

Modelling in Public Health

SE Scientific Communication
Summer 2019

Lukas Richter

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Background

Public Health is “[...] the science and art of preventing disease, prolonging life and promoting human health [...]”

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

Loss of QUALYs and also money

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

Outbreaks vs endemic infection

Different chains of **transmission**:



How can modellers help?

Outbreak situations:

- Exploit** all available data

- Inform** response team in real time

- Prioritise** interventions

Non outbreak situations:

- Evaluate** health programmes (vaccination, WHO elimination targets)

- Find **high impact and cost-effective** interventions

- Allow **evidence** based decisions

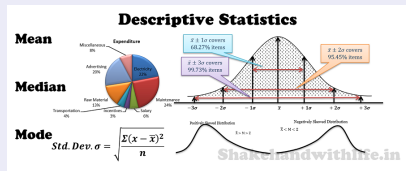
Benefits of modelling:

- Low cost!** Clinical trials are expensive and seldom large enough

- Often little or no data to analyse (new emerging diseases)

Types of models

Statistical



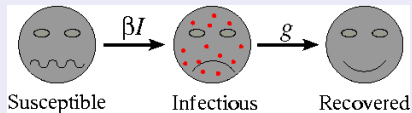
Regression

Descriptive

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**

Vaccine introduced in 2012 in AT for children



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Vaccine effect? Direct? Indirect (elderly)?

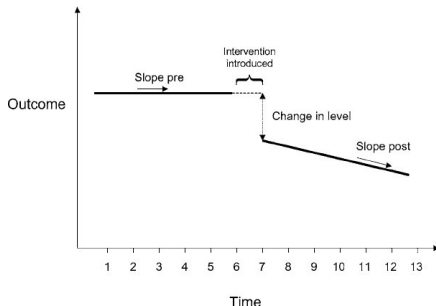
IPD – A Segmented Regression Model

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

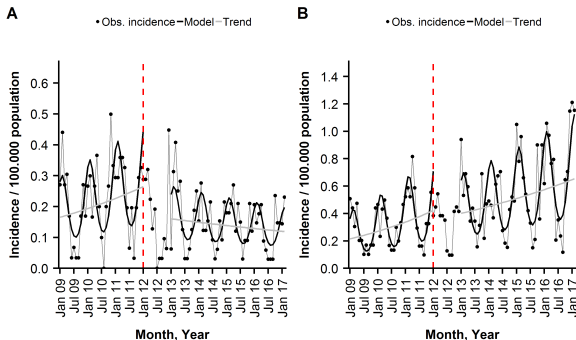
$$(x)^+ = \begin{cases} x, & \text{if } x > 0, \\ 0, & \text{otherwise.} \end{cases}$$



Richter et al., 2019

IPD – Results

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



The vaccine type IPD was **reduced by 67%** (95% CI: 32%; 84%).

Richter et al., 2019

Mathematical modelling – Zika Virus

Humans infected by **mosquitos**
daytime-active *Aedes* family

Latin American Zika epidemic (Feb 2016)

Summer Olympics in Rio

Global transmission (75 countries)

e.g. *A. albopictus* **found in AT** in 2012

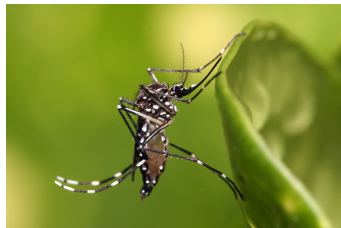
Mostly **flu-like** or **no** symptoms

Dangerous for **foetuses and neonates**

Brain malformations

Microcephaly (small head)

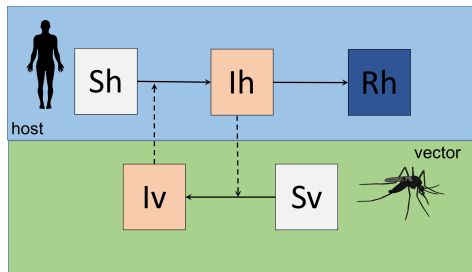
Figure: *Aedes aegypti*



Source: Muhammad Mahdi Karim, Wikipedia

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

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

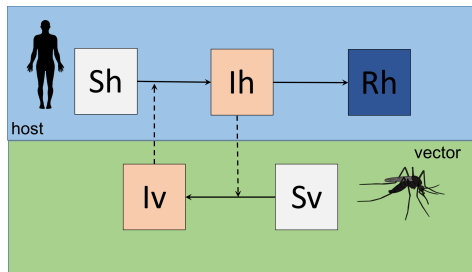
$$\frac{dI_h}{dt} = \frac{\beta_h b}{N_h} S_h I_v - (\gamma_h + \mu_h) I_h$$

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

Vectors

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

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



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

Zika Virus - Modelling Outcome

Herd immunity after first epidemic

Epidemic will **re-occur** every 15-20 yrs

An epidemic will last about 3-5 yrs

Shorter on local scale: 6 months

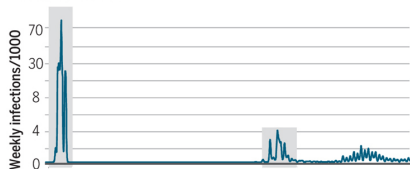
Intervention on mosquitoes has also negative effects

Outbreak lasts longer

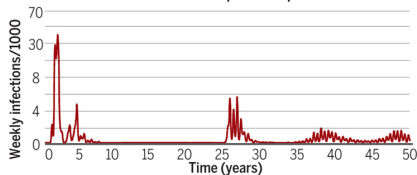
Less time between epidemics

Zika epidemic simulations

No intervention



With intervention to reduce mosquito life span



Ferguson et al., 2016

Conclusion

Modelling **increasingly important**

Guide the highest **impact** and **cost-effective** preventions

Critical tool for public health action

Model limitations

Decision makers **benefit** - so does the population

Challenges need to be solved

[illegible]



Any questions?

References

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Backup Slides

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, estimated 1 Mio cases in Brazil only and 2,000 confirmed severe complications in newborns

Measles

Europe, 2019, ca. 6,300 cases from Jan–Apr

Austria, 2019, more than 130 cases up to this week

Other Applications

Sexually transmitted
infections (STI)

Ebola

Malaria

Influenza mortality

Foodborne outbreaks

Tuberculosis

Hepatitis C elimination

Example of outbreak analytics workflow.

