Modelling in Public Health

SE Scientific Communication, 2019

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Content

Background

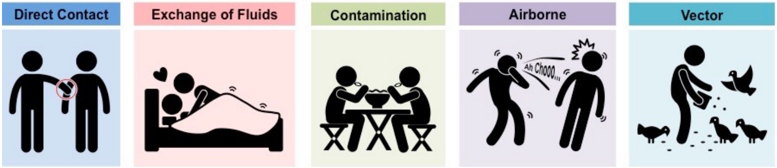
Infectious diseases are a serious **burden** for human health

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

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

Outbreaks vs endemic infection

Different chains of **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:

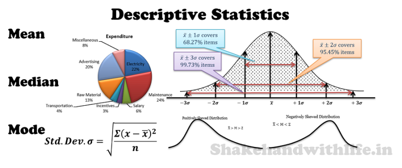
- Evaluate health programmes (vaccination, WHO elimination targets)
- Find high impact and cost-effective interventions
- Allow evidence based decisions

Benefits of modelling:

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

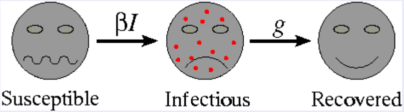
Types of models

Statistical



- Descriptive
- Regression
- Bayesian statistics
- Spatial models

Mathematical



- Dynamic, compartmental (SIR)
- Stochastic - Markov chain
- Deterministic
- Agent-based

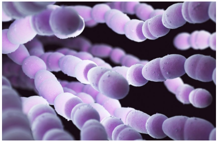
Intervention effect - Invasive Pneumococcal Disease (IPD)

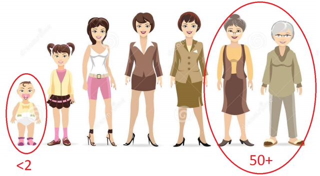
Caused by ***Streptococcus pneumoniae***

90 distinct pneumococcal serotypes

Highest burden: **infants** and **elderly**

Pneumococcal conjugate **vaccine introduced** in 2012 in AT for children





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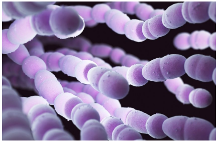


Vaccine effect? Direct? Indirect (elderly)?

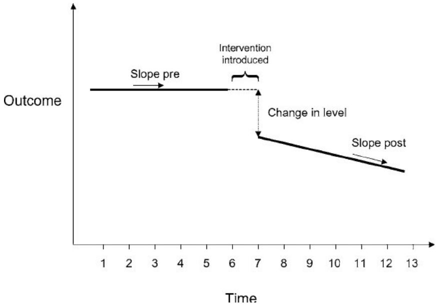
Segmented Regression - The Model

Serfling-like Model

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

with

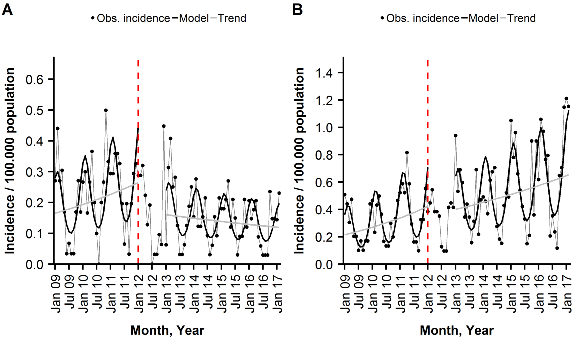
$$(x)^{+} = \begin{cases} x, & \text{if } x > 0, \\ 0, & \text{otherwise.}\end{cases}$$



Richter et al., 2019

IPD - Results

Figure: Monthly incidence of (A) **vaccine type** IPD (B) **non vaccine type** IPD, among the $\geq$**50 years old**, observed and modelled, Austria



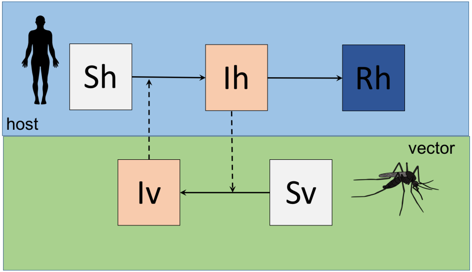
Richter et al., 2019

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

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

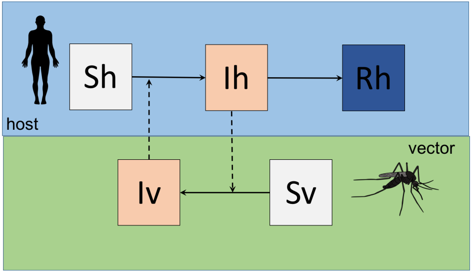
$$\frac{dI_h}{dt} = \frac{\beta_h b}{N_h} S_h I_v - (\gamma_h + \mu_h) I_h$$

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

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

Influenza mortality

Sexually transmitted infections (STI)

Foodborne outbreaks

Ebola

Tuberculosis

Malaria

Hepatitis C elimination

Conclusion/Wrap up

We saw some examples of applied modelling

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

Decision makers benefit - so do the affected people

still a lot to do - a number of challenges in achieving a successful interface between modelling and public health

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তোমাকে ধন্যবাদ
감사합니다
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merci

Any questions?

References

[1] Lukas Richter et al. "Invasive Pneumococcal Diseases in Children and Adults before and after Introduction of the 10-Valent Pneumococcal Conjugate Vaccine into the Austrian National Immunization Program". In: *PloS One* 14.1 (2019), e0210081. ISSN: 1932-6203. DOI: 10.1371/journal.pone.0210081. pmid: 30629620.

[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).

[3] J. Nielsen et al. "European All-Cause Excess and Influenza-Attributable Mortality in the 2017/18 Season: Should the Burden of Influenza B Be Reconsidered?" In: *Clinical Microbiology and Infection* (Feb. 18, 2019). ISSN: 1198-743X. DOI: 10.1016/j.cmi.2019.02.011. URL: http://www.sciencedirect.com/science/article/pii/S1198743X19300588 (visited on 04/08/2019).

[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.

[6] C. J. E. Metcalf, W. J. Edmunds, and J. Lessler. "Six Challenges in Modelling for Public Health Policy". In: *Epidemics*. Challenges in Modelling Infectious DIsease Dynamics 10 (Mar. 1, 2015), pp. 93–96. ISSN: 1755-4365. DOI: 10.1016/j.epidem.2014.08.008. URL: http://www.sciencedirect.com/science/article/pii/S1755436514000620 (visited on 06/23/2019).