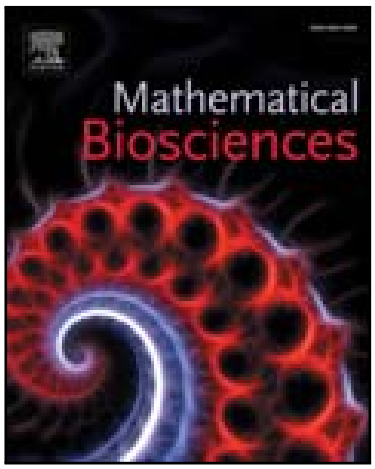

Simple multi-scale modeling of the transmission dynamics of the 1905 plague epidemic in Bombay

Bruce Pell, Tin Phan, Erica M. Rutter, Gerardo Chowell, Yang Kuang

PII: S0025-5564(18)30085-3
DOI: 10.1016/j.mbs.2018.04.003
Reference: MBS 8065

To appear in: *Mathematical Biosciences*

Received date: 9 February 2018
Revised date: 10 April 2018
Accepted date: 10 April 2018

Please cite this article as: Bruce Pell, Tin Phan, Erica M. Rutter, Gerardo Chowell, Yang Kuang, Simple multi-scale modeling of the transmission dynamics of the 1905 plague epidemic in Bombay, *Mathematical Biosciences* (2018), doi: 10.1016/j.mbs.2018.04.003

Simple multi-scale modeling of the transmission dynamics of the 1905 plague epidemic in Bombay

Bruce Pell[a,1], Tin Phan[b,1,*], Erica M Rutter[c], Gerardo Chowell[d], Yang Kuang[b]

[a]*Department of Mathematics, Statistics, and Computer Science, St. Olaf College, Minnesota, USA*
[b]*School of Mathematical and Statistical Sciences, Arizona State University, Arizona, USA*
[c]*Department of Mathematics, North Carolina State University, North Carolina, USA*
[d]*School of Public Health, Georgia State University, Georgia, USA*

Abstract

The first few disease generations of an infectious disease outbreak is the most critical phase to implement control interventions. The lack of accurate data and information during the early transmission phase hinders the application of complex compartmental models to make predictions and forecasts about important epidemic quantities. Thus, simpler models are often times better tools to understand the early dynamics of an outbreak particularly in the context of limited data. In this paper we mechanistically derive and fit a family of logistic models to spatial-temporal data of the 1905 plague epidemic in Bombay, India. We systematically compare parameter estimates, reproduction numbers, model fit, and short-term forecasts across models at different spatial resolutions. At the same time, we also assess the presence of sub-exponential growth dynamics at different spatial scales and investigate the role of spatial structure and data resolution (district level data and city level data) using simple structured models. Our results for the 1905 plague epidemic in Bombay indicates that it is possible for the growth of an epidemic in the early phase to be sub-exponential at sub-city level, while maintaining near exponential growth at an aggregated city level. We also show that the rate of movement between districts can have a significant effect on the final epidemic size.

Keywords: multi-scale modeling, sub-exponential growth, plague epidemic, 1905 Bombay plague, mathematical modeling, disease transmission dynamics

1. Introduction

Compartmental dynamic models have become a standard tool to investigate mechanisms of infectious disease transmission and control [1]. This approach is particularly successful in improving our understanding of the spread of infectious diseases when sufficient outbreak data or key epidemiological parameters such as transmission rates are available. However, in reality each new outbreak emerges with factors that may differ from previously well-studied outbreaks, e.g. geographical, socio-economical, strain variation. Thus, we can argue that during the early stage of a new outbreak, when data is scarce and is subject to significant

*Corresponding author
Email addresses: pell1@stolaf.edu (Bruce Pell), tin.t.phan@asu.edu (Tin Phan), erutter@ncsu.edu (Erica M Rutter), gchowell@gsu.edu (Gerardo Chowell), kuang@asu.edu (Yang Kuang)
[1]Contributed equally