Non-trophic interactions: consequences on secondary extinctions

Alexandre Génin

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1 The trophic model

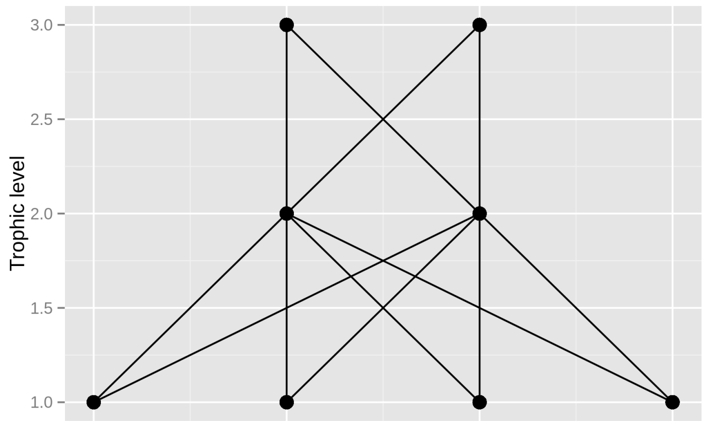

Figure 1
The fixed trophic topology : 4 basal producers, 2 grazers and 2 consumers. Species consume everyone on the lower trophic level. x-axis has no meaning.

The dynamic model is inspired from Brose et al's (2006). It is given by its main equation that describes the dynamics of one species' biomass :

$$\frac{dB_i}{dt} = r_i B_i (1 - \frac{B_i}{K_i}) + \sum_{i=1}^{i=N} B_i w_{ij} F_{ij} - \sum_{j=1}^{i=N} B_j w_{ji} F_{ji} / e_{ji} - x_i B_i \tag{1}$$

where F_{ij} describes a generic functional response in which species i feeds on j :

$$F_{ij} = \frac{a_{ij} w_{ij} B_j^{q+1}}{1 + h_i w_{ij} \sum_k a_{ik} B_k^{q+1}} \tag{2}$$

Parameters are described in Table 1. In the functional response, q is a coefficient taken randomly between 0 (type-II functional response) and 1 (type-III functional response).

Many of these parameters can be chosen using metabolic scaling rules yielding a model with few free parameters [1] .

Details on the default parameter values can be found in Table 1. The trophic topology (values for which $a_{ij} > 0$) is held constant.

1.1 Results

1.1.1 Example output

The simulation process is as follow :

1. Note that we need to think about how closely we want to follow metabolic scaling rules [26 mars 2015]

— Species initial biomasses are chosen randomly in the range $]0; K_i]$, q is chosen randomly between 0 and 1.
— The simulation is run until $t = 3000$ is reached, when a species is removed. The run lasts until $t = 5000$ is reached.

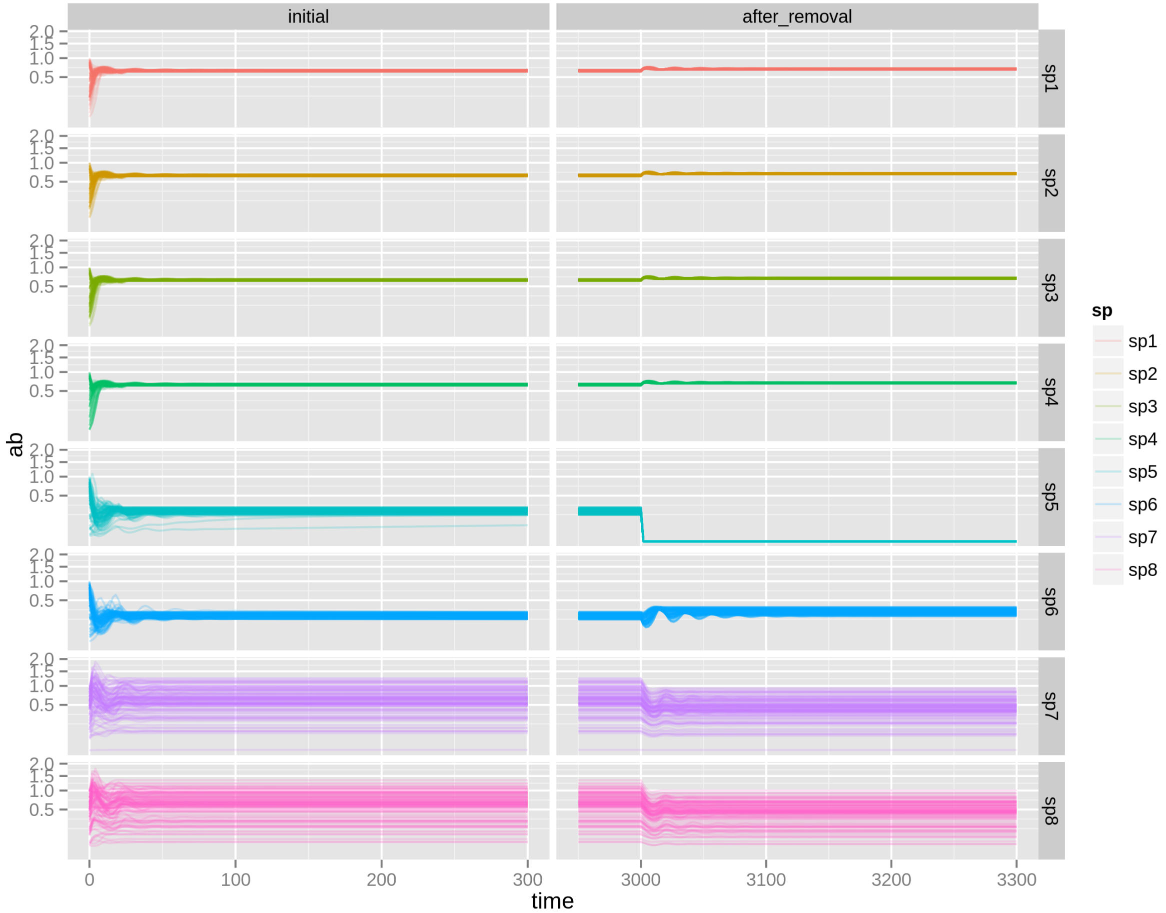

FIGURE 2
100 replicates. sp1-4 are producers, sp5-6 are intermediate consumers and sp7-8 are top predators. In this simulation, species 5 (grazer) is removed at time $t = 3000$. Mind the non-linear vertical scale

2 An example of non-trophic interaction

All the parameters of the model here are fixed beforehand and do not depend on the biomasses of species. Non-trophic interactions can be implemented by introducing that dependence on species abundances.

For example, let's consider species i, a producer : its logistic growth is controlled by its fixed carrying capacity K. However, let's consider that some species from upper trophic levels create new space for algaes to grow on, thus increase its value (e.g. mussels/propagules).

Instead of a fixed value K in Eq. 1, we replace it by K_i that depends on interactions with other species :

$$K_i = \sum_{j=1|\delta K_{ij} \neq 0}^{N} \frac{K_0 B_0 + (K_0 + \delta K_{ij}) B_j}{B_0 + B_j} \tag{3}$$

δK_{ij} represents the bonus (if positive), or penalty (if negative) on parameter K that species i receives from species j.

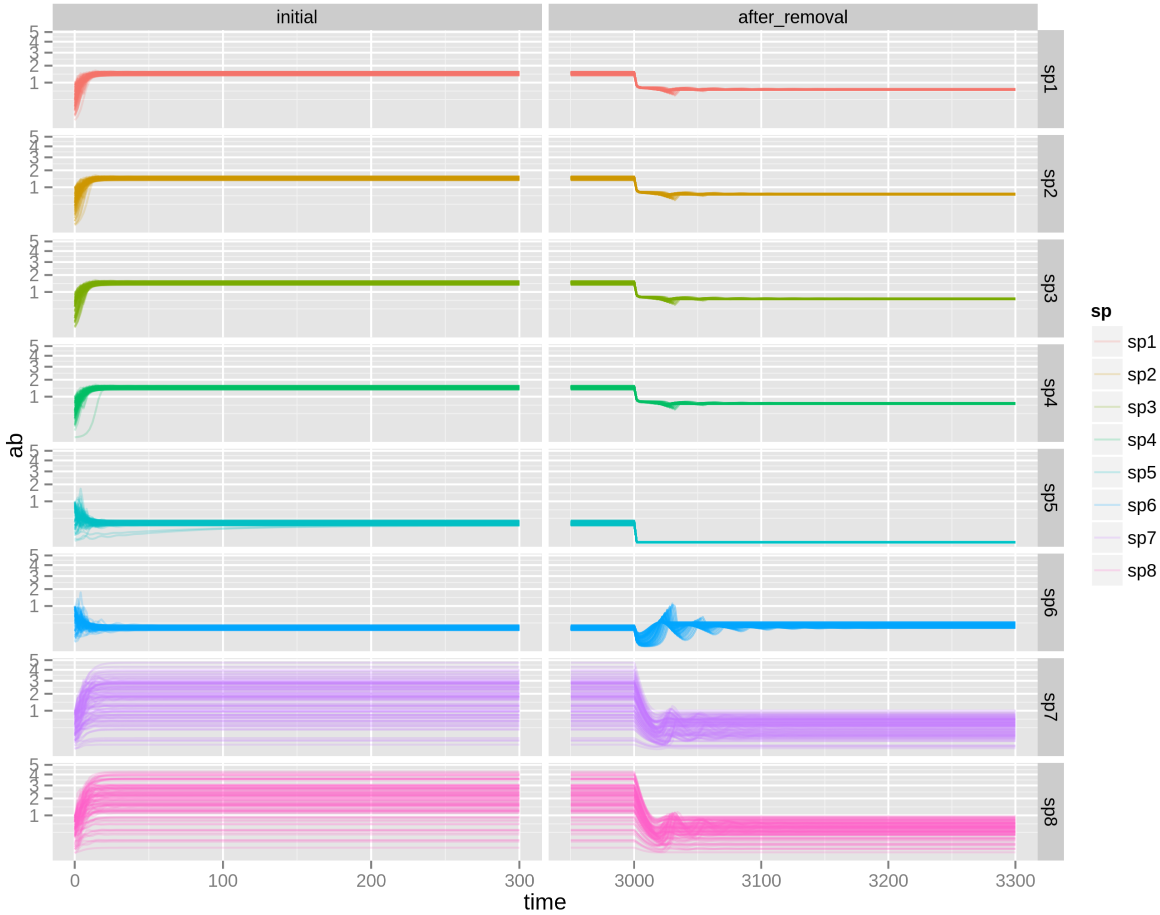

FIGURE 3
Example output for 100 simulations, where the carrying capacity K of producers (sp1-4) depend on the abundance of species 5 i.e. $\delta K_{5(1,2,3,4)}$ is set to 0.3. In this simulation, species 5 (grazer) is removed at time $t = 3000$. Notice the higher drop in predators abundances (sp7-8) compared to 2, and the absence of secondary extinctions.

3 “Generalization“ of NTIs

This approach can be generalized to any parameter p : however, not all parameters can be changed in a way that makes sense. For example, the grazers and predators have no K thus the above example is not easily generalizable.

A possibility would be to introduce a generic coefficient of bonus/penalty in trophic interactions, on w_{ij} for instance.

TODO

- Why are top predators not identical ? due to different initial ab
- Think about how to set body masses
- Check and think about metabolic relationships
- So far, parameters are chosen a bit arbitrarily : think about which ones should be free and which ones should be fixed.

Param.	Comment	Value
r_i	Reproductive rate of species i	1 for producers, 0 otherwise
K_i	The carrying capacity of species i	1 for all producers
w_{ij}	The consumption rate of species j by species i	equal between all preys (e.g. 0.25 for grazers (4 preys))
F_{ij}	The functional response of species i on j	
q	The "hill" coefficient in the functional response	random between 0 and 1
e_{ji}	The conversion efficiency of species i into j	0.85 for all i and j
b_i	**Body mass of species** i	producers : 1, grazers : 3 predators : 6
x_i	The metabolic (mortality) rate	scaling rule with body size $x_i = 0.223 b_i^{-.25}$
a_{ij}	The attack rate of species i on j	scaling rule with
h_i	The handling time of species i	$1/(8{*}x_i)$

Table 1

Default parameters and values used in the model. Some of them (e.g. x_i use metabolic scaling relationships).