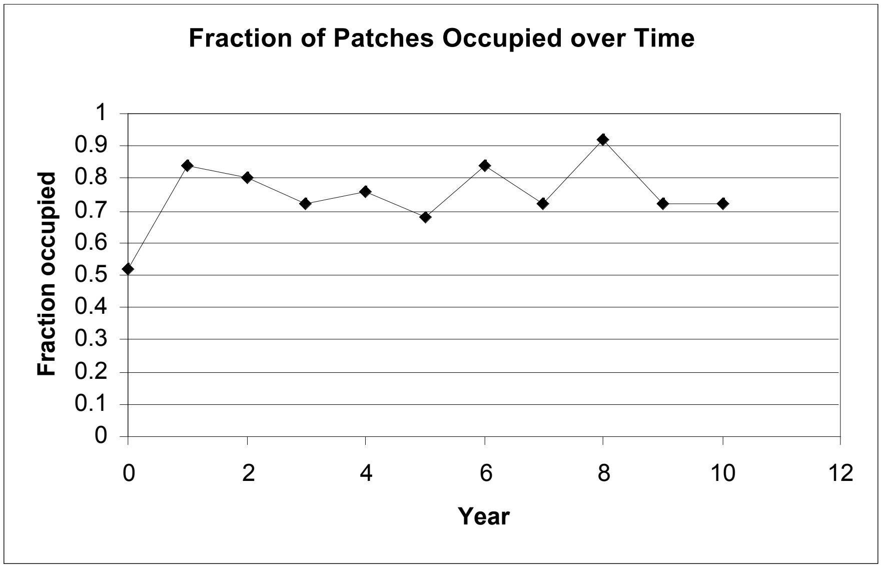
Answers to Exercise 20

Metapopulation Dynamics

1. In our simulation, the population never reaches an equilibrium point, calculated as $f = 0.75$, where the fraction of patches remains constant over time.

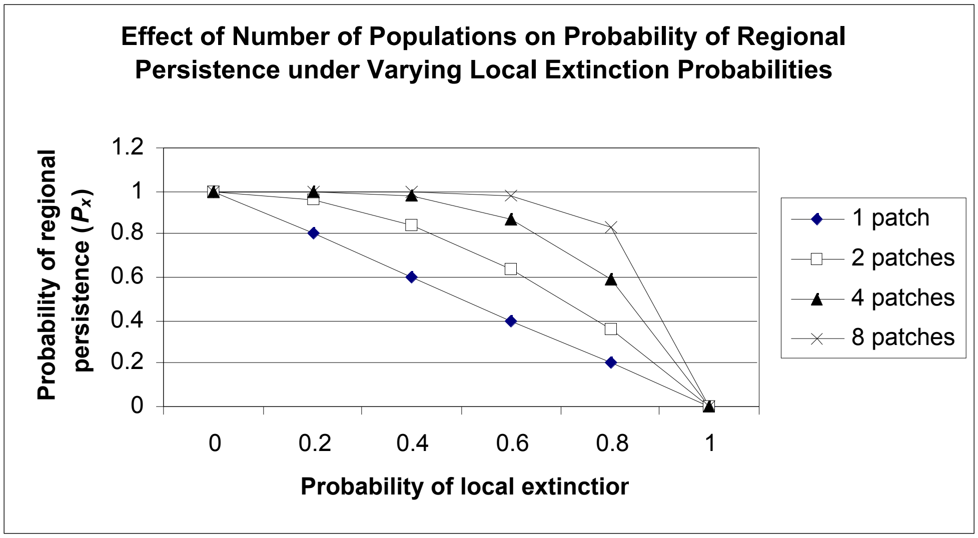


This is likely due to the relatively small size of the metapopulation modeled (25 patches). If you have completed Exercise 17 on demographic stochasticity, you know that random fluctuations in population dynamics occur when population size is small. The same idea holds for metapopulations. When the number of patches in the system is small, there are chance variations in extinction and colonization for each patch, creating unpredictable variation in the system. Thus, even when $I = E$, the population may not reach a stable equilibrium.

2. Your table should have the following values, which give the probability of regional persistence:

	J	K	L	M	N
8		**Number of patches**			
9	***Pe***	**1**	**2**	**4**	**8**
10	0	1	1	1	1
11	0.2	0.8	0.96	0.998	0.999
12	0.4	0.6	0.84	0.974	0.999
13	0.6	0.4	0.64	0.87	0.983
14	0.8	0.2	0.36	0.59	0.83
15	1	0	0	0	0

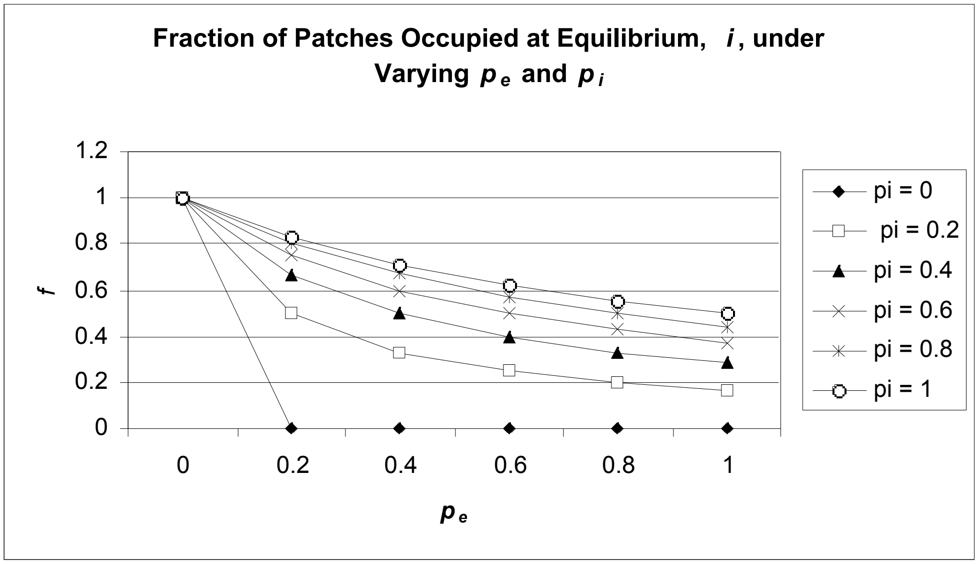
A graph of the results shows that as the number of patches in the system increases, the probability of regional persistence increases dramatically. Thus, the probability that all patches will simultaneously go extinct decreases considerably as the number of patches increases. This illustrates an important point: the existence of multiple patches "spreads the risk" of extinction (Gotelli 2001).



3. Your table should have the following values, which estimate f at equilibrium:

	J	K	L	M	N	O	P
18		P_i					
19	P_e	$p_i = 0$	$p_i = 0.2$	$p_i = 0.4$	$p_i = 0.6$	$p_i = 0.8$	$p_i = 1$
20	0	1	1	1	1	1	1
21	0.2	0	0.5	0.667	0.75	0.8	0.83
22	0.4	0	0.33	0.5	0.6	0.67	0.71
23	0.6	0	0.25	0.4	0.5	0.57	0.625
24	0.8	0	0.2	0.33	0.43	0.5	0.55
25	1	0	0.167	0.285	0.375	0.44	0.5

Graphically, the relationship between p_e and p_i is:



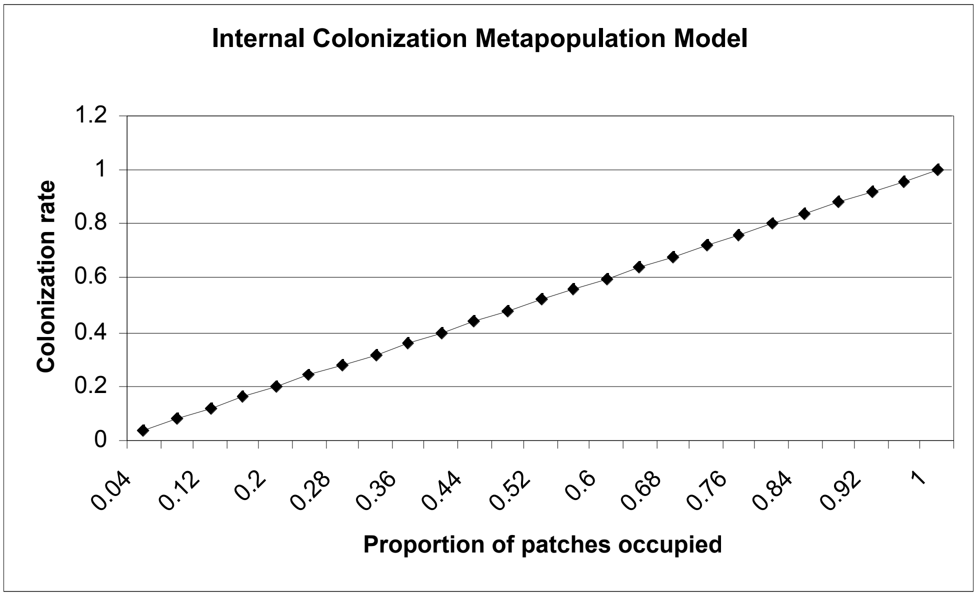
4. With p_e = 1, and p_i = 0.9, the metapopulation persists over time with an equilibrium f = 0.47. This persistence occurs because colonization of vacant patches is independent of how many patches in the system are occupied. In other words, even if all patches are extinct, each has a 90% chance of being colonized in the next time step. This sort of metapopulation system is called a **propagule rain metapopulation**, or an **island-mainland system** (Gotelli 2001), because the colonists originate from someplace other than the 25-patch system.

5. The simplest way to let p_i increase as the number of patches increase is to write an equation so that the colonization rate is directly related to the proportion of patches that are occupied. Thus, if a large fraction of patches are occupied, the colonization rate will be high, and if there is small fraction of patches occupied, the colonization rate will be low.

   Graphically, the relationship between the colonization rates and fraction of patches occupied is shown on the next page. We entered **=E35** in cell E9 to reflect internal colonization. When the simulation is run under these conditions, the population persists and approaches an equilibrium fraction of patches. (Again, note the stochastic nature of the metapopulation, due to the low number of patches in the system). The equilibrium fraction of patches occupied in an internal colonization model can be calculated as

$$\hat{f} = 1 - \frac{p_e}{i}$$

   See Gotelli (2001) for further information.



6. The rescue effect can be incorporated into the model by entering **=1-E35** in cell E6. This formula establishes a proportional relationship between the extinction probability of a patch, p_i, and the fraction of patches currently occupied. Given the starting conditions of the metapopulation, the population dynamics proceed roughly as follows:

	A	B	C	D	E
3	**Model parameters:**				
4	**x = number of patches in system**				25
5	**n = number of years under consideration**				10
6	**p_e = probability of local extinction**				0.36
7	**$1 - p_e$ = probability of local persistence**				0.64
8	**p_n = probability of continued local persistence**				0.01152922
9	**p_i = probability of local colonization**				0.6
10	**P_x = probability of regional extinction**				8.0828E-12
11	**$1 - P_x$ = probability of regional persistence**				1
12	**f = equilibrium number of patches occupied**				0.625

The equilibrium fraction of patches for a rescue effect metapopulation model can be calculated as

$$\hat{f} = \frac{p_i}{e}$$

See Gotelli (2001) for additional information.