Disease

Ben Bolker

2014-04-03

Introduction

Disease as a natural enemy

- Infectious diseases can be classified as parasites
- Symbiotic, harm (but mostly don't kill) host
- Diseases certainly benefit from their hosts (**obligate** association)
- Can lump infectious diseases and classical parasites together

Micro- and macroparasites

- **Microparasites**: viruses, bacteria, fungi
- **Macroparasites**: worms, ticks, etc.
- Taxonomic/morphological definition: prokaryote/eukaryote; (non)-metazoan; etc.
- Modelling definition: **intensity-independent** (micro) vs. **intensity-dependent**
- i.e., we generally track *worm burden*, but not virus burden
- microparasite models are simpler (Anderson and May 1991; Keeling and Rohani 2008)

The SIR model

- "Susceptible-Infected-Removed"
- **compartmental** model
- Susceptibles are resource, Infected are exploiters

SIR model for a single epidemic

- Short time scale
- Ignore host birth and death (except recovery)

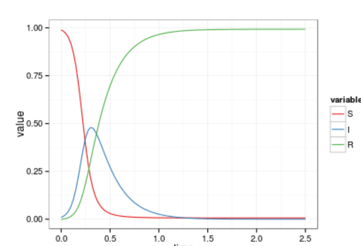

Figure 1: plot of chunk unnamed-chunk-1

SIR model for repeated epidemics

- Add host birth and death
- Damped oscillations

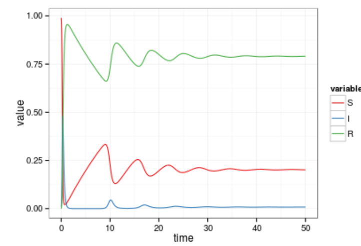

Figure 2: plot of chunk unnamed-chunk-2

SIR model with seasonal forcing

- Allow contact (predation) rate to vary seasonally
- Environmental variation (humidity, temperature), school

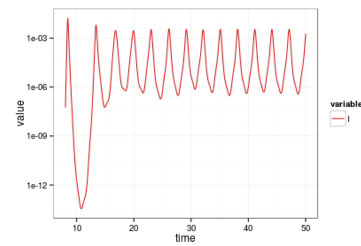

Figure 3: plot of chunk unnamed-chunk-3

Vector-host models

- mosquitoes: malaria, dengue, West Nile
- other (ticks/fleas): Lyme, bubonic plague
- cross-coupled host and vector populations
- susceptible mosquitoes bite infected humans
- infected mosquitoes bite susceptible humans
- humans are often *spillover* or *dead-end* hosts

Insight #1 from simple epidemic models

- R_0 tells you a lot
- reducing $R_0 < 1$ prevents outbreaks
- need effective treatment rate $p = 1 - 1/R_0$
- don't need p=100%: **herd immunity**
- treatment: vaccination, education, hygiene, quarantine, culling ...

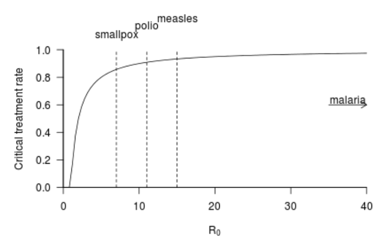

Figure 4: plot of chunk unnamed-chunk-4

Other insights from simple epidemic models

- at equilibrium $S^* = 1/R_0$
- final size of a single epidemic $\approx 1 - e^{-R_0}$
- cycles pop up everywhere
- treatment increases average age at infection
- treatment lengthens cycle periods

Focus on R_0 and eradication

- R_0 is mathematically easy
- eradication is politically attractive

- r is important if you need to predict the course of an outbreak
- we're often stuck with diseases we can't eradicate: need to *manage* them instead

Complications

- Host heterogeneity, core groups (80/20 rule)
- Complex contact patterns
- Evolution: virulence, host compatibility, antibiotic resistance
- Vector ecology

References

Anderson, Roy M., and Robert M. May. 1991. *Infectious Diseases of Humans: Dynamics and Control*. Oxford: Oxford Science Publications.

Keeling, Matthew James, and Pejman Rohani. 2008. *Modeling Infectious Diseases in Humans and Animals*. Princeton: Princeton University Press.