Modelling in Public Health

SE Scientific Communication
Summer 2019

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Content

Background

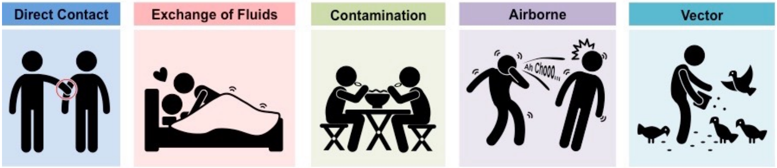
Infectious diseases are a serious **burden** for human health

Loss of QUALYs and also money

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

Outbreaks vs endemic infection

Different chains of **transmission**:



Background

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Different chains of **transmission**:

QUALY = quality-adjusted life year

many are preventable (vaccines) or curable

infection is constantly maintained at a baseline level in a geographic area without external inputs (steady state) / regularly found among particular people or in a certain area.

Outbreaks

Influenza pandemic "swine flu"

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

Ebola

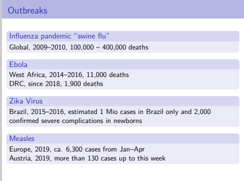
West Africa, 2014–2016, 11,000 deaths
DRC, since 2018, 1,900 deaths

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



Flu: this time: not more than usual season (see also Spanish flu 1918), 10-15 weeks earlier then normal

Ebola: CFR up to 40%

Measles EU: Romania, Lithuania, Italy, Poland, Bulgaria, Czech Republic, France, Greece, Slovakia

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)

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WHO elimination target for HIV-AIDS, Hepatitis C

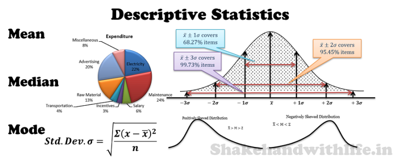
mathematical models can help to assess potential threats and impacts early in the process, and later aid in interpreting data

Public health programmes are usually implemented over a long period of time with broad benefits to many in the community.

WHO: over 30 new diseases emerged in the last 20 years

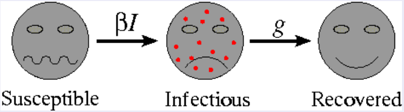
Types of models

Statistical



- Descriptive
- Regression
- Bayesian statistics
- Spatial models

Mathematical



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

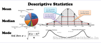
2019-06-26

Modelling in Public Health

└─Background

└─Types of models

Statistical



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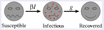

- Dynamic, compartmental (SIR)
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Dynamic models: origin is in the early 20th century

Modelling: higher influence with increasing computer power

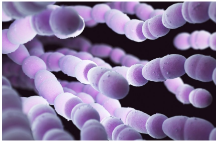
Intervention effect – Invasive Pneumococcal Disease (IPD)

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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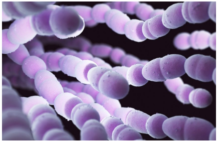

Vaccine effect? Direct? Indirect (elderly)?

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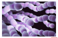

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s. pneumoniae: bacteria

Serotypes: Only a small number account for IPD

Risk: <2 and 50+

can result in: meningitis, bacterial pneumonia, sepsis

vaccine: covering 10 serotypes (PCV10)

3 doses in the first year (3rd, 5th, 12th month)

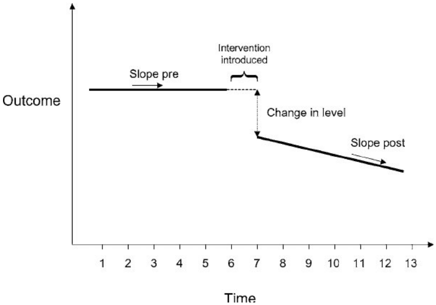
IPD – A Segmented Regression Model

Serfling-like Model

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

with

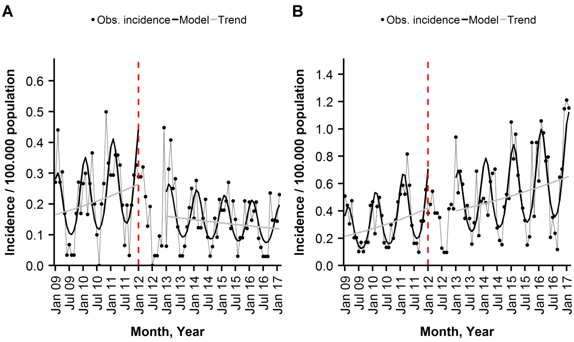
$$(x)^+ = \begin{cases} x, & \text{if } x > 0,\\ 0, & \text{otherwise.}\end{cases}$$



Richter et al., 2019

IPD – Results

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



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

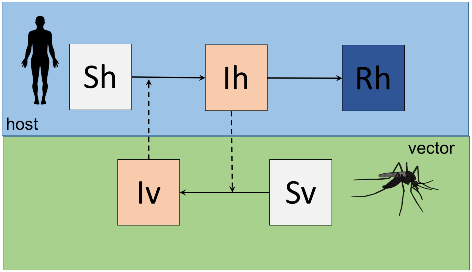
Microcephaly (small head)

Figure: *Aedes aegypti*

Source: Muhammad Mahdi Karim, `https://commons.wikimedia.org/w/index.php?curid=9556152`

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

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

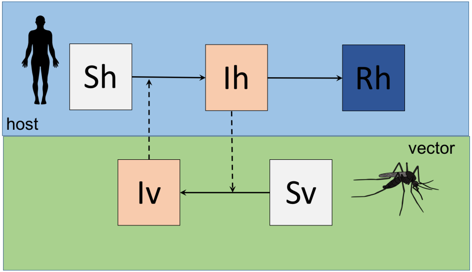
$$\frac{dI_h}{dt} = \frac{\beta_h b}{N_h} S_h I_v - (\gamma_h + \mu_h) I_h$$

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

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

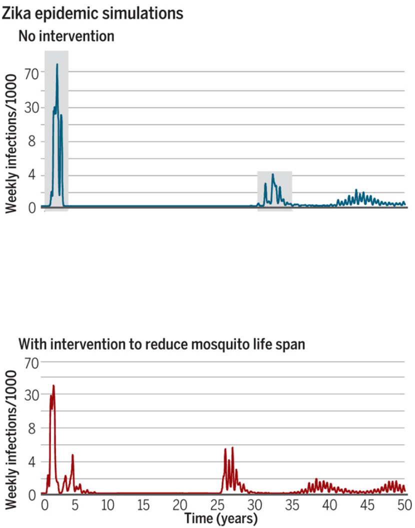
Herd immunity after first epidemic

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

An epidemic will last about 3-5 yrs

Shorter on local scale: 6 months

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



Ferguson et al., 2016

Other Applications

Sexually transmitted infections (STI)

Ebola

Malaria

Influenza mortality

Foodborne outbreaks

Tuberculosis

Hepatitis C elimination

Conclusion

Modelling plays an **increasingly important** role in helping to guide the most high **impact** and **cost-effective** preventions.

It can be a **critical tool** for guiding public health action.

Model limitations.

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

Still a number of **challenges** in achieving a successful interface between modelling and public health actors.


شكراً جزيلاً
thank you
gracias
danke
謝謝
ngiyabonga
teşekkür ederim
merci
obrigado
go raibh maith agat
mochchakkeram
sukriya
kop khun krap
dziękuję
bedankt
спасибо
terima kasih
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감사합니다
ありがとう
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Баярлалаа
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Any questions?

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