Modelling in Public Health

SE Scientific Communication
Summer 2019

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Content

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Background

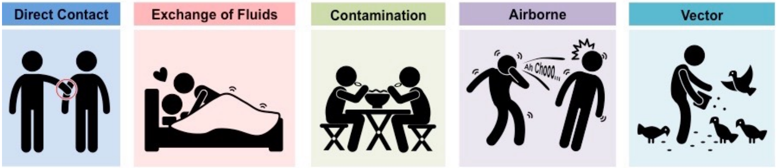
Infectious diseases are a serious **burden** for human health

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, 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

How can modellers help?

Outbreak situations:

- **Exploit** all available data
- **Inform** response team in real time
- **Prioritise** interventions

Non outbreak situations:

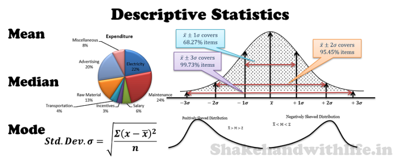
- **Evaluate** health programmes (vaccination, WHO elimination targets)
- Find **high impact and cost-effective** interventions
- Allow **evidence** based decisions

Benefits of modelling:

- **Low cost!** Clinical trials are expensive and seldom large enough
- Often little or no data to analyse (new emerging diseases)

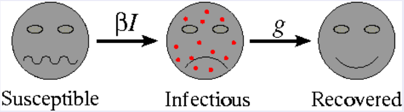
Types of models

Statistical



- Descriptive
- Regression
- Bayesian statistics
- Spatial models

Mathematical



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

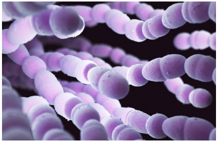
Intervention effect - Invasive Pneumococcal Disease (IPD)

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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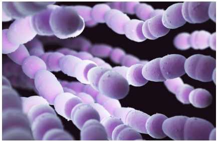


Vaccine effect? Direct? Indirect (elderly)?

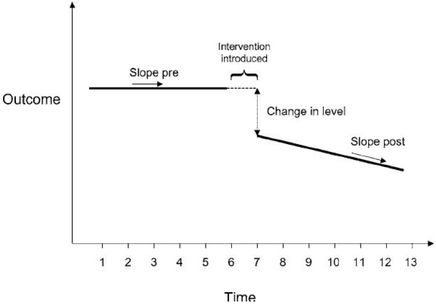
Segmented Regression - The Model

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

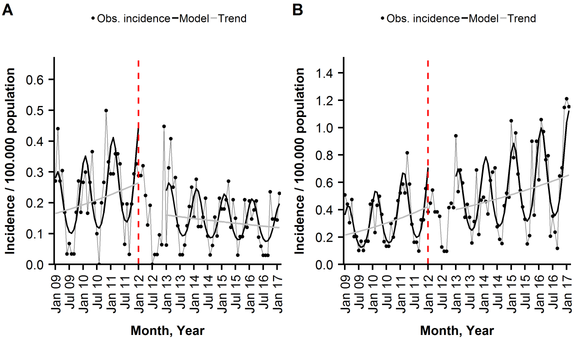
$$(x)^+ = \begin{cases} x, & \text{if } x > 0, \\ 0, & \text{otherwise.}\end{cases}$$



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

Humans are infected by **mosquitos**

daytime-active *Aedes* family

Latin American Zika epidemic in 2016

Summer Olympics in Rio

Global transmission to about 75 countries

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

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

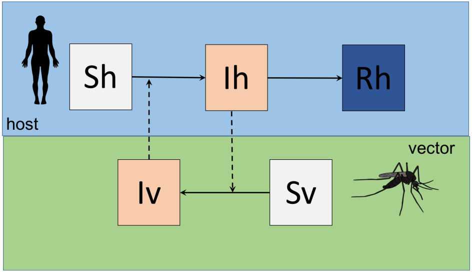
Dangerous for **foetuses and neonates**

Brain malformations

Microcephaly (small head)

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

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

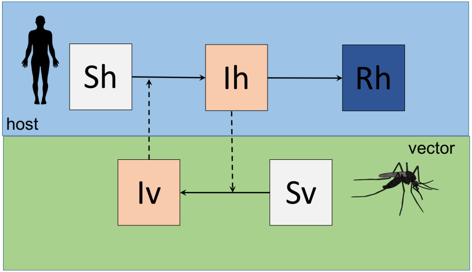
$$\frac{dI_h}{dt} = \frac{\beta_h b}{N_h} S_h I_v - (\gamma_h + \mu_h) I_h$$

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

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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Zika Virus - Modelling Outcome

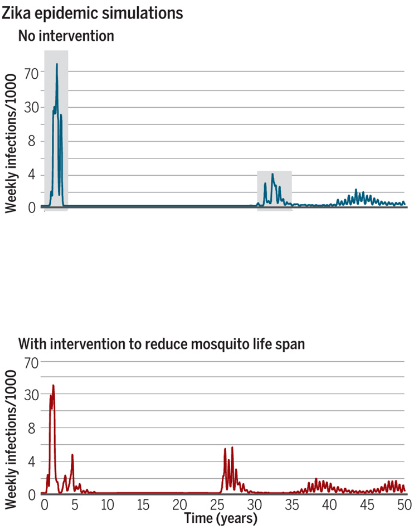
Herd immunity after first epidemic

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

An epidemic will last about 3-5 yrs

Shorter on local scale: 6 months

Develop **new interventions** before new large-scale outbreaks occur



Ferguson et al., 2016

Other Applications

Influenza mortality

Sexually transmitted infections (STI)

Foodborne outbreaks

Ebola

Tuberculosis

Malaria

Hepatitis C elimination

Conclusion

We presented two examples of applied modelling

Modelling plays an **increasingly important** role in helping to guide the most high **impact** and **cost-effective** prevention of disease

Models can be **critical tools** in guiding public health action.

Always comes with limitations

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

Still a number of **challenges** in achieving a successful interface between modelling and public health actors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謝謝
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Баярлалаа
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thank you
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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).