Modelling in Public Health

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Content

Background

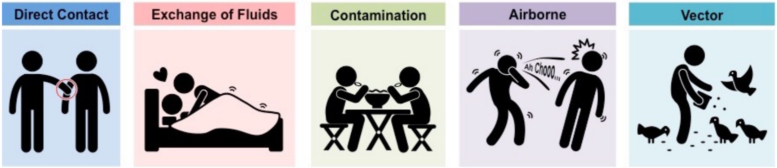
Infectious diseases are a serious **burden** for human health

Results in **loss of QUALYs** and also money

WHO: **50,000 deaths per day** due to infectious diseases

Outbreaks vs endemic infection

Different chains **transmission**:



Outbreaks

Influenza pandemic “swine flu”

Global, 2009-2010, 100,000 – 400,000 deaths

Ebola

West Africa, 2014-2016, 11,000 deaths
DRC, since 2018, 1,900 deaths

Zika Virus

Brazil, 2015-2016, ca. 215,000 cases (CHECK!) wolrdwide

Measles

Europe, 2019, ca. 6,300 cases from Jan–Apr
Austria, 2019, more than 130 cases up to this week

How can modellers help?

Outbreak situations:

- Exploit all data
- Inform response team in real time

Non outbreak situations:

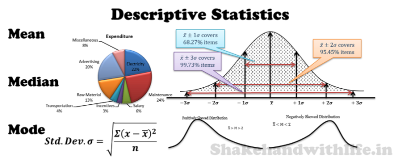
- Evaluate health programmes (vaccination, WHO elimination targets)
- Find high impact and cost-effective interventions
- Allow evidence based decisions

Benefits of modelling:

- Cheap: Clinical trials are expensive and seldom large enough
- Often little or no data to analyse (new emerging diseases)

Types of models

Statistical



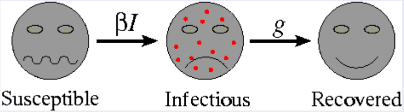
Descriptive

Regression

Bayesian statistics

Spatial models

Mathematical



Dynamic, compartmental (SIR)

Stochastic - Markov chain

Deterministic

Agent-based

Intervention effect - Invasive Pneumococcal Disease (IPD)

Streptococcus pneumoniae-related infections:
among children main cause of
meningitis bacterial pneumonia sepsis
90 distinct pneumococcal serotypes Only a small number account for invasive pneumococcal disease (IPD) January 2012: pneumococcal conjugate vaccine introduced in the national childhood immunisation program:
covering 10 serotypes (PCV10) administered at 3rd, 5th and 12th month of life unded
Other vaccines: PCV13, PPV23

IPD - The Model

Serfling-like Model

$$
\begin{aligned}
\log(Y_t) = & \beta_0 + \beta_1 t + \beta_2 \sin\left(\frac{2\pi t}{12}\right) + \beta_3 \cos\left(\frac{2\pi t}{12}\right) \\
& + \beta_5 (t - t_0)^+ + \mathbb{1}_{t - t_0 > 0}\left[\beta_4 + \beta_6 \sin\left(\frac{2\pi t}{12}\right) + \beta_7 \cos\left(\frac{2\pi t}{12}\right)\right] \\
& + \log(pop_t)
\end{aligned}
$$

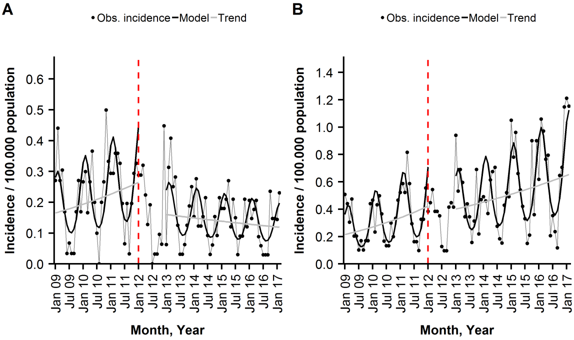
with

$$
(x)^+ = \begin{cases} x, & \text{if } x > 0, \\ 0, & \text{otherwise.} \end{cases}
$$

Richter et al., 2019

IPD - Results

Figure: Monthly incidence of (A) PCV10 ST-IPD and (B) non-PCV10 ex ST 6A-/19A-IPD, among the ≥50 years old, observed and modelled by a segmented negative binominal regression, Austria, January 2009-February 2017, shown are overall and seasonal trends.

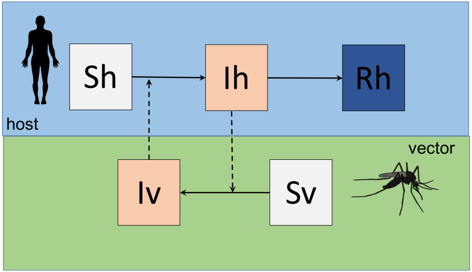


Mathematical modelling - Zika Virus

Zika introduction

Transmission model of Zika Virus

Vars	Description
S_h	Susceptible Humans
I_h	Infected/Infectious humans
R_h	Humans recovered from infection (with lifelong immunity)
S_v	Susceptible vectors
E_v	Exposed vectors



adapted from
https://www.reconlearn.org/ and Ferguson et al., 2016

Transmission model of Zika Virus

Humans/Host

$$\frac{dS_h}{dt} = \mu_h N_h - \frac{\beta_h b}{N_h} S_h I_v - \mu_h S_h$$

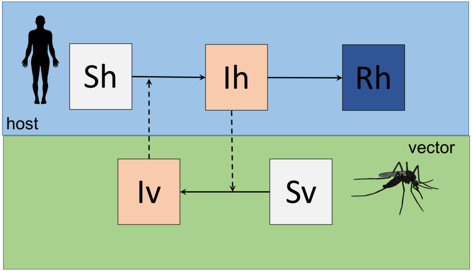
$$\frac{dI_h}{dt} = \frac{\beta_h b}{N_h} S_h I_v - (\gamma_h + \mu_h) I_h$$

$$\frac{dR_h}{dt} = \gamma_h I_h - \mu_h I_h$$

Vectors

$$\frac{dS_v}{dt} = \mu_v N_v - \frac{\beta_v b}{N_h} I_h S_v - \mu_v S_v$$

$$\frac{dI_v}{dt} = \frac{\beta_v b}{N_h} I_h S_v - \mu_v I_v$$



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other applications

Sexually transmitted infections
Ebola
Malaria
Influenza (Nielsen) Nielsen et al., 2019
Foodborne outbreaks to identify the source of infection (poisson model)

Conclusion/Wrap up

We saw some examples of applied modelling
plays an increasingly important role in helping to guide the most high impact and cost-effective prevent disease
models can be critical tools in guiding public health action.
always comes with limitations (as other studies)
decision makers benefit, so do the affected people still a lot to do -
However, there are a number of challenges in achieving a successful interface between modelling and public health.

Any questions?

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[2] Neil M. Ferguson et al. "Countering the Zika Epidemic in Latin America". In: *Science* 353.6297 (July 22, 2016), pp. 353–354. ISSN: 0036-8075, 1095-9203. DOI: 10.1126/science.aag0219. pmid: 27417493. URL: https://science.sciencemag.org/content/353/6297/353 (visited on 06/19/2019).

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[4] Polonsky Jonathan A. et al. "Outbreak Analytics: A Developing Data Science for Informing the Response to Emerging Pathogens". In: *Philosophical Transactions of the Royal Society B: Biological Sciences* 374.1776 (July 8, 2019), p. 20180276. DOI: 10.1098/rstb.2018.0276. URL: https://royalsocietypublishing.org/doi/10.1098/rstb.2018.0276 (visited on 06/18/2019).

[5] R. E. Serfling, I. L. Sherman, and W. J. Houseworth. "Excess Pneumonia-Influenza Mortality by Age and Sex in Three Major Influenza A2 Epidemics, United States, 1957-58, 1960 and 1963". In: *American Journal of Epidemiology* 86.2 (Sept. 1967), pp. 433–441. ISSN: 0002-9262. DOI: 10.1093/oxfordjournals.aje.a120753. pmid: 6058395.

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