Module 6:
Introduction to Stochastic Epidemic Models with Inference

Instructors:

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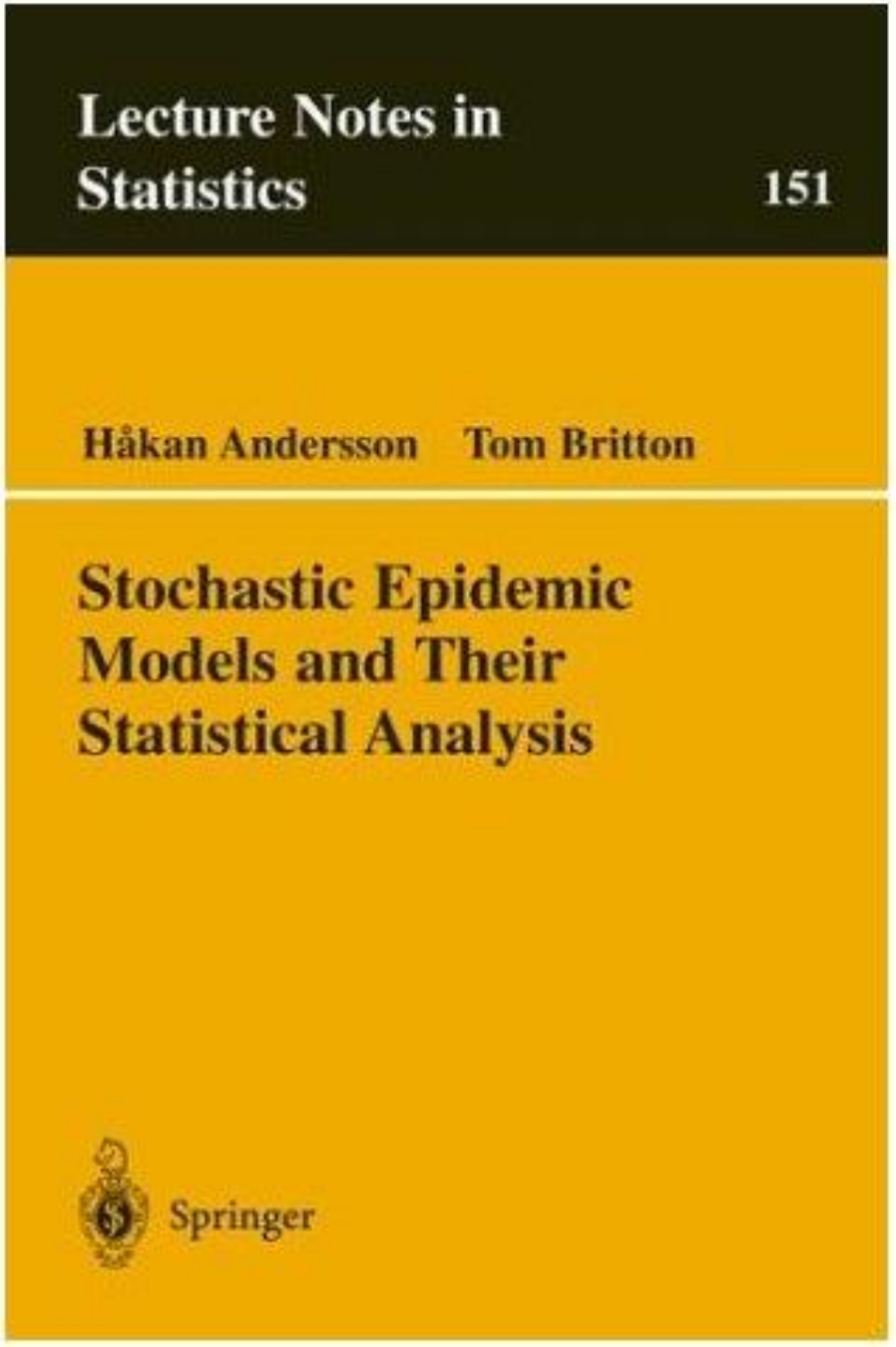
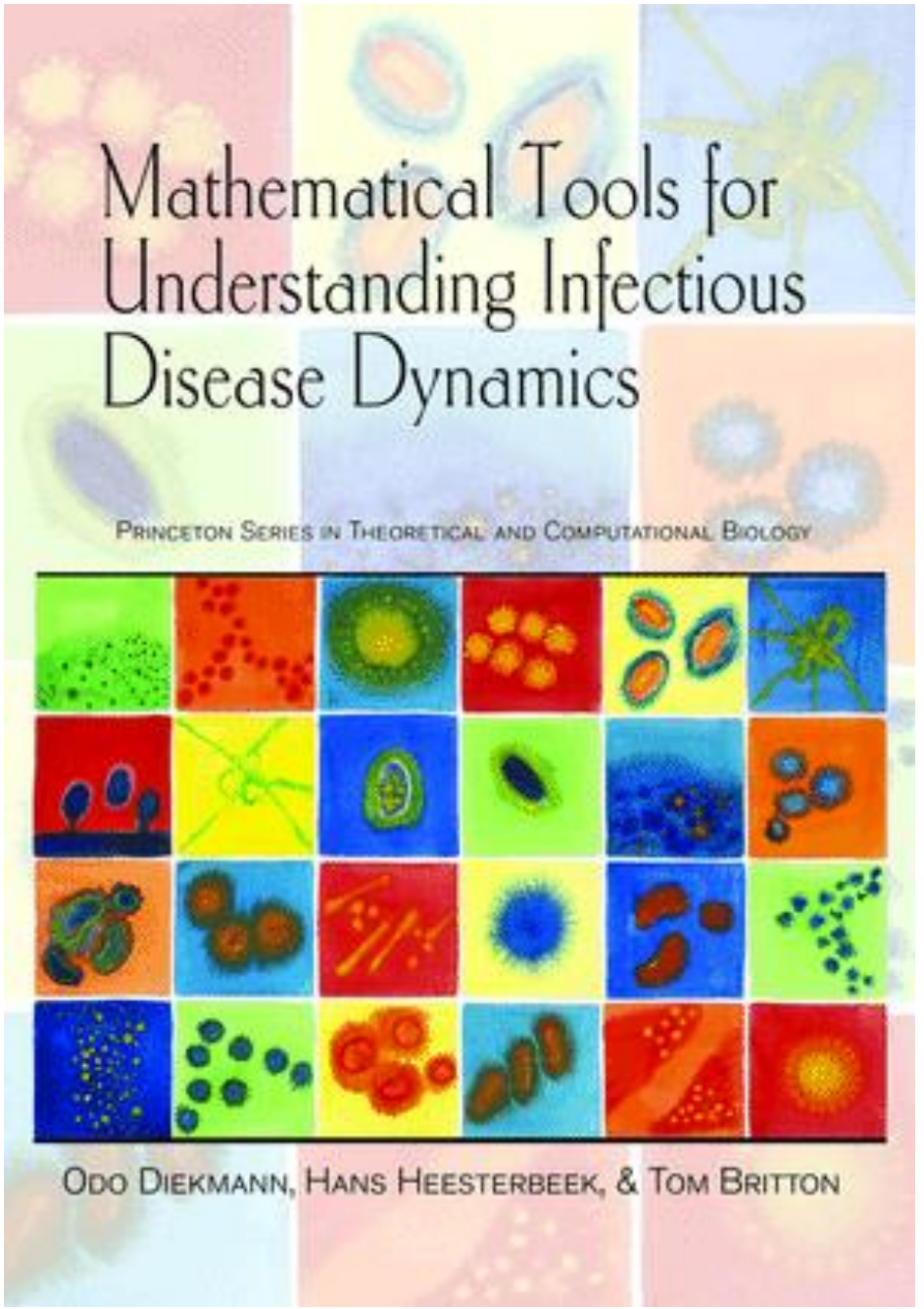
Philosophy of this course (i.e., Reductionist statements)

- Analytic work on the transmission and control of infectious diseases depends on an understanding of epidemic theory
- A technical understanding of the underlying non-linear, stochastic dynamics of infectious disease transmission is the basis for this understanding
  - This almost always involves non-linear functions for the interaction of ***x*** susceptible and ***y*** infected people at time *t*.
- This technical understanding leads to sound inferential structures for estimation of governing parameters and functions

Some Books of Interest for This Course





CENTER FOR INFERENCE & DYNAMICS OF INFECTIOUS DISEASES

UF UNIVERSITY of FLORIDA

csquid CENTER FOR STATISTICS & QUANTITATIVE INFECTIOUS DISEASES

Stockholm University

Statistics for Biology and Health

M. Elizabeth Halloran • Ira M. Longini, Jr. • Claudio J. Struchiner

Design and Analysis of Vaccine Studies

Widespread immunization has many different kinds of effects in individuals and populations, including in the unvaccinated individuals. The challenge is in understanding and estimating all of these effects. This book presents a unified conceptual framework of the different effects of vaccination at the individual and at the population level. The book covers many different vaccine effects, including vaccine efficacy for susceptibility, for disease, for post-infection outcomes, and for infectiousness. The book includes methods for evaluating indirect, total and overall effects of vaccination programs in populations. Topics include household studies, evaluating correlates of immune protection, and applications of casual inference. Material on concepts of infectious disease epidemiology, transmission models, casual inference, and vaccines provides background for the reader. This is the first book to present vaccine evaluation in this comprehensive conceptual framework.

This book is intended for colleagues and students in statistics, biostatistics, epidemiology, and infectious diseases. Most essential concepts are described in simple language accessible to epidemiologists, followed by technical material accessible to statisticians.

Elizabeth Halloran and Ira Longini are professors of biostatistics at the University of Washington and the Fred Hutchinson Cancer Research Center in Seattle. Claudio Struchiner is professor of epidemiology and biostatistics at the Brazilian School of Public Health of the Oswaldo Cruz Foundation in Rio de Janeiro. The authors are prominent researchers in the area. Halloran and Struchiner developed the study designs for dependent happenings to delineate indirect, total, and overall effects. Halloran has made contributions at the interface of epidemiological methods, causal inference, and transmission dynamics. Longini works in the area of stochastic processes applied to epidemiological infectious disease problems, specializing in the mathematical and statistical theory of epidemics. Struchiner has contributed to understanding the role of transmission in interpreting vaccine effects.

EPIDEMIOLOGY

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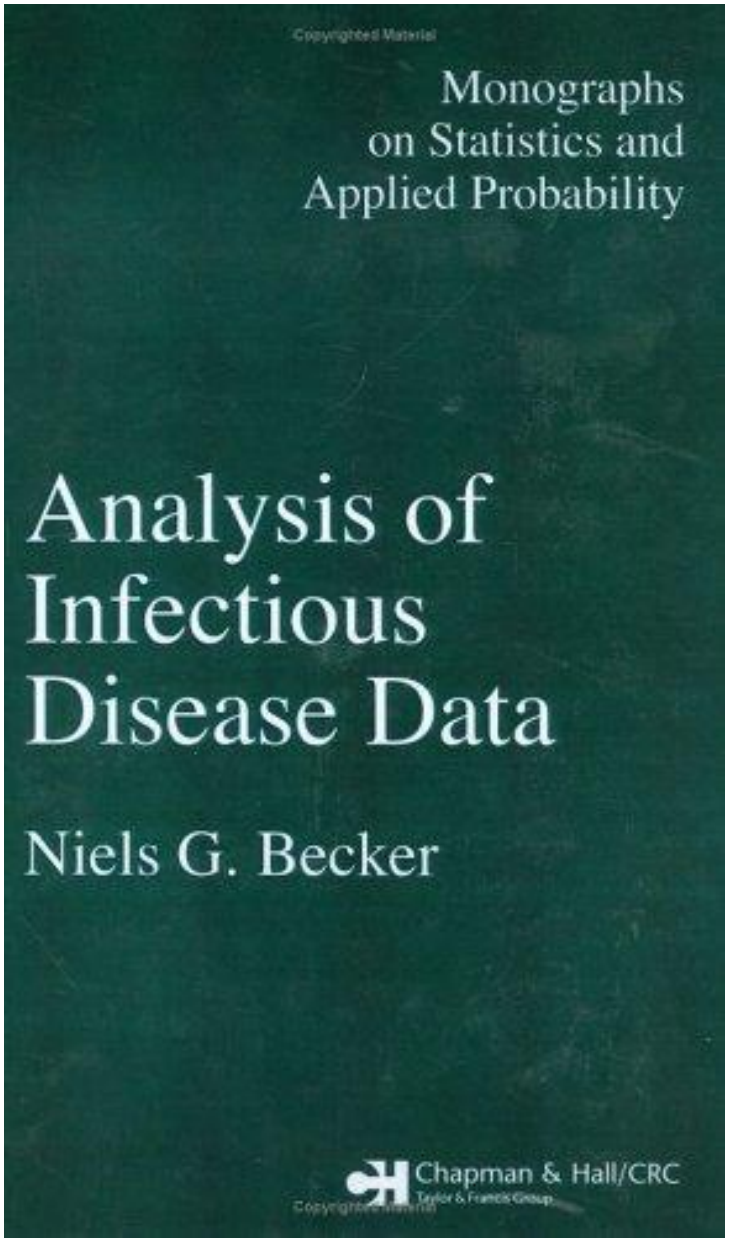
The Mathematical Theory of Infectious Diseases
and its Applications

Norman T. J. Bailey, M.A., D.Sc.
Unit of Health Statistical Methodology, World Health Organization, Geneva. Formerly Professor of Biomathematics, Cornell University Graduate School of Medical Sciences, and Member of the Sloan-Kettering Institute for Cancer Research

Second edition

CHARLES GRIFFIN & COMPANY LTD
London and High Wycombe



1975, 1st addition 1957

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Inference on infectious diseases modules in addition to this one

- **Module 7**: MCMC I for Infectious Diseases, July 15 – 17
- **Module 10**: Simulation-based Inference for Epidemiological Dynamics, July 17 – 19
- **Module 13**: MCMC II for Infectious Diseases, July 22 – 24
- **Module 14**: Spatial Statistics in Epidemiology and Public Health, July 22 – 24

Lectures

July 10:

1. Introduction to stochastic epidemic models; notation, properties, examples, IL, TB
2. Important properties: R_0, growth rate, generation intervals, etc., TB

July 11:

3. Inference on stochastic epidemic models, TB
4. Stochastic models for arboviruses, IL
5. Modeling using networks and other heterogeneities, TB
6. Different models for vaccine mechanisms, IL

Lectures

July 12:

7. Inference for small groups such as households, IL
8. Inference for large groups such as cities, TB
9. Study designs for evaluating vaccine efficacy, IL
10. Cluster randomized vaccine trials for emerging infectious disease epidemics: The case of ring vaccination for Ebola, IL

Some Infectious Diseases Under Study

- Influenza
- Novel Coronavirus, SARS-CoV, MERS-CoV
- Ebola and other filoviruses
- Cholera, Typhoid, Rotavirus
- Dengue, Zika, Chikungunya
- Lassa, Nipah, plague
- HIV
- Others, polio, pertussis, hand-foot-and-mouth (EV71)
- Agent X

WHO Blueprint to prevent epidemics

World Health Organization

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A research and development Blueprint for action to prevent epidemics

2018 annual review of the Blueprint list of priority diseases

The second annual review of the Blueprint priority diseases was held in February 2018. WHO has developed a special tool for determining which diseases and pathogens to prioritize for research and development in public health emergency contexts. This tool seeks to identify those diseases that pose a public health risk because of their epidemic potential and for which there are no, or insufficient, countermeasures. Experts consider that given their potential to cause a public health emergency and the absence of efficacious drugs and/or vaccines, there is an urgent need for accelerated research and development for nine diseases.

List of Blueprint priority diseases

https://www.who.int/blueprint/en/

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WHO Blueprint priority diseases

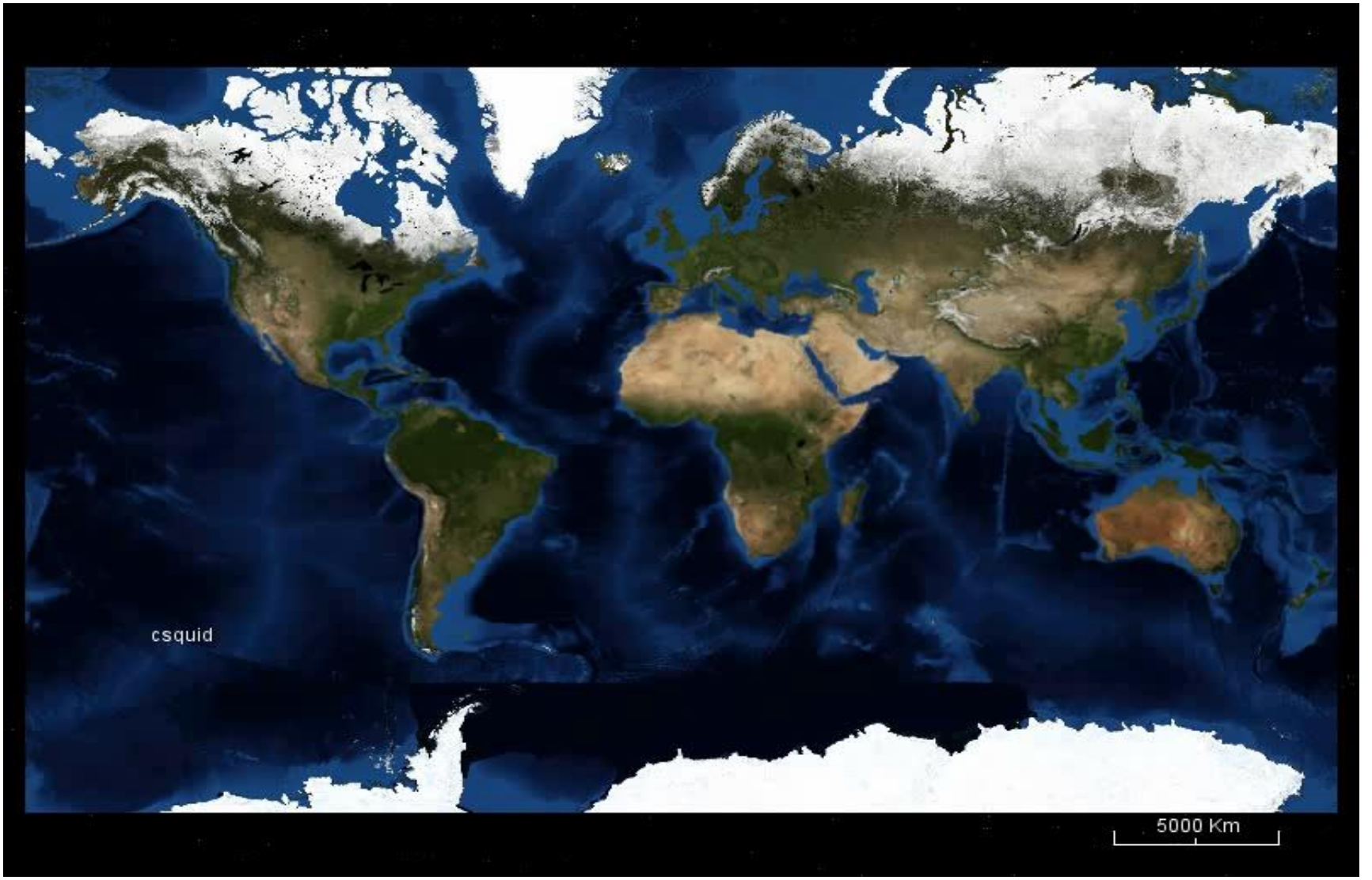
- Crimean-Congo haemorrhagic fever (CCHF)
- Ebola virus disease and Marburg virus disease
- Lassa fever
- Middle East respiratory syndrome coronavirus (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS)
- Nipah and henipaviral diseases
- Rift Valley fever (RVF)
- Zika
- Disease X

https://www.who.int/blueprint/priority-diseases/en/

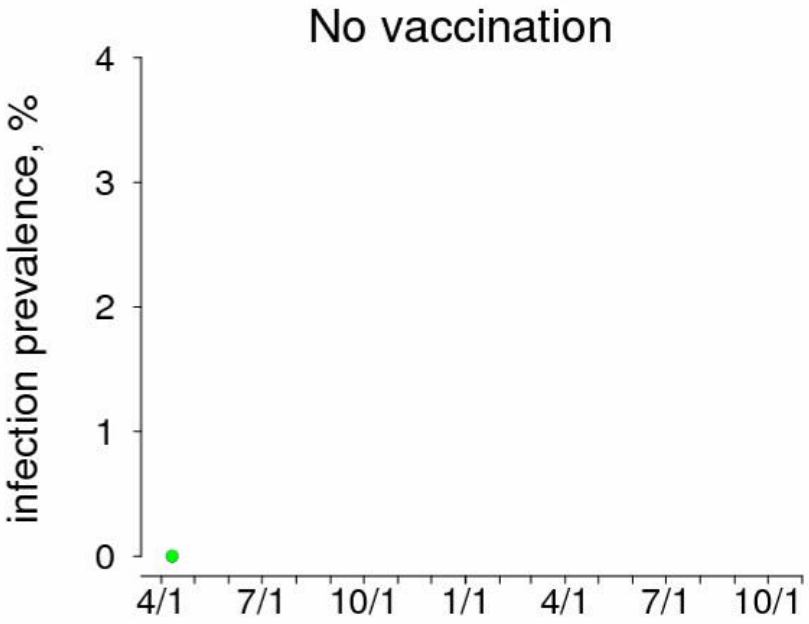
Some Examples

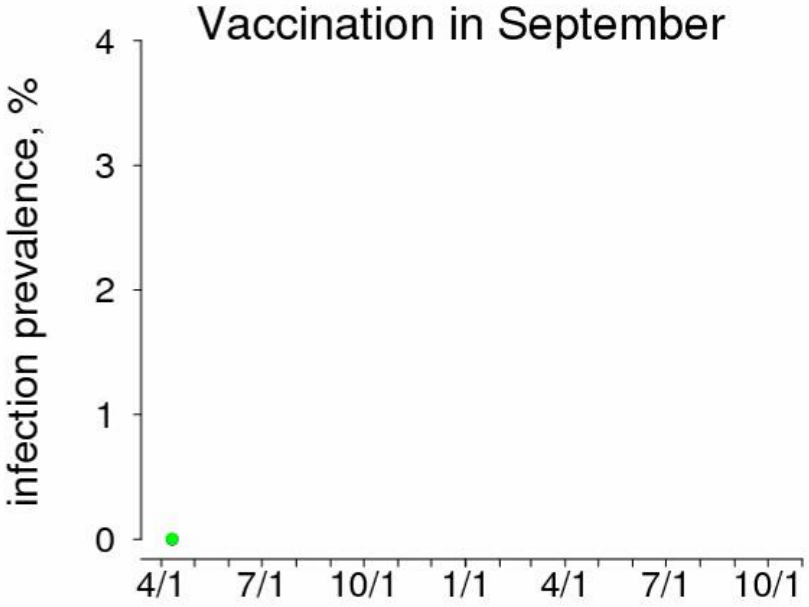
Pandemic H1N1, 2009-2010

Stochastic, Compartmental, Patch



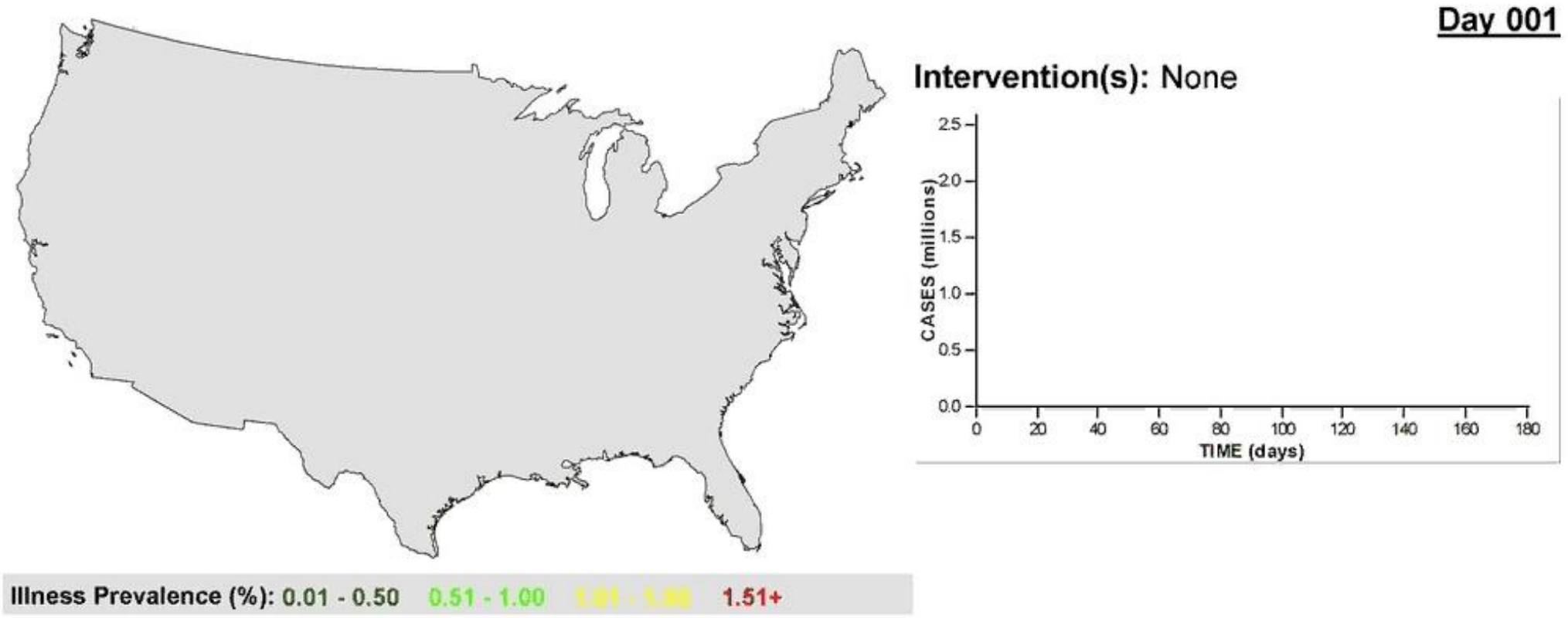
Pandemic H1N1 With Vaccination



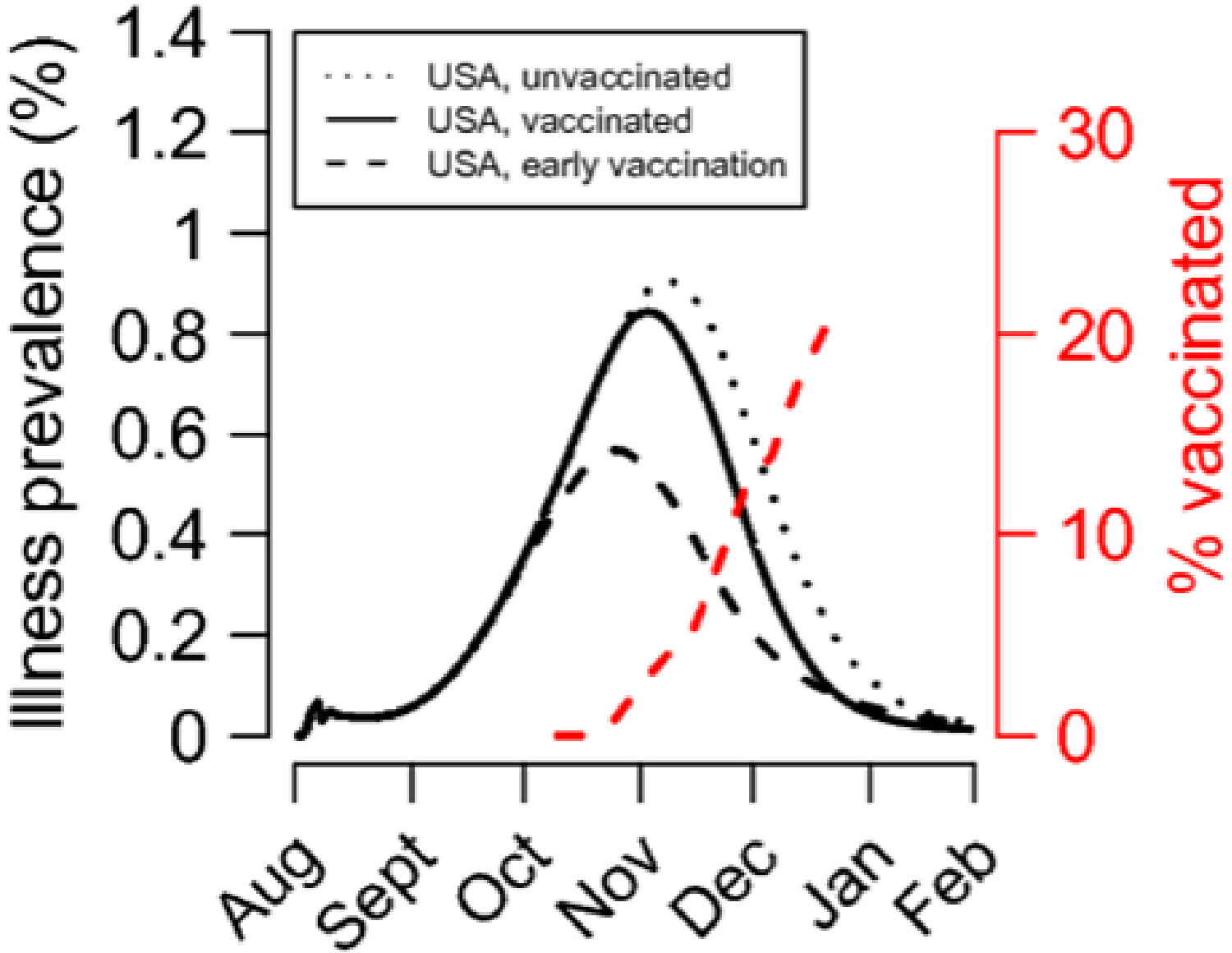


Spread the within US

Agent-based, RF



Simulated Mass Vaccination in US

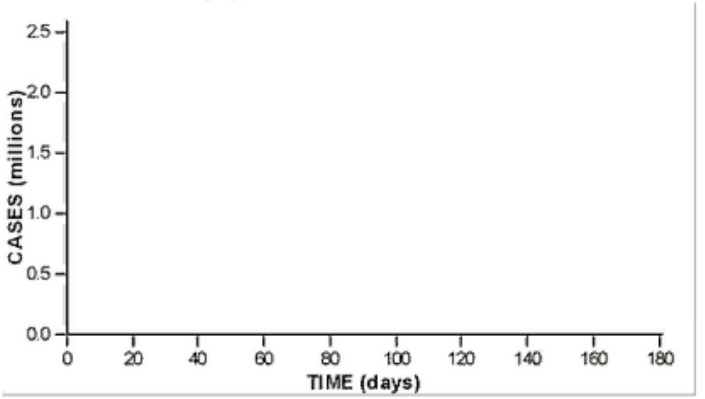


What Could Have Been Done

Agent-based, RF

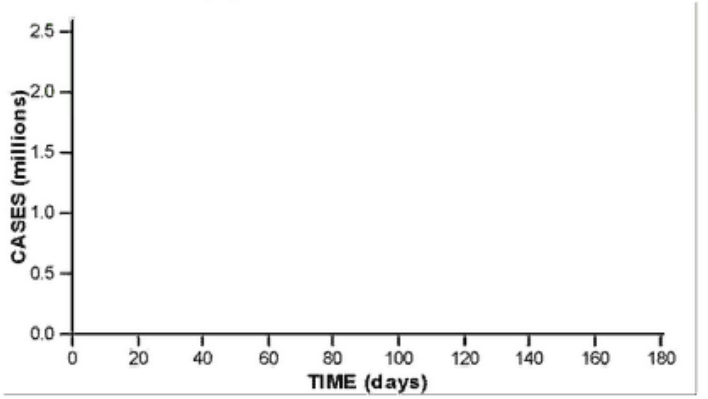
Day 001

Intervention(s): None



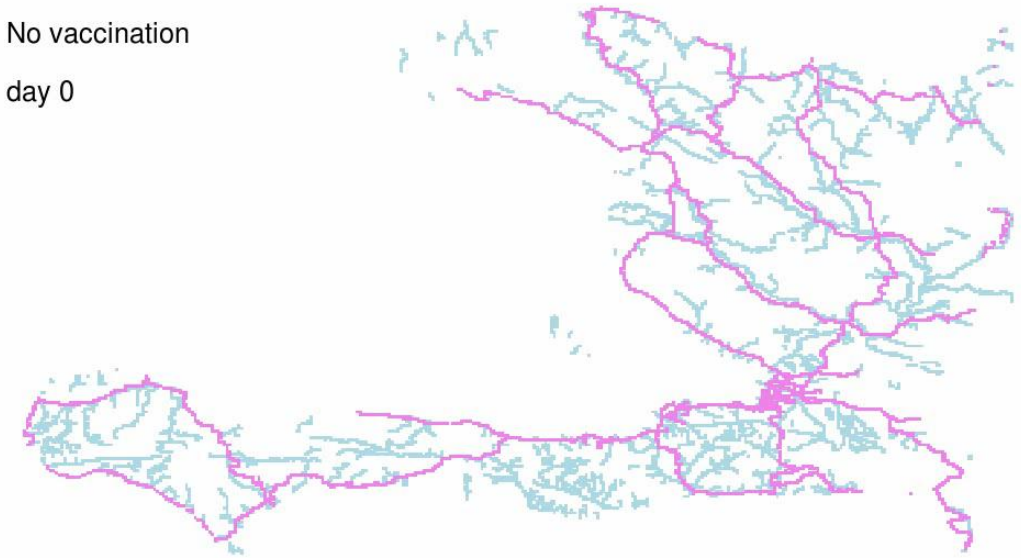
Illness Prevalence (%): 0.01 - 0.50 0.51 - 1.00 1.01 - 1.50 1.51+

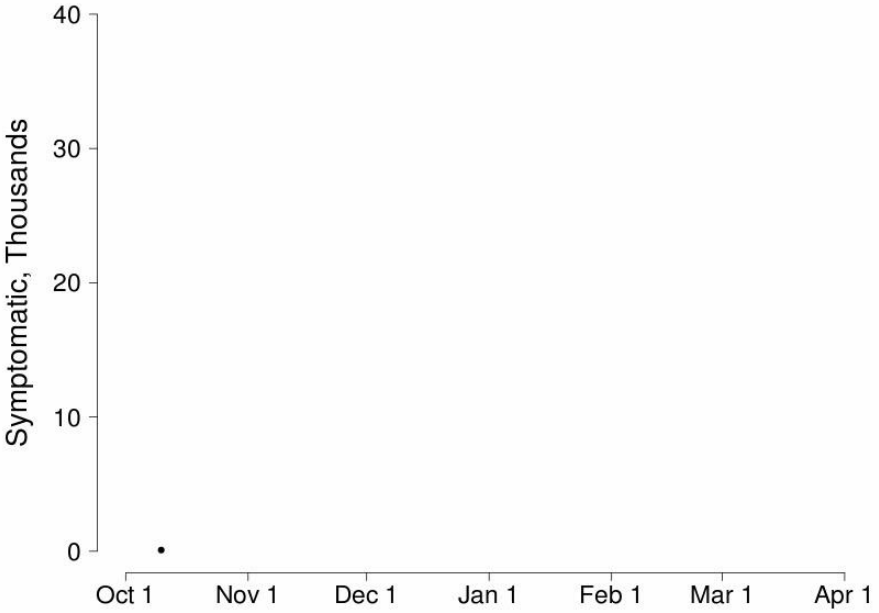
Intervention(s): Vaccination

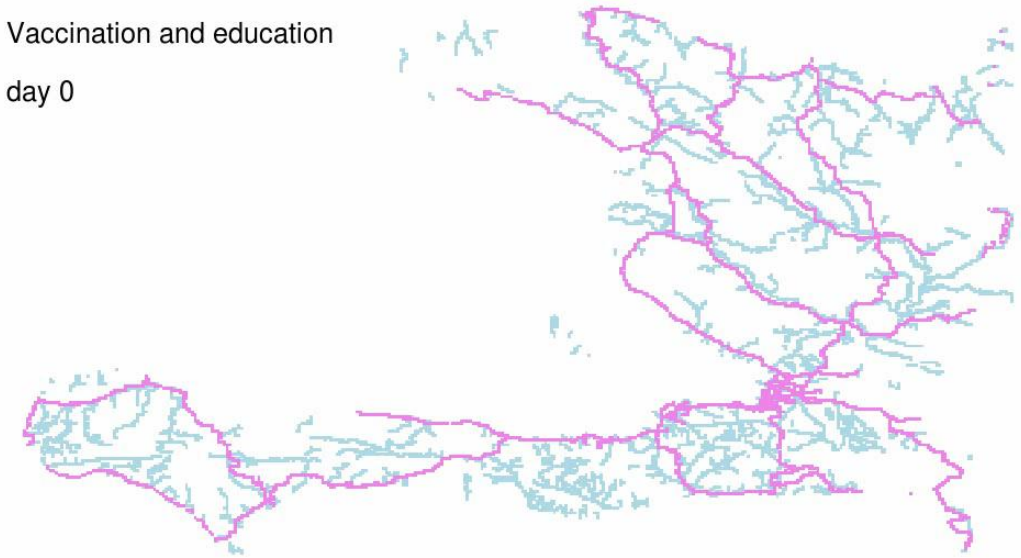


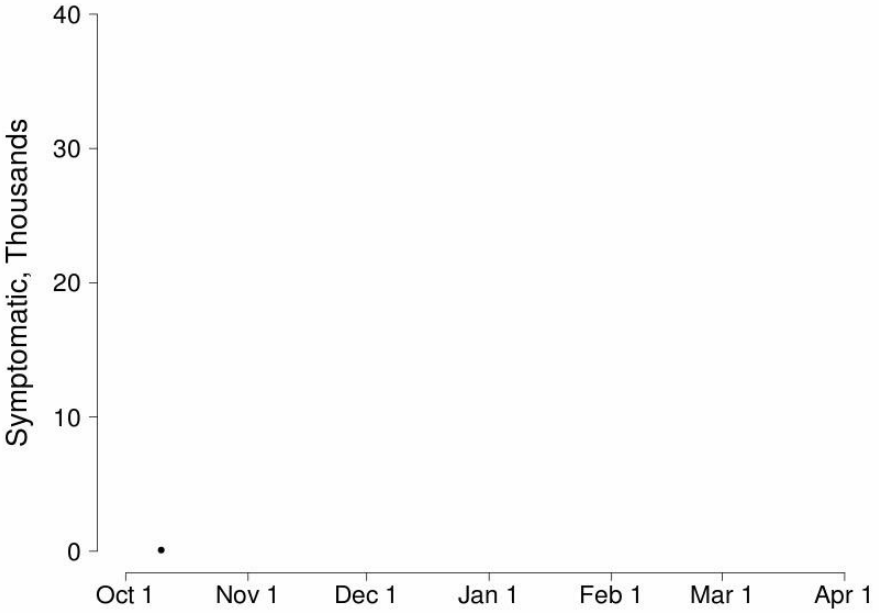
Cholera Epidemic in Haiti with Reactive Vaccination,

Agent-based, RF



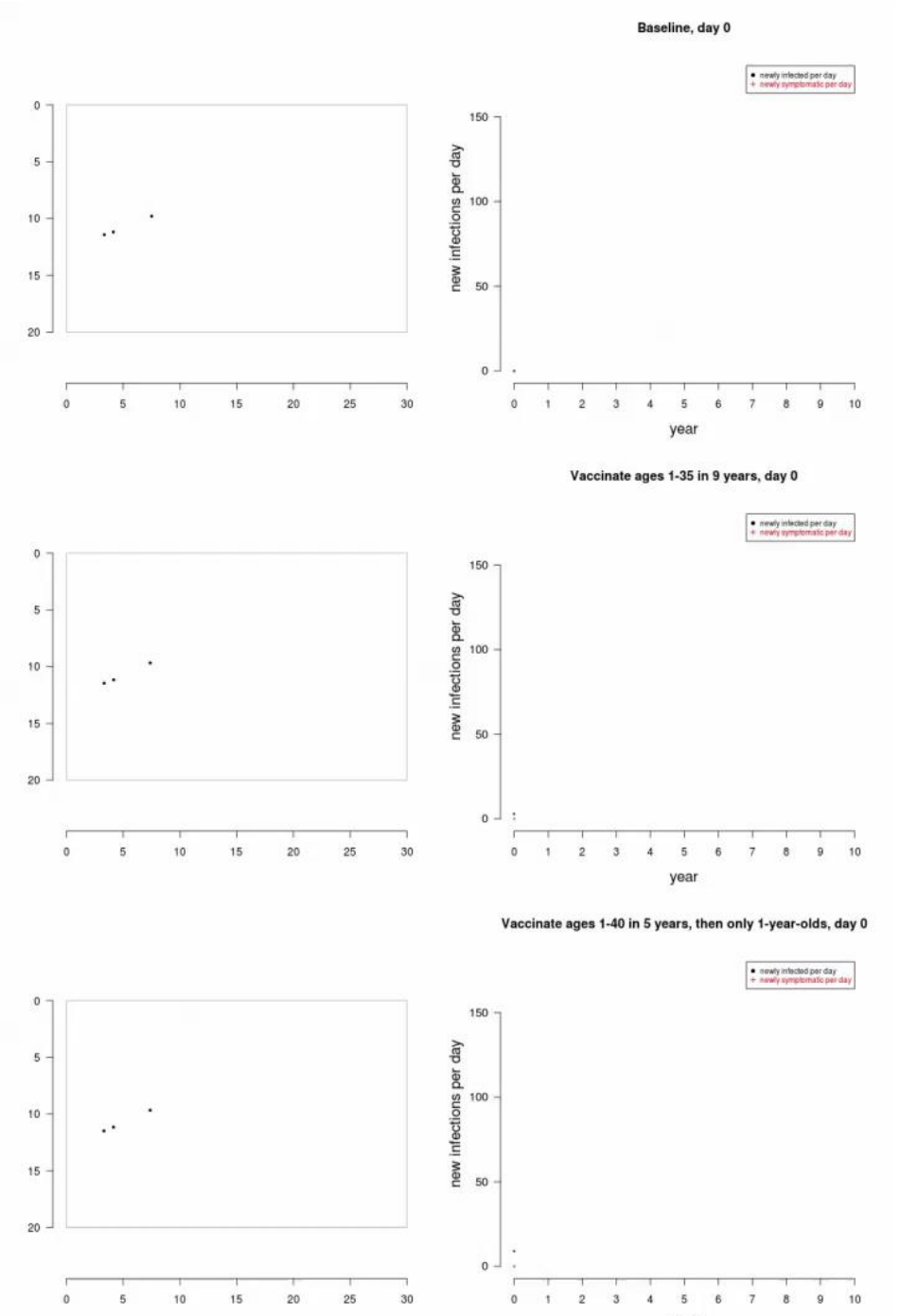






Dengue Vaccines in Thailand

Agent-based, RF



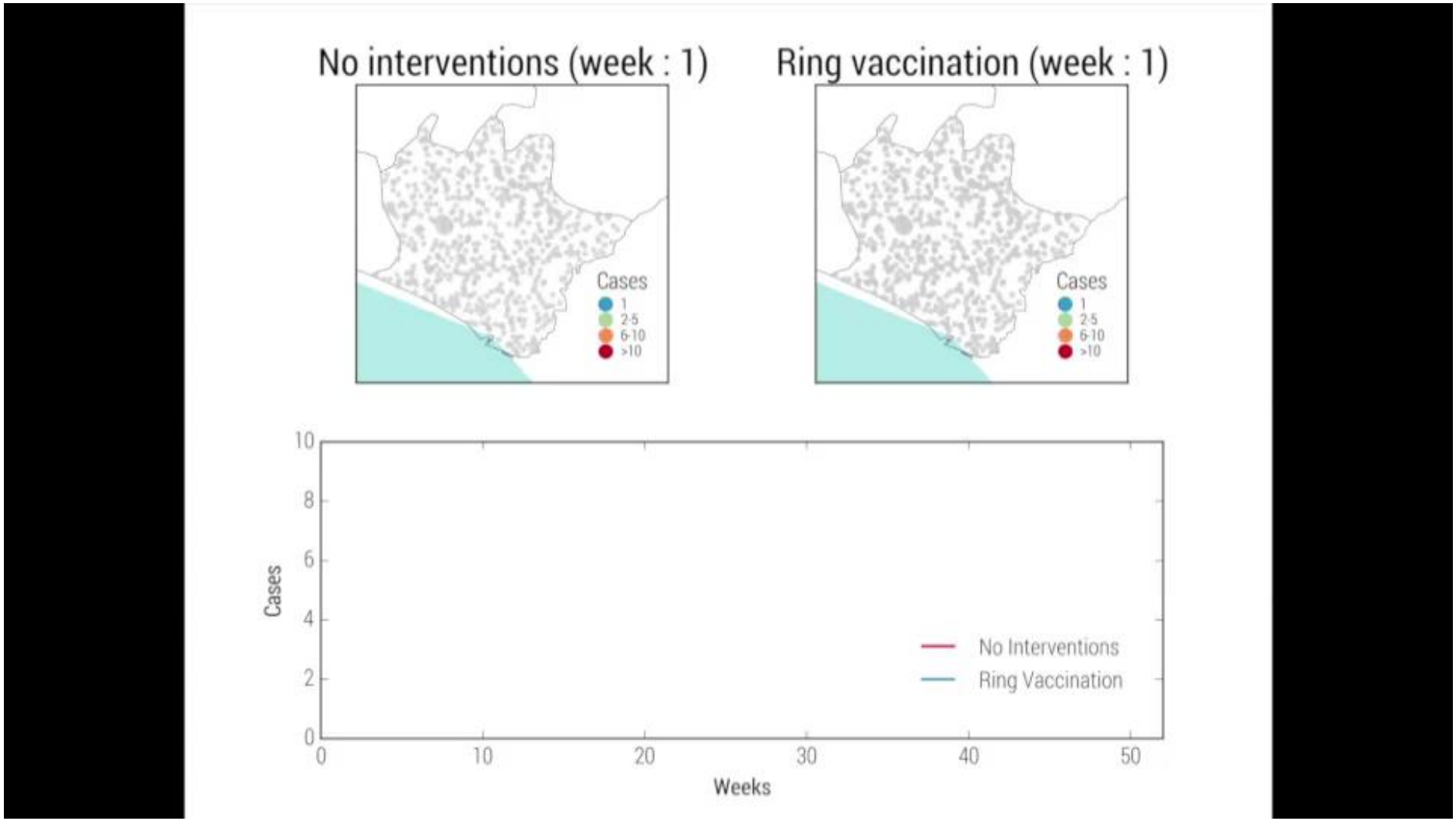
Ebola vaccine trials

- Phase III Ebola ring vaccination efficacy trial in Guinea – VSV vaccine estimated to have 100% efficacy.
- Stochastic transmission models have been used to help estimate vaccine efficacy and effectiveness
- Ring vaccination is used to eliminate Ebola in human populations, e.g., smallpox eradication

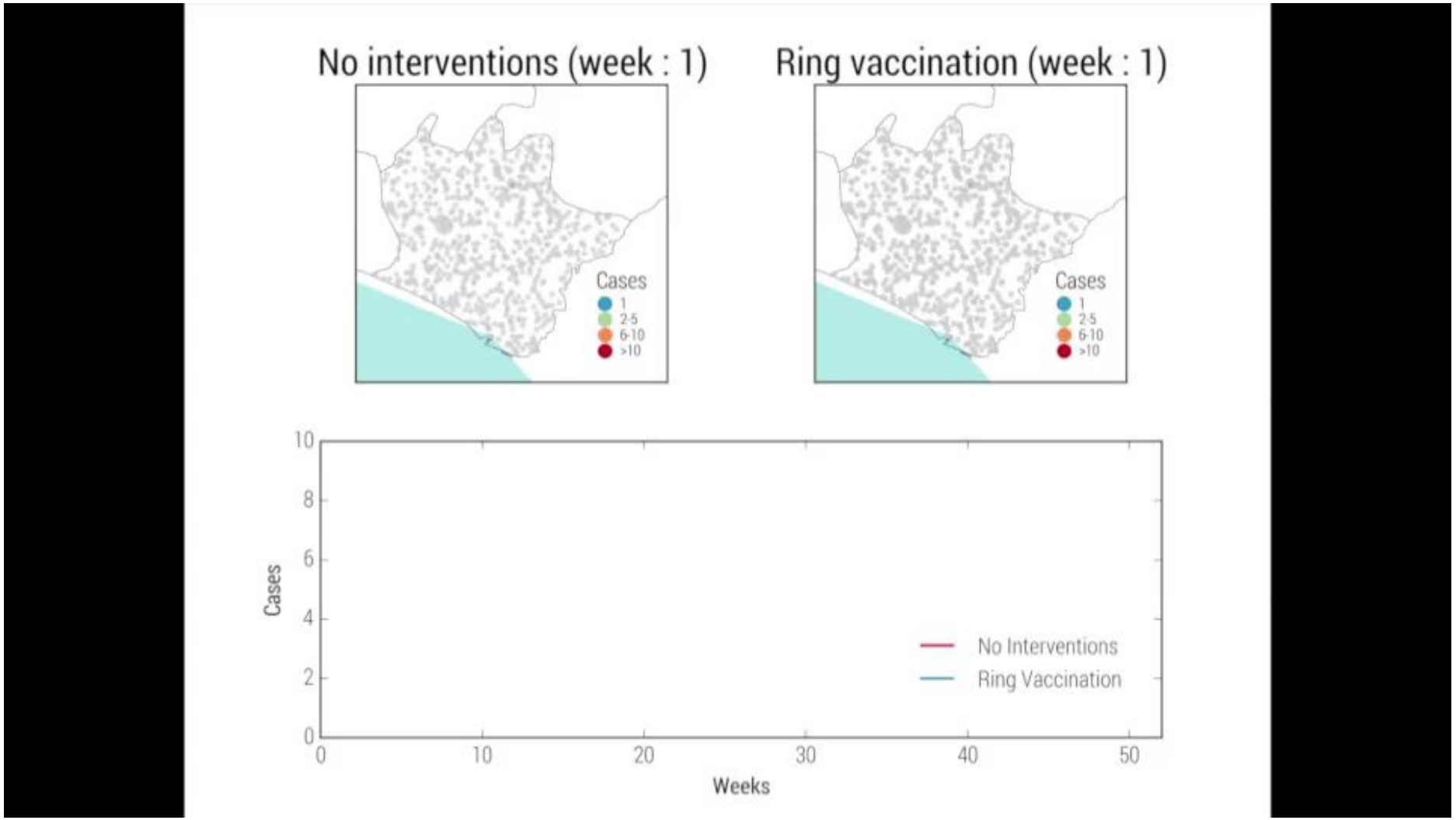
Current epidemic in the DRC July 7, 2019

- 2,418 confirmed cases
- 1,630 deaths, crude CFR 67%
- 154,878 people vaccinated with rVSV-ZEBOV vaccine in a ring vaccination strategy
- Cases are concentrated in the provinces of North Kivu and Ituri
- Significant violence and instability in many of the affected areas

Ring vaccination contained



Ring vaccination not contained



To lecture 1