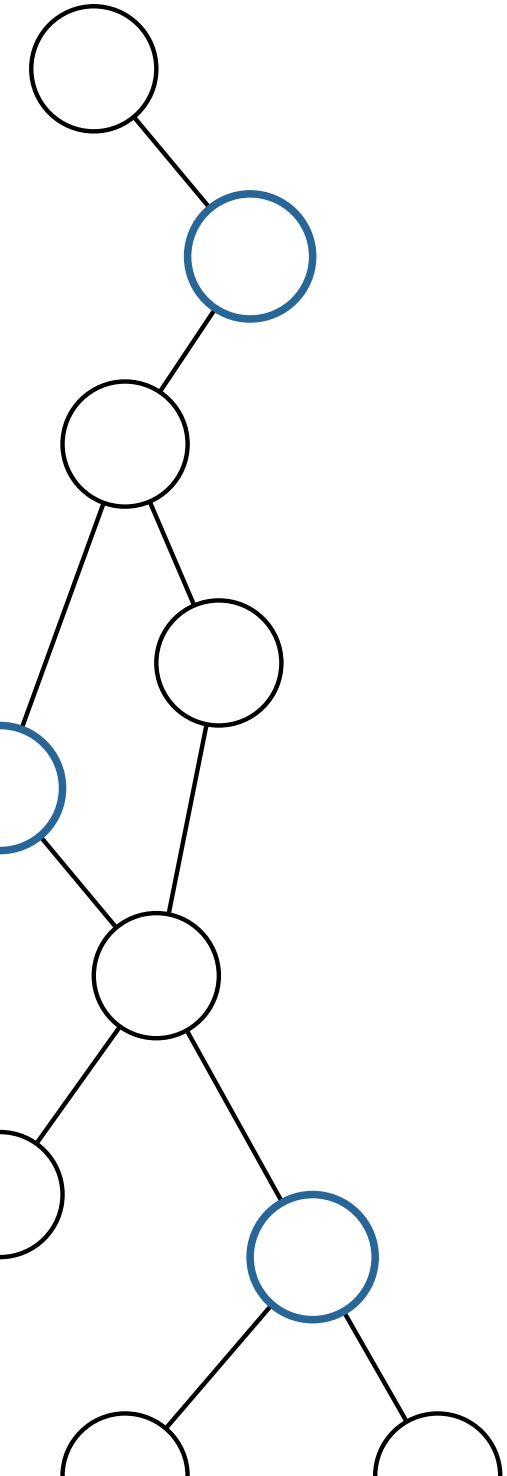


UQAR – Canada Research Chair in Biogeography and metacommunity ecology

Ecological networks in the anthropocene

Dominique Gravel

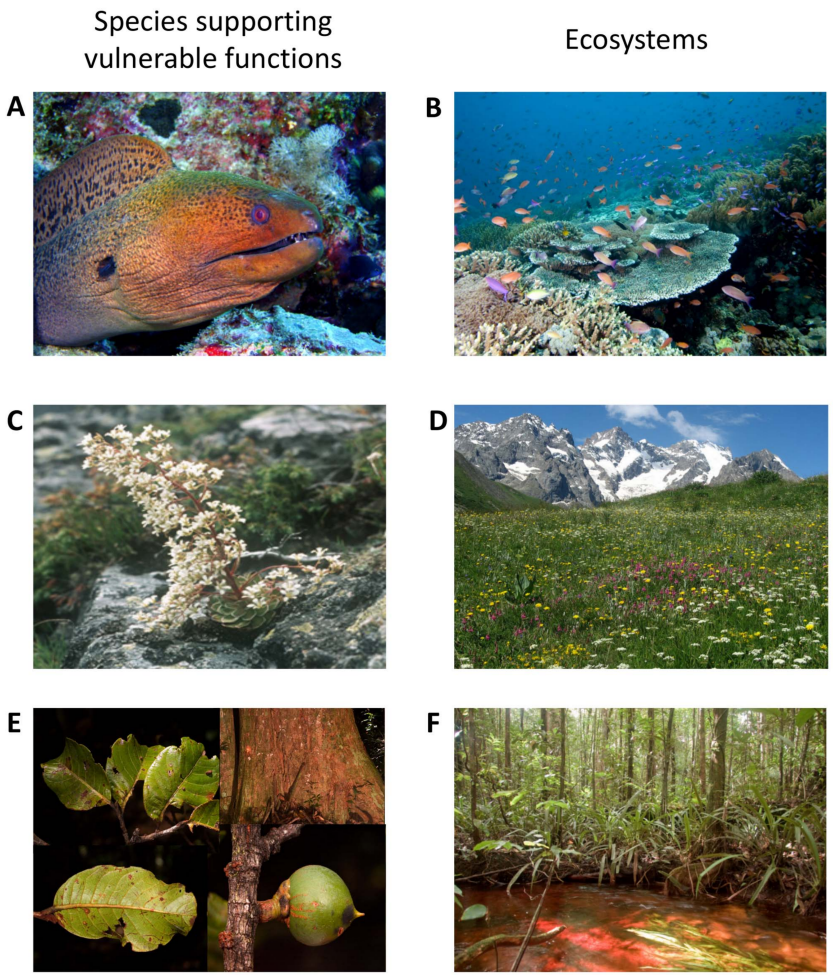
http://www.chaire-eec.uqar.ca/

April 9, 2014

UQAR

We need a novel appproach to quantify biodiversity taking into account the diversity of ecological interactions

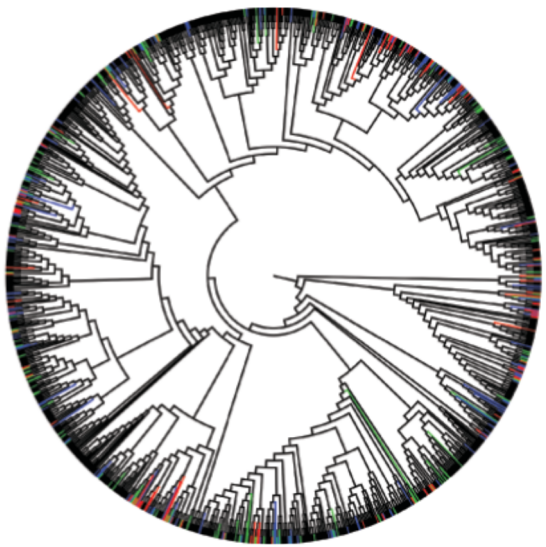
Trends in biogeography



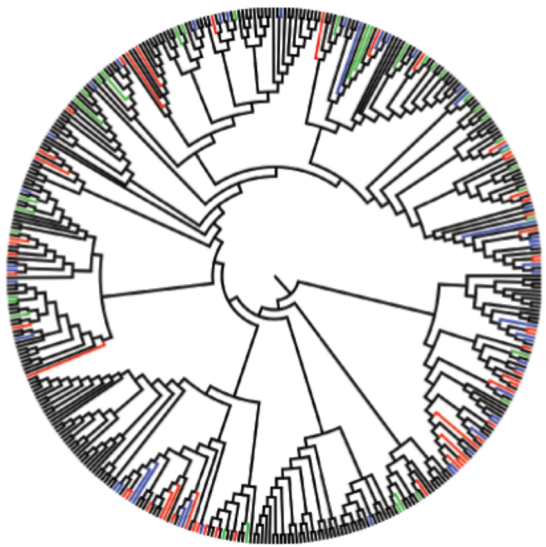
Mouillot et al. (2013)

Trends in biogeography

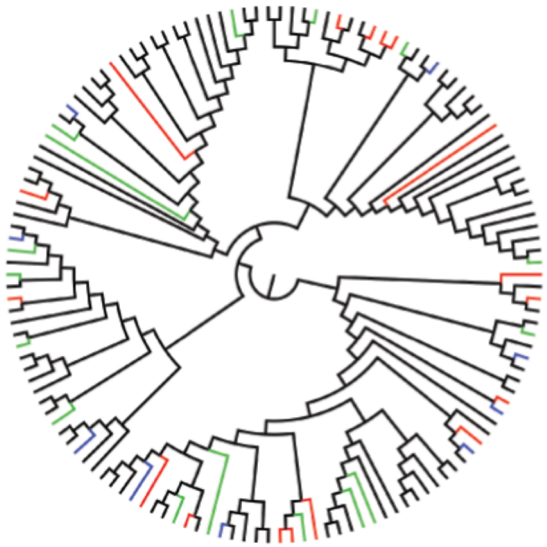
Plants



Birds

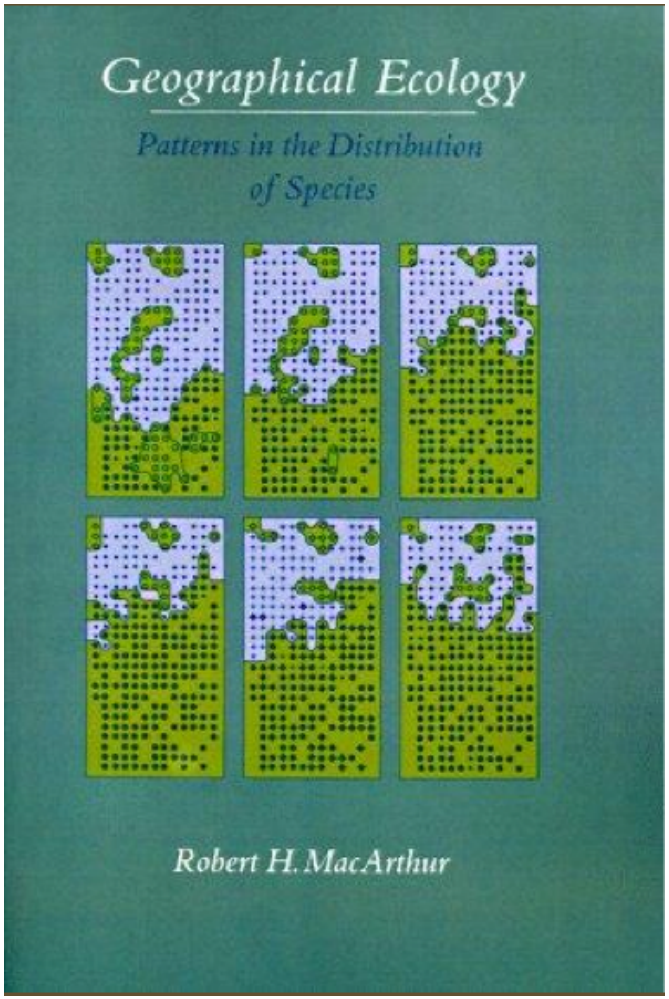


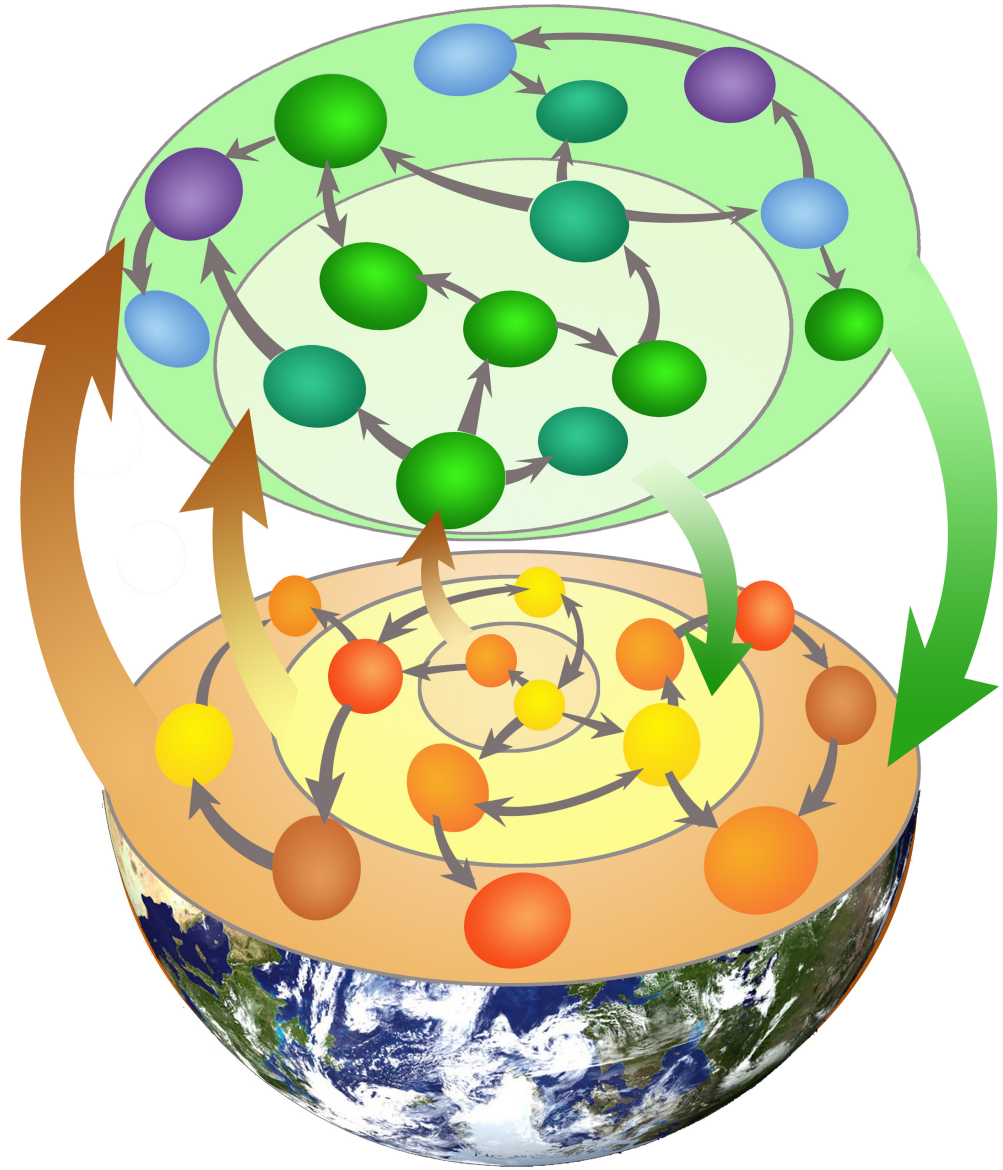
Mammals



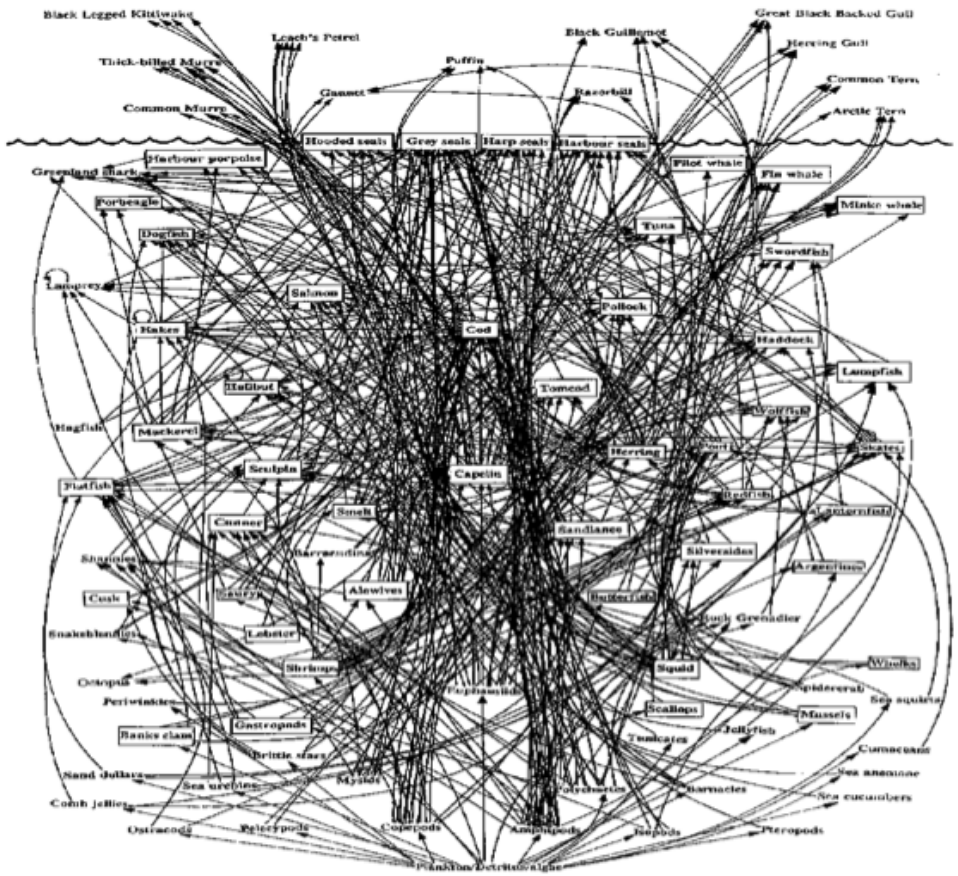
Thuiller et al. (2011)
Mazel et al. (2014)

The rich history of community ecology

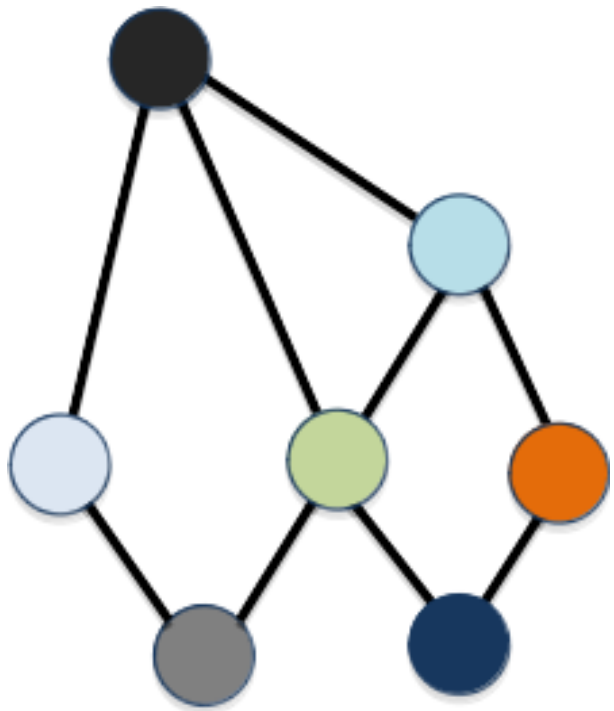




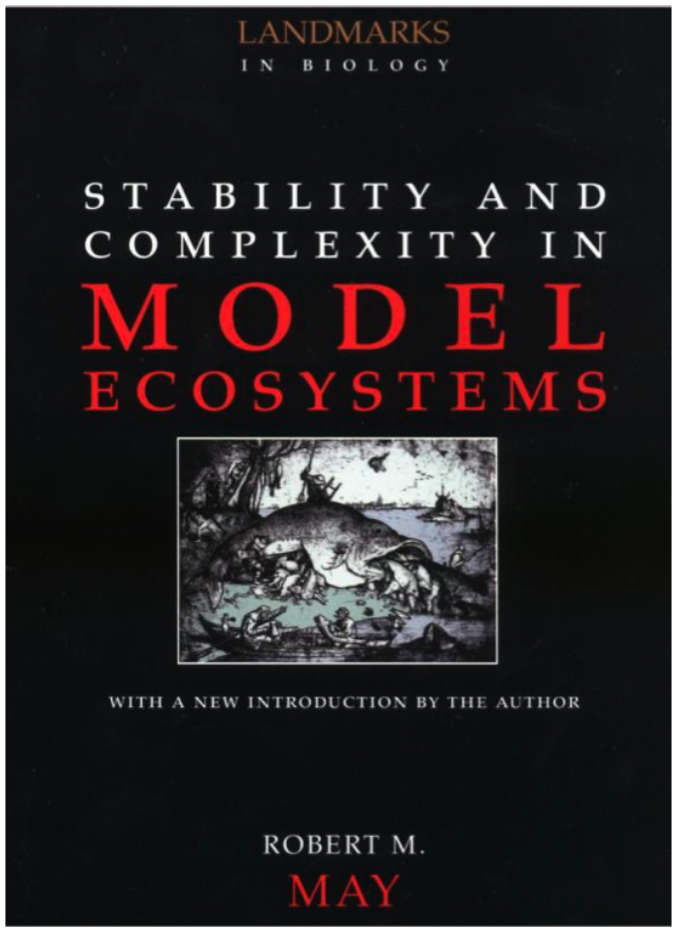
Communities are messy

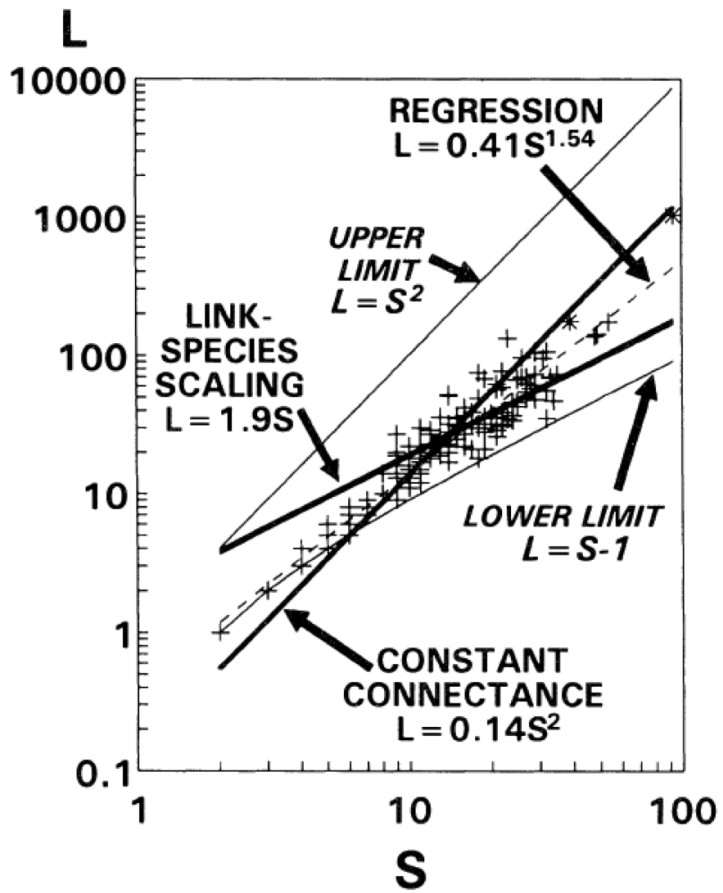


Compressing information

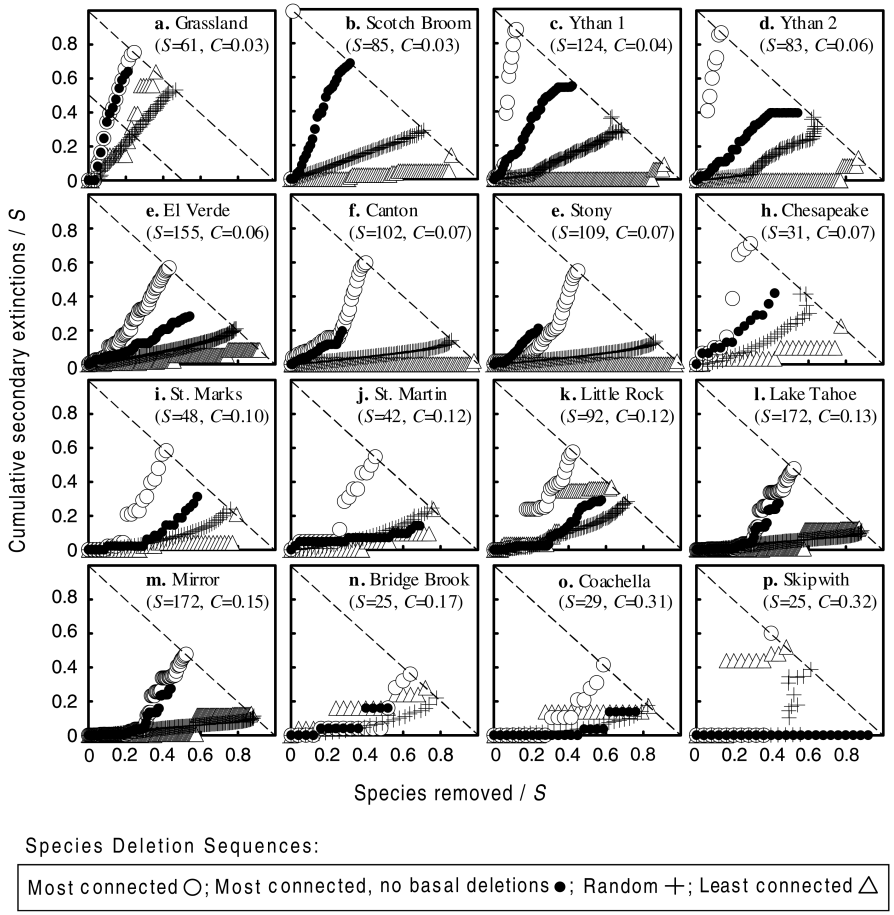


A successfull program

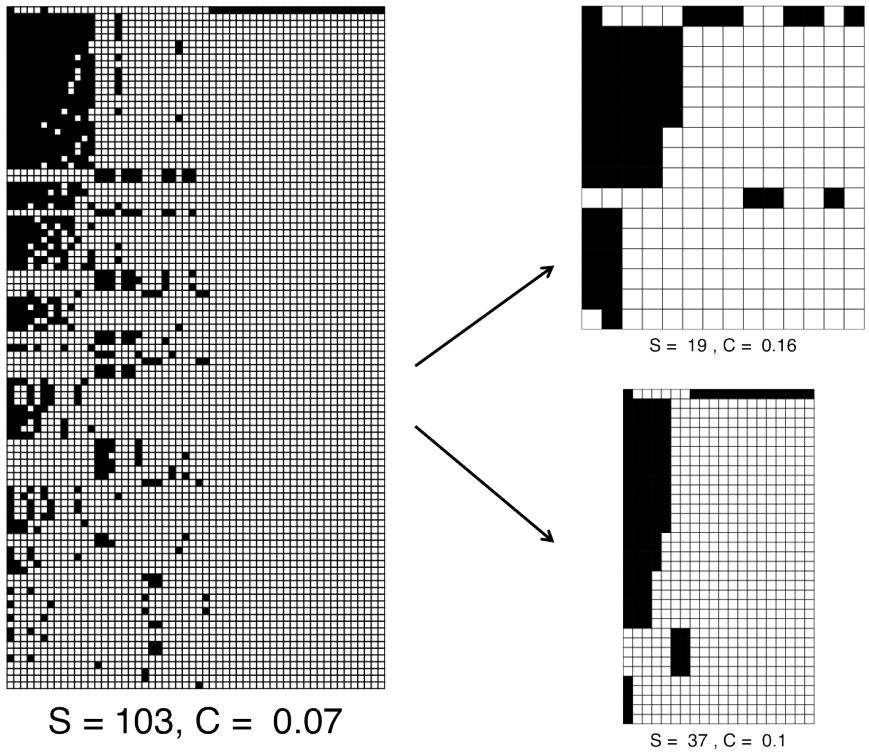




Martinez (1992)

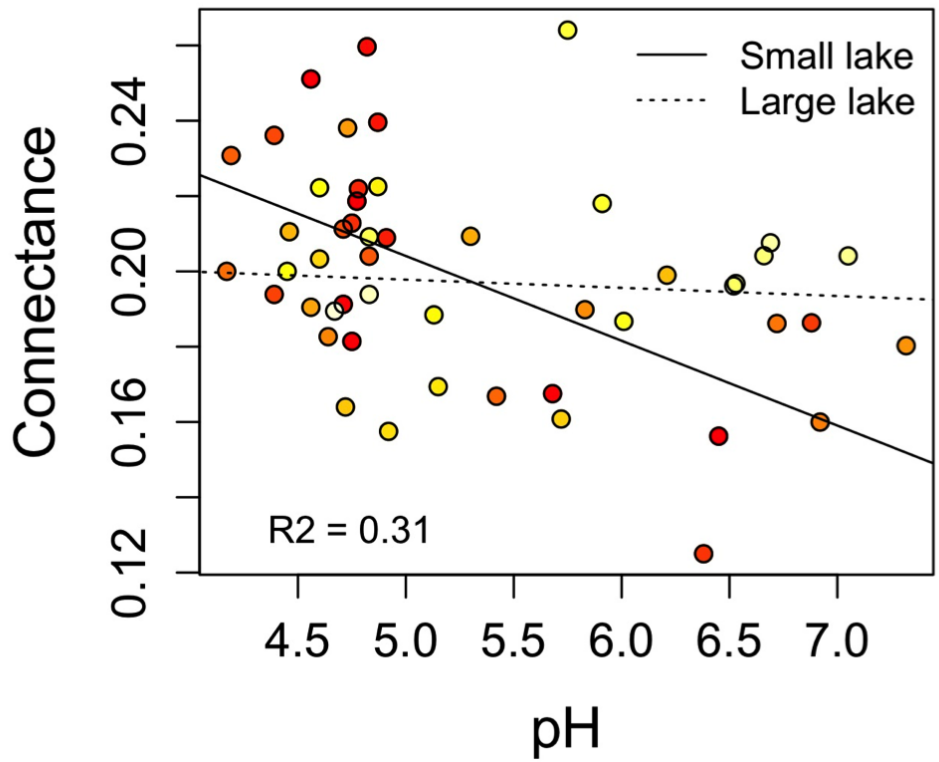


Dunne et al. (2002)

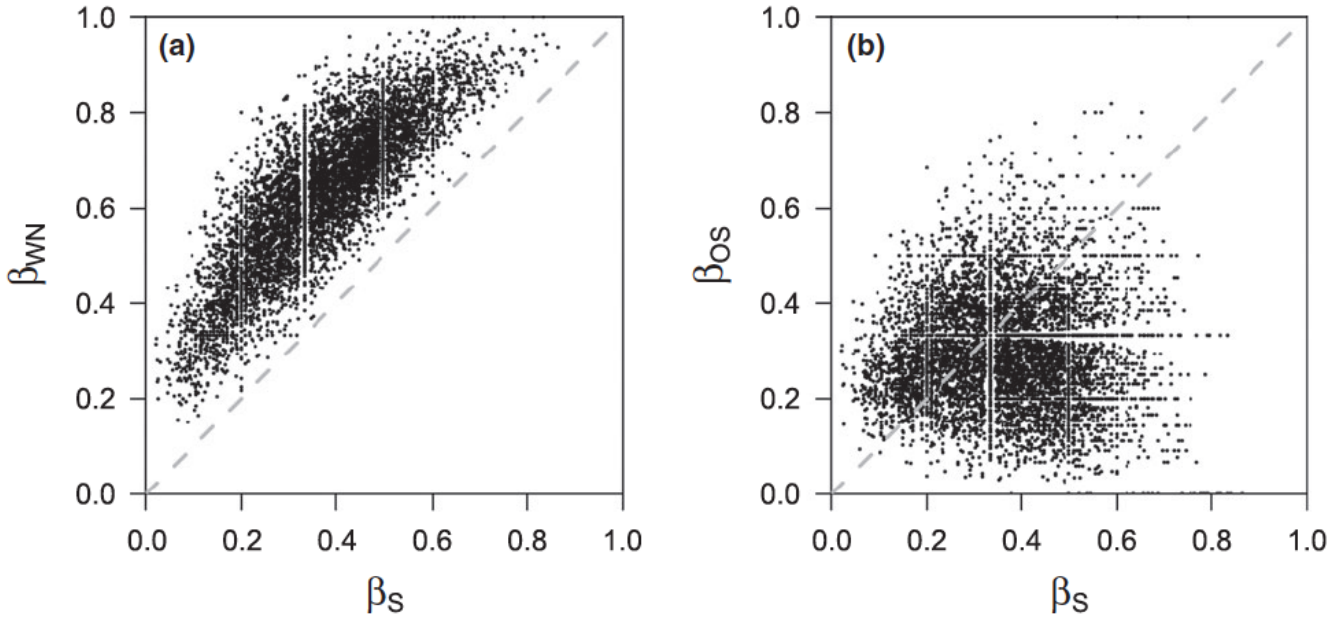


Gravel et al. (2011). *Ecol. Lett.*

What are the processes explaining how we move from a regional network (a metaweb) to a local community?


Small lake
Large lake
Connectance
0.12
0.16
0.20
0.24
R2 = 0.31
4.5
5.0
5.5
6.0
6.5
7.0
pH

Spatial variation of interaction networks



Poisot et al. (2012). *Ecol. Lett.*

Networks do vary in space because of:

- Species turnover;
- Link turnover;

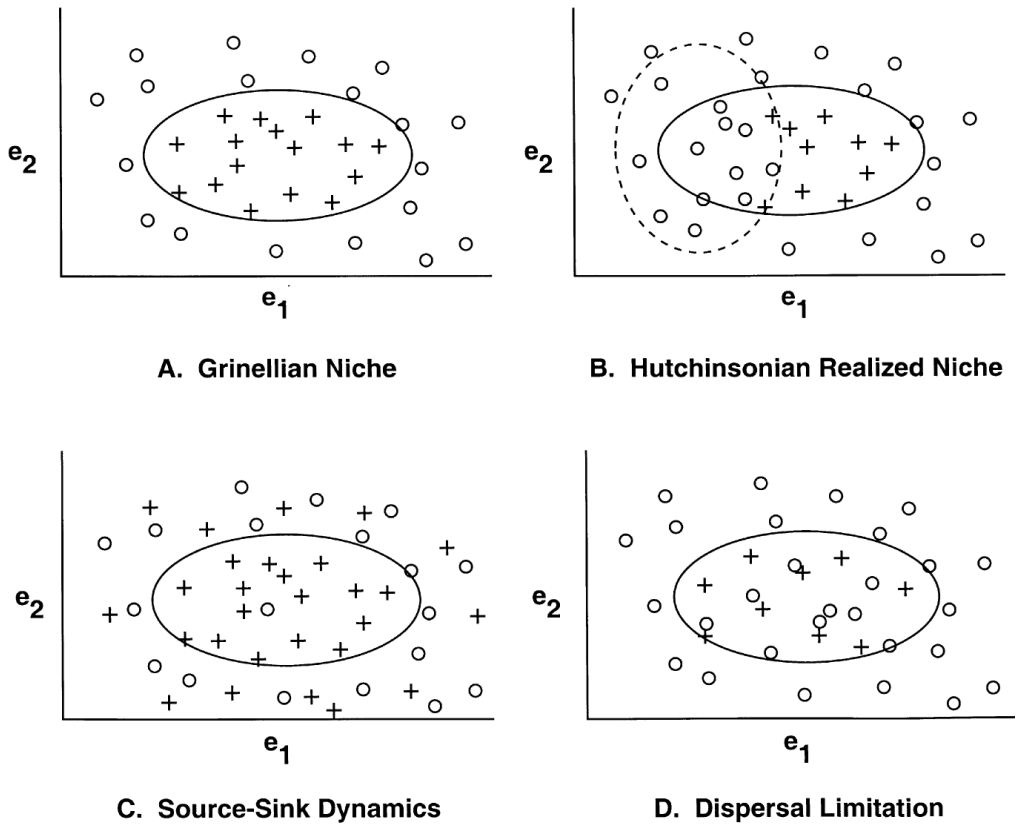
The variation of network structure is independent of the variation in species composition

The determinism of network models

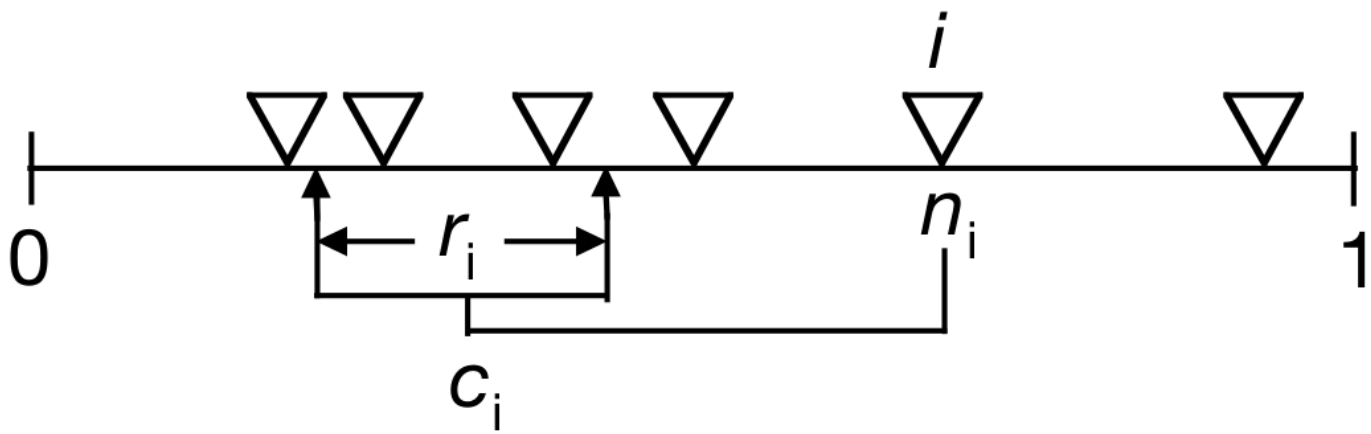
- Random networks
- Cascade & Generalized cascade
- Niche model, Minimal potential niche model & Probabilistic niche model
- Nested hierarchy
- *Neutral networks*

Definition of the niche

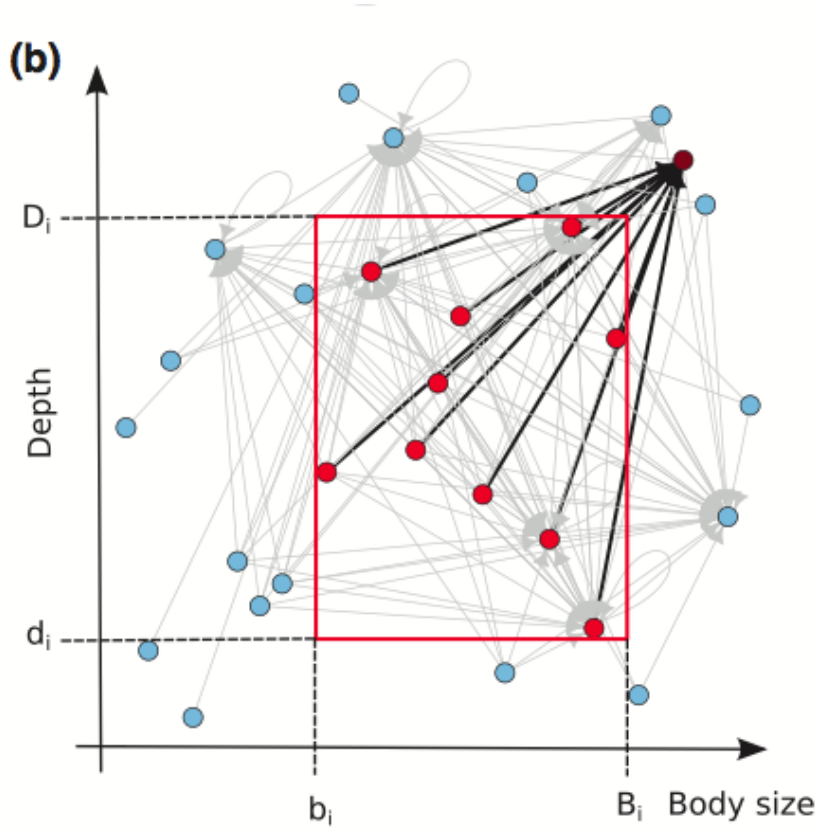
[The niche is] the joint description of the environmental conditions that allow a species to satisfy its minimum requirements so that the birth rate of a local population is equal or greater than its death rate along with the set of per capita effects of that species on these environmental conditions.
(Chase and Leibold, 2003)



Pulliam (2000)

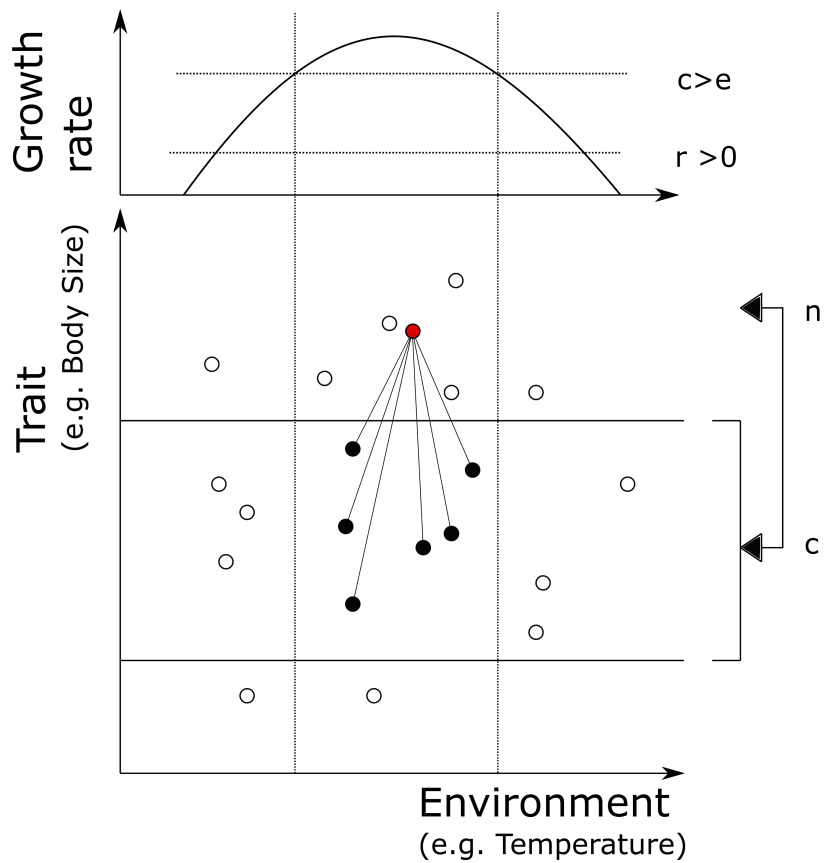


Williams & Martinez (2000)



Eklof et al (2013)

Mapping an integrated niche



Define the stochastic variable X_{ix} representing the occurrence of species i in a local community x.

And the variable L_{ijx} representing the occurrence of an interaction between species i and j at location x.

We are looking for the probability that an interaction occurs:

$$P(L_{ijx} = 1, X_{ix} = 1, X_{jx} = 1)$$

Obtained from the product rule we get:

$$P(L_{ijx}, X_{ix}, X_{jx}) = P(L_{ijx}|X_{ix}, X_{jx})P(X_{ix}, X_{jx})$$

Where:
$P(L_{ijx}|X_{ix}, X_{jx})$ is the metaweb (the Eltonian niche)
$P(X_{ix}, X_{jx})$ is the co-occurrence matrix (the Grinnellian niche)

We could refine the model with the addition of a condition on the environment, such as:

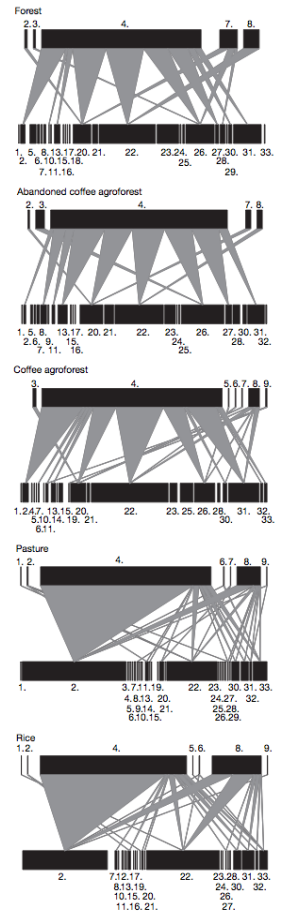
$$P(L_{ijx} | X_{ix}, X_{jx}, E_x)$$
and
$$P(X_{ix}, X_{jx} | E_x)$$

We could also specify neutral dynamics underlying community assembly:

$$P(X_{ix}, X_{jx} | E_x) = P(X_{ix} | E_x) P(X_{jx} | E_x)$$

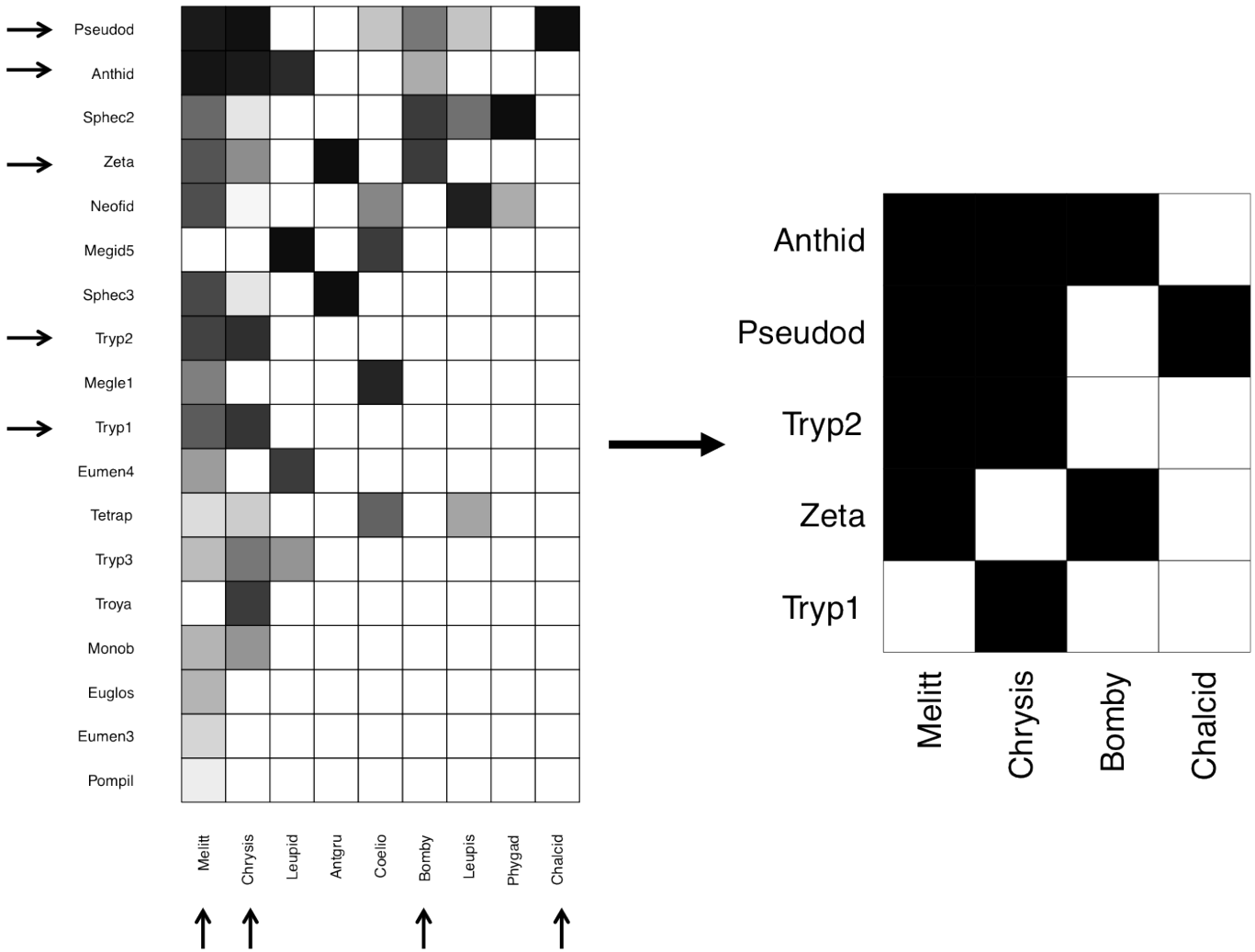
From *Tylianakis et al. 2007. Habitat modification alters the structure of tropical host-parasitoid food webs. Nature, 44:202-205*

- 48 networks, 4 090 recorded interactions
- 5 habitats: forest, abandoned coffee agroforest, coffee agroforest, pasture, rice
- 33 species of bees and wasps (Hymenoptera: Apidae, Megachilidae, Mutilidae, Pompilidae, Sphecidae, Vespidae)
- 9 parasitoid and kleptoparasite (Hymenoptera: Eulophidae, Ichneumonidae, Leucospidae, Megachilidae and Chrysididae; Dyptera: Bombyliidae)



Example

Network #34, Pasture

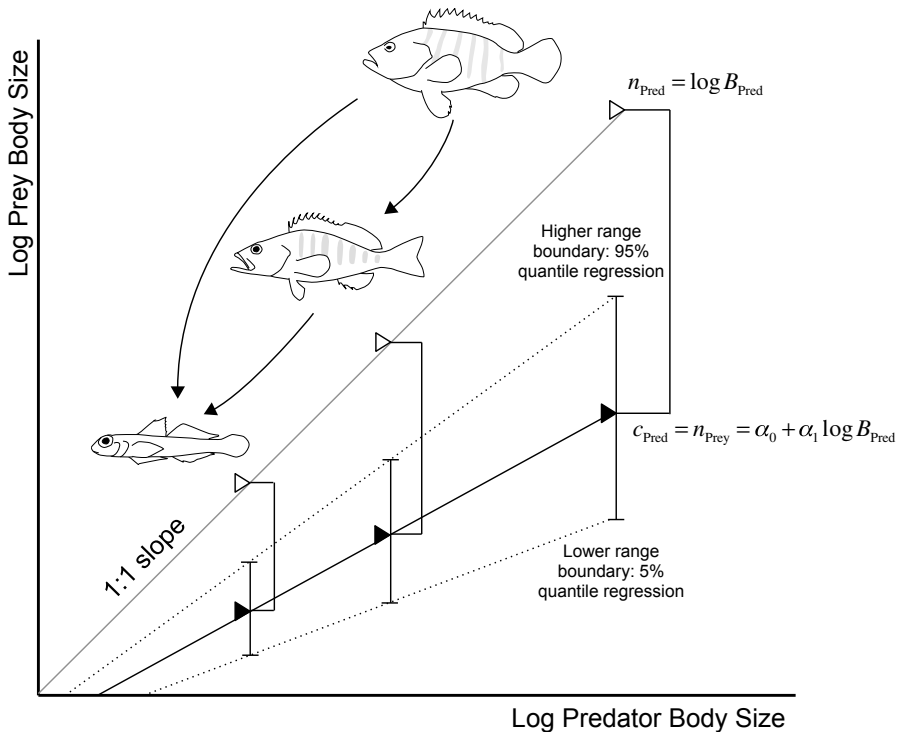


Interpretation	**Model**	$L(H\|D)$
Basic model		
No effect of E	$P(L_{ijx}\|X_{ix}, X_{jx})P(X_{ix}, X_{jx})$	-19.36
Metaweb definitions		
Conditional on E	$P(L_{ijx}\|X_{ix}, X_{jx}\|E_x)P(X_{ix}, X_{jx})$	-10.37
Aggregated metaweb	$P(L^*_{ijx}\|X_{ix}, X_{jx})P(X_{ix}, X_{jx})$	-27.96
Co-occurrence		
Neutral assembly	$P(L_{ijx}\|X_{ix}, X_{jx})P(X_{ix})P(X_{jx})$	-20.15
Conditional on E	$P(L_{ijx}\|X_{ix}, X_{jx})P(X_{ix}\|E_x)P(X_{jx}\|E_x)$	-13.30

Summary of the key ideas

- Networks are not deterministic
- Links do change with the environment
- The environment also affect species turnover and thus network turnover
- Very weak effect of non-random species associations on the variation of network structure

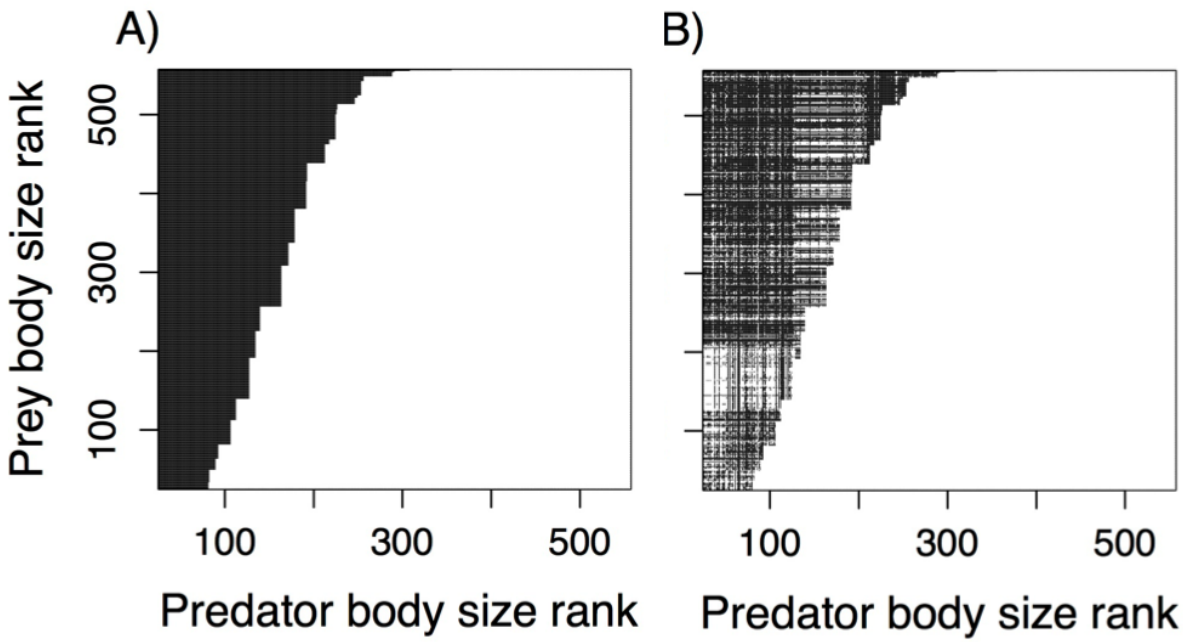
The problem: inferring interactions from species that never co-occurred and will be found in novel assemblages



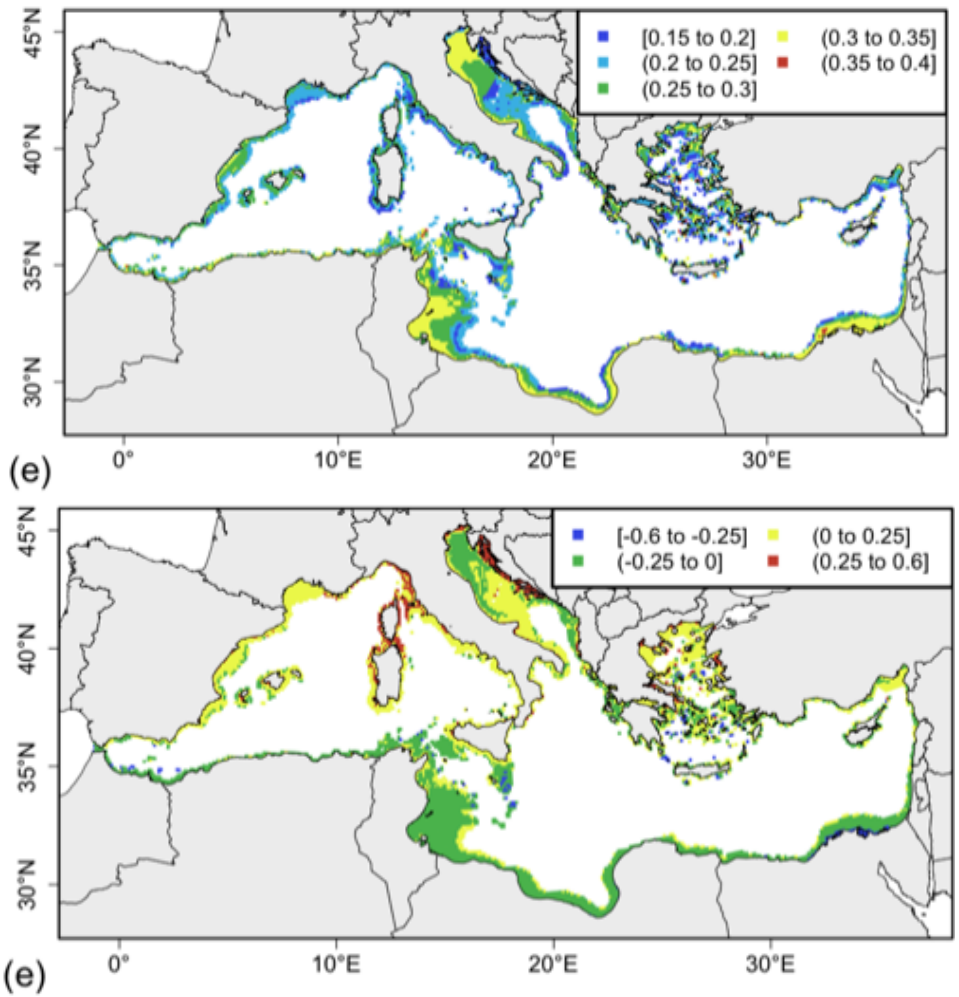
Gravel et al. (2013). *Meth. Ecol. Evol.*

Without information on the probability of interactions, we considered a metweb *à la Havens* and neutral co-occurrence:

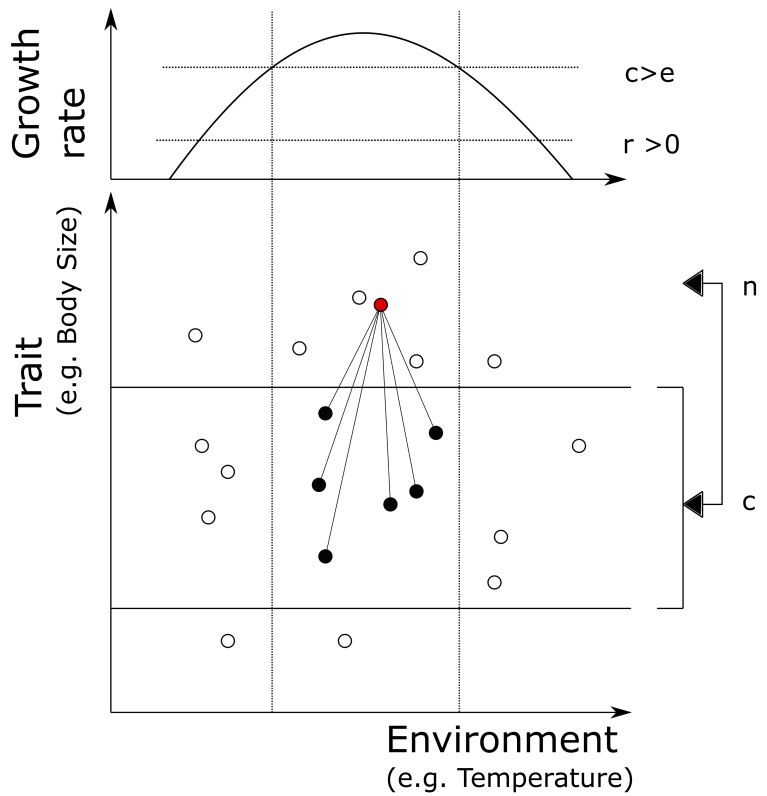
$$P(L_{ijx}, X_{ix}, X_{jx} | E_x) = P(L_{ijx} | X_{ix}, X_{jx}) P(X_{ix} | E_x) P(X_{jx} | E_x)$$



Gravel et al. (2013)



Albouy et al. (2014)



$$P(L_{ijx}, X_{ix}, X_{jx}) = P(L_{ijx} | X_{ix}, X_{jx}) P(X_{ix}, X_{jx})$$

Given a theory for species co-occurrence, we could re-arrange information:

$$P(L_{ijx}, X_{ix}, X_{jx} | E_x) = P(L_{ijx} | X_{ix}, X_{jx}, E_x) P(X_{ix}, X_{jx} | E_x)$$
$$= P(L_{ijx} | X_{ix}, X_{jx}, E_x) P(X_{ix} | X_{jx}, E_x) P(X_{jx} | E_x)$$

And invert it to derive a probability of species occurrence, accounting for the environment and interactions:

$$P(X_{jx} | E_x) = \frac{P(L_{ijx} | X_{ix}, X_{jx}, E_x) P(X_{ix} | X_{jx}, E_x)}{P(L_{ijx}, X_{ix}, X_{jx} | E_x)}$$

Acknowledgements

Co-authors: Range limits working group, Timothée Poisot, Camille Albouy, Jason Tylianakis, Daniel Stouffer, Jennifer Dunne, SFI, David Mouillot, Working group on gradient-based network research;

Funding: NSERC, FRQNT, Canada Research Chair program, Quebec Center for Biodiversity Sciences, Santa Fe Institute, UQAR.