A binomial stochastic simulated study of mutualism

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Mutualism = Win / Win

Xylocopa darwini & *Parkinsonia aculeata*
Author: James van Gundy

Bipartite weighted directed networks

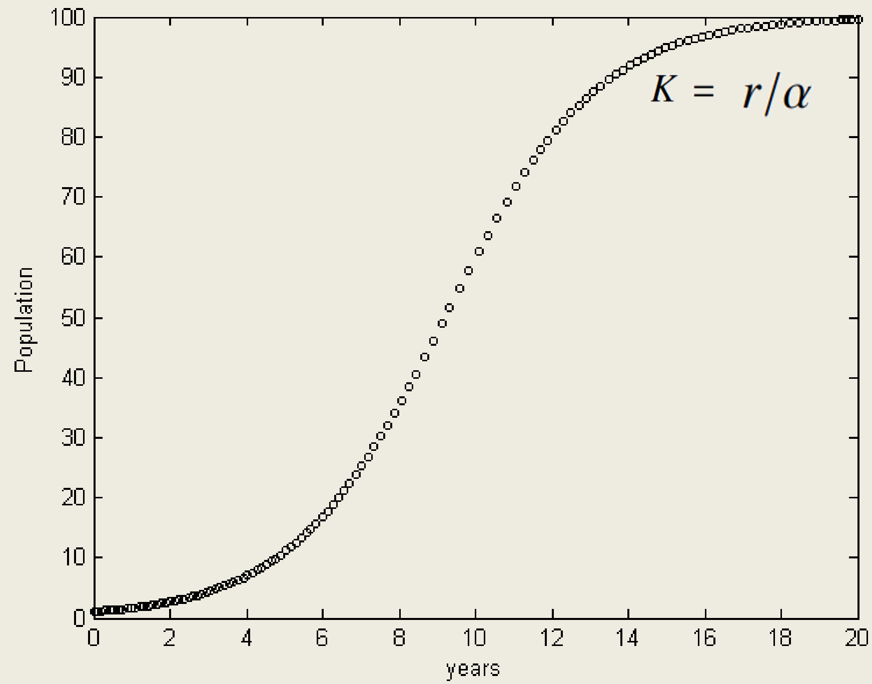
Source: Nicholas S. Fabina. UC Davis

$$\frac{dN}{dt} = r\,N$$

$$N = N_o\,e^{rt}$$

P. F. VERHULST.

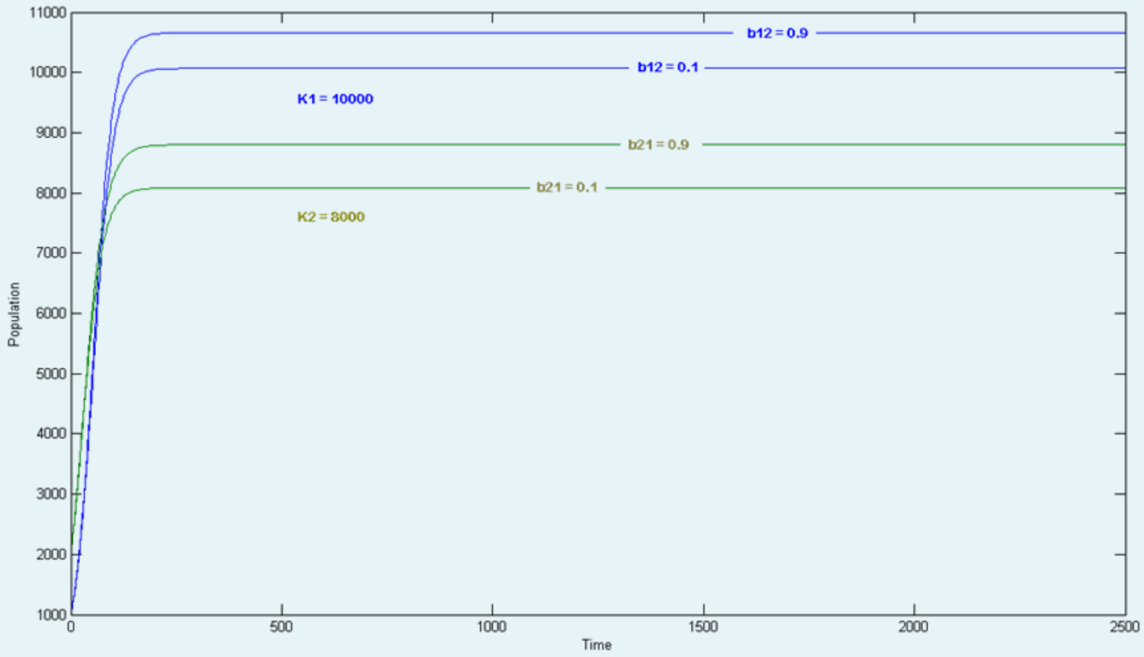
$$\frac{dN}{dt} = r\,N - \alpha\,N^2$$



$$\frac{dN}{dt} = r\,N\left(1 - \frac{N}{K}\right)$$

$$\frac{dN_1}{dt} = r_1 N_1 \left(1 - \frac{N_1}{K_1}\right) + r_1 N_1 \beta_{12} \frac{N_2}{K_1}$$

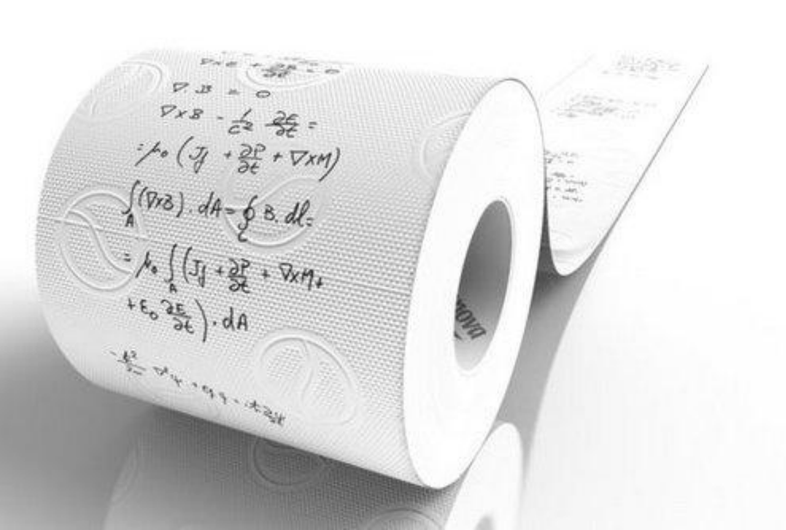
$$\frac{dN_2}{dt} = r_2 N_2 \left(1 - \frac{N_2}{K_2}\right) + r_2 N_2 \beta_{21} \frac{N_1}{K_2}$$



$$\frac{1}{N}\frac{dN}{dt} = \left(r - |r|\frac{N}{K}\right) = r\left(1 - sign(r)\frac{N}{K}\right)$$

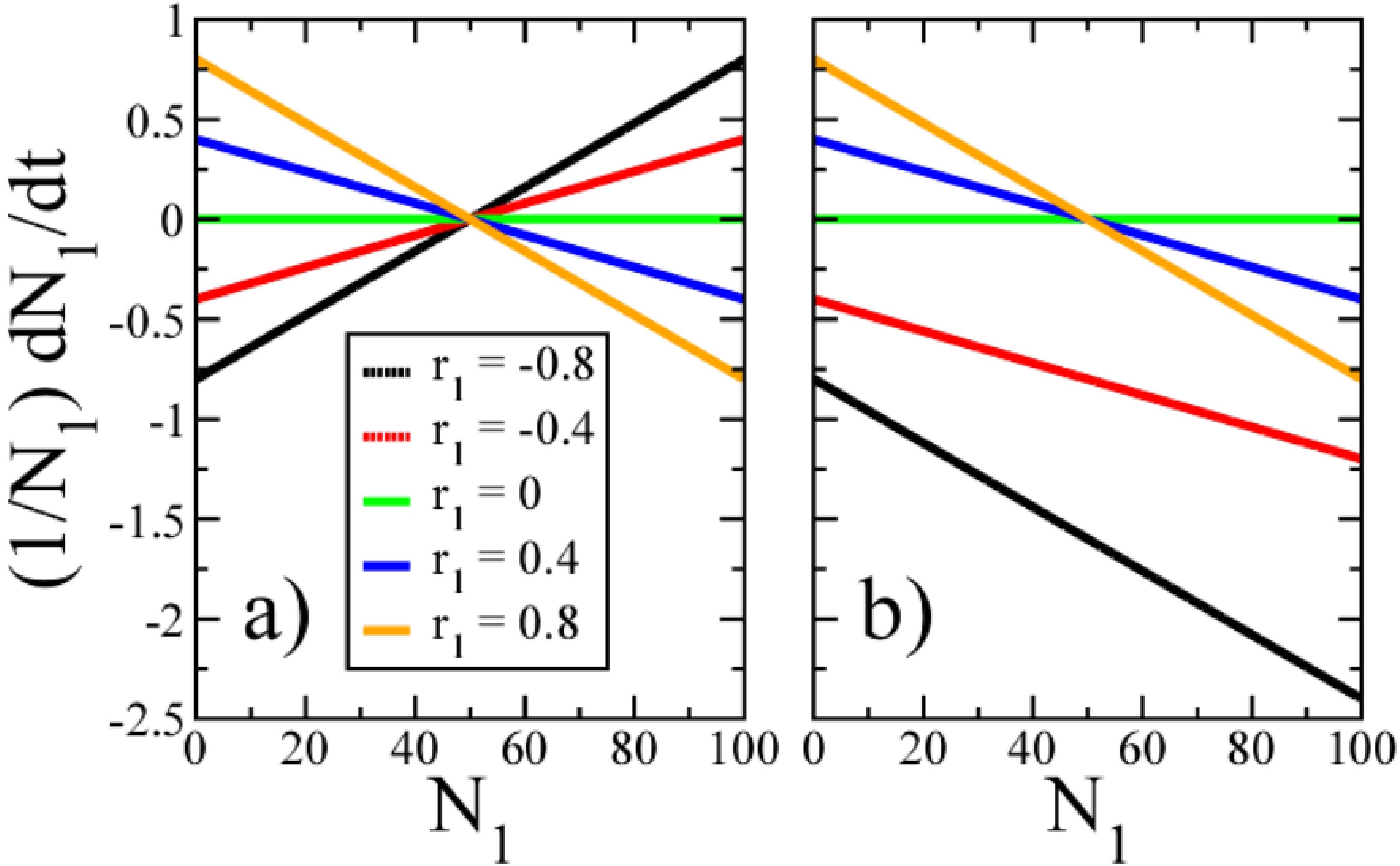
$$r^a_{ef_i} = r^a_{b\,i} - r^a_{d\,i} + \sum_{k=1}^{m} b_{ik}\, N^p_k$$

$$r^p_{ef_j} = r^p_{b\,j} - r^p_{d\,j} + \sum_{s=1}^{n} b_{js}\, N^a_s$$

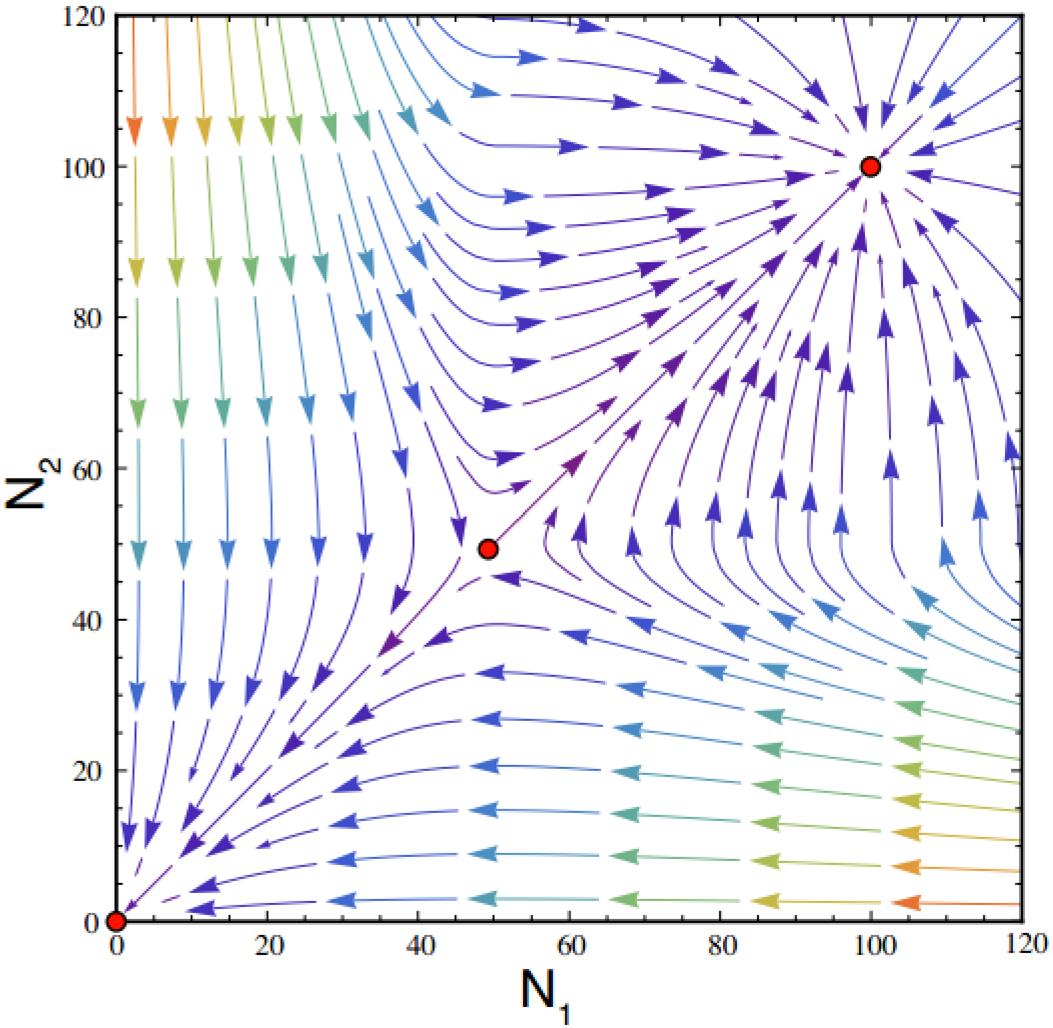


$$\frac{1}{N^a_i}\frac{dN^a_i}{dt} = r^a_{ef_i} - |r^a_{ef_i}|\frac{N^a_i}{K^a_i}$$

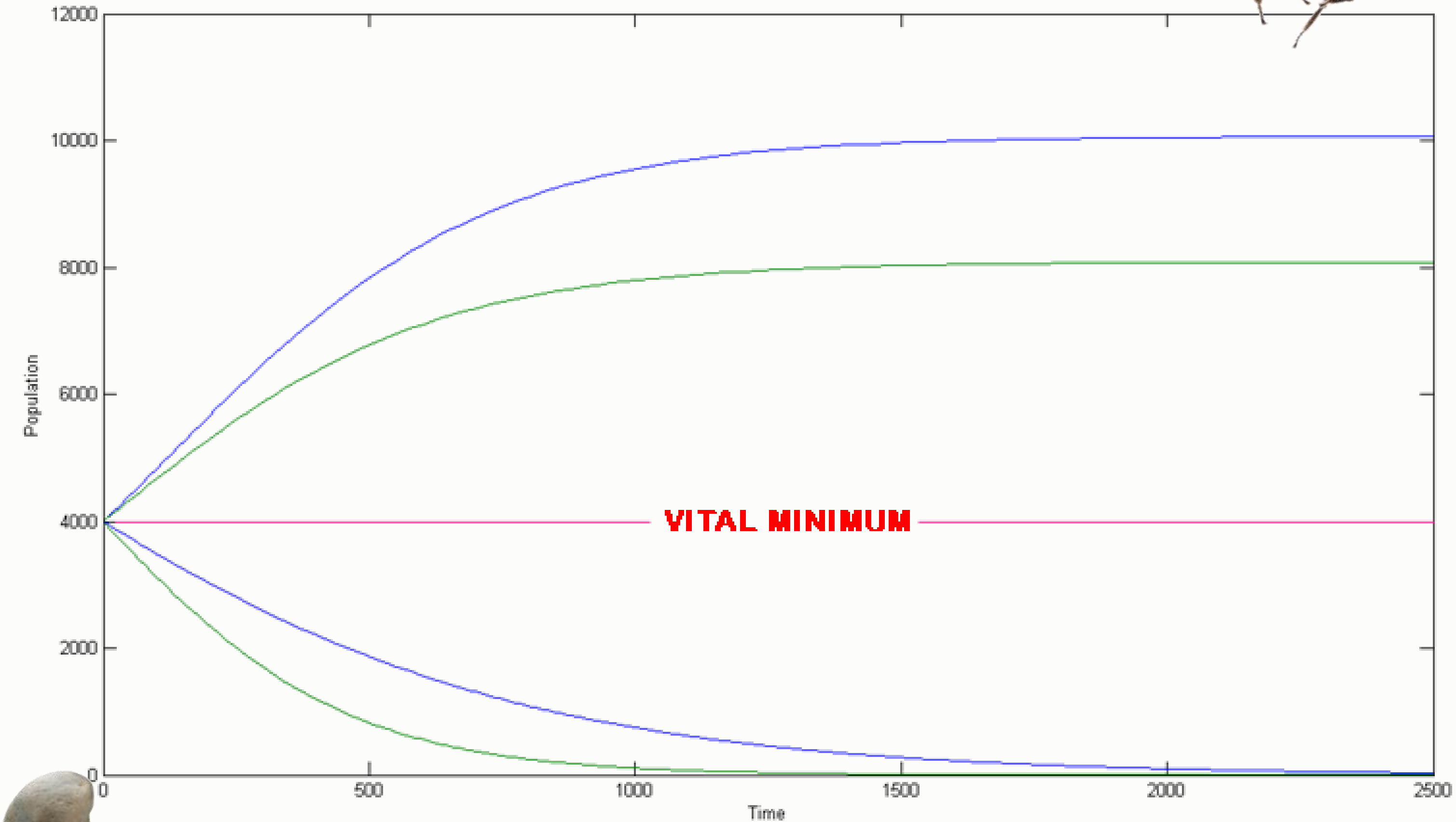
$$\frac{1}{N^p_j}\frac{dN^p_j}{dt} = r^p_{ef_j} - |r^p_{ef_j}|\frac{N^p_j}{K^p_j}$$



(1/N1) dN1/dt
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
20
40
60
80
100
N1
a)
b)
r1 = -0.8
r1 = -0.4
r1 = 0
r1 = 0.4
r1 = 0.8



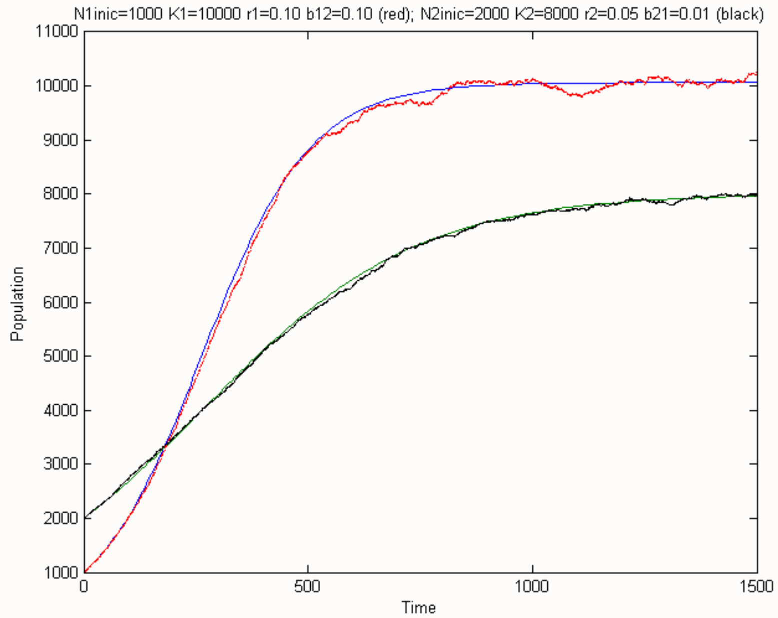
$r_1^a = r_2^p = -2.5$, $b_{12} = b_{21} = 0.05$ and $K_1^a = K_2^p = 100$

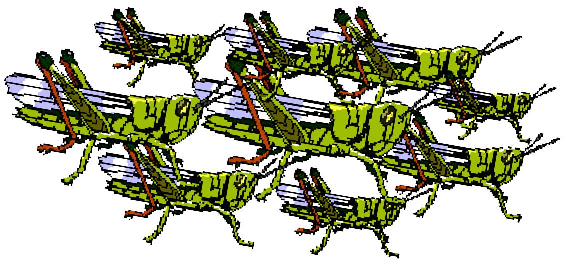

12000
10000
8000
6000
4000
2000
0
Population
0
500
1000
1500
2000
2500
Time
VITAL MINIMUM

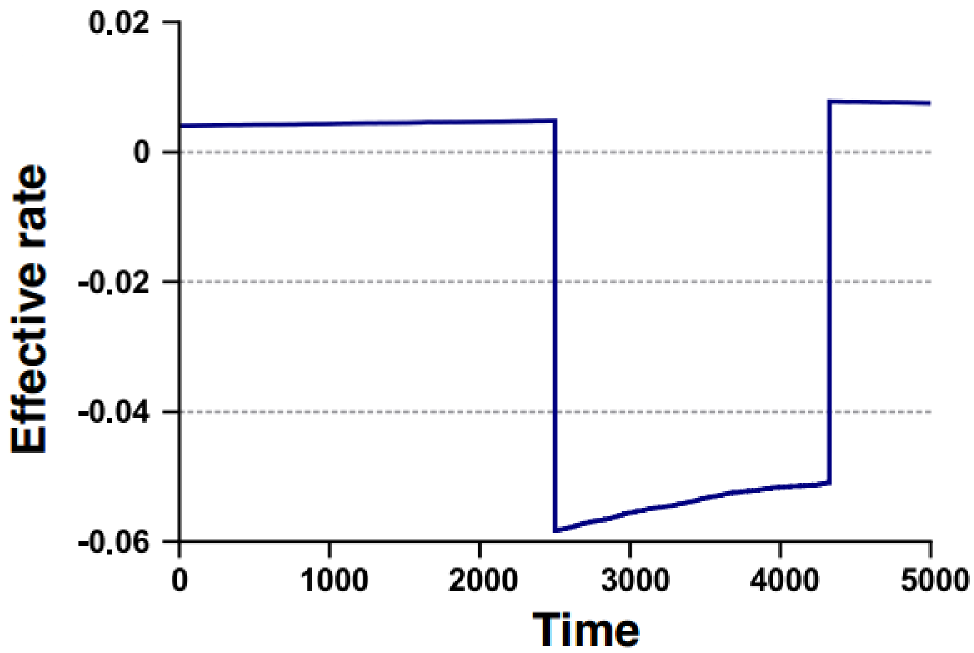
$$P = \int_0^{\Delta T} e^{-r\,T}\,dt = 1 - e^{-r\,\Delta T}$$

$$N(t+\Delta T) = N(t) + sgn\,(r)\,Binomial\,(N(t), P)$$

$$\hat{r}_{eq} = e^{r_{eq}/365} - 1$$





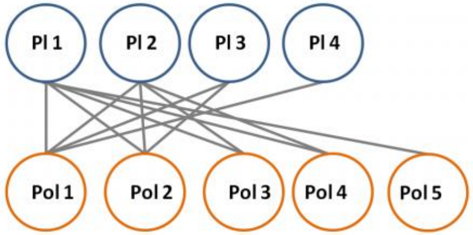

0.02
0
-0.02
-0.04
-0.06
Effective rate
0
1000
2000
3000
4000
5000
Time

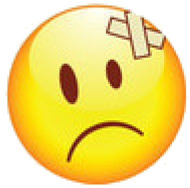
python
powered

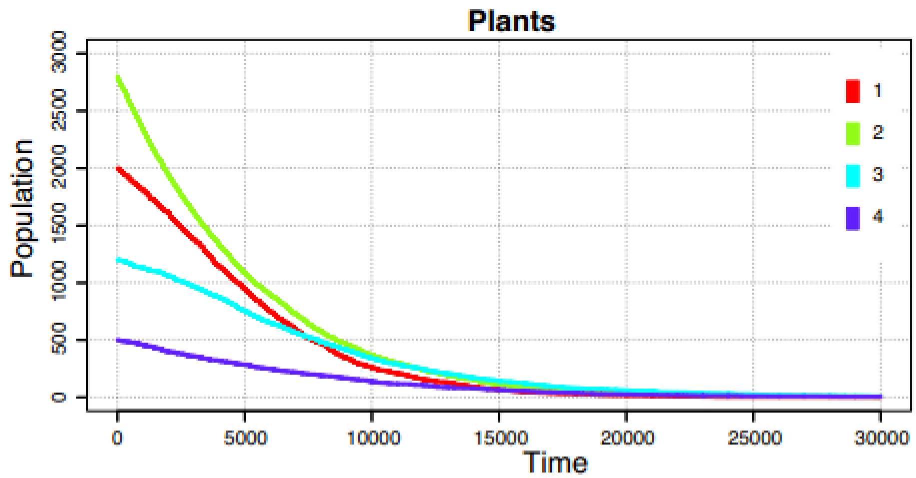
```
print("Hello, world!")
```

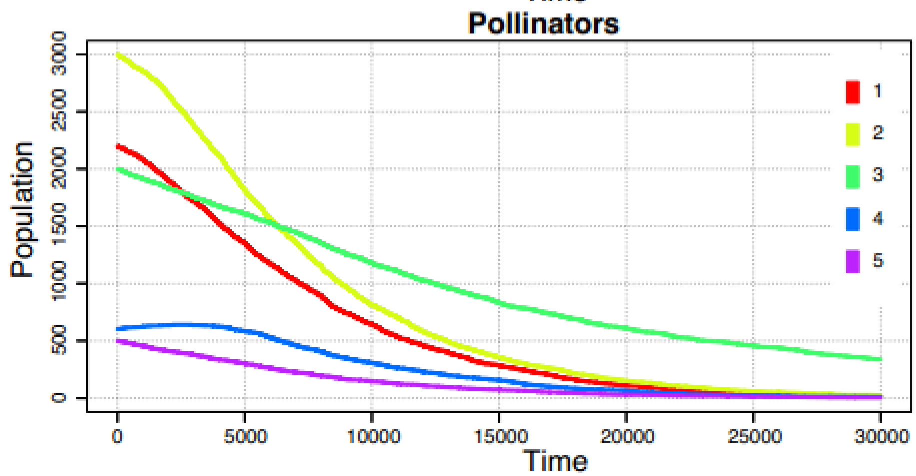
NumPy

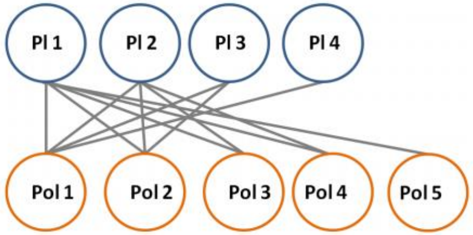
matplot


Pl 1
Pl 2
Pl 3
Pl 4
Pol 1
Pol 2
Pol 3
Pol 4
Pol 5




Plants
Population
Time
1
2
3
4
0
500
1000
1500
2000
2500
3000
5000
10000
15000
20000
25000
30000


Pollinators
Population
Time
1
2
3
4
5
0
500
1000
1500
2000
2500
3000
5000
10000
15000
20000
25000
30000


Pl 1
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Pol 1
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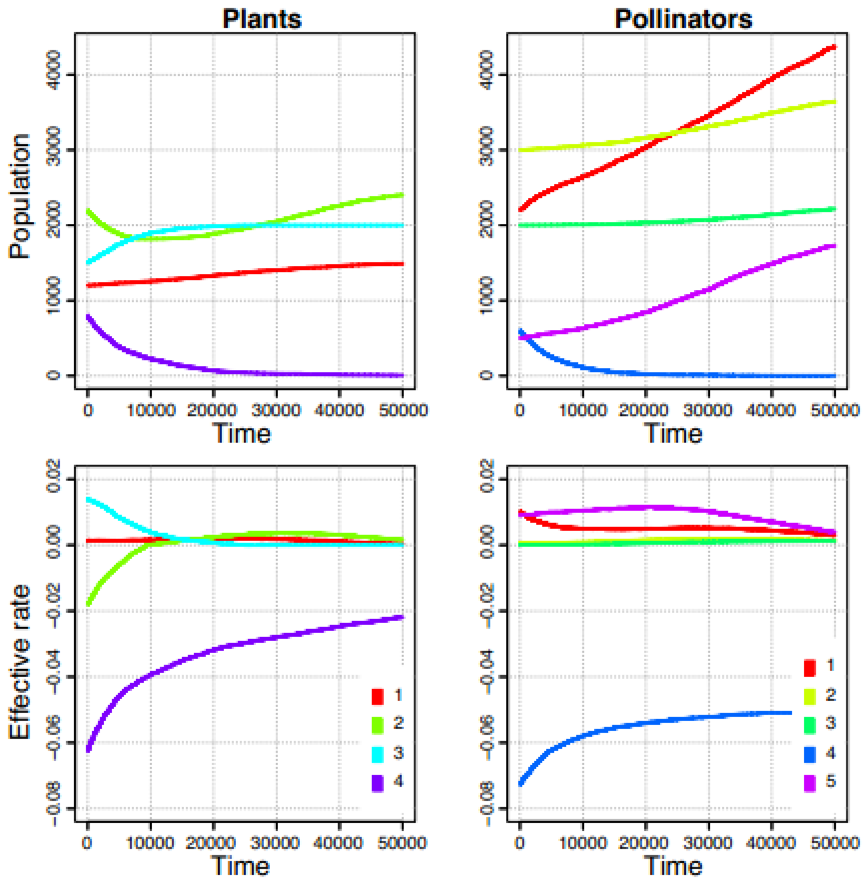
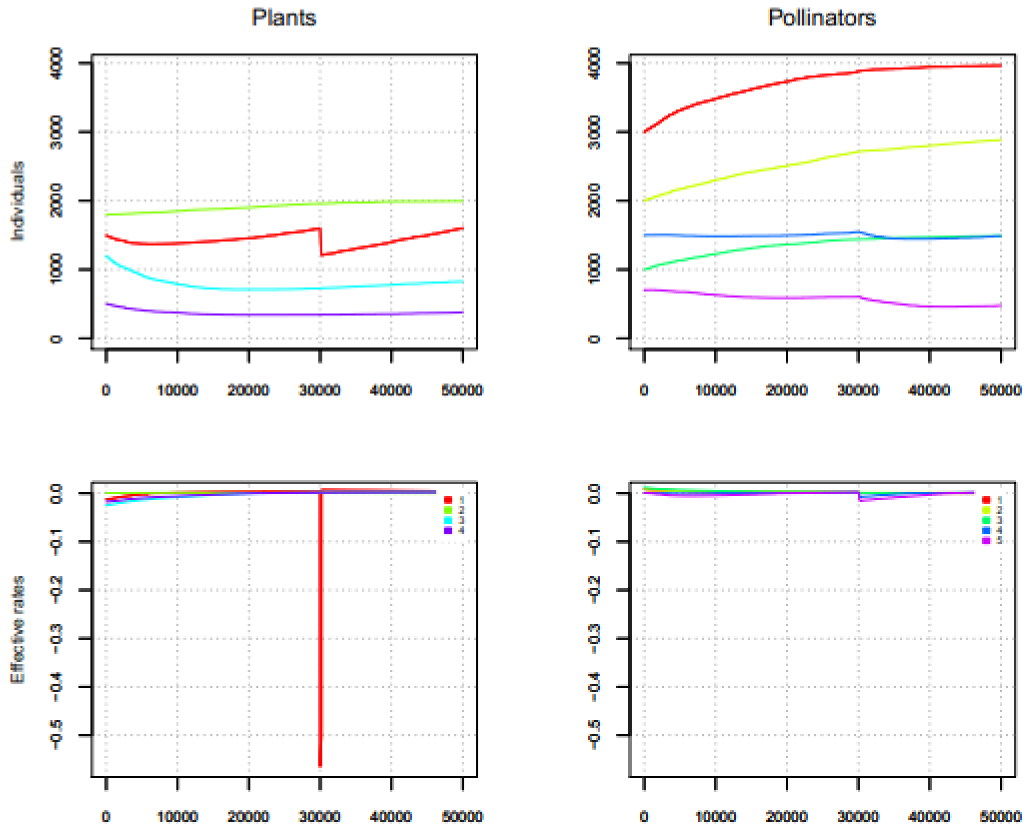
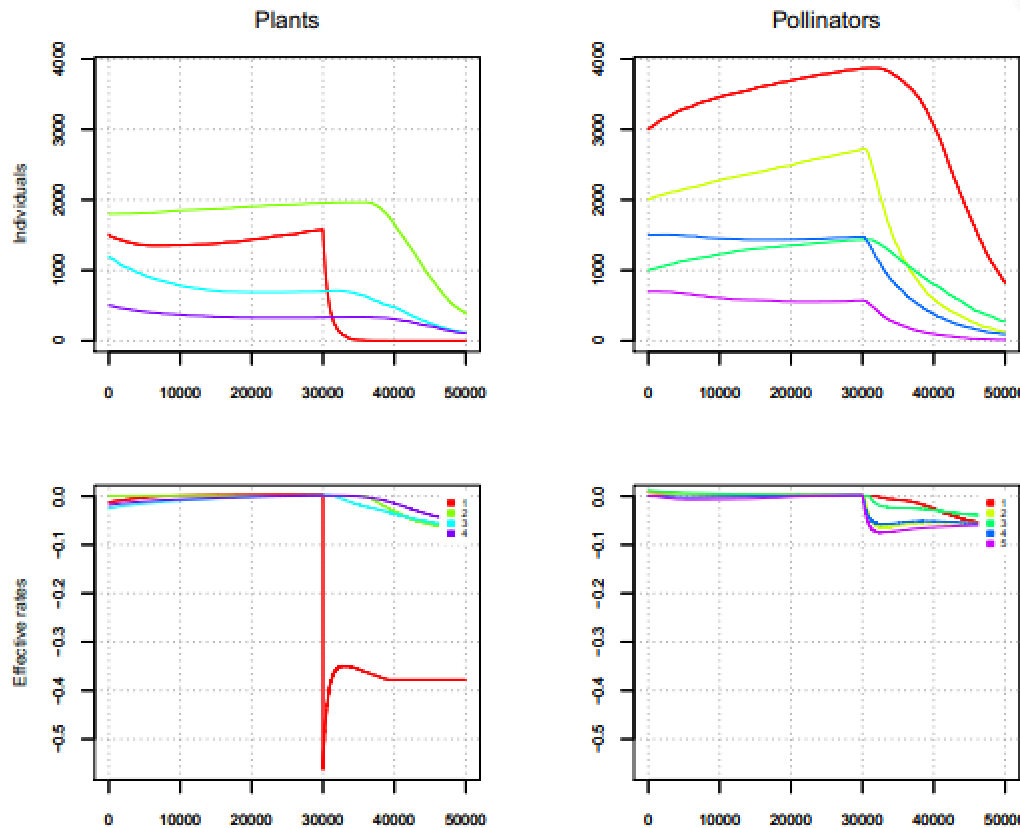
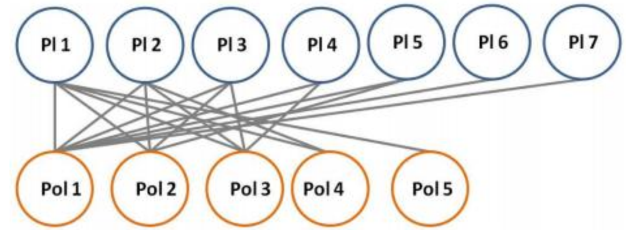
Pol 3
Pol 4
Pol 5

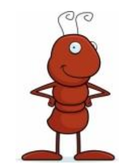

Plants
Pollinators
Population
Effective rate
Time
1
2
3
4
5

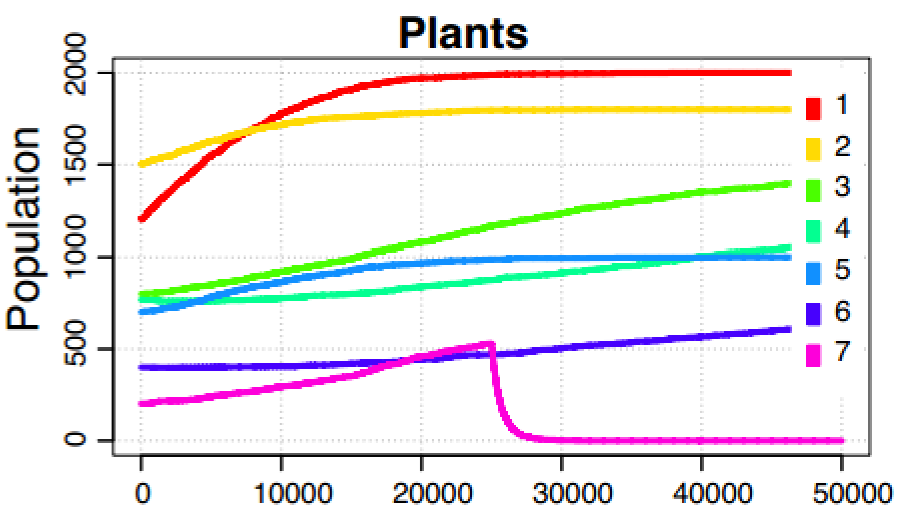

Plants
Pollinators
Individuals
Effective rates
0
1000
2000
3000
4000
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
0
10000
20000
30000
40000
50000


Plants
Pollinators
Individuals
Effective rates
0
1000
2000
3000
4000
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
0
10000
20000
30000
40000
50000

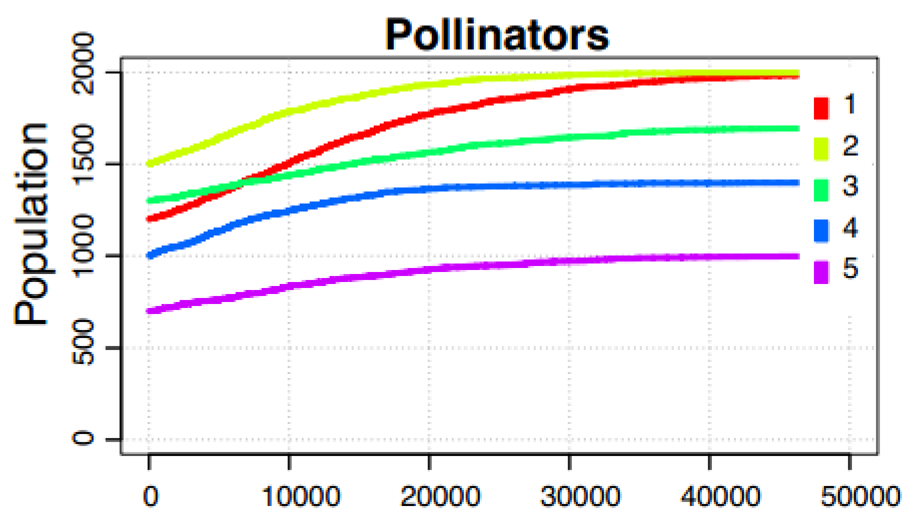


Pl 1
Pl 2
Pl 3
Pl 4
Pl 5
Pl 6
Pl 7
Pol 1
Pol 2
Pol 3
Pol 4
Pol 5

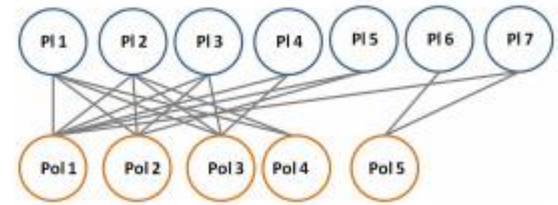


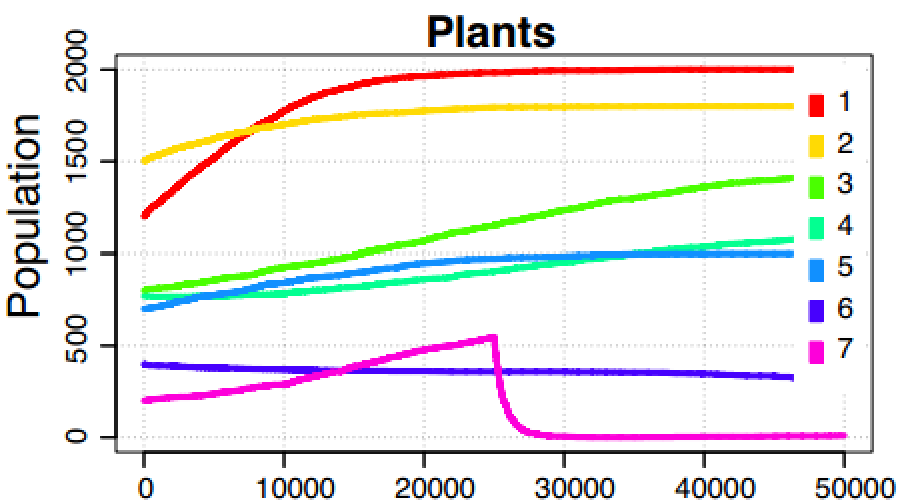


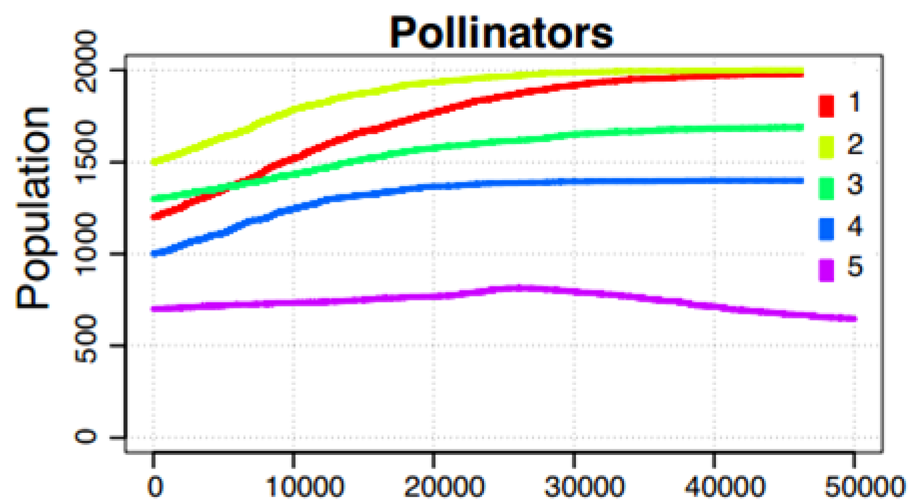
Plants
Population
0
500
1000
1500
2000
0
10000
20000
30000
40000
50000
1
2
3
4
5
6
7



Pollinators
Population
0
500
1000
1500
2000
0
10000
20000
30000
40000
50000
1
2
3
4
5


Pl 1
Pl 2
Pl 3
Pl 4
Pl 5
Pl 6
Pl 7
Pol 1
Pol 2
Pol 3
Pol 4
Pol 5


Plants
Population
0
500
1000
1500
2000
0
10000
20000
30000
40000
50000
1
2
3
4
5
6
7


Pollinators
Population
0
500
1000
1500
2000
0
10000
20000
30000
40000
50000
1
2
3
4
5

$$\frac{1}{N}\frac{dN}{dt} = \left(r - |r|\,\frac{N}{K}\right)$$