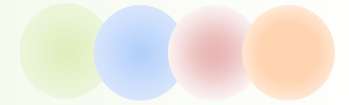


A Spatial Dengue Simulation Model of Cairns, Queensland, Australia

Stephan Karl

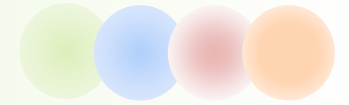
Walter and Eliza Hall Institute of Medical Research, Melbourne, Australia

The University of Western Australia, Perth, Australia



Simulation Models

- Simulation models are **abstractions/simplifications of reality**
- They are aimed at estimating **factors that influence disease spread** (control, environmental, human, vector)
- an advantage of simulating disease scenarios is the opportunity to **estimate the impact of control measures** and **optimize their application**
- the value of a simulation model depends on the **quality of the data**: more detailed data allows for more confident conclusions and less far-reaching assumptions



The Cairns Scenario

- frequent dengue case introductions lead to local transmission through an endemic *Aedes aegypti* population
- There is a potential for re-establishment of continuous dengue transmission in Northern Australia
- The Queensland Government maintains a task force to stamp out dengue outbreaks
- This includes the collection of detailed case data (in time and space), reconstruction of index cases and well documented vector control efforts) → detailed data: favourable environment for mathematical modelling



The aim of this study was to build a detailed simulation
Model describing dengue transmission in Cairns

Modelling Area

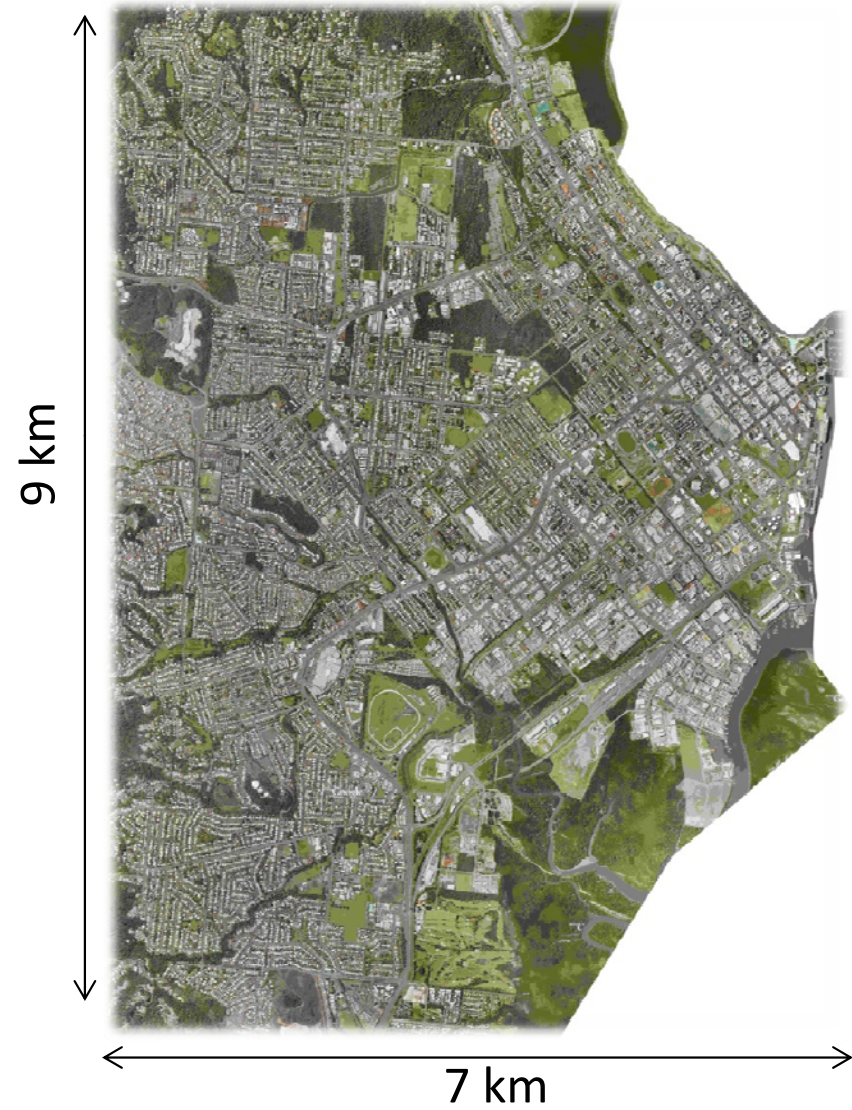


Central Cairns, Queensland, Australia

~25,000 properties

~56,000 people

~50 km²





The model is...

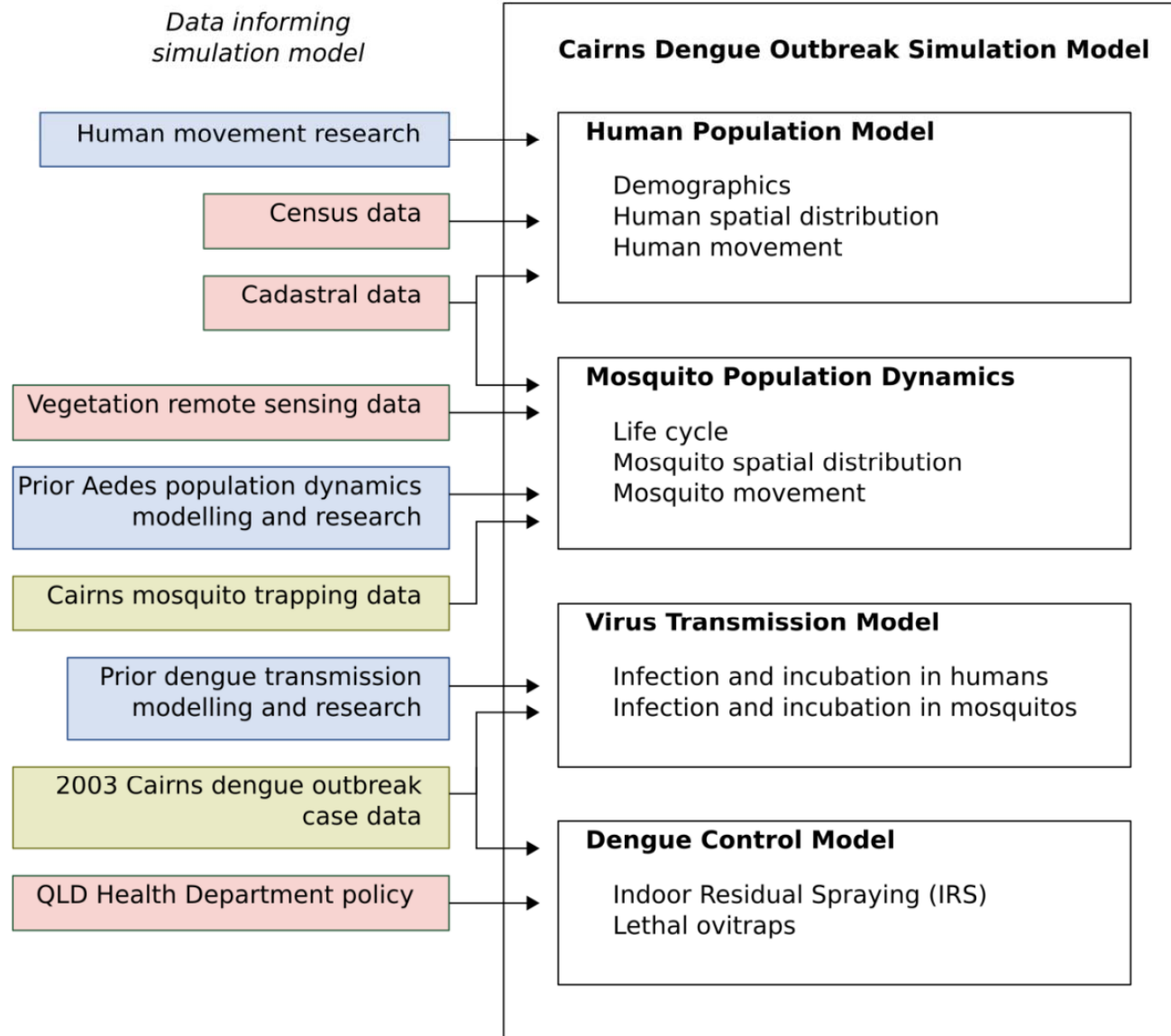
- **Temporally discrete:** 6h time steps
- **Spatially discrete:** over 70000 different locations
- **Stochastic:** based on probabilities
- **Weather driven:** rainfall, temperature and evaporation based
- **Calibrated** using: Human demographic data, Mosquito trapping data and Dengue outbreak data

The model includes

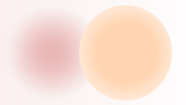
- **Human population dynamics** (movement)
- **Mosquito population dynamics** (life cycle and flight)
- **Virus transmission**
- **Vector control**

...integrated into one model structure

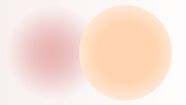
Model Overview



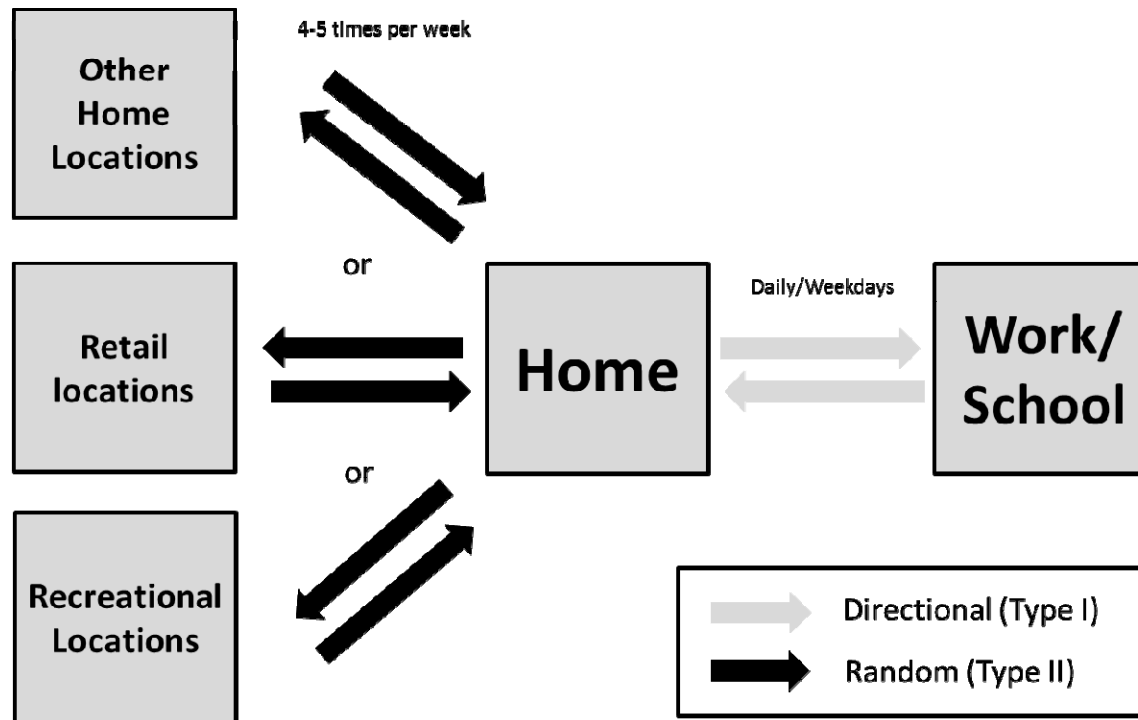
Human Population Model



Human Population Model



Human Movement

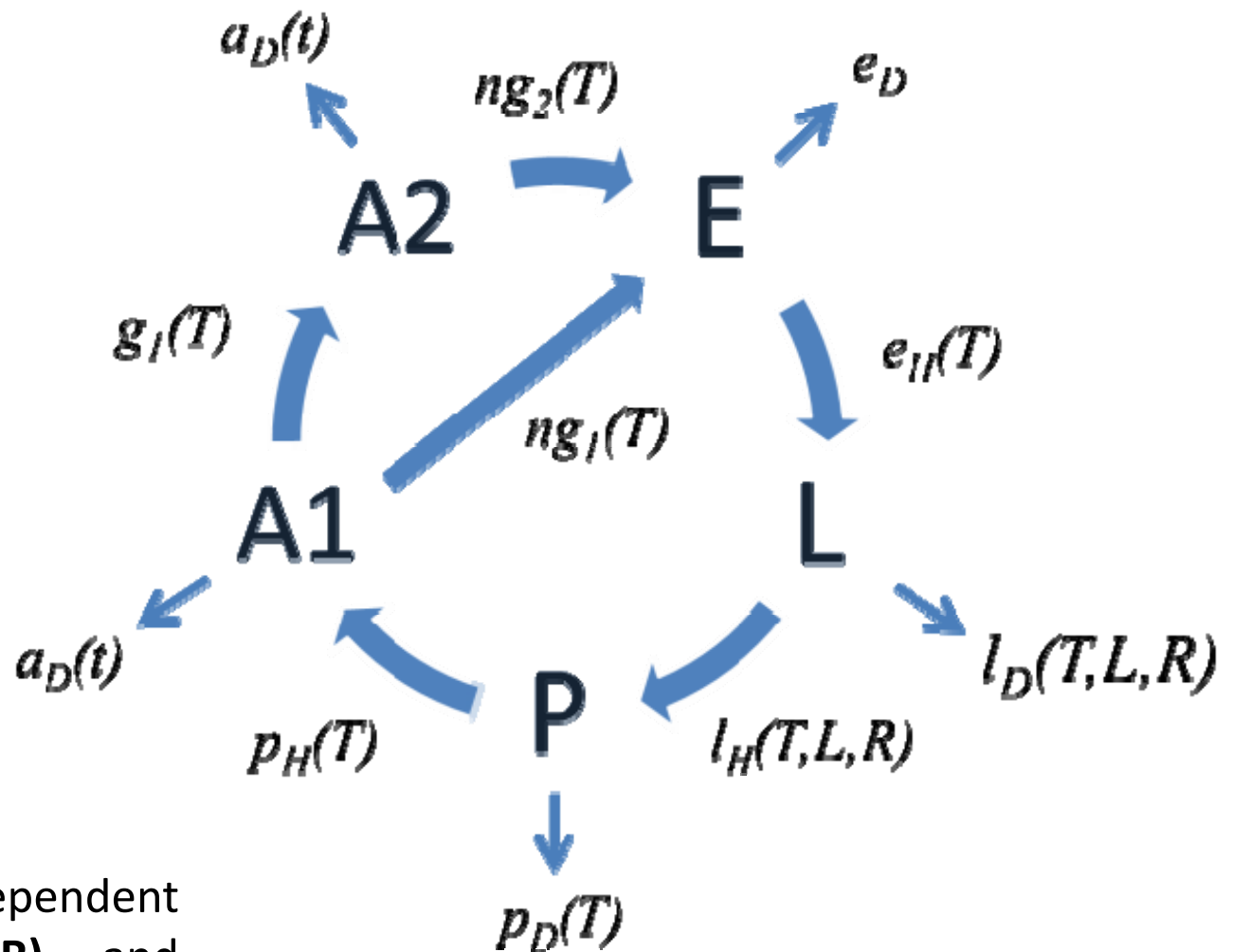


Human movement distance is assumed to be gamma distributed

Mosquito Population Dynamics Model

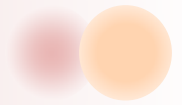
Mosquito life cycle

- E – Eggs
- L – Larvae
- P – Pupae
- A1 – Young adults
- A2 – Adults



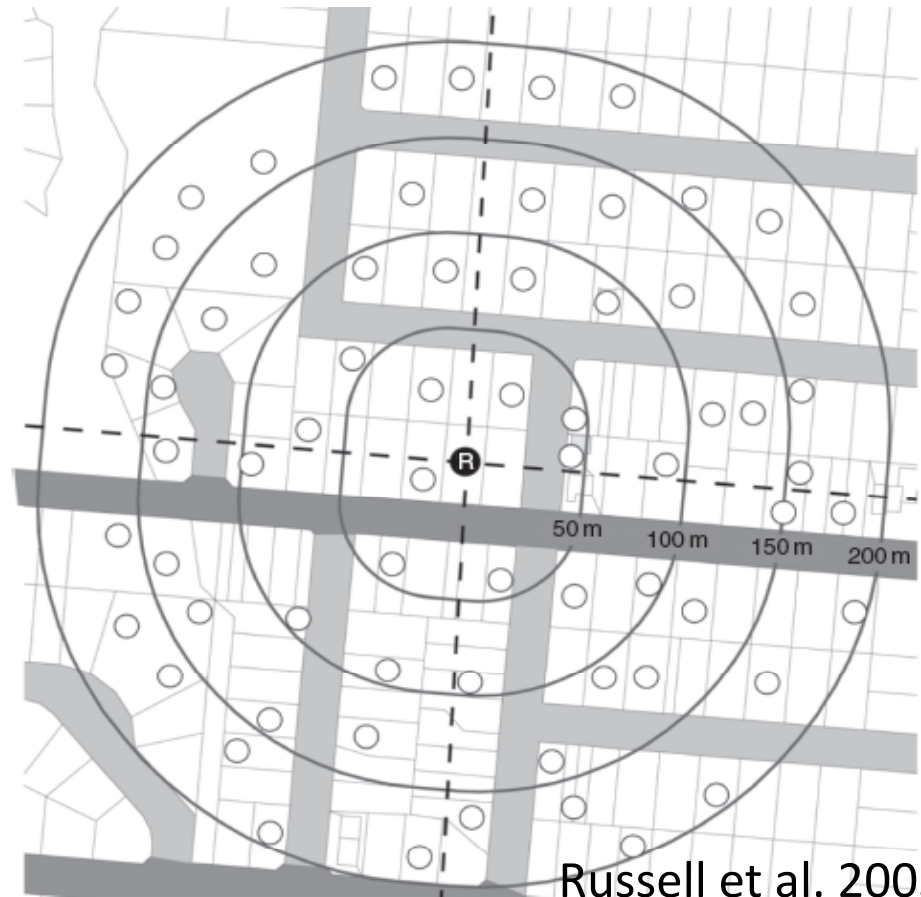
The mosquito population is dependent on **temperature (T)**, **rainfall (R)** and density of **larvae (L)**

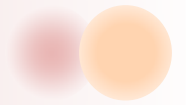
Based on Focks et al. 1999, Otero et al. 2006



Mosquito Movement

- Based on *Aedes aegypti* mark-release-recapture data from Cairns
- approximately 75% of mosquitoes stay within 100 m radius of release point
- 25% of mosquitoes are captured outside a 100 m radius (at day 15 after release)





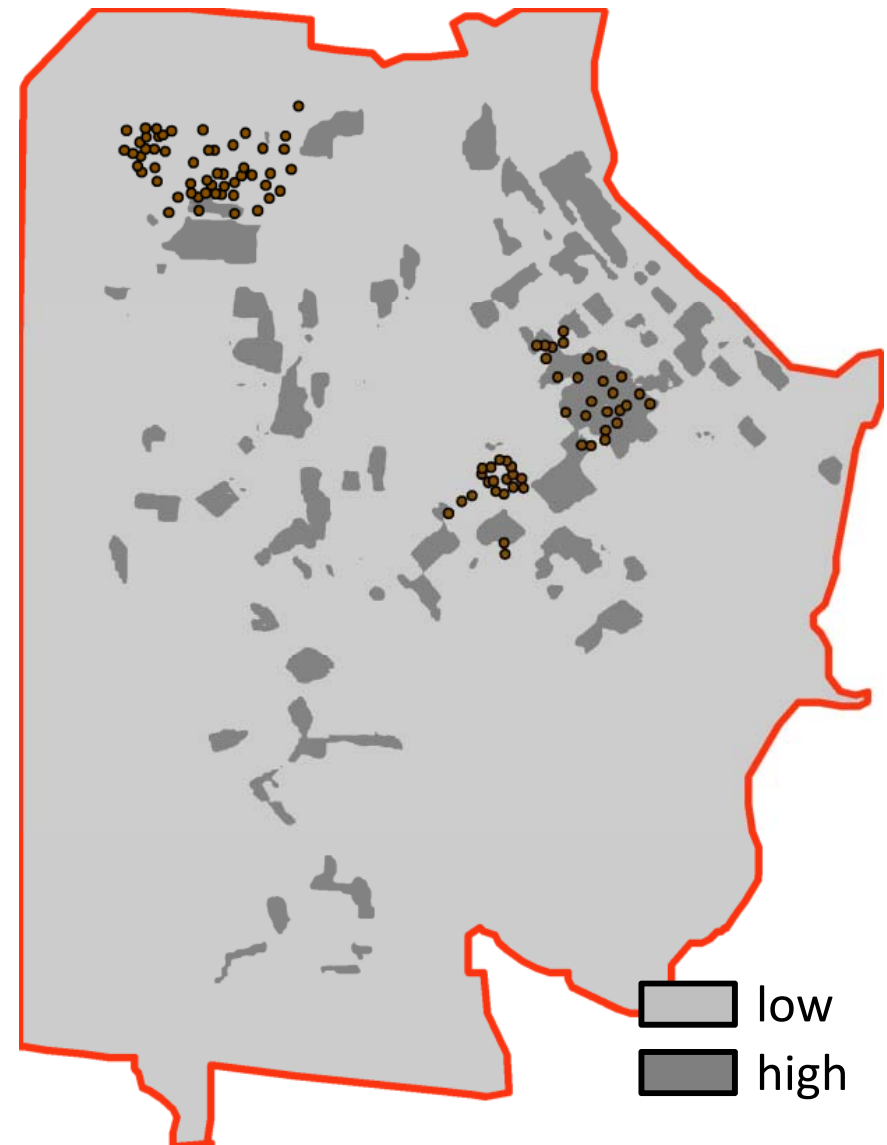
Mosquito Population Heterogeneity

Estimation of suitability of cells for mosquito breeding based on...

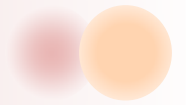
- i) **housing density (census data)** and
- ii) **vegetation cover (GIS data)**

...and validation using mosquito trapping data

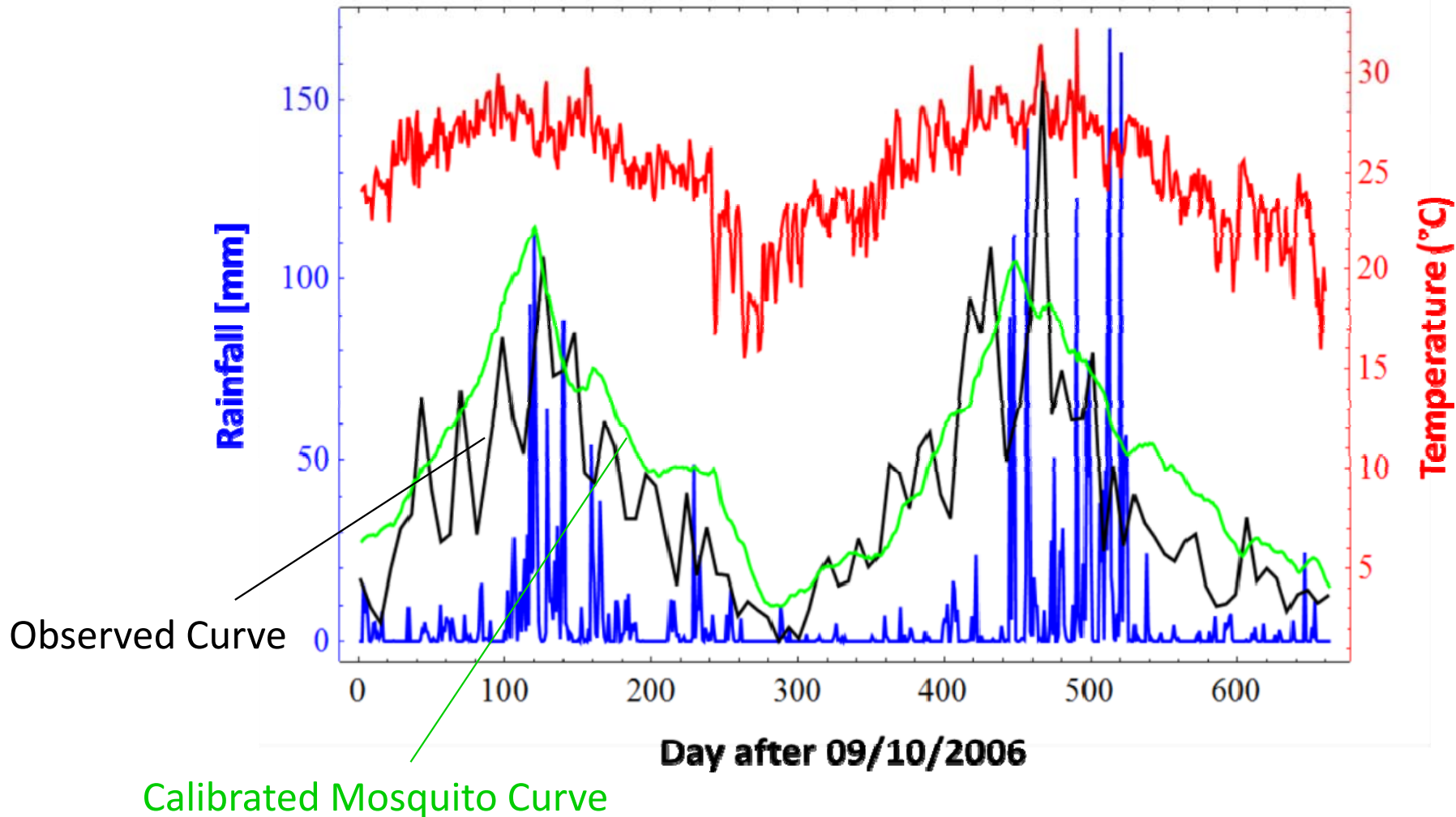
Limited trapping data allows only for classification of 2 (high and low) mosquito breeding site densities



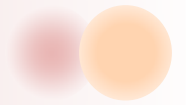
Mosquito Population Dynamics Module



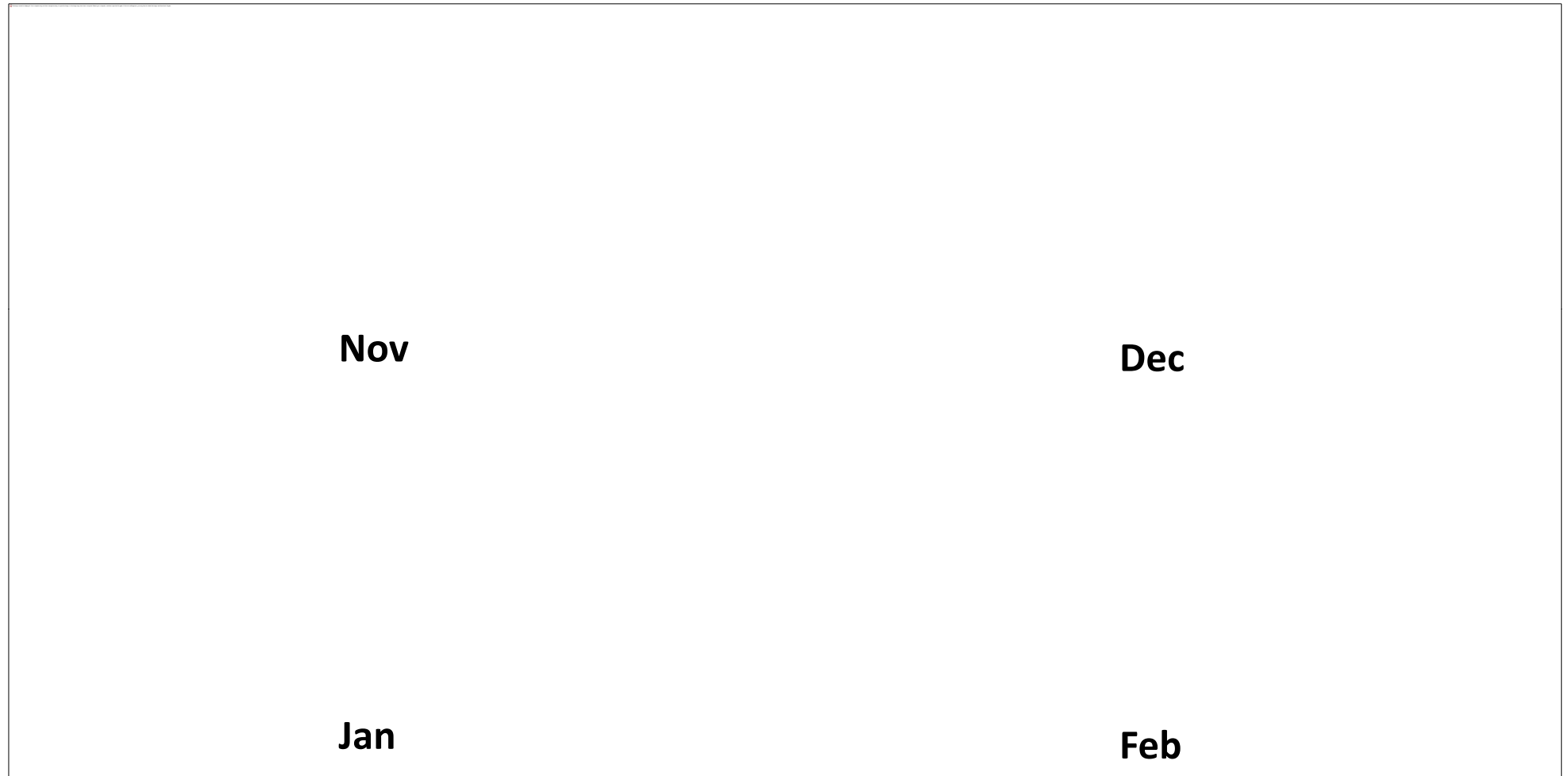
Calibration of Mosquito Population Dynamics Model using Trapping Data



Dynamic Spatial Mosquito Population Patterns

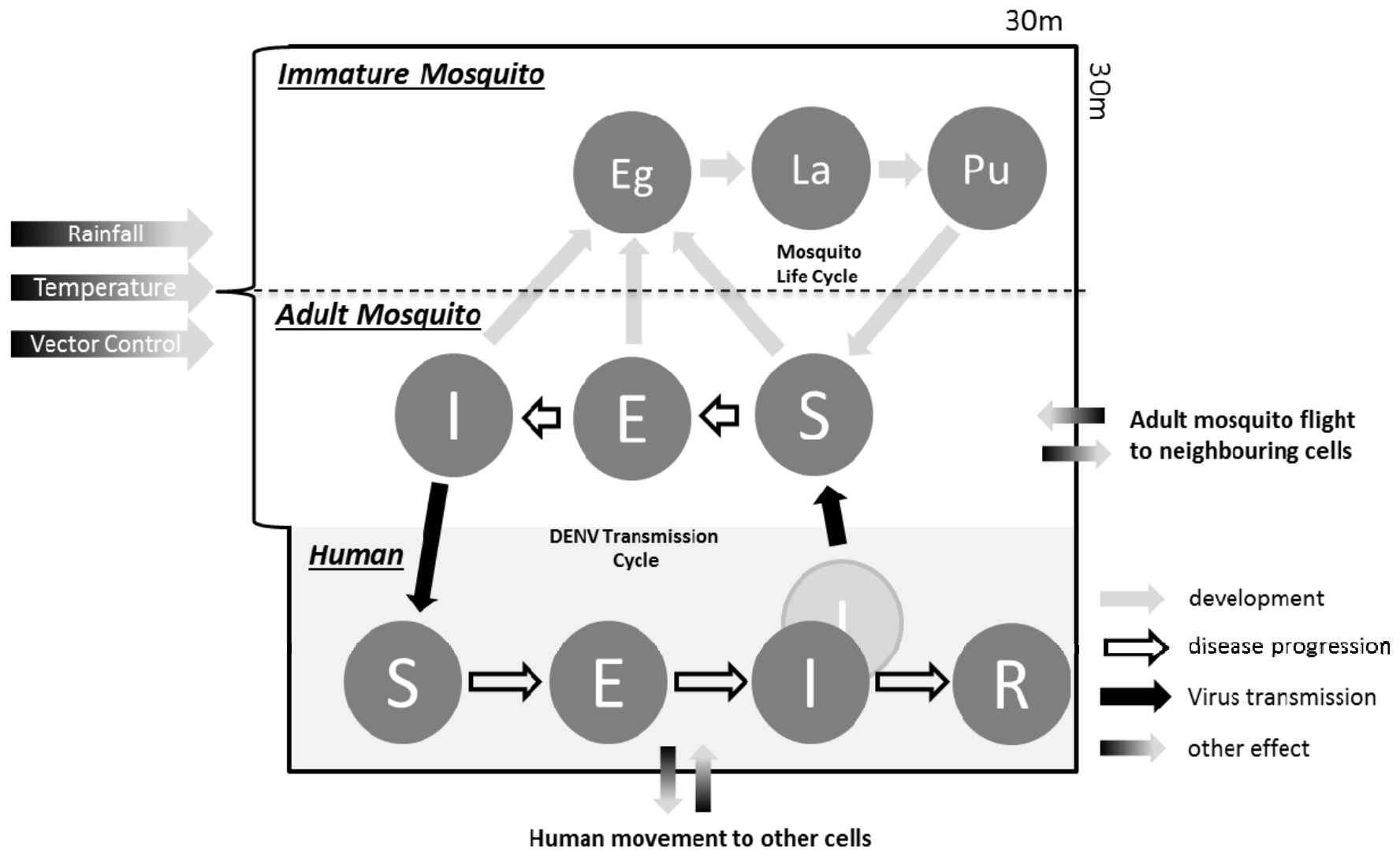


Beginning of Rainy Season

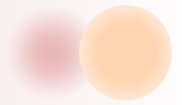


Height of Rainy Season

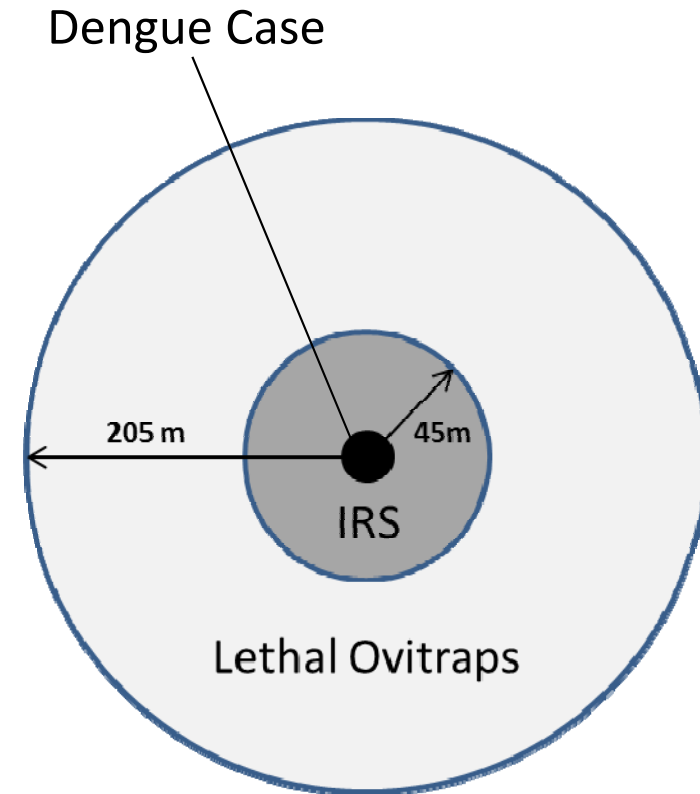
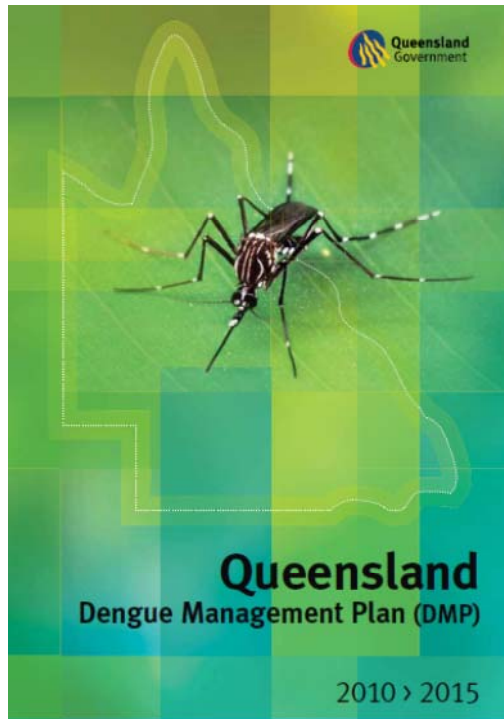
Virus Transmission Module



Control Module

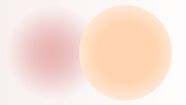


- Guided by specifications outlined in the QLD Dengue Management Plan

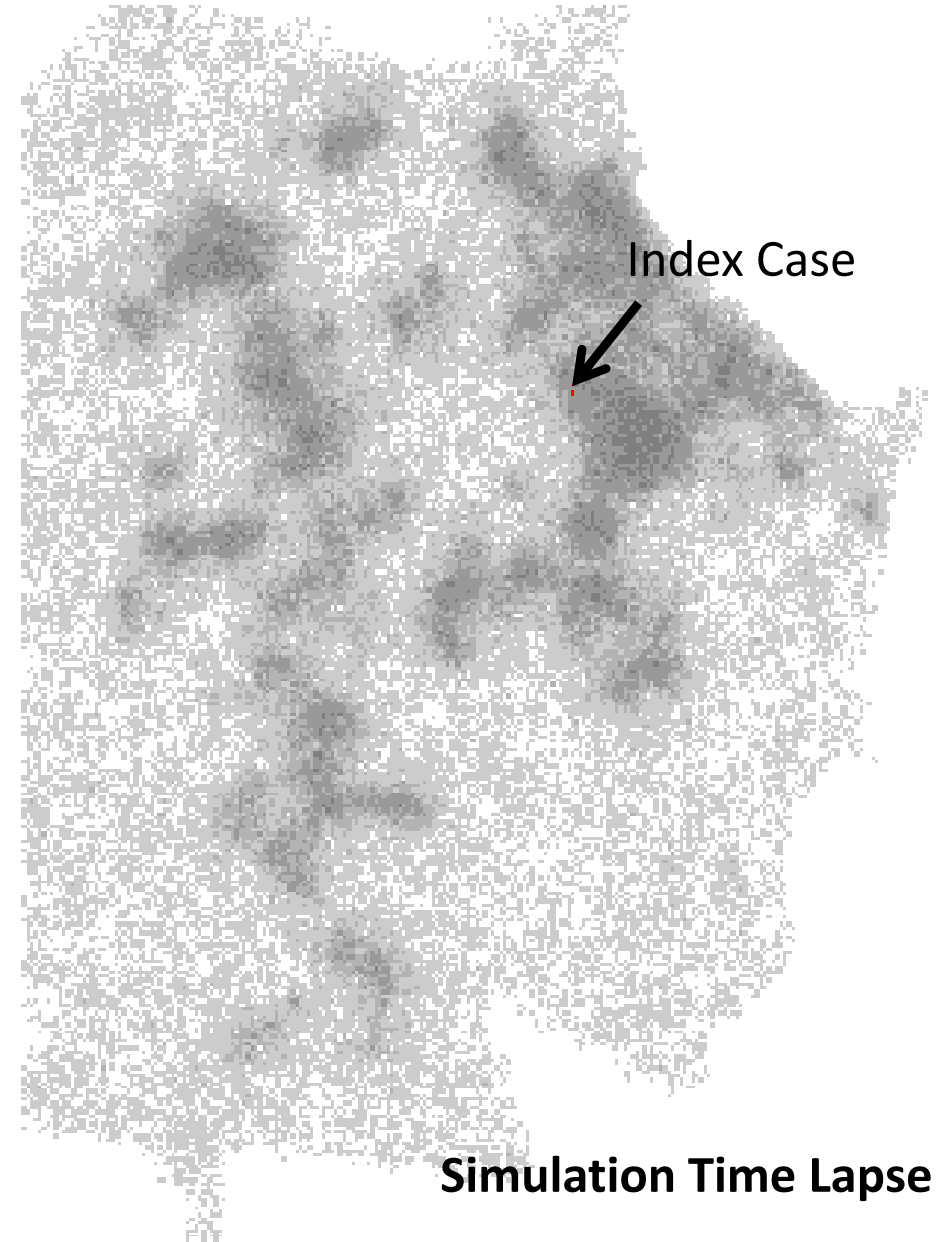


- Case property and surrounding properties are treated with in-house residual spraying (killing 80% of all mosquitoes per day)
- The wider area around the case is treated with lethal ovitraps (killing 20% of adult mosquitoes per day)

Complete Simulation Model



Observed Cases

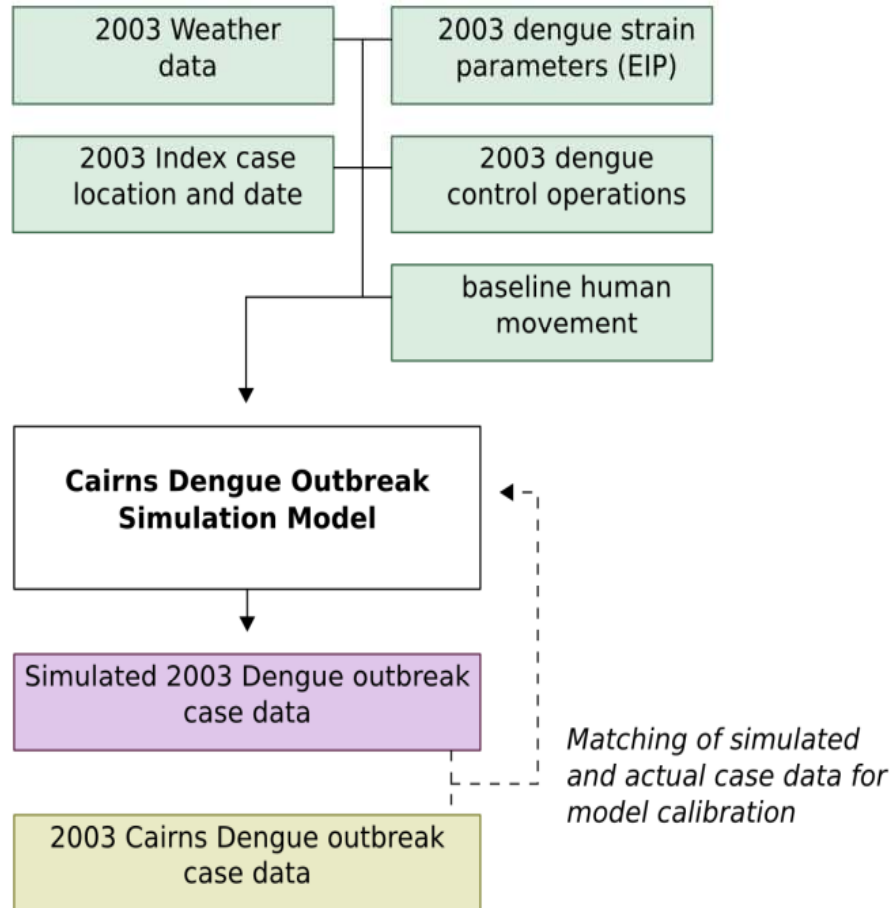


Simulation Time Lapse

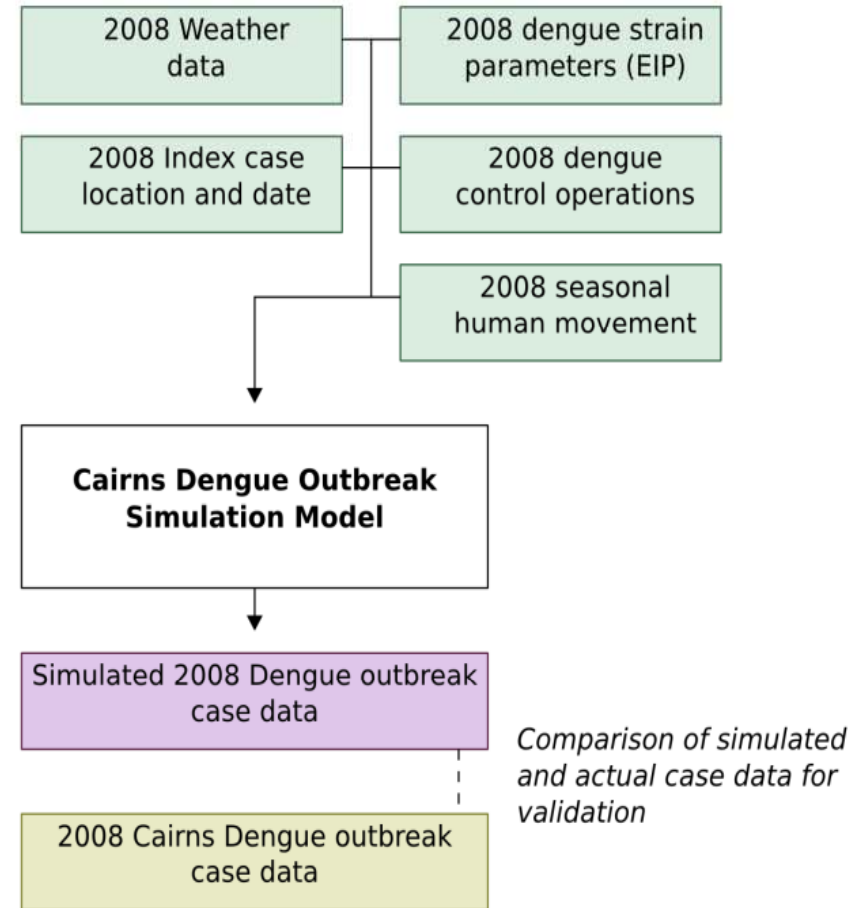
Model calibration and validation



Simulation calibration



Simulation validation

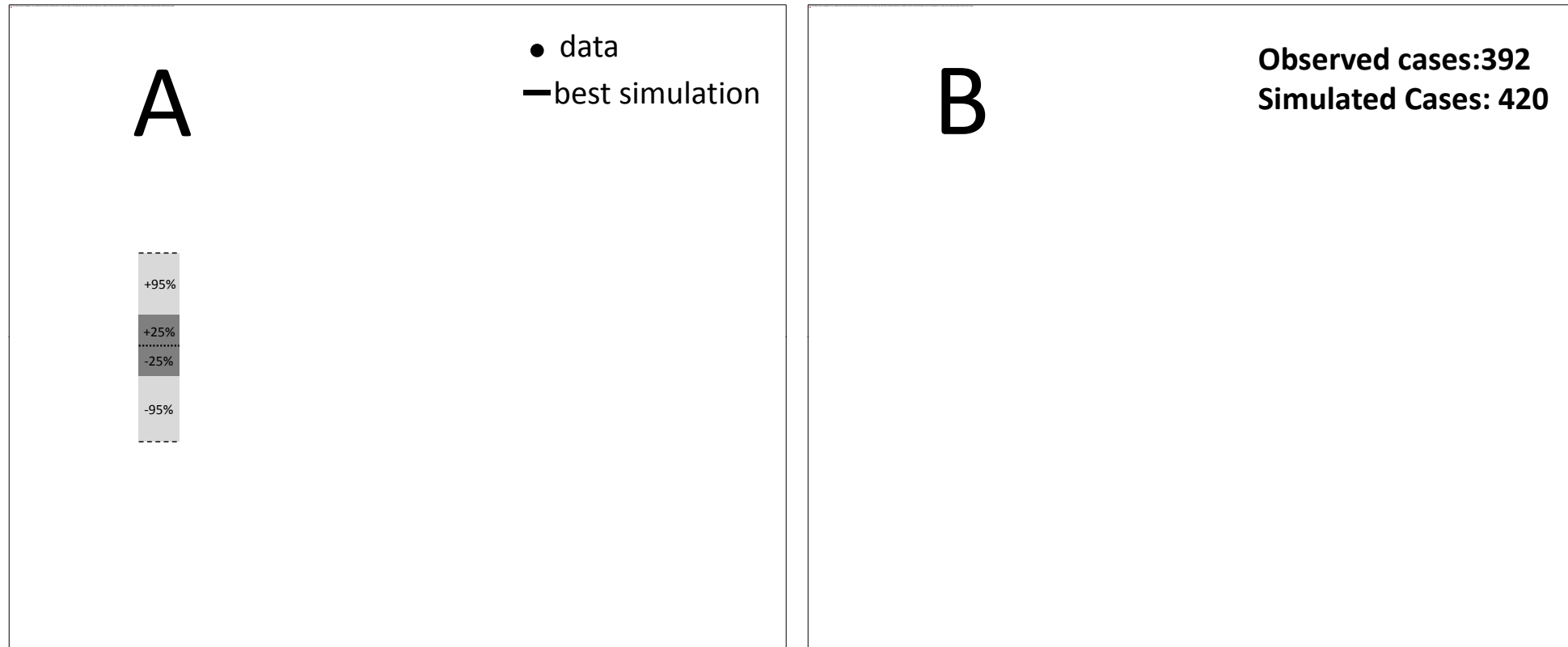


Model calibration using 2003 dengue outbreak data



Cases per Week

Cumulative Cases



- Adjustment of outbreak scale by variation of uncertain parameters
 - e.g., transmission probabilities

Model validation using 2008 dengue outbreak data

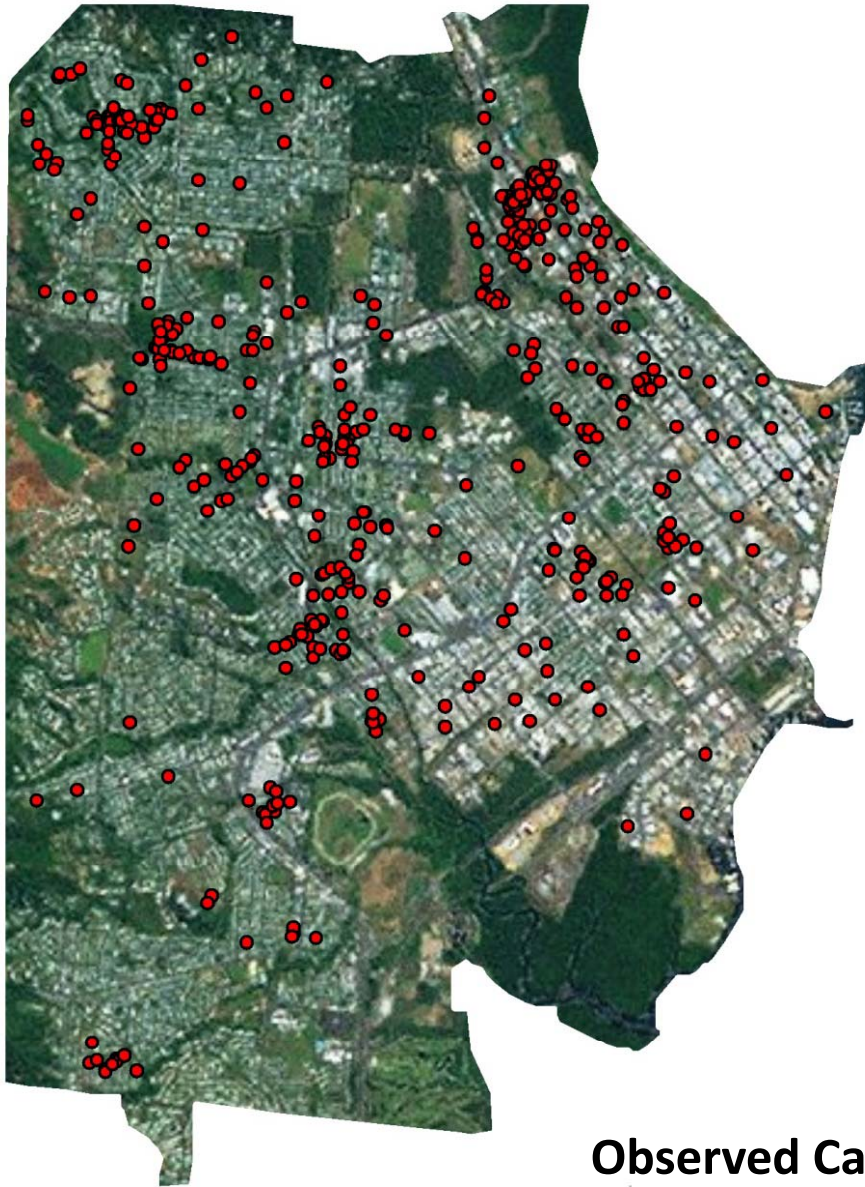


A

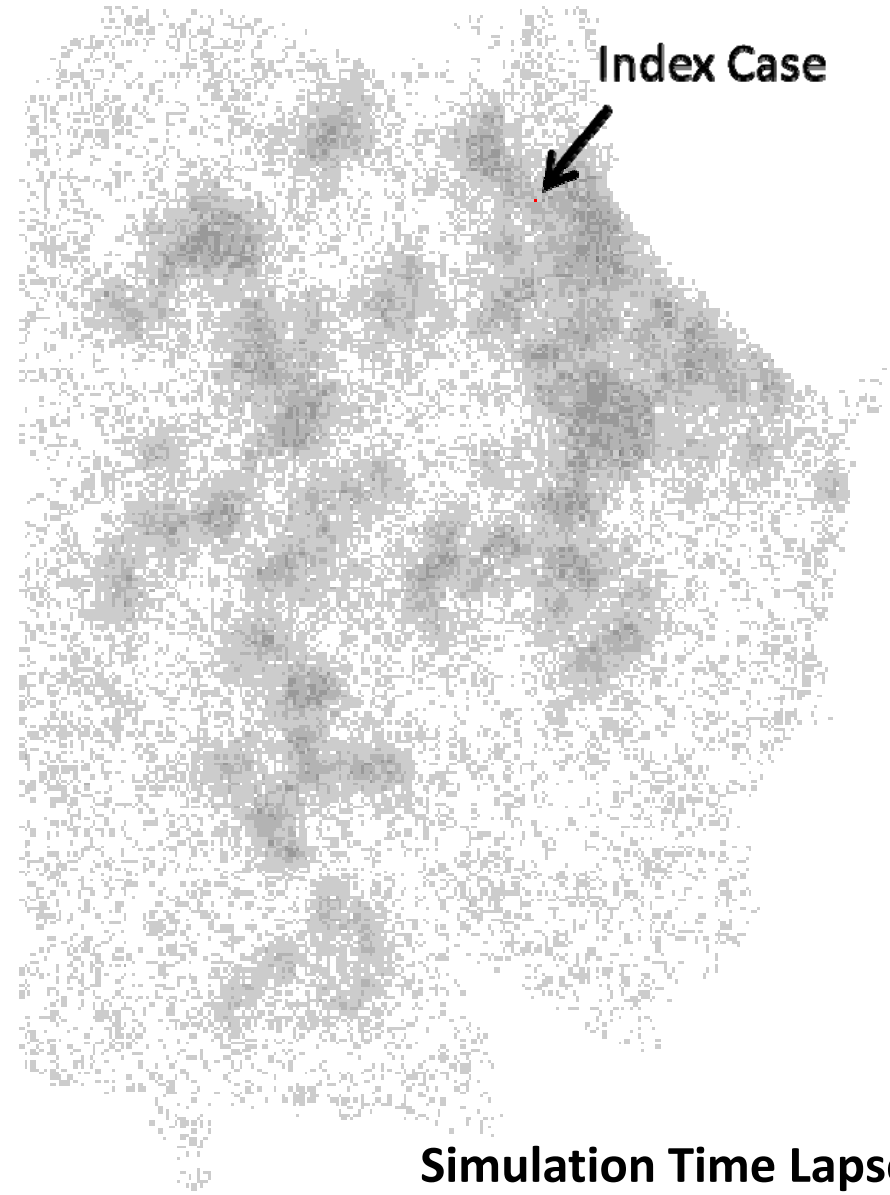
B

Observed cases: 696
Simulated Cases: 692

Model calibration using 2003 dengue outbreak data



Observed Cases

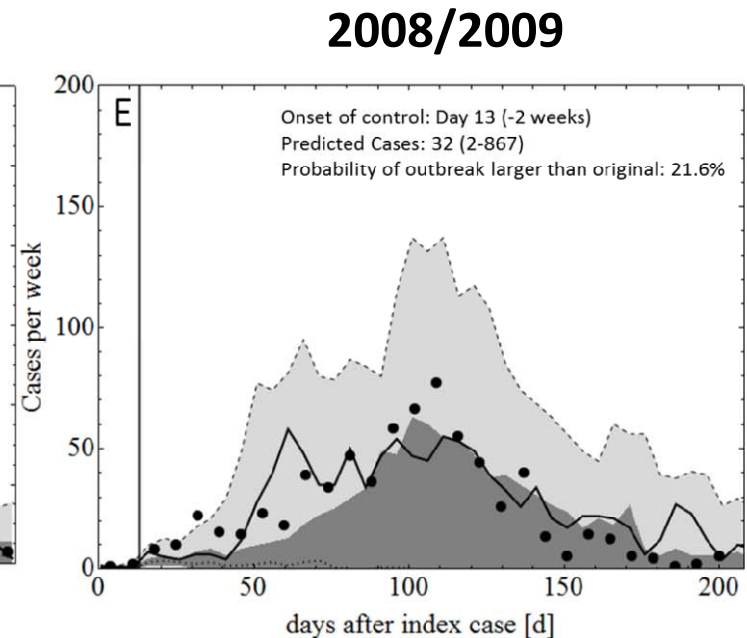
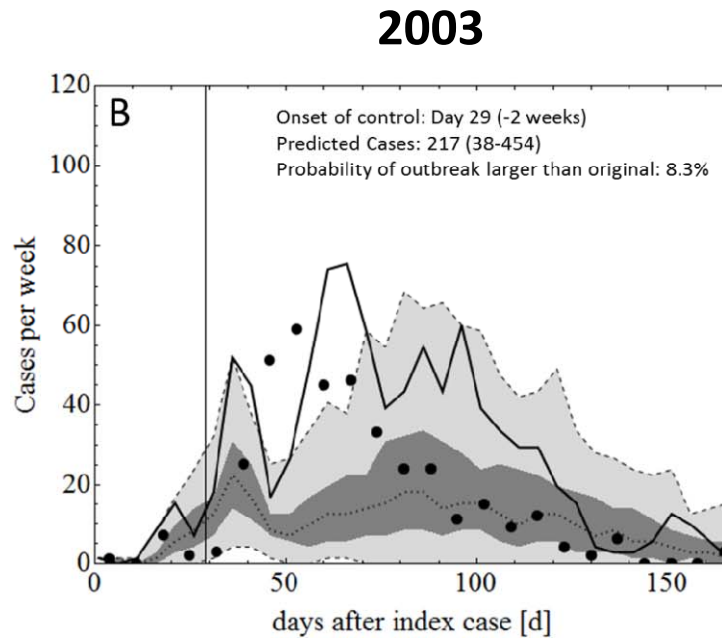


Simulation Time Lapse

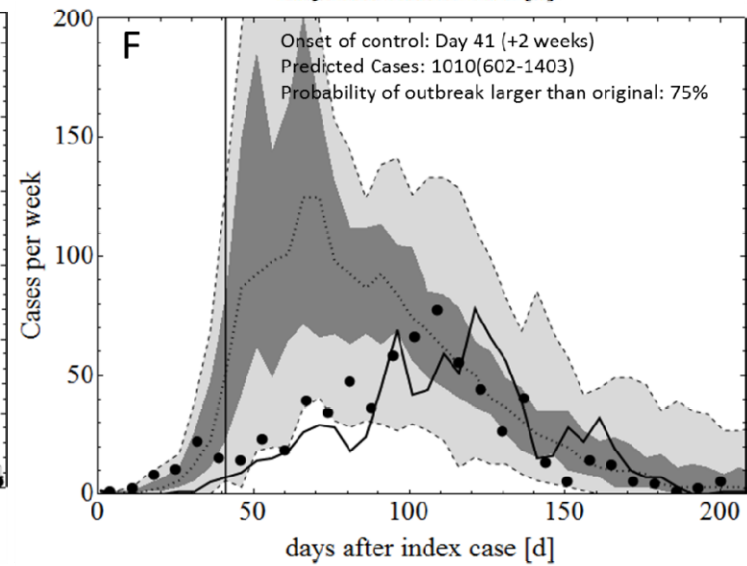
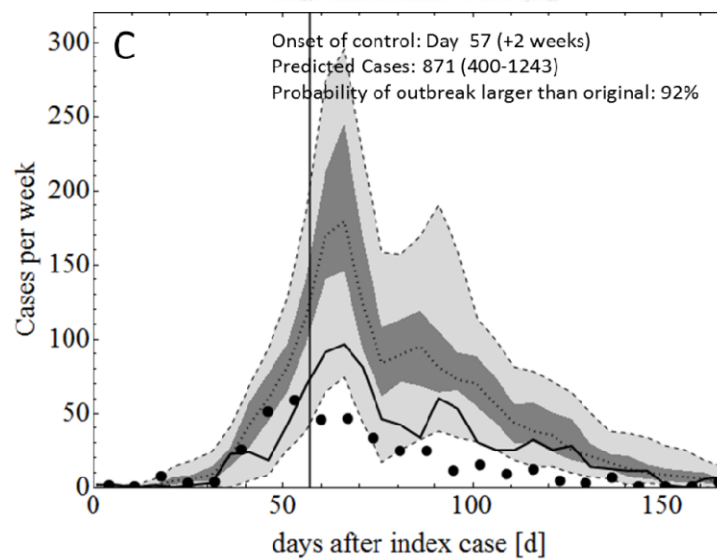
Variation of the Onset of Control Measures



**- 2 week onset
of control**



**+ 2 week onset
of control**





- We present a spatial, complex simulation model for Cairns
- The model was calibrated and validated using actual dengue outbreak data
- The present dengue model can be used to evaluate strategies for vector control in Cairns

Future work will include:

- Extension of the model to allow for circulation of multiple virus strains simultaneously
- Transfer of the model to other geographic locations
- Modelling of other potential control strategies including vaccination and release of Wolbachia infected mosquitoes

Acknowledgements



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