Modularity

Marilia P. Gaiarsa & Camille Coux

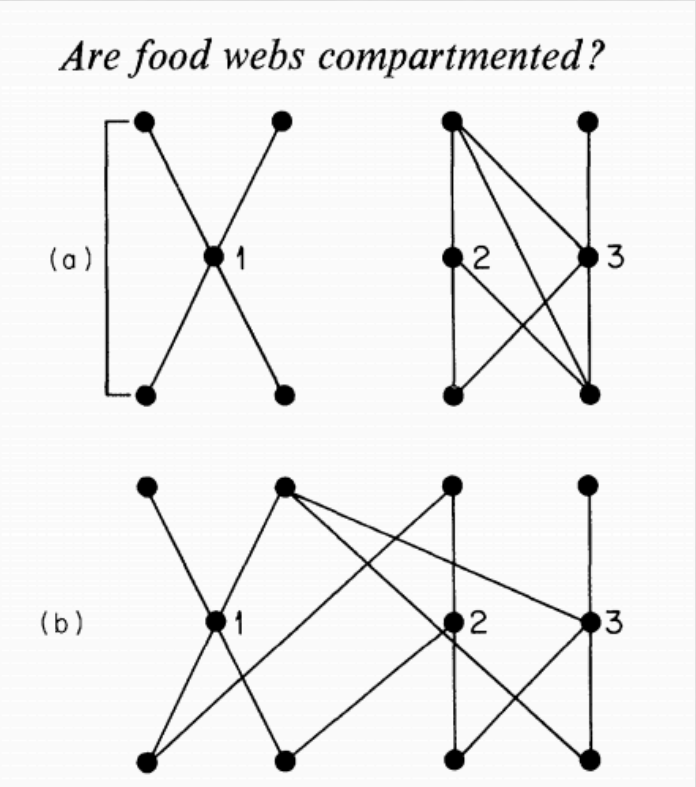
Introduction to the study of ecological networks

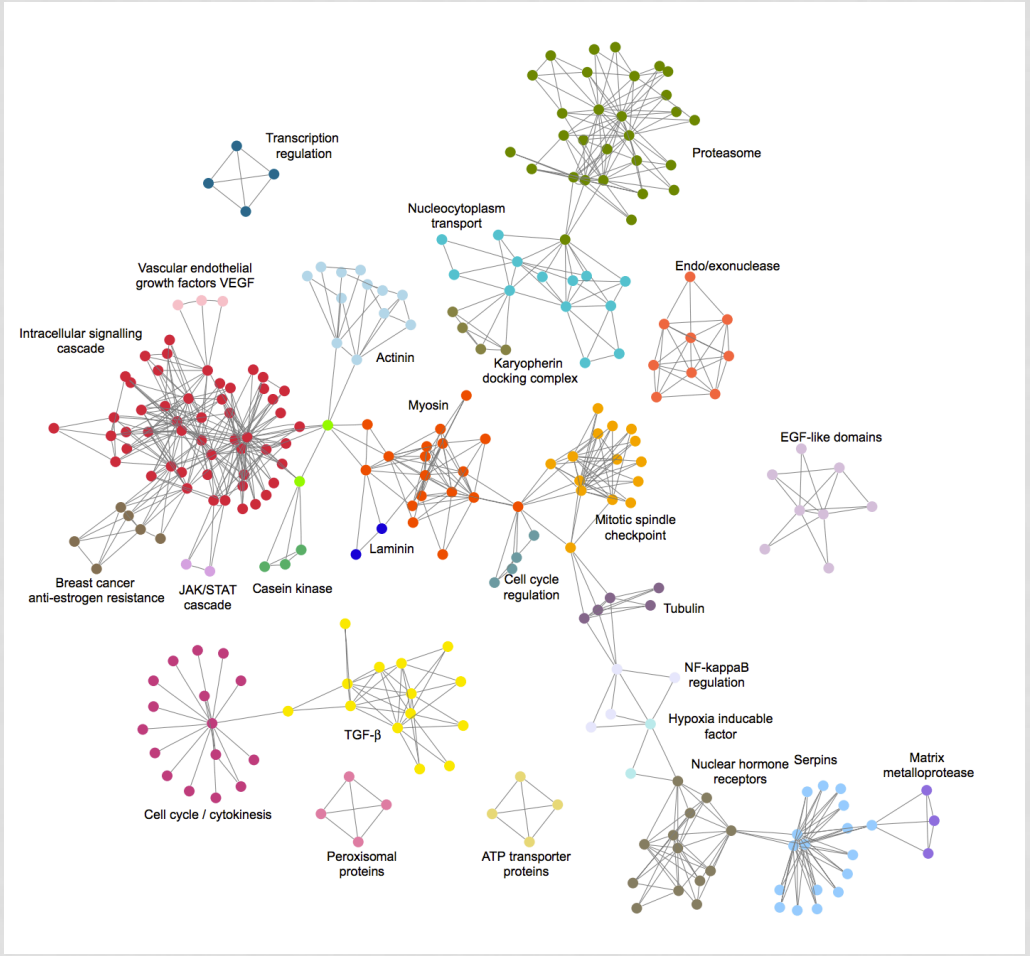
Workshop NZES

Journal of Animal Ecology (1980), **49**, 879–898

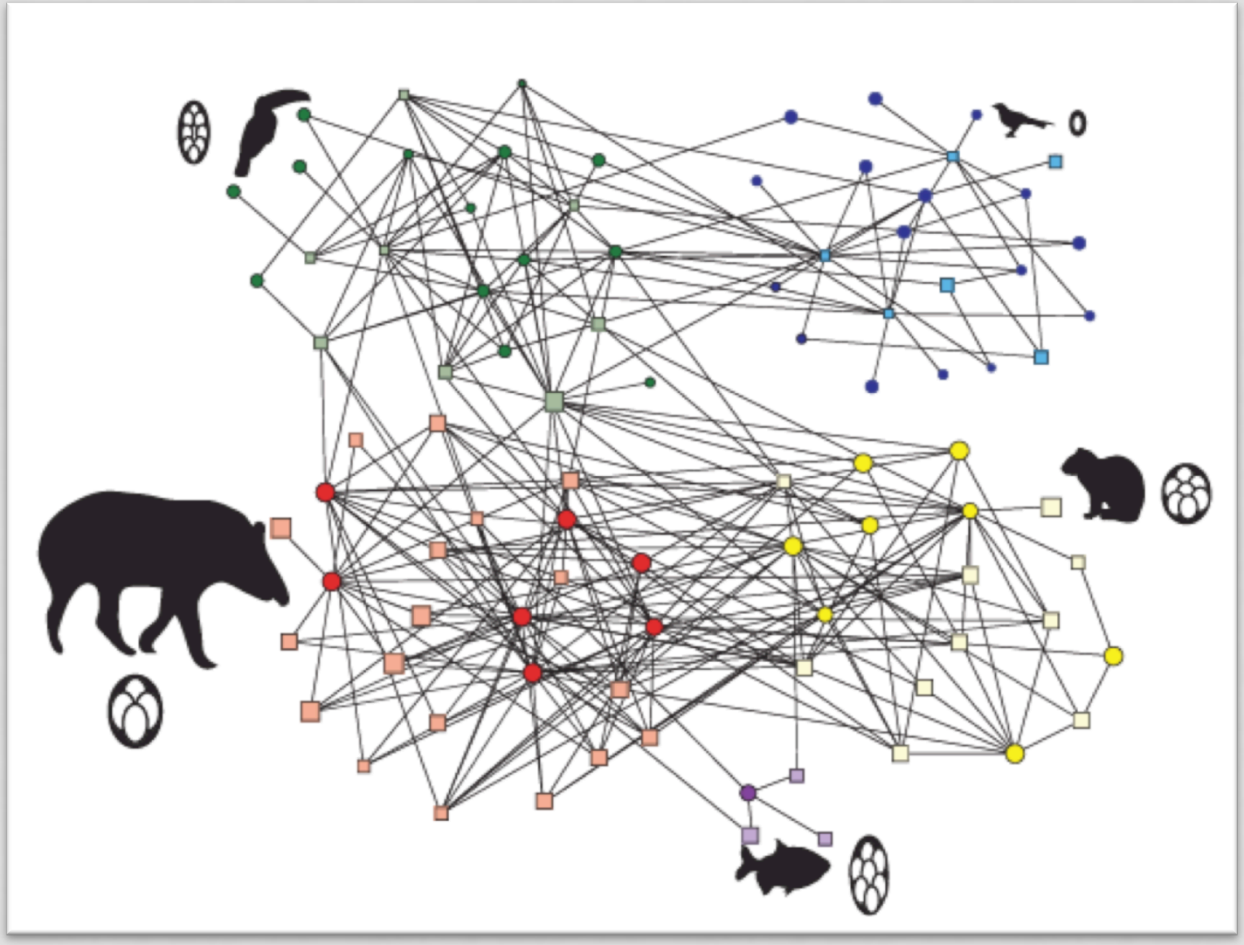
ARE FOOD WEBS DIVIDED INTO COMPARTMENTS?*

BY STUART L. PIMM† AND JOHN H. LAWTON

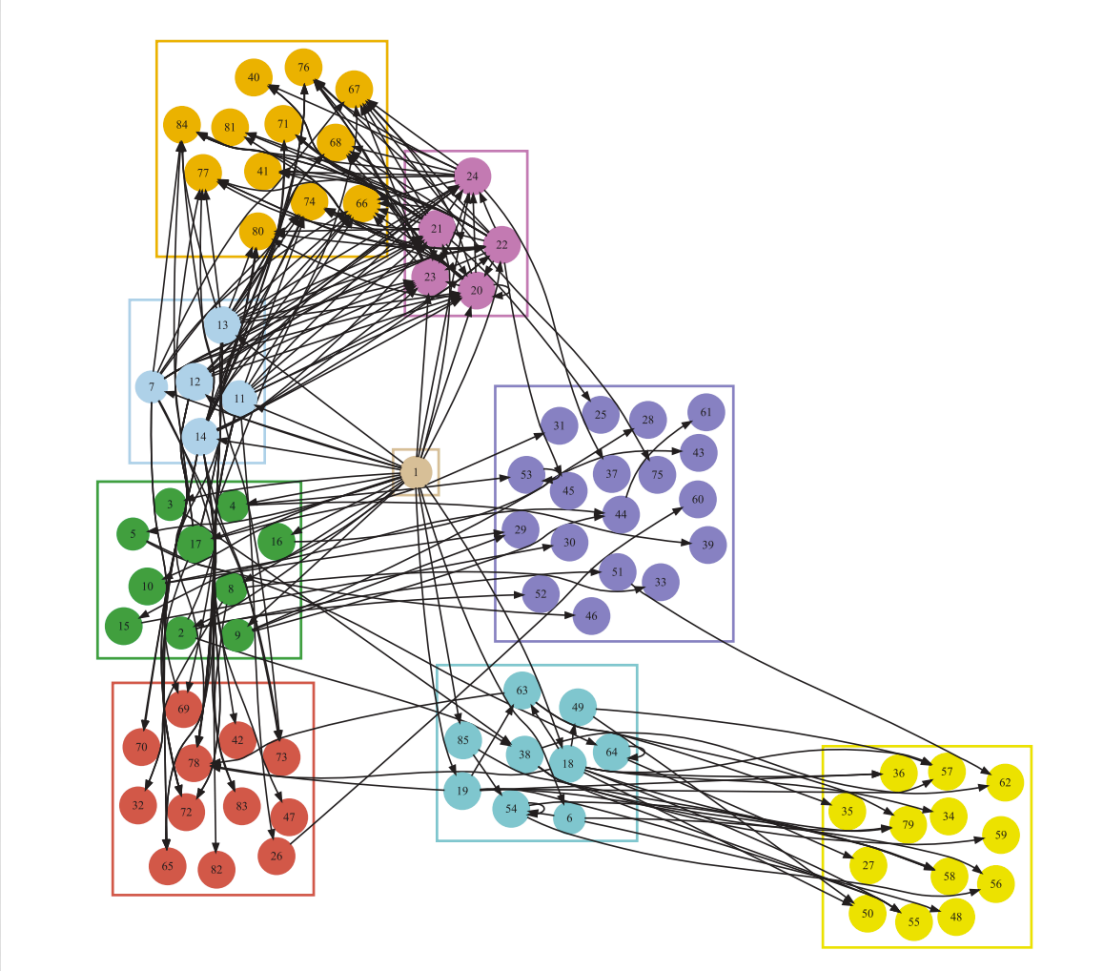




Jonsson et al. 2006, Fortunato 2010

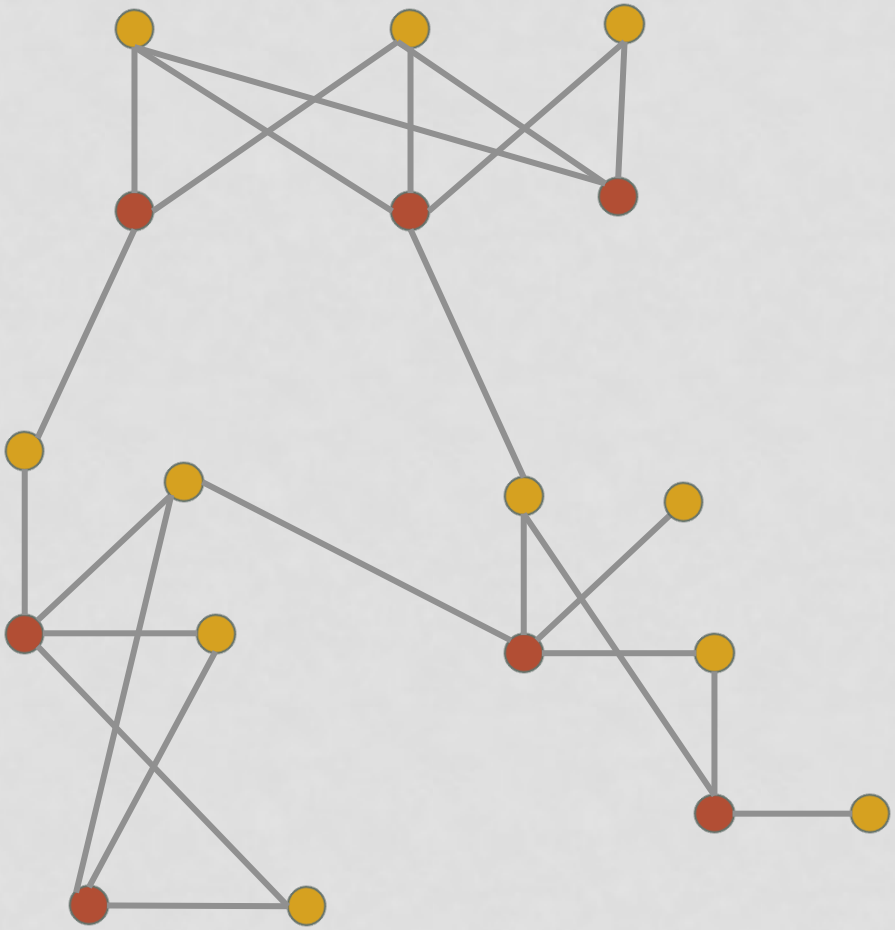


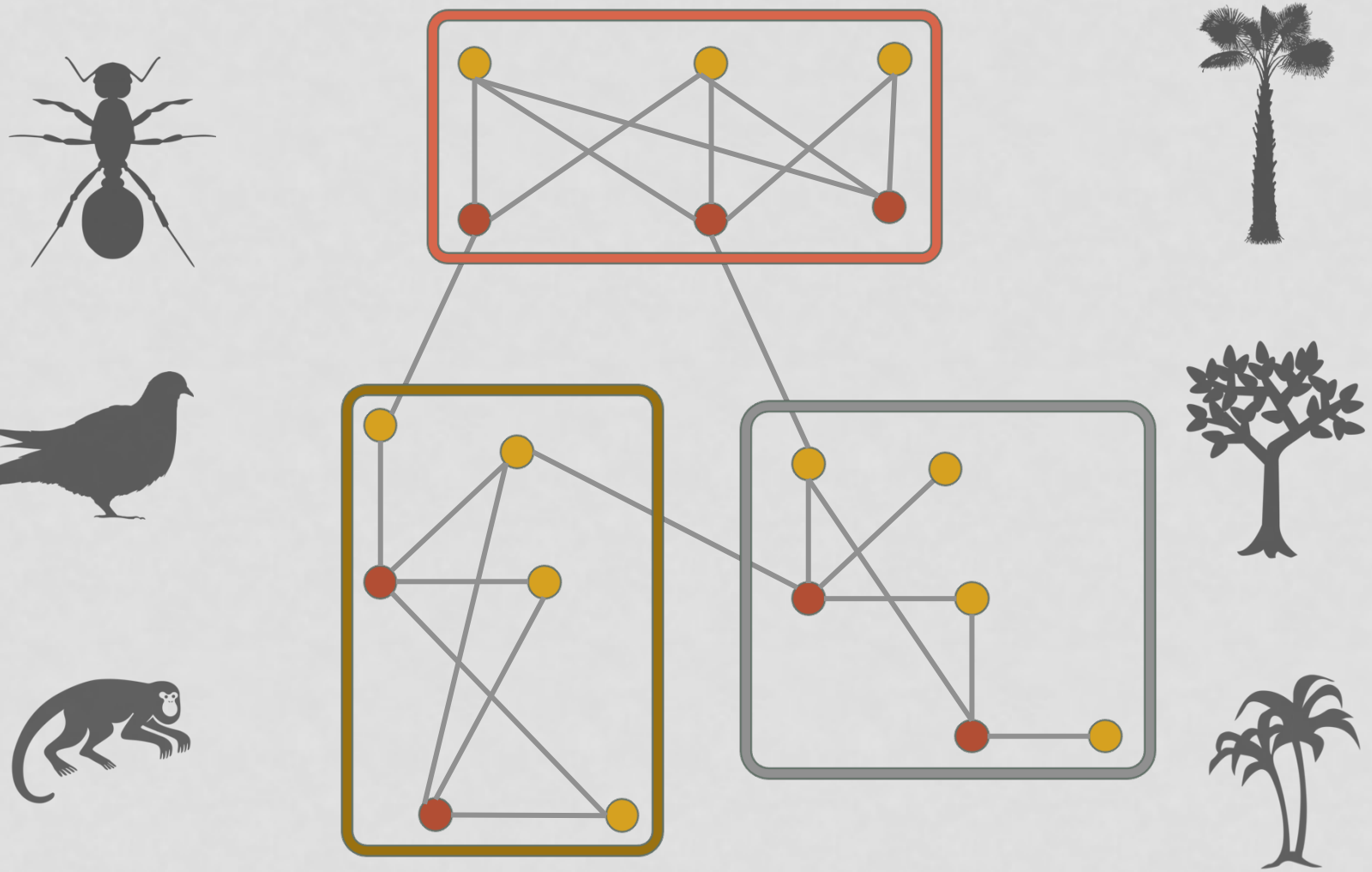
Donatti et al. 2011

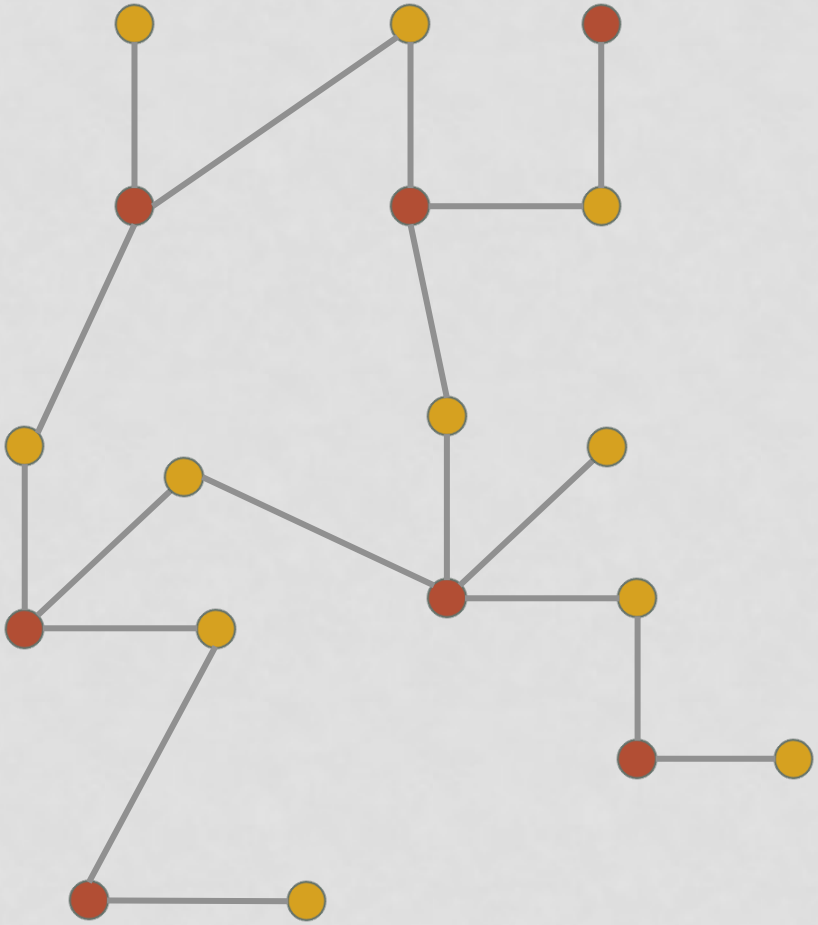


Allesina & Pascual 2009

"Modularity is the tendency where species within a module tend to interact with a much higher frequency among them than they do with species from other modules" (Bascompte & Jordano 2014)





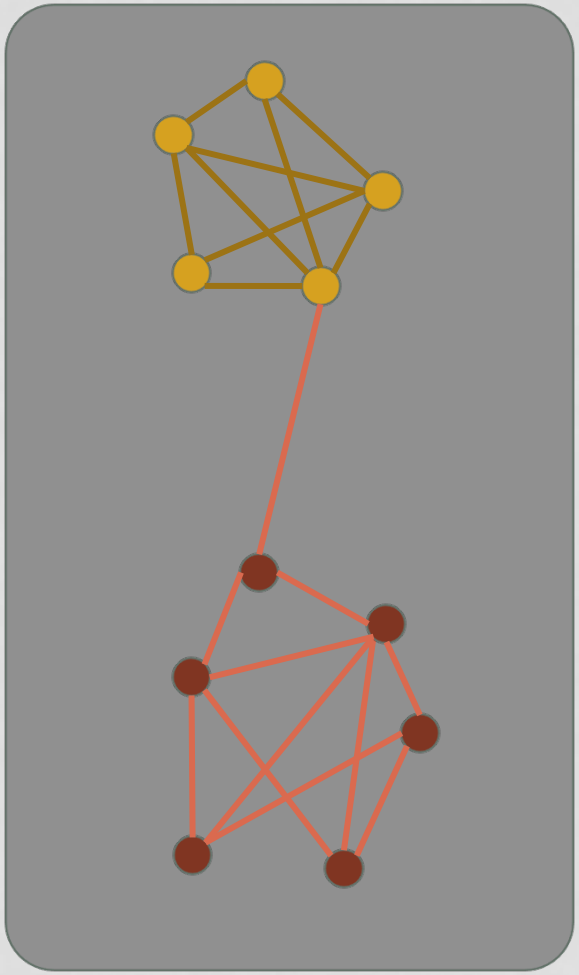


How to characterize groups of interactions?

The metric M

$$M = \sum_{\text{all modules s}} \left(\frac{l_s}{L} - \frac{d_s^P}{L} \frac{d_s^A}{L} \right)$$

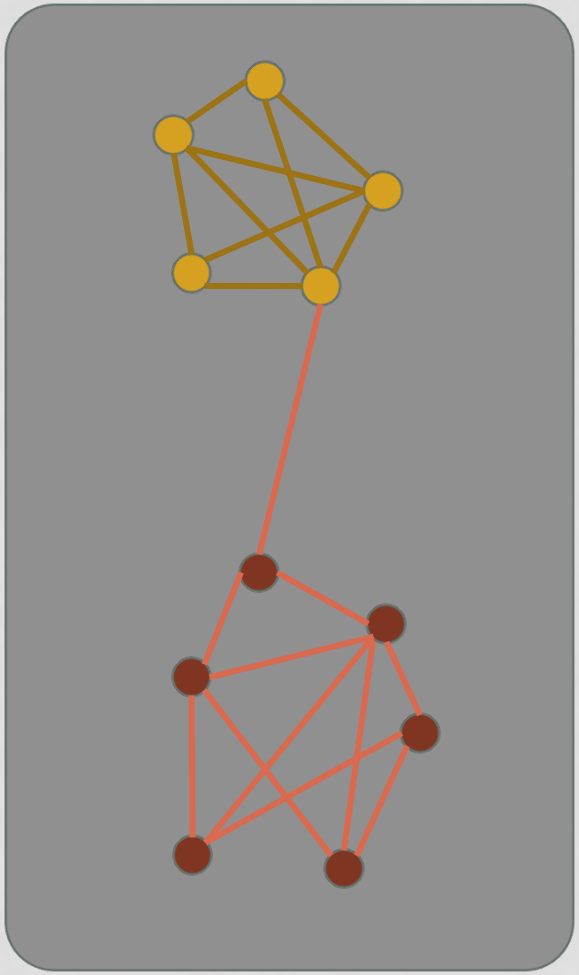
Barber 2007, Guimerà et al. 2007



# of interactions inside module ***s***

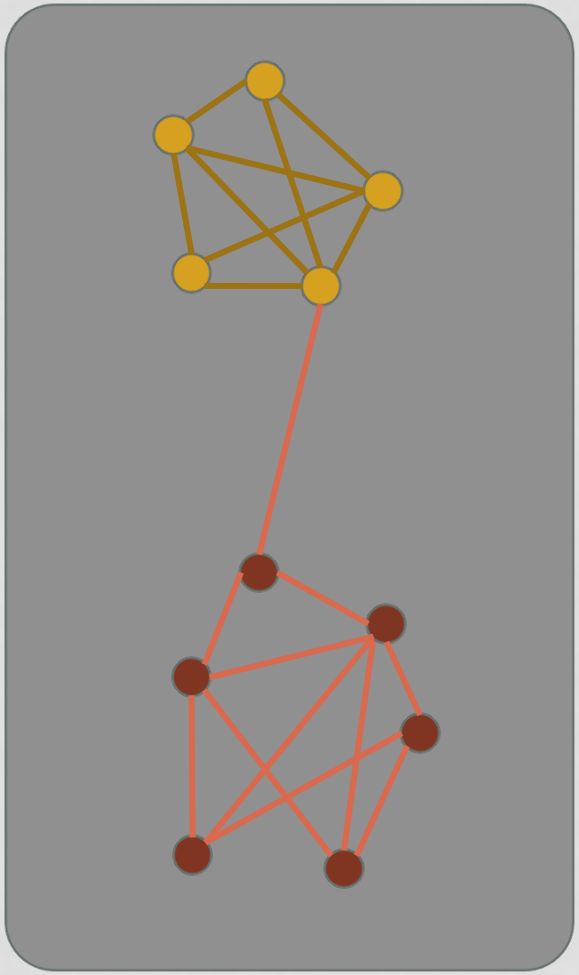
$$M = \sum_{\text{all modules s}} \left(\frac{l_s}{L} - \frac{d_s^P}{L} \frac{d_s^A}{L} \right)$$

# of interactions in the whole network



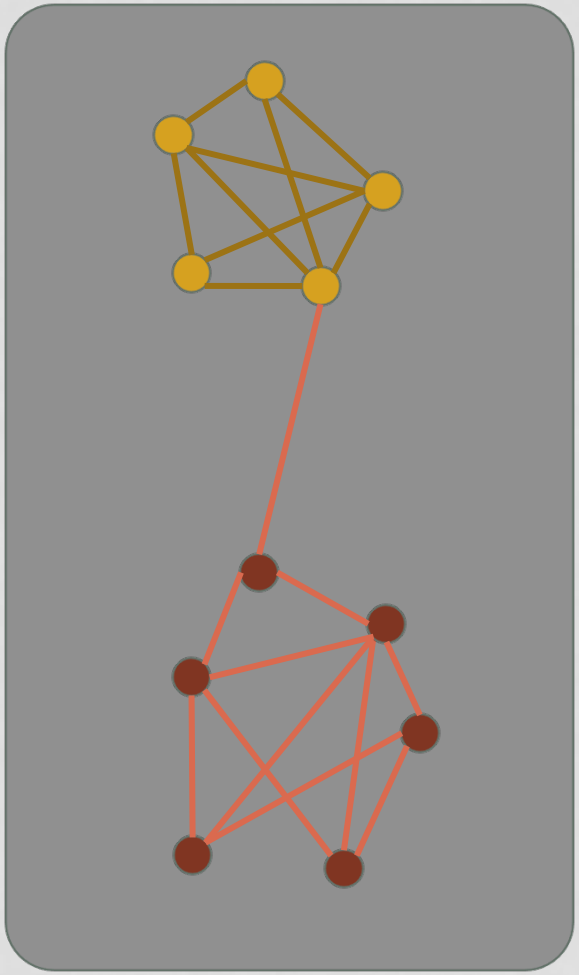
Sum of the plants' degree inside module s

$$M = \sum_{\text{all modules s}} \left(\frac{l_s}{L} - \frac{d_s^P}{L} \frac{d_s^A}{L} \right)$$



Sum of the animals' degree inside module s

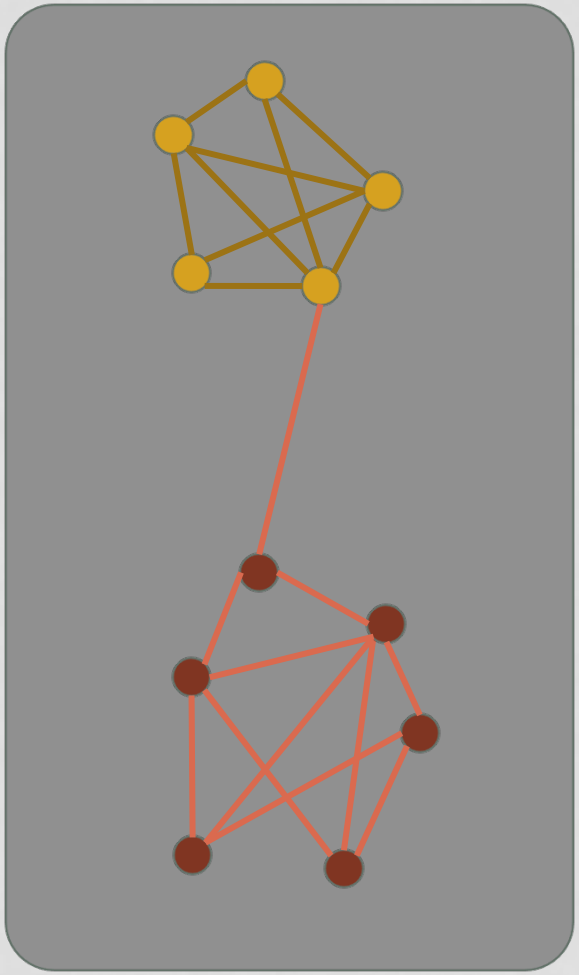
$$M = \sum_{\text{all modules s}} \left(\frac{l_s}{L} - \frac{d_s^P}{L} \frac{d_s^A}{L} \right)$$



The metric M

$$M = \sum_{\text{all modules s}} \left[\frac{l_s}{L} - \left(\frac{d_s}{L} \right)^2 \right]$$

Newman & Girvan 2004



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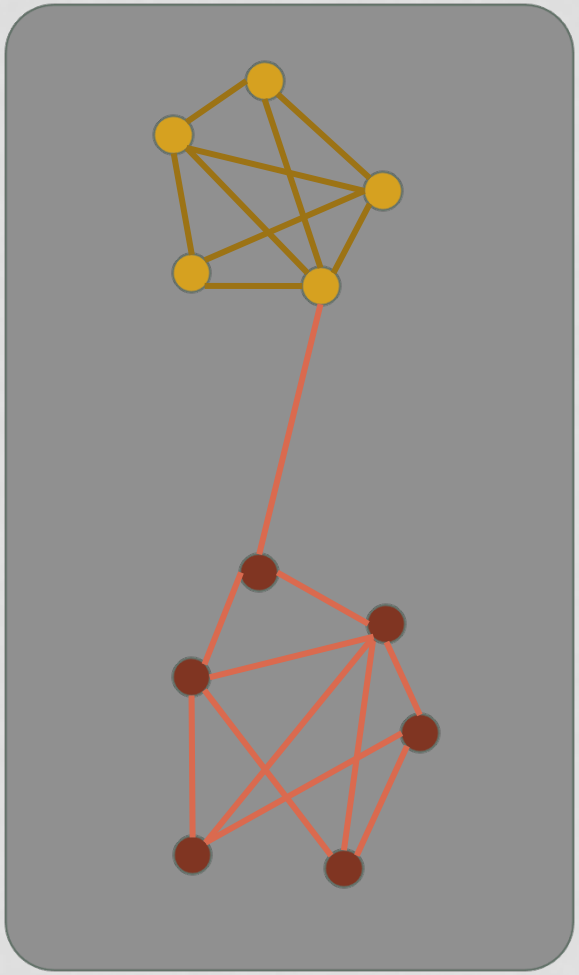
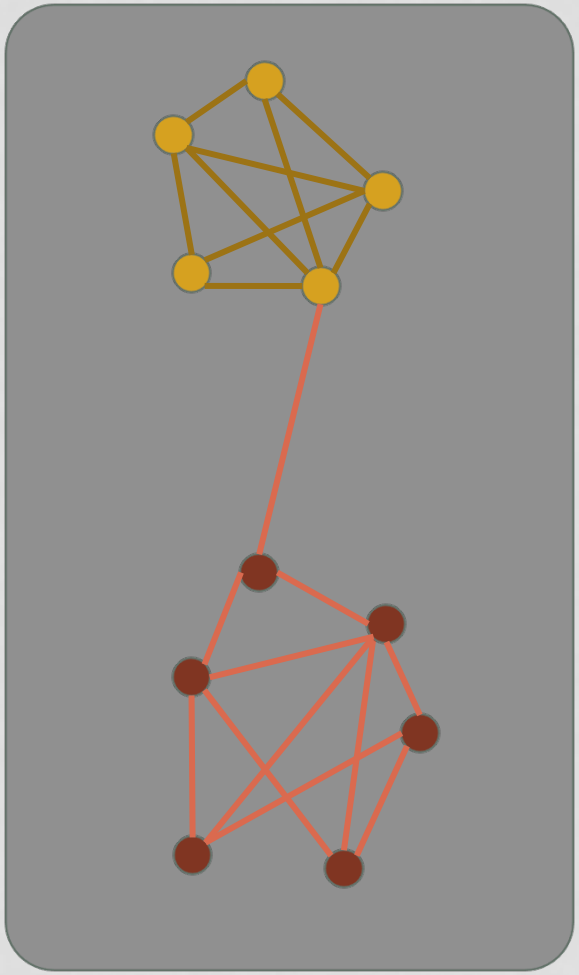
# of interactions in the whole network



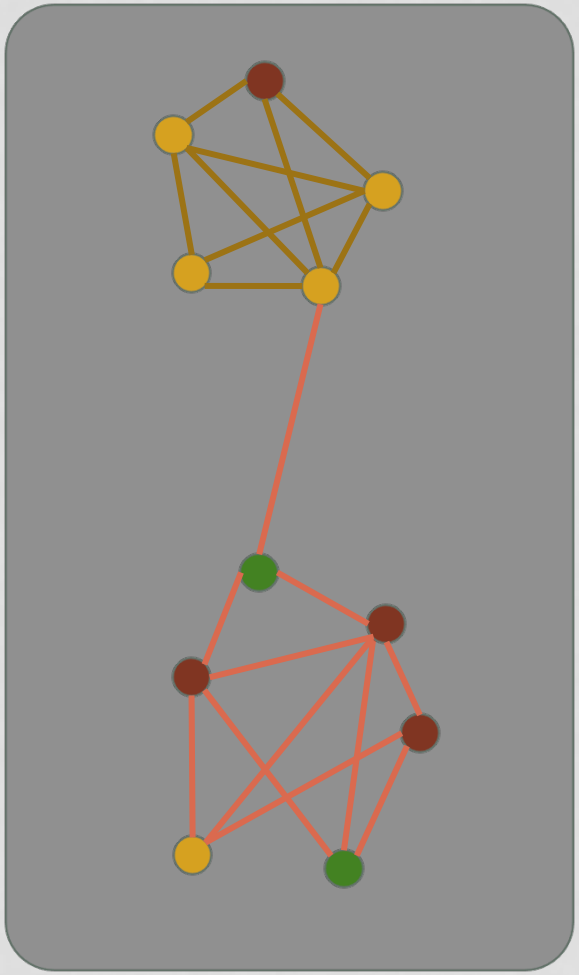
Sum of the species' degree inside module s

$$M = \sum_{\text{all modules s}} \left[\frac{l_s}{L} - \left(\frac{d_s}{L} \right)^2 \right]$$



How to find the modules?

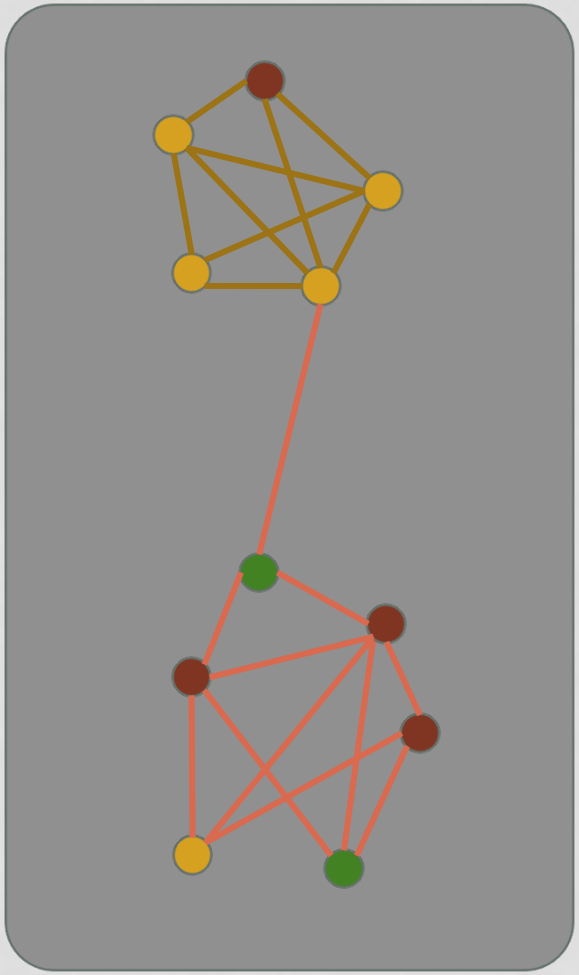
$$M = \sum_{\text{all modules s}} \left[\frac{l_s}{L} - \left(\frac{d_s}{L} \right)^2 \right]$$



How to find the modules?

$$M = \sum_{\text{all modules s}} \left[\frac{l_s}{L} - \left(\frac{d_s}{L} \right)^2 \right]$$

- (2/21) – (15/42)^2
- (6/21) – (18/42)^2
- (0/21) – (6/42)^2



How to find the modules?

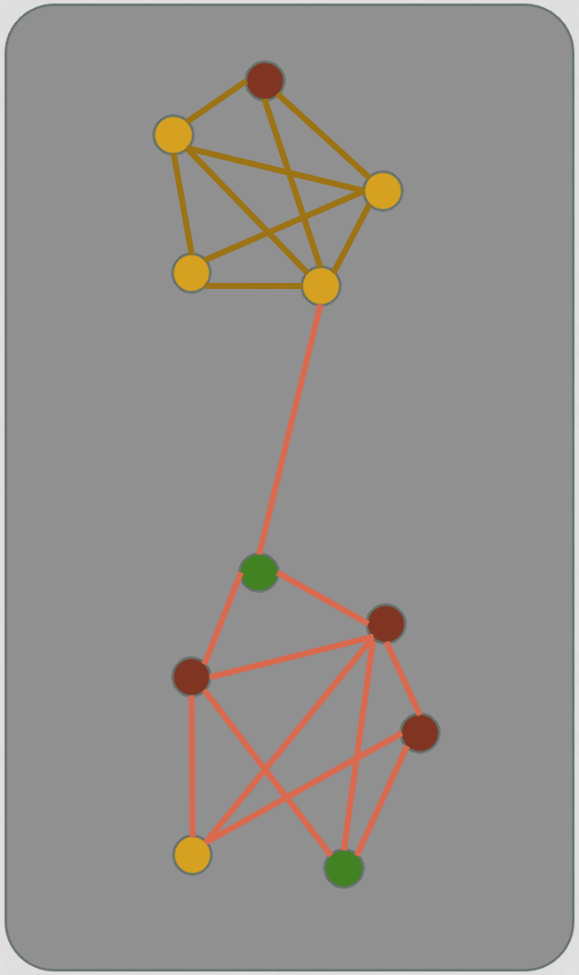
$$M = \sum_{\text{all modules s}} \left[\frac{l_s}{L} - \left(\frac{d_s}{L} \right)^2 \right]$$

- 0.04

0.10

- 0.02

M = 0.04



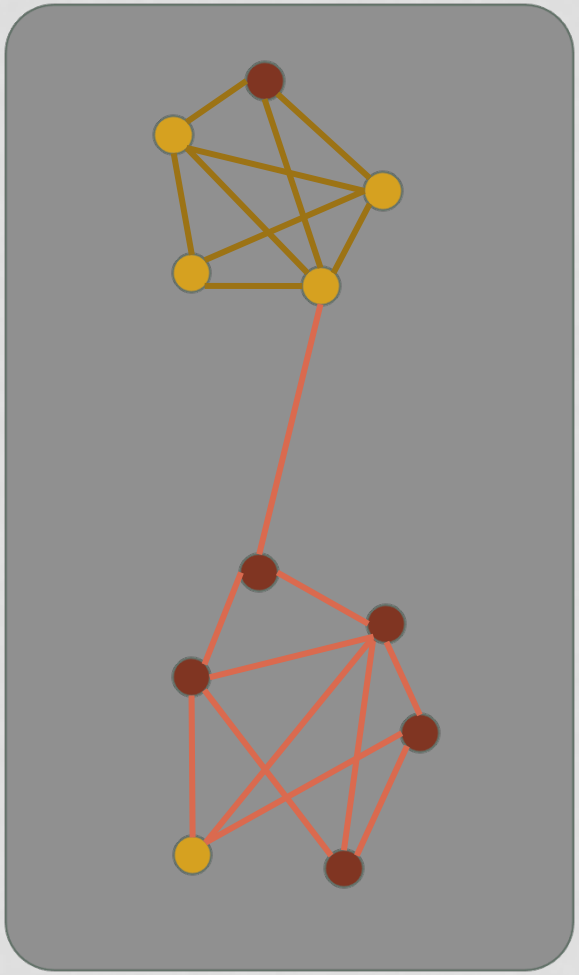
How to find the modules?

$$M = \sum_{\text{all modules s}} \left[\frac{l_s}{L} - \left(\frac{d_s}{L} \right)^2 \right]$$

0.01

0.15

M = 0.16



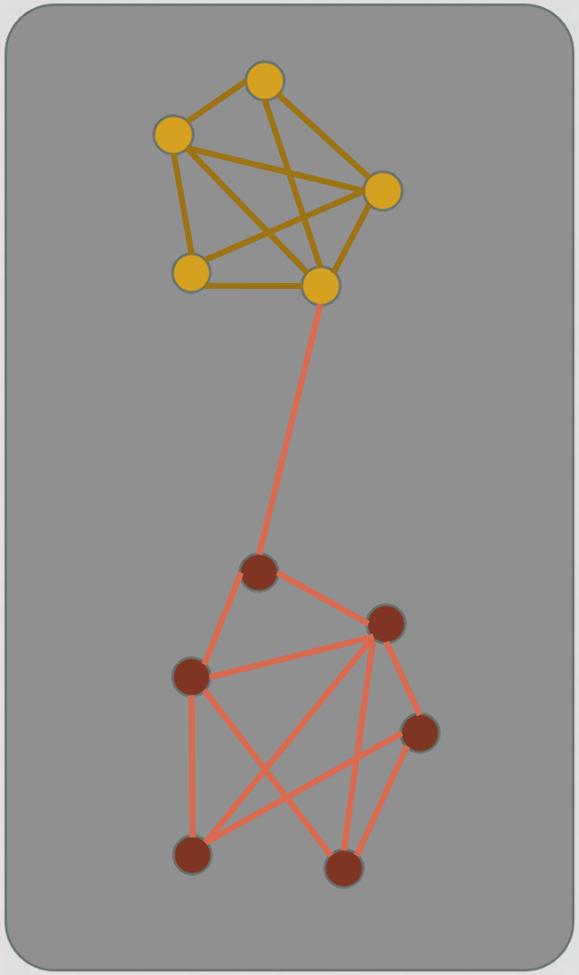
How to find the modules?

$$M = \sum_{\text{all modules s}} \left[\frac{l_s}{L} - \left(\frac{d_s}{L} \right)^2 \right]$$

0.22

0.25

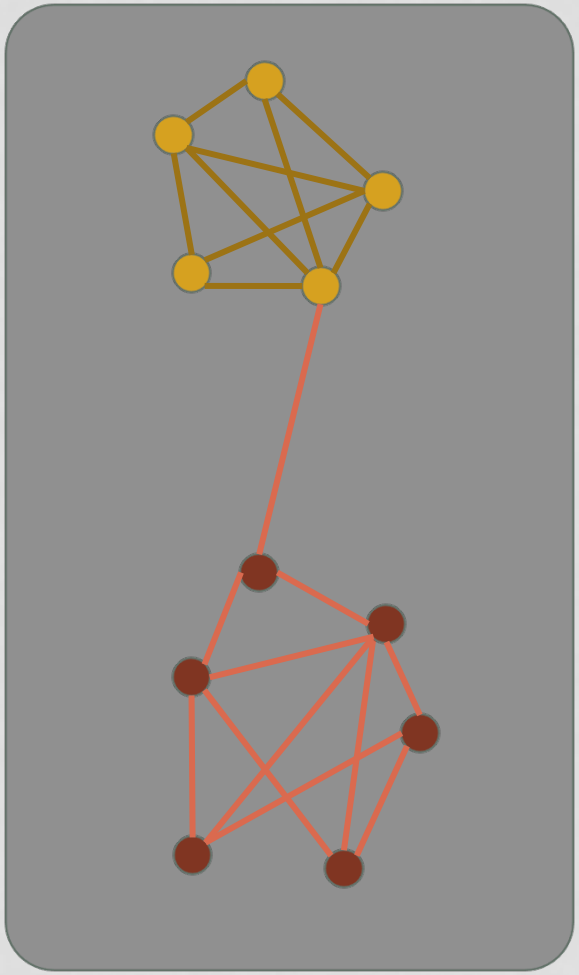
M = 0.47



11 species: 1 – 11 modules;

Different sizes;

How to optimize?



11 species: 1 – 11 modules;

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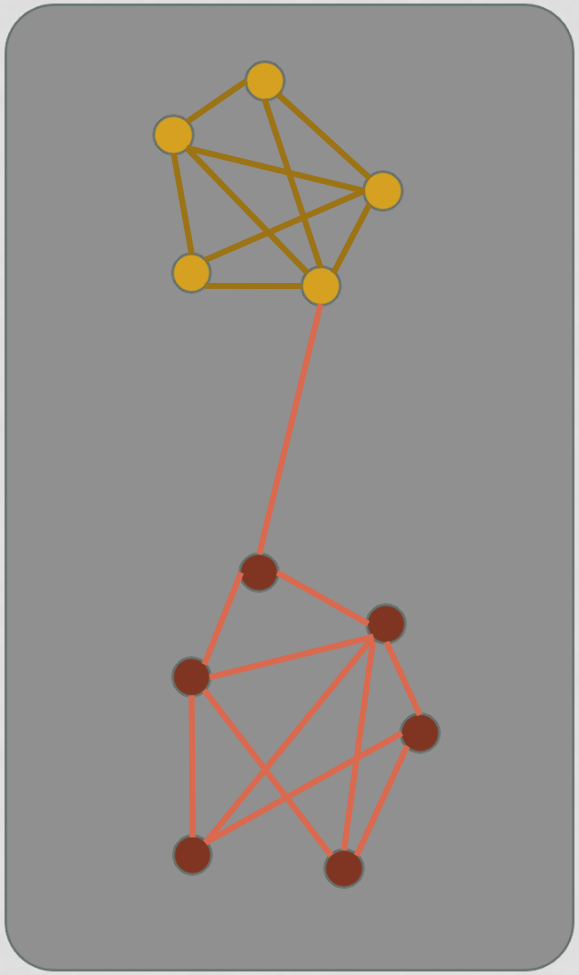
How to optimize?

Simulated annealing



11 species: 1 – 11 modules;

Different sizes;

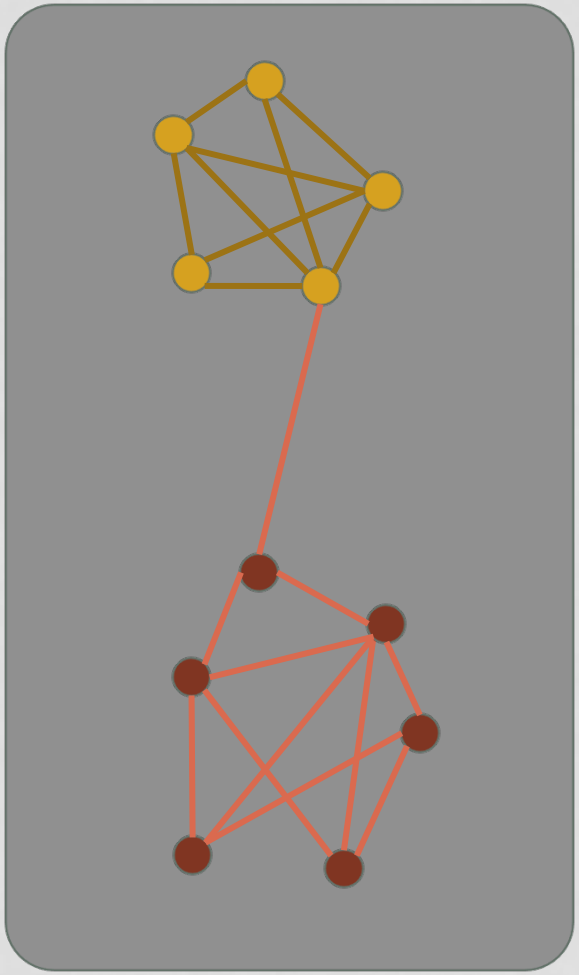
How to optimize?

Simulated annealing

Netcarto (Guimera & Amaral)

Rnetcarto (Doulcier)

Modular (Marquitti et al.)



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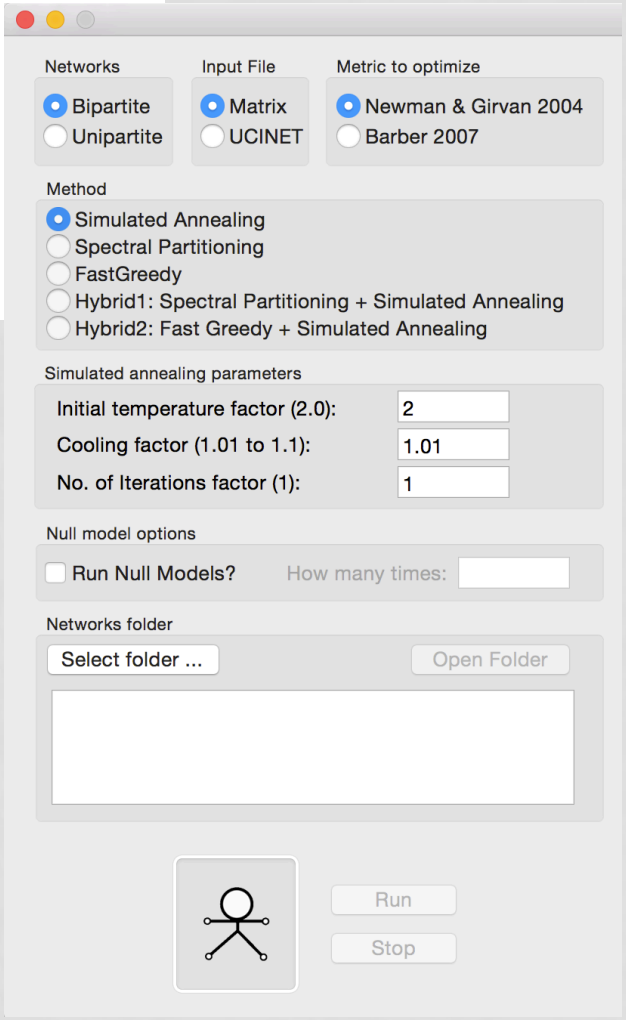
Software notes

Ecography 37: 221–224, 2014
doi: 10.1111/j.1600-0587.2013.00506.x

Subject Editor: Thiago Rangel. Accepted 18 October 2013

MODULAR: software for the autonomous computation of modularity in large network sets

Flavia Maria Darcie Marquitti, Paulo Roberto Guimarães Jr, Mathias Mistretta Pires and Luiz Fernando Bittencourt



File	N.modules	Modularity
q_modelo 1 1 40 .txt	2	0.500000
q_modelo 1 10 50 .txt	4	0.533504
q_modelo 1 100 42 .txt	2	0.500000
q_modelo 1 11 38 .txt	4	0.645329
q_modelo 1 12 38 .txt	4	0.530181
q_modelo 1 13 47 .txt	2	0.500000
q_modelo 1 14 55 .txt	4	0.595577
q_modelo 1 15 40 .txt	4	0.548201
q_modelo 1 16 23 .txt	2	0.500000
q_modelo 1 17 44 .txt	3	0.501417
q_modelo 1 18 39 .txt	4	0.627704
q_modelo 1 19 35 .txt	4	0.509849
q_modelo 1 2 50 .txt	2	0.500000
q_modelo 1 20 44 .txt	4	0.607114
q_modelo 1 21 40 .txt	4	0.672936
q_modelo 1 22 48 .txt	4	0.523752
q_modelo 1 23 41 .txt	2	0.500000
q_modelo 1 24 27 .txt	4	0.506483
q_modelo 1 25 27 .txt	4	0.514467
q_modelo 1 26 46 .txt	4	0.524399
q_modelo 1 27 44 .txt	2	0.500000
q_modelo 1 28 43 .txt	4	0.540542
q_modelo 1 29 54 .txt	2	0.500000
q_modelo 1 3 27 .txt	4	0.526535
q_modelo 1 30 41 .txt	2	0.500000
q_modelo 1 31 48 .txt	3	0.501357
q_modelo 1 32 45 .txt	4	0.588084
q_modelo 1 33 40 .txt	4	0.555611
q_modelo 1 34 40 .txt	2	0.500000

Node	Module
R1	2
C1	5
C5	0
C7	1
C8	4
C13	4
C16	2
C17	2
C19	2
C22	0
C23	2
C24	0
C25	2
C28	1
C29	0
C33	0
C39	5
C44	5
C46	2
C47	2
R2	0
C18	0
C26	0
R3	2
C9	3
C12	1
C30	2
C31	4

Package 'rnetcarto'

November 12, 2015

Type Package

Title Fast Network Modularity and Roles Computation by Simulated Annealing (Rgraph C Library Wrapper for R)

Version 0.2.4

Date 2015-11-11

Maintainer Guilhem Doulcier <guilhem.doulcier@ens.fr>

Description It provides functions to compute the modularity and modularity-related roles in networks. It is a wrapper around the rgraph library (Guimera & Amaral, 2005, doi:10.1038/nature03288).

Package 'rnetcarto'

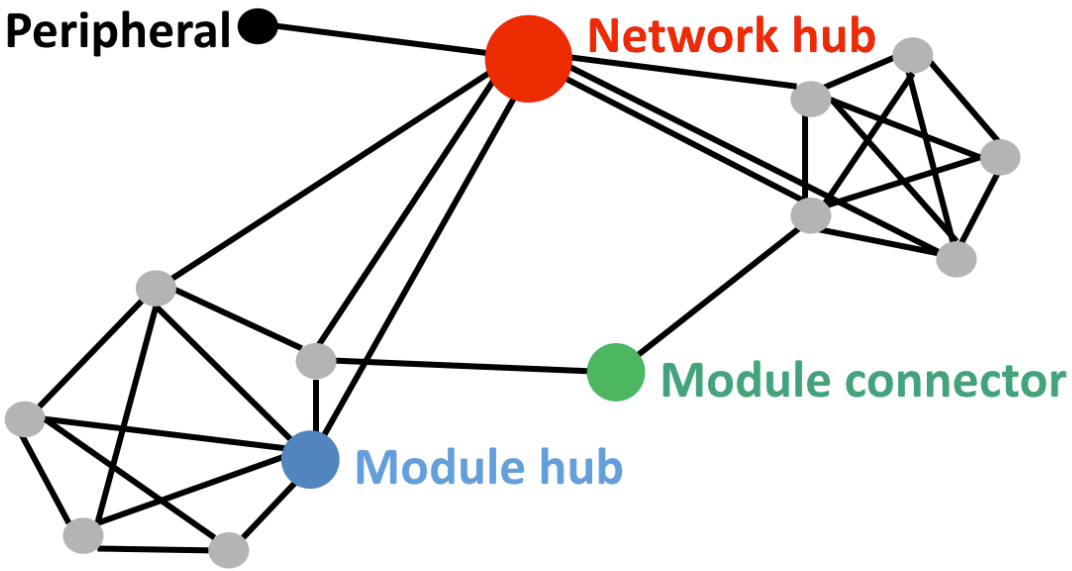
```
## [[1]]
##   name module connectivity participation            role
## 8    h      0   -1.4142136     0.0000000 Ultra peripheral
## 5    d      0    0.7071068     0.0000000 Ultra peripheral
## 4    c      0    0.7071068     0.6400000        Connector
## 2    b      1   -0.7071068     0.5000000       Peripheral
## 6    f      1   -0.7071068     0.6666667        Connector
## 9    i      1    1.4142136     0.0000000 Ultra peripheral
## 1    a      2   -0.7071068     0.0000000 Ultra peripheral
## 7    g      2   -0.7071068     0.5000000       Peripheral
## 3    b      2    1.4142136     0.4444444       Peripheral
##
## [[2]]
## [1] 0.2024793
```

Functional cartography of complex metabolic networks

Roger Guimerà and **Luís A. Nunes Amaral**
NICO and Department of Chemical and Biological Engineering, Northwestern University, Evanston, Illinois 60208, USA

The modularity of pollination networks

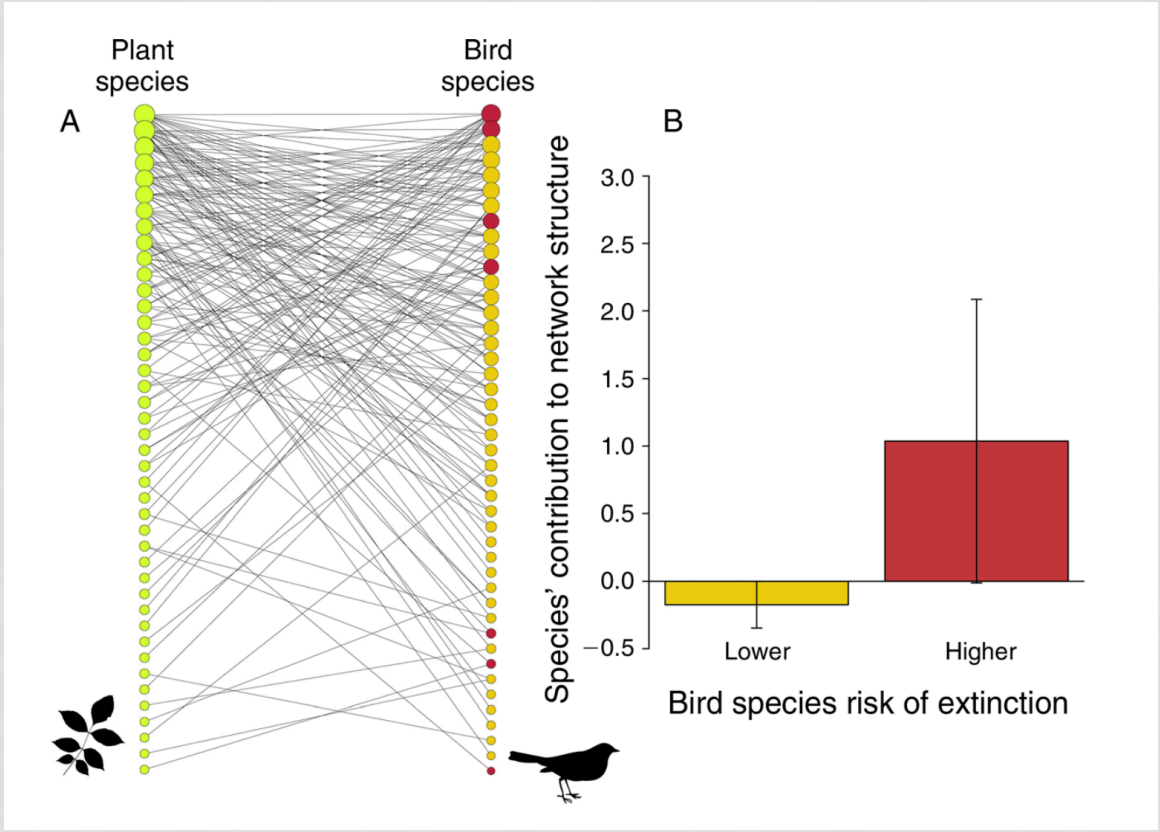
Jens M. Olesen*†, Jordi Bascompte‡, Yoko L. Dupont*, and Pedro Jordano‡



Ecology, 95(12), 2014, pp. 3440–3447

Frugivores at higher risk of extinction are the key elements of a mutualistic network

Mariana M. Vidal,[1] Erica Hasui,[2] Marco A. Pizo,[3] Jorge Y. Tamashiro,[4] Wesley R. Silva,[5] and Paulo R. Guimarães, Jr.[1,6]

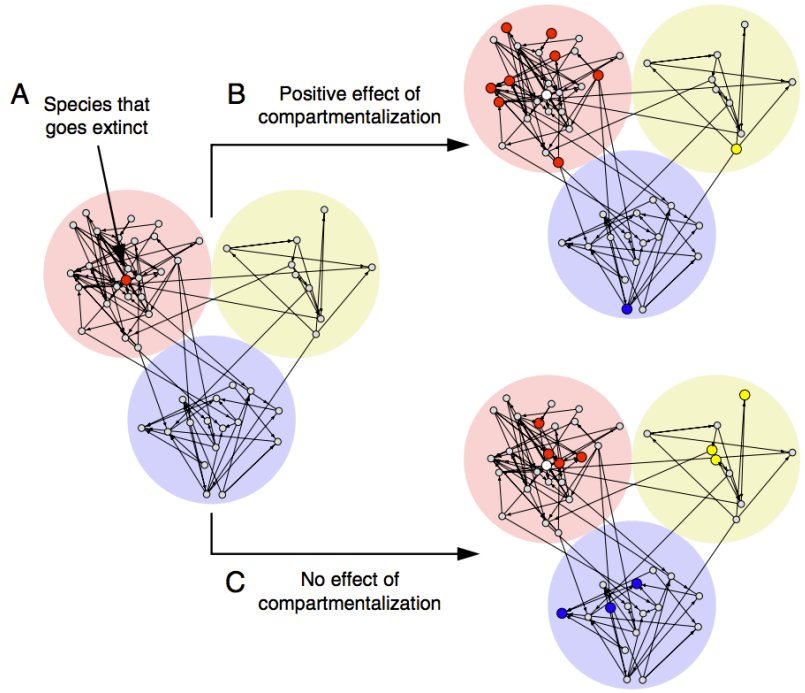


Strong contributors to network persistence are the most vulnerable to extinction

Serguei Saavedra[1,2,3]*, Daniel B. Stouffer[4,5]*, Brian Uzzi[1,2] & Jordi Bascompte[4]

Compartmentalization increases food-web persistence

Daniel B. Stouffer[1] and Jordi Bascompte



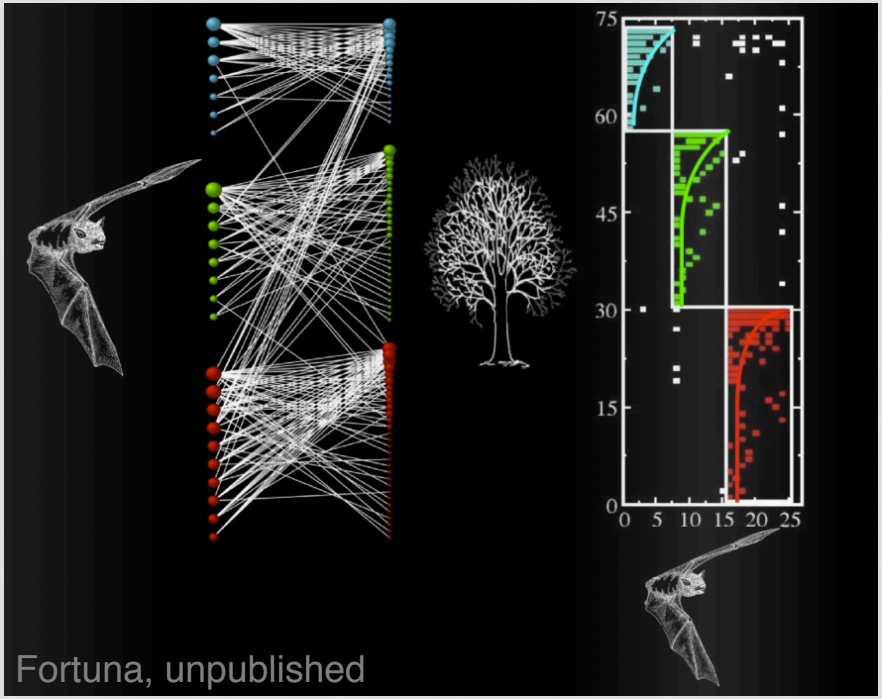
Journal of Animal Ecology

British Ecological Society

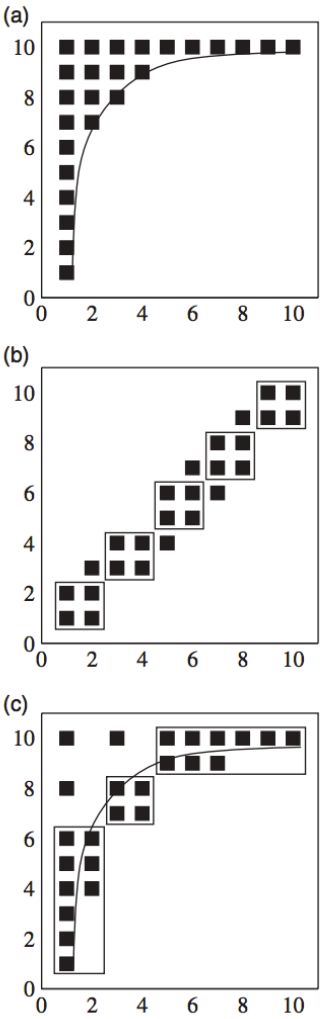
Journal of Animal Ecology 2010, **79**, 811–817 doi: 10.1111/j.1365-2656.2010.01688.x

Nestedness versus modularity in ecological networks: two sides of the same coin?

Miguel A. Fortuna[1]*, Daniel B. Stouffer[1], Jens M. Olesen[2], Pedro Jordano[1], David Mouillot[3], Boris R. Krasnov[4], Robert Poulin[5] and Jordi Bascompte[1]



Fortuna, unpublished



Plant-Seed Disperser

Network	Size	Connectance	Nestedness	Modularity
1	28	0.085	* 0.763	0.311
2	58	0.106	** 0.944	0.312
3	78	0.026	** 0.842	0.308
4	26	0.264	* 0.847	0.121

Plant-Pollinator

Network	Size	Connectance	Nestedness	Modularity
23	61	0.090	** 0.925 *	0.591 **
24	185	0.043	** 0.960	0.516 **
25	107	0.071	** 0.907	0.519 **
26	90	0.098	** 0.811 *	** 0.569 **

Host-Parasite

Network	Size	Connectance	Nestedness	Modularity
57	35	0.247	** 0.819	** 0.516 **
58	36	0.384	** 0.662	0.268
59	45	0.217	** 0.783	** 0.437 **
60	46	0.191	** 0.749	0.312

Fortuna et al. 2010