The structure and stability of networks with antagonistic and mutualistic interactions

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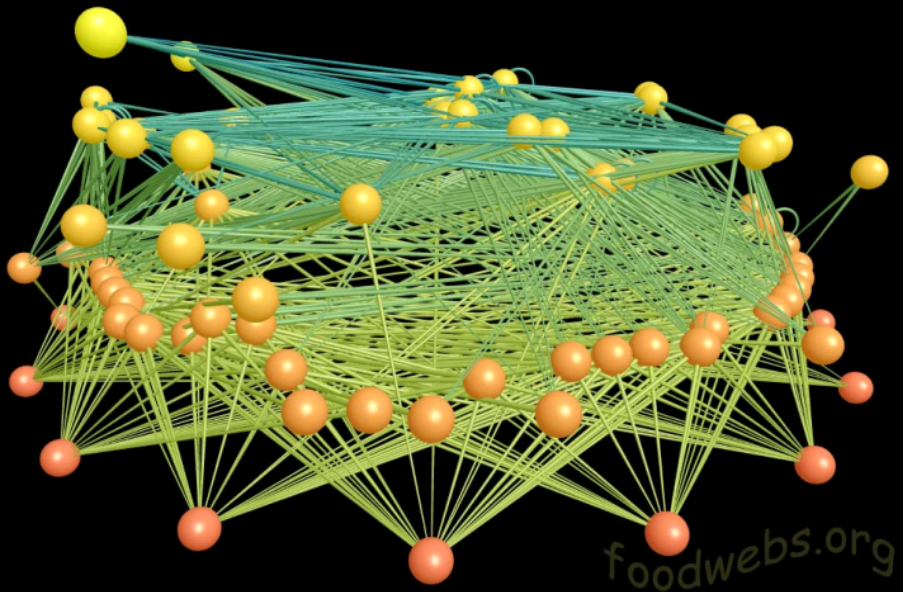
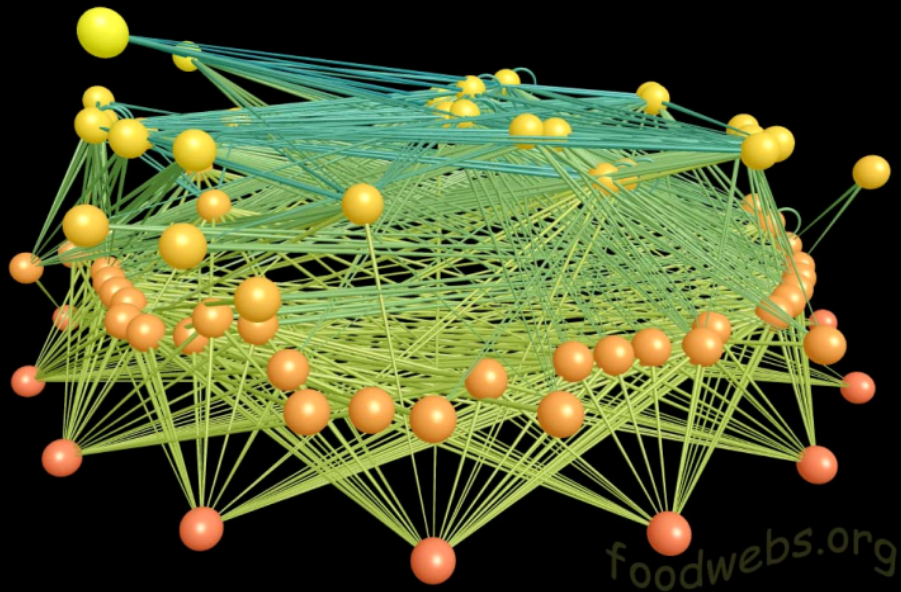
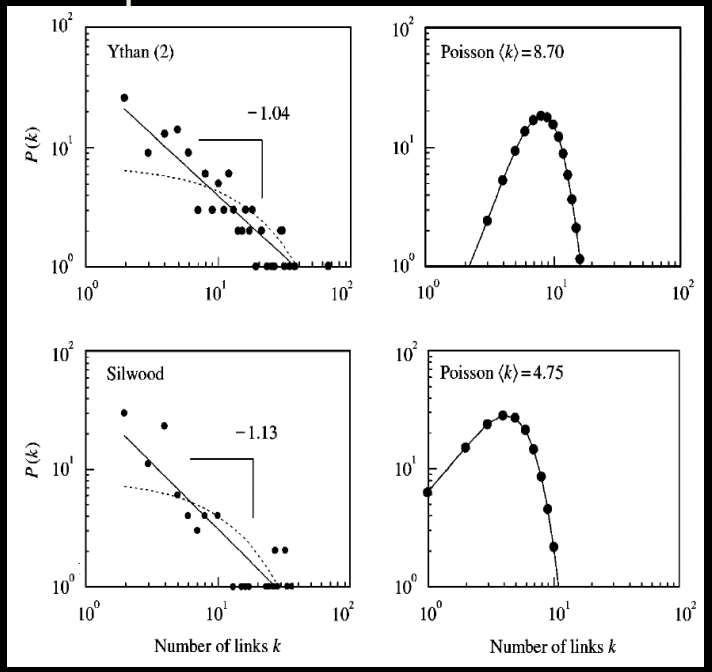
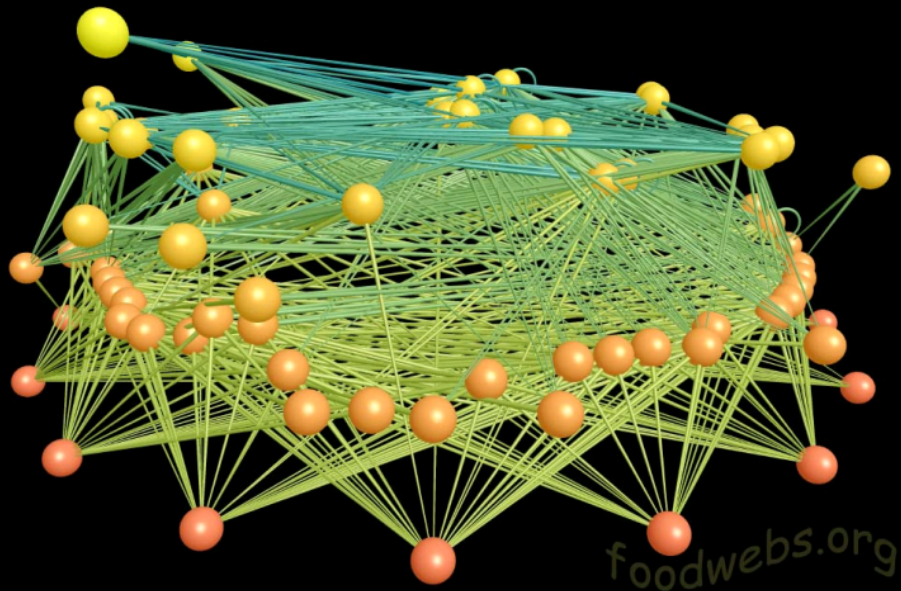

foodwebs.org



Structure

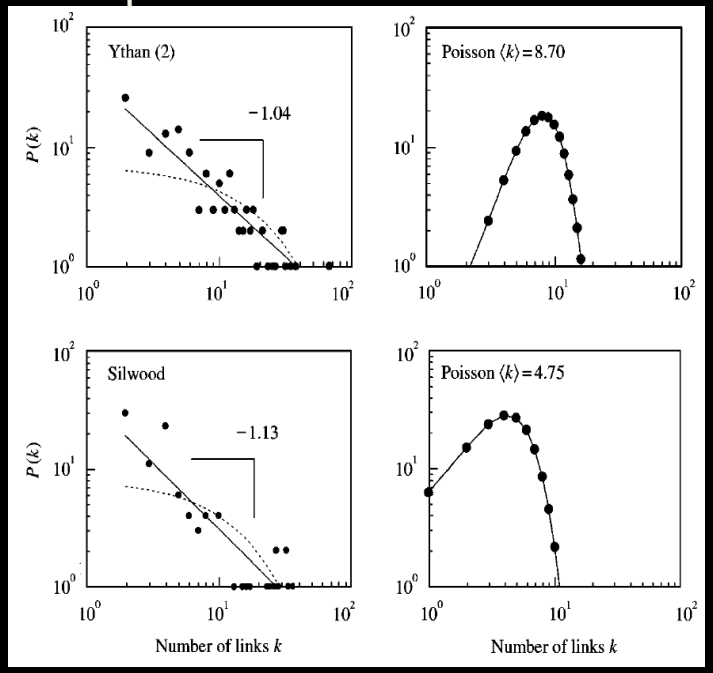
Empirical data Random data

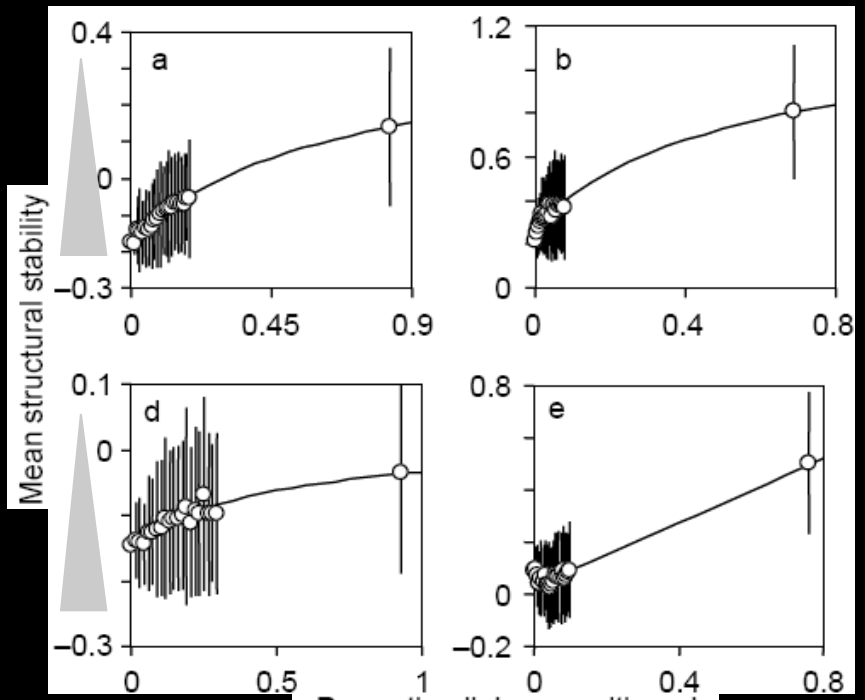




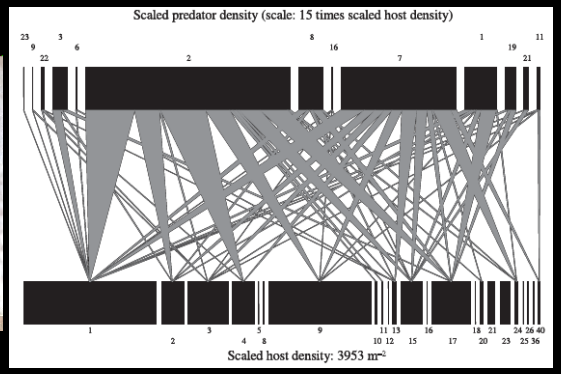
Structure ⟷ Stability

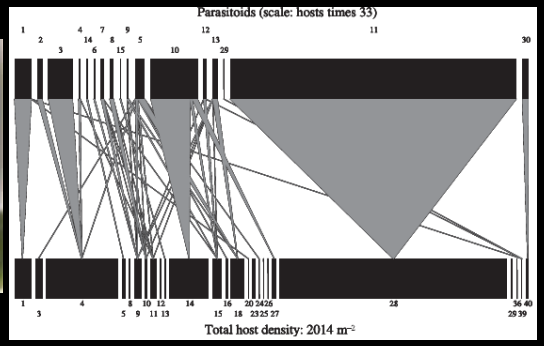
Empirical data Random data



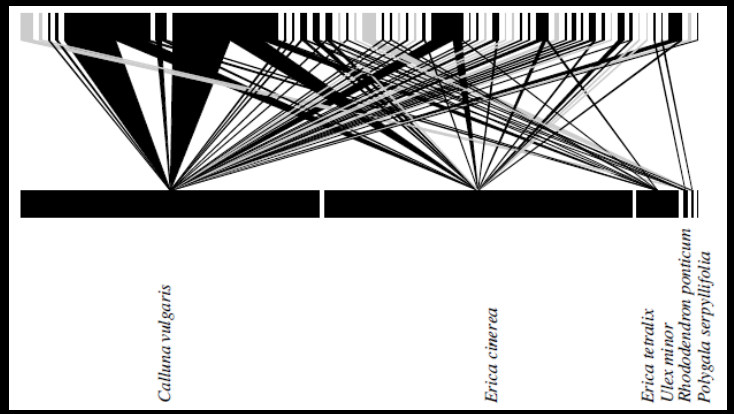


Diversity of interaction types





Structure ⟷ **Stability**

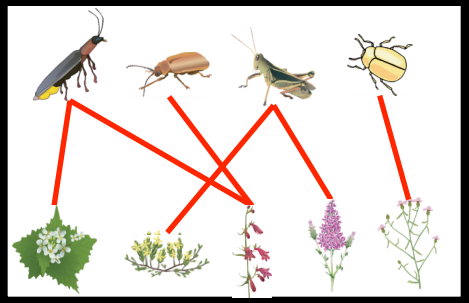


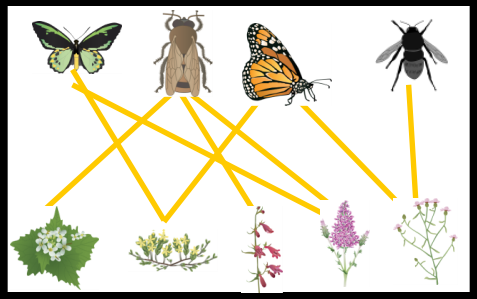
I. Comparing networks with mutualistic and antagonistic interactions

Structure ⟷ **Stability**

Differences between herbivory & pollination networks?

Consequences on species coexistence and stability?





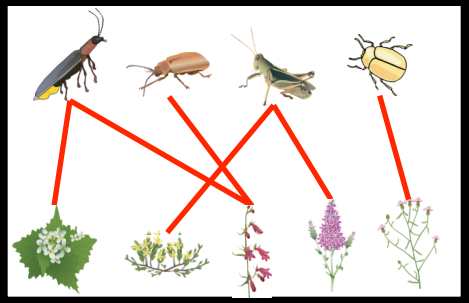
Bascompte et al. *PNAS* 2003

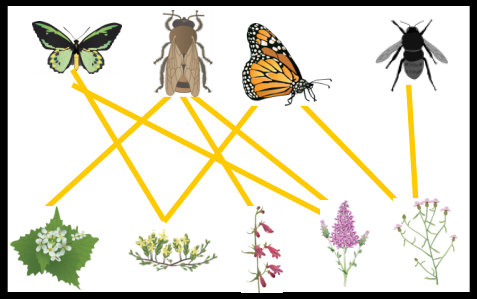
Lewinsohn et al. *Oikos* 2006

I. Comparing networks with mutualistic and antagonistic interactions

Structure

Differences between herbivory & pollination networks?

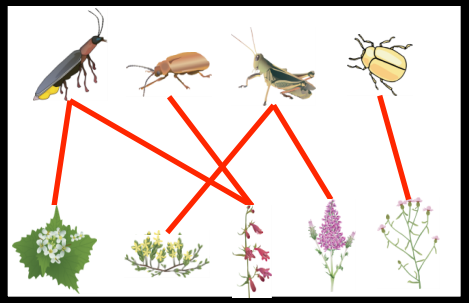


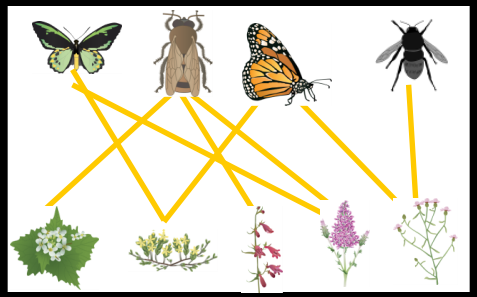


I. Comparing networks with mutualistic and antagonistic interactions

Structure

Differences between herbivory & pollination networks?

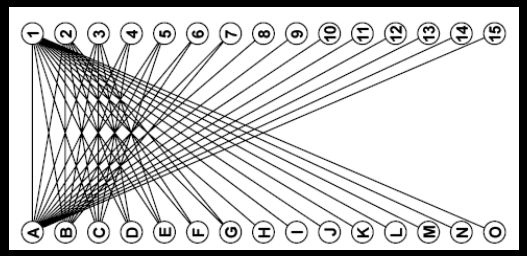




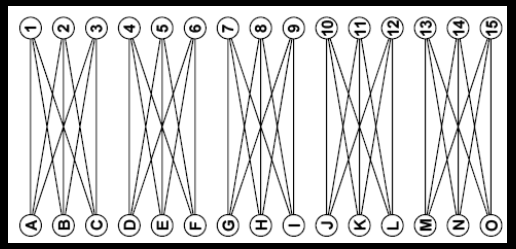
Diversity

Connectance

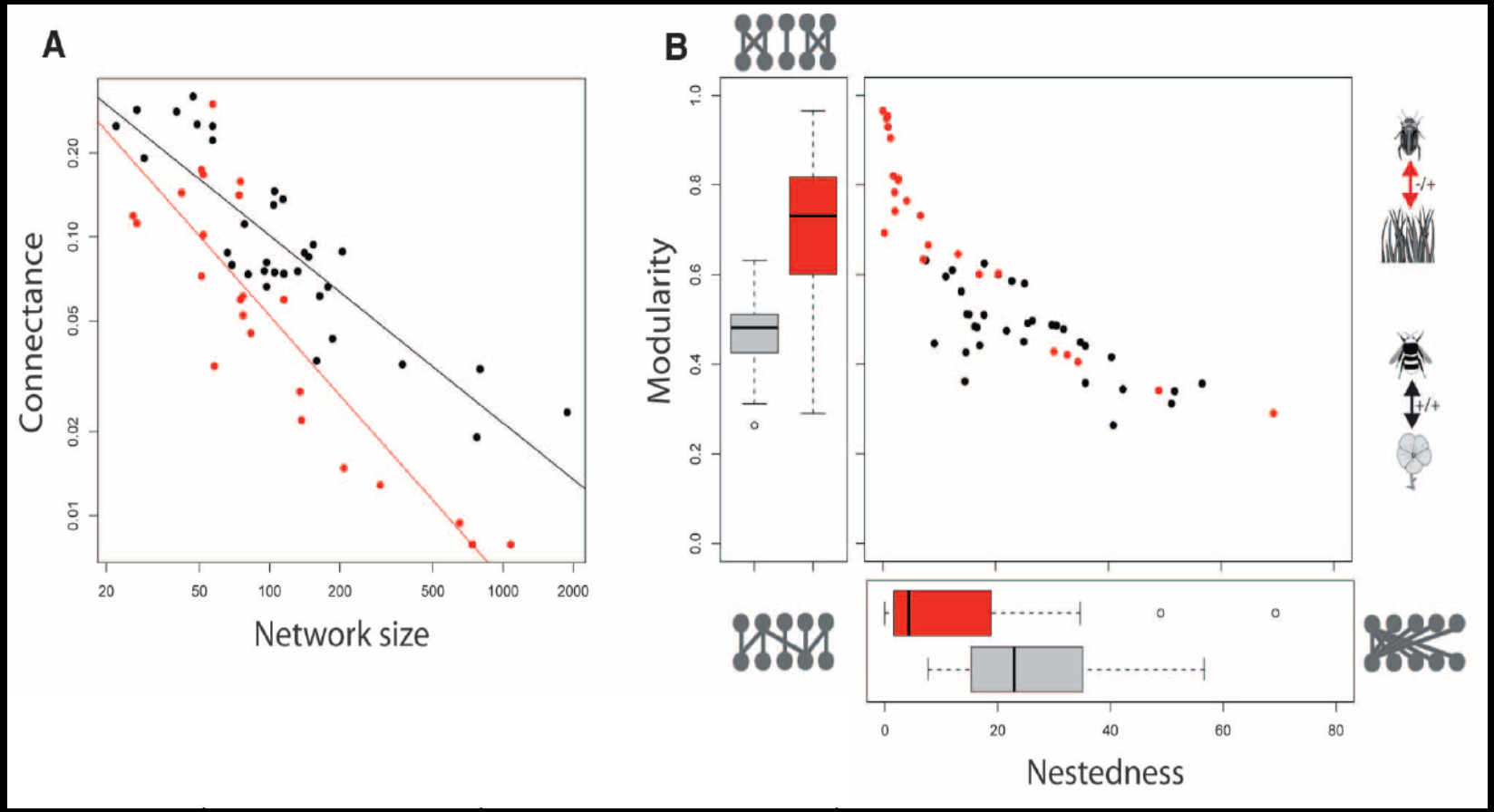
Nestedness



Modularity

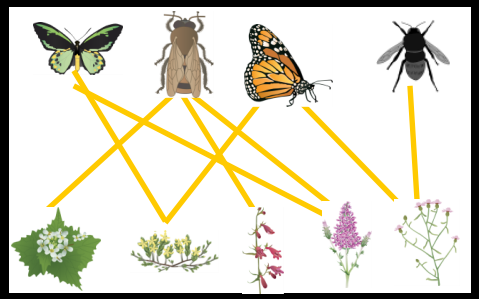


Network structure and interaction type

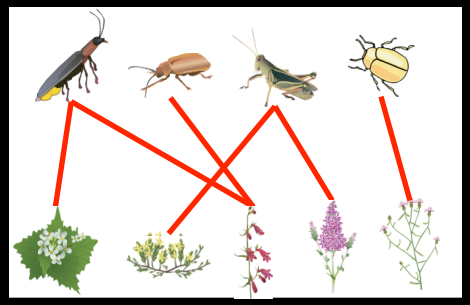


Thébault & Fontaine *Science* 2010

The model: dynamics of mutualistic and trophic webs



Mutualistic



Antagonistic

$$\frac{dA_i}{dt} = r_{Ai}A_i - I_{Ai}A_i^2 + \sum_{j=1}^{Np} \frac{c_{ji}A_iP_j}{\alpha_{ji}^{-1} + \sum_{Pk \in mut(Ai)} P_k}$$

$$\frac{dP_i}{dt} = r_{Pi}P_i - I_{Pi}P_i^2 + \sum_{j=1}^{Na} \frac{c_{ij}A_jP_i}{\alpha_{ij}^{-1} + \sum_{Ak \in mut(Pi)} A_k}$$

-intrinsic growth rates
r_P and $r_A < 0$ ➔ obligate mutualism

-density dependence term

-interaction term
saturates with mutualistic partner densities

$$\frac{dA_i}{dt} = r_{Ai}A_i - I_{Ai}A_i^2 + \sum_{j=1}^{Np} \frac{c_{ji}A_iP_j}{\alpha_{ji}^{-1} + \sum_{Pk \in prey(Ai)} P_k}$$

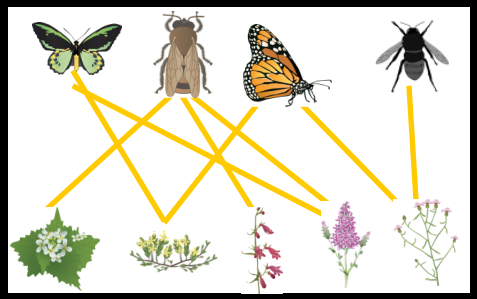
$$\frac{dP_i}{dt} = r_{Pi}P_i - I_{Pi}P_i^2 - \sum_{j=1}^{Na} \frac{c_{ij}A_jP_i}{\alpha_{ij}^{-1} + \sum_{Pk \in prey(Aj)} P_k}$$

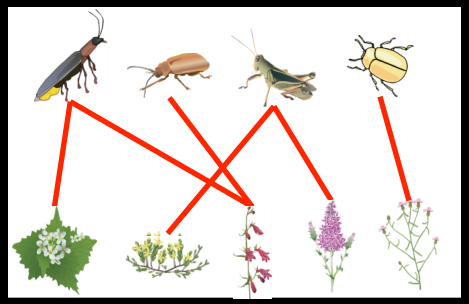
-intrinsic growth rates
$r_P > 0$ and $r_A < 0$

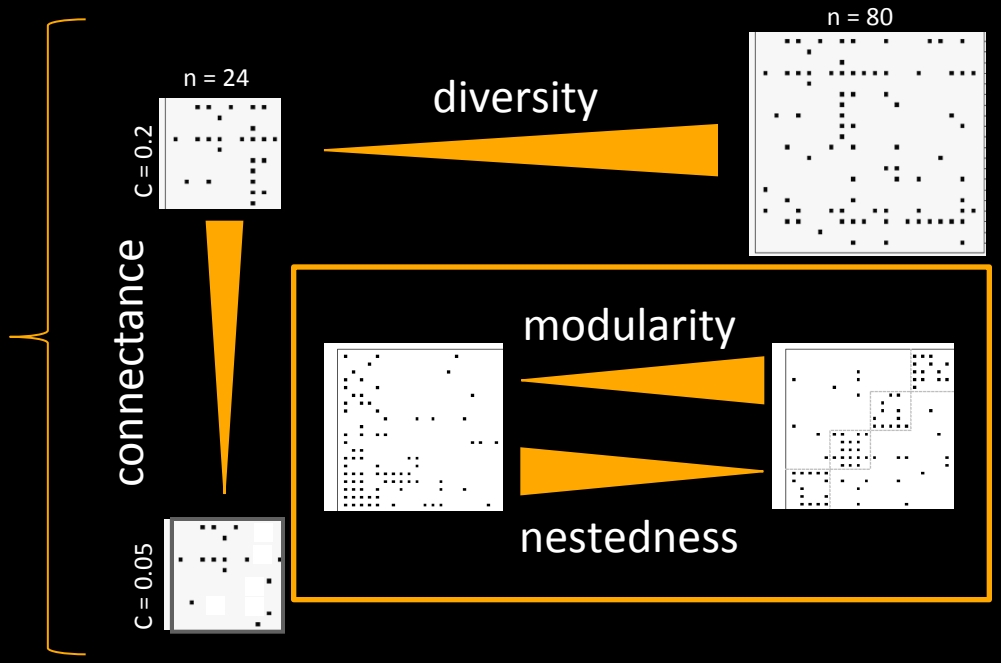
-density dependence term

-interaction term
saturates with prey densities

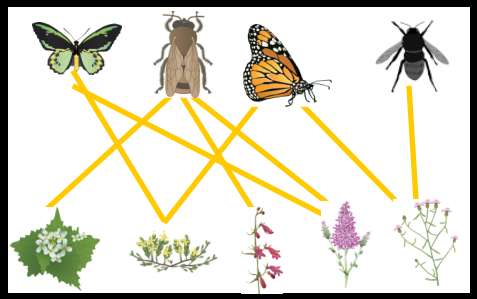
The model: network structure and stability

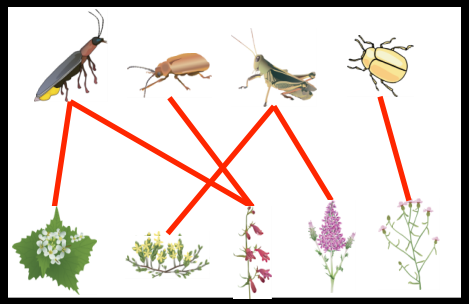


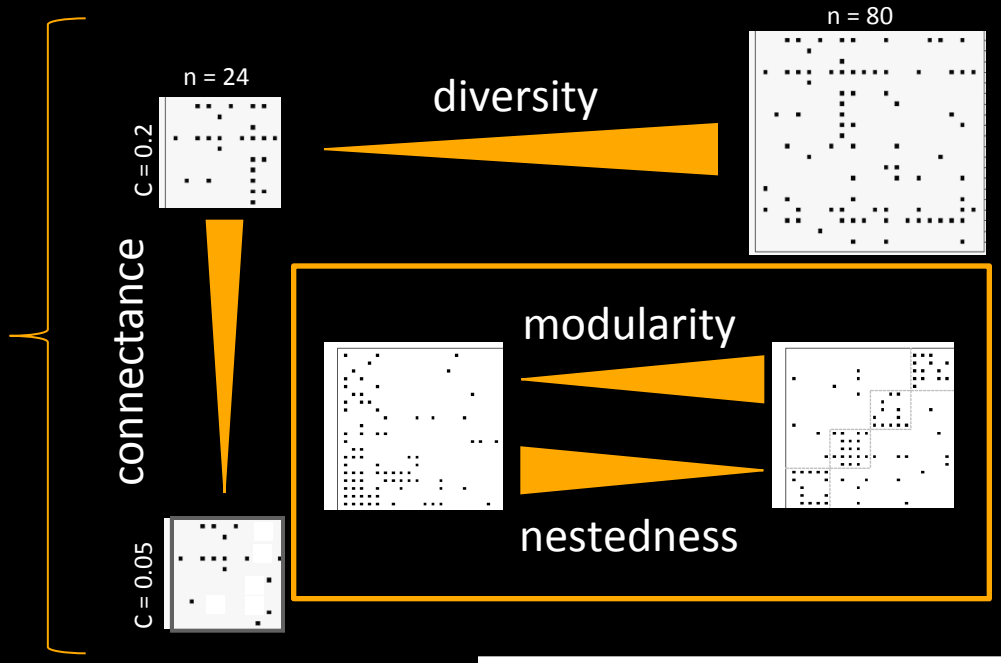




The model: network structure and stability





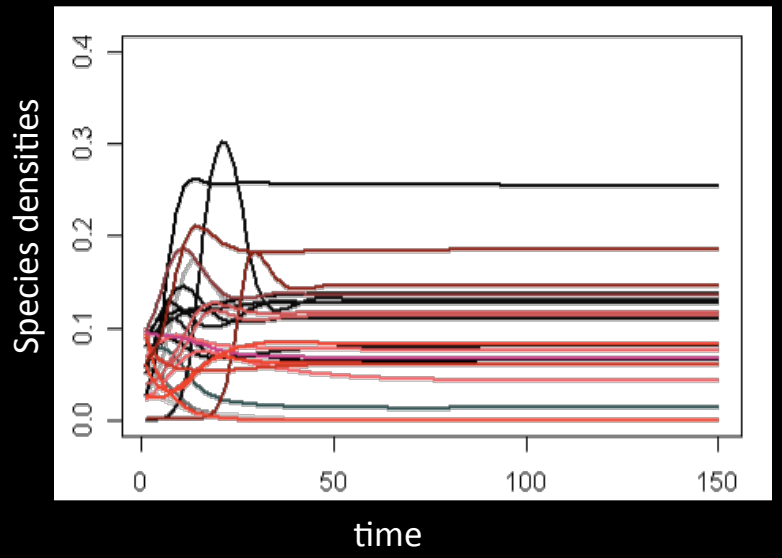


- Persistence:

proportion of species persisting at the equilibrium

- Resilience:

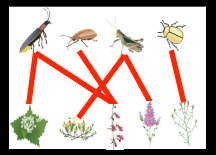
measure of the speed at which a system returns to its original state after a perturbation

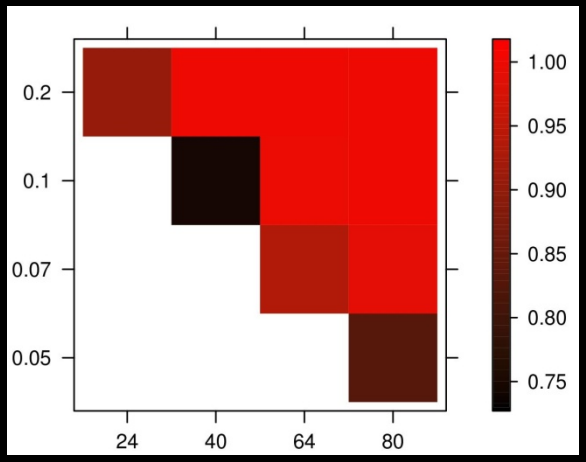


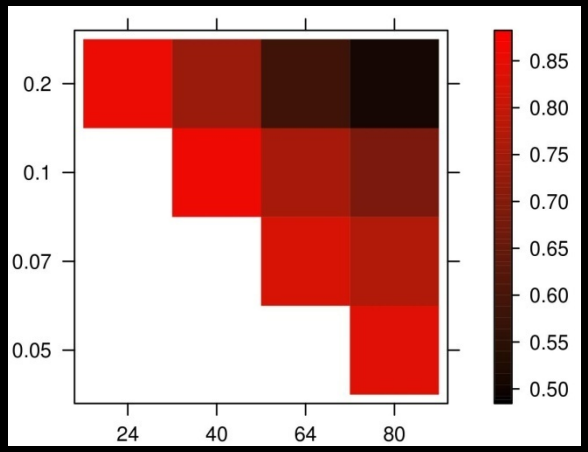
Results: impact of network structure on species persistence

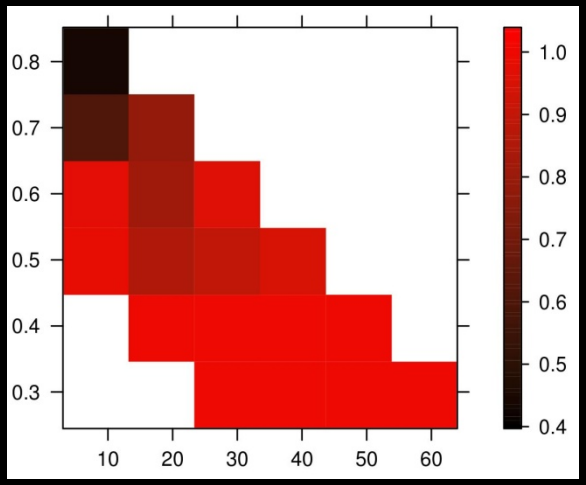
Mutualistic networks

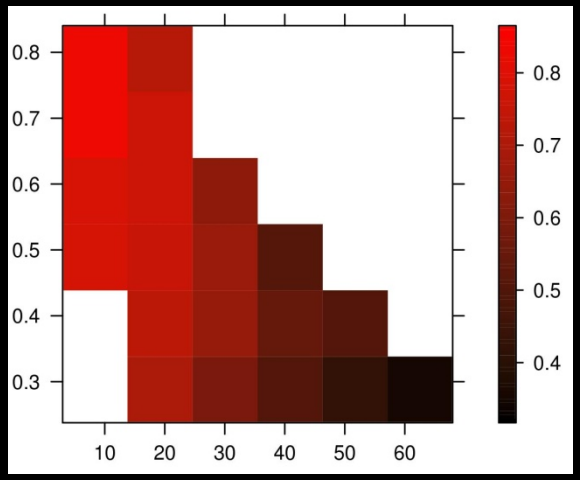
Antagonistic networks



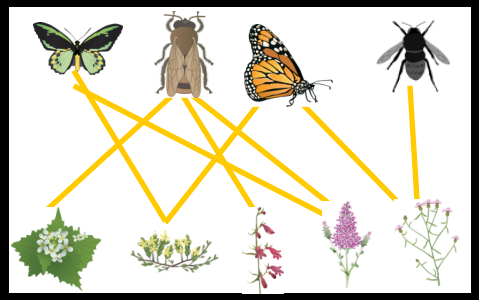




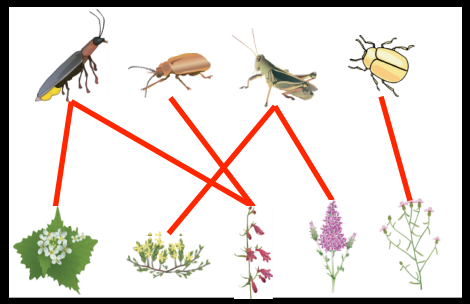




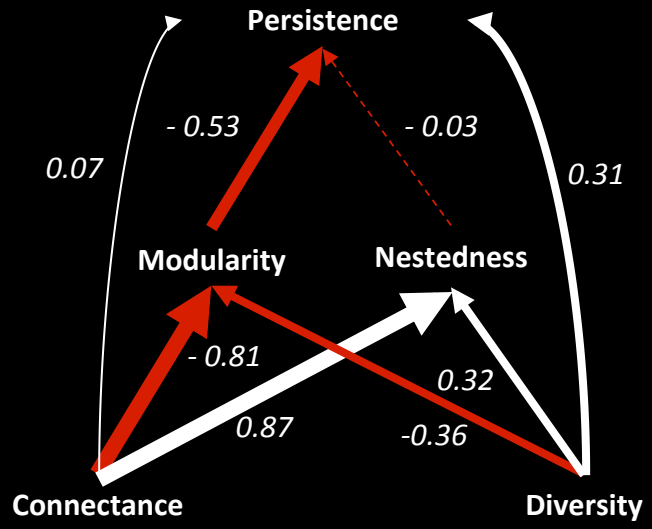
Results: impact of network structure on species persistence

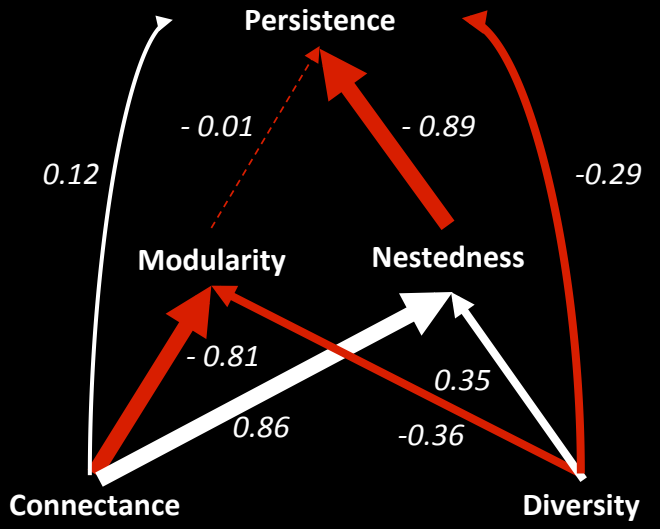


Mutualistic



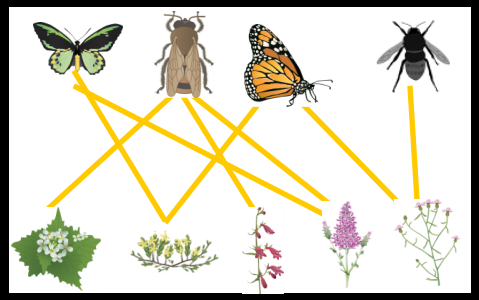
Antagonistic



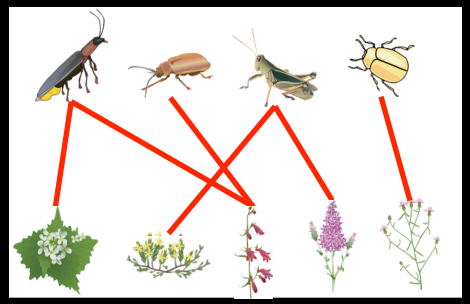


➢ opposite effect of network structure on the persistence of mutualistic and trophic networks

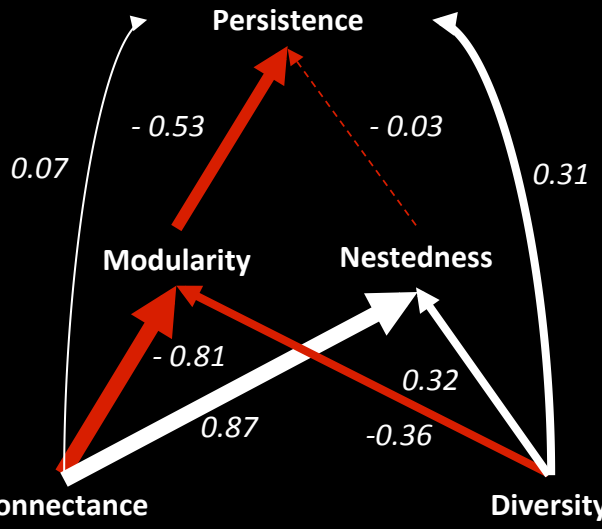
Results: impact of network structure on species persistence



Mutualistic

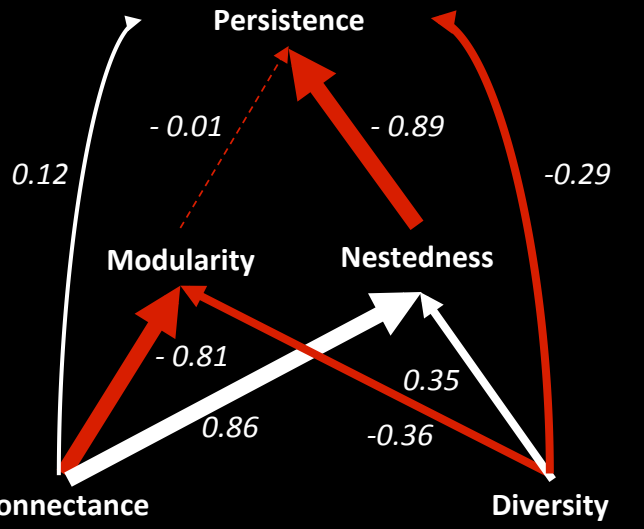


Antagonistic



indirect effect: 0.40

indirect effect: 0.18

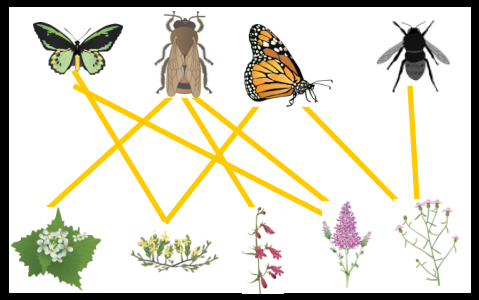


indirect effect: -0.76

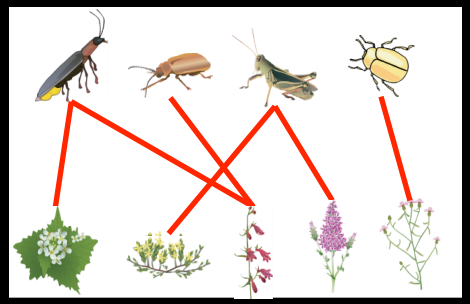
indirect effect: -0.31

➢ Importance of nestedness and modularity for network stability

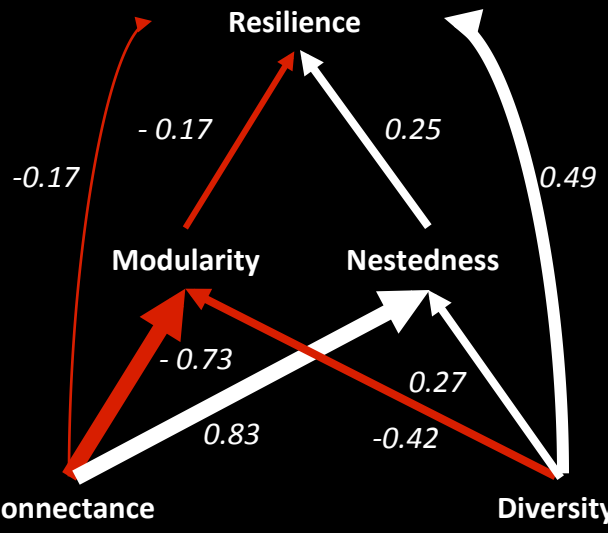
Results: impact of network structure on resilience



Mutualistic

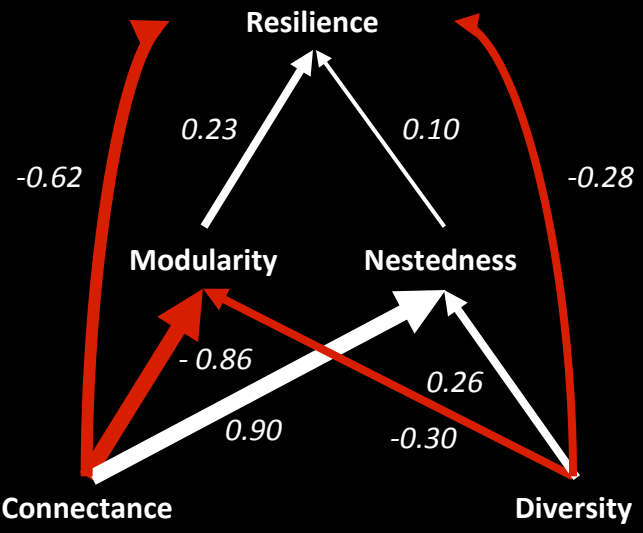


Antagonistic



indirect effect: 0. 32

indirect effect: 0.13



indirect effect: -0.10

indirect effect: -0.04

➢ opposite effect of network structure on the resilience of mutualistic and trophic networks

I. Comparing networks with mutualistic and antagonistic interactions

Structure  **Stability**

The structure of mutualistic and antagonistic networks seem to differ

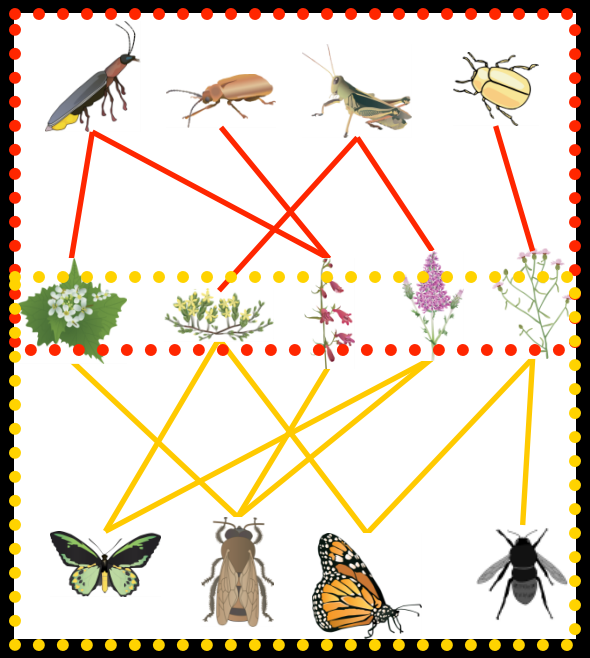
Strong effects of network structure on community stability that depends on interaction types

Importance of the fine architecture of interaction networks in determining their stability

II. Networks with both mutualistic and antagonistic interactions

Structure ⟷ **Stability**

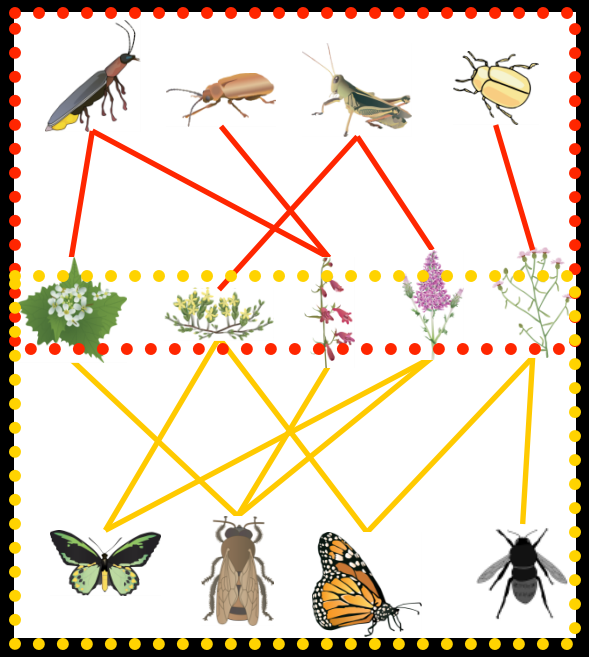
Structure of networks with interaction type diversity



Same consequences on species coexistence and stability than when considered in networks with one interaction type?

The model: dynamics with both mutualistic and trophic interactions

Antagonistic network



Mutualistic network

$$\frac{dH_i}{dt} = r_{Hi}H_i - I_{Hi}H_i^2 + \sum_{j=1}^{Np} \frac{c_{ji}H_iP_j}{\alpha_{ji}^{-1} + \sum_{Pk \in prey(Hi)} P_k}$$

$$\frac{dM_i}{dt} = r_{Mi}M_i - I_{Mi}M_i^2 + \sum_{j=1}^{Np} \frac{c_{ji}M_iP_j}{\alpha_{ji}^{-1} + \sum_{Pk \in mut(Mi)} P_k}$$

$$\frac{dP_i}{dt} = r_{Pi}P_i - I_{Pi}P_i^2 + \sum_{j=1}^{Nm} \frac{c_{ij}M_jP_i}{\alpha_{ij}^{-1} + \sum_{Mk \in mut(Pi)} M_k} - \sum_{j=1}^{Na} \frac{c_{ij}H_jP_i}{\alpha_{ij}^{-1} + \sum_{Pk \in prey(Hj)} P_k}$$

-intrinsic growth rates

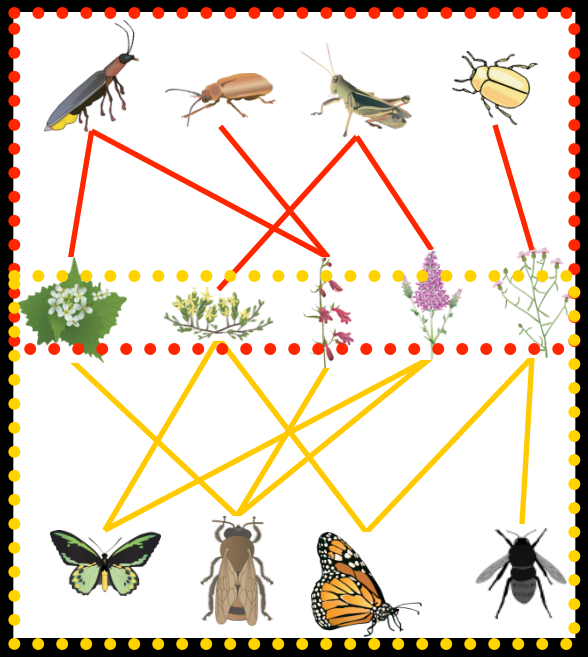
-density dependence term

- mutualistic interaction, saturates with mutualistic partner densities

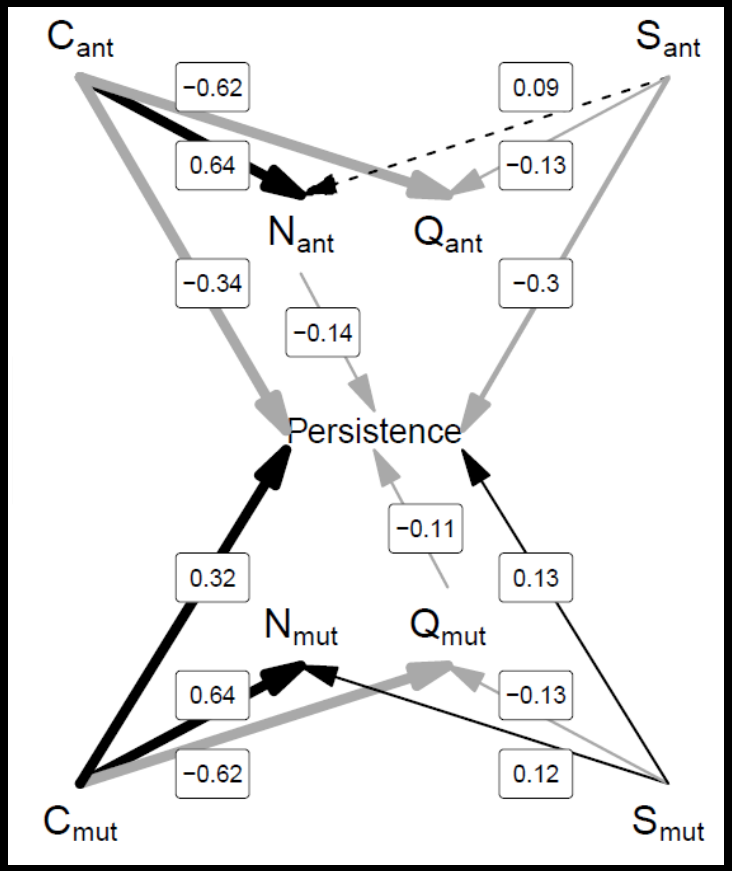
- plant-herbivore interaction term, saturates with prey densities

Results: impact of network structure on species persistence

Antagonistic network



Mutualistic network

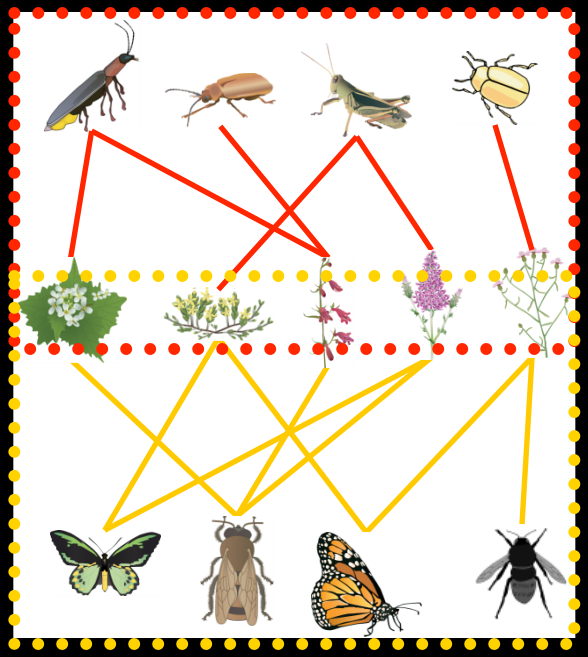


Sauve et al. *Oikos* in press

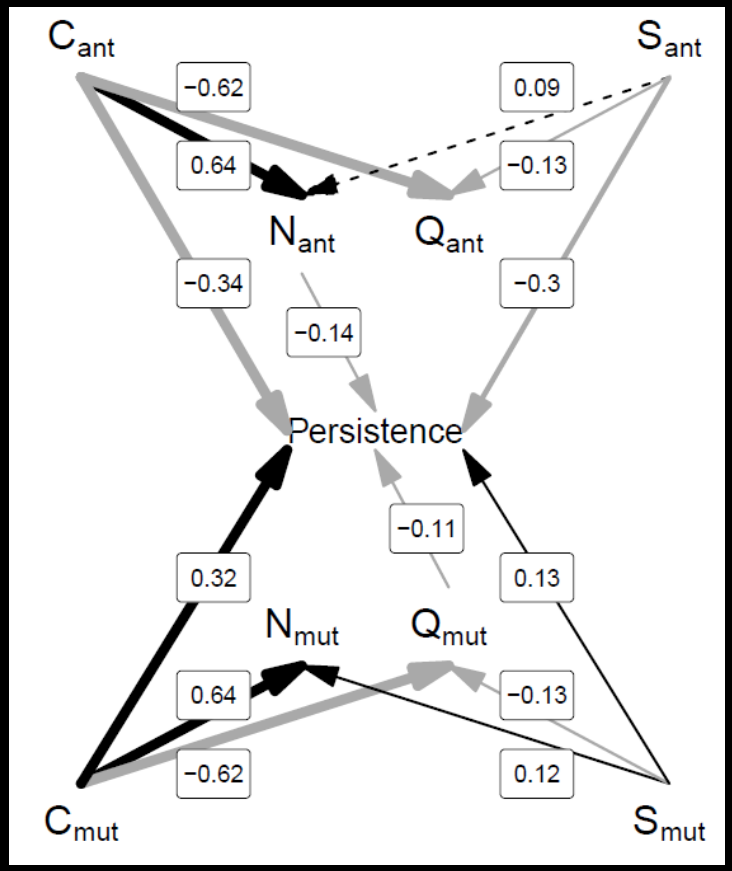
➢ opposite effect of mutualistic and trophic network structure on the persistence

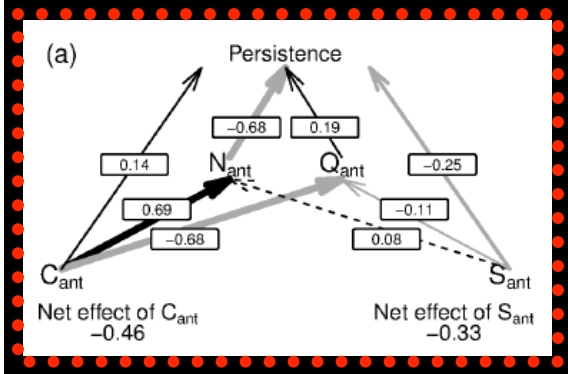
Results: impact of network structure on species persistence

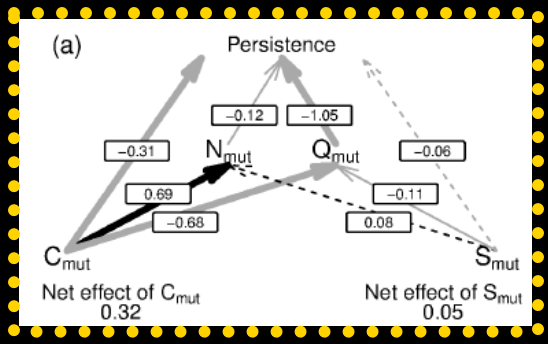
Antagonistic network



Mutualistic network







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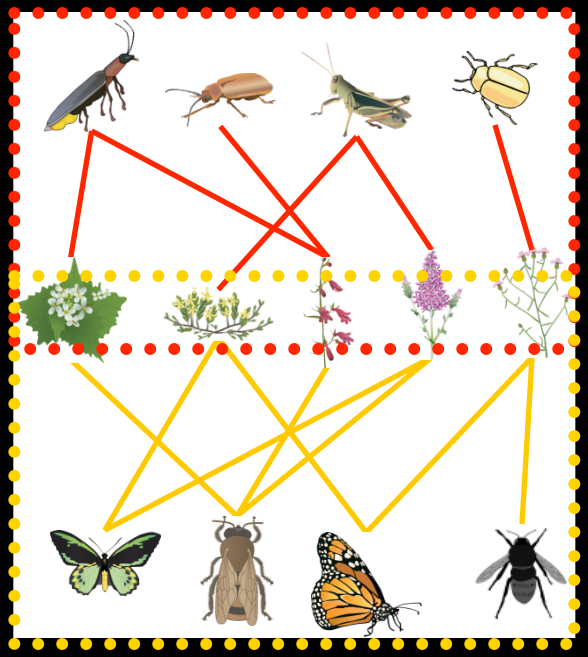
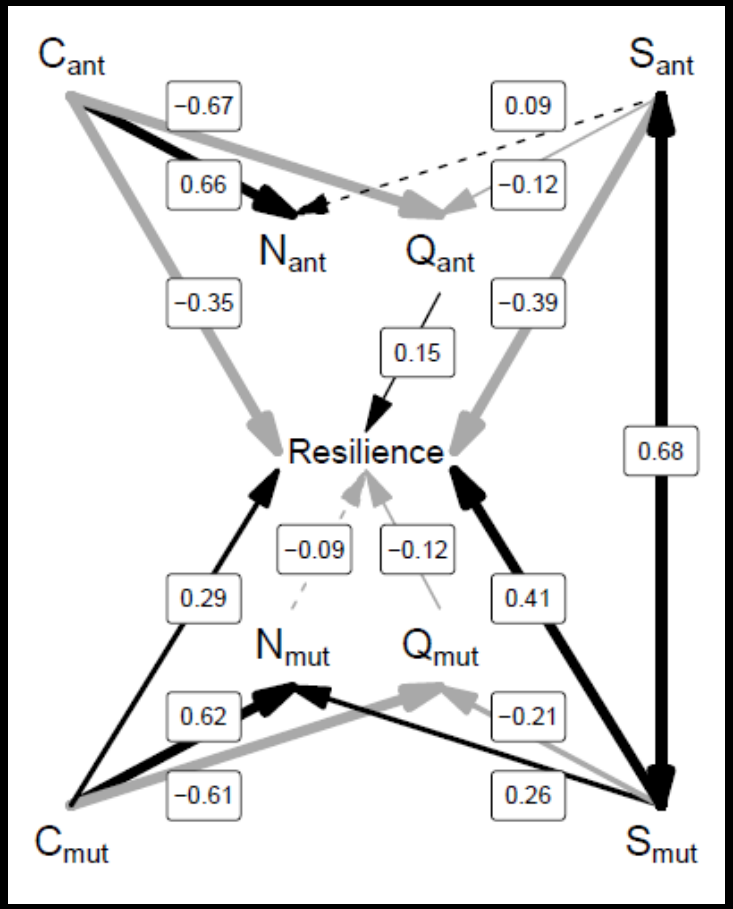
➢ main effects of diversity and connectance

Results: impact of network structure on resilience

Antagonistic network



Mutualistic network



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➢ opposite effect of mutualistic and trophic network structure on resilience

II. Networks with both mutualistic and antagonistic interactions

Structure ⟷ **Stability**

Effects of diversity and connectance mostly unchanged

Effects of modularity and nestedness strongly weakened

Are structural indices developed for network with a single interaction type relevant to describe network with multiple interaction types?

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Thank you for your attention