# What types of networks in ecology?

Part I: Sonia Kéfi

FRB
FONDATION POUR LA RECHERCHE SUR LA BIODIVERSITÉ

CESAB
CENTRE FOR THE SYNTHESIS AND ANALYSIS OF BIODIVERSITY

# Why ecological networks?

"Méditerranée, une mer sous surveillance." 2017. Andromède océanologie/ Agence de l'eau Rhône Méditerranée Corse

# A relatively young science

Alexander von Humboldt
1859: Charles Darwin
1866: Ernst Haeckel
1905: Frederic Clements

# Q1: Why do species coexist?

# Gause (1932)

# The paradox of the plankton

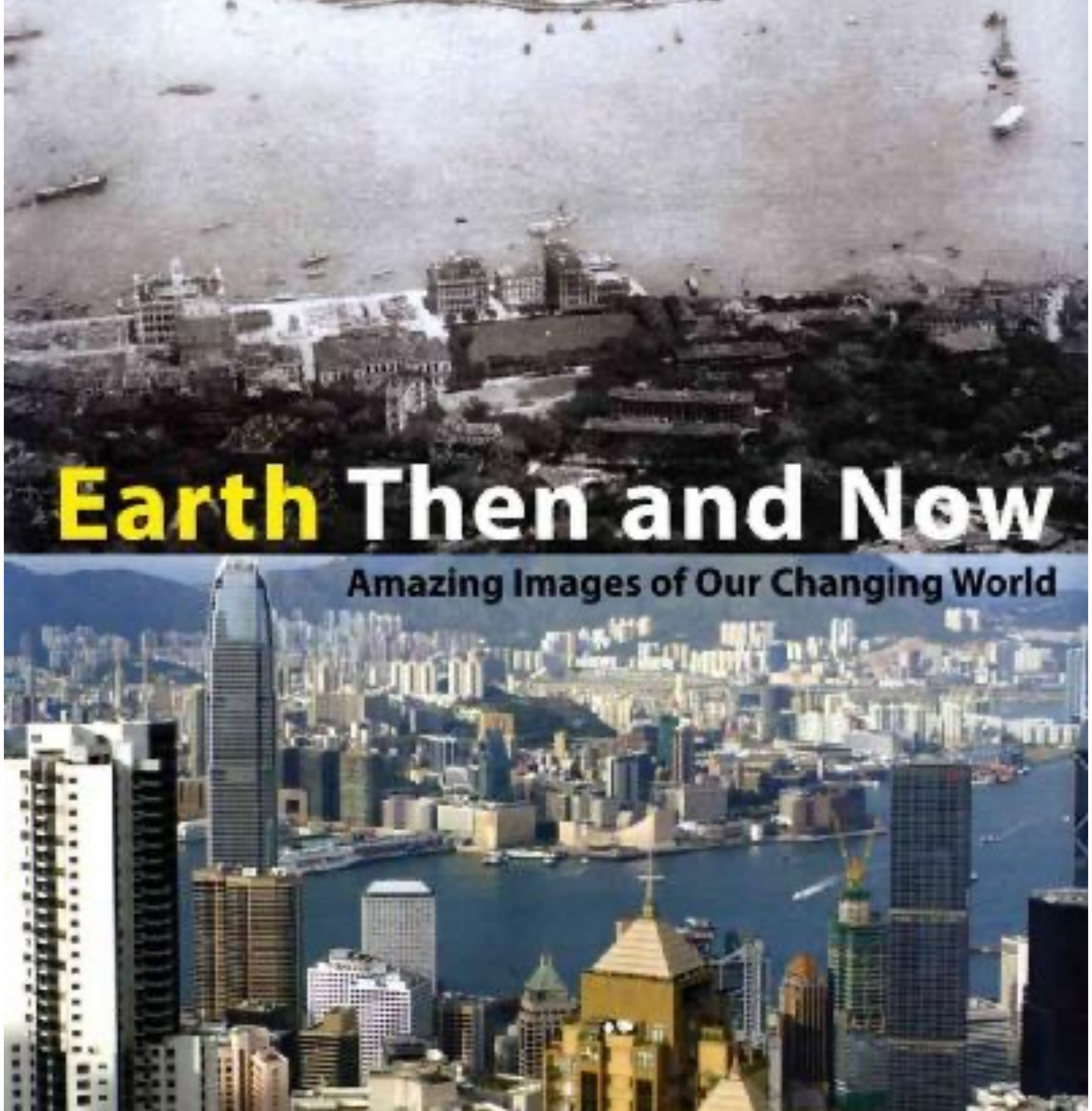
Hutchinson (1961)

# Q1 (bis): Why and how do so many species coexist?

# “The silent spring”

RACHEL CARSON, 1962

# A context of global change


Earth Then and Now
Amazing Images of Our Changing World


**NEWS** • 06 MAY 2019 • UPDATE 06 MAY 2019

# Humans are driving one million species to extinction

*Landmark United Nations-backed report finds that agriculture is one of the biggest threats to Earth's ecosystems.*

http://www.picturenation.co.uk/

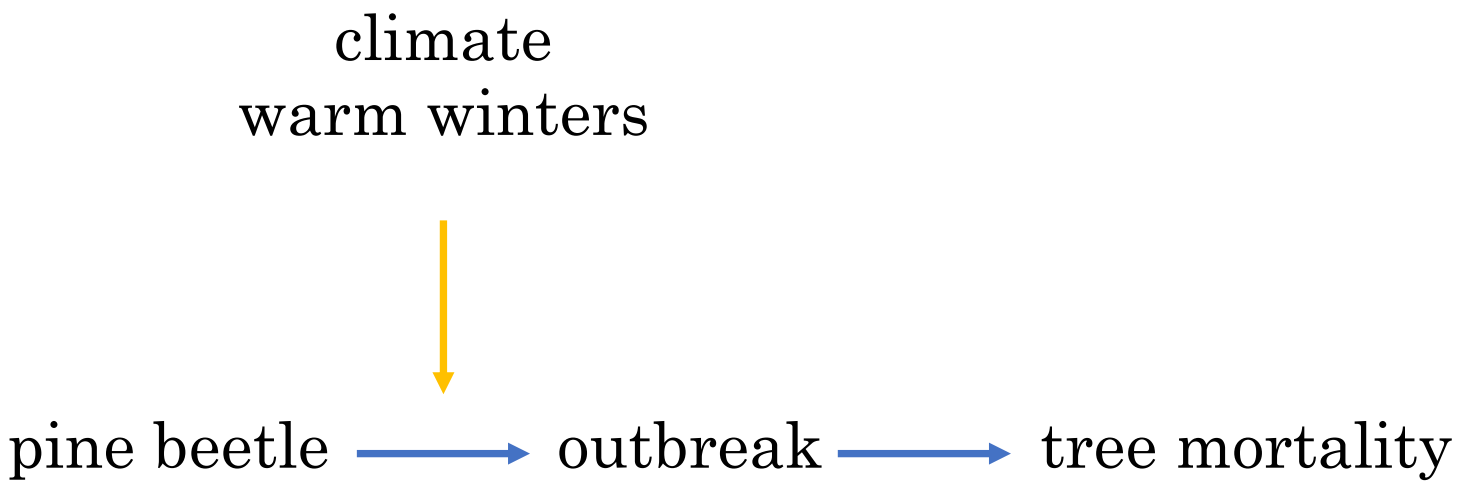
# Q2: What are the factors that contribute to the stability of ecological communities?

# A world of interconnections

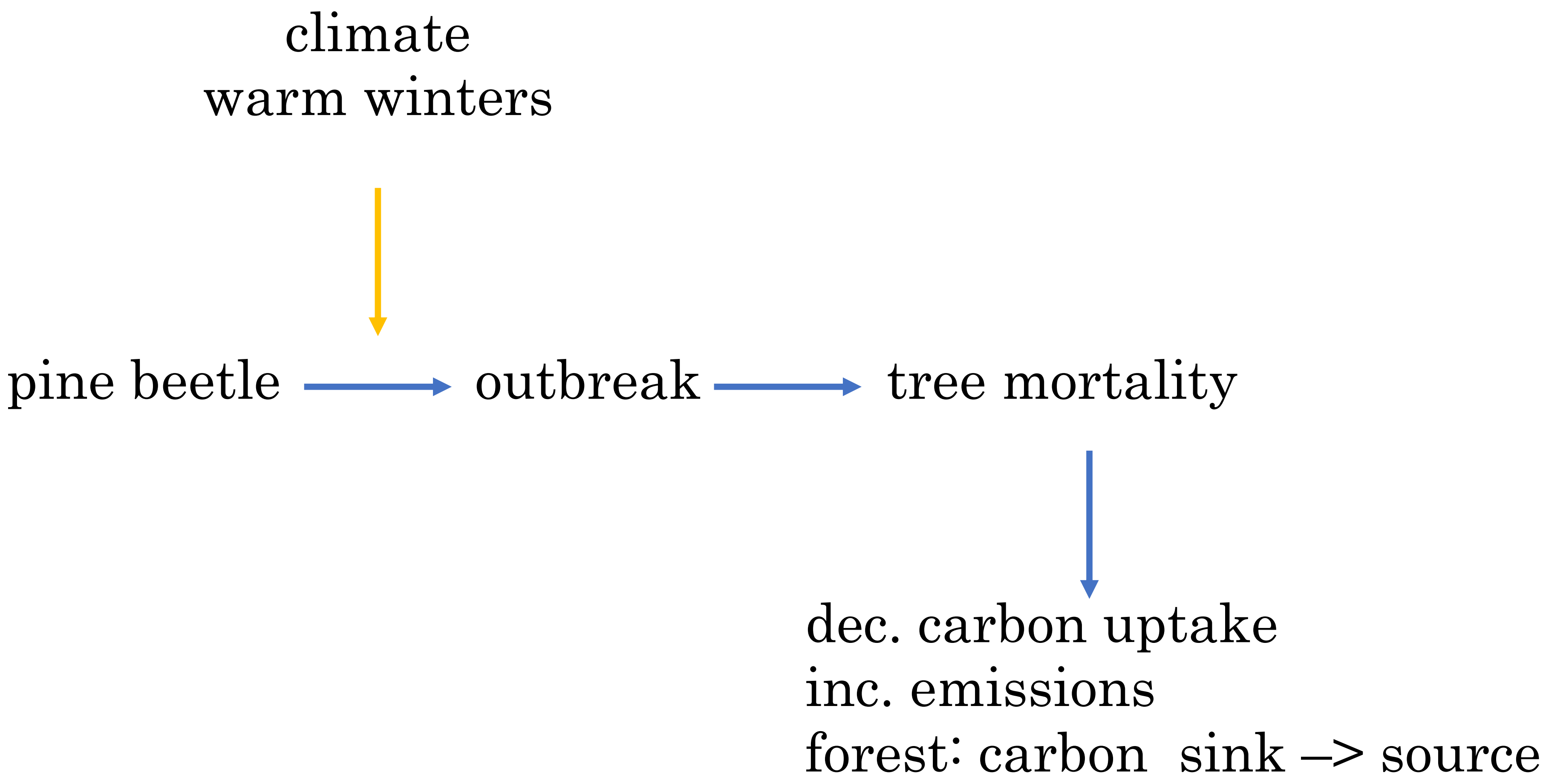
Mountain pine beetle

https://www.nationalgeographic.com/video/shorts/1187972675527/

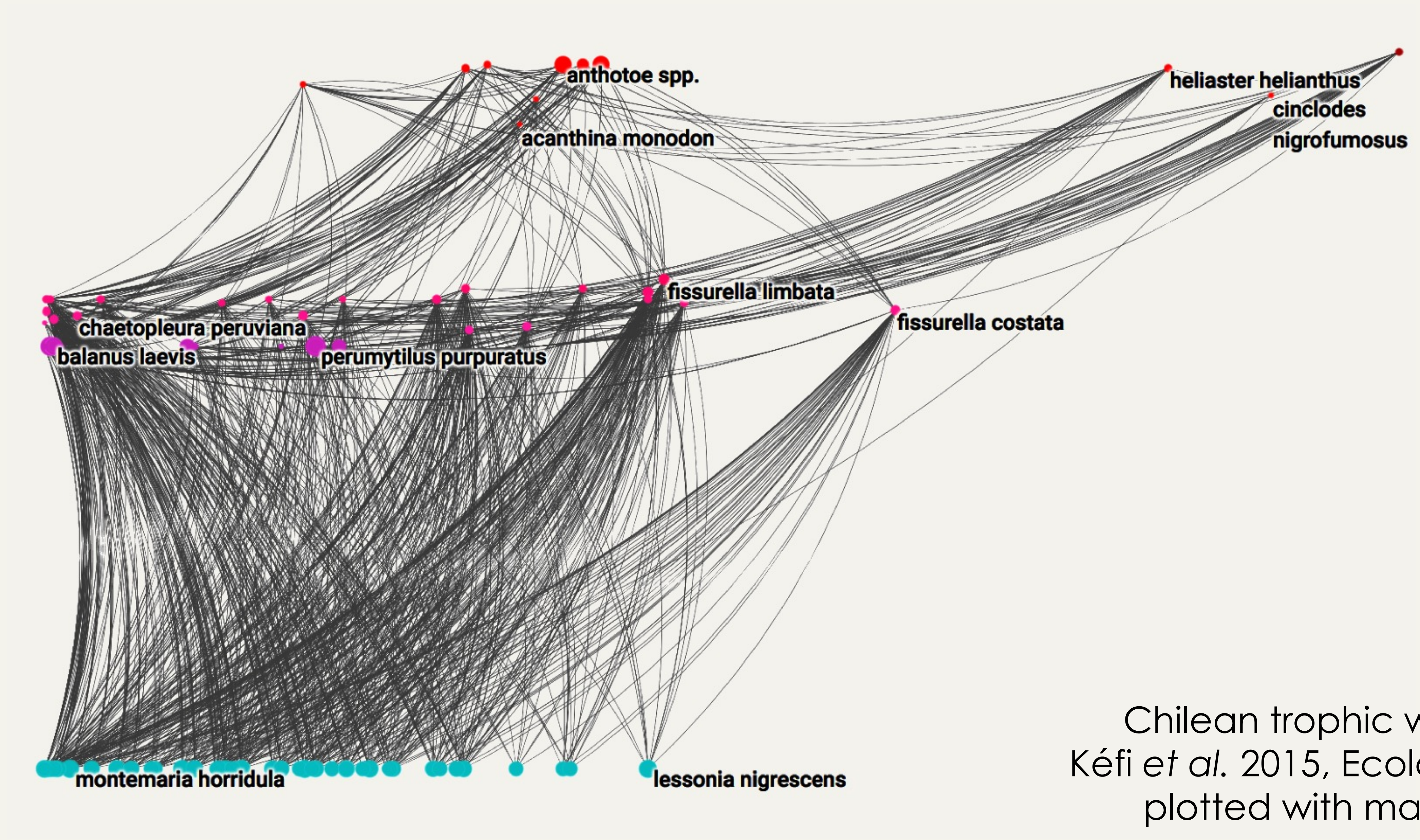
Kurtz et al. 2008 Nature




Kurtz et al. 2008 Nature




Kurtz et al. 2008 Nature

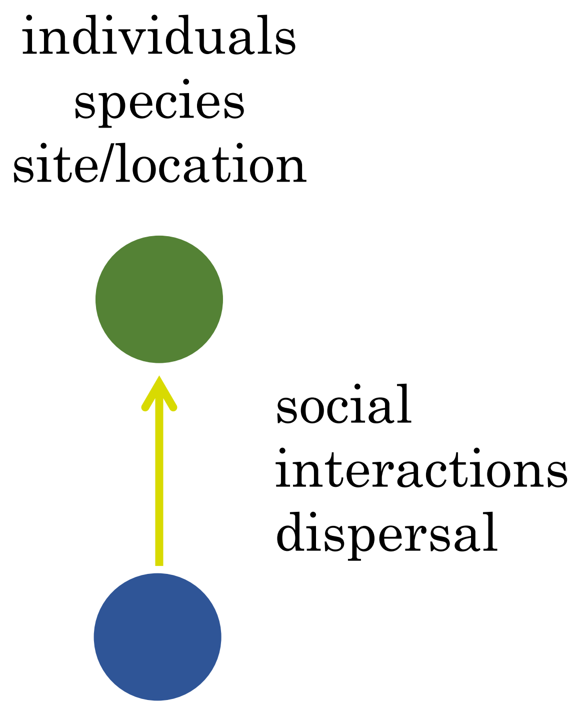



Chilean trophic web
Kéfi *et al.* 2015, Ecology
plotted with mappr

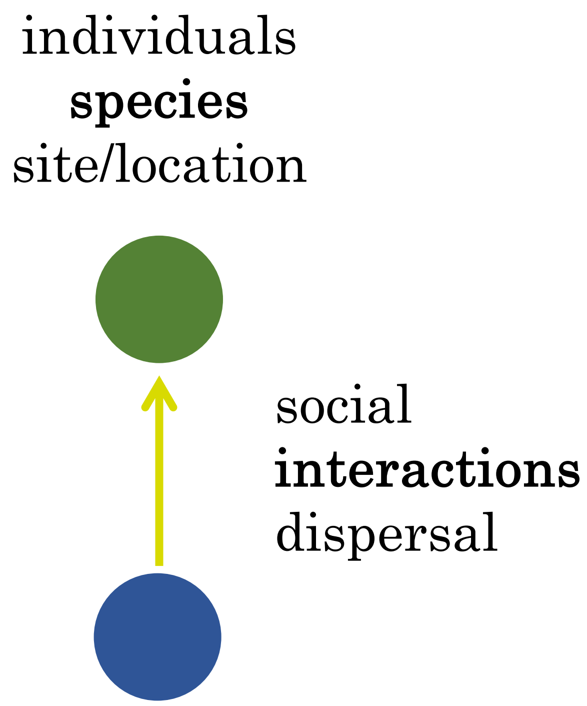
# Ecological networks

# Part I
# What are ecological networks?
# (what types of networks are there in ecology?)

# Ecological networks

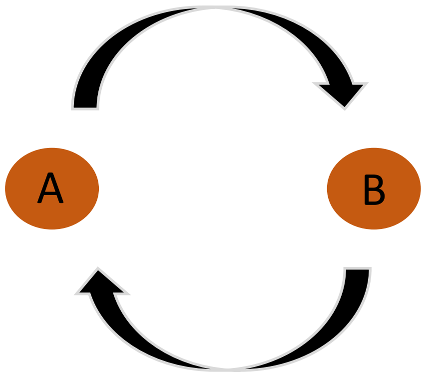


# Interaction networks



# Interaction networks

Effect of A on B

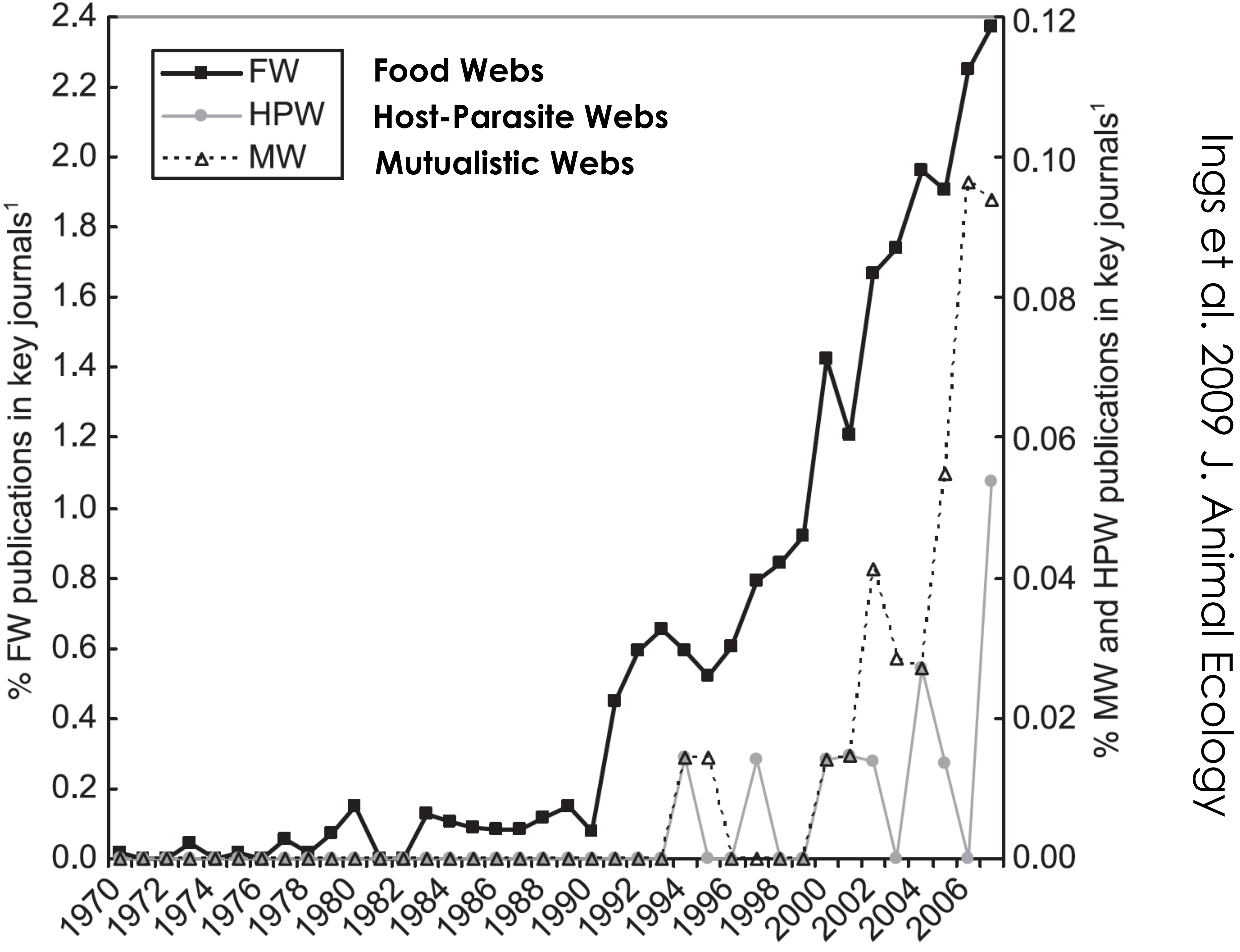



Effect of B on A

Effect of A on B

Effect of B on A

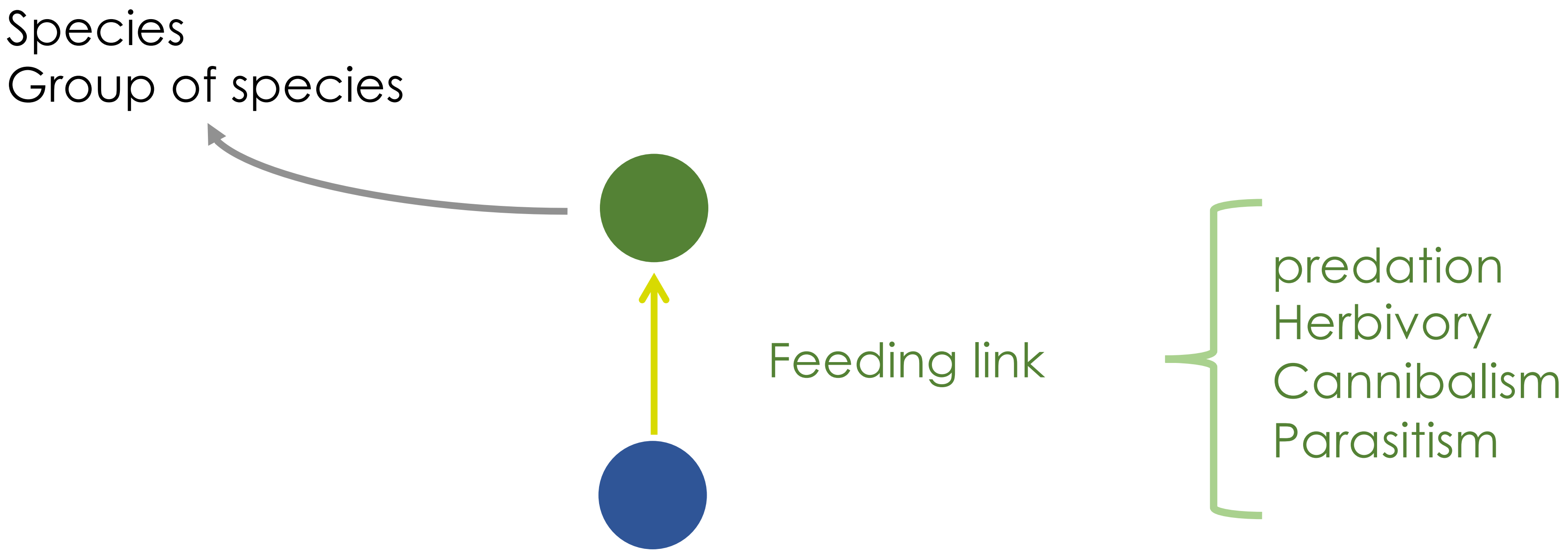
| | - | 0 | + |
|---|---|---|---|
| **-** | competition | amensalism | **predation** |
| **0** | | - | commensalism |
| **+** | | | Mutualism |



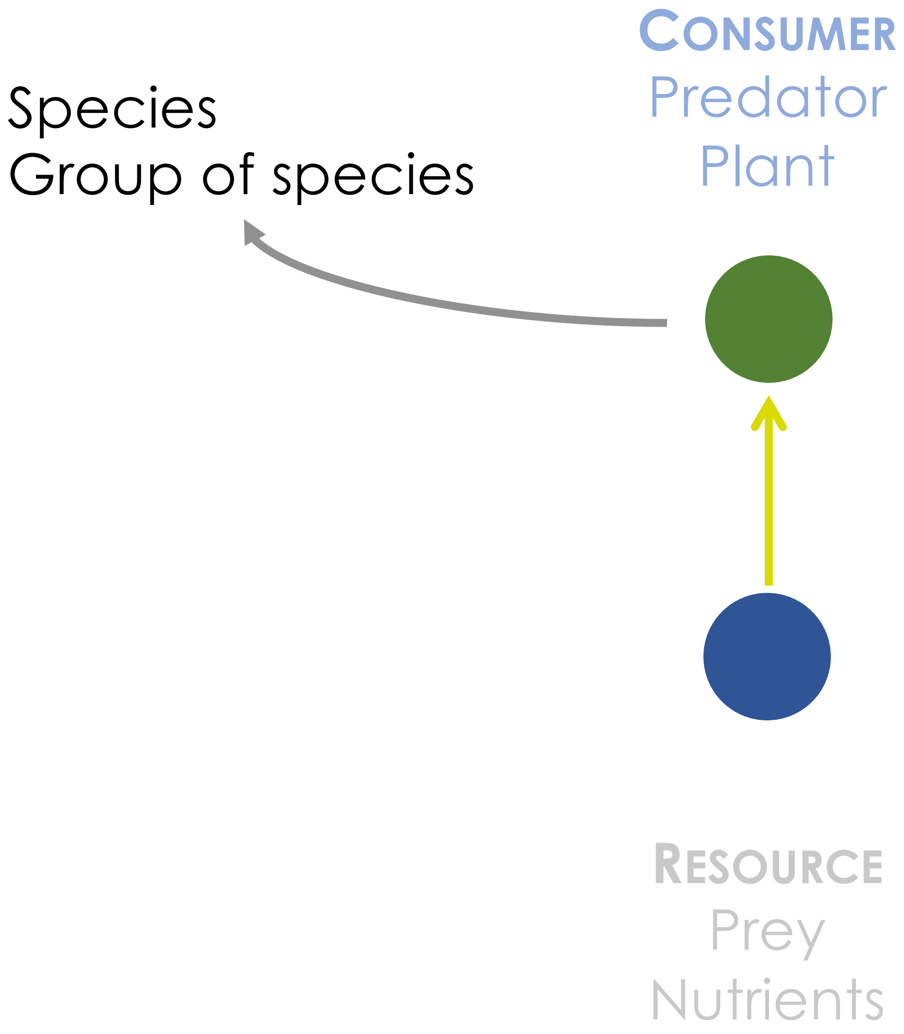
FW
HPW
MW
Food Webs
Host-Parasite Webs
Mutualistic Webs
% FW publications in key journals[1]
% MW and HPW publications in key journals[1]
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Ings et al. 2009 J. Animal Ecology

# Food Webs

Pimm 1982
Cohen et al. 1993
De Ruiter et al. 1995
Brose et al. 2005, 2006
Neutel et al. 2007

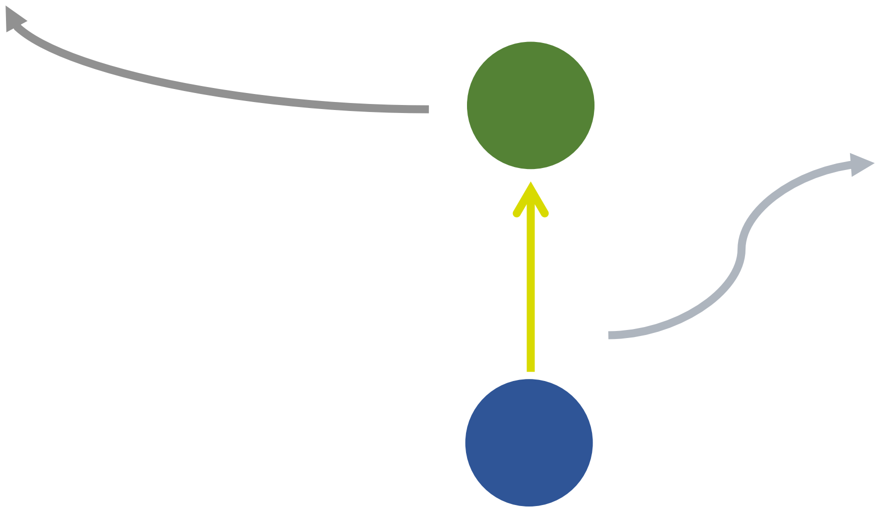



Berlow et al. 2004 J. Ecol.




Berlow et al. 2004 J. Ecol.

Species
Group of species



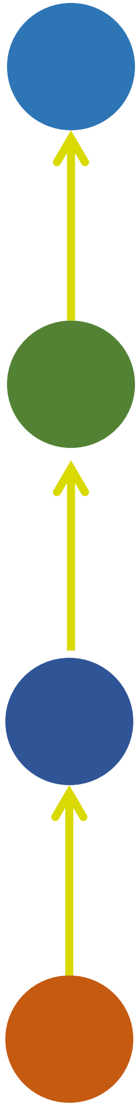
**interaction strength**

- Binary
- interaction frequency
- Biomass flux
- Relative prey preference
- Consumption rate
- Elements of the Jacobian matrix

Berlow et al. 2004 J. Ecol.

Trophic position:

$$TP = 1 + mean\ TP\ of\ prey$$

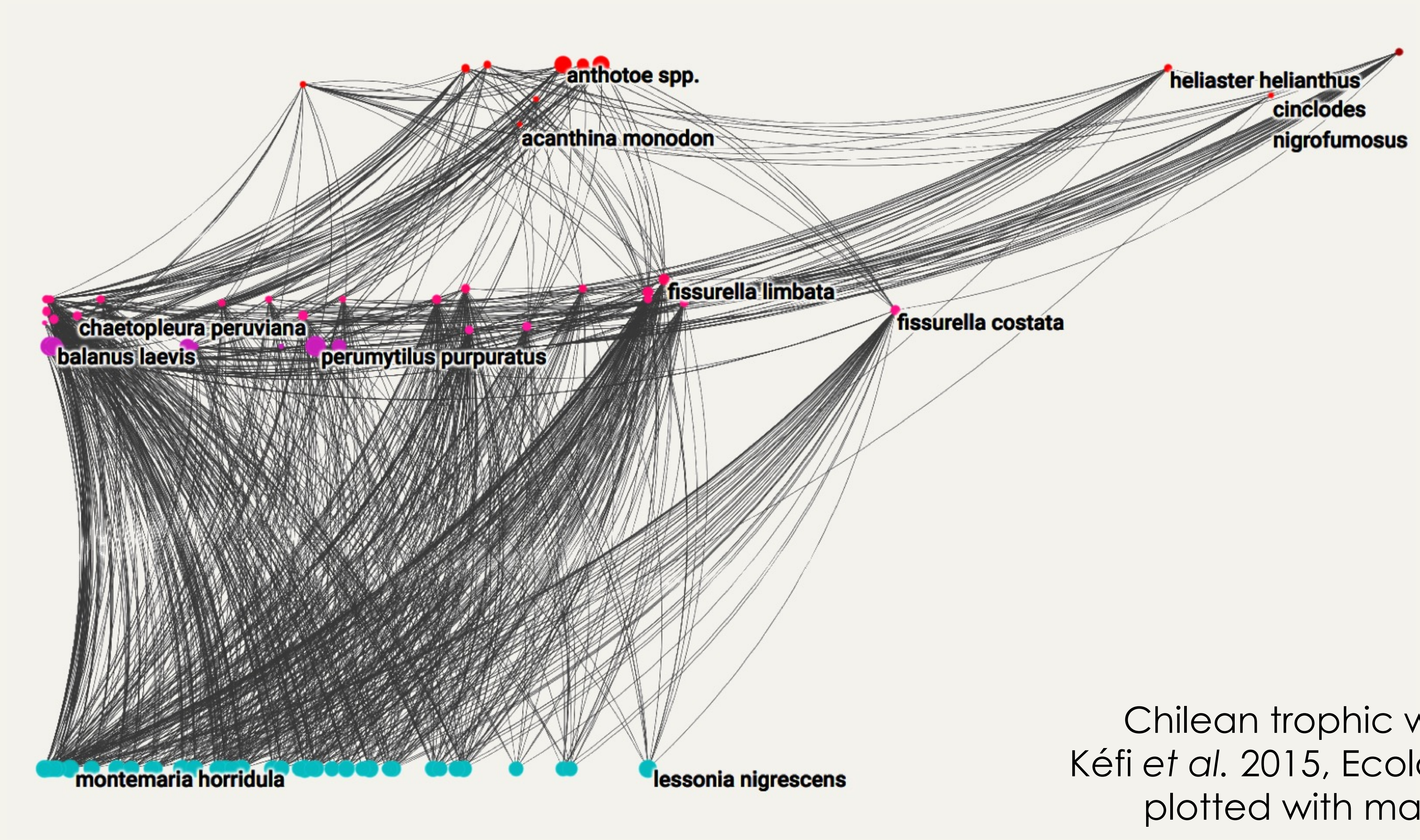


**Top predator**
Carnivores

**Intermediate species**
Secondary consumer
Carnivores, insect parasitoids

**Intermediate species**
Primary consumer
Herbivores

**Basal species**
Primary producers
Plants




Chilean trophic web
Kéfi *et al.* 2015, Ecology
plotted with mappr

1800
1927 Food chain (Elton)
1977 First collection of food webs (Cohen)
1986 113-web catalog (Cohen)
1991 Higher resolution data (Polis, Martinez)
…

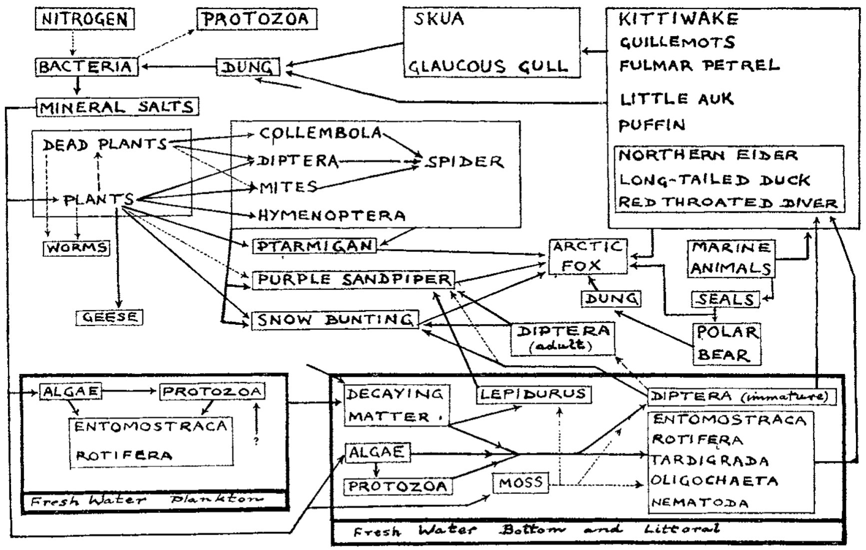
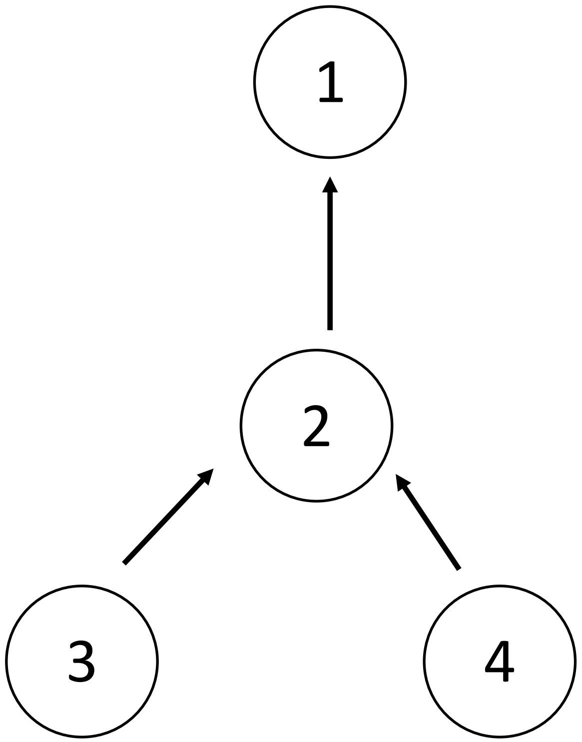
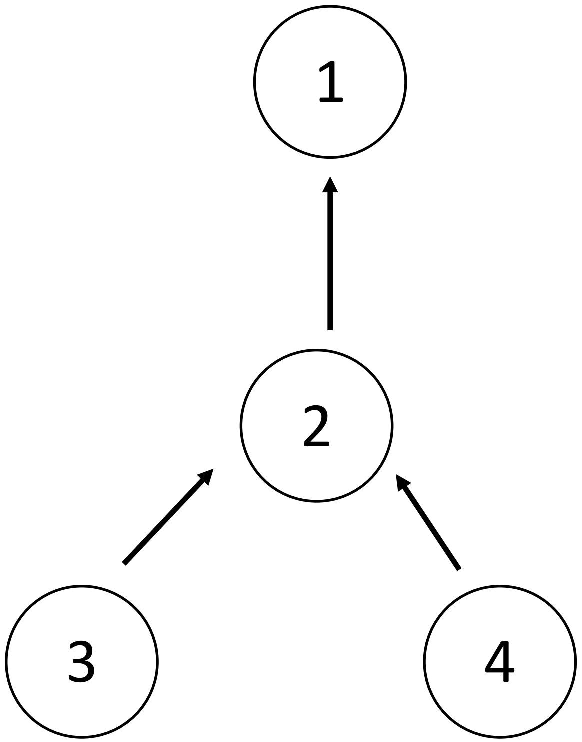



FIG. 2. Diagram of "Nitrogen Cycle" on Bear Island.
....... Probable, but no evidence from here.
----- Transformation.

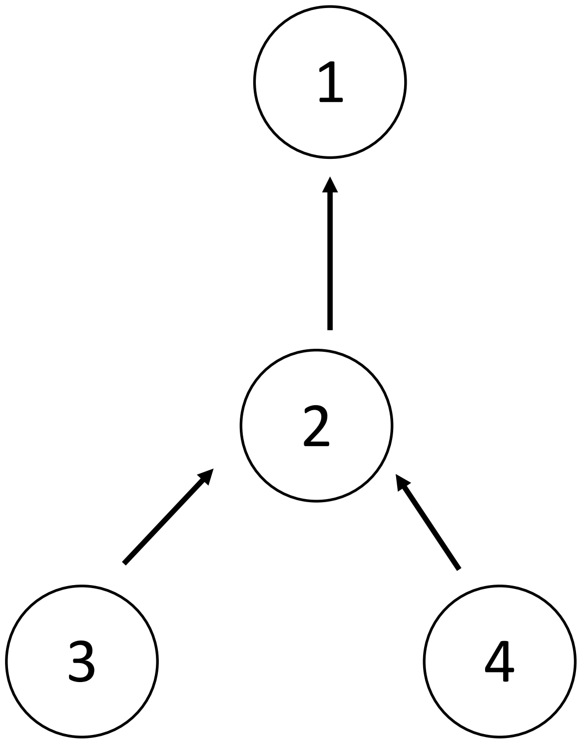
Summerhayes and Elton 1923


1
2
3
4

**interaction (=adjacency) matrix, A**




$A_{ij}$=1 if j affects i

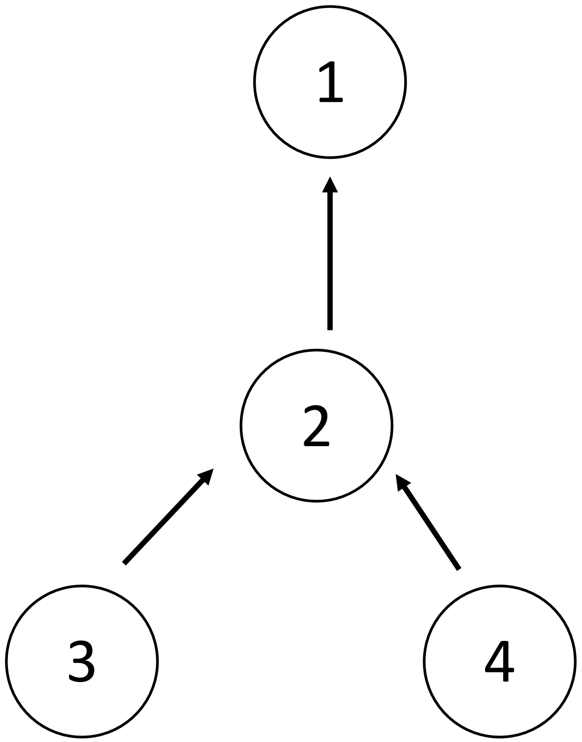



## interaction (=adjacency) matrix, A

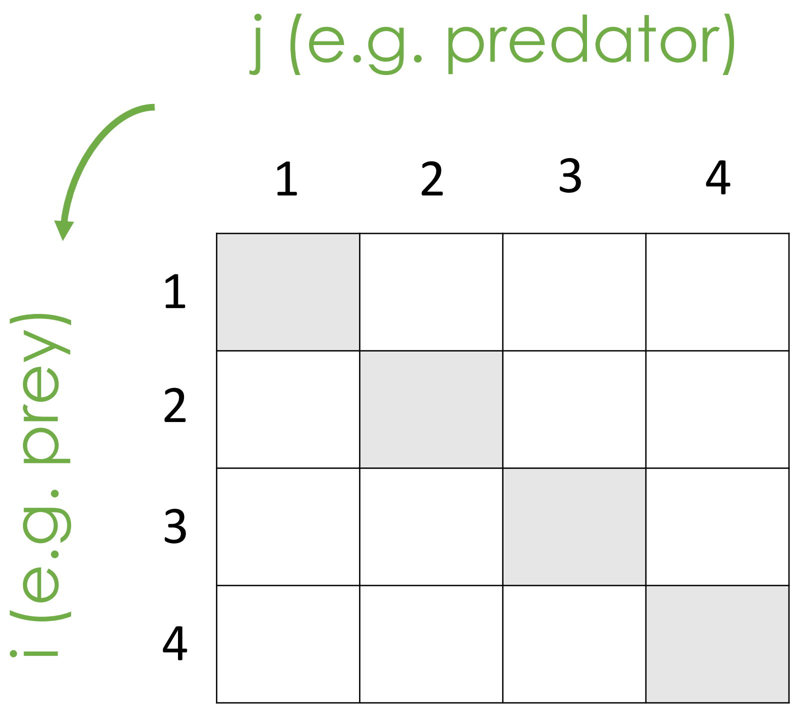
$A_{ij}$=1 if j affects i

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |

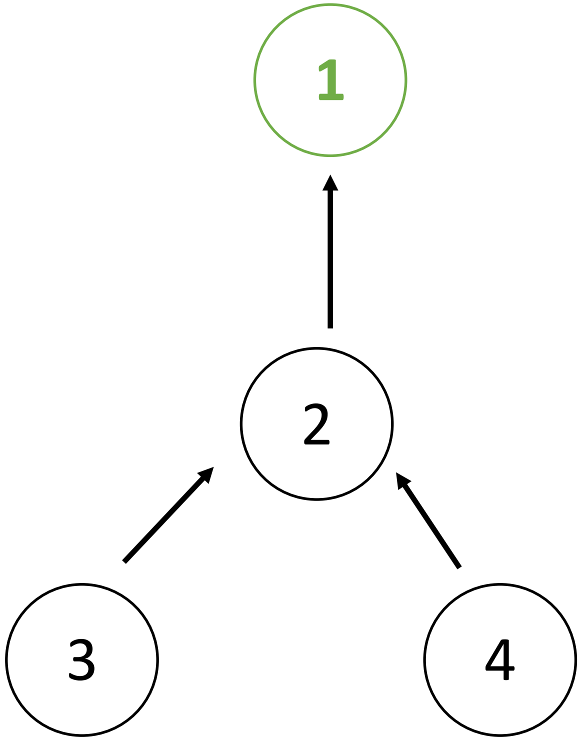
**interaction (=adjacency) matrix, A**




$A_{ij}$=1 if j affects i



## interaction (=adjacency) matrix, A



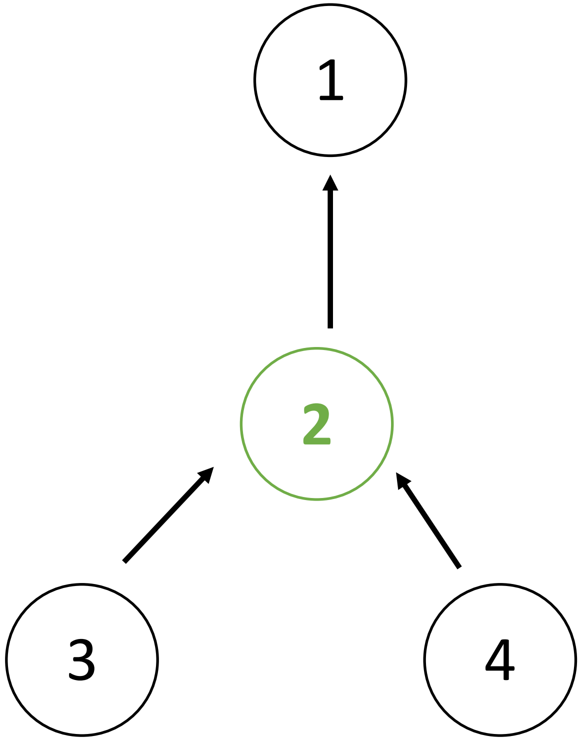

$A_{ij}=1$ if j affects i

j (e.g. predator)

i (e.g. prey)

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0 | | | |
| 2 | 1 | | | |
| 3 | 0 | | | |
| 4 | 0 | | | |

## interaction (=adjacency) matrix, A

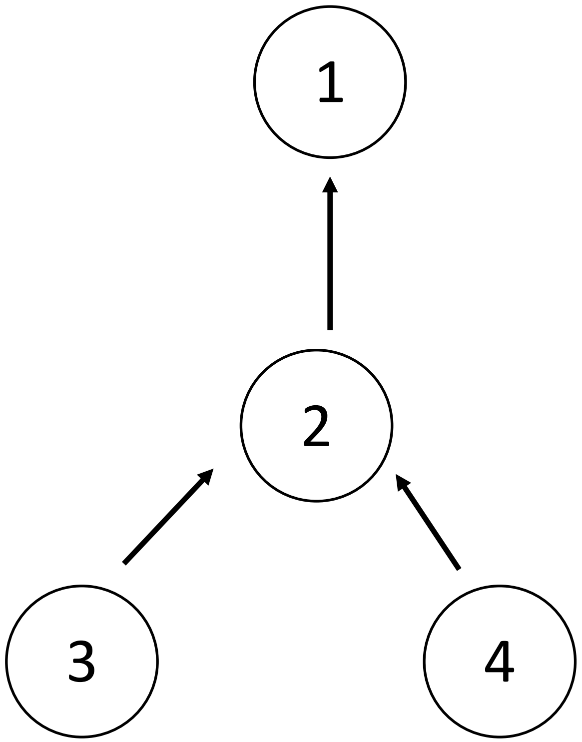



$A_{ij}=1$ if j affects i

j (e.g. predator)

i (e.g. prey)

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0 | 0 | | |
| 2 | 1 | 0 | | |
| 3 | 0 | 1 | | |
| 4 | 0 | 1 | | |




## interaction (=adjacency) matrix, A

$A_{ij}=1$ if j affects i

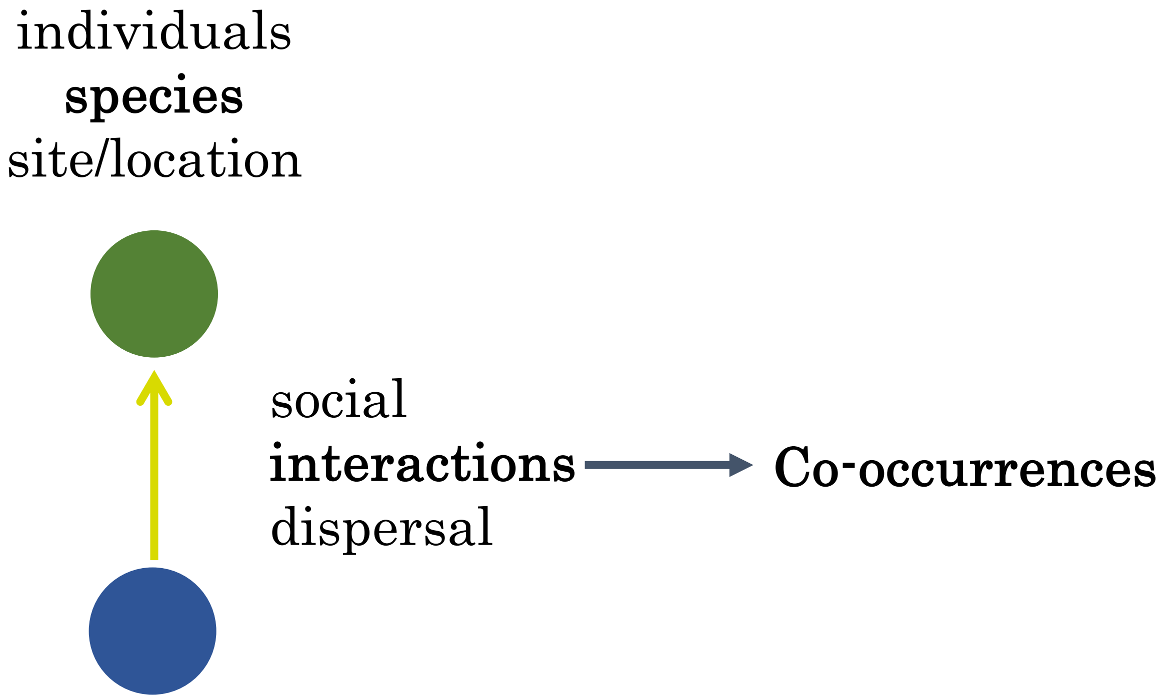
j (e.g. predator)

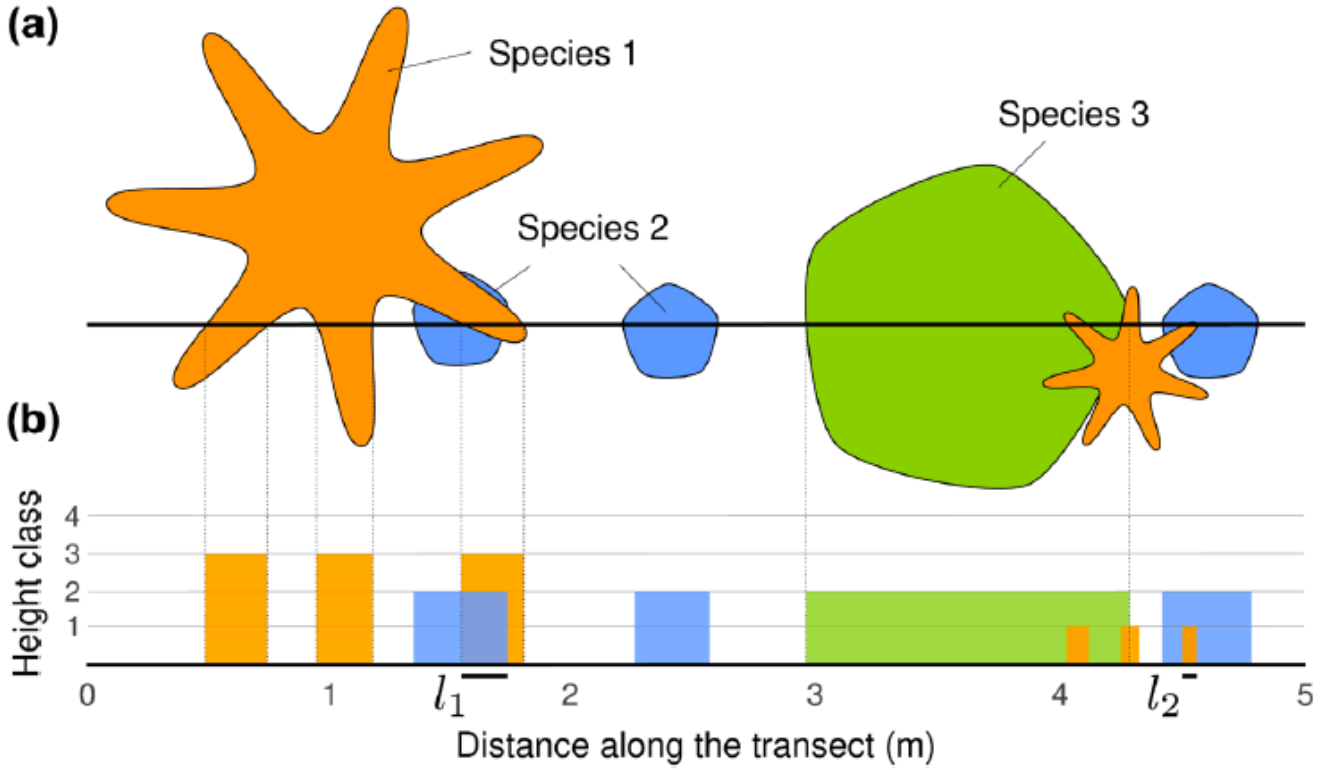
i (e.g. prey)

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 |
| 2 | 1 | 0 | 0 | 0 |
| 3 | 0 | 1 | 0 | 0 |
| 4 | 0 | 1 | 0 | 0 |

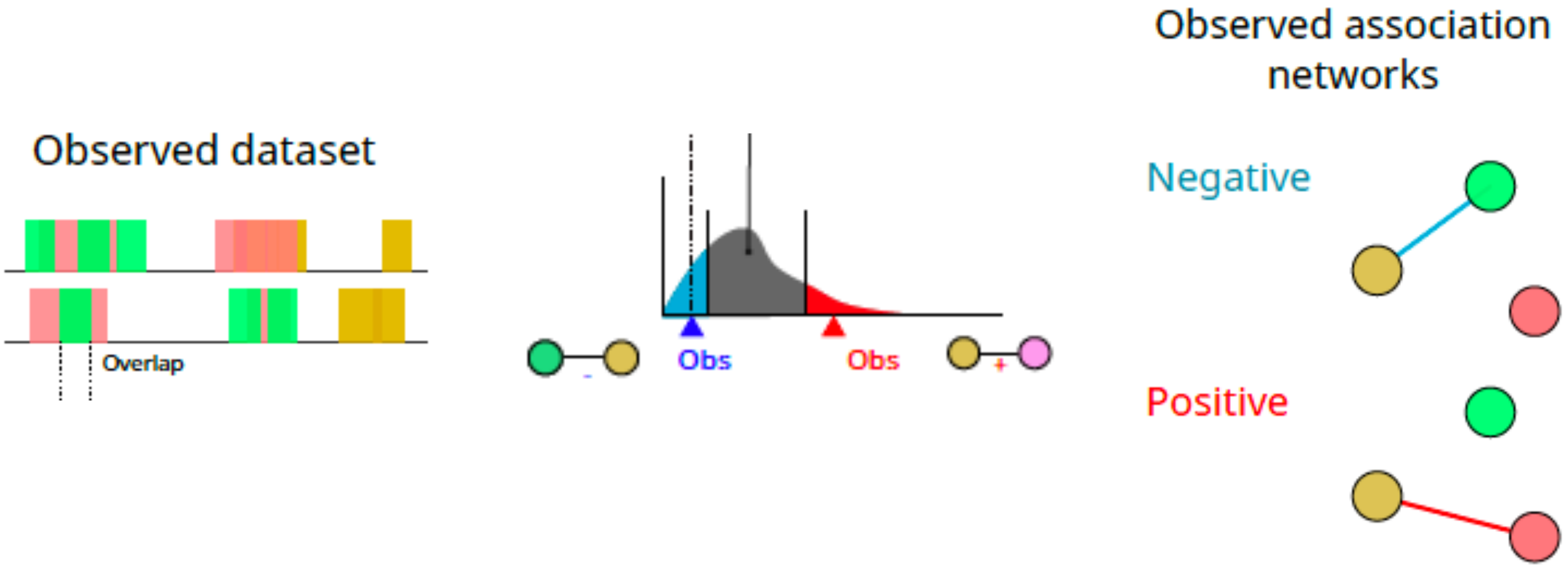
# Co-occurrence networks

# Co-occurrence networks



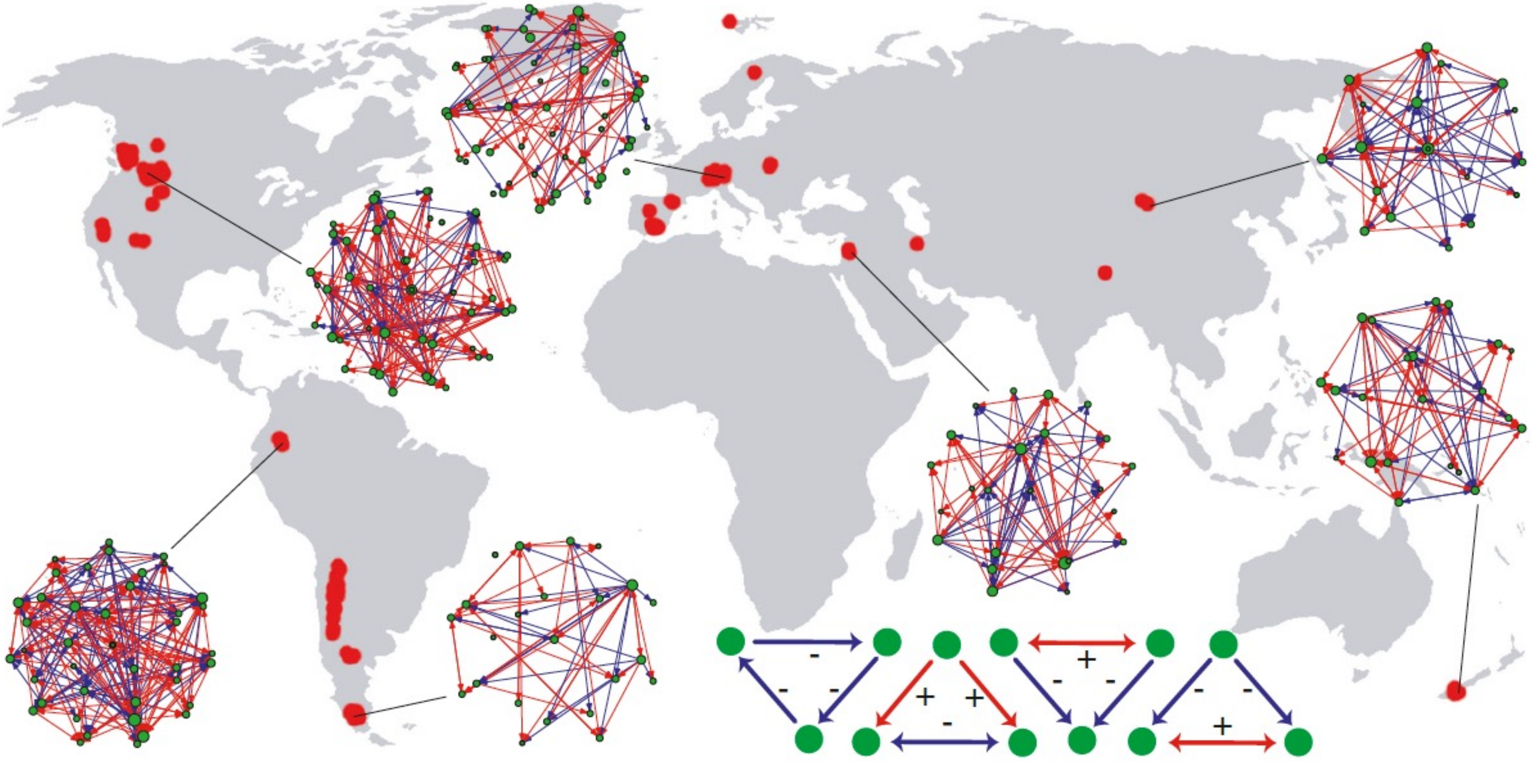


(a)
Species 1
Species 2
Species 3
(b)
Height class
4
3
2
1
0
1
$l_1$
2
3
4
$l_2$
5
Distance along the transect (m)


Observed dataset
Overlap
Obs
Obs
Observed association networks
Negative
Positive

# Network motifs involving both competition and facilitation predict biodiversity in alpine plant communities

Gianalberto Losapio[a,b,1], Christian Schöb[a,1], Phillip P. A. Staniczenko[c], Francesco Carrara[d], Gian Marco Palamara[e], Consuelo M. De Moraes[a], Mark C. Mescher[a], Rob W. Brooker[f], Bradley J. Butterfield[g], Ragan M. Callaway[h], Lohengrin A. Cavieres[i], Zaal Kikvidze[j], Christopher J. Lortie[k,l], Richard Michalet[m], Francisco I. Pugnaire[n], and Jordi Bascompte[o]

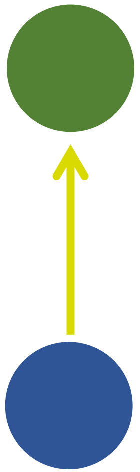



Losapio et al. 2021 PNAS

# Spatial networks

# Spatial networks

individuals
species
**site/location/habitat fragment** → Spatial coordinates
Size
Shape
Habitat quality



social
interactions
**connectivity** → distance
measure of similarity
(often bidirectional)

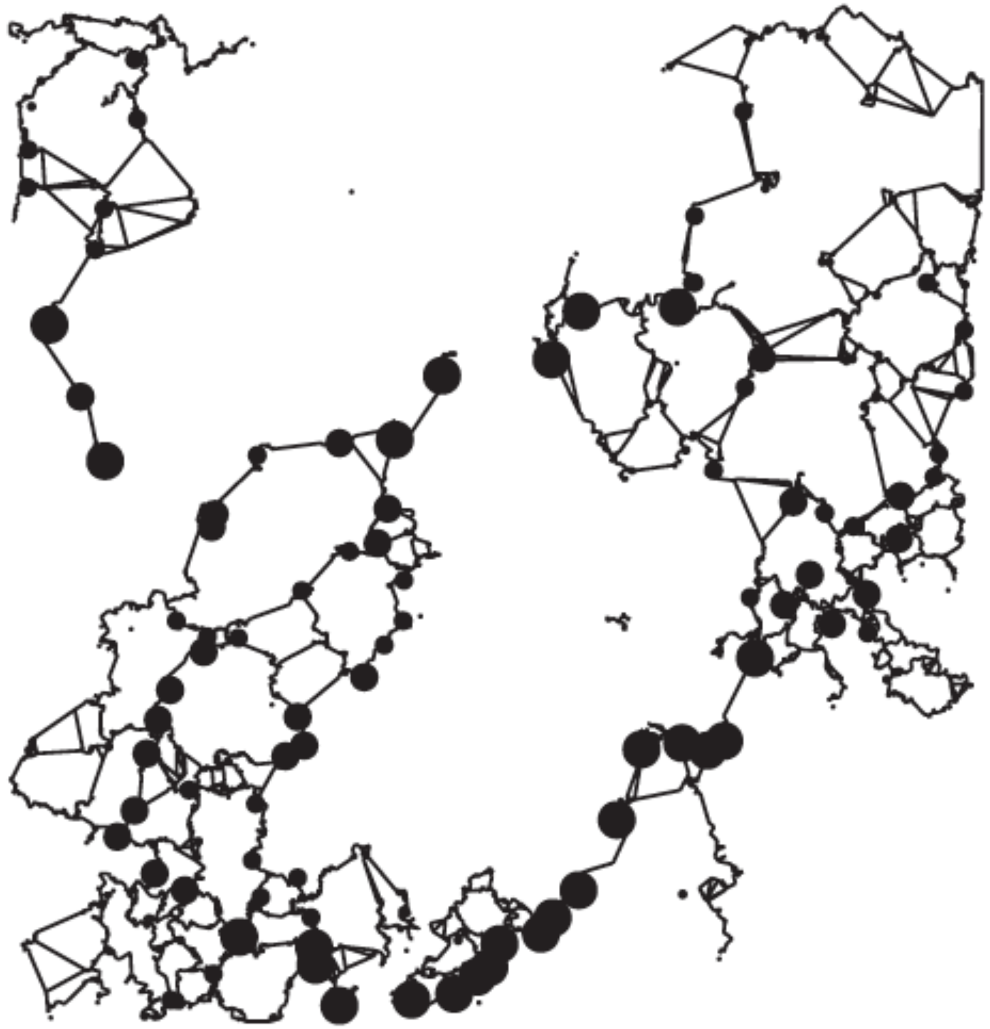
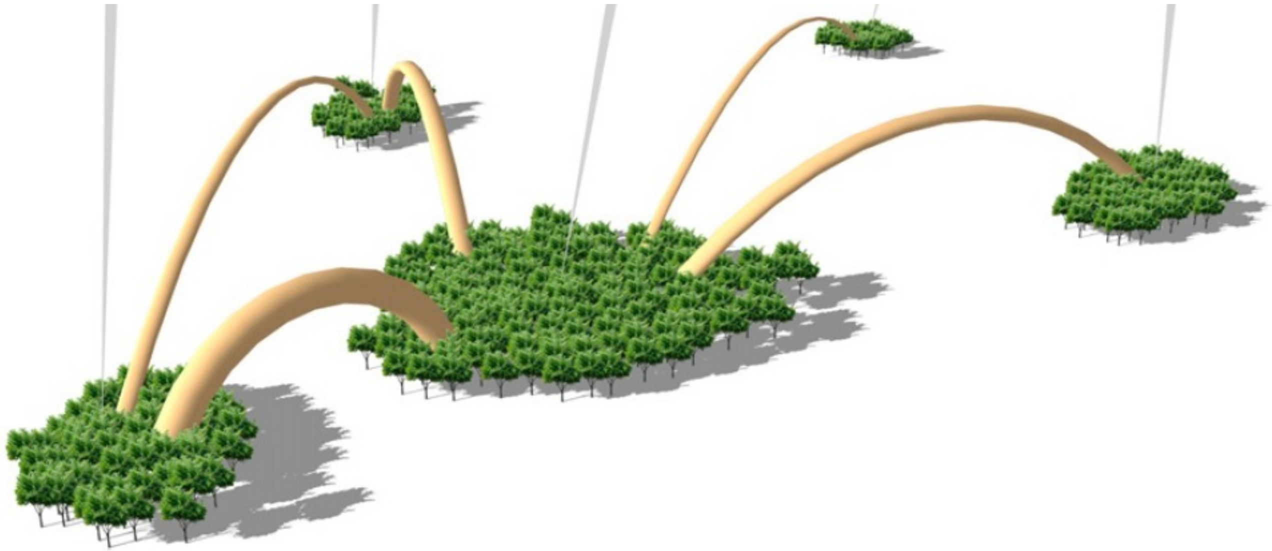
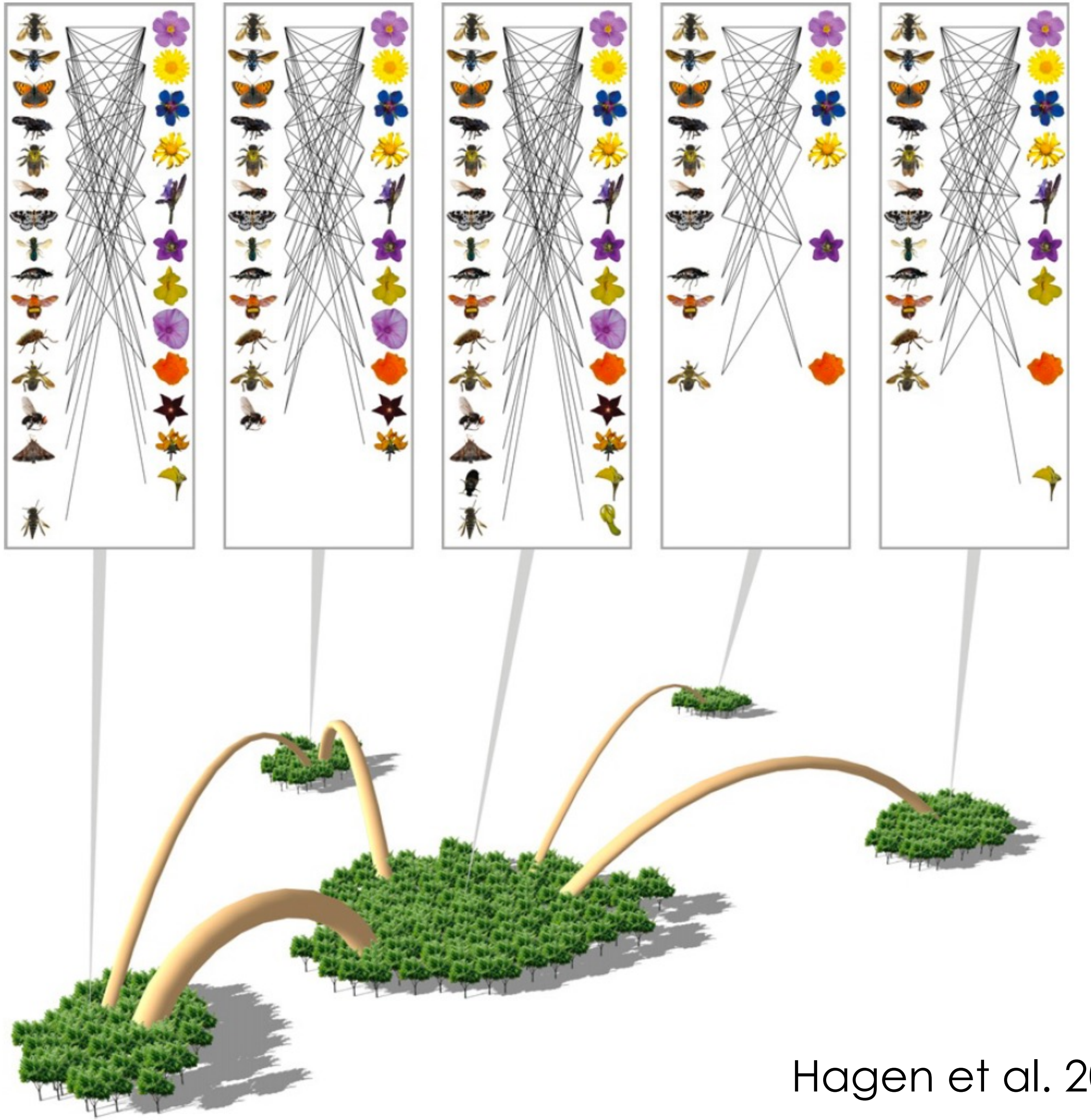


**Figure 4** A graph of forest habitat patches in the Piedmont of North Carolina, with nodes sized in proportion to their betweenness centrality. Larger nodes have higher centrality, and highlight the pattern of flow across the landscape (after Bodin & Norberg 2007).

Urban et al. 2009 Eco Lett



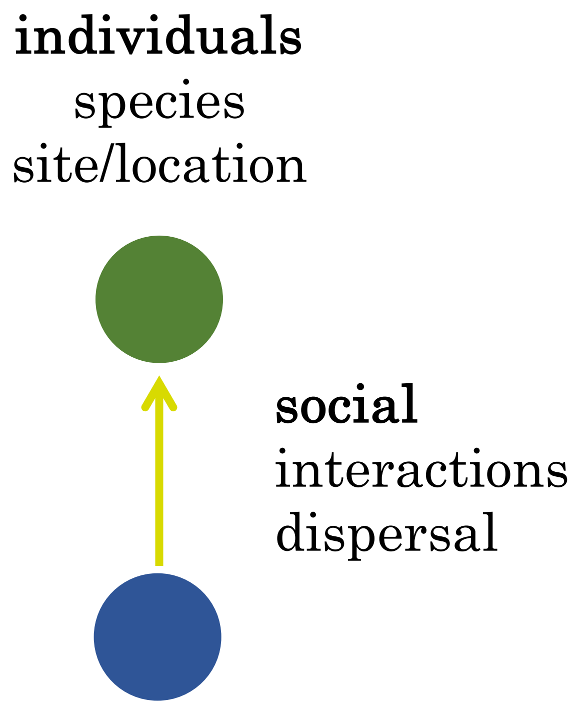
Hagen et al. 2012 Adv. Ecol. Res.



Hagen et al. 2012 Adv. Ecol. Res.

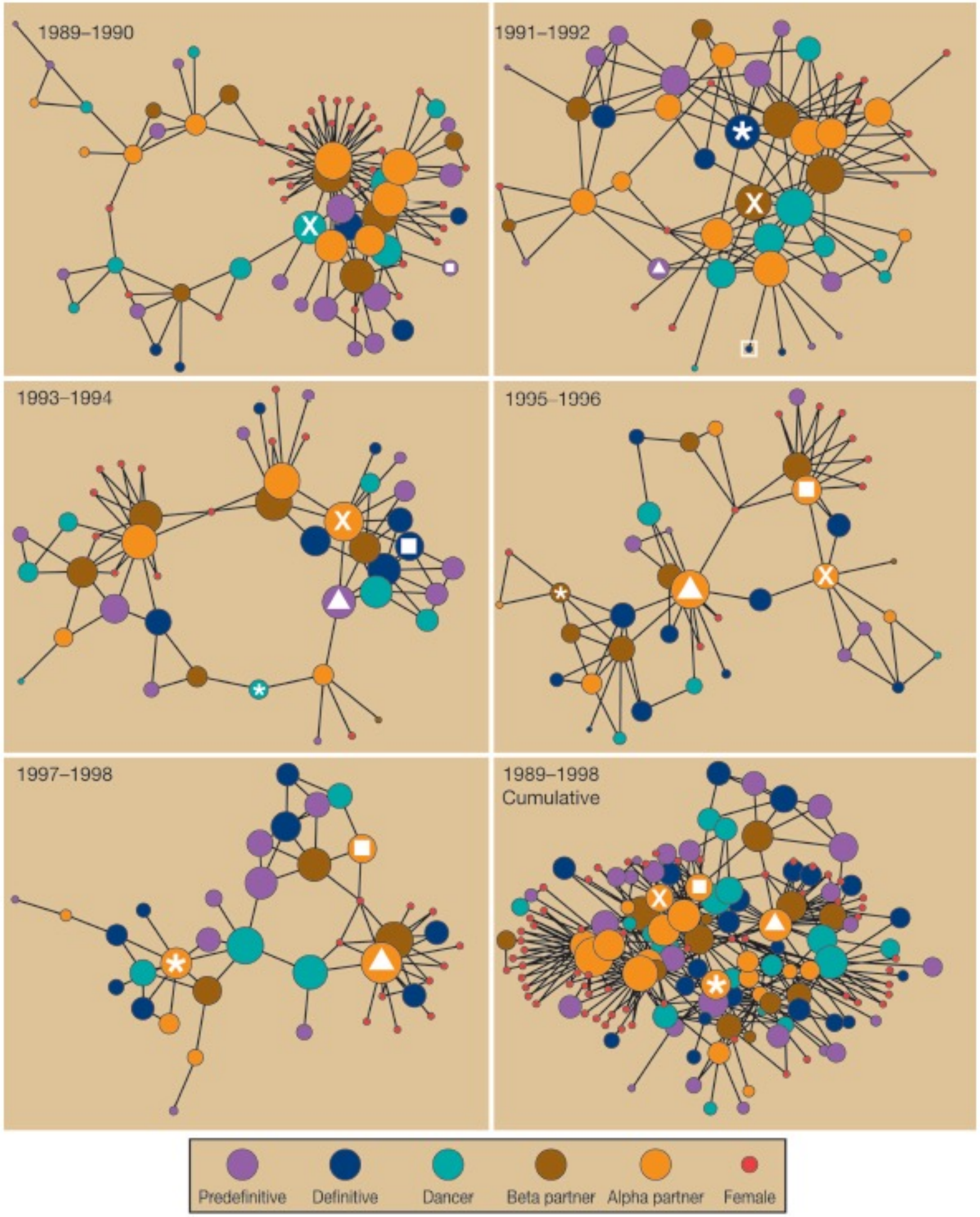
# Social networks

# Social networks

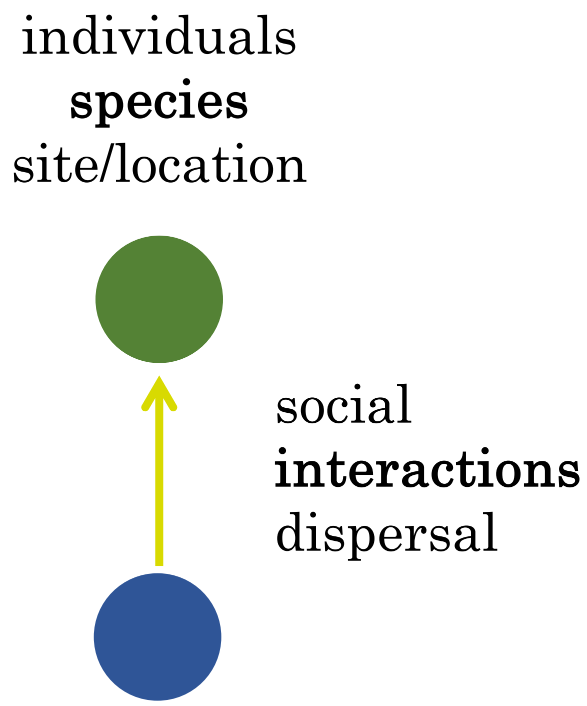


Long-tailed manakins

McDonald 2007 PNAS



# Ecological networks



# Part II
# How is data collected?
# What type of data is there?