How can the structure of ecosystems predict species' survival?

Violeta Calleja Solanas,
Emilio Hernández García &
Sandro Meloni

04 Mar 2022

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Emilio Hernández-García

Sandro Meloni

Olena Shmahalo/Quanta Magazine

Environmental changes may alter species interactions


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Biodiversity loss, cascades of extinctions

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How does an ecosystem break?

Olena Shmahalo/Quanta Magazine

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→ Biodiversity loss, cascades of extinctions

How does an ecosystem break?

→ How does the network break?

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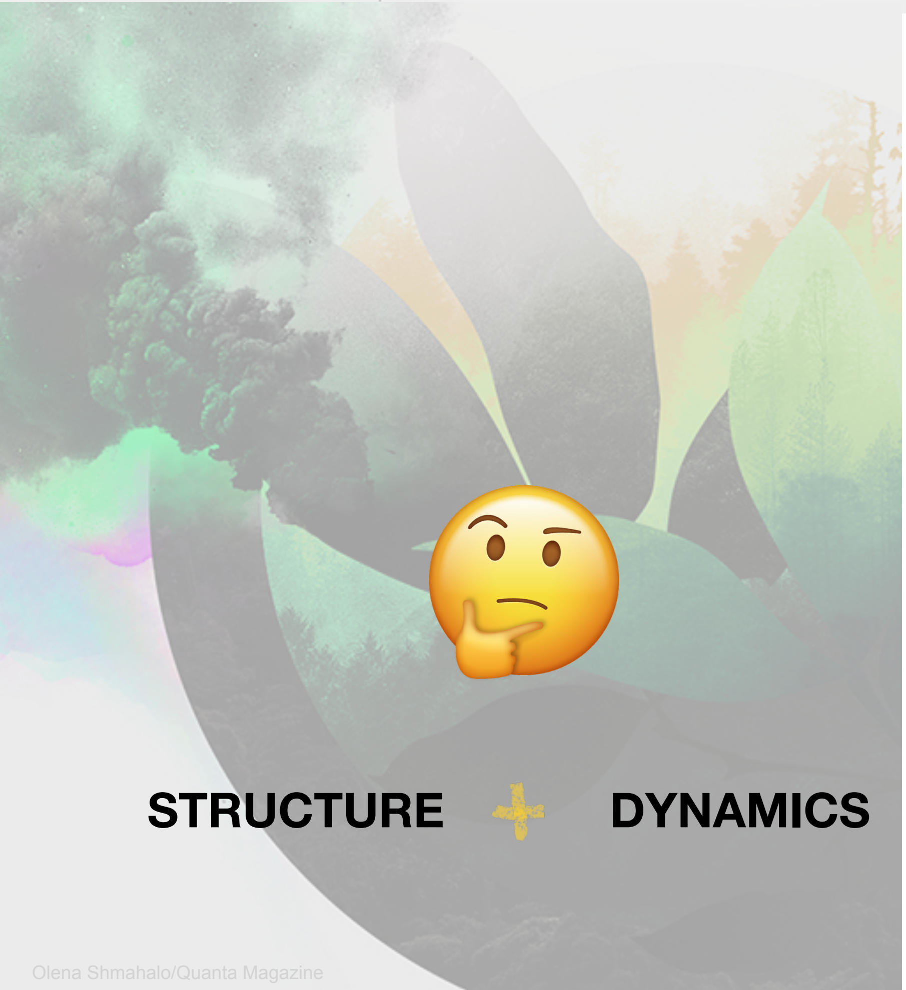
How does an ecosystem break?

How does the network break?

Predictor of species vulnerability?



Olena Shmahalo/Quanta Magazine

Environmental changes may alter species interactions

↳ Biodiversity loss, cascades of extinctions

How does an ecosystem break?

↳ How does the network break?

STRUCTURE + **DYNAMICS** = **Predictor** of species vulnerability?

Predictors typically are...

- general measures of whole network structure

Ex: Fragility, robustness

THE ROYAL SOCIETY

doi 10.1098/rspb.2001.1767

Complexity and fragility in ecological networks

Ricard V. Solé[1,2*] and José M. Montoya[1,3]

Predictors typically are...

- Static measures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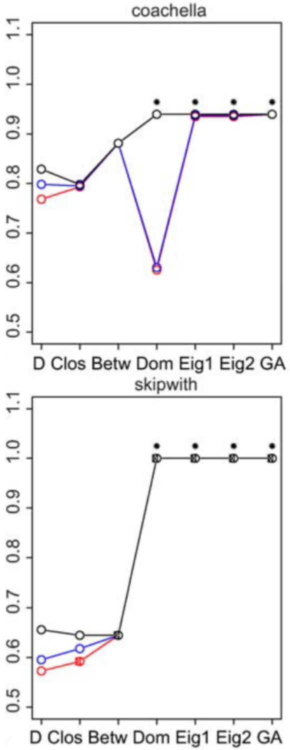
PLoS COMPUTATIONAL BIOLOGY

Googling Food Webs: Can an Eigenvector Measure Species' Importance for Coextinctions?

Stefano Allesina[1*], **Mercedes Pascual**[2,3,4]



Predictors typically are...

- Measured over one type of interaction

ARTICLE

https://doi.org/10.1038/s41467-021-21824-x OPEN

An ecological network approach to predict ecosystem service vulnerability to species losses

Aislyn A. Keyes[1✉], John P. McLaughlin[2], Allison K. Barner[3] & Laura E. Dee[1]

ARTICLE

Received 21 May 2015 | Accepted 23 Nov 2015 | Published 18 Jan 2016 DOI: 10.1038/ncomms10245 OPEN

Using food-web theory to conserve ecosystems

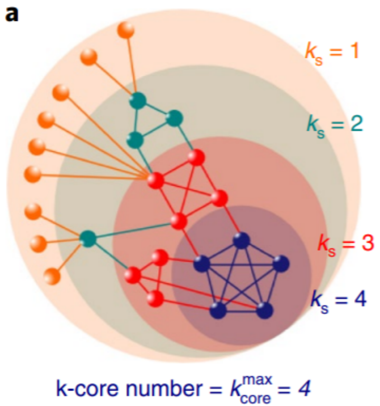
E. McDonald-Madden[1], R. Sabbadin[2], E.T. Game[3], P.W.J. Baxter[4,†], I. Chadès[5] & H.P. Possingham[6,7]

Exception: k-core as predictor of collapse in mutualistic communities


nature physics
ARTICLES
https://doi.org/10.1038/s41567-018-0304-8

The k-core as a predictor of structural collapse in mutualistic ecosystems

Flaviano Morone, Gino Del Ferraro and Hernán A. Makse*



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ECOLOGY LETTERS

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The ecological and evolutionary implications of merging different types of networks

Colin Fontaine, Paulo R. Guimarães Jr, Sonia Kéfi, Nicolas Loeuille, Jane Memmott, Wim H. van der Putten, Frank J. F. van Veen, Elisa Thébault

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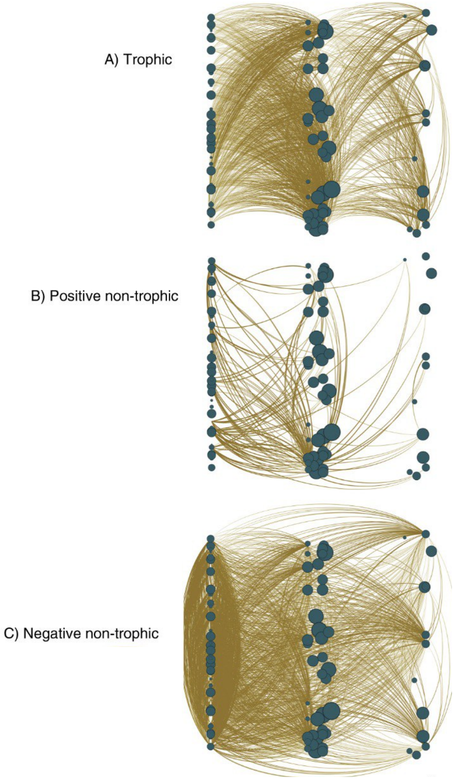
ECOLOGY
ECOLOGICAL SOCIETY OF AMERICA

Article

Network structure beyond food webs: mapping non-trophic and trophic interactions on Chilean rocky shores

Sonia Kéfi, Eric L. Berlow, Evie A. Wieters, Lucas N. Joppa, Spencer A. Wood, Ulrich Brose, Sergio A. Navarrete



Our question:

How do species properties
explain which one survives…

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Our question:

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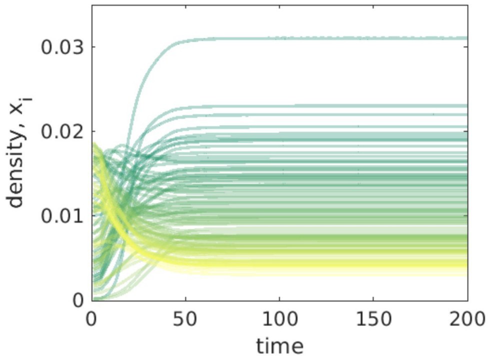
and **different interactions**?

Replicator equation:

$$\dot{x}_i = x_i \left(\sum_j \Lambda_{ij} x_j - \sum_{jk} \Lambda_{jk} x_j x_k \right)$$

local fitness   mean fitness



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intra $\Lambda_{ii} = -1$

inter $\Lambda_{ij} = \alpha A_{ij}$

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Replicator equation:

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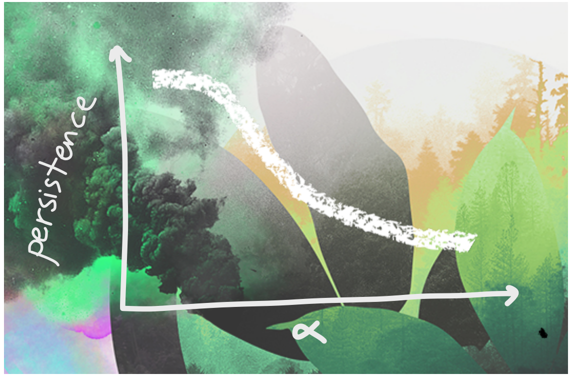
local fitness   mean fitness



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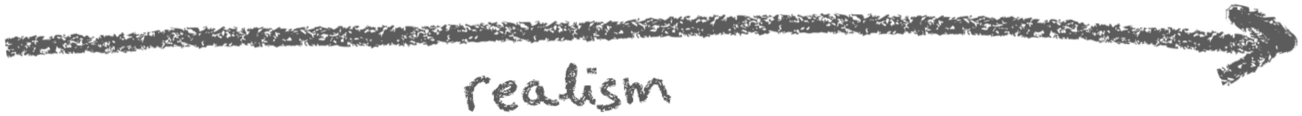
$\Lambda_{ij} = \Lambda_{ji}$

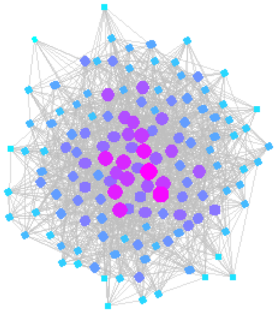
$$\begin{cases} \alpha > 0 & \text{mutualism} \\ \alpha < 0 & \text{competition} \end{cases}$$

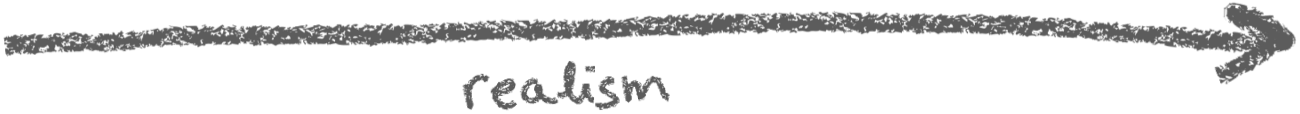
Our question:

How do species properties
explain which one survives
in an ecological **network** → types
with an embedded dynamics
and different interactions?

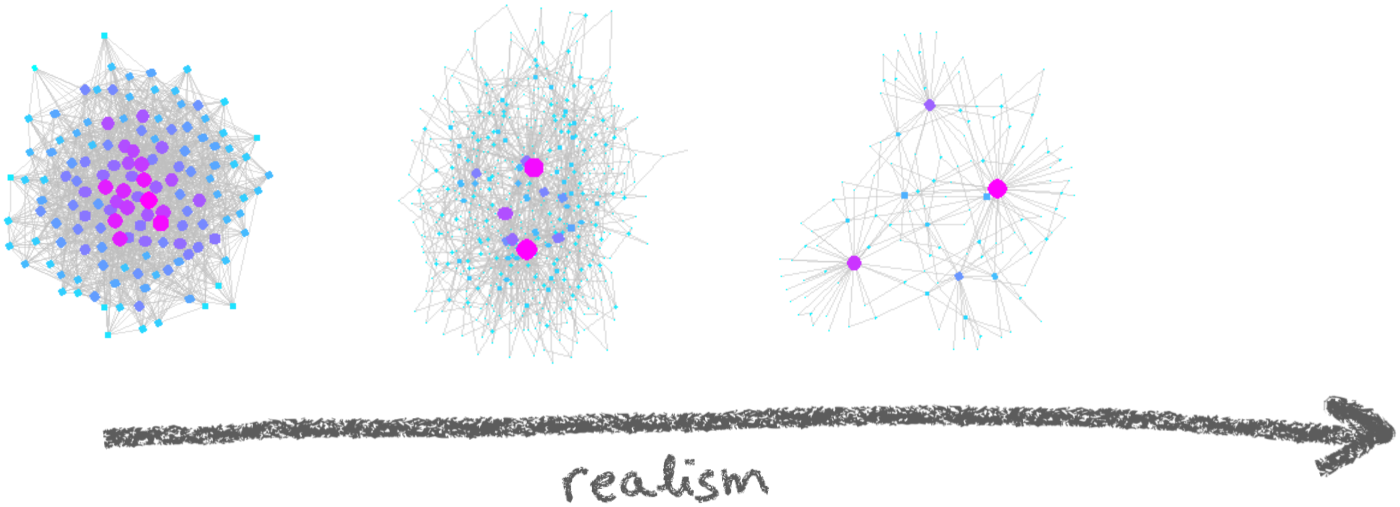

realism

Erdős–Rényi

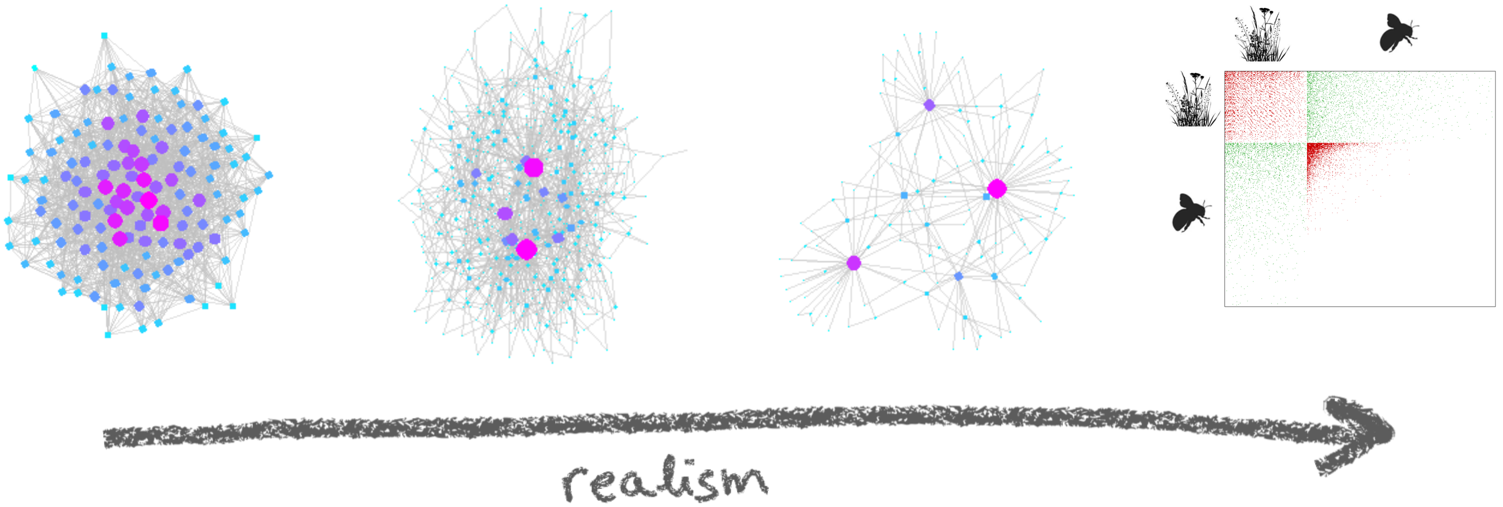




Erdős–Rényi **Barabasi-Albert** **Holme-Kim**



Erdős–Rényi | Barabasi-Albert | Holme-Kim | Empirical (Pollination)



Our question:

How do species **properties** nodes properties
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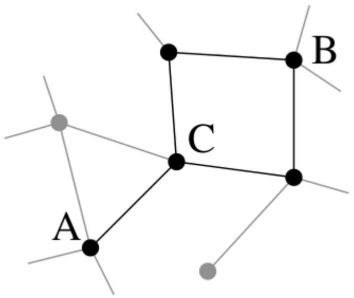
Centrality

- Degree
- Betweenness
- Eigenvector
- Page Rank
- …



Identifying important species: Linking structure and function in ecological networks

Ferenc Jordán[a,b,], Thomas A. Okey[c,d], Barbara Bauer[e], Simone Libralato[f]*

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Stefano Allesina[1*], Mercedes Pascual[2,3,4]

Characterization of topological keystone species
Local, global and "meso-scale" centralities in food webs

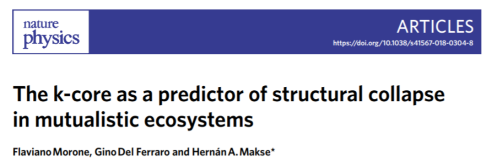
Ernesto Estrada[*]

Centrality

- Degree
- Betweenness
- Eigenvector
- Page Rank
- …

Groups of nodes

- K-core
- …



nature physics

ARTICLES

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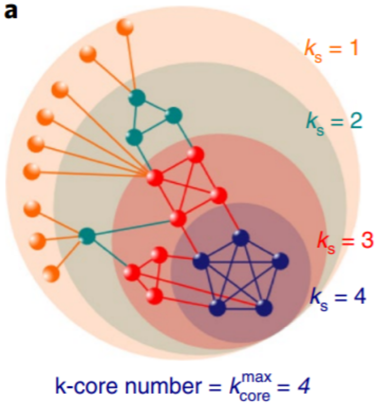

Centrality

- Degree
- Betweenness
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- …

Groups of nodes

- K-core
- …

Interactions

- Ratio mutualistic and competitive links
- Competitive degree
- Mutualistic degree

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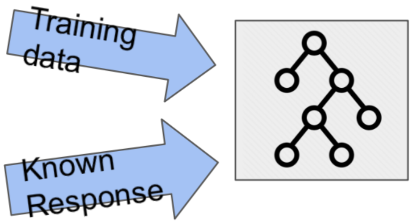
Decision trees

Decision Trees

Machine Learning algorithms

- Simple
- Multiple predictors at the same time
- “Gray boxes”



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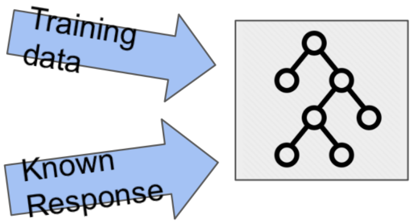

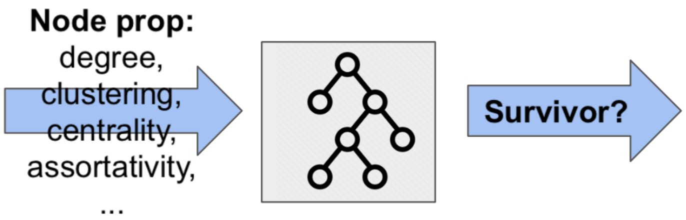

Decision Trees

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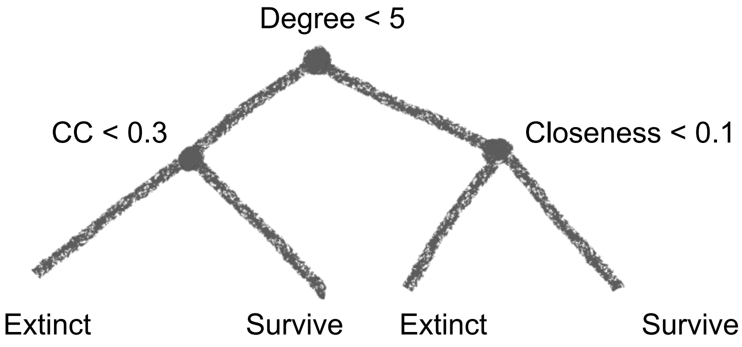

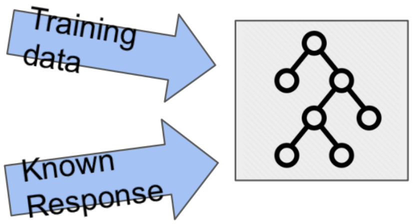

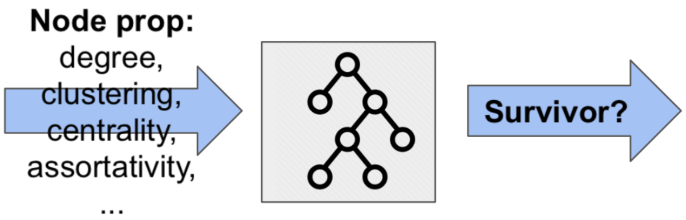

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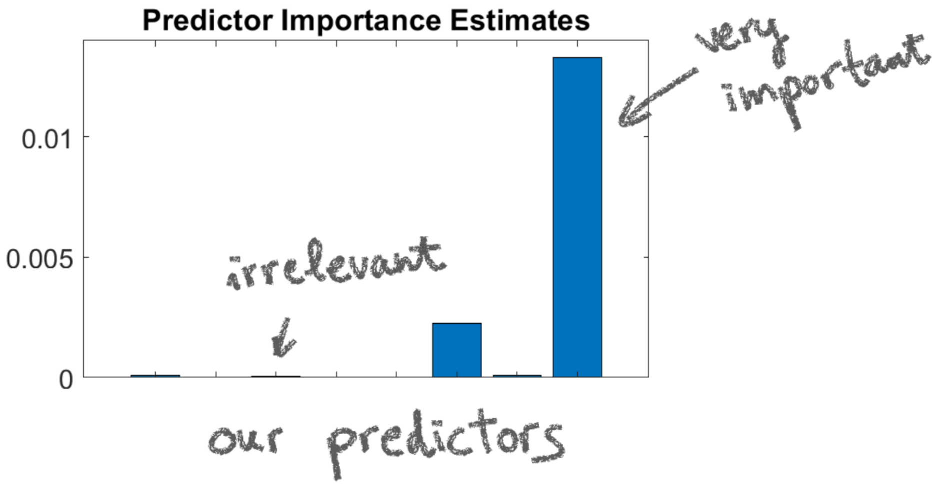

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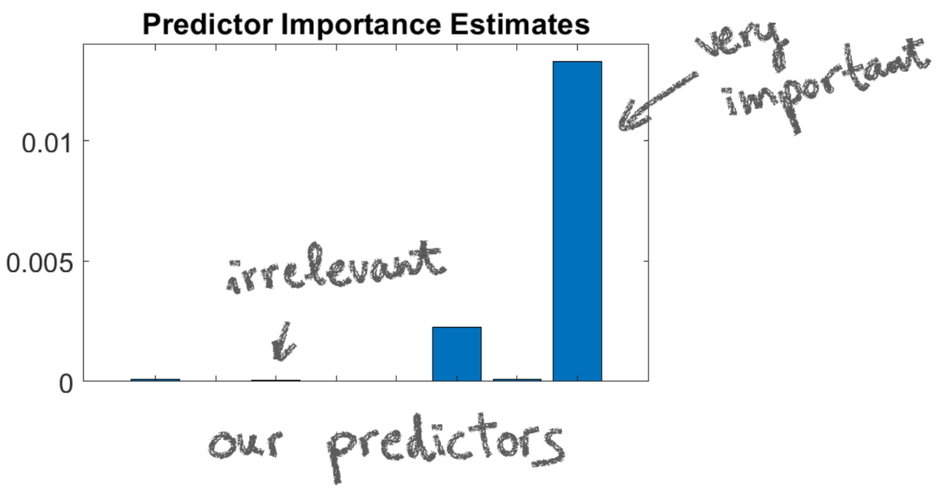

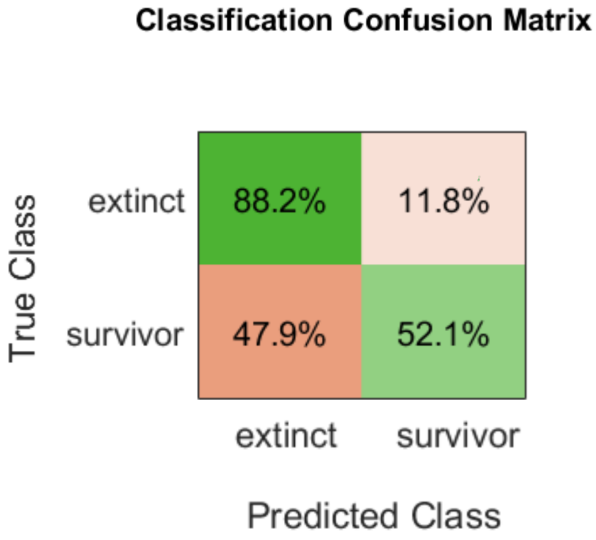

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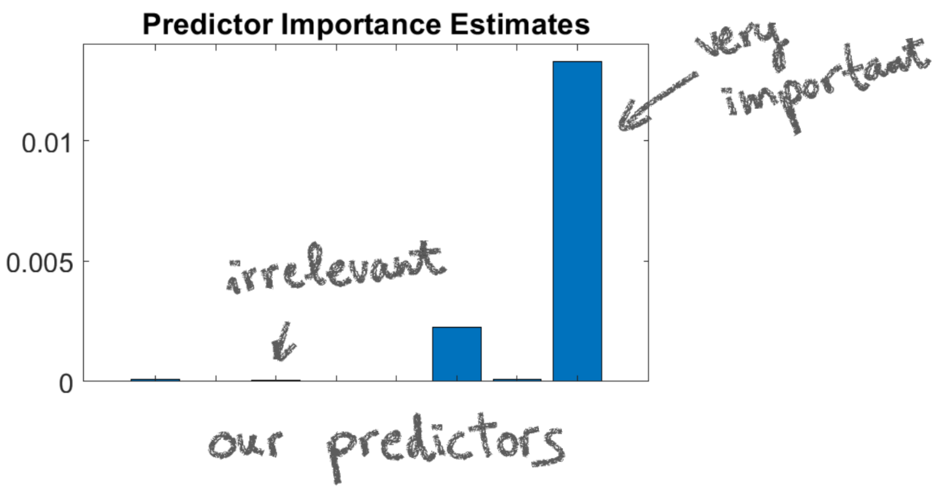

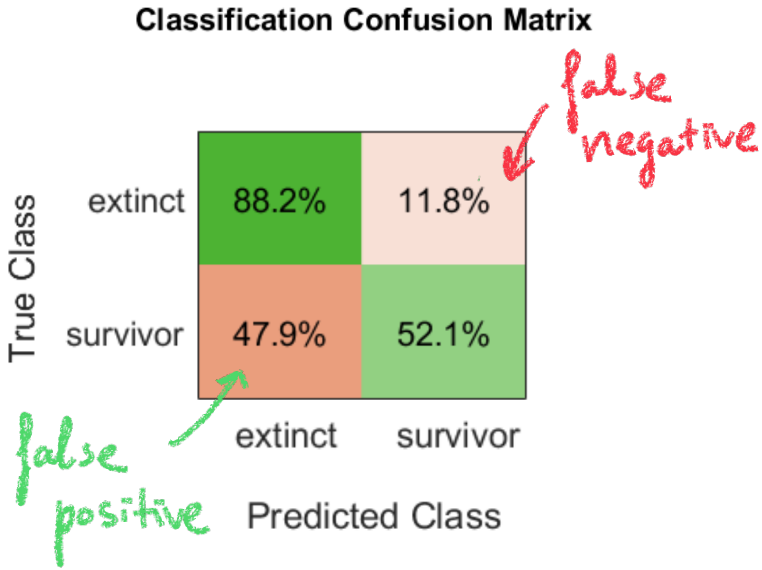

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Basic case:

COMPETITION

$$\alpha < 0$$

- More negative local fitness makes densities decrease faster
- More neighbours lower your fitness (more negative)

$$\dot{x}_i = x_i \left(\underbrace{\sum_j \Lambda_{ij} x_j}_{\text{local fitness}} - \underbrace{\sum_{jk} \Lambda_{jk} x_j x_k}_{\text{mean fitness}} \right)$$

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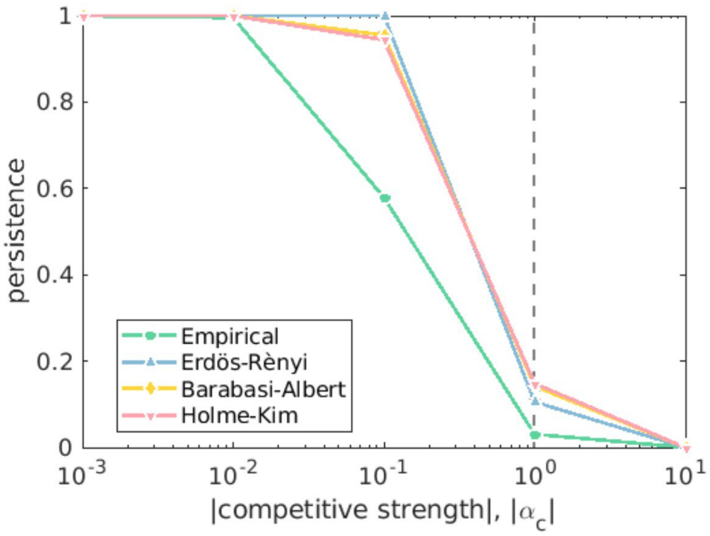

$\alpha < 0$ competition

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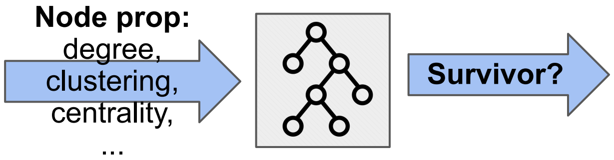
Predictor?



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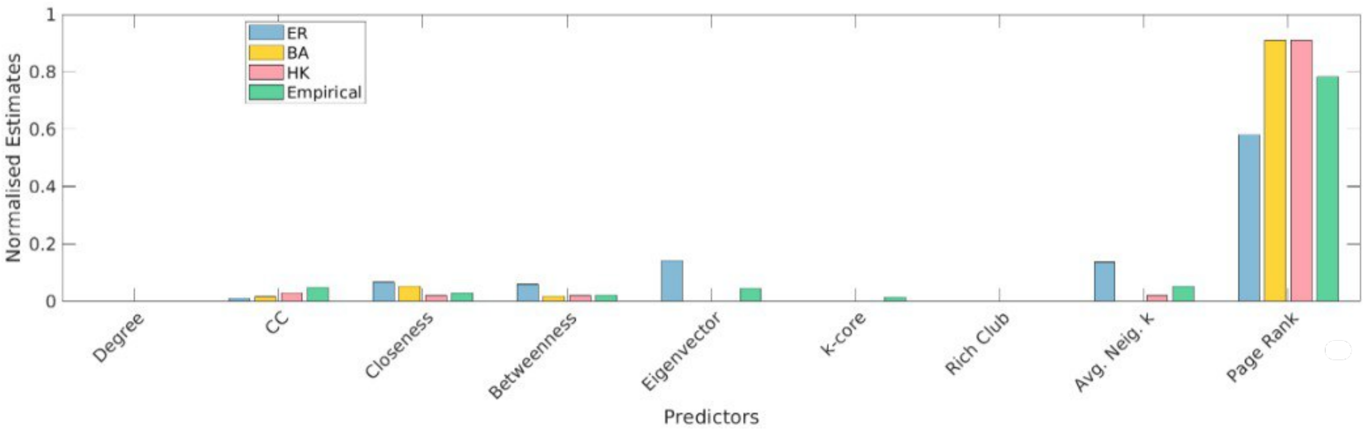
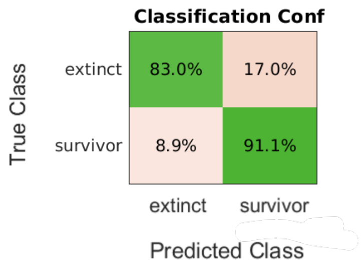
Main Predictor = PAGE RANK





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local fitness mean fitness

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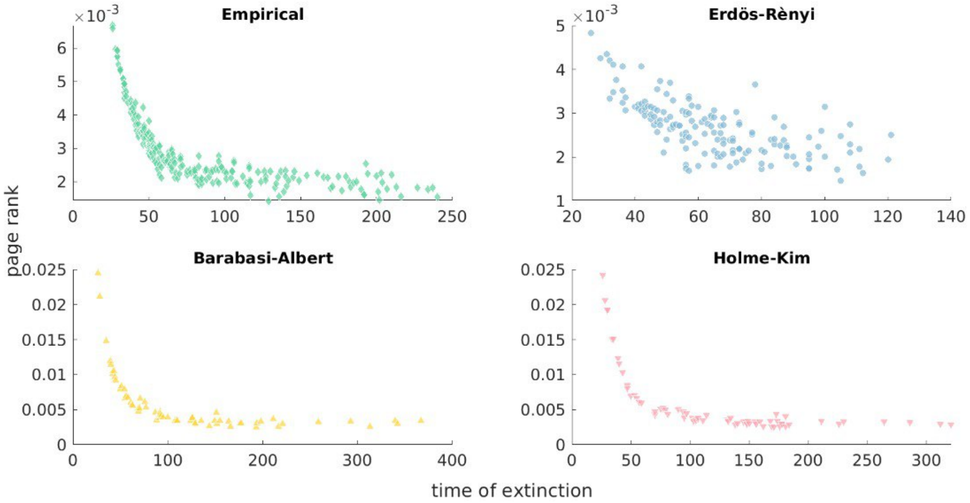

Basic case II:

mutualism

$$\alpha > 0$$

- More neighbours increase your fitness

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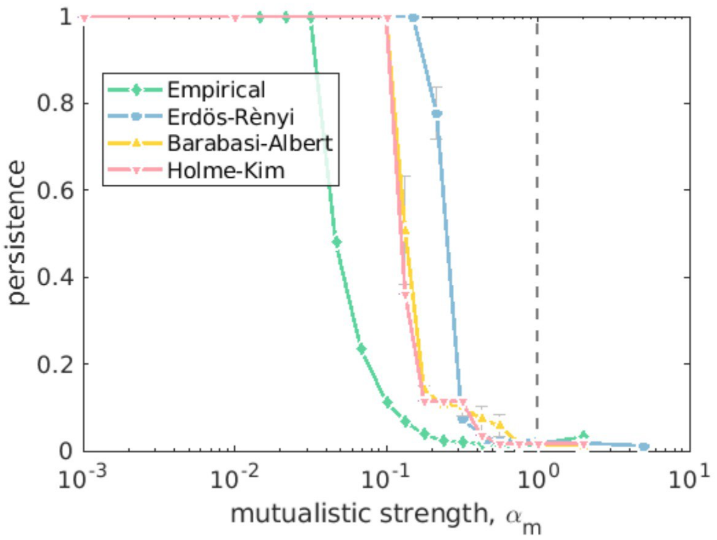

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local fitness — mean fitness

Predictor?

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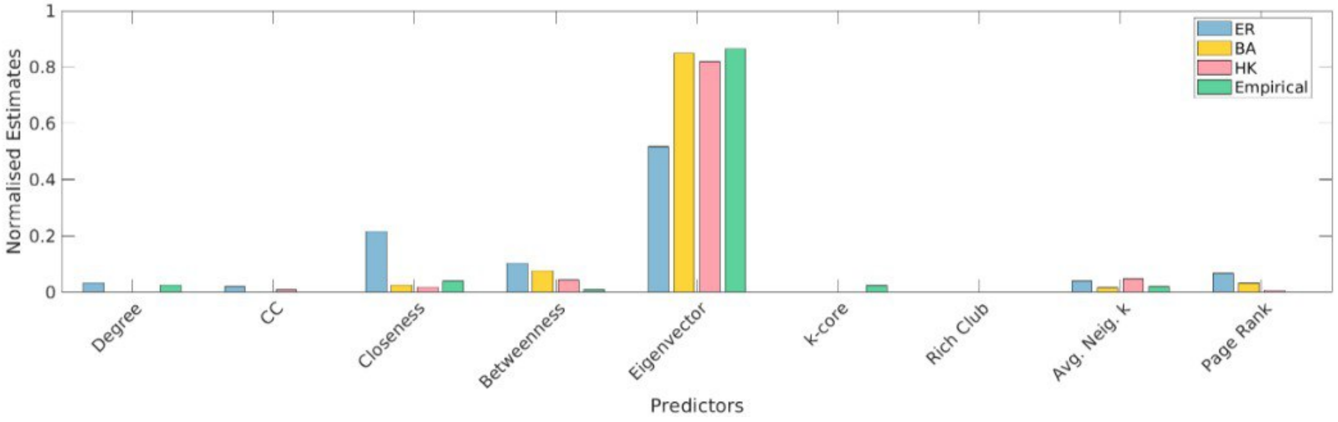
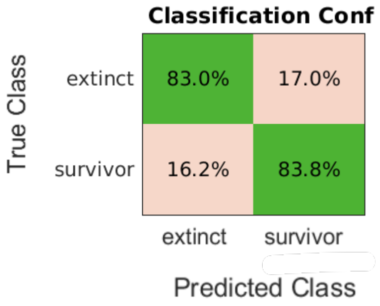
local fitness — mean fitness

Main Predictor = EIGENVECTOR CENTRALITY





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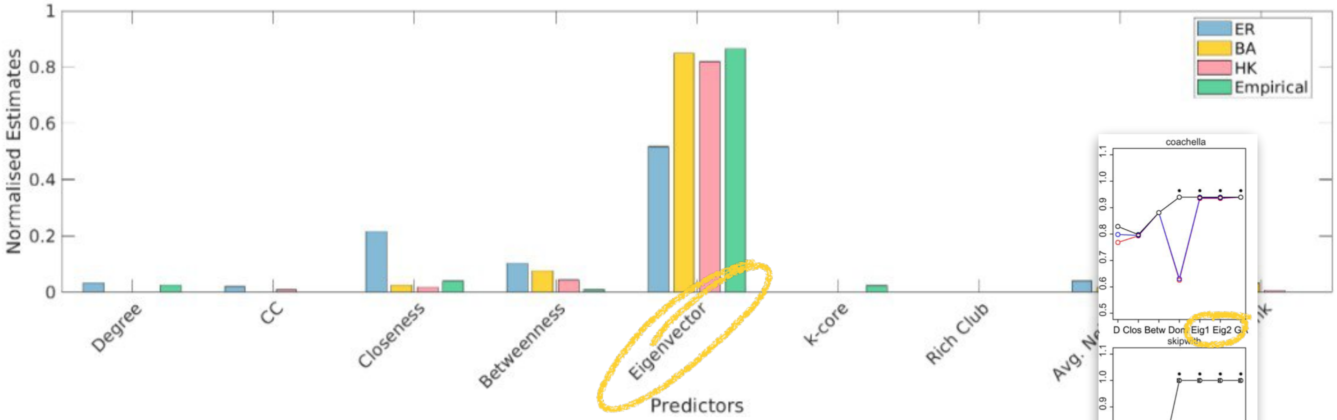

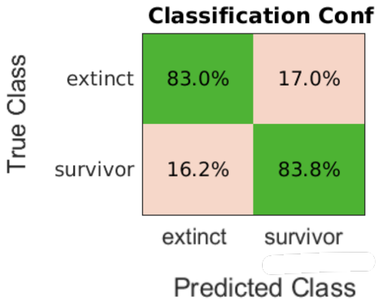


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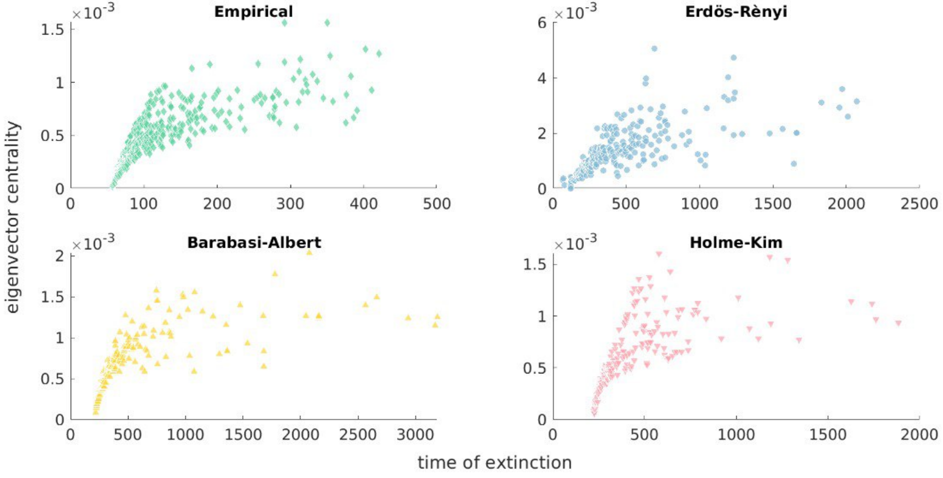

COMPETITION & mutualism

COMPETITION & mutualism

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Erdos-Renyi

- Same percentage of competitive links than empiric

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Empirical network

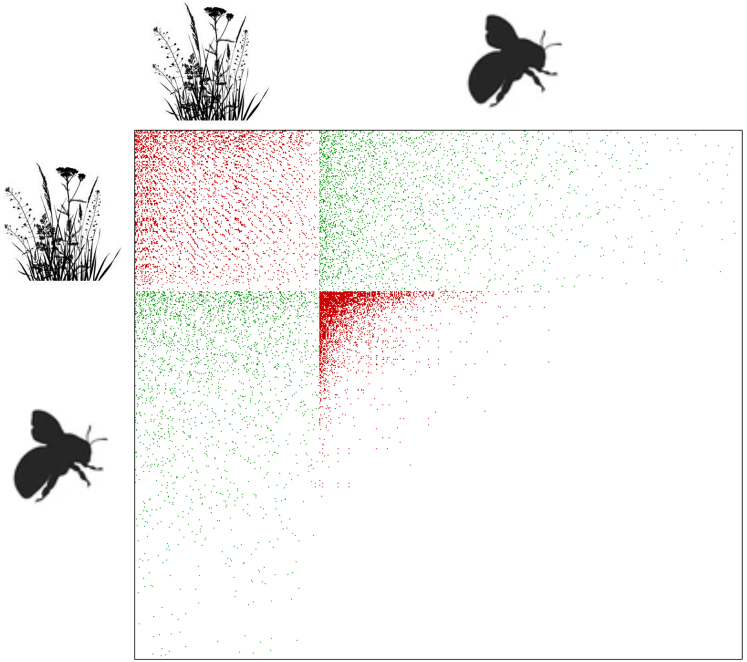
- Mutualism
- Competition = projected matrix of guilds

Erdos-Renyi

- Same percentage of competitive links than empirical

Empirical network

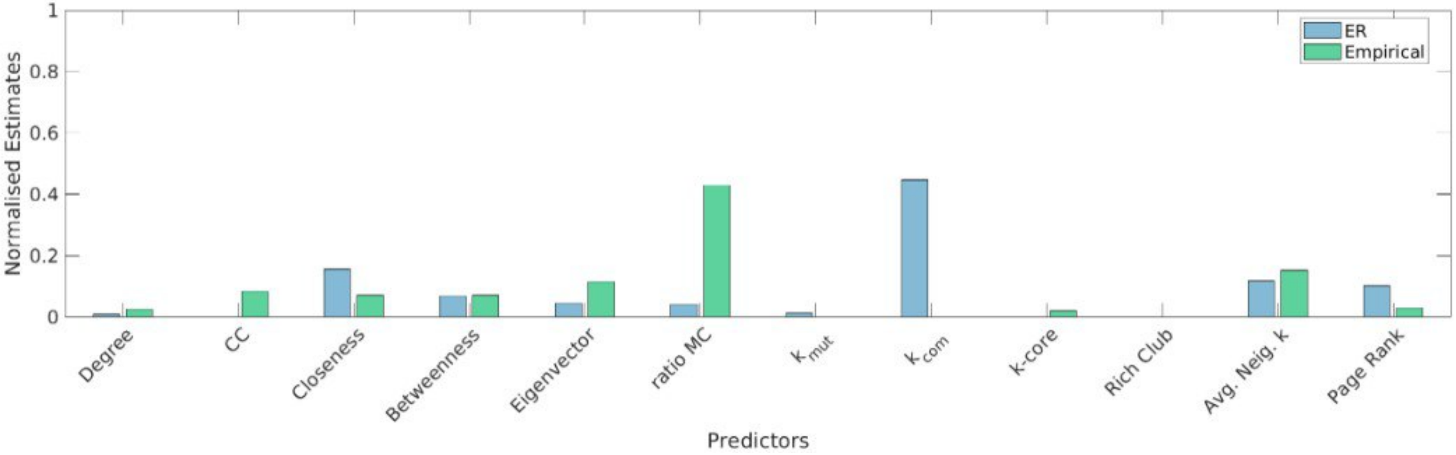
- Mutualism
- Competition = projected matrix of guilds
- 1500 species = 456 plants + 1044 pollinators
- Ratio competitive/mutualistic interactions = 1.4

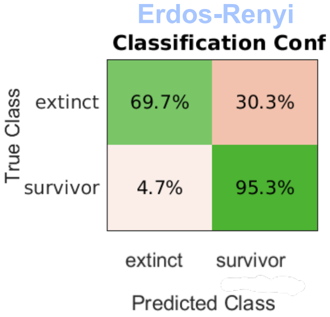


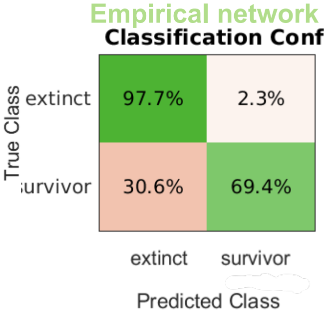
Robertson, C. 1929. Flowers and insects: lists of visitors to four hundred and fifty-three flowers. Carlinville, IL, USA.

web of life
ecological networks database

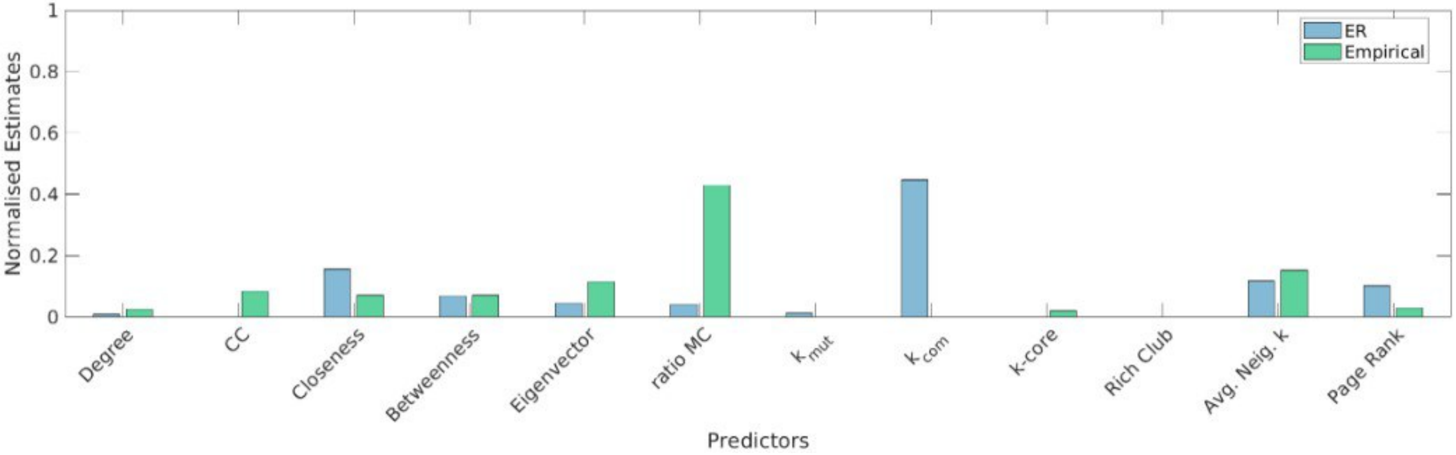
Main Predictors = ??

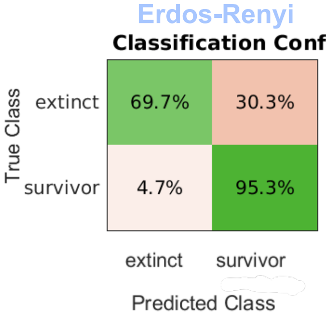


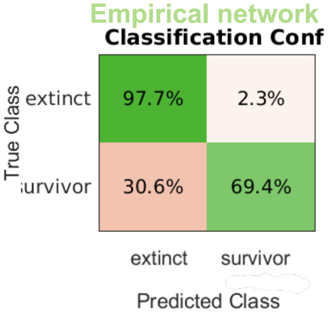




Main Predictors = ratio, competitive degree, and others!







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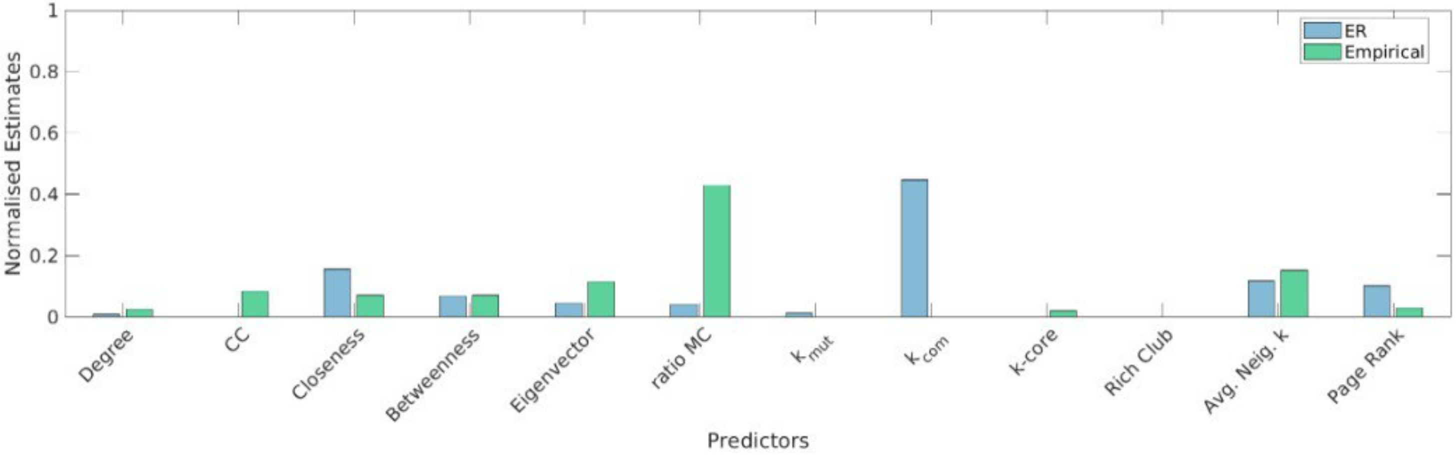
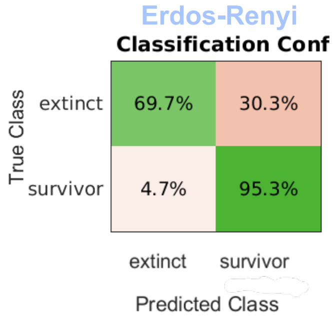
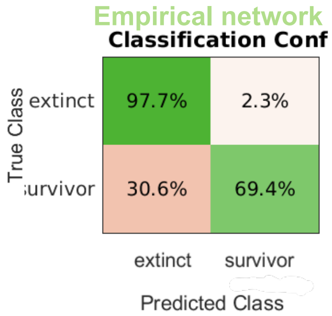
Interactions' properties

No a single predictor







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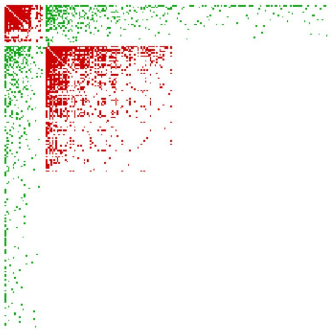
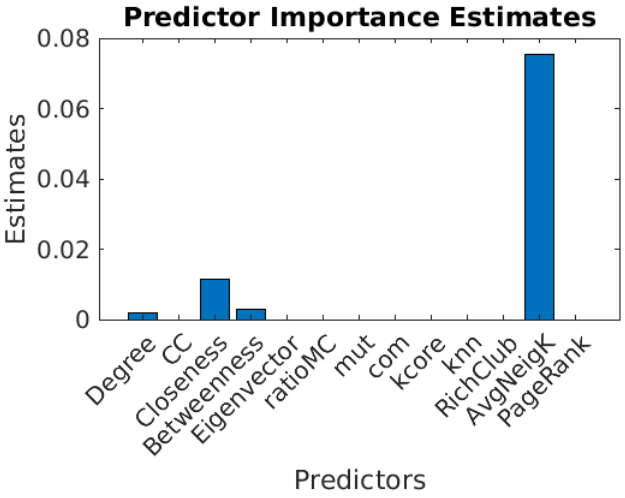
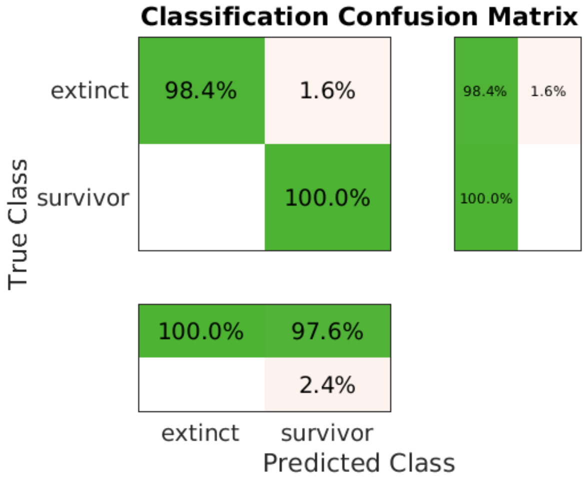
THANK YOU!

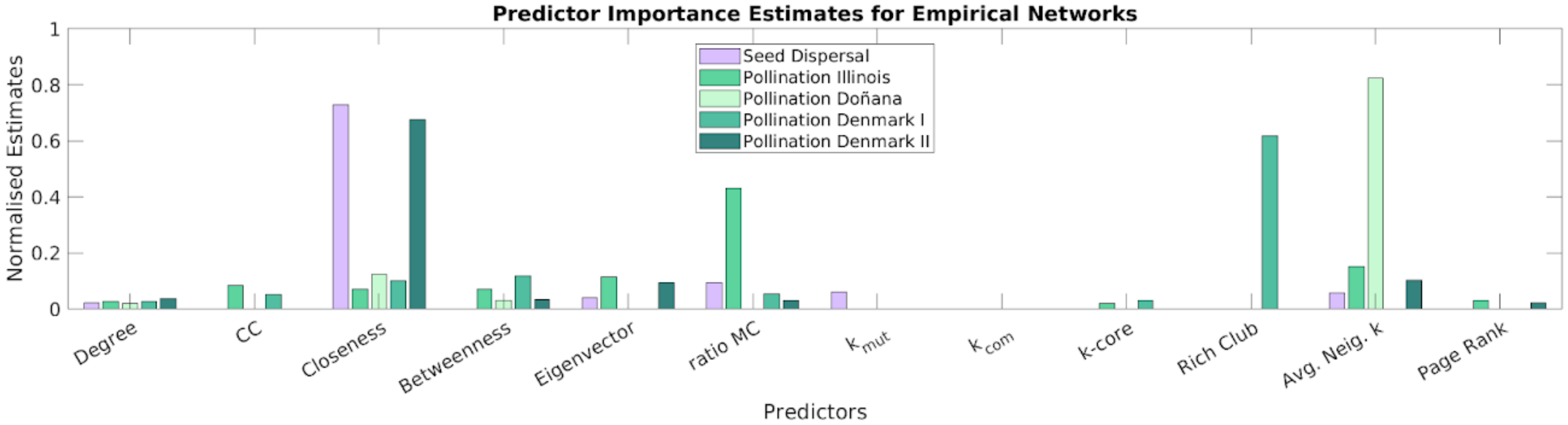
Doñana
Species:205
Plants (Rows): 26
Pollinators (Columns): 179
Interactions: 412
Connectance: 0.089



Herrera, J. (1988) Pollination relatioships in southern spanish mediterranean shrublands. Journal of Ecology 76: 274-287






Predictor Importance Estimates for Empirical Networks
Normalised Estimates
1
0.8
0.6
0.4
0.2
0
Seed Dispersal
Pollination Illinois
Pollination Doñana
Pollination Denmark I
Pollination Denmark II
Degree
CC
Closeness
Betweenness
Eigenvector
ratio MC
k_{mut}
k_{com}
k-core
Rich Club
Avg. Neig. k
Page Rank
Predictors