Computational Scenario Testing of Infectious Diseases

Siew Ann CHEONG
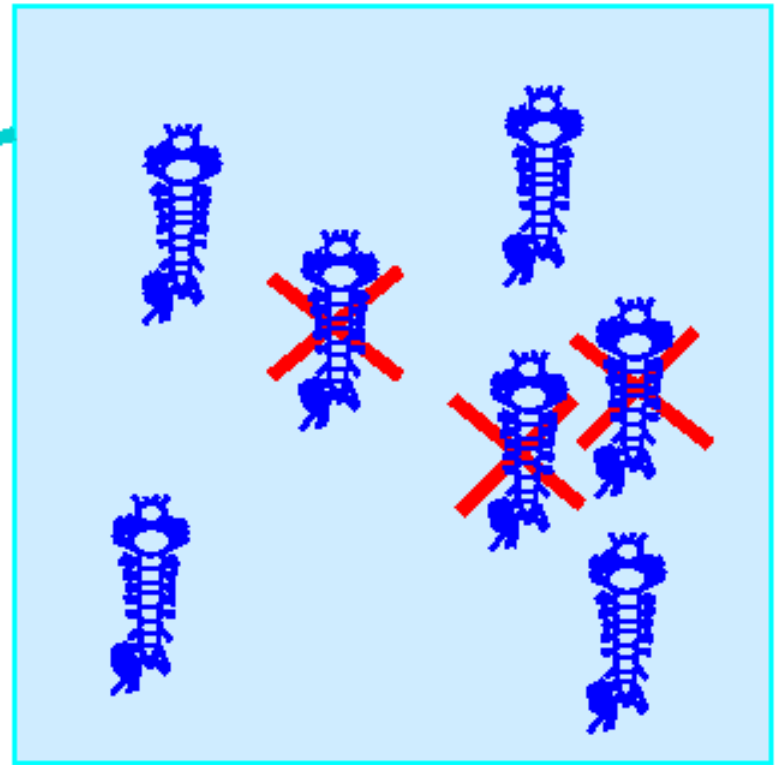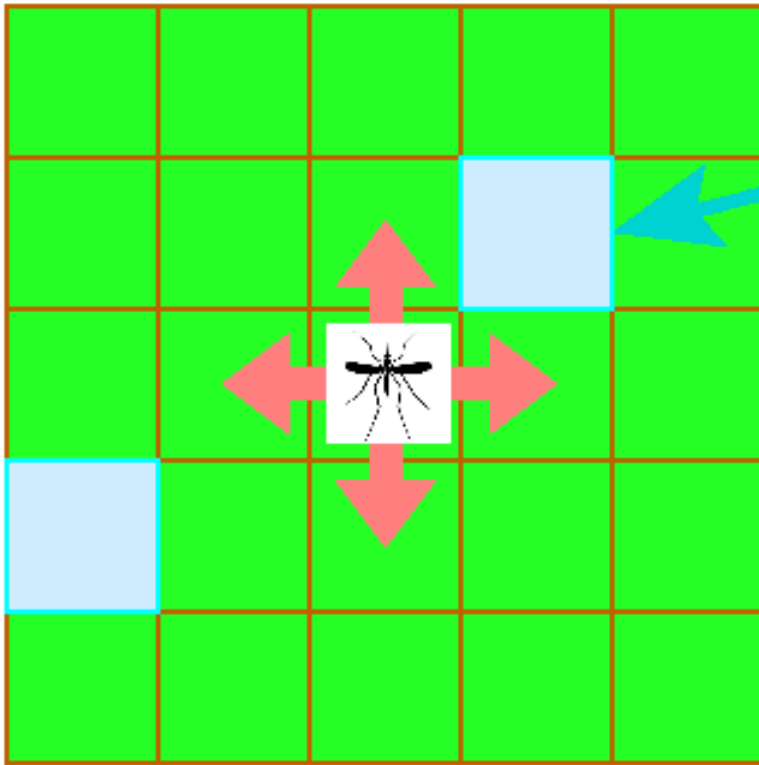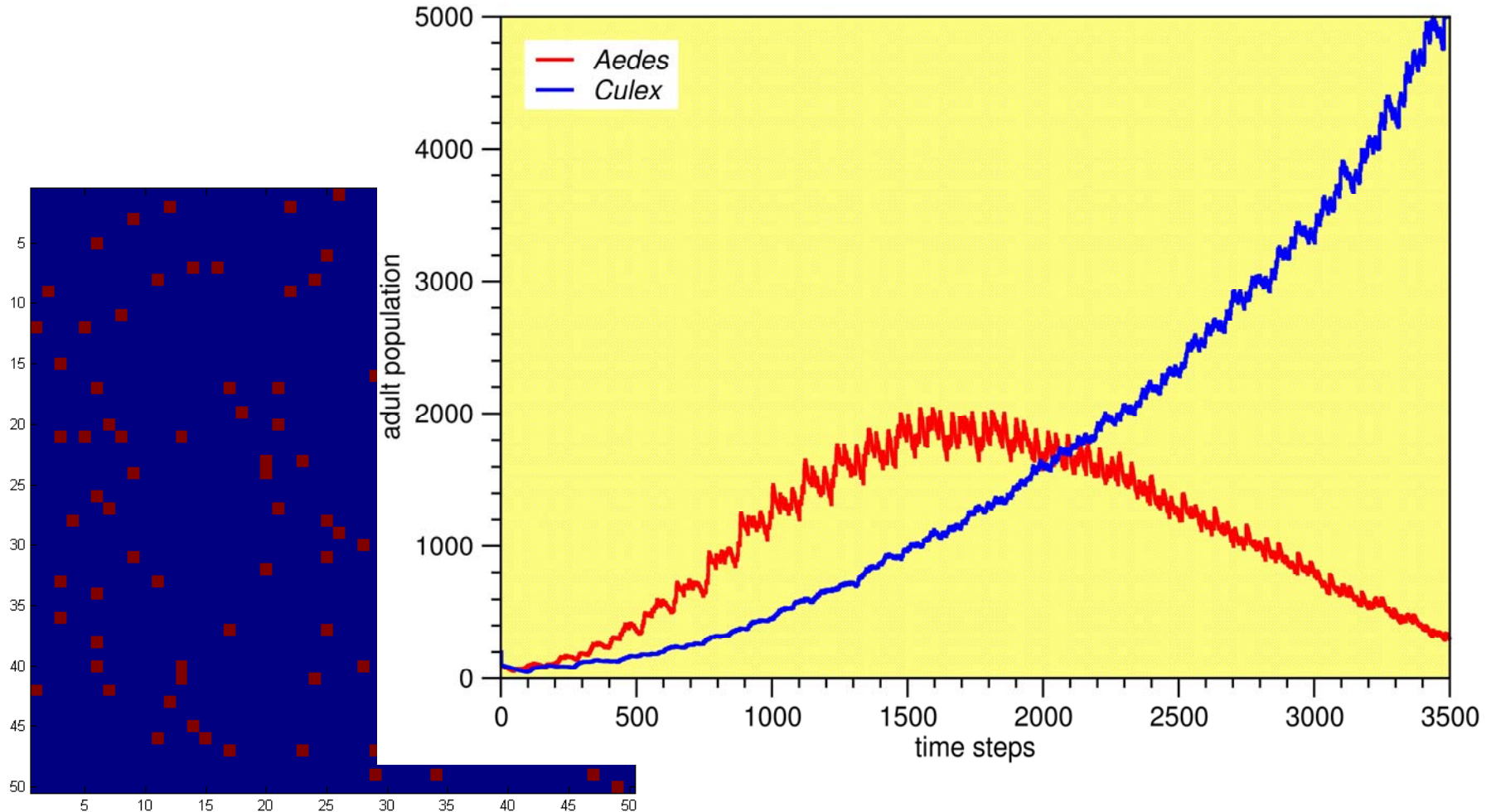
NANYANG TECHNOLOGICAL UNIVERSITY

Acknowledgments

- Competitive breeding between *Aedes* and *Culex*
  - Hui Rong Amanda TEO (NTU)
  - Choon Siang TANG (NEA)
- Human-vector interaction
  - Whei Yeap SUEN (NTU)
- Viral integration into *Aedes* genome
  - Michael Kia Liang THAN (NTU)
- Evolutionary model of dengue epidemics
  - Dr Khoa TD THAI (Amsterdam Medical Center)
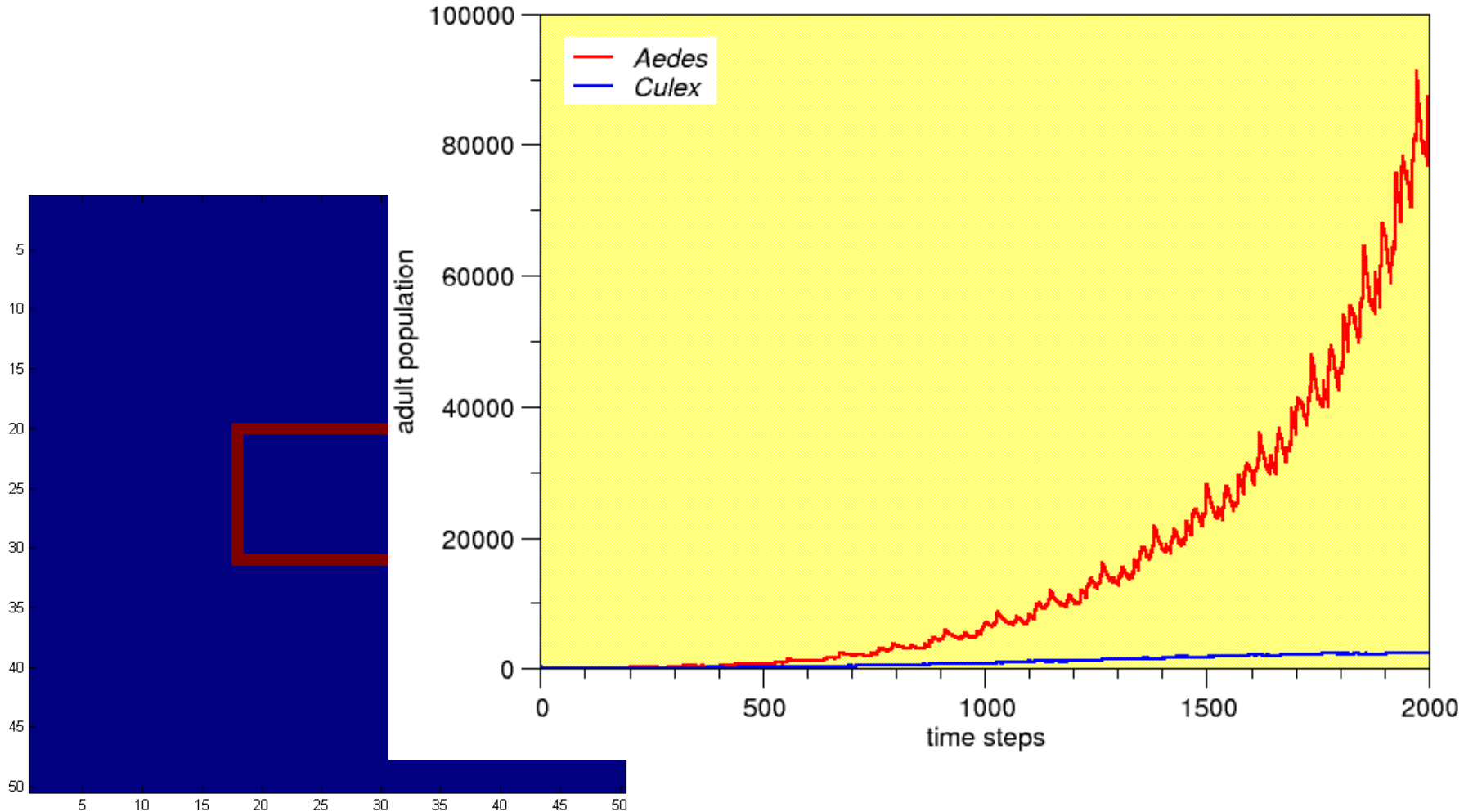 - David HALIM (NTU)

Competitive Breeding Between *Aedes* and *Culex*

Competitive Breeding Between *Aedes* and *Culex*

Competitive Breeding Between *Aedes* and *Culex*

Competitive Breeding Between *Aedes* and *Culex*

Density	2%	3%	5%
Benchmark	0.0%	5.0%	9.0%
Straight line	33.3%	47.5%	80.0%
Three branch	23.3%	43.3%	60.0%
Closed loop	23.3%	33.3%	43.3%
Four branch	13.3%	26.7%	36.7%

Competitive Breeding Between *Aedes* and *Culex*

Density	2%	3%	5%
Benchmark	0.0%	5.0%	**9.0%**
Straight line	33.3%	47.5%	80.0%
Three branch	23.3%	43.3%	60.0%
Closed loop	23.3%	33.3%	43.3%
Four branch	13.3%	26.7%	36.7%

Competitive Breeding Between *Aedes* and *Culex*

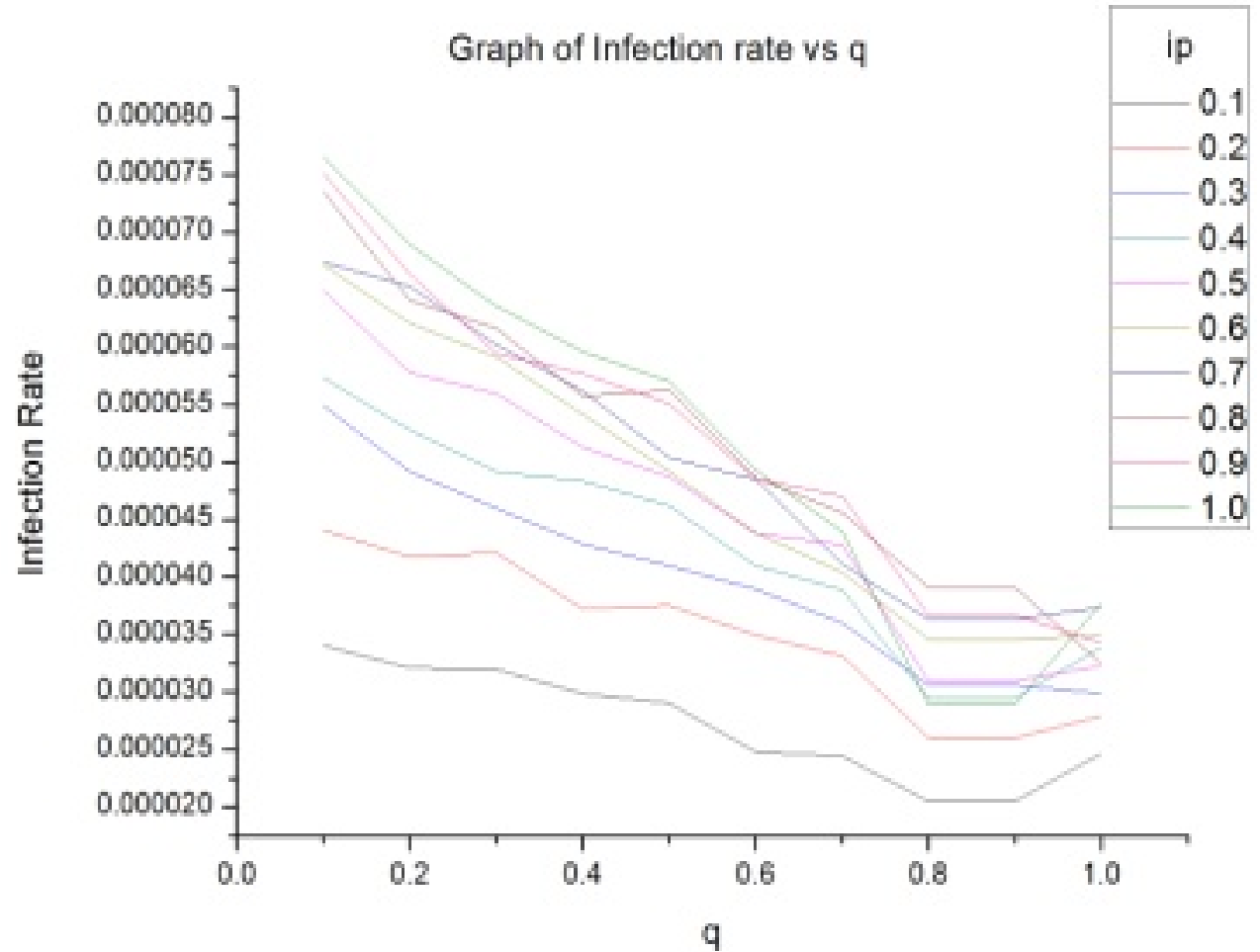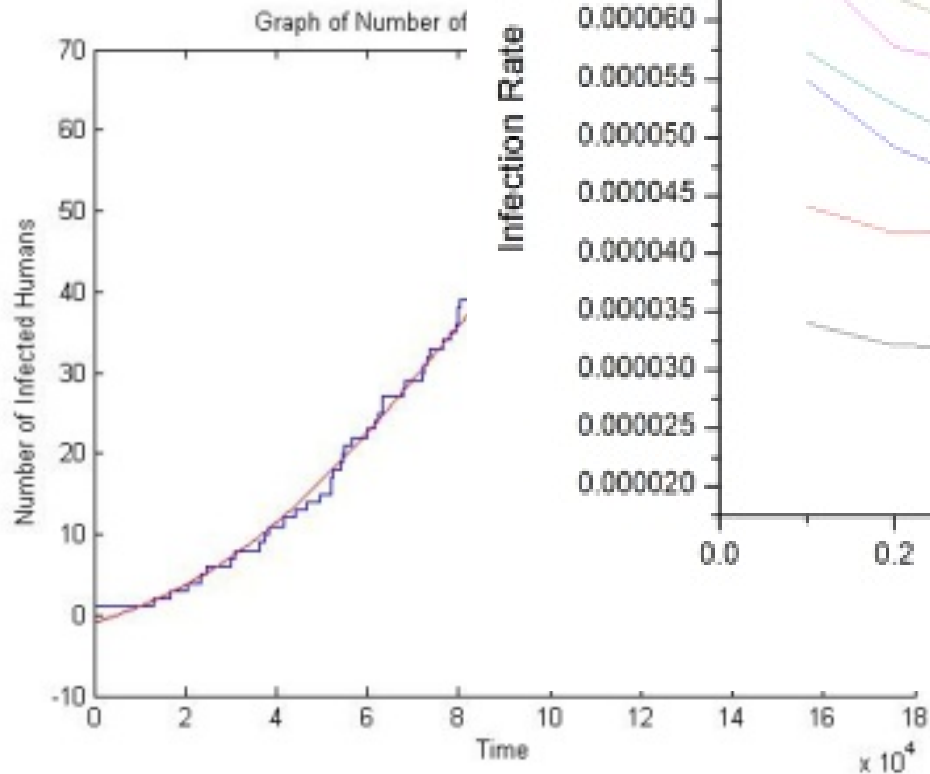| Density	2%	3%	5%
Benchmark	0.0%	5.0%	**9.0%**
Straight line	33.3%	**47.5%**	80.0%
Three branch	23.3%	43.3%	60.0%
Closed loop	23.3%	33.3%	43.3%
Four branch	13.3%	26.7%	36.7%

Human-Vector Interaction

- 10 × 10 km^2 town = 1024 × 1024 grid
- 100 humans + 5000 mosquitoes
- Slower mosquito, 0 < q < 1
- Same cross-infection probability ip
- Epidemiological models
  - Susceptible-Infected (SI)
  - Susceptible-Infected-Recovered (SIR)
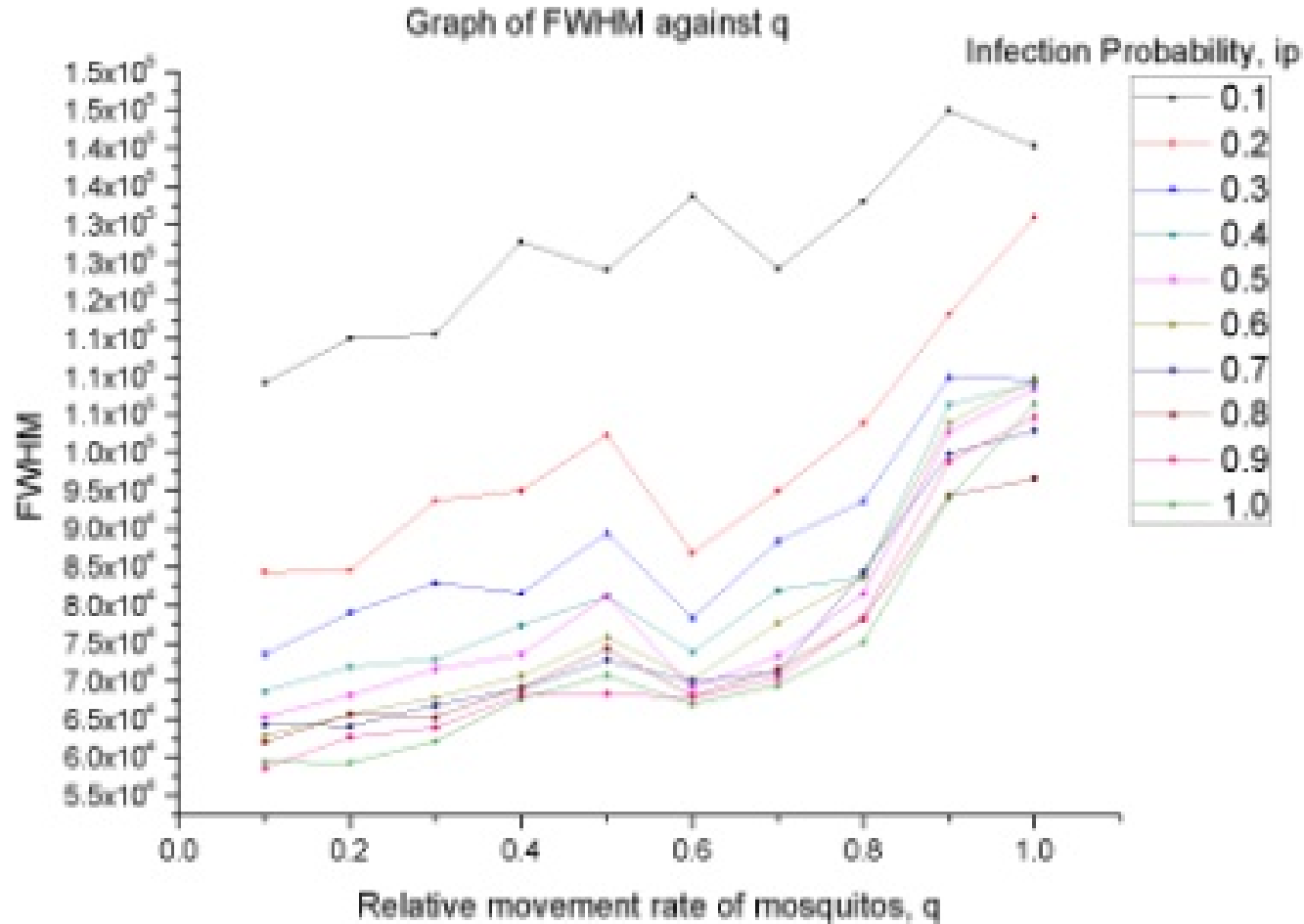 - Susceptible-Subclinical-Infected-Recovered (SsIR)
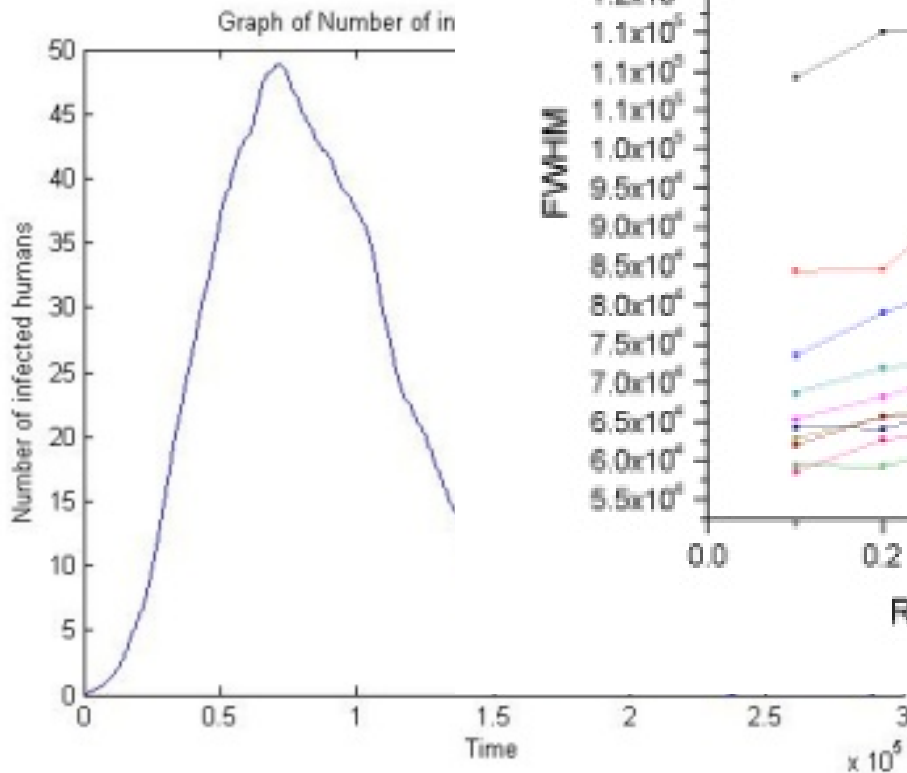
Human-Vector Interaction

SI Epidemic

Human-Vector Interaction

SIR/SsIR Epidemic

Graph of Number of in

Graph of FWHM against q

Infection Probability, ip
- 0.1
- 0.2
- 0.3
- 0.4
- 0.5
- 0.6
- 0.7
- 0.8
- 0.9
- 1.0

Human-Vector Interaction

- Partially completed
  - Structured human mobility
    - infection rate increases 10–100 times
- To start soon
  - 80% subclinical, 20% clinical
    - Quarantine
    - Social distancing

Viral Integration into Mosquito Genome

- Facts
  - DENV
    - Endemic strain
  - DENV vectors
    - *Aedes aegypti* & *Aedes albopictus*
    - Habitat segregation
  - Low rate of vertical transmission
- Puzzle
  - Long inter-epidemic periods
    - Dengue should be extinct!

Viral Integration into Mosquito Genome
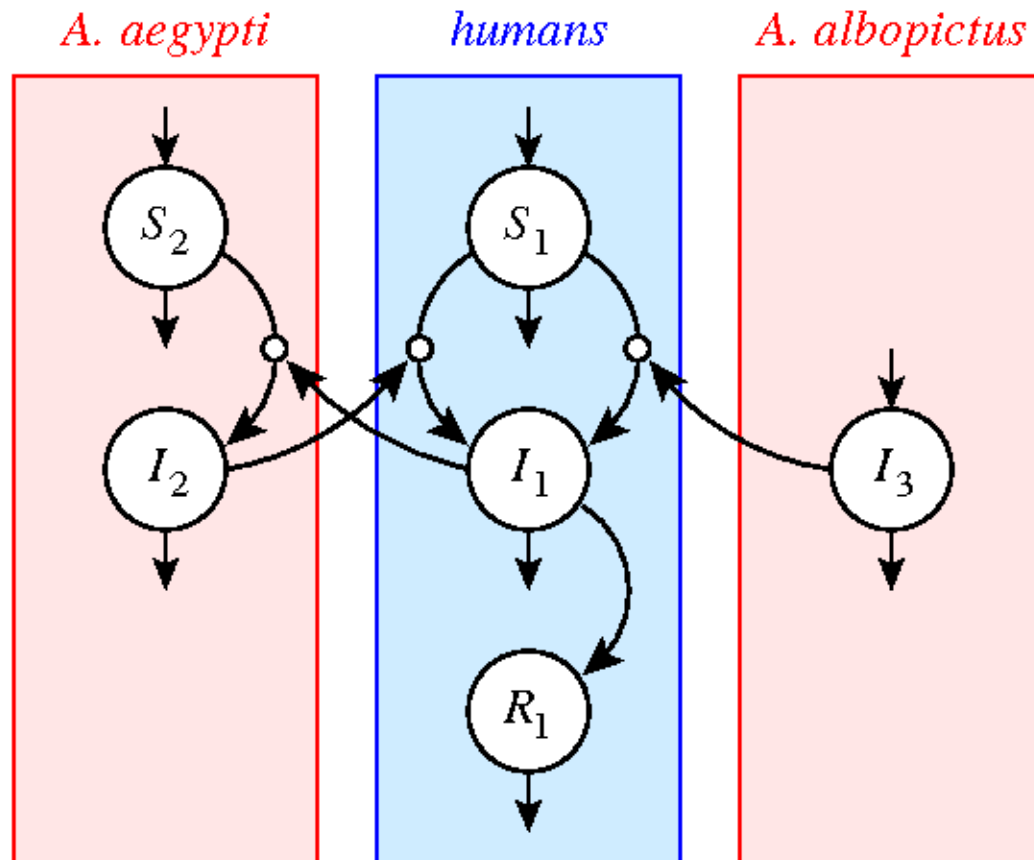
- Facts
  - Viral integration into host genome
  - Crochu *et al*, 2004. *J. Gen. Virol.* **85**, 1971.
  - Roiz *et al*, 2009. *Virol. J.* **6**, 93.
- Scenario
  - DENV integrated into *Aedes albopictus* genome
  - Temperature-driven release (*El Nino*?)
  - *Aedes albopictus* seeds epidemic
  - *Aedes aegypti* spreads epidemic

Viral Integration into Mosquito Genome

○ Coupled SIR Model

Viral Integration into Mosquito Genome

- Future plans
  - Periodic driving
    - *Aedes albopictus* population
    - *Aedes albopictus* infectivity
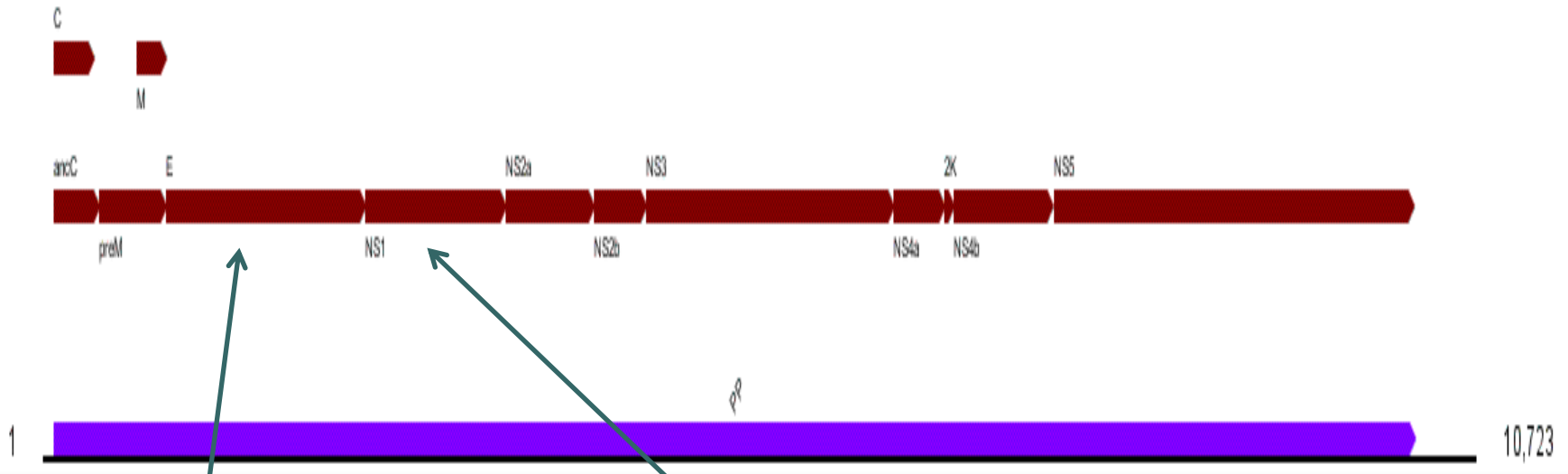 - Spatial extension
    - Urban *Aedes aegypti*
    - Rural *Aedes albopictus*

DENV Evolution & Epidemiology

- Exciting interface between evolution and epidemiology
  - Advances in phylogenetic techniques
  - Growing interest in past decade
- DENV evolution
  - Accelerated during epidemic
  - Ecological competition between strains

DENV Evolution & Epidemiology

infectivity →
infection probability

severity → virus
copy number

DENV Evolution & Epidemiology

- Simulate N = 10,000 sequences
  - SIR dynamics for each sequence
  - Fitness driven substitution
  - Point mutations
- Each sequence consists of
  - E subsequence
    - Different infectivity
  - $NS1$ subsequence
    - Different reproductive rate

The Next Step…

- Complete present studies
    - Compare with empirical data
- Collaborations with regional partners
    - Modeling + simulation to understand clinical data
    - Test experimentally inaccessible scenarios

Thank You!

Contact Information

Siew Ann CHEONG
Assistant Professor
Division of Physics and Applied Physics
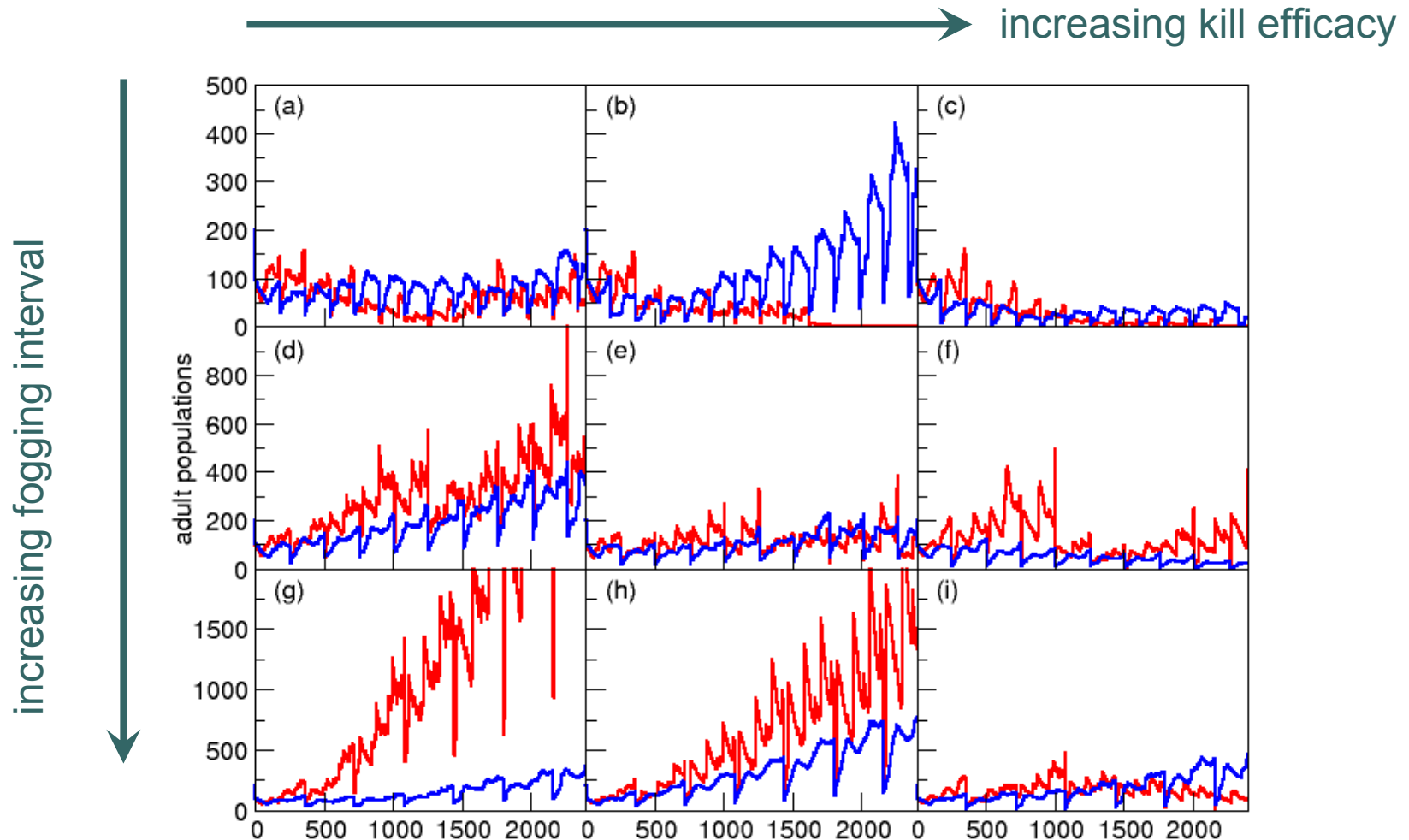*School of Physical and Mathematical Sciences*
Nanyang Technological University
21 Nanyang Link, Singapore 637371
Tel: +65-6513-8084
Fax: +65-6795-7981
Email: cheongsa @ntu.edu.sg

Competitive Breeding Between *Aedes* and *Culex*

increasing kill efficacy

increasing fogging interval

Competitive Breeding Between *Aedes* and *Culex*