BASE

Rescue effect in metapopulations

We have already seen a simpler model for metapopulations, in which the probability colonization for each patch is always the same, due to a constant propagule rain coming from a core area. We have also seen a slightly more complex model, in which the colonization probability varies according to the number of occupied patches - and with this we don't need to assume a constant propagule rain. In the second model, the colonization was internal to the studied area, meaning that the migration of individuals happens between the patches.

Now, you should be asking yourselves: does it make any sense that the extinction probability remains constant? The answer to this is 'no'. Whenever the number of occupied patches increases, the migration to empty patches increases, but the migration to already occupied patches is also increased. This means that the income of propagules from other patches in the landscape may prevent the local extinction! Imagine a forest fragment in which individuals from a plant species germinate and grow, but are unable to reproduce due to lack of a pollinator. After some time, this population will become extinct in this patch - but if there is a constant arrival of seeds from other patches, the species will subsist. This is called **rescue effect**.

How can we include the rescue effect in the model

Let's get to work! What do we need to change in our basic model to incorporate the effect of rescue? If the arrival of seeds from other patches is reducing the probability of local extinction, then a smaller fraction of occupied patches will lead to a greater chance of extinction:

$$p_e=e(1-f)$$

here, e is a measure of how much the local extinction probability increases as the fraction of occupied patches f decreases.

So, our model now has the following formula:

$$ \frac{df}{dt}=p_i * (1-f) - ef (1-f)$$

And the fraction of occupied patches in equilibrium (F) becomes:

$$F=\frac{p_i}{e} $$

Moreover, in equilibrium:

$$p_e=e-p_i$$

Simulating

Let's see the options of parameters in the Rescue Effect function:

option name	**parameter**	**what it does**
data set	R object	stores the simulation results
Maximum time	tmax	Number of simulated iterations
columns	cl	number of columns in the simulated landscape
rows	rw	number of rows in the simulated landscape
initial occupance	f0	number of occupied patches when the simulation begins
colonization probability	pi	colonization probability
extinction coef.	ce	extinction coefficient

Try the following parameters:

```
tmax = 100
cl = 10
rw = 10
f0 = 0.1
pi = 0.1
ce = 1
```

In the graphs that will open we will see, other than the trajectory of **f** (the solid black line) and **F** (the dashed red line), the trajectory of the extinction probability **pe** (solid blue line) and the value of **pe** in equilibrium. Can you see that one of the lines is a mirror image of the other, but after a small delay? Why does this happen?

PROBLEM:

Suppose that a metapopulation with follows a propagule rain and rescue effect dynamics. Its parameters are:

1. colonization probability **pi = 0.3**,
2. rescue effect **e = 0.5** and
3. fraction of occupied patches **f = 40%**.

Will this population grow or decline?

Combined rescue effect and internal colonization

Now that we have tested two improvements to our initial model (rescue effect and internal colonization), how about combining both in a single model? Doing so, we are suppressing once and for all one of the most important assumptions: the propagule rain coming from an external source.

Our model will be expressed by the following formula:

$$\frac{df}{dt}=if(1-f)-ef(1-f)$$

And the equilibrium point will be given by:

$$if(1-f)=ef(1-f)$$

When we try to solve this equation, we come to the identity $i=e$. This means that equilibrium is only possible if i is equal to e.

Simulating 2

The parameters of our function are:

option	**parameter**	**definition**
data set	R object	stores the simulation results
Maximum time	tmax	Número de iterações da simulação
columns	cl	número de colunas de habitat da paisagem
rows	rw	número de linhas de habitat da paisagem
initial occupance	f0	no. de manchas ocupadas no inicio
colonization coef.	ci	colonization coefficient
extinction coef.	ce	extinction coefficient

You can now simulate the model with the parameter choices that you prefer. For example:

```
tmax = 100
```

```
cl = 10
rw = 10
f0 = 0.5
ci = 0.5
ce = 0.5
```

In the produced graphs, the solid black line is the trajectory for **f** and the dotted lines are the extinction (blue) and colonization (pink) probabilities.

Questions

- How does p_i changes in relation to p_e if we increase the number of occupied patches?
- Is there really an equilibrium when $e = i$? Show it with some simulations.
- What happens if $e > i$ and if $e < i$?

To learn more

- **Gotelli, N. 2007. Ecologia.** Londrina, Ed. Planta. Capítulo 4.
- **Stevens, M. H. 2009. A primer of ecology with R.** New York. Springer.Capítulo 4.
- **Gotelli, N.J. 1991. Metapopulation models: the rescue effect, the propagule rain, and the core-satellite hypothesis**. The American Naturalist 138:768-776. pdf no site do autor