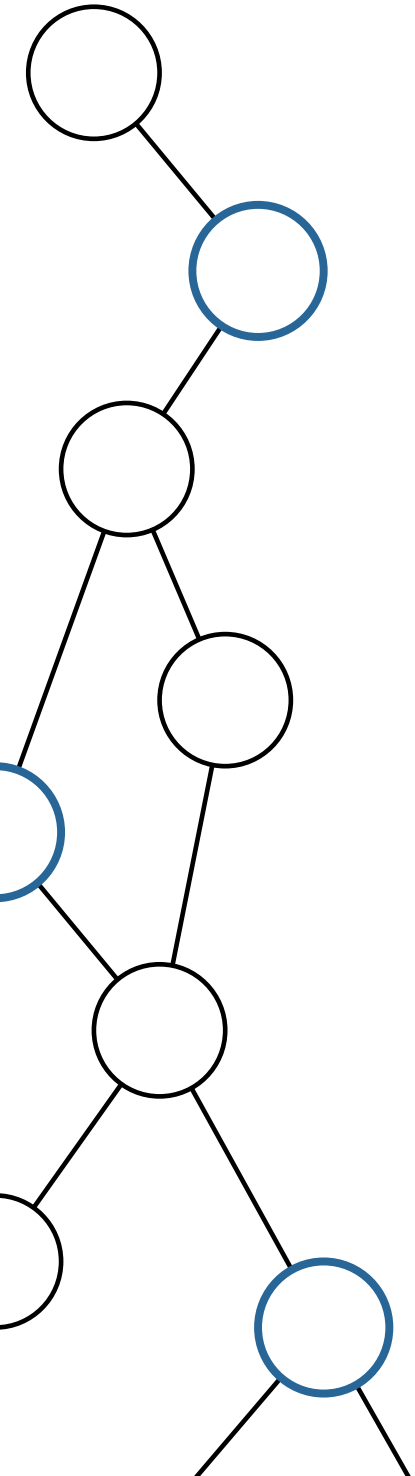

Université de Sherbrooke

A size-based theory for inferring global change impacts on food web structure

Dominique Gravel, Camille Albouy, Timothée Poisot

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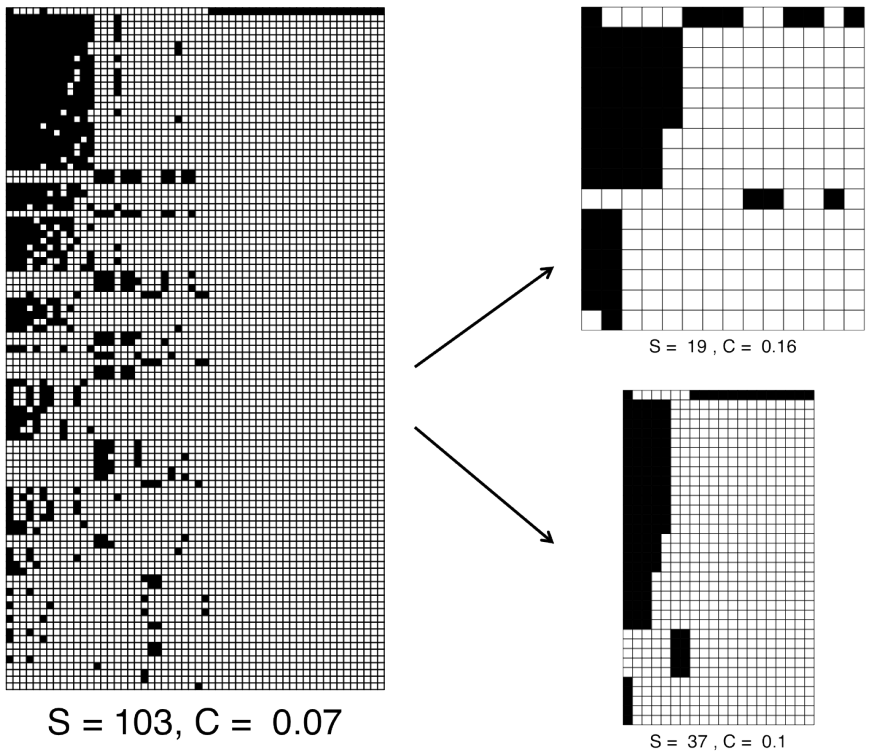
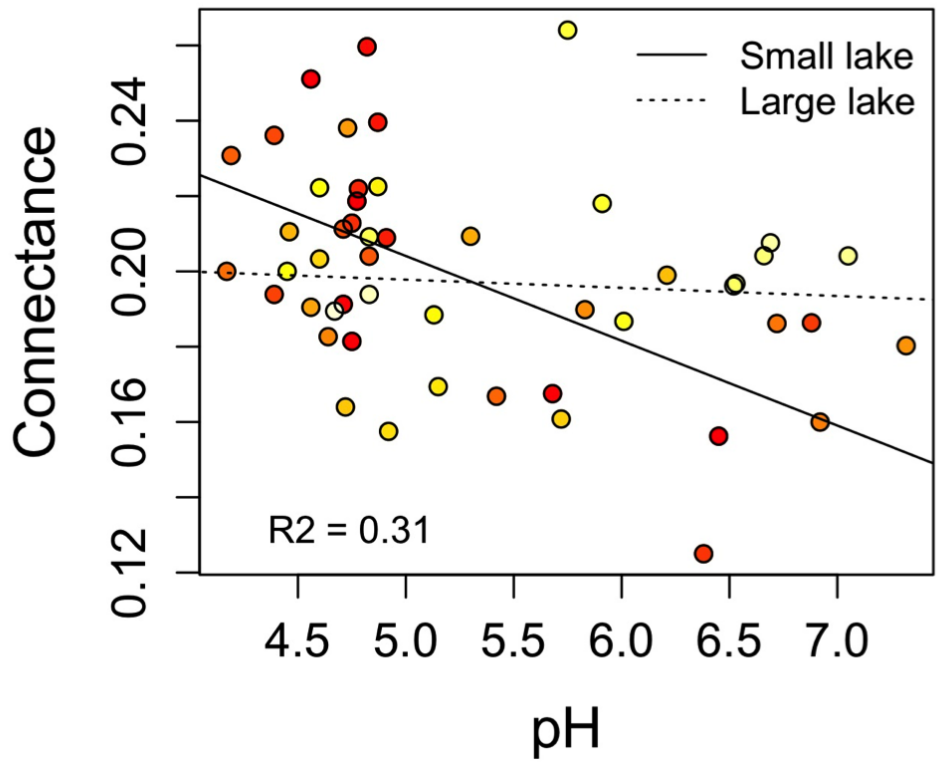
Biogeography of ecological interactions

Challenge of getting network data at large spatial scales

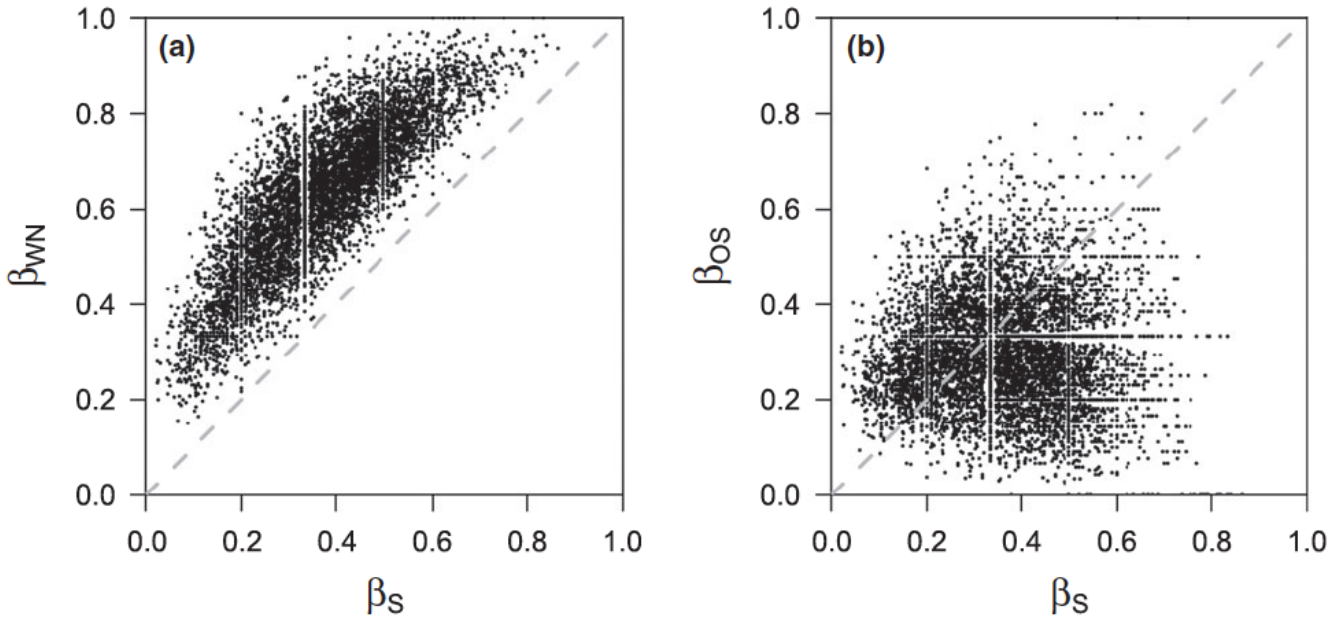
- Hard to document;
- Usually not replicated;
- Applies only to co-occurring species;
- Network structure is deterministic and stationary.



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



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



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

Networks do vary in space because of:

- Species turnover;
- Link turnover;

Propose a quantitative framework to understand and predict the spatial variation in network structure at the biogeographical scale

Define the stochastic variable X_{iz} representing the occurrence of species i at location z.

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

We are looking for the probability that an interaction occurs given the environment E_z:

$$P(L_{ijz} = 1, X_{iz} = 1, X_{jz} = 1 | E_z)$$

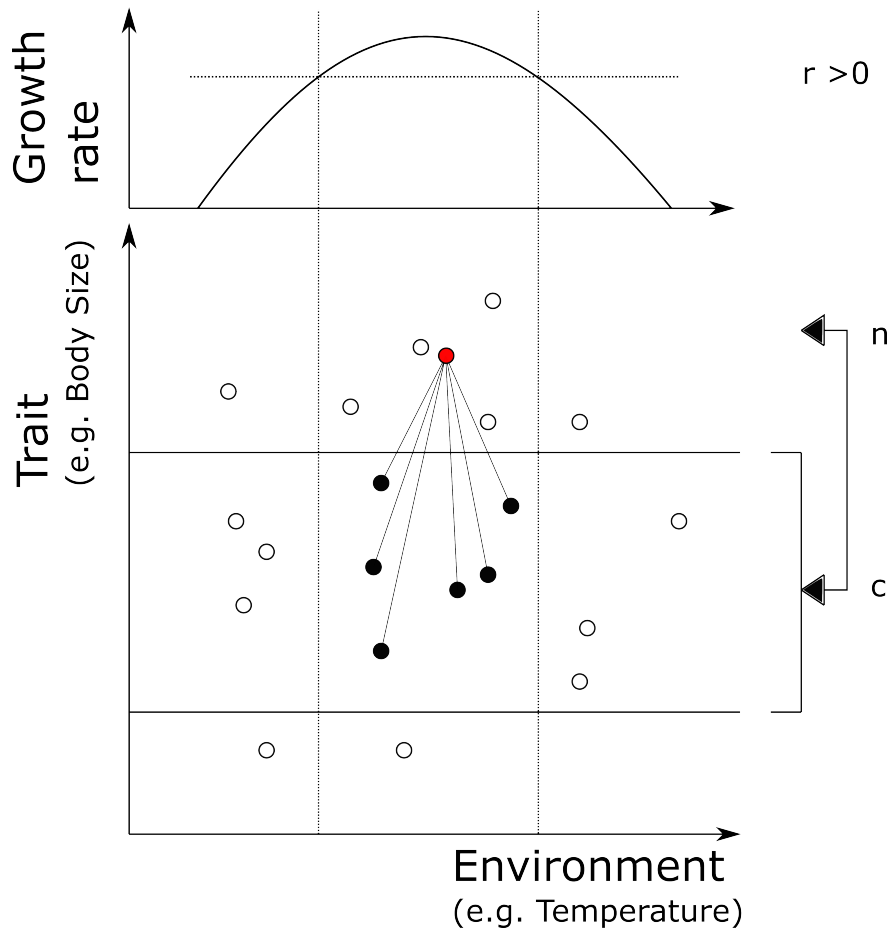
Using the product rule we get:

$$P(L_{ijz}, X_{iz}, X_{jz} | E_z) = P(L_{ijz} | X_{iz}, X_{jz}, E_z) P(X_{iz}, X_{jz} | E_z)$$

Where:
$P(L_{ijz} | X_{iz}, X_{jz}, E_z)$ is the metaweb
$P(X_{iz}, X_{jz} | E_z)$ is the co-occurrence matrix

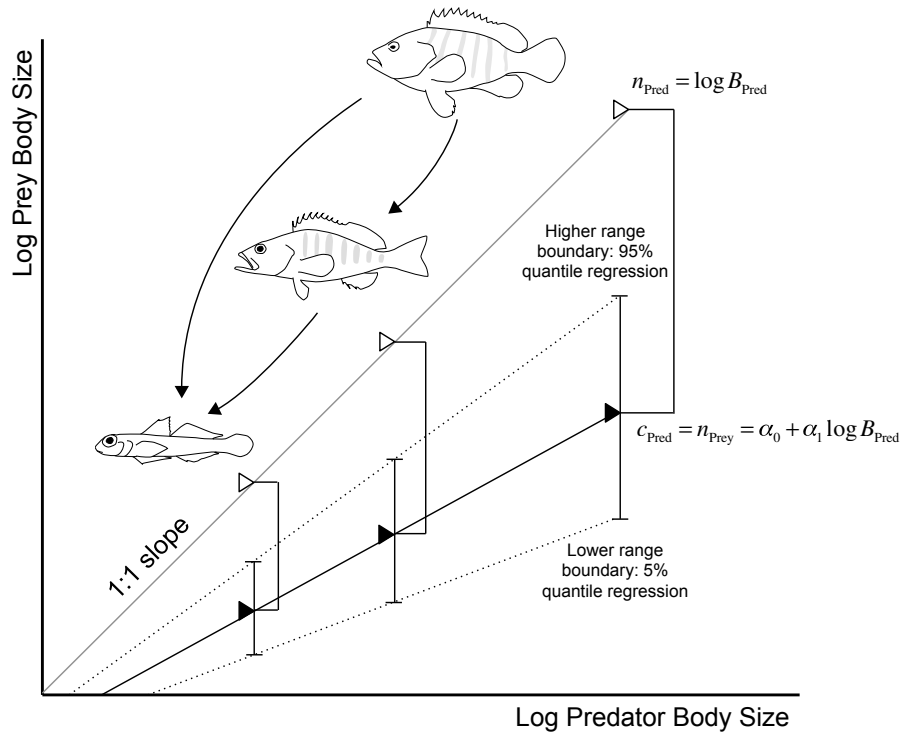
$P(L_{ijx}|X_{iz}, X_{jz}, E_z)$ is the Eltonian niche

$P(X_{ix}, X_{jz}|E_z)$ is the Grinnellian niche



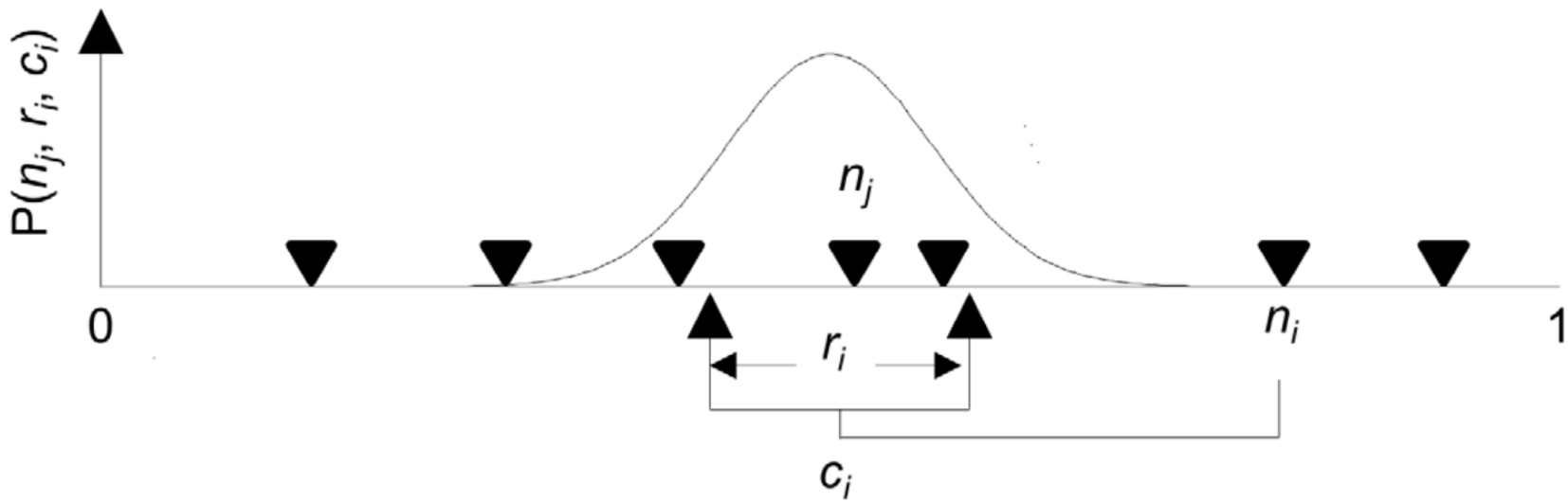
The problem: inferring interactions for species that never co-occurred and with incomplete data

Inferring the metaweb from traits



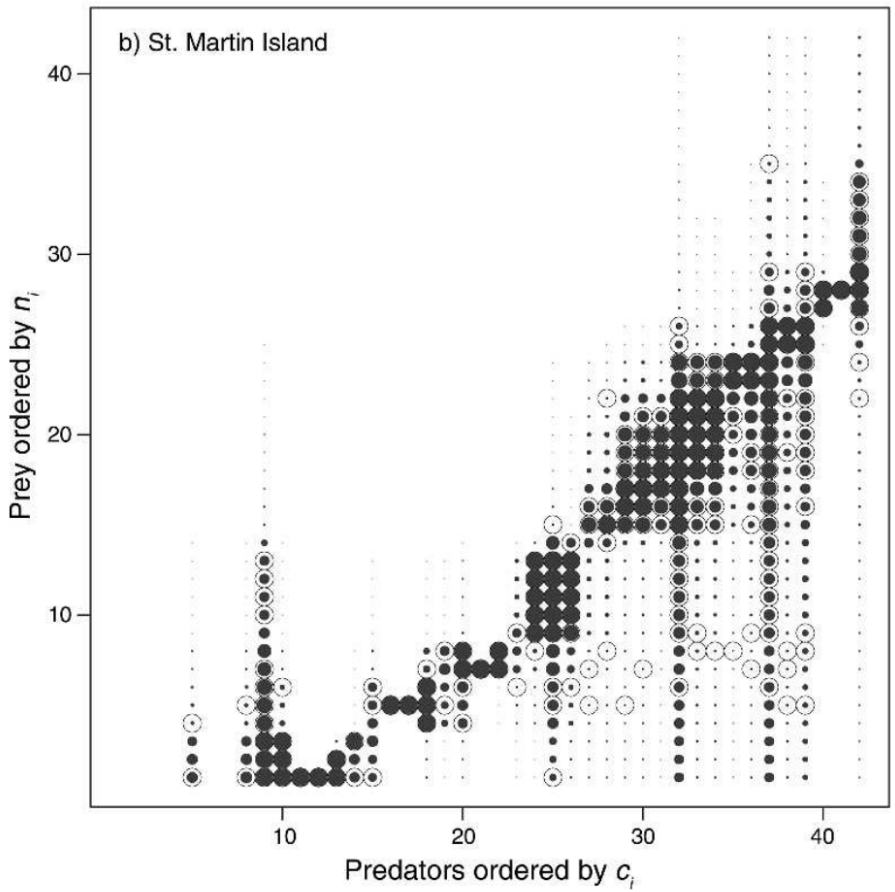
Gravel et al. (2013). *Meth. Ecol. Evol.*

$$P(L_{ij} = 1|\theta) = \alpha e^{(-\frac{\beta(M_j - M_i)^2}{r_i})}$$



Williams et al. (2010). *PLoS One*

The likelihood function



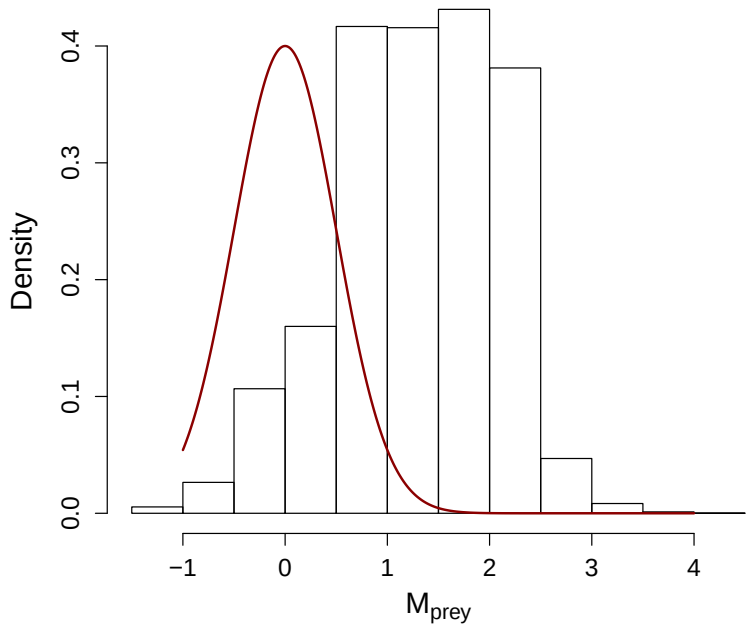
Williams et al. (2011). *Ecology*

How to tweak the likelihood when we have presence-only data ?

- What is the data ?
- What are the parameters to estimate ?
- What information do we have in hands ?

A key : predators are 'sampling' prey from a regional pool.

Bayesian formulation of the interaction probability

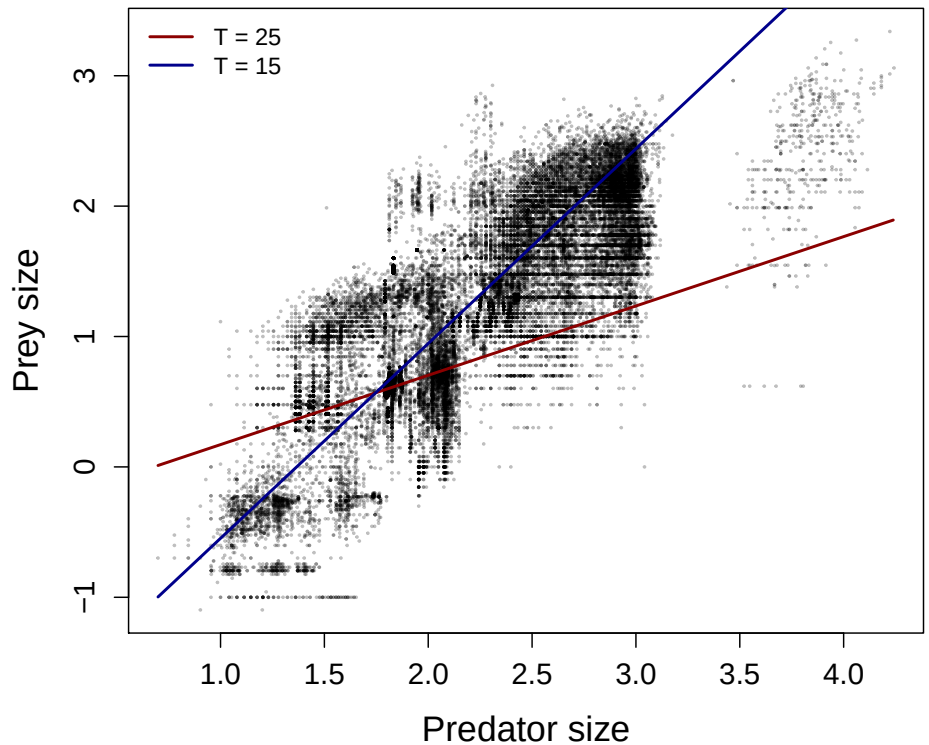


Bayesian formulation of the interaction probability

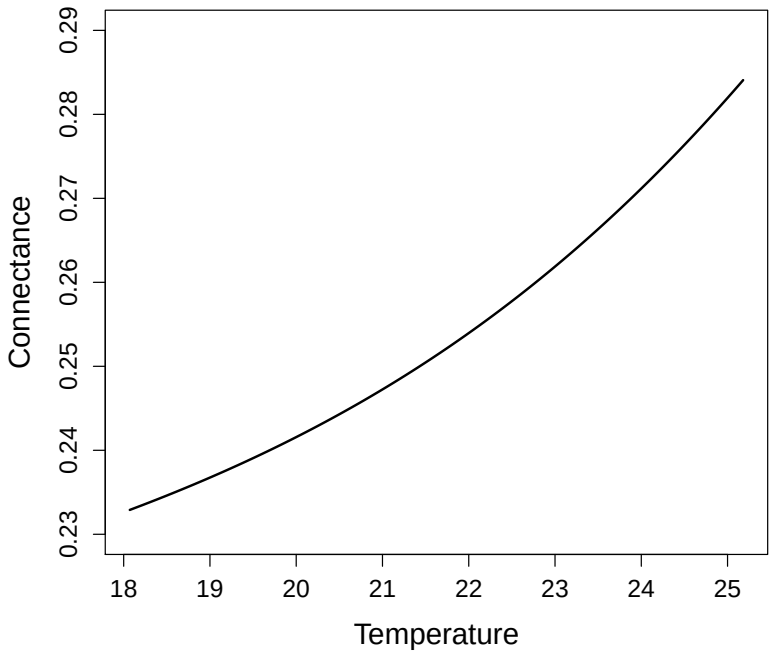
The likelihood function:

$$P(M_{prey} | L_{ij}, M_{pred}) = \frac{P(L_{ij} | M_{prey}, M_{pred}) P(M_{prey})}{P(L_{ij} | M_{pred})}$$

- Data from *Barnes et al. (2008), Predator and prey body sizes in marine food webs, Ecology 86: 881*;
- 34 931 recorded interactions;
- 25 sites.



Effect of temperature on the metaweb



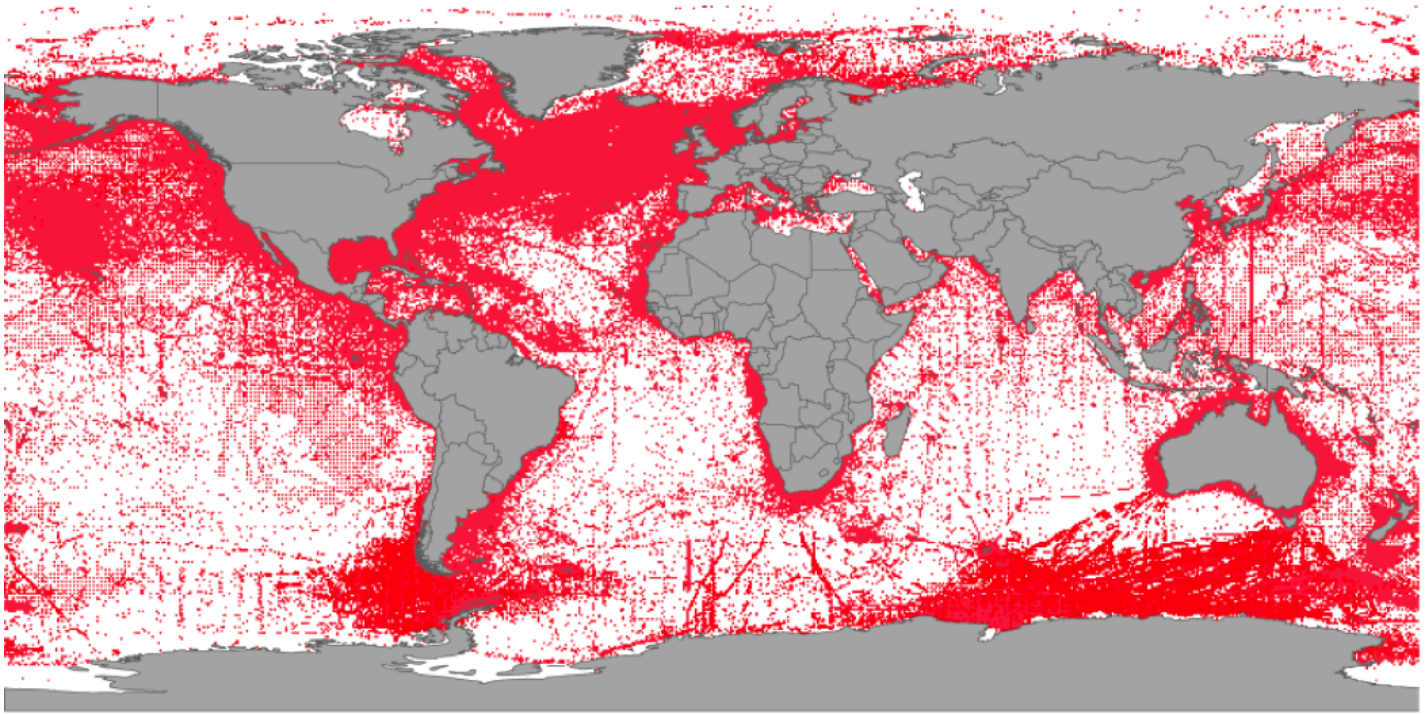
$$P(L_{ijz}, X_{iz}, X_{jz} | E_z) = P(L_{ijz} | X_{iz}, X_{jz}, E_z) P(X_{iz}, X_{jz} | E_z)$$

Where:

$P(L_{ijz} | X_{iz}, X_{jz}, E_z)$ is the metaweb (the Eltonian component)

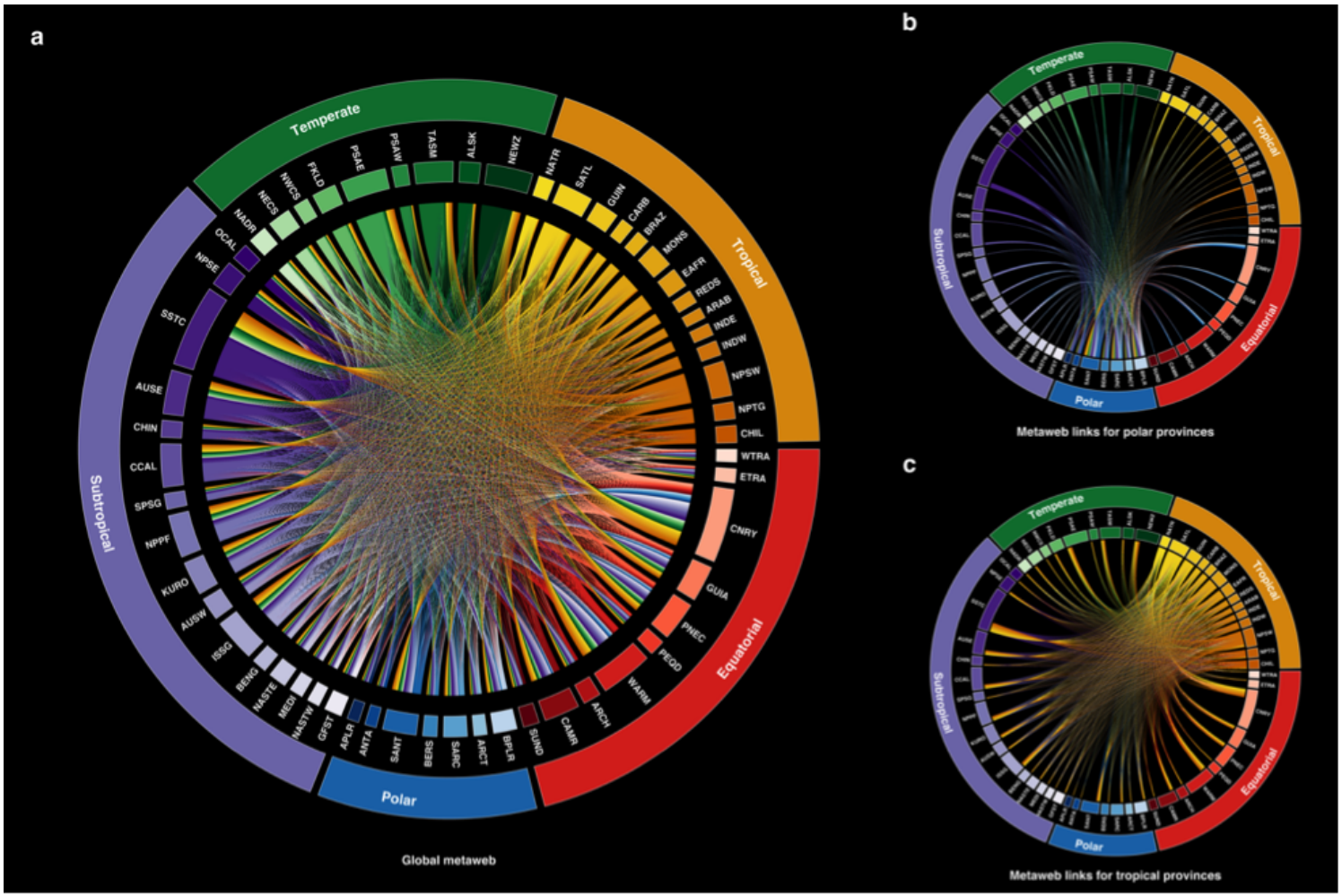
$P(X_{iz}, X_{jz} | E_z)$ is the co-occurrence matrix (the Grinnellian component)

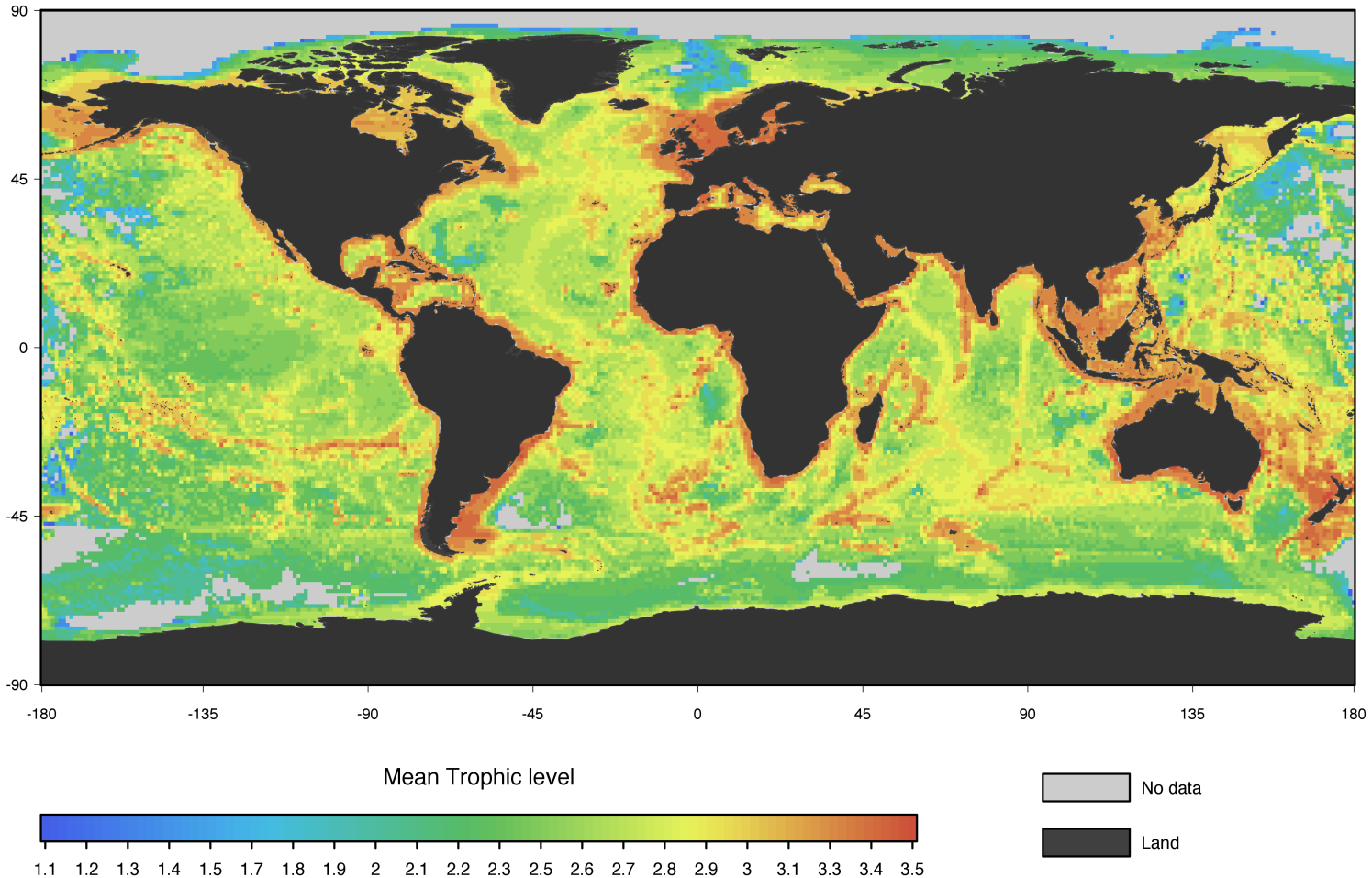
Distribution data



- 13 982 108 occurrences
- 14 168 species

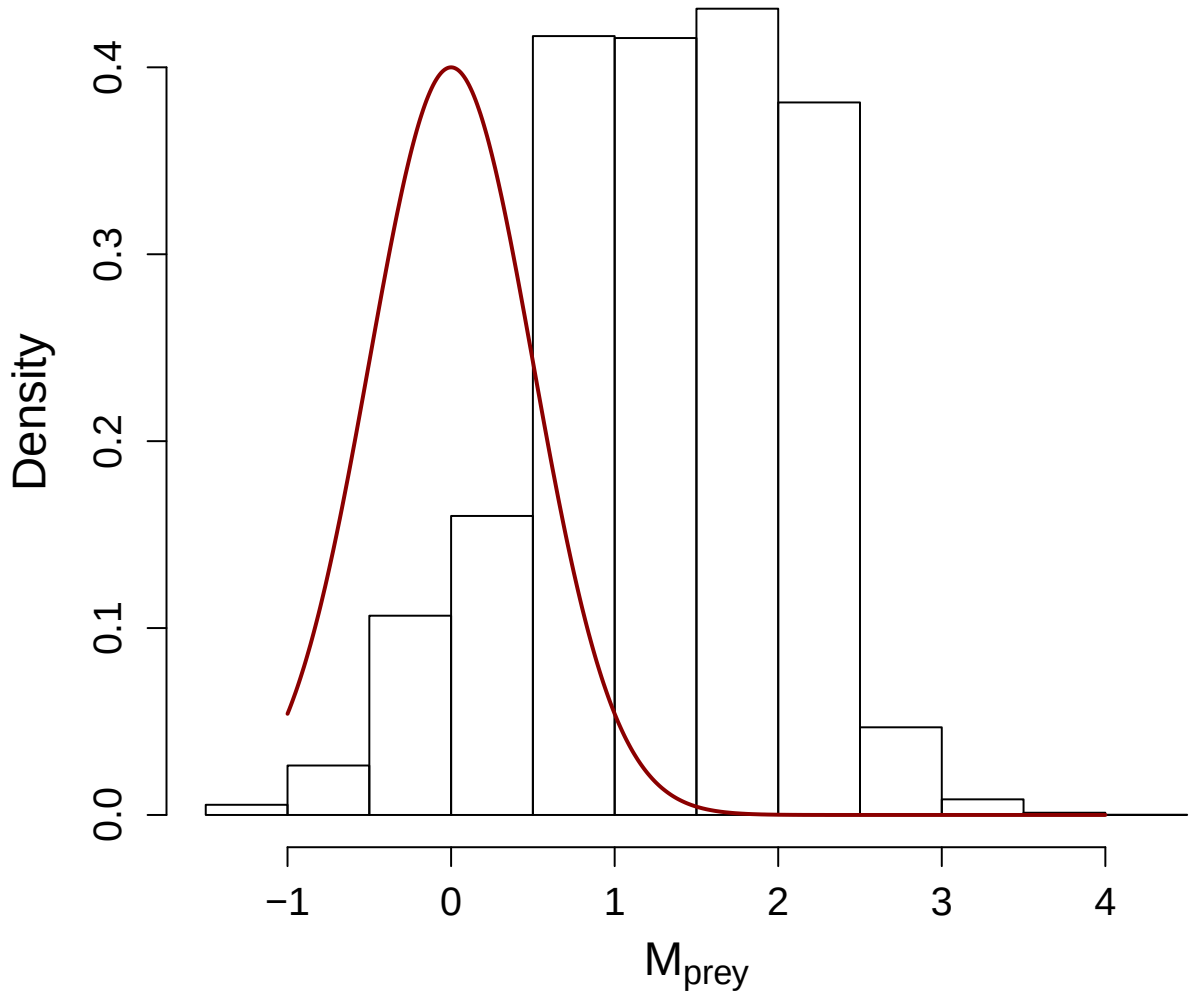
Reconstructing the global interaction network




90
45
0
-45
-90
-180
-135
-90
-45
0
45
90
135
180
Mean Trophic level
1.1 1.2 1.3 1.4 1.5 1.7 1.8 1.9 2 2.1 2.2 2.3 2.5 2.6 2.7 2.8 2.9 3 3.1 3.3 3.4 3.5
No data
Land

The multiple roles of the environment on network structure:

- Predator-prey body size relationship
- Regional species pool
- Species distribution


Density
0.0
0.1
0.2
0.3
0.4
−1
0
1
2
3
4
M_{prey}