

# A MECHANISTIC MODEL TO COMPARE THE IMPORTANCE OF INTERRELATED POPULATION MEASURES: HOST POPULATION SIZE, DENSITY AND COLONY SIZE

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TABLE 1. A summary of all symbols used along with their units and default values. The justifications for parameter values are given in Section ??.

Symbol	Explanation	Units	Value
$\rho$	Number of pathogens		2
$x, y$	Colony index		
$p$	Pathogen index i.e. $p \in \{1, 2\}$ for pathogens 1 and 2		
$q$	Disease class i.e. $q \in \{1, 2, 12\}$		
$S_x$	Number of susceptible individuals in colony $x$		
$I_{qx}$	Number of individuals infected with disease(s) $q \in \{1, 2, 12\}$ in colony $x$		
$R_x$	Number of individuals in colony $x$ in the recovered with immunity class		
$N$	Total Population size		30,000
$m$	Number of colonies		10
$n$	Colony size		3,000
$a$	Area	km <sup>2</sup>	10,000
$\beta$	Transmission rate		0.1 – 0.4
$\alpha$	Coinfection adjustment factor		0.1
$\gamma$	Recovery rate	year <sup>-1</sup> .individual <sup>-1</sup>	1
$\xi$	Dispersal rate	year <sup>-1</sup> .individual <sup>-1</sup>	0.001–0.1
$\Lambda$	Birth rate	year <sup>-1</sup> .individual <sup>-1</sup>	0.05
$\mu$	Death rate	year <sup>-1</sup> .individual <sup>-1</sup>	0.05
$k_x$	Degree of node $x$ (number of colonies that individuals from colony $x$ can disperse to).		
$\delta$	Waiting time until next event	years	
$e_i$	The rate at which event $i$ occurs	year <sup>-1</sup>	

TABLE 2. Raw data for range size simulations. The population parameters are shown along with the number of invasions and the number of simulations. Note that simulations where both pathogens went extinct have been removed (100 simulations were originally run for each parameter set).  $\beta$  is the transmission rate,  $n$  is colony size,  $m$  is the number of colonies and  $N$  is the total population size.

$\beta$	$n$	$m$	Area ( $\times 1000 \text{ km}^2$ )	$N$ ( $\times 1000$ )	Density ( $\text{km}^{-2}$ )	Invasions	Sims
0.1	400	20	2.5	8	3.2	2	100
0.1	400	20	5.0	8	1.6	3	100
0.1	400	20	10.0	8	0.8	2	100
0.1	400	20	20.0	8	0.4	3	100
0.1	400	20	40.0	8	0.2	2	100
0.2	400	20	2.5	8	3.2	3	100
0.2	400	20	5.0	8	1.6	3	100
0.2	400	20	10.0	8	0.8	1	100
0.2	400	20	20.0	8	0.4	4	100
0.2	400	20	40.0	8	0.2	1	100
0.3	400	20	2.5	8	3.2	3	100
0.3	400	20	5.0	8	1.6	3	100
0.3	400	20	10.0	8	0.8	3	100
0.3	400	20	20.0	8	0.4	5	100
0.3	400	20	40.0	8	0.2	9	100

TABLE 3. Raw data for colony size simulations. The population parameters are shown along with the number of invasions and the number of simulations. Note that simulations where both pathogens went extinct have been removed (100 simulations were originally run for each parameter set).  $\beta$  is the transmission rate,  $n$  is colony size,  $m$  is the number of colonies and  $N$  is the total population size.

$\beta$	$n$	$m$	Area ( $\times 1000 \text{ km}^2$ )	$N$ ( $\times 1000$ )	Density ( $\text{km}^{-2}$ )	Invasions	Sims
0.1	100	20	2.5	2	0.8	4	88
0.1	200	20	5.0	4	0.8	5	100
0.1	400	20	10.0	8	0.8	2	100
0.1	800	20	20.0	16	0.8	0	100
0.1	1600	20	40.0	32	0.8	55	100
0.2	100	20	2.5	2	0.8	3	92
0.2	200	20	5.0	4	0.8	6	100
0.2	400	20	10.0	8	0.8	0	100
0.2	800	20	20.0	16	0.8	39	100
0.2	1600	20	40.0	32	0.8	95	100
0.3	100	20	2.5	2	0.8	1	91
0.3	200	20	5.0	4	0.8	4	100
0.3	400	20	10.0	8	0.8	7	100
0.3	800	20	20.0	16	0.8	67	100
0.3	1600	20	40.0	32	0.8	100	100

TABLE 4. Raw data for number of colonies simulations. The population parameters are shown along with the number of invasions and the number of simulations. Note that simulations where both pathogens went extinct have been removed (100 simulations were originally run for each parameter set).  $\beta$  is the transmission rate,  $n$  is colony size,  $m$  is the number of colonies and  $N$  is the total population size.

$\beta$	$n$	$m$	Area ( $\times 1000 \text{ km}^2$ )	$N$ ( $\times 1000$ )	Density ( $\text{km}^{-2}$ )	Invasions	Sims
0.1	400	5	2.5	2	0.8	0	97
0.1	400	10	5.0	4	0.8	0	100
0.1	400	20	10.0	8	0.8	2	100
0.1	400	40	20.0	16	0.8	2	100
0.1	400	80	40.0	32	0.8	7	100
0.2	400	5	2.5	2	0.8	2	99
0.2	400	10	5.0	4	0.8	1	100
0.2	400	20	10.0	8	0.8	0	100
0.2	400	40	20.0	16	0.8	3	100
0.2	400	80	40.0	32	0.8	11	100
0.3	400	5	2.5	2	0.8	1	96
0.3	400	10	5.0	4	0.8	2	100
0.3	400	20	10.0	8	0.8	7	100
0.3	400	40	20.0	16	0.8	15	100
0.3	400	80	40.0	32	0.8	17	100

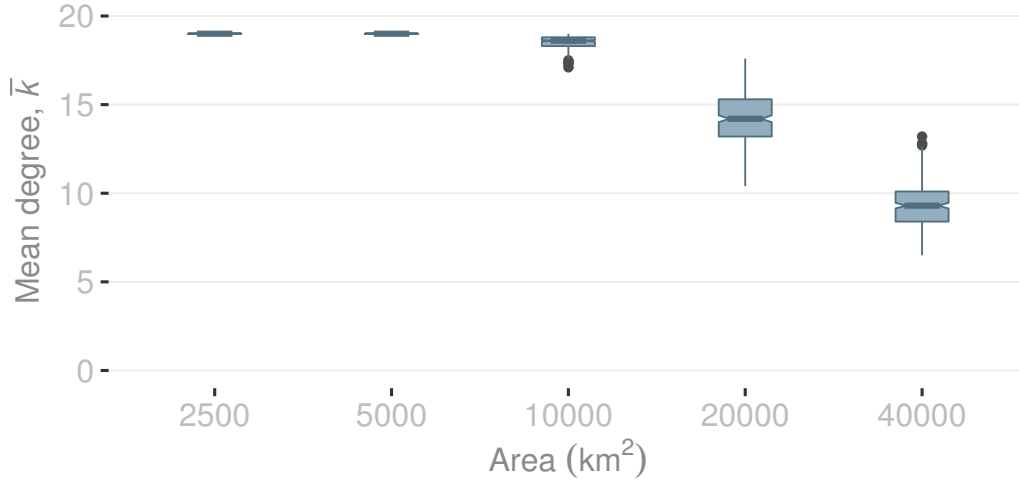


FIGURE 1. Change in average metapopulation network degree ( $\bar{k}$ ) with increasing range size. Bars show the median, boxes show the interquartile range, vertical lines show the range and grey dots indicate outlier values. Notches indicate the 95% confidence interval of the median. All simulations had 20 colonies, meaning 19 is the maximum value of  $\bar{k}$ .

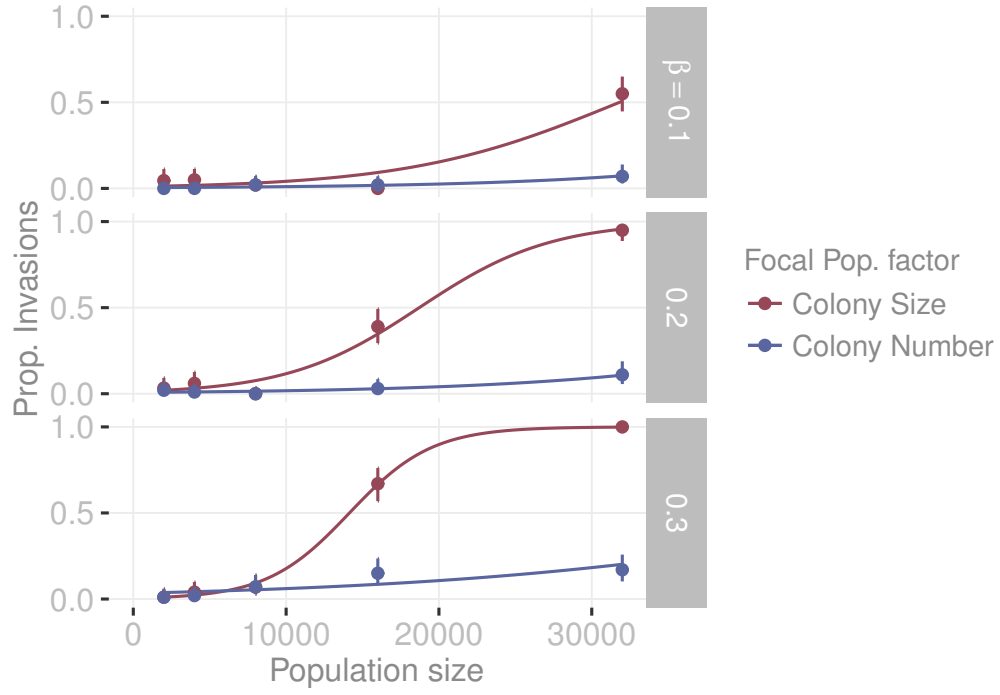


FIGURE 2. Comparison of the effect of host population size on probability of invasion when population size is altered by changing colony size or colony number. Relationships are shown separately for each transmission value,  $\beta$ . It can be seen that changes in colony size give a much greater increase in invasion probability than changes in colony number. Note that this is the same data as Figure ?? but with the  $x$ -axis scaled by population size, rather than relative parameter change.