Ecological Networks: Evolution and Interaction between topology and dynamics

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Motivation

Plant animal interaction have played a very important role in generation of Earth's biodiversity. Flowering plants and insects are two of the mayor groups of living beings. Animal-pollinated angiosperm families are more diverse than their abiotically pollinated sister clades. Information from the fossil record shows clearly that major extinction of flowering plants resulted from episod of insect diversity decline. To assess the likelihood and magnitude of these coextintion cascades, we need a network approach to plant-animal mutualistic interactions. Most higher plants rely on animals to pollinate their flowers. The resulting plant-mutualism constitutes a critical free service in all natural terrestrial ecosystems and in many agrosystems.

Model from Saavedra et al. 2008

Stochastic model of bipartite cooperation that uses specialization and interaction rules to generate matrices of interactions.

This matrices have the same degree distribution, nestedness and modularity of the empirical networks.

The inputs of the model: A, P, L.

Specialization Rule: Each specie has random reward traits value (tR randomly obtained from a uniform [0,1] distribution), and a coefficient representing external factors (λ, obtained from a exponential distribution with parameter β) which might attenuate or amplify the value of reward and the number of partners a specie collaborates with.

$$\beta = \frac{P(A-1)}{2(L-P)} - 1$$

The number of links for each node p is a function of its reward trait and the external factor:

$$l_p = 1 + Round\left((L-P)\frac{t_{Rp}\lambda_p}{\sum_j t_{Rj}\lambda_j}\right)$$

Interaction Rule: Determines wiche members of the plant group collaborates with which members of the animal group. Interactions are limited by the complementarity between reward traits (tRp Є U[0,1]) for plants and organizational traits (tFa Є U[0,1]) for animals. External factors amplifying and attenuating the system are also taken into account (λp and λlp from the exponential distribution).

Nodes P sorted in ascending order and nodes A in descending order according to their traits. Starting from the first node pi and continuing sequentially, if tRpi> λlpi, each of his links is connected to free nodes a in order. If tRpi≤λlpi the link is randomly connected to an already occupied node a.

Dynamical Study of a reduced model

A reduced model with one plant-one pollinator is studied, in a dimensionless equation system:

$$\frac{dp}{dt} = a(1-d-p) - k_1 p$$
$$\frac{da}{dt} = \alpha a(p-a) - \alpha k_2 a$$

$$k_1 = \frac{e_p}{c_p} \quad k_2 = \frac{e_a}{c_a} \quad \alpha = \frac{c_p}{c_a}$$

There is a trivial solution with a=0, p=0. In some cases two non-trivial physical solutions appear, depending in d, k_1, k_2

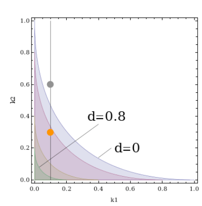


Fig1: Solutions varying k2, and leaving k1 fixed

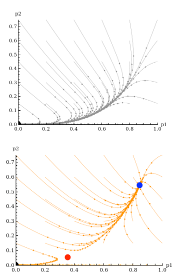


Fig2. One trivial steady state → No ecosystem. One stable and one unstable steady state → Posibility of ecosystem dependent on initial conditions.

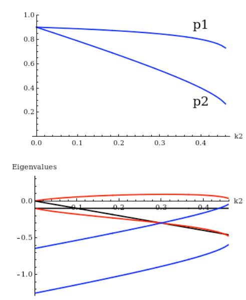


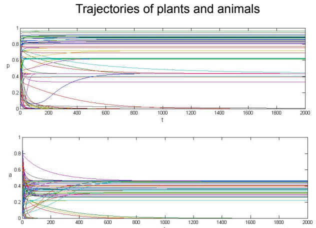
Fig 3.Stable non-trivial solution Eigenvalues corresponding to the three steady states.

Metacommunitary Stochastic Model by Fortuna & Bascompte 2006

$$\frac{da_j}{dt} = c_{a_j} a_j(\Omega - a_j) - e_{a_j} a_j$$

Real Network without rewriring d=0.0 kp=ka=0.5

Trajectories of plants and animals



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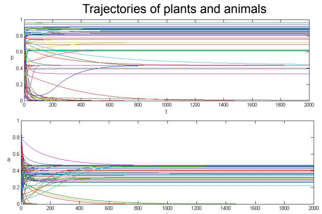
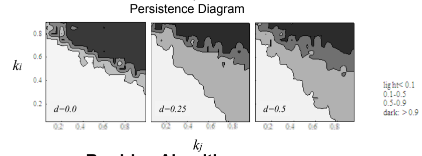
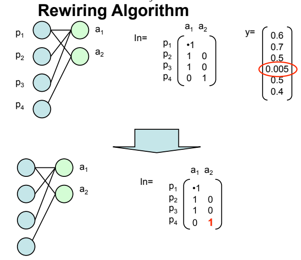


Persistence Diagram

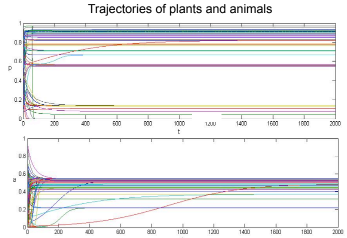


Rewiring Algorithm

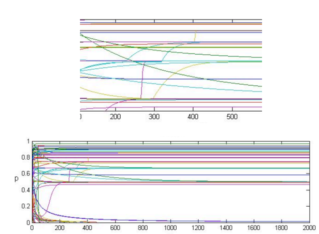


Real Network with rewiring

Trajectories of plants and animals



Effect of Rewiring



Differences in persistence between Saavedra and real matrix with and without rewiring