Complexity-stability debate

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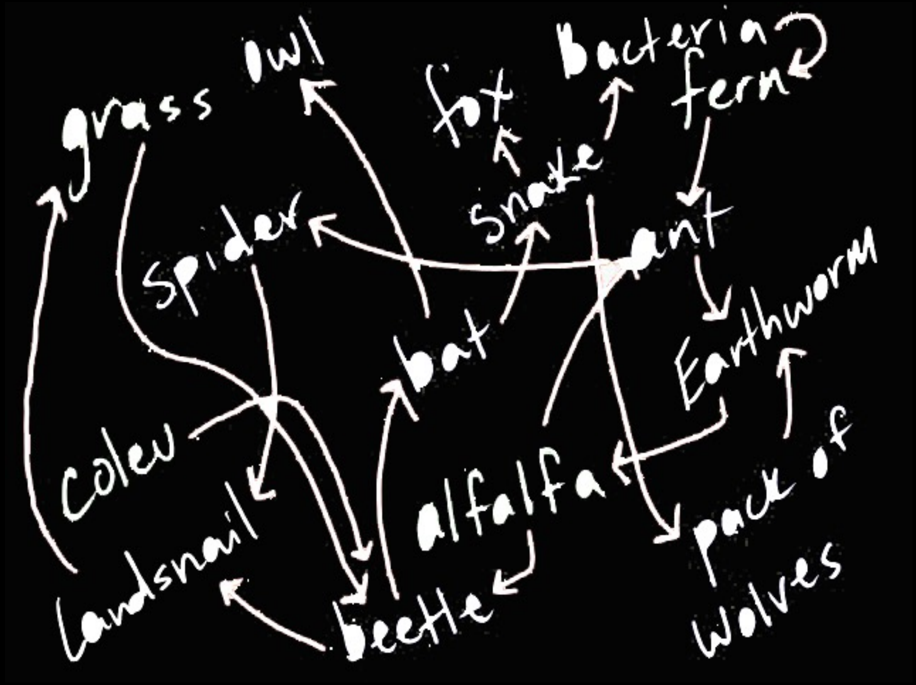
Q2: What are the factors that contribute to the stability of ecological communities?

« Complexity begets stability »

Odum 1953
MacArthur 1955
Elton 1958

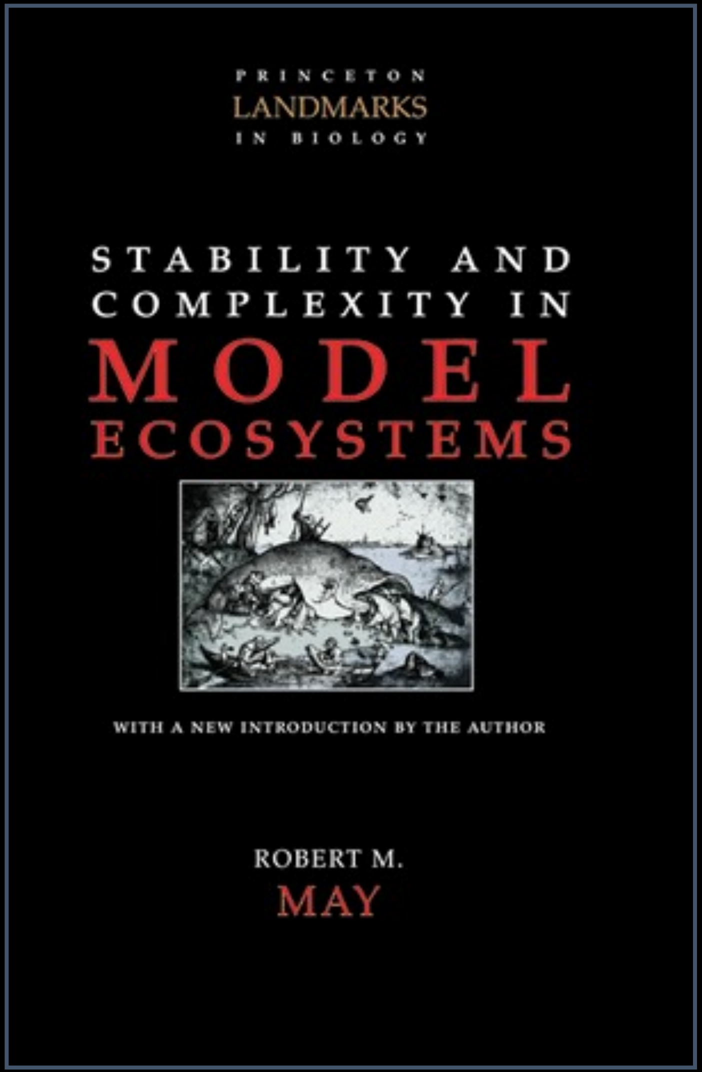
« Complexity begets stability »

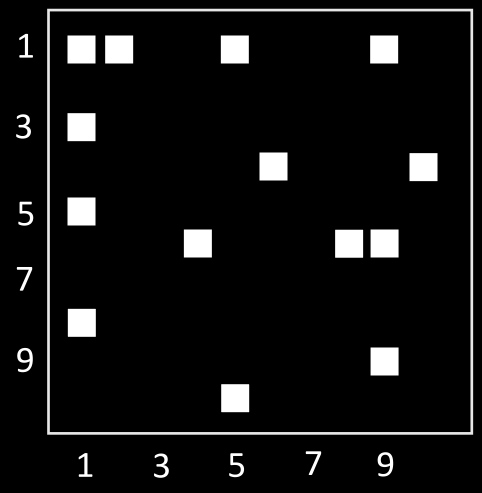
« Stability increases as the number of links increases »

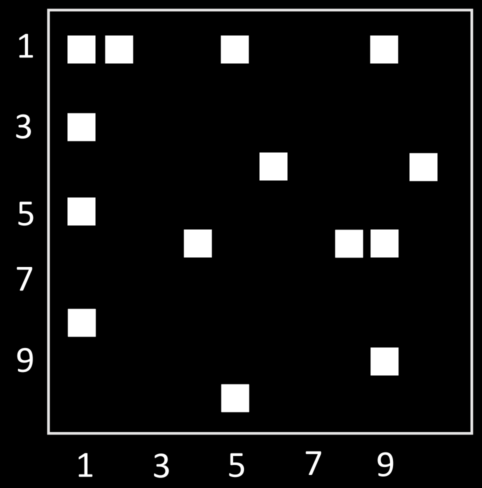
MacArthur 1955

Robert May

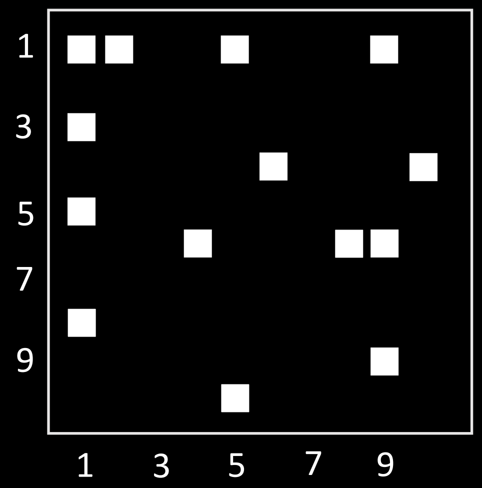

PRINCETON
LANDMARKS
IN BIOLOGY
STABILITY AND
COMPLEXITY IN
MODEL
ECOSYSTEMS
WITH A NEW INTRODUCTION BY THE AUTHOR
ROBERT M.
MAY

« community » matrix





Random links
Random interaction strengths



Random links
Random interaction strengths
Local stability analysis

$$\alpha < (n\ C)^{-1/2}$$

Std of interaction strengths

species

Connectance

Local stability decreases with connectance, diversity and average interaction strength.

$$\alpha < (n\ C)^{-1/2}$$

Std of interaction strengths

species

Connectance

"In general mathematical models of multispecies communities, complexity tends to beget instability"

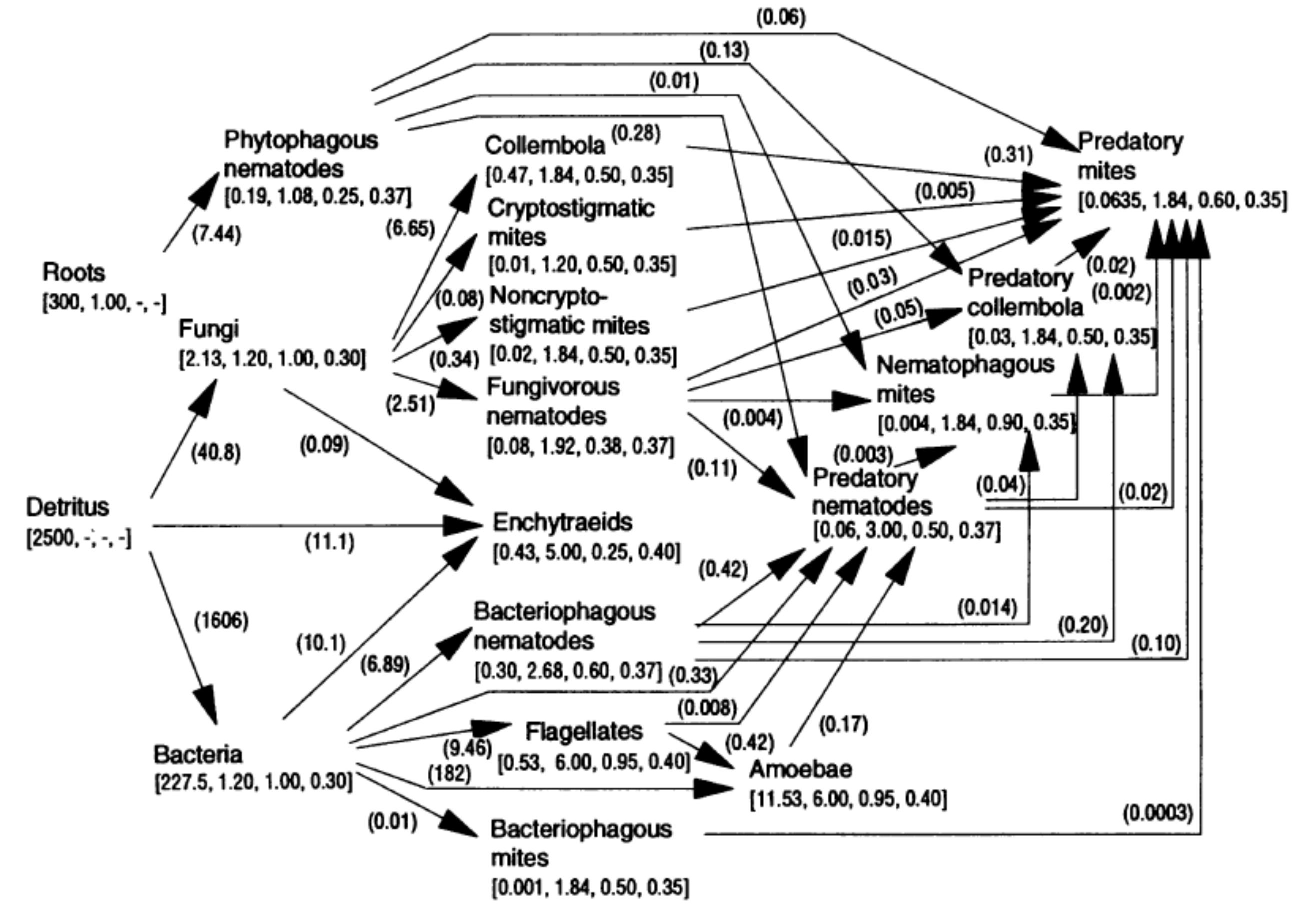
Robert May, 1973

"The task, therefore, is to elucidate the devious strategies which make for stability in enduring natural systems"

Robert May

What are the characteristics of complex ecological networks that allow for the stability of natural communities?

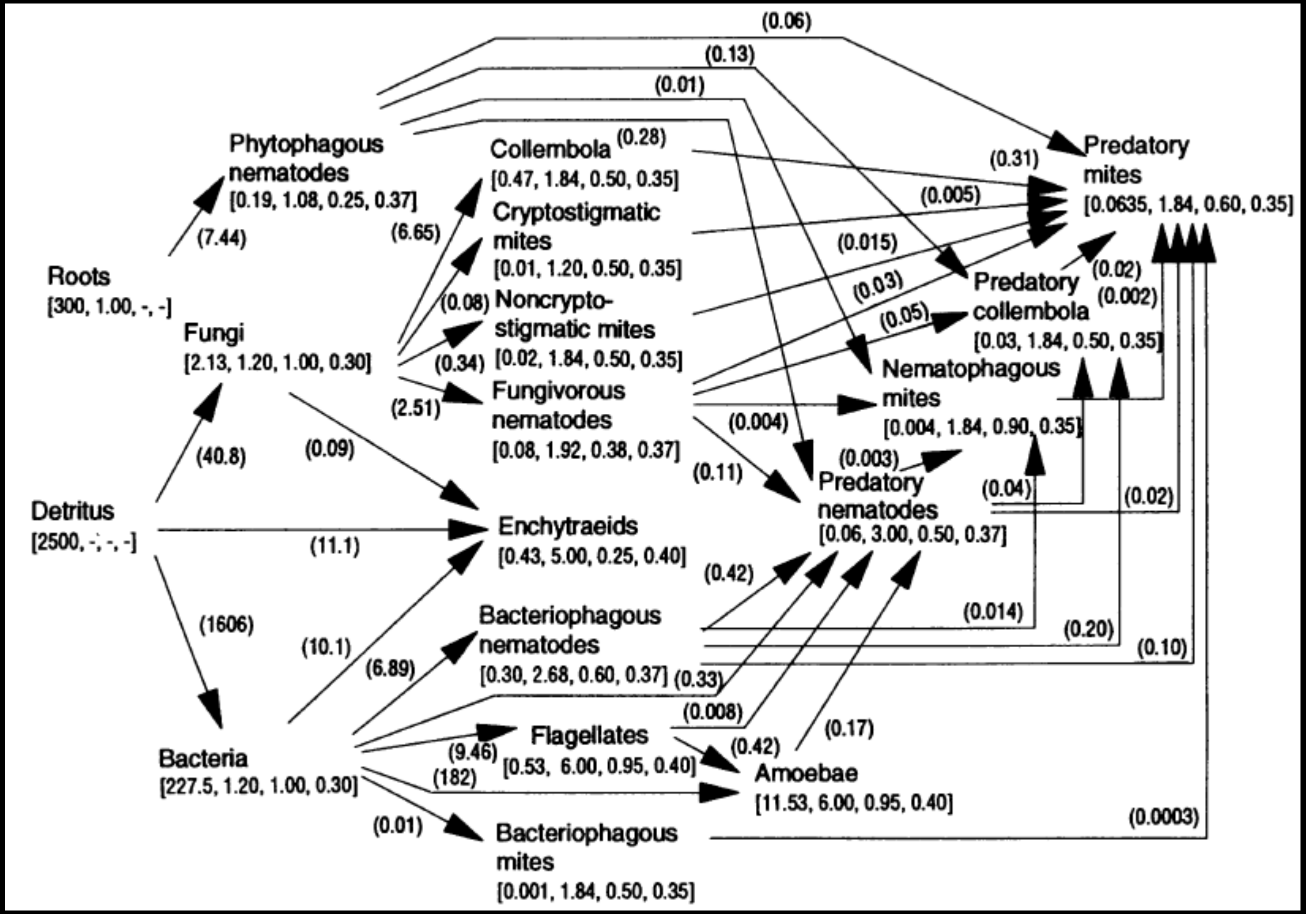
Interaction strengths



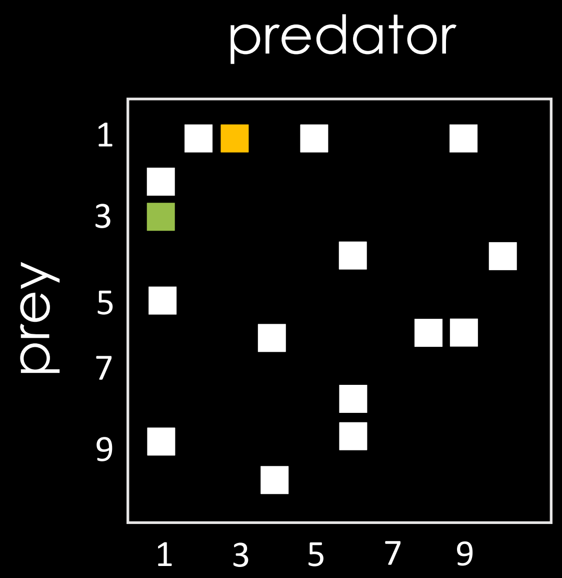
7 food webs
native and agricultural soils

Empirical estimates of:
- feeding rates
- death rates
- energy conversion efficiencies

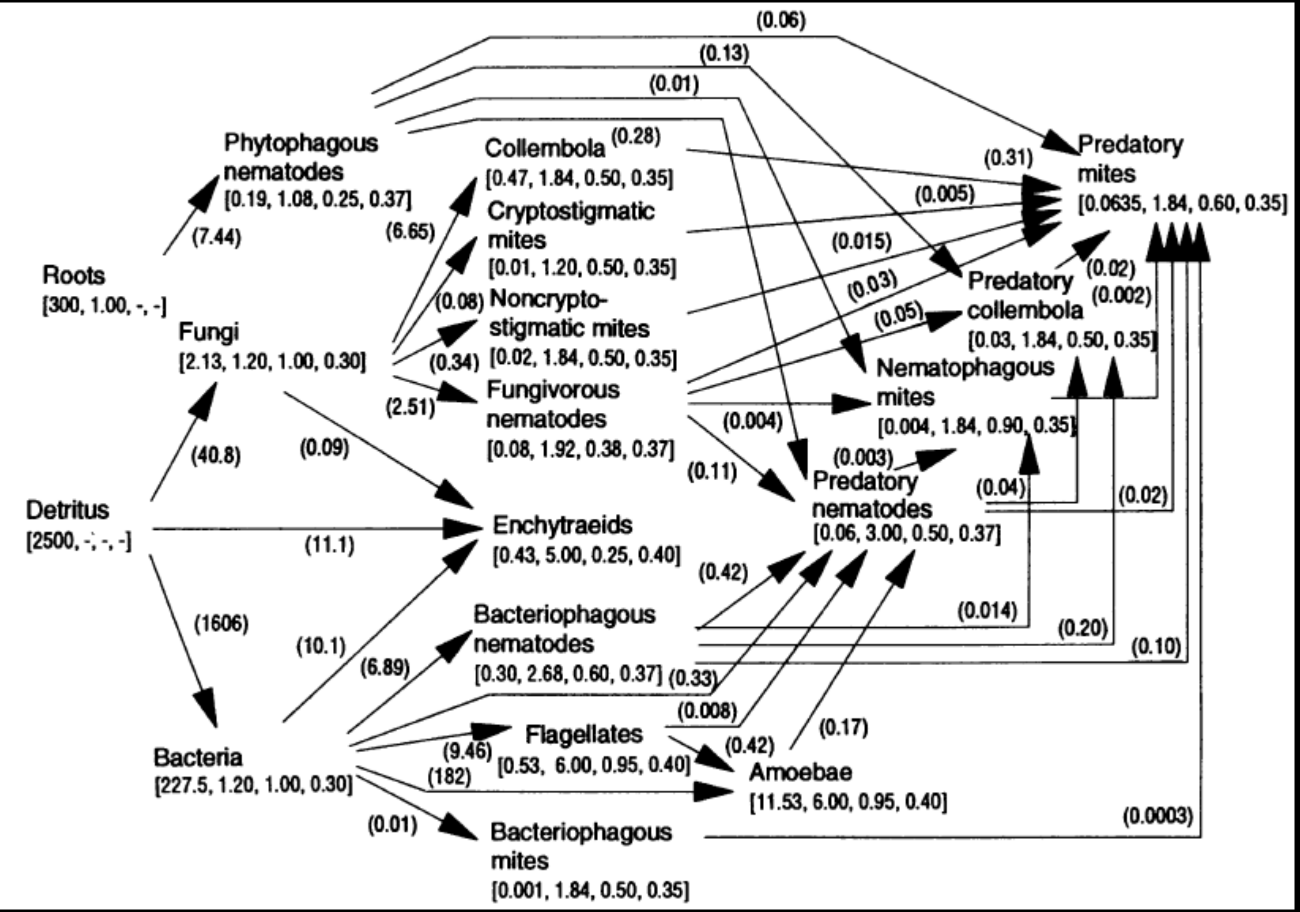
De Ruiter et al. 1995 Science



community matrix



De Ruiter et al. 1995 Science

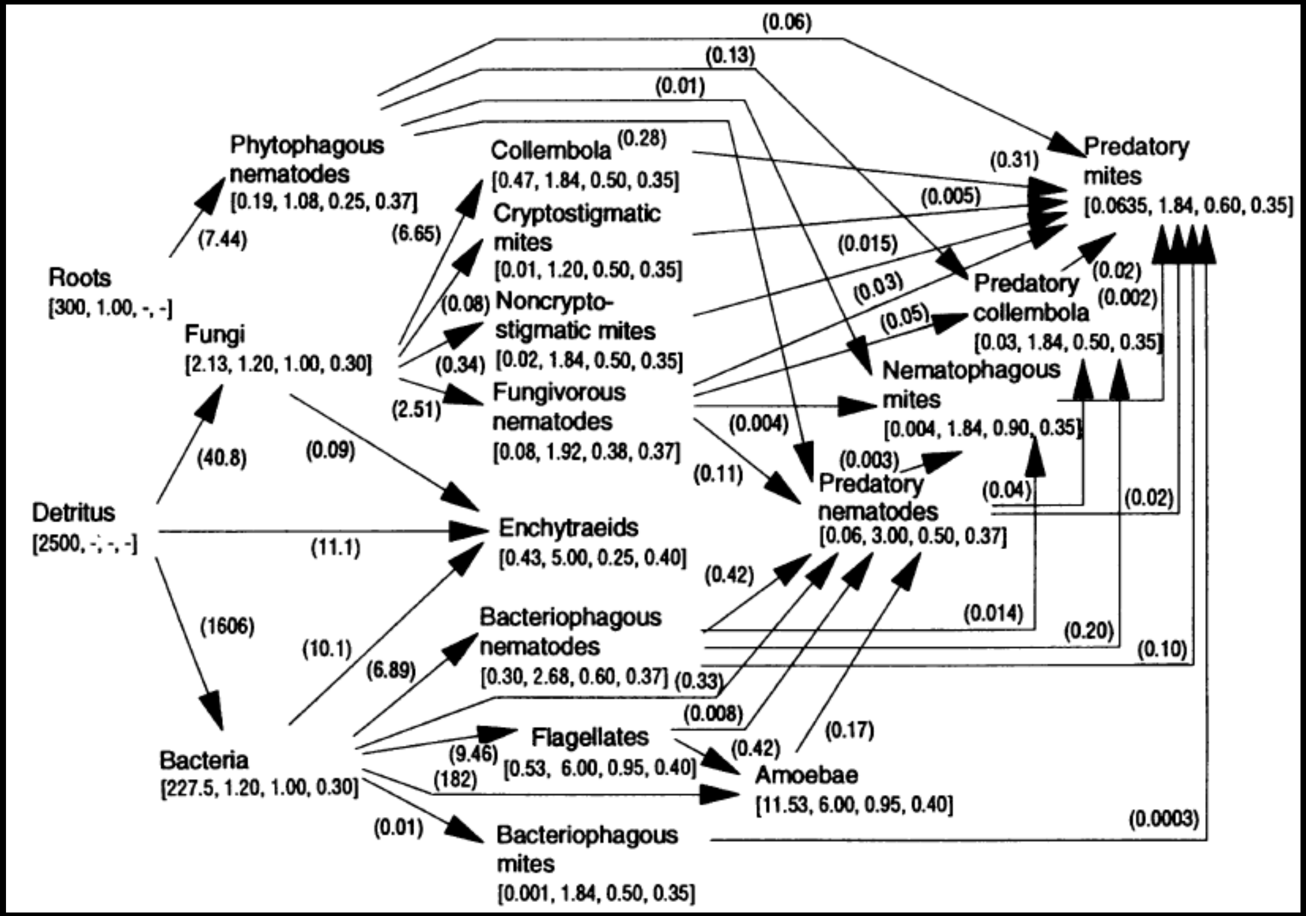


Lotka-Volterra equations

Interaction coeff.

$$\frac{dB_i}{dt} = b_i B_i + \sum_{j=1}^{n} c_{ij} B_j B_i$$

De Ruiter et al. 1995 Science



Lotka-Volterra equations

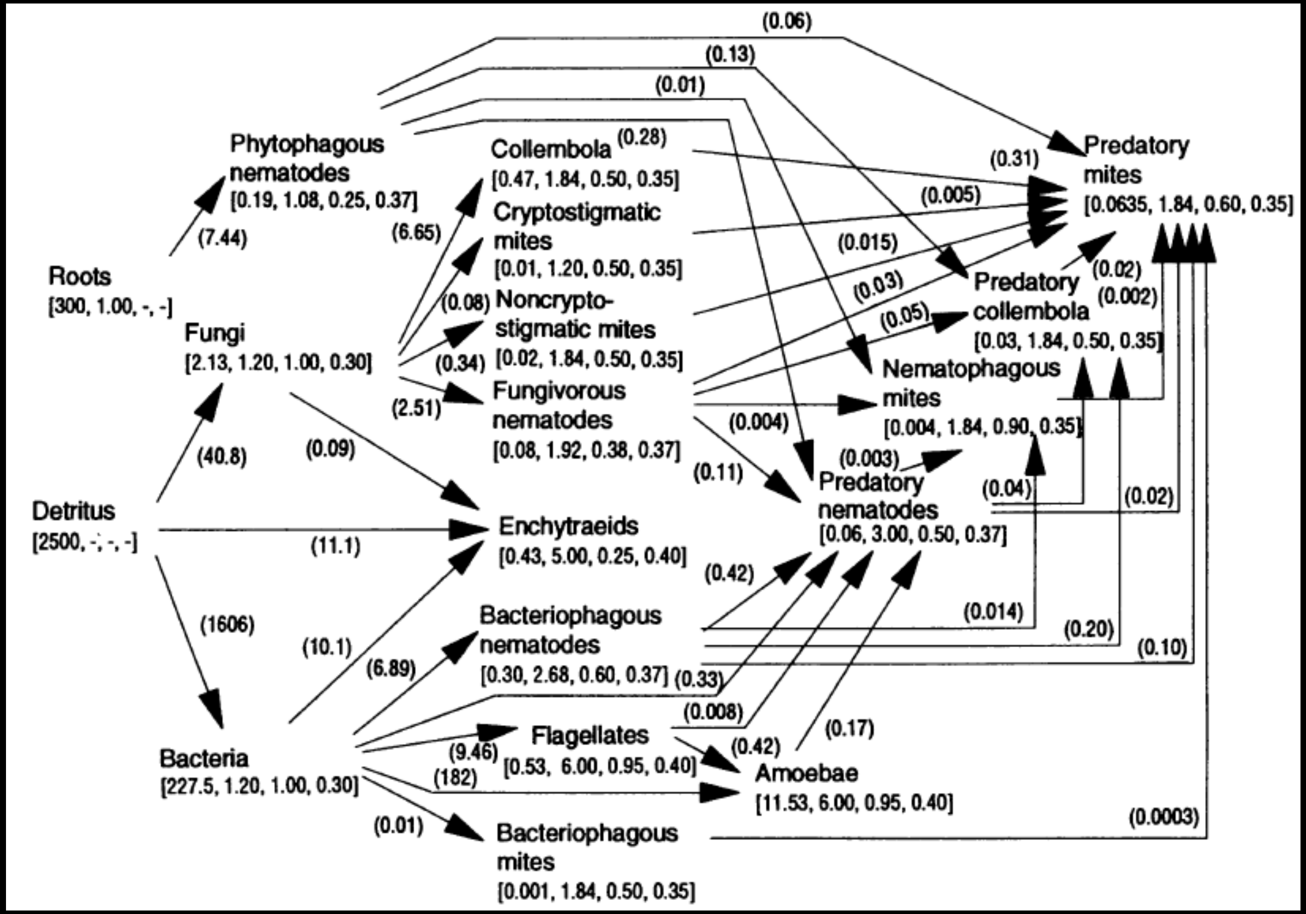
Interaction coeff.

$$\frac{dB_i}{dt} = b_i B_i + \sum_{j=1}^{n} c_{ij} B_j B_i$$

Interaction strength

$$\left(\frac{\partial \frac{dB_i}{dt}}{\partial B_j} \right)^* = \alpha_{ij}$$

De Ruiter et al. 1995 Science



Lotka-Volterra equations

Interaction coeff.

$$\frac{dB_i}{dt} = b_i B_i + \sum_{j=1}^{n} c_{ij} B_j B_i$$

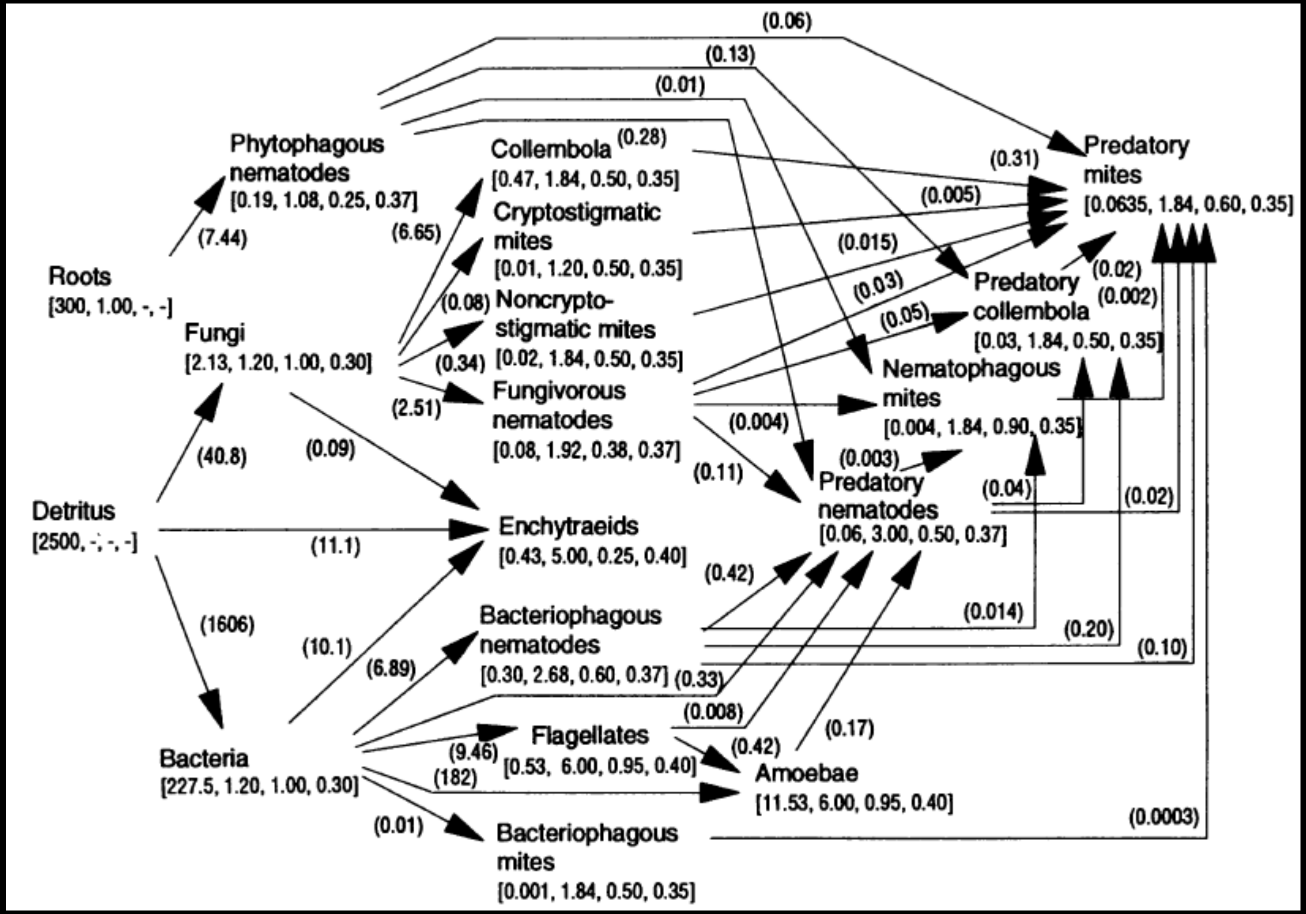
Interaction strength

$$\alpha_{ij} = \left(\frac{\partial \frac{dB_i}{dt}}{\partial B_j} \right)^*$$

Per capita effect of j on i

$$\alpha_{ij} = c_{ij} B_i^*$$

De Ruiter et al. 1995 Science



LV equations

Interaction coeff.

$$\frac{dB_i}{dt} = b_i B_i + \sum_{j=1}^{n} c_{ij} B_j B_i$$

$$\alpha_{ij} = \left(\frac{\partial \frac{dB_i}{dt}}{\partial B_j} \right)^*$$

Interaction strength

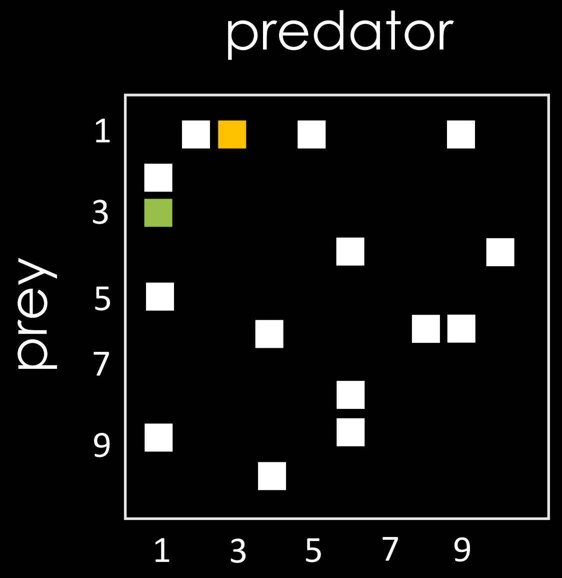
$$\alpha_{ij} = c_{ij} B_i^*$$

Per capita effect of pred j on prey i

$$\alpha_{ji} = c_{ji} B_j^*$$

Per capita effect of prey i on pred j

De Ruiter et al. 1995 Science



Terms of the Jacobian

Interaction coeff.

$$\frac{dB_i}{dt} = b_i B_i + \sum_{j=1}^{n} c_{ij} B_j B_i$$

$$\alpha_{ij} = \left(\frac{\partial \frac{dB_i}{dt}}{\partial B_j} \right)^*$$

Interaction strength

$$\alpha_{ij} = c_{ij} B_i^*$$

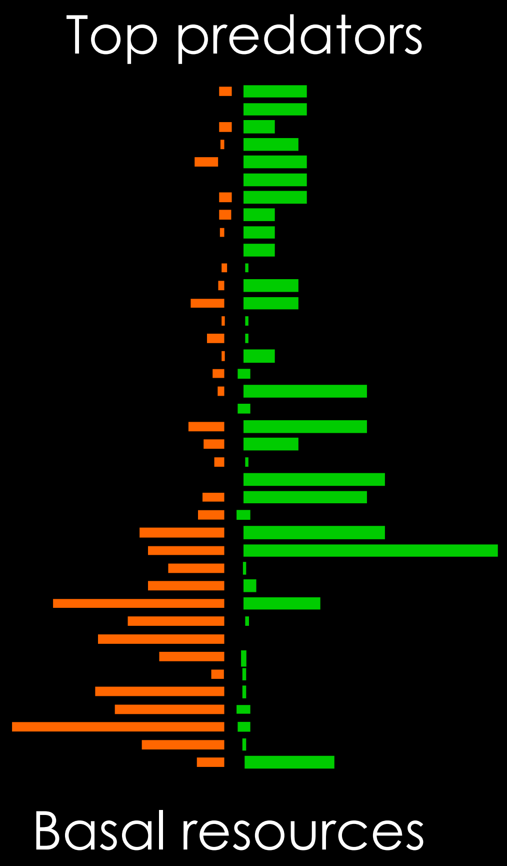
Per capita effect of pred j on prey i

$$\alpha_{ji} = c_{ji} B_j^*$$

Per capita effect of prey i on pred j

De Ruiter et al. 1995 Science

Interaction strengths (year^{-1})

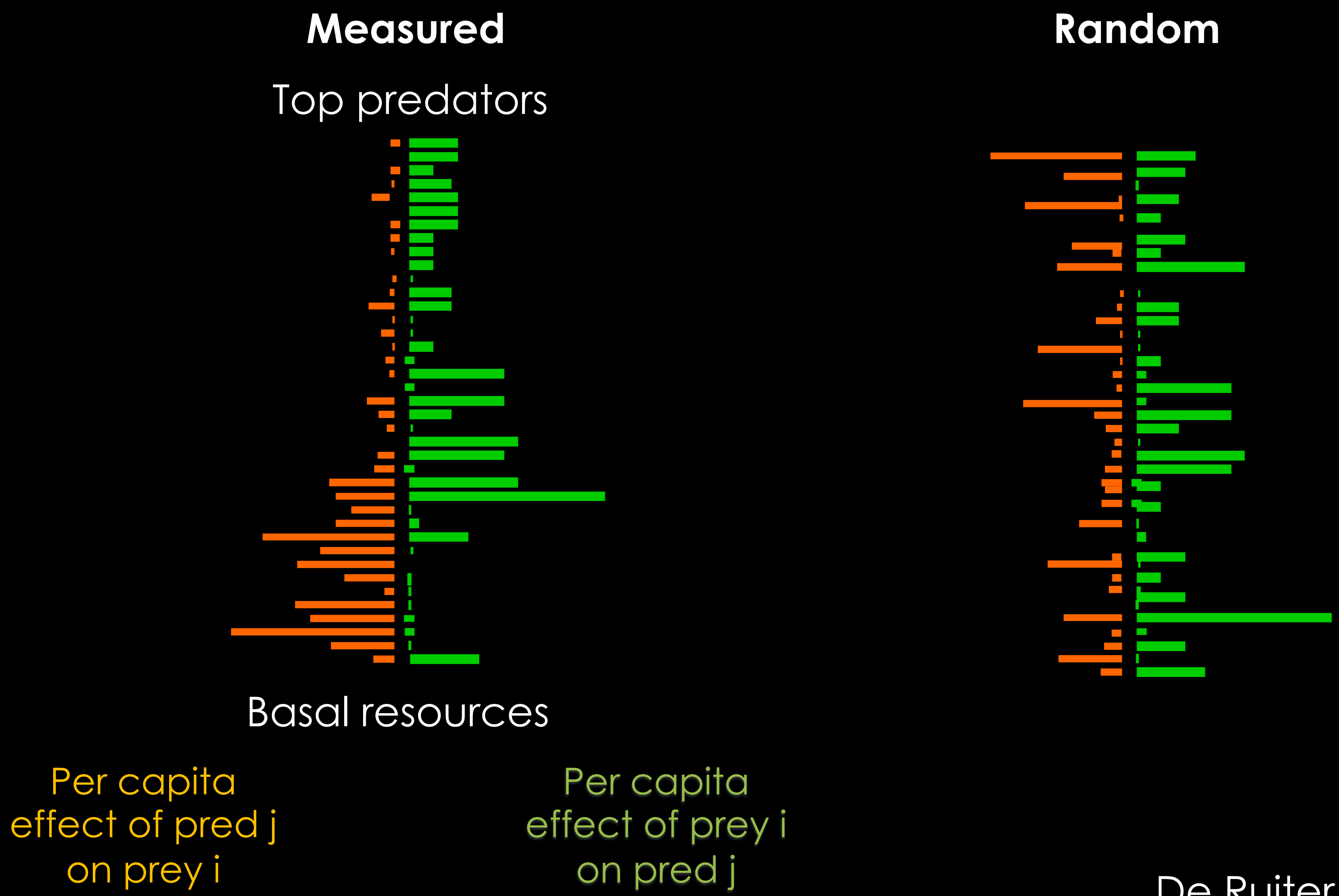


Per capita
effect of pred j
on prey i

Per capita
effect of prey i
on pred j

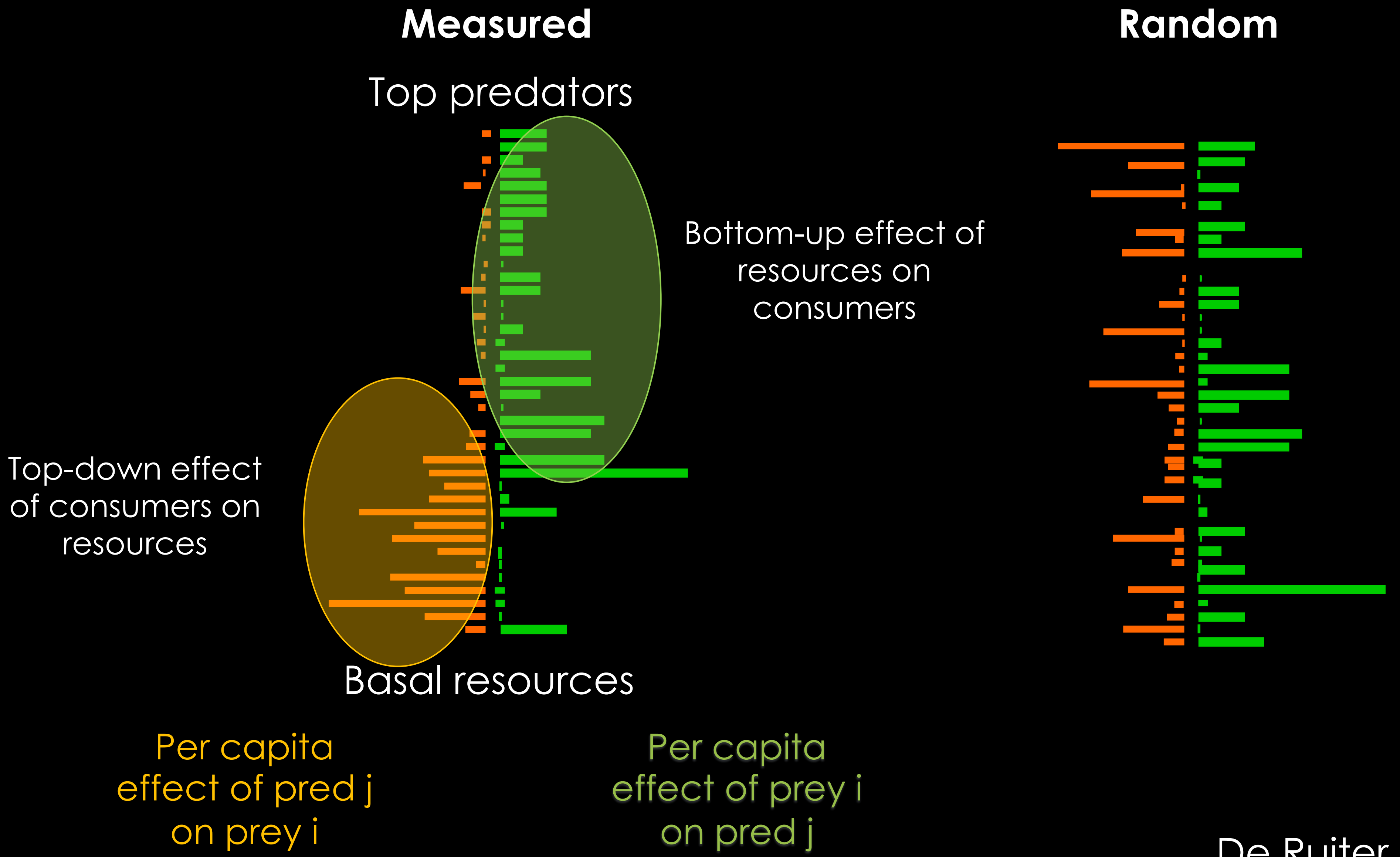
De Ruiter et al. 1995 Science

Interaction strengths ($year^{-1}$)



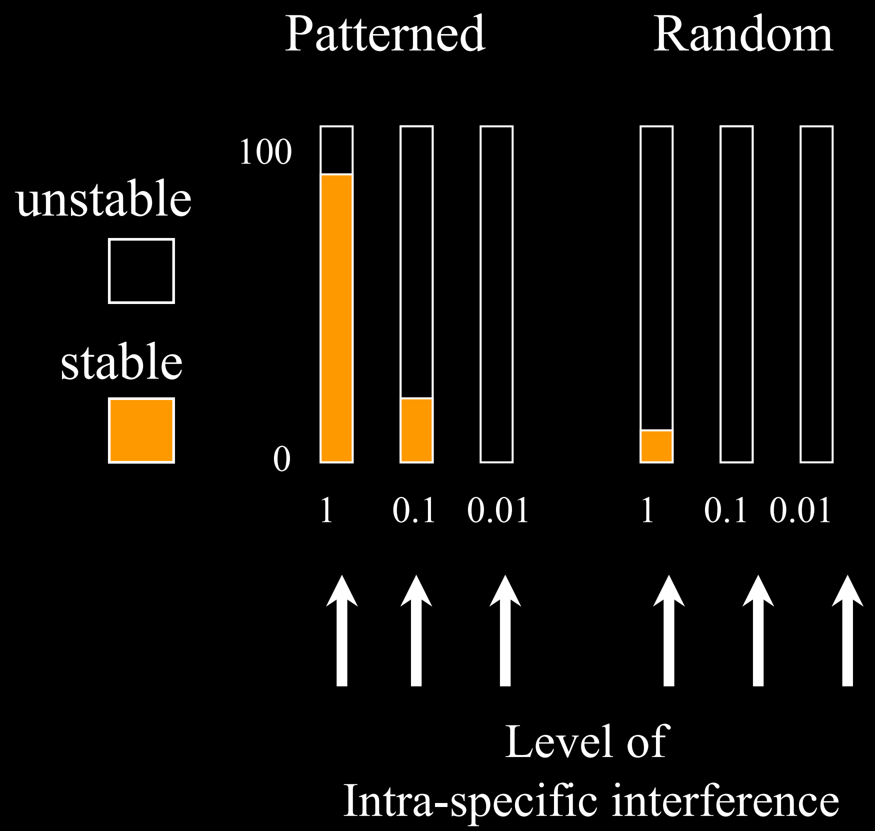
De Ruiter et al. 1995 Science

Interaction strengths ($year^{-1}$)



De Ruiter et al. 1995 Science

Probability of community matrix stability (%)



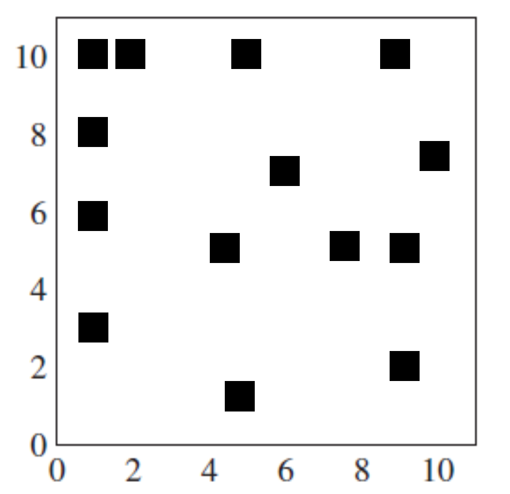
De Ruiter et al. 1995 Science

Including interaction strengths enhances stability

Compartments

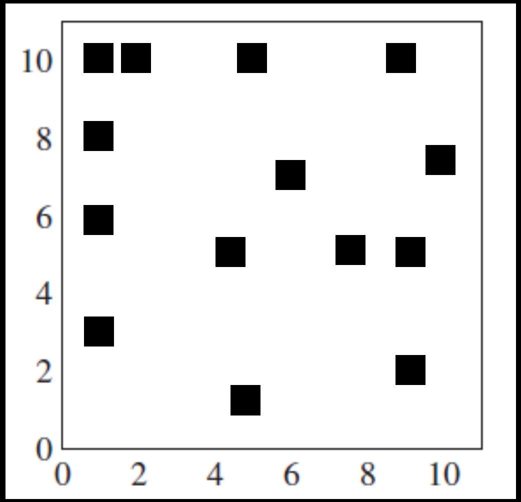
Compartments

May 1973:
Random matrices

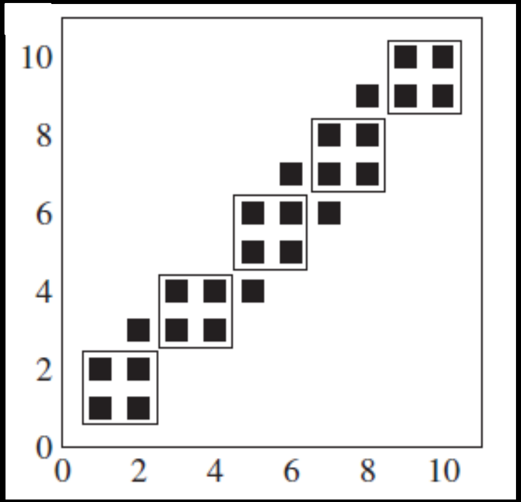


COMPARTMENTS

May 1973:
Random matrices



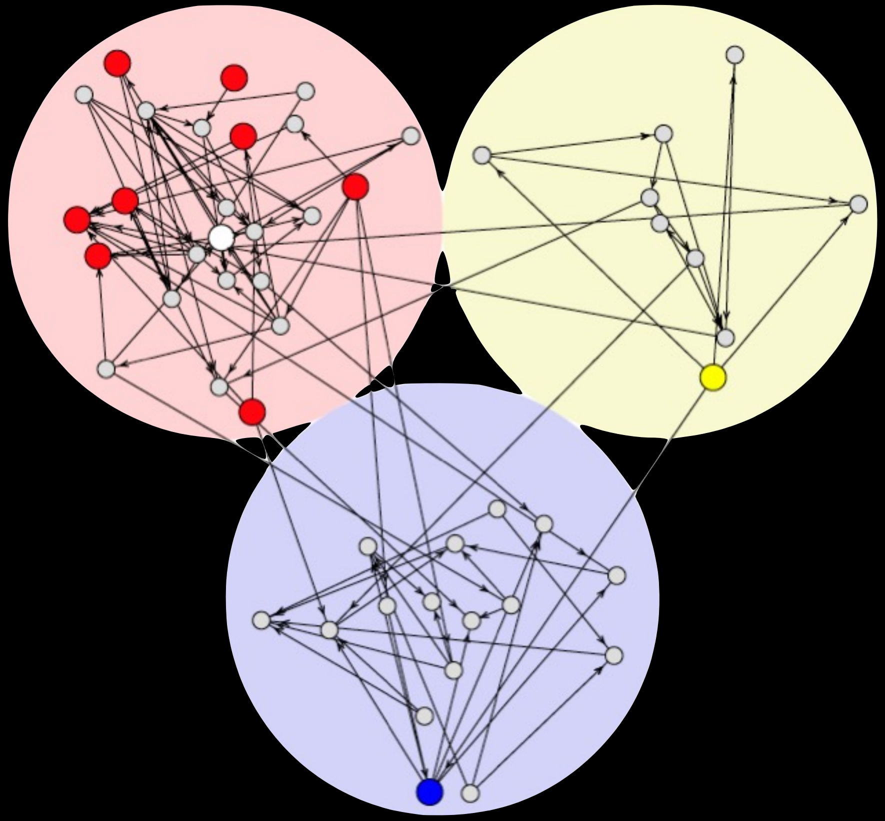
Pimm 1980
Moore and Hunt 1988
Krause et al. 2003
Rezende et al. 2009
Stouffer and Bascompte 2011



letters to nature

Compartments revealed in food-web structure

Ann E. Krause[1], Kenneth A. Frank[1,2], Doran M. Mason[3], Robert E. Ulanowicz[4] & William W. Taylor[1]



5 complex food webs
Compartment algorithm from social science
→ 3 food webs have signi. compartments

Krause et al. 2003 Nature

COMPARTMENTS

modularity

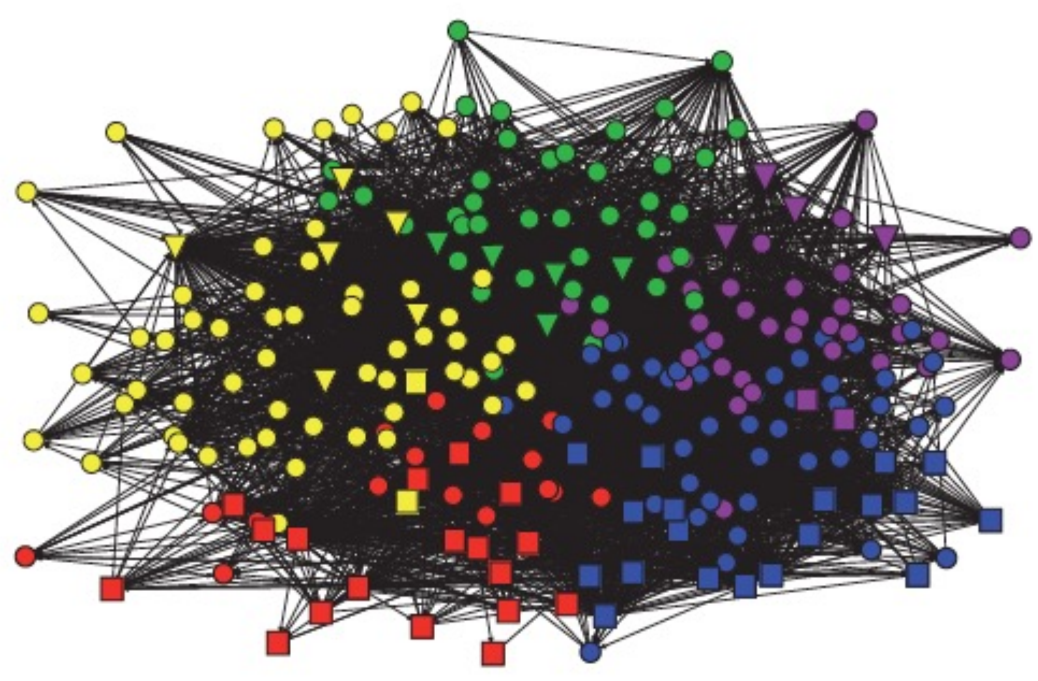
Newman and Girvan 2004 PRE
Guimera et al. 2007 PRE

Ecology Letters, (2009) **12**: 779–788 doi: 10.1111/j.1461-0248.2009.01327.x

LETTER

Compartments in a marine food web associated with phylogeny, body mass, and habitat structure

Enrico L. Rezende,* Eva M. Albert, Miguel A. Fortuna and Jordi Bascompte



Caribbean marine food web
249 sp, 3313 links
→ Modularity = 0.212 ± 0.001 (signi)
→ 5 compartments

Rezende et al. 2009 Eco Lett

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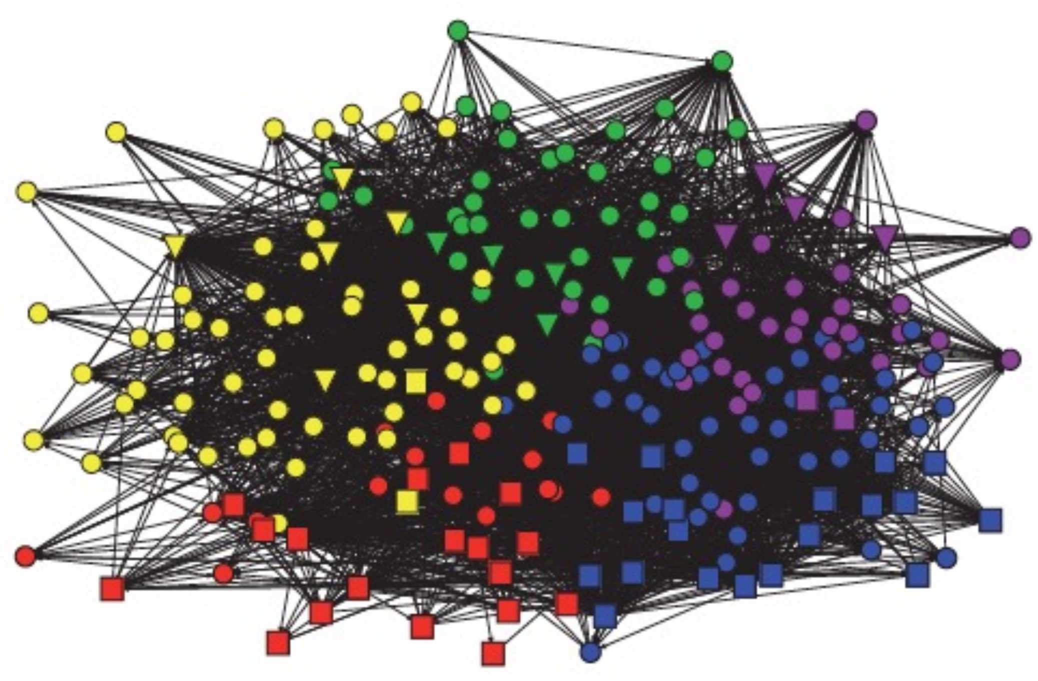


Habitat
Body size
(diet, prey size)
Phylogeny

Rezende et al. 2009 Eco Lett

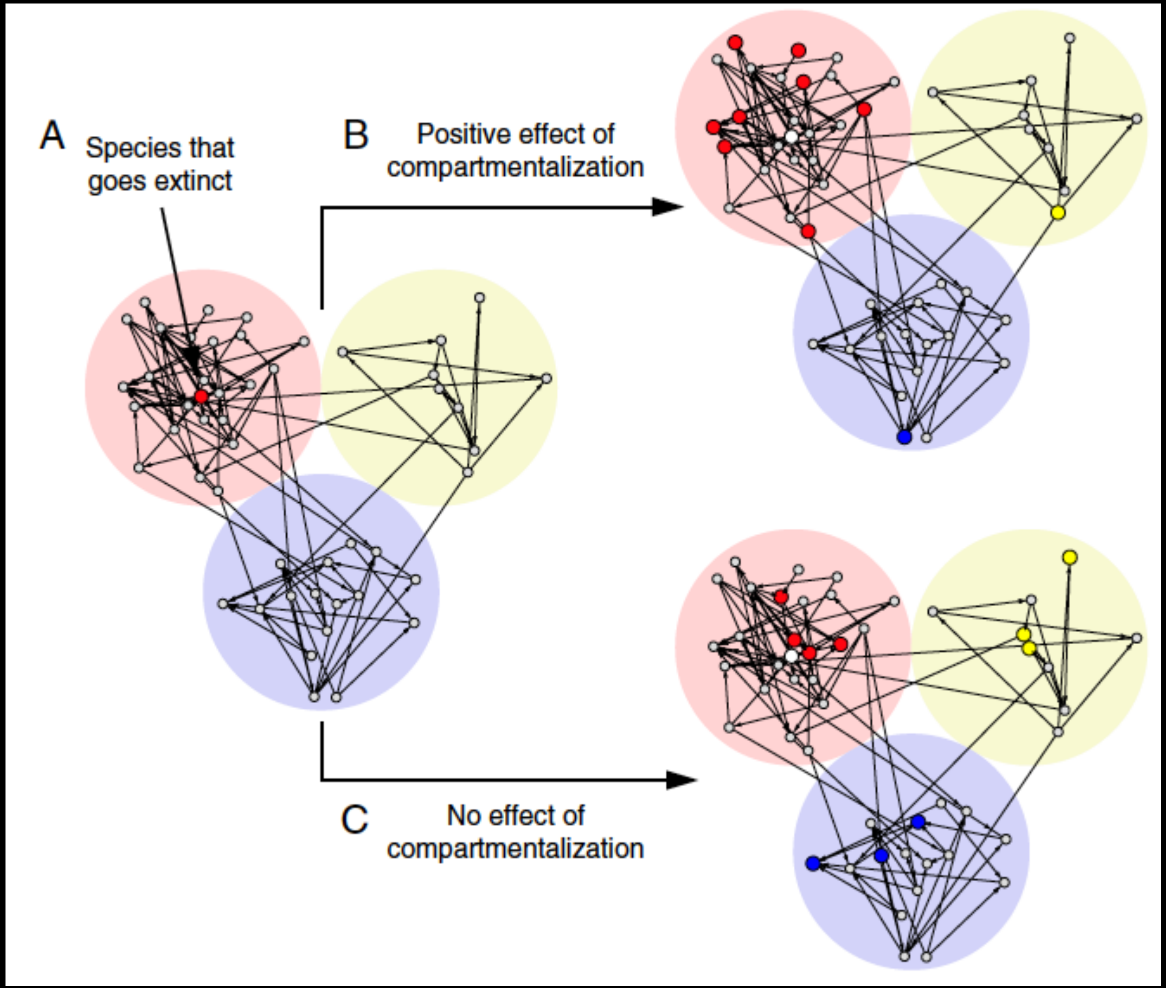
Food webs tend to be compartmented.

Functional consequences of compartments?

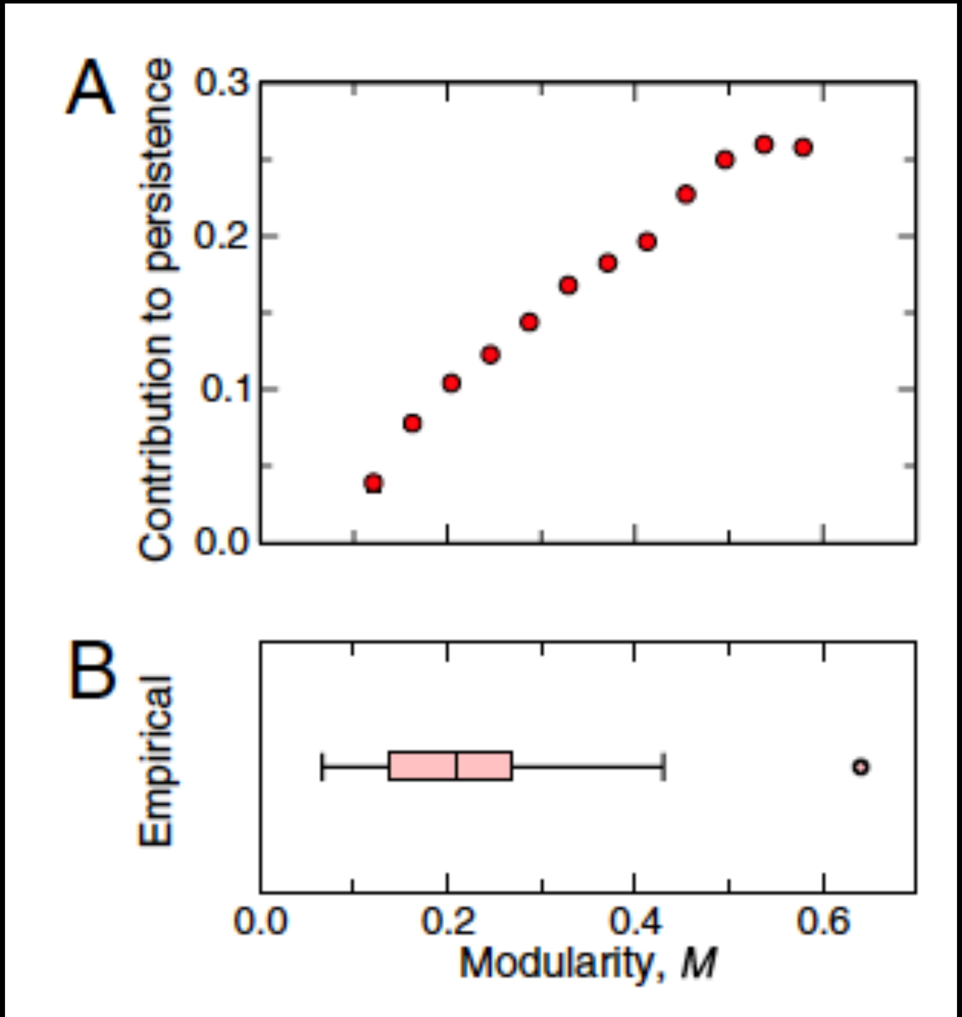
Compartmentalization increases food-web persistence

Daniel B. Stouffer[1] and Jordi Bascompte

Model
Simu 1: food web intact
Simu 2: one random species removed
→ Persistence ?



Stouffer and Bascompte 2011 PNAS



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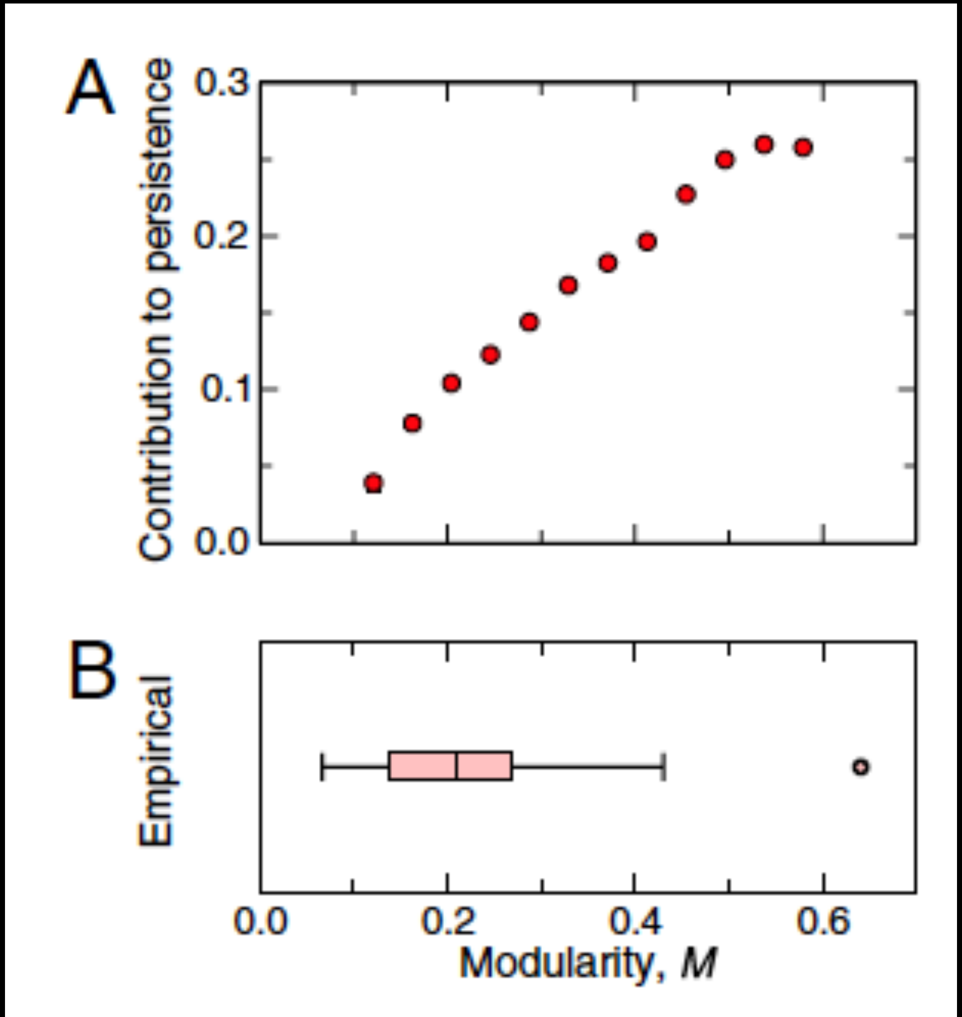
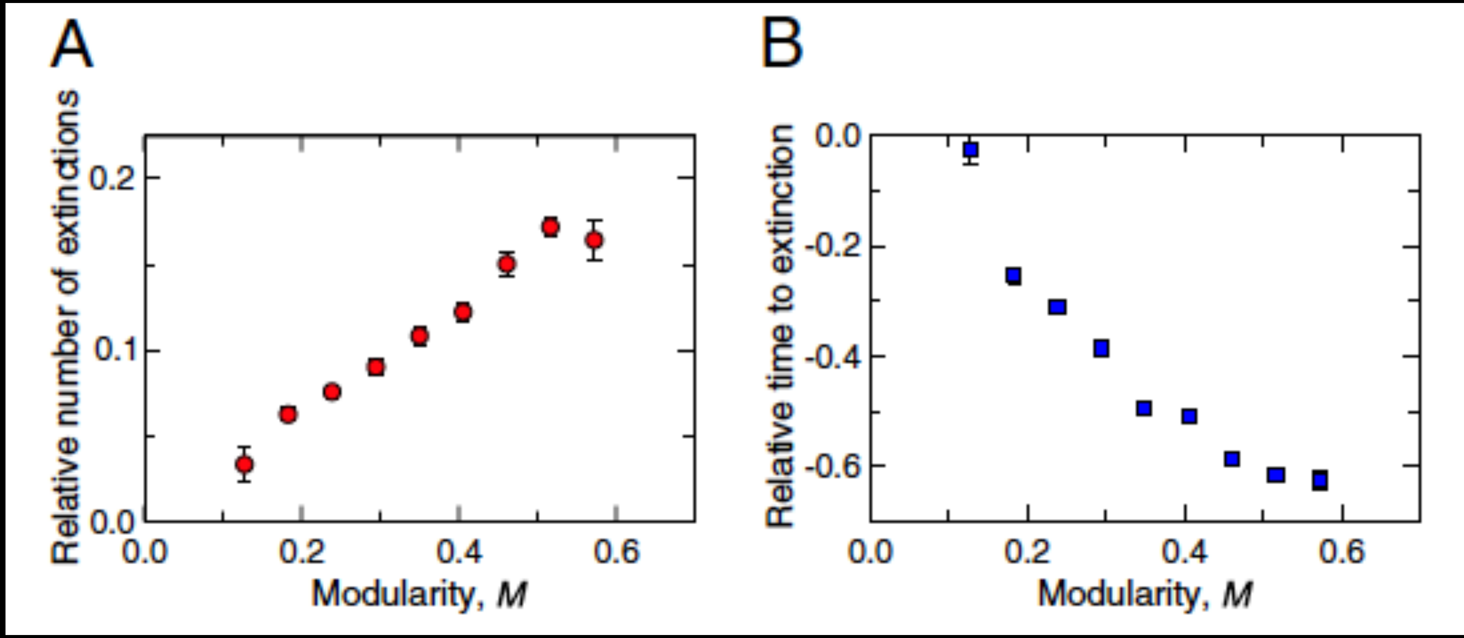




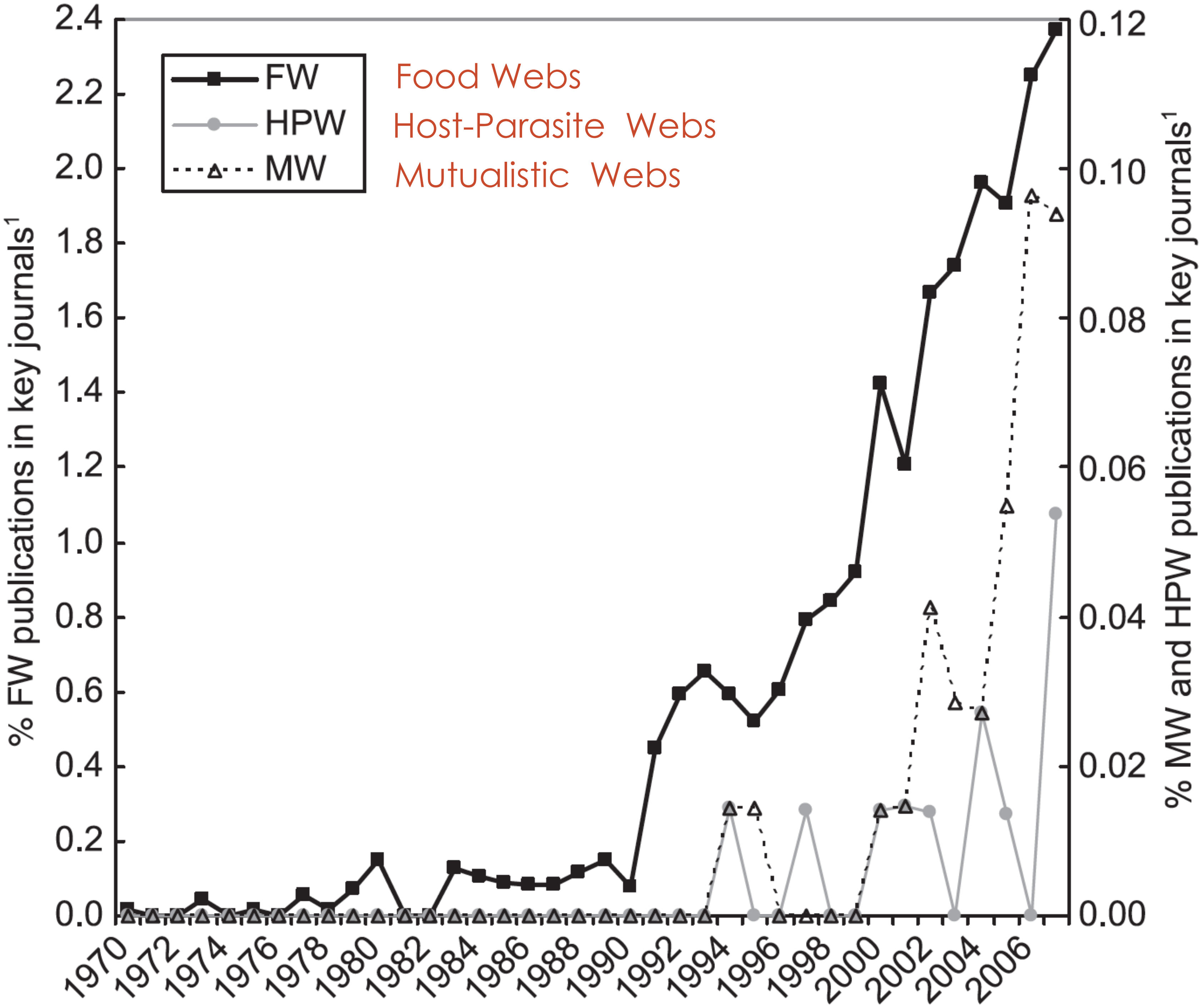
Stouffer and Bascompte 2011 PNAS

Compartments in food webs buffer the propagation of extinctions throughout the community and augment the long-term persistence of its constituent species.

Real food webs….

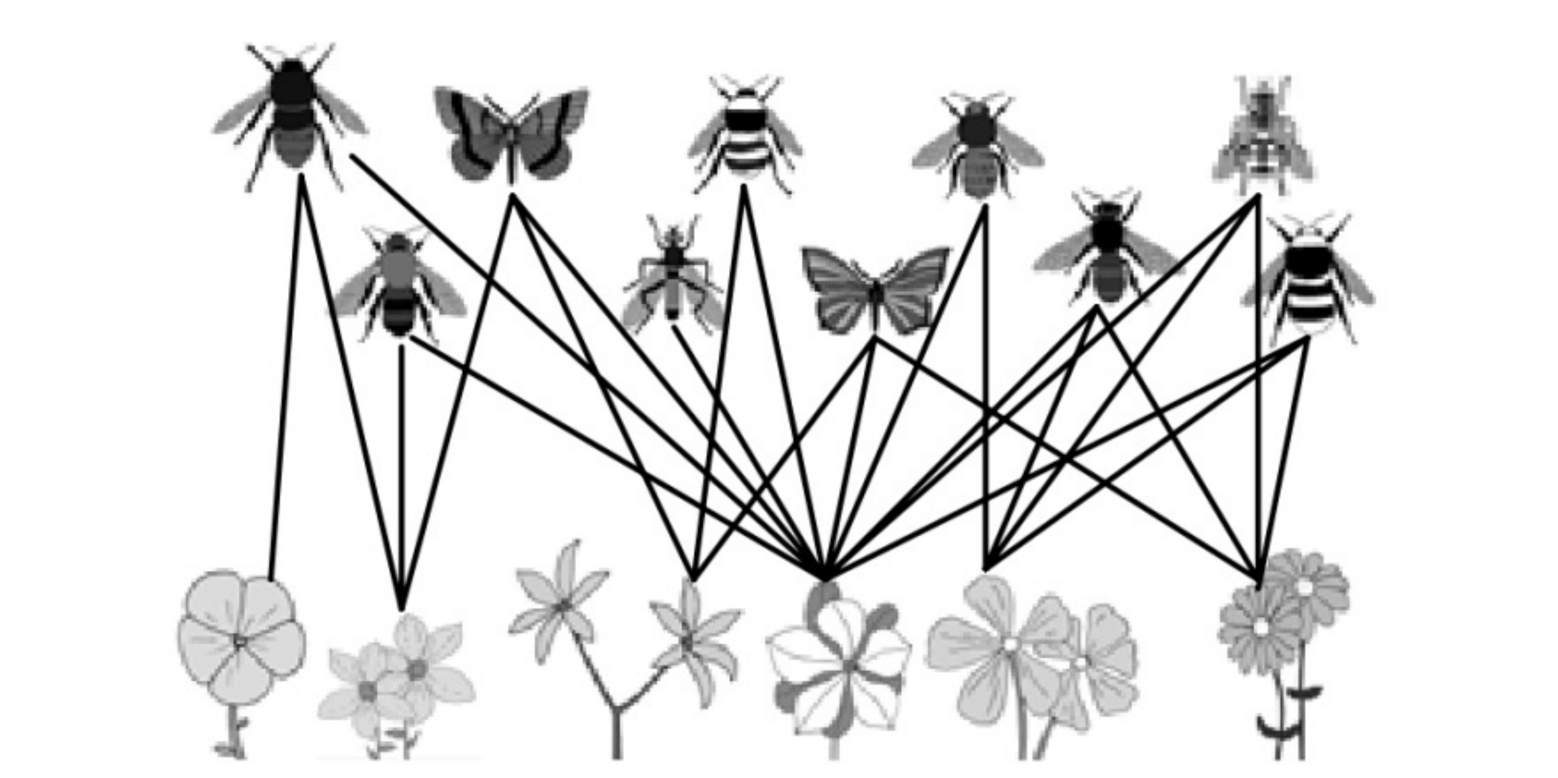
deviate from random in terms of interaction strength and structure.

Those structural properties seem to increase persistence compared to what would be expected in random webs.



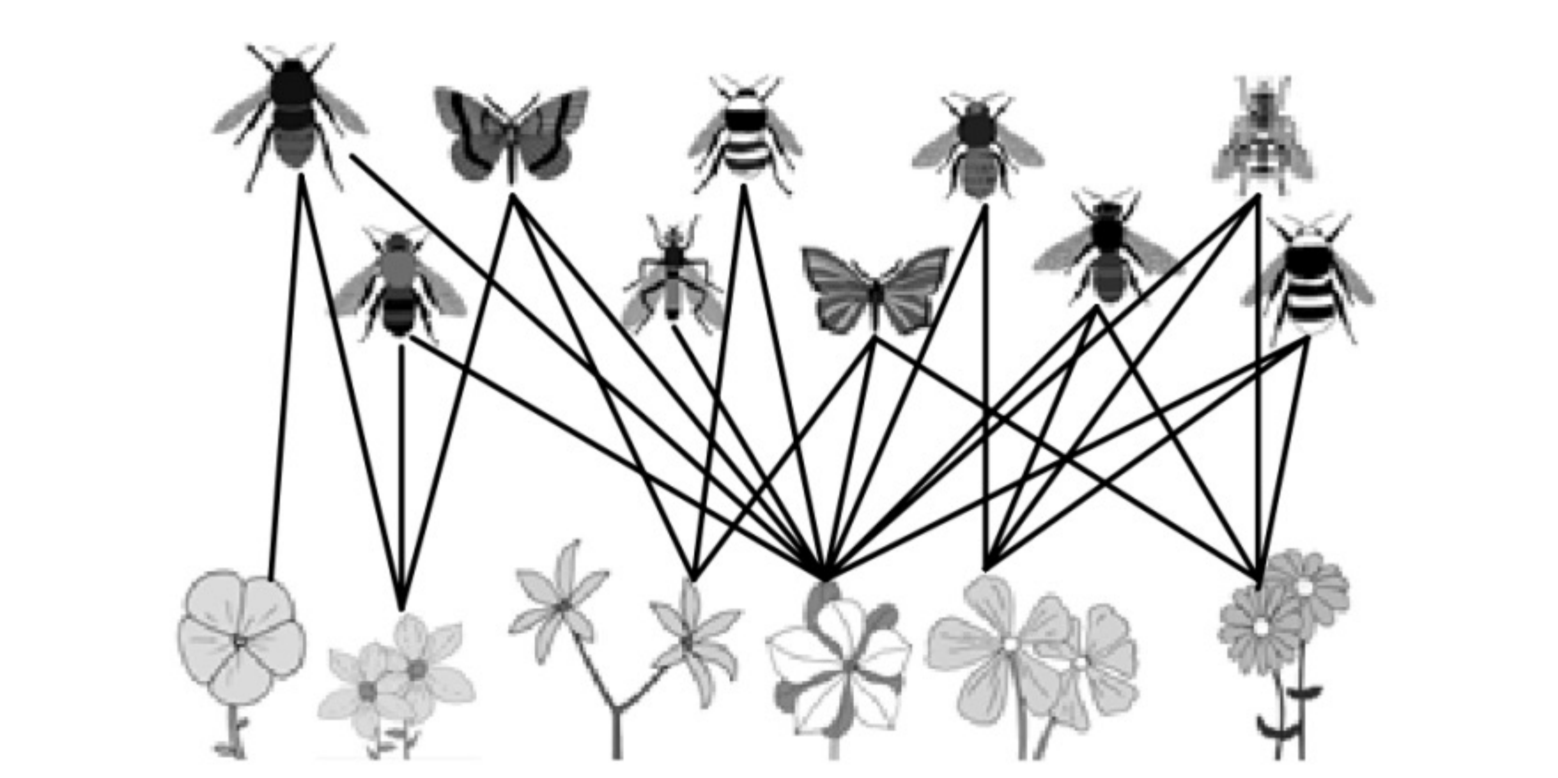
Ings et al. 2009 J. Animal Ecology

Jordano 1987
Bascompte et al. 2003
Blüthgen et al. 2007



Thébault and Fontaine 2010 Science

Bipartite web



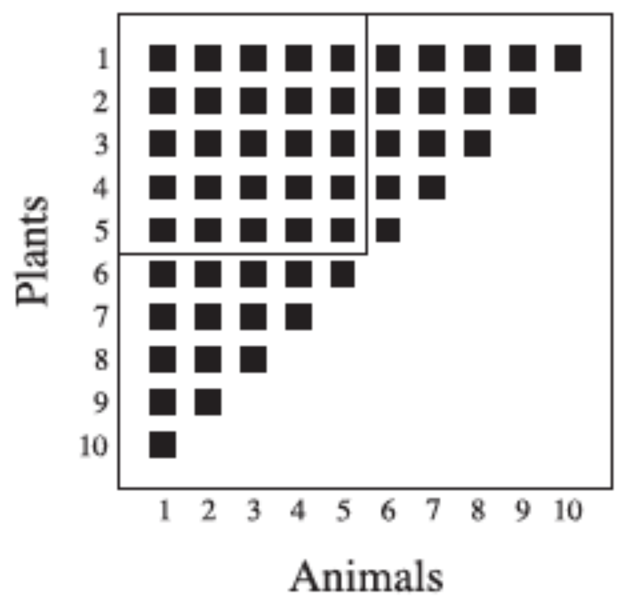
Thébault and Fontaine 2010 Science

The nested assembly of plant–animal mutualistic networks

Jordi Bascompte[†‡], Pedro Jordano[†], Carlos J. Melián[†], and Jens M. Olesen[§]

[†]Integrative Ecology Group, Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas, A
[§]Department of Ecology and Genetics, University of Aarhus, Ny Munkegade, Building 540, DK-8000 Aarhus, D

PNAS | August 5, 2003 | vol. 100 | no. 16 | 9383–9387



Bascompte et al. 2003, 2006

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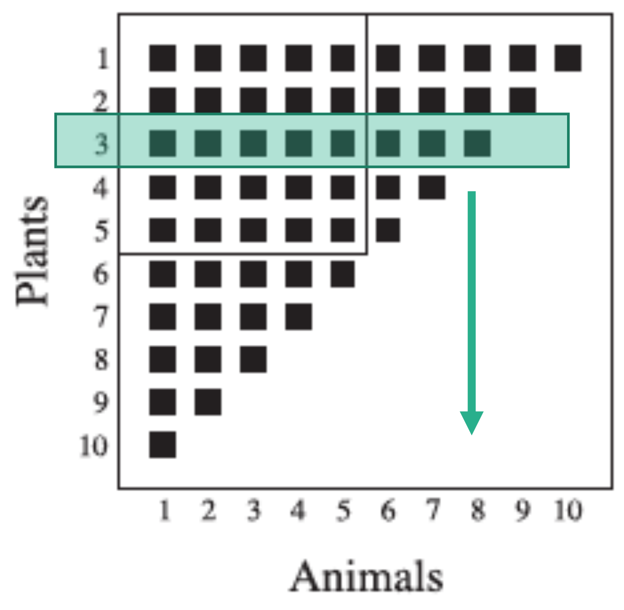
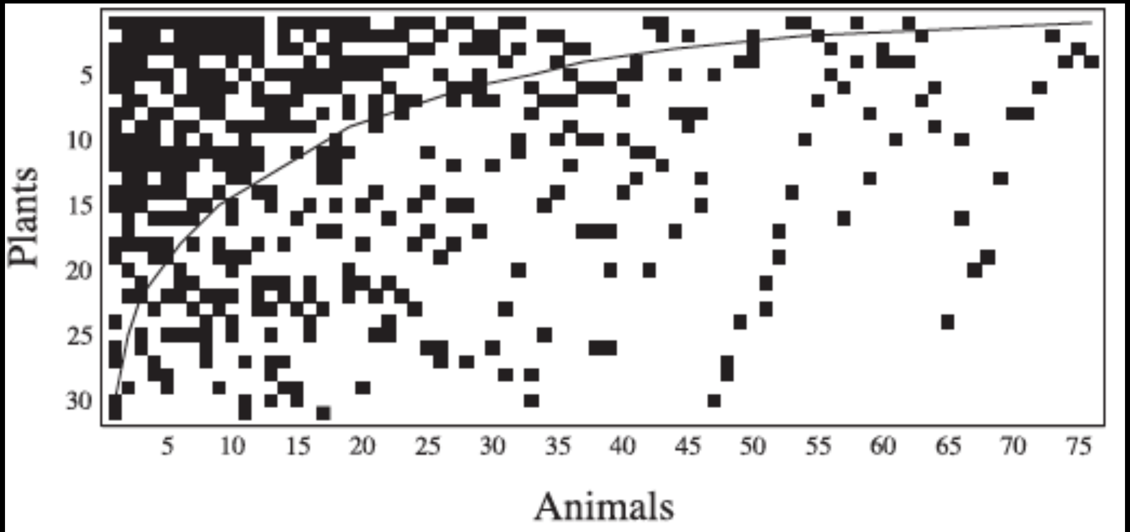
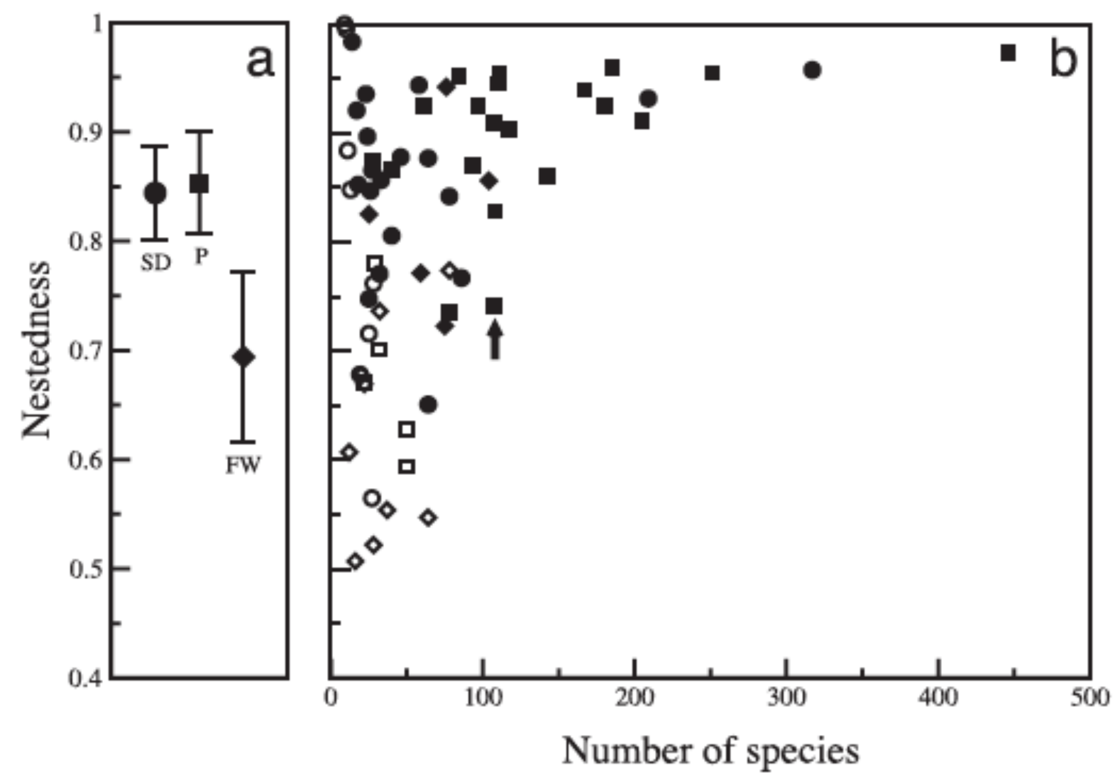


Bascompte et al. 2003, 2006

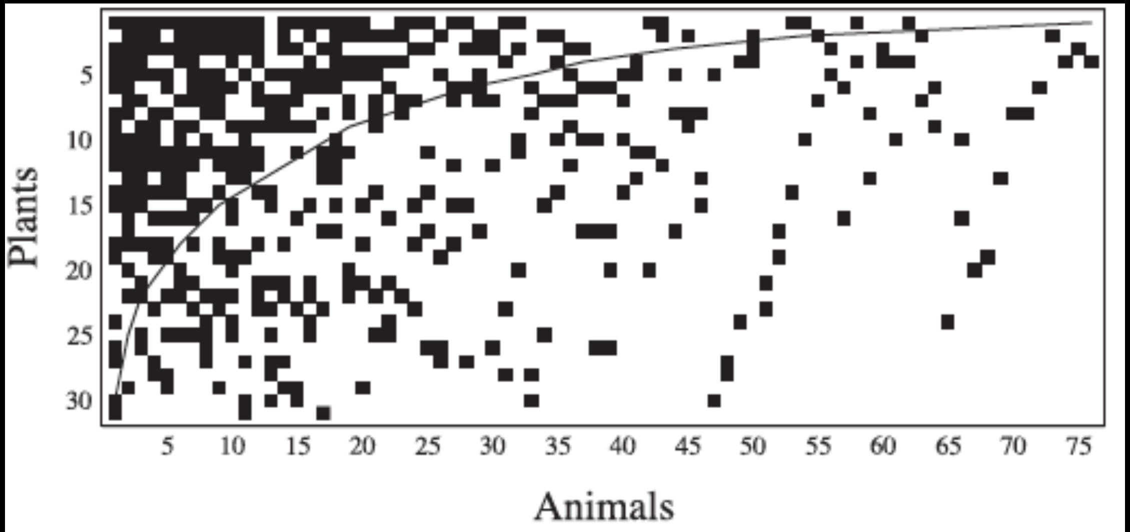
52 mutualistic networks



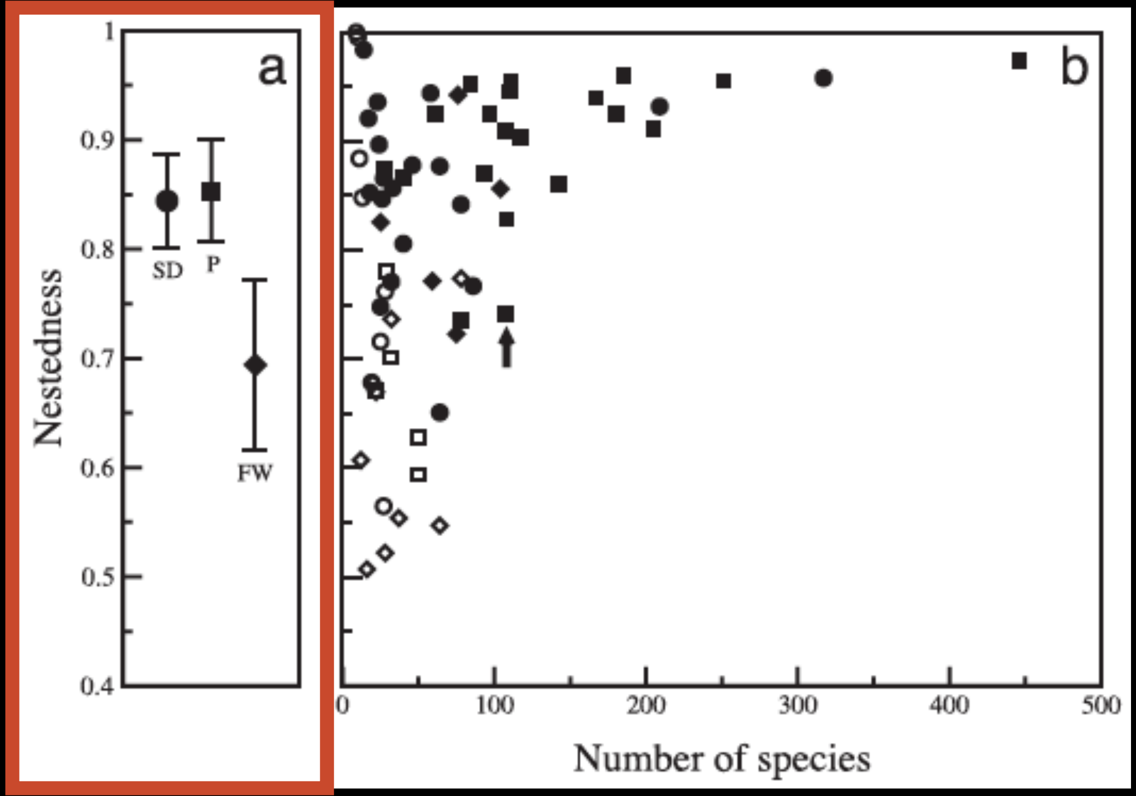


SD: seed dispersal
P: pollination
FW: food web

Bascompte et al. 2003 PNAS



52 mutualistic networks



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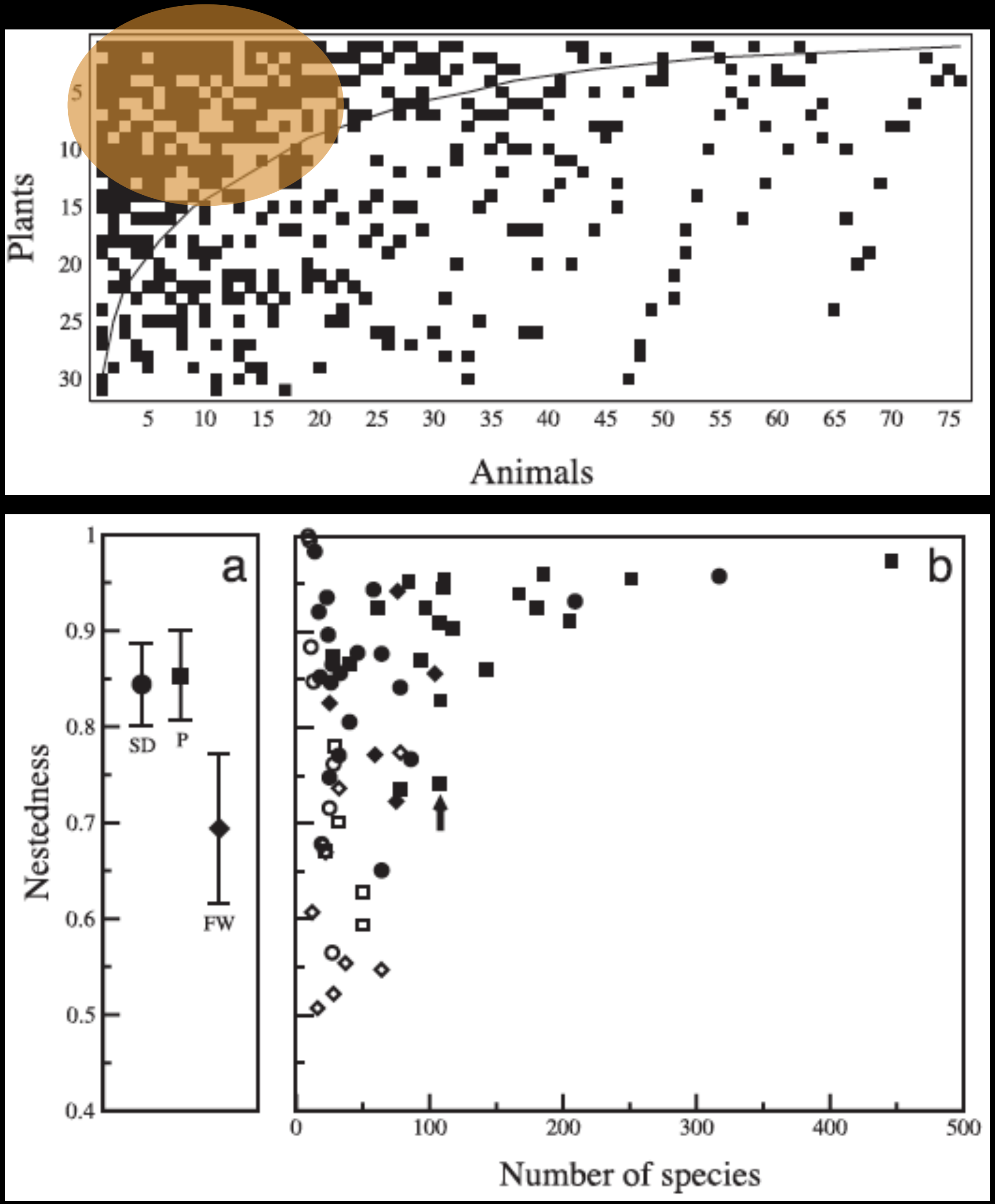

52 mutualistic networks

a cohesive core of species

SD: seed dispersal
P: pollination
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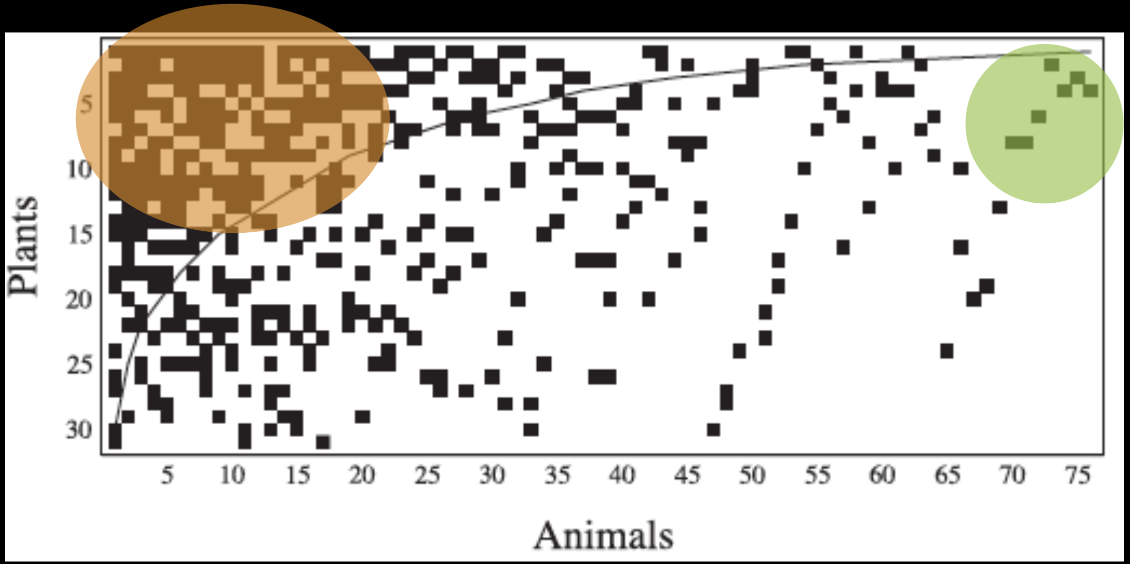
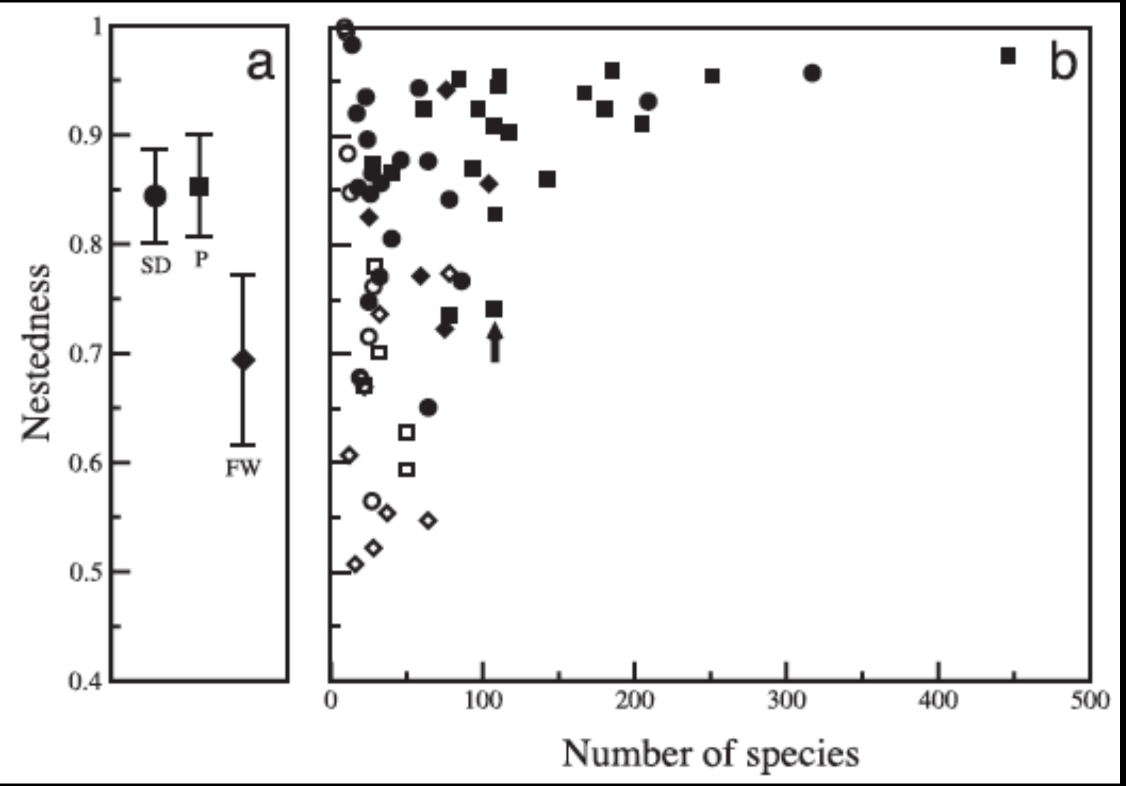
Bascompte et al. 2003 PNAS



52 mutualistic networks

a cohesive core of species

asymmetric specialization



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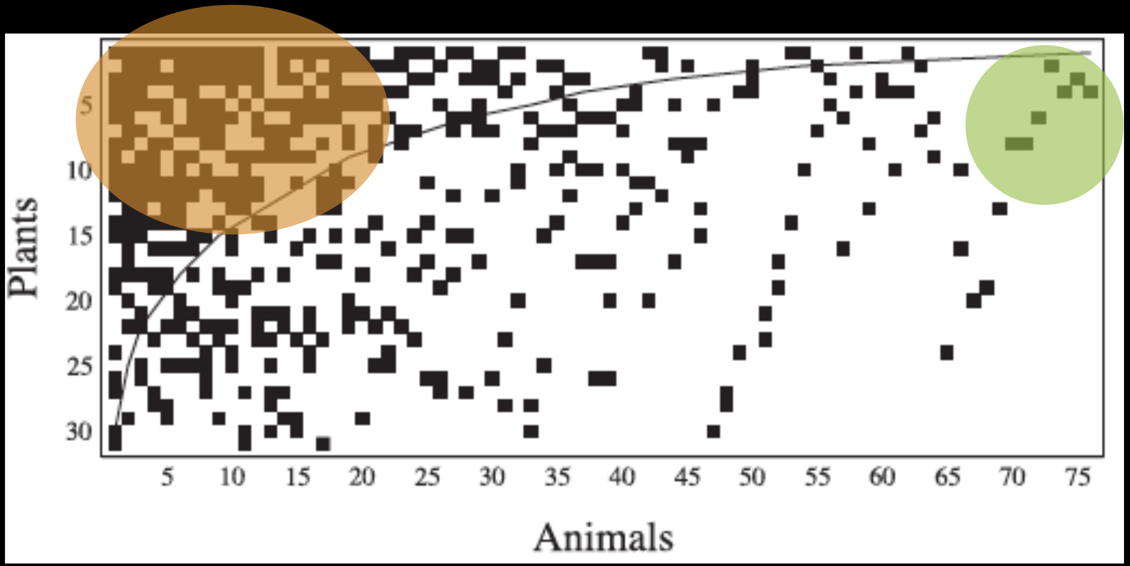
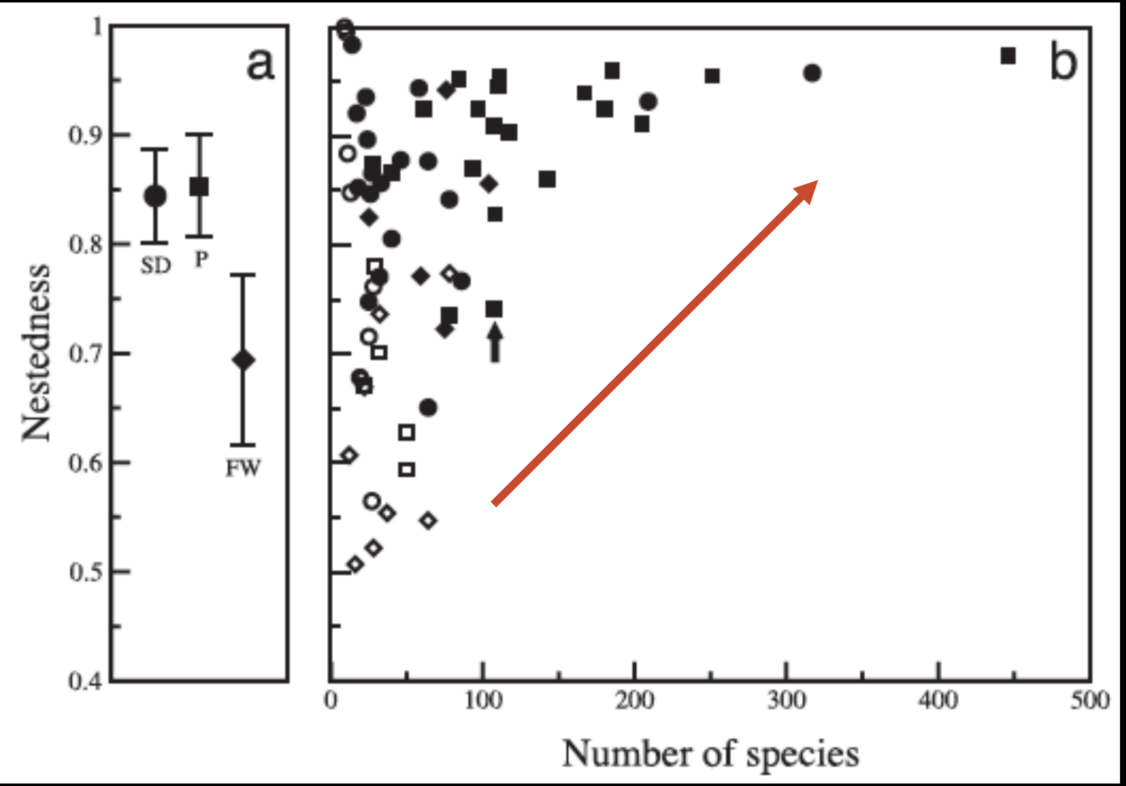
Bascompte et al. 2003 PNAS





52 mutualistic networks

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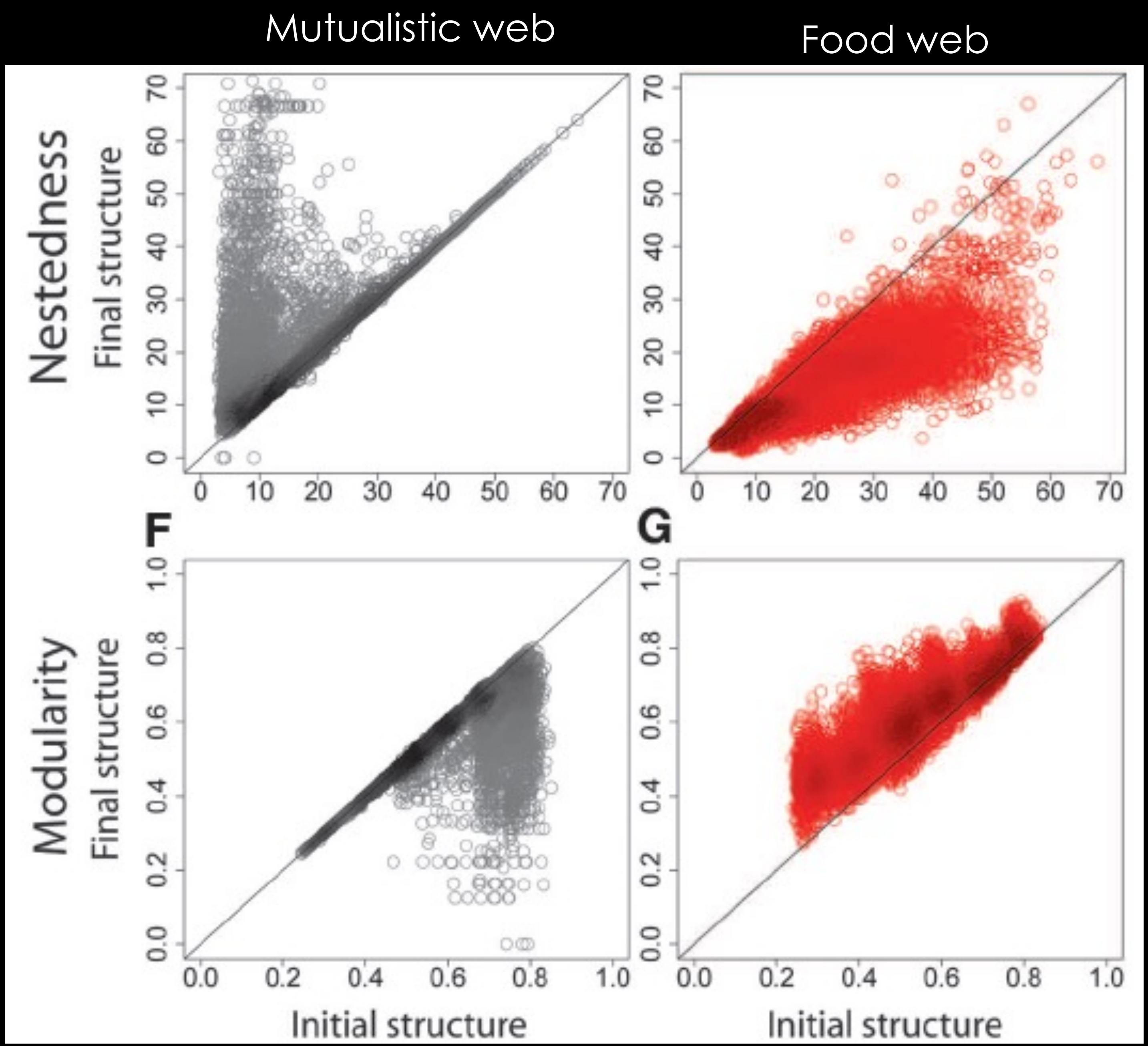

Thébault and Fontaine 2010 Science

Food webs tend to be compartmented.
Mutualistic networks tend to be nested.

- May : complexity – stability
- But real networks deviate from randomness
- They do so differently for different interaction types
- This seems to increase stability (species persistence)

- May : local stability analysis
- But other stability metrics as well

Thanks

BioDICée Lab

cnrs

isem

Institut des Sciences de l'Evolution-Montpellier