2022-2023 Harvard/University of Global Health Equity
Mathematical Modeling for Infectious Disease Planning

ESTIMATING R_o[1]

This activity sheet will serve as a guide to help you in estimating the basic reproduction number R_0 and the effective reproductive numbers given some disease transmission scenarios.

1. **Given the following information, calculate R_0 for the infection described.**

i. A directly transmitted infection has the following natural history. Just after infection, an individual goes through a latent period of being totally noninfectious (period 1); this lasts one month. Then there is a primary illness (period 2), which lasts 2 months; in an uninfected population, an average individual during this phase will infect 4 people per month. Then there is a long period (period 3), average length 10 years. During this period, individuals alternate between an infectious phase (10% of the time) and a noninfectious phase (90% of the time). During the infectious phase, an infectious individual would infect 1 person per month; during the noninfectious phase, the person is uncontagious. At the end of period 3 the individual recovers or dies. What is the value of R_0?

0 new infections in period 1; 8 new infections in period 2; (12 months)*(1 person per month) = 12 new infections in period 3. That's a total of R0 = 20.

ii. Consider an infection identical to that described in (i). The only difference is that there is no latent period (period 1 has length 0). How will this affect R_0? How will it affect r, the initial, exponential rate of increase of the prevalence of infection in the population?

R0 doesn't change, but the growth rate will increase (infections can start to occur sooner, and those people will go on to infect others sooner, etc.).

iii. In a vector-borne infection, the following is true: During parasitemia, a host is bitten once per day by mosquitoes, and the parasitemia lasts 10 days. 70% of bites on an infected host are infectious to mosquitoes. 50% of mosquitoes last long enough to bite another host, and 80% of mosquito bites are on other humans (the rest are on species that cannot

[1] Most of this material was adapted from the EPI 260 (Mathematical Modeling of Infectious Diseases) course by Professor Marc Lipsitch at the Harvard School of Public Health.

be infected). If an infected mosquito bites a human host, there is a 90% chance of infection. What is the value of R_0?

$R_0 = (10)(1)(0.7)(0.5)(0.8)(0.9) = 2.52$

iv. Consider an STD in a heterosexual population. All males behave the same, and all females behave the same. The duration of infectiousness is 3 months in either sex. Each month, a male has 3 partners and there is a 90% chance of transmission to each of these partners. Each month, a female has 3 partners and there is a 30% chance of transmission to each of these partners. What is the value of R_0?

For males: (3 months)*(3 partners/month)*(90% transmission) = 8.1. For females: (3 months)*(3 partners/month)*(30% transmission) = 2.7. R_0 is the expected number of people infected by an average infectious person in a fully susceptible population, so we take the average of these two quantities (assuming an equal proportion of males and females in the population): $R_0 = 5.4$.

2. Read the review paper by Li et al. (link below) and discuss the following within your teams.
   a. The methods for estimating R0
   b. Failures of R0 identified in the paper

Li et al. (2011): https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3157160/pdf/CMMM2011-527610.pdf