Zone (PZ):

- cattle: all herds clinical inspection plus 95:5 sampling
- sheep: all flocks clinical inspection plus 95:5 sampling
- pigs: all herds clinical inspection only

Surveillance Zone (SZ):

- cattle: 95:2 herds clinical inspection plus 95:5 sampling
- sheep: 95:2 flocks clinical inspection plus 95:5 sampling
- pigs: all herds clinical inspection only

Post-outbreak surveillance – testing regime

- A testing regime is defined in terms of test pairs [screening, confimatory], appropriate to whether vaccination was used during the control program.
- Testing regimes are user configurable with respect to species, test sensitivity & specificity, and cost, e.g.,

  - cattle no vacc: [C-ELISA Se=0.99 Sp=0.99, 3ABC-ELISA Se=0.93 Sp=0.99]
  - cattle with vacc: [3ABC-ELISA Se=0.8 Sp=0.99, 3ABC, ELISA Se=0.8, Sp=0.99]
  - sheep no vacc: [C-ELISA Se=0.99 Sp=0.99, 3ABC-ELISA Se=0.9 Sp=0.99]
  - sheep with vacc: [3ABC-ELISA Se=0.8 Sp=0.99, 3ABC, ELISA Se=0.8, Sp=0.99]
  - pigs no vacc: [C-ELISA Se=0.99 Sp=0.82, 3ABC-ELISA Se=0.73 Sp=0.99]
  - pigs with vacc: [3ABC-ELISA Se=0.7 Sp=0.99, 3ABC, ELISA Se=0.7, Sp=0.99]

- AADIS reports the number of true/false positives and true/false negatives, and the duration and cost of the surveillance program.

Post-outbreak management of vaccinated animals

- AADIS models three separate strategies for the management of vaccinated animals after an outbreak:
  - 'vaccinate-and-retain'
  - 'vaccinate-and-remove-to-waste'
  - 'vaccinate-and-remove-for-salvage'

- The user configures:
  - waiting periods until FMD-free status can be sought
  - number of surveillance teams
  - sampling and testing regimes
  - surveillance costs and throughput
  - lab costs and throughput
  - removal costs and throughput (destruction, disposal for waste, salvage)
  - compensation rates
  - daily control centre costs
  - daily trade loss figure

Case Study

- Outbreak scenario: FMD (Type O panAsia) is introduced into a small Victorian pig farm (n=247, sows=25) and detected after 14 days, at which point there are 18 infected herds.

- 1000 iterations of each of the vaccination strategies:
  - no vaccination (stamping out only)
  - vaccinate-and-retain
  - vaccinate-and-remove-to-waste
  - vaccination-and-remove-for-salvage

- Control program based on AUSVETPLAN guidelines:

Selected control program settings

Component	Description
Movement restrictions	3-day national livestock standstill Surveillance zone (SZ) initially the whole of state of Victoria reducing to a 10 km radius around each Infected Holding (IH) after 14 days Protection Zone (PZ) 10 km radius around each IH reducing to 3 km after 14 days.
Stamping out	Culling of all susceptible animals on confirmed IHs only
Vaccination	Suppressive ring vaccination (3 km radius around IHs) of cattle (plus sheep on mixed cattle-sheep properties only) Commences on the 14th day of control program Applied in previously identified high risk region, Vaccination around new IHs only (i.e., no retrospective vaccination).
Surveillance and tracing	Investigation of all reported suspect premises Periodic visits to premises in PZ Tracing of direct and indirect movements onto and off IHs
Resources	Three surveillance teams available at the start of the control program ramping up a maximum of 50 teams over a 3-week period. Two culling teams available at the start of the control program ramping up to a maximum of 25 teams over a 4-week period. Five disposal teams available at the start of the control program ramping up to a maximum of 40 teams over a 30-day period. Vaccination is carried out by lay vaccinators and is not constrained

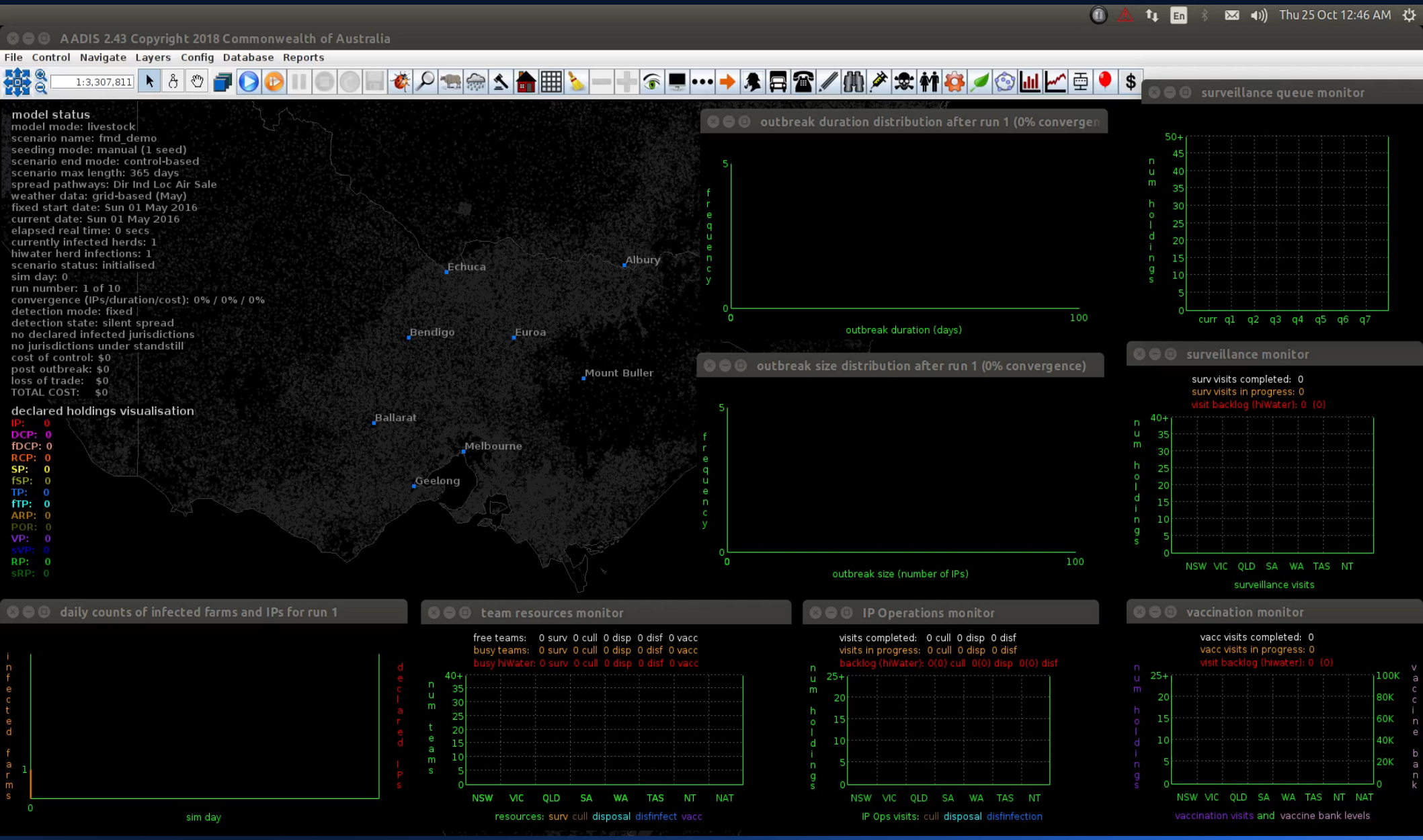
Selected post-outbreak management settings

Component	Description
Surveillance sampling regime	PZ & VZ cattle: all herds clinical inspection plus 95:5 sampling PZ & VZ sheep: all flocks clinical inspection plus 95:5 sampling PZ, VZ & SZ pigs: all herds clinical inspection only SZ cattle: 95:2 herds clinical inspection plus 95:5 sampling SZ sheep: 95:2 flocks clinical inspection plus 95:5 sampling
Testing regime	cattle (no vacc) [C-ELISA Se=0.99 Sp=0.99, 3ABC-ELISA Se=0.93 Sp=0.99] cattle (with vacc) [3ABC-ELISA Se=0.8 Sp=0.99, 3ABC-ELISA Se=0.8, Sp=0.99]
Removal rates	cattle: 1000 head/day to waste; 800 head/day to salvage sheep: 5000 head/day to waste; 400 head/day to salvage pigs: 2000 head/day to waste; 1600 head/day to salvage
Removal costs ($AUD)	beef cattle: destruction $6; disposal $67.50; compensation $743 (waste) dairy cattle: destruction $6; disposal $67.50; compensation $895 (waste) sheep: destruction $4; disposal $2.25; compensation $69 (waste) pigs: destruction $4; disposal $9; compensation $222.50 (waste)
Waiting periods	vaccinate-and-retain: 6 months from the last cull/vaccination vaccinate-and-remove: 3 months from the removal of the last vaccinated animal
Control centres	Daily cost of local and jurisdictional disaster control centres = $120,000 AUD
Loss of trade	Daily national figure for loss of trade = $32,500,000 AUD

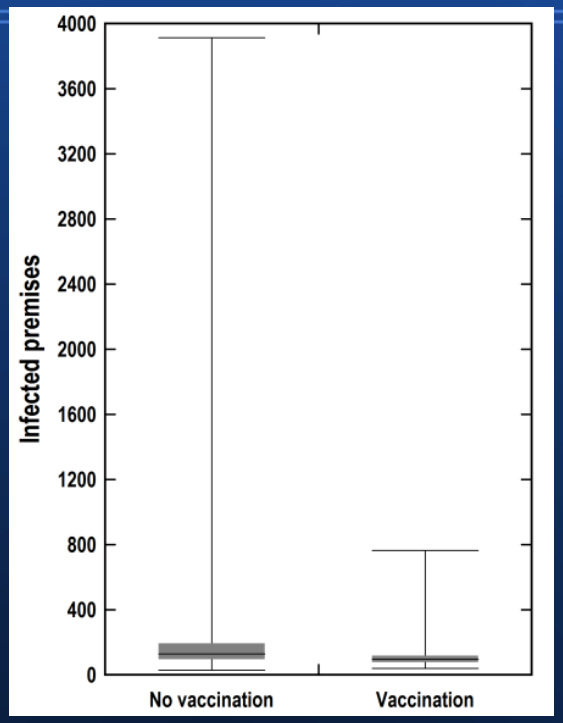
Selected model outputs

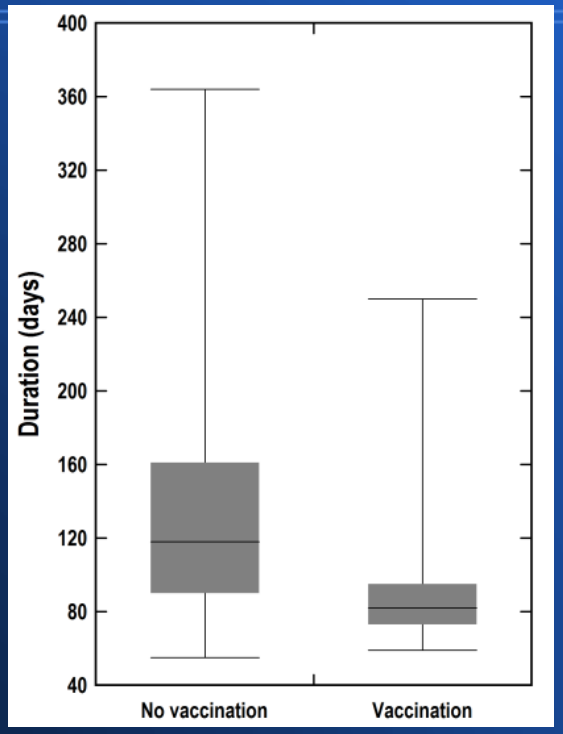
Outbreak characteristics	Post-outbreak surveillance statistics	Cost statistics
• Number of infected holdings • Number of vaccinated holdings • Number of animals culled • Number of animals vaccinated • Number of jurisdictions infected • Control program duration • Post-outbreak surveillance duration • Post-outbreak vaccination management duration • Days out of market	• Number of herds clinically inspected • Number of non-vaccinated herds tested • Number of vaccinated herds tested • Number of non-vaccinated samples collected • Number of vaccinated samples tested • Number of true/false positive herds found • Number of true/false negative herds found	• Control centre costs • Surveillance costs • Cull costs • Disposal costs • Disinfection costs • Compensation payments • Vaccination costs • Total control costs • Post-outbreak surveillance costs • Post-outbreak lab costs • Post-outbreak cull costs • Post-outbreak disposal costs • Total post-outbreak management costs • Trade losses • Total outbreak costs

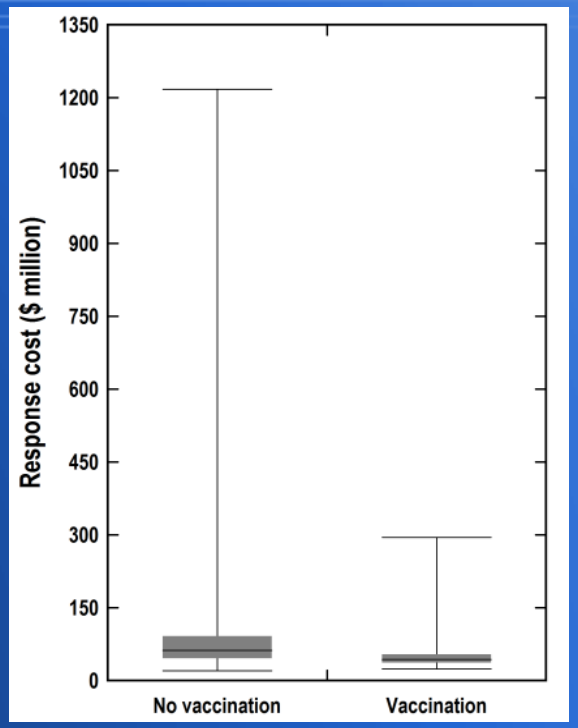
Video: post-outbreak management



Case study results: control without vaccination vs. control with vaccination







The inclusion of suppressive ring vaccination reduced (on average):

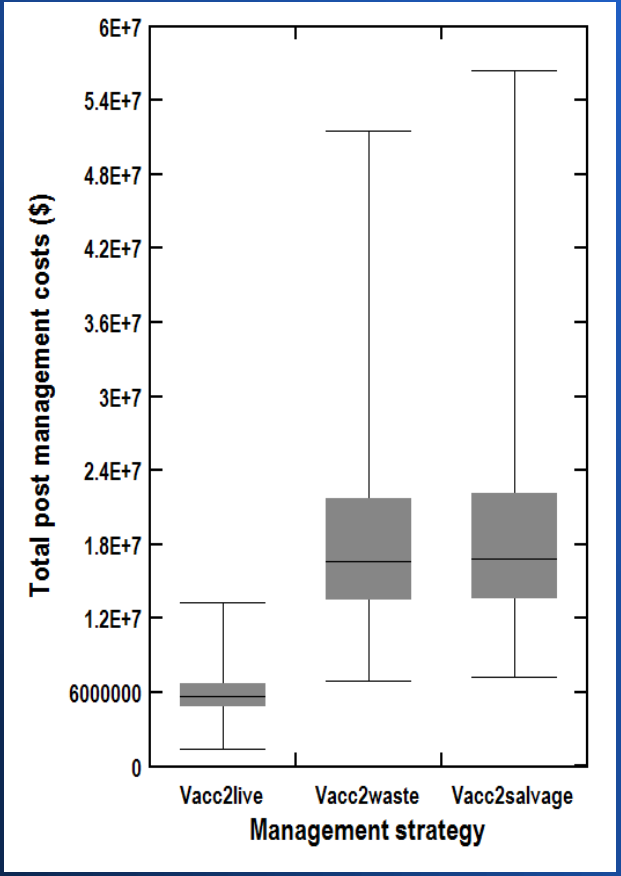
- the number of infected holdings by 43%
- the duration of the control program by 36%
- the cost of the control program by 40%
- the likelihood of a large outbreak

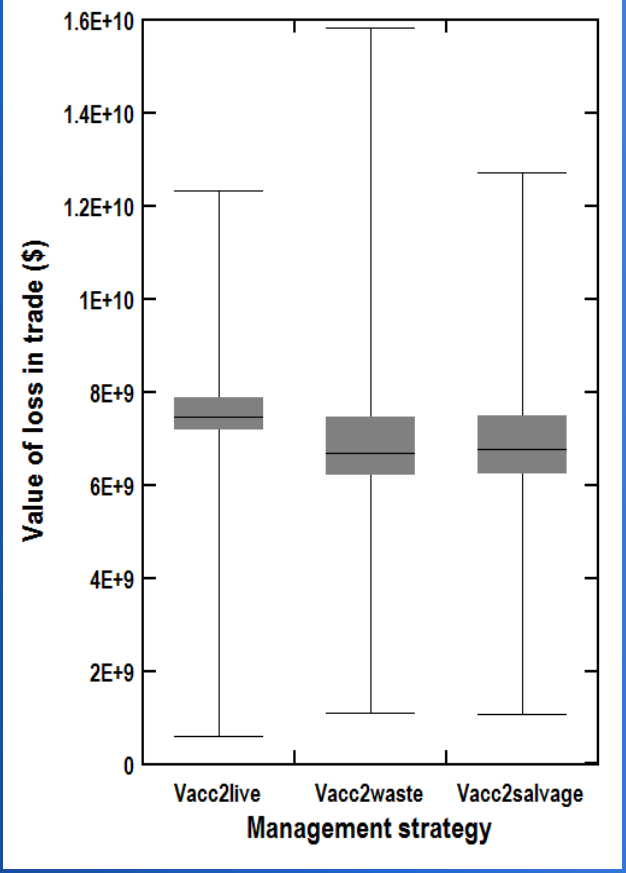
Case study results: retention of vaccinated animals vs. removal

- Retaining vaccinated animals in the population resulted in:

  - lower post-outbreak management costs (on average by 68% or $13 million AUD)

  - higher loss of trade costs (on average by 9% or $650 million AUD)





Case study results: discussion

- Whilst emergency vaccination may help contain disease in a previously FMD-free jurisdiction, it's use complicates post-outbreak management:

  → post-outbreak surveillance must include NSP tests

  → longer waiting period for FMD freedom if vaccinated animals are retained

  → additional logistics and costs if vaccinated animals are removed

  → public opinion on the removal of disease-free animals

- The performance of the vaccinate-and-remove approaches depends on removal rates for disposal/salvage. Delays in removal lead to increased days out of the market and increased trade losses.

- When the rates of removal were doubled, the average total costs under a vaccinate-and-remove-to-waste strategy fell by 10%, a saving of $1.3B AUD.

Case study results: discussion

- Under the assumptions for removal rates used in the case study there was no cost advantage to salvaging removed animals. Salvage revenue was offset by trade losses associated with additional time required to remove vaccinated animals.
- Loss of trade figures are conservative as they do not include time needed to win back market share once FMD-freedom has been restored.
- The goal of the case study was to illustrate the new modelling functionality - not to make a definitive statement on the most appropriate post-outbreak management strategy.
- AADIS now provides many useful model 'dials' to help users investigate the relative costs and benefits of post-outbreak management strategies.

Acknowledgements

- Project team: Richard Bradhurst[1], Graeme Garner[2], Iain East[2], Clare Death[2], Aaron Dodd[1], Tom Kompas[1]

[1] Centre of Excellence for Biosecurity Risk Analysis (CEBRA), University of Melbourne, Australia
[2] Animal Health Policy Branch, Australian Department of Agriculture and Water Resources

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Future work

- Ongoing FMD modelling collaborations between Australia, NZ, USA and EUFMD.
- Refinement as a training tool for disease managers

- EuFMDiS – multi-country extension of AADIS