



Laboratoire  
d'écologie  
intégrative



# Warming impacts in fish food web dynamics

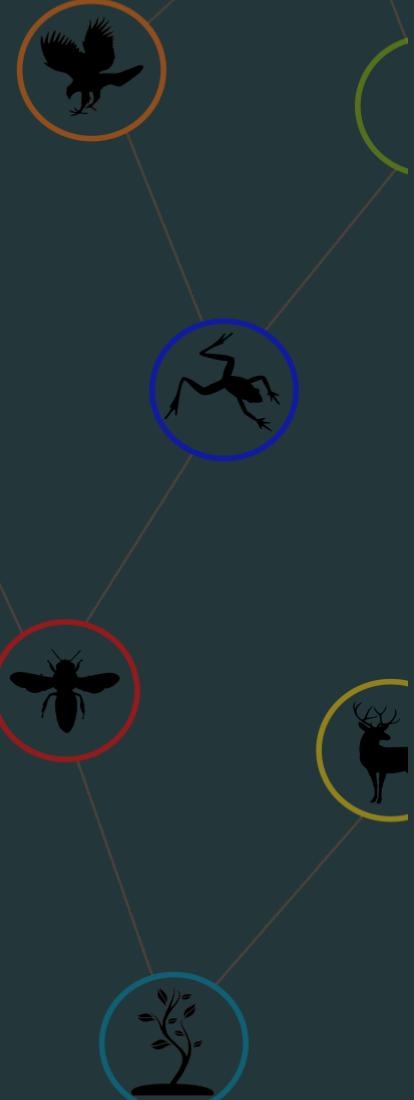
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## Econet 2021

Azenor Bideault, Matthieu Barbier, Arnaud Sentis,  
Michel Loreau & Dominique Gravel

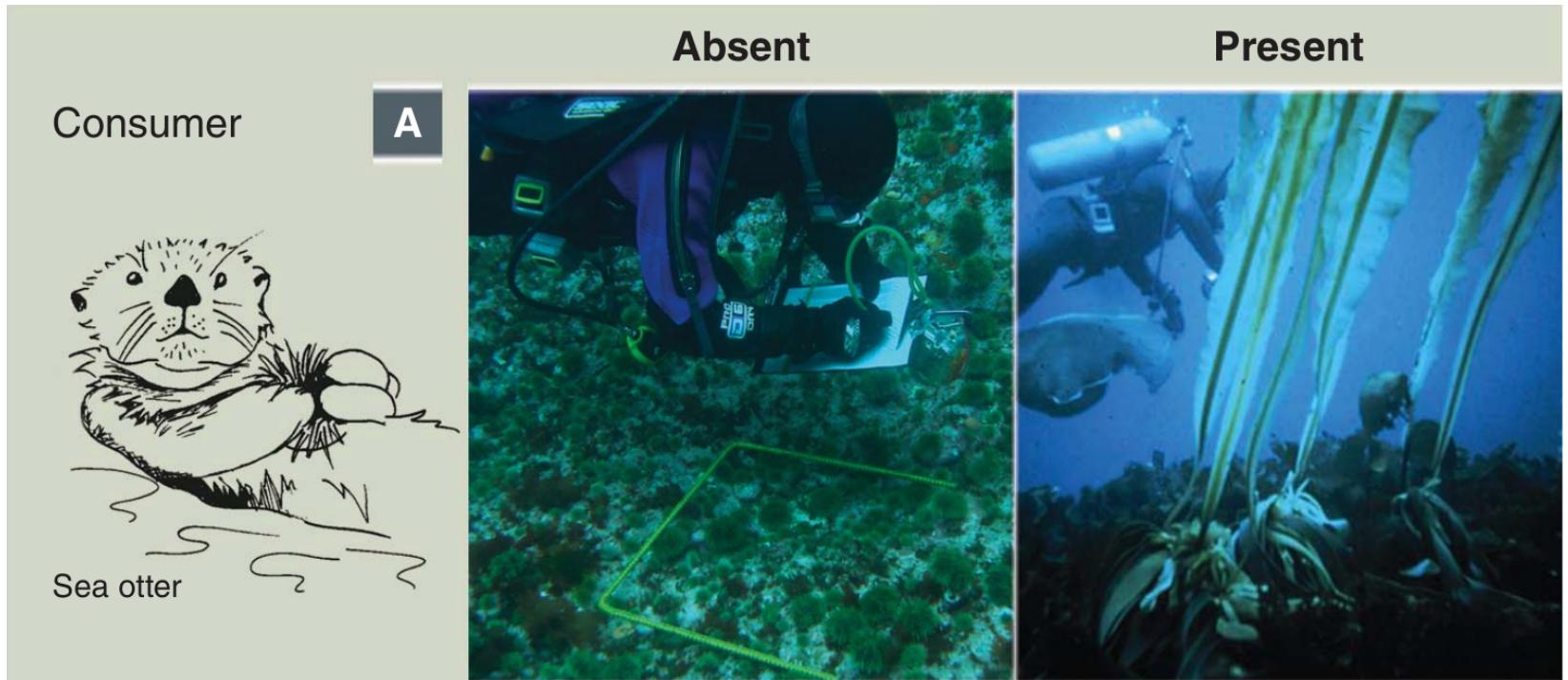
Azenor/talk\_Econet2021

@Azenor\_Bideault



# Trophic interactions

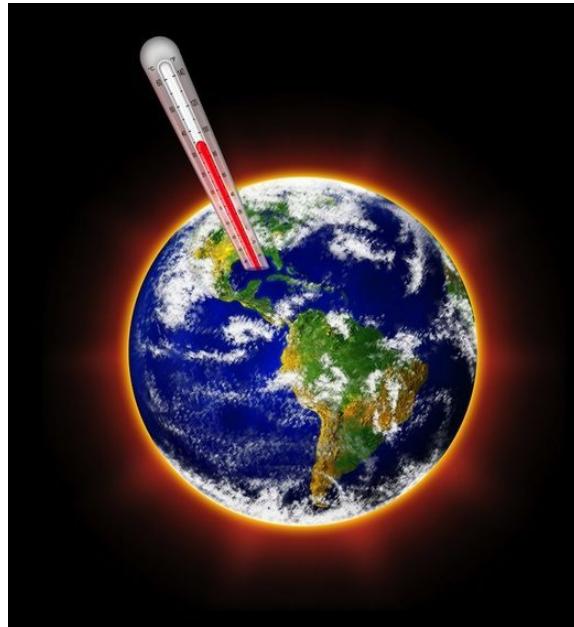
Are at the core of ecological systems



Trophic cascade : Sea otters indirectly enhance kelp abundance by consuming herbivorous sea urchins

# Temperature

Climate change

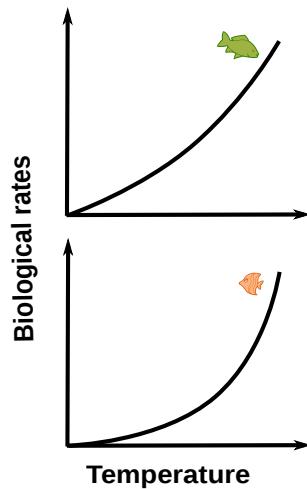
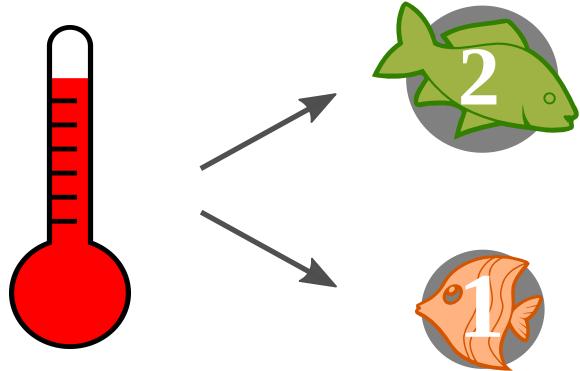


What are the effects of temperature ?

- Alter trophic control
- Decrease stability
- Trigger extinctions

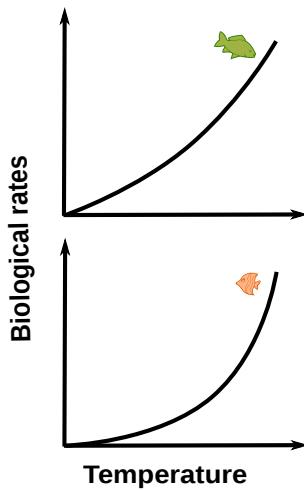
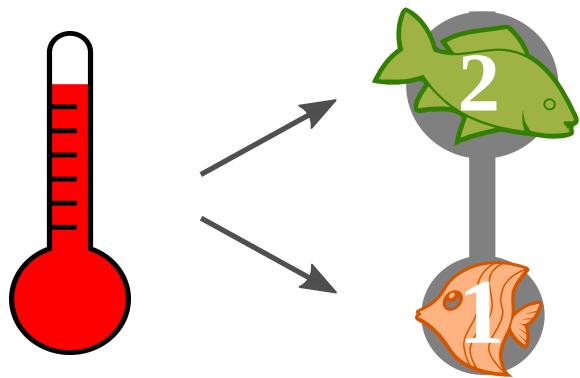
# Direct effect of temperature

On populations



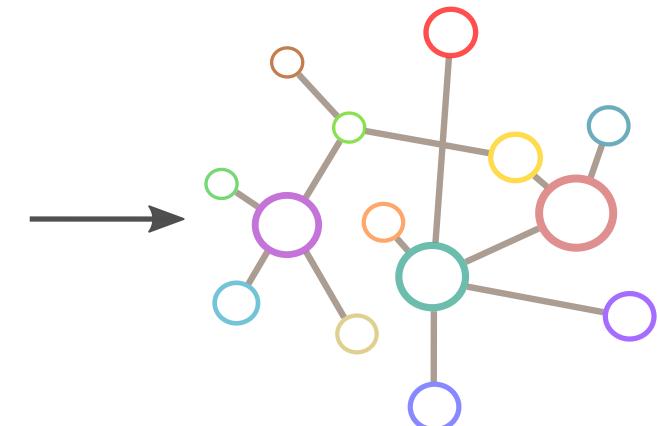
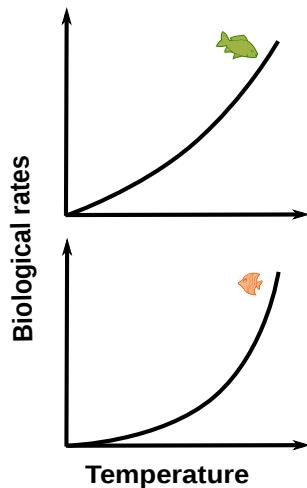
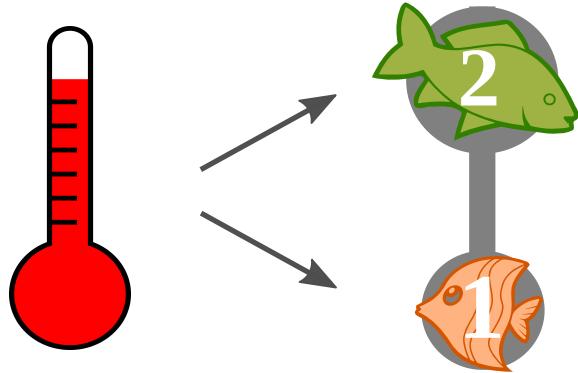
# Direct effect of temperature

On their interactions



# Effect of temperature

On the dynamics of food webs



*Dynamical properties*

# No synthetic understanding yet

Most studies explore :

- One particular ecological system
- Food chains (vs food webs)

with different

- experimental design
- study system
- theoretical framework
- model assumptions

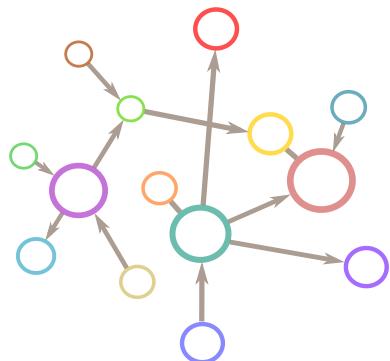
Hard to disentangle the various effects of temperature

How do they propagate from the populations to the community?

# Food webs dynamical properties

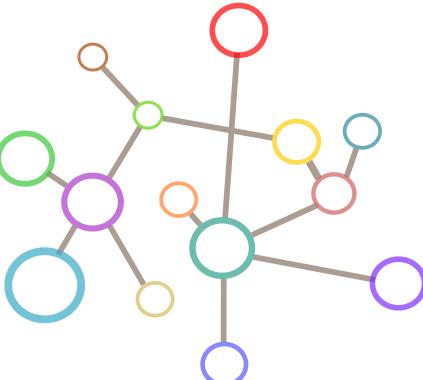
## Trophic control

Bottom-up vs top-down

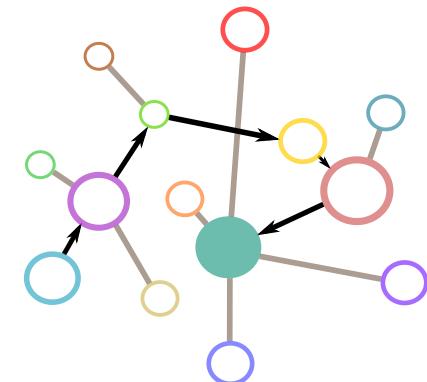


## Biomass change

Total biomass, species biomass, temporal variance



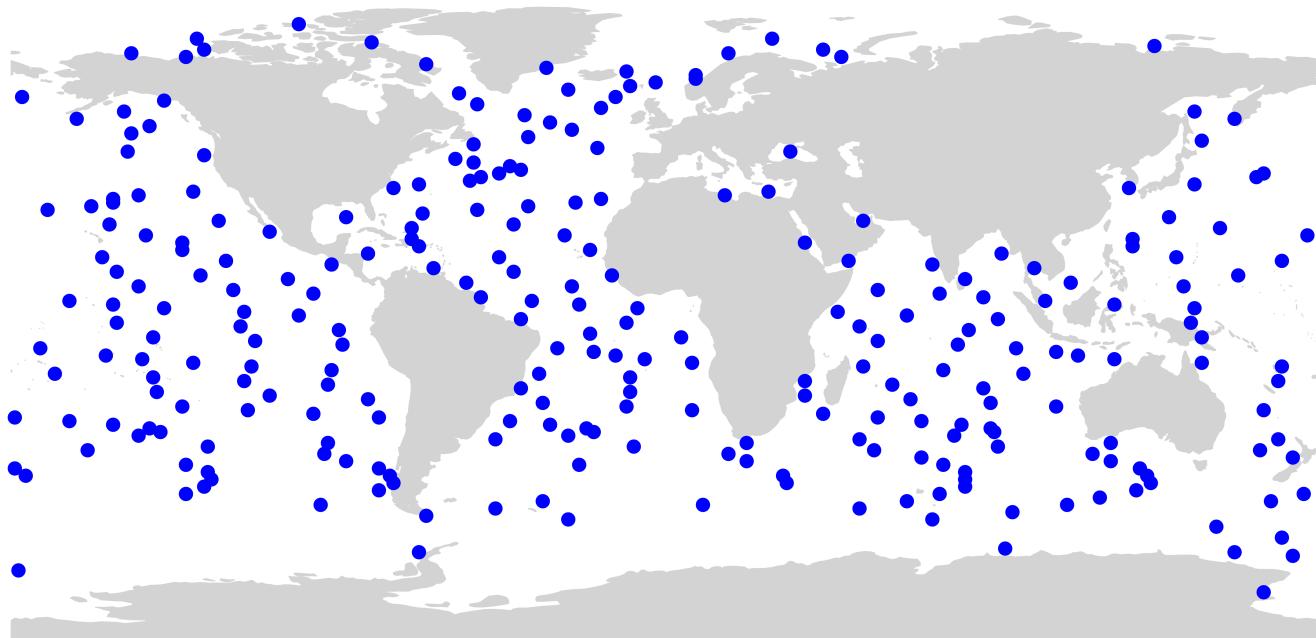
## Importance of indirect interactions



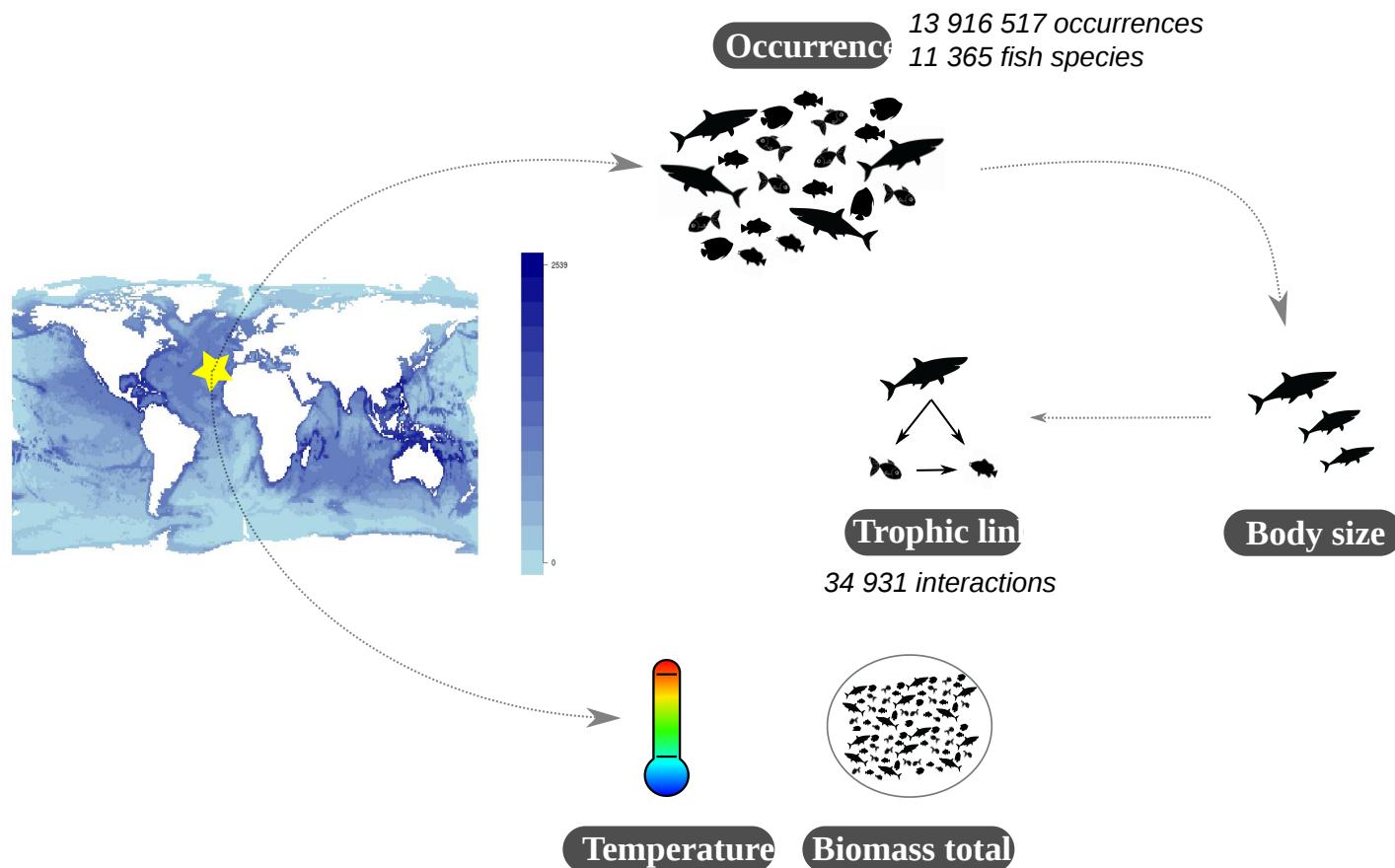
Effects of warming : compare changes in the dynamics at the community and species levels

# Method

# Fish food webs at large scale



# Data



# Theoretical approach

Modelling communities to infer their structural and dynamical properties

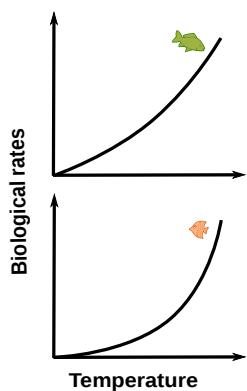
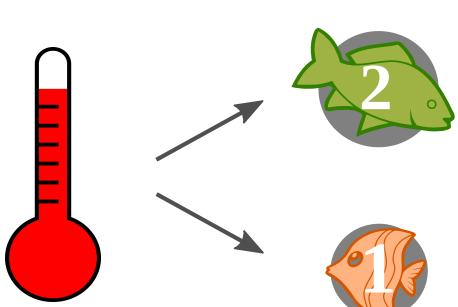
Lotka-Volterra system

$$\frac{dB_i}{dt} = \text{production} - \text{predation losses} - \text{internal losses}$$

$$\frac{dB_i}{dt} = g_i B_i + \sum_j \epsilon A_{ij} B_i B_j - \sum_k A_{ki} B_i B_k - D_i B_i^2$$

- $B$  biomass
- $A_{ij}$  interaction matrix
- $g_i$  net growth rate
- $D_i$  self regulation
- $\epsilon$  conversion efficiency

# Temperature and body-mass dependence of biological rates



$$b_i = m_i^\beta b_0 e^{-E/kT}$$

- $m$  body mass
- $\beta$  exponent
- $b_0, k$  constants
- $T$  temperature
- $E$  activation energy

Growth and attack rate

# Theoretical approach

Modelling communities to infer their structural and dynamical properties

Lotka-Volterra system

$$\frac{dB_i}{dt} = g_i + \sum_j \epsilon A_{ij} B_j - \sum_k A_{ki} B_k - D_i B_i$$

- $B$  biomass
- $A$  interaction matrix
- $g$  net growth rate
- $D$  self regulation
- $\epsilon$  conversion efficiency

# Self-regulation

An important but not well known parameter

## Intraspecific density dependent regulation

A population's growth rate is negatively affected by its own population density

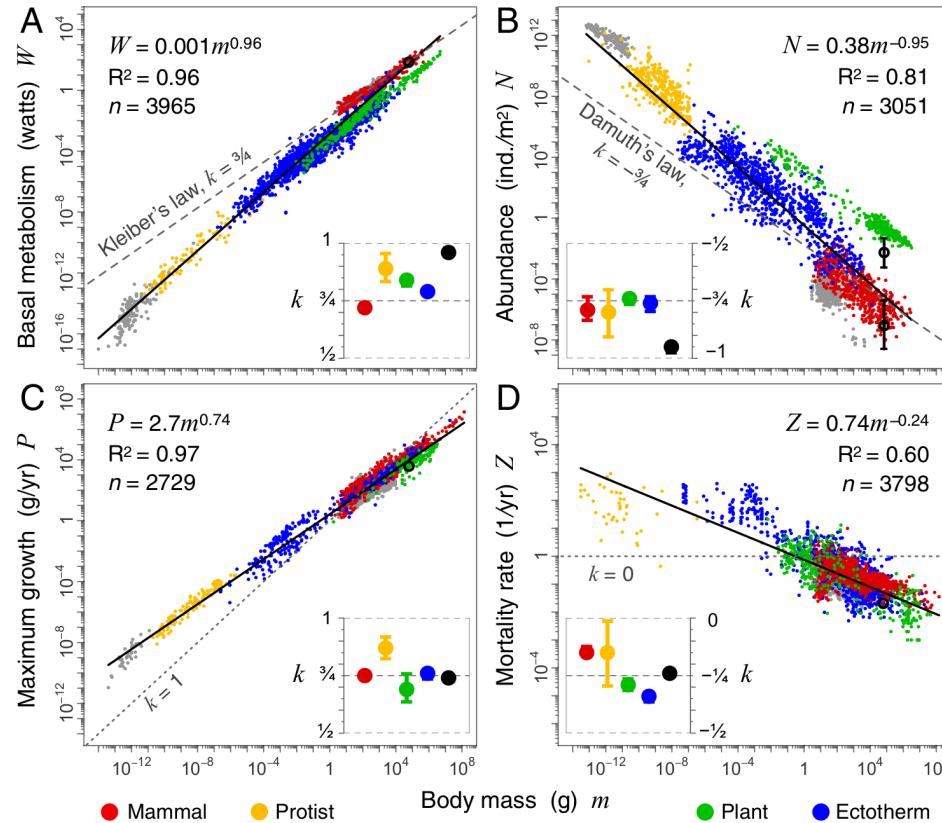
Examples :

- territoriality
- infanticide
- intra-guild predation
- competition for light

Important to match stability levels observed in nature

# Estimation of species biomass

Self-regulation is completely unknown...  
Biomass can be inferred from allometric relationship



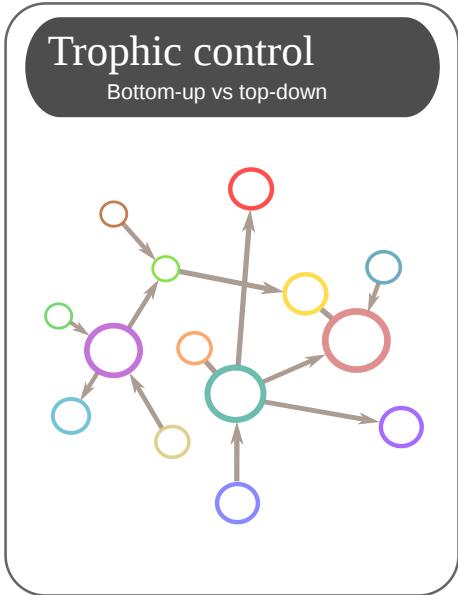
# Method to estimate self-regulation

$$\frac{dB_i}{dt} = g_i B_i + \sum_j \epsilon A_{ij} B_i B_j - \sum_k A_{ki} B_i B_k - D_i B_i^2$$

- using estimations of biological rates and biomass
- allow coexistence
- equilibrium

Simulate the dynamics of communities and measure some dynamical properties

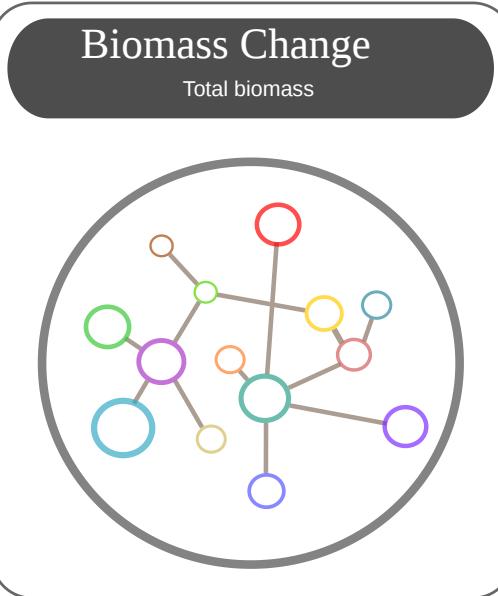
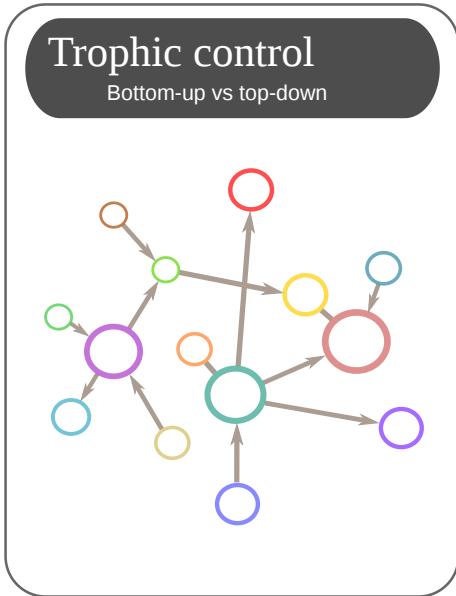
# Metrics of community dynamics



Trophic control (bottom-up vs top-down)

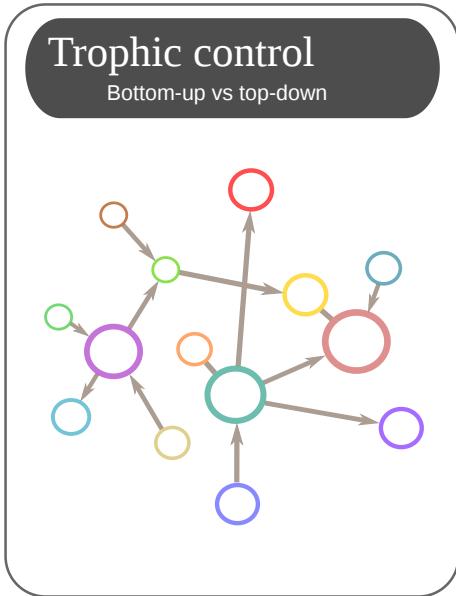
$$\lambda = \frac{\epsilon A_{21}^2}{D_1 D_2}$$

# Metrics of community dynamics



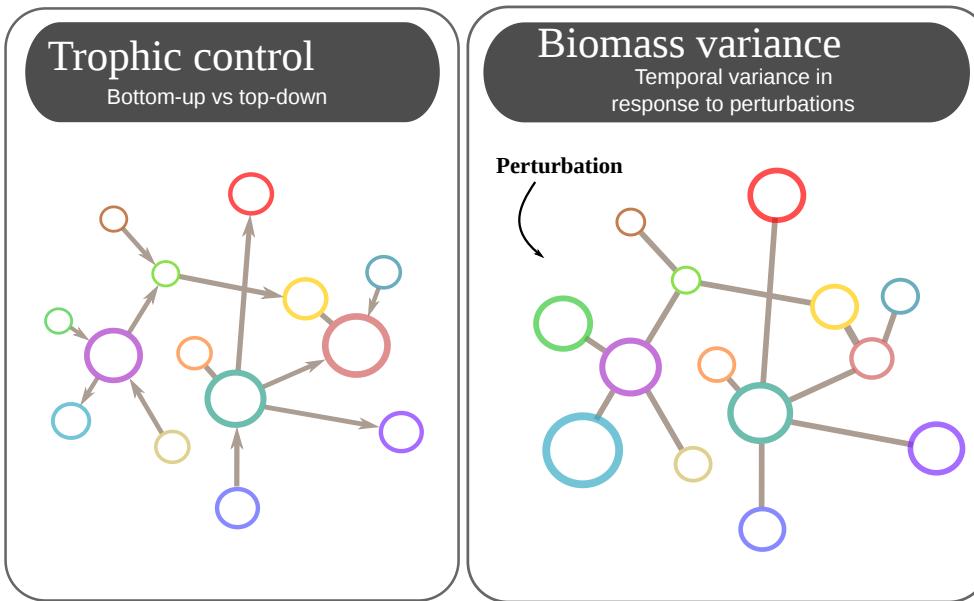
Sum species biomass

# Metrics of species dynamics



Relative change in species biomass

# Metrics of community dynamics

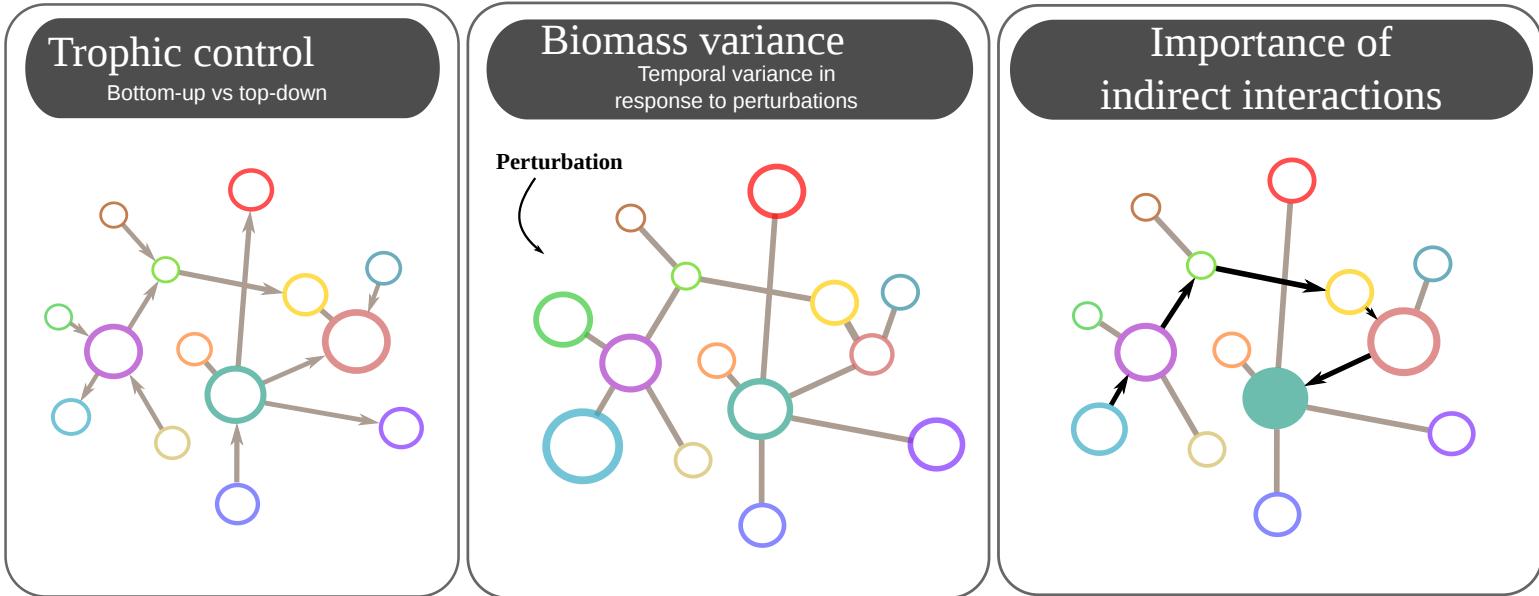


Variability : temporal biomass variance in response to stochastic perturbations  
(community average)

$$\mathcal{V} = \text{tr}(C)$$

$C$  covariance matrix, solution of the Lyapunov equation  $J\mathbf{C} + \mathbf{C}J^T = \mathbb{I}$  with  
 $J$  Jacobian matrix

# Measures of community dynamics

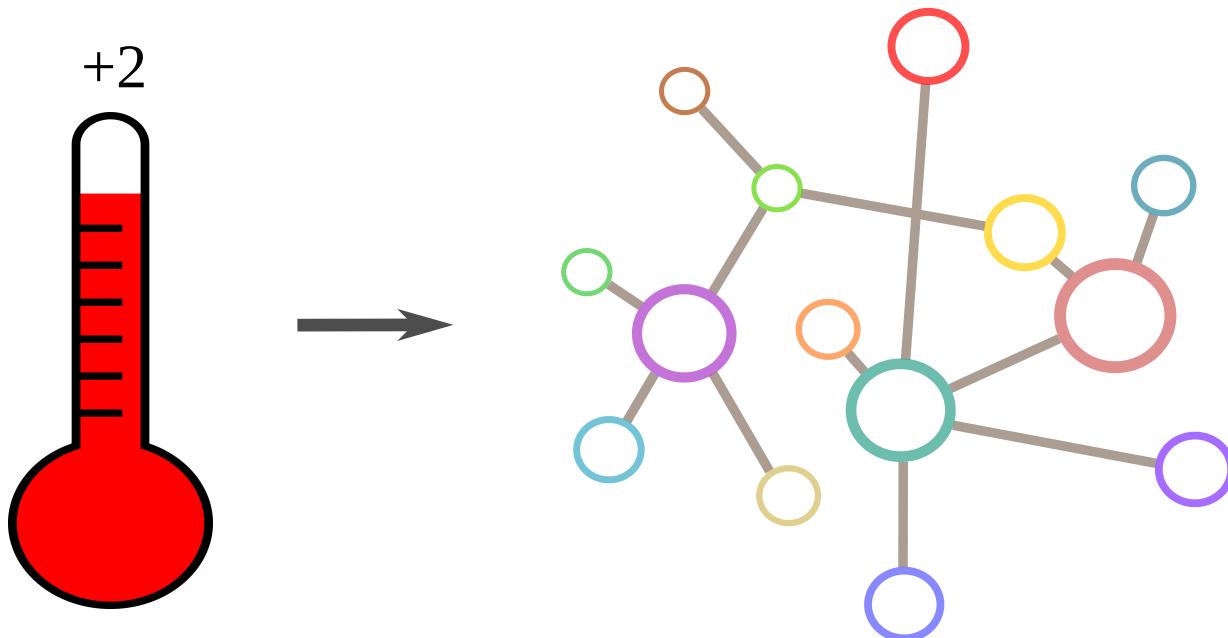


Collectivity : importance of indirect interactions (collectivity = 1, a change in species abundance affect other species far in the network)

$$\phi = \rho(M_{ij}) = \max_i |\lambda_i(M)|$$

spectral radius of  $M_{ij} = A_{ij}/D_i$ ,  $\lambda_i(M)$  is the ith eigenvalue of matrix  $M$

# Simulate warming



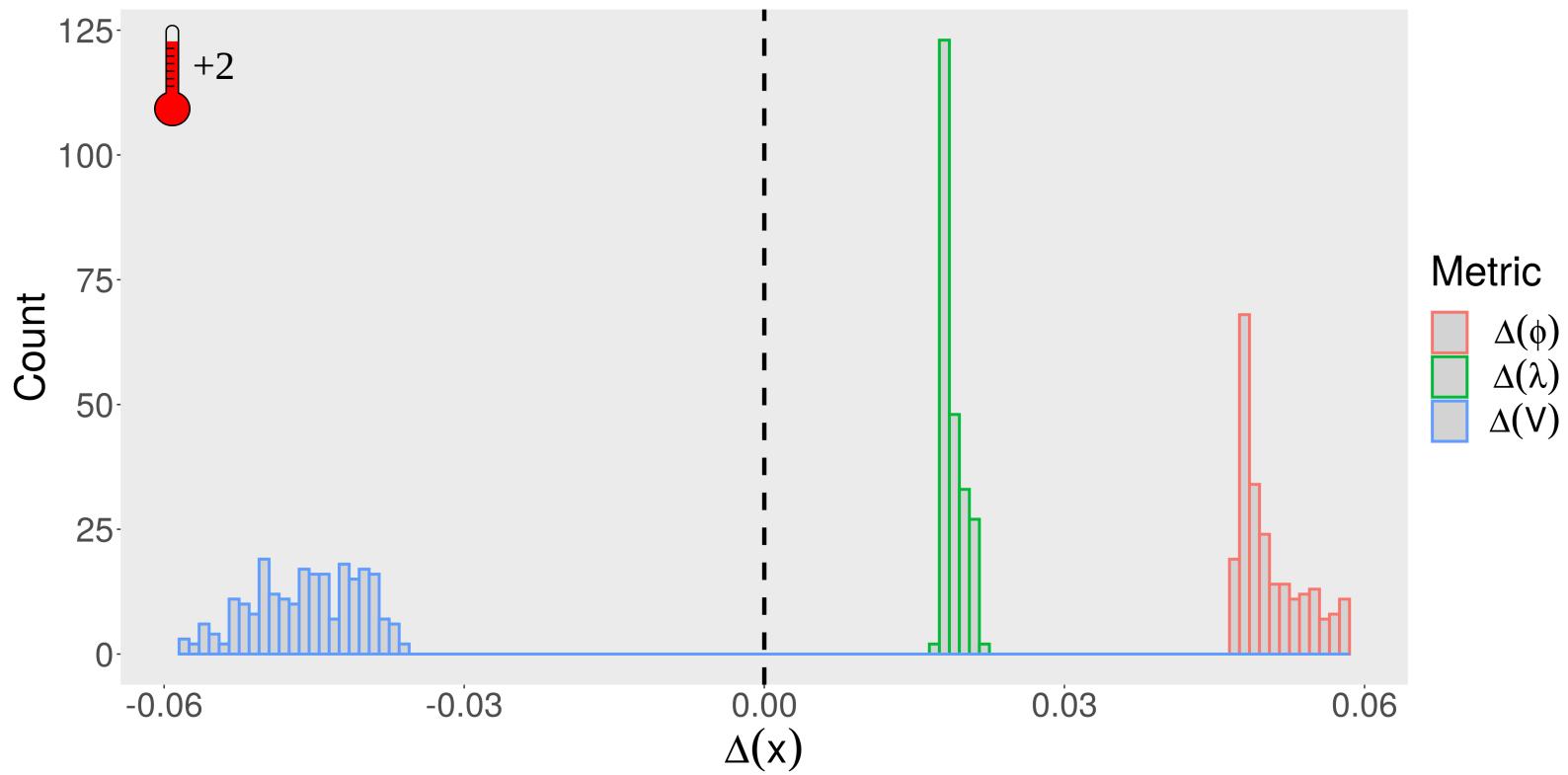
- Direct effect of warming on species biological rates
- Compute the relative change in community metrics

$$\Delta(x) = \log_{10}(x_{\text{warm}}) - \log_{10}(x) \approx (x_{\text{warm}} - x)/x$$

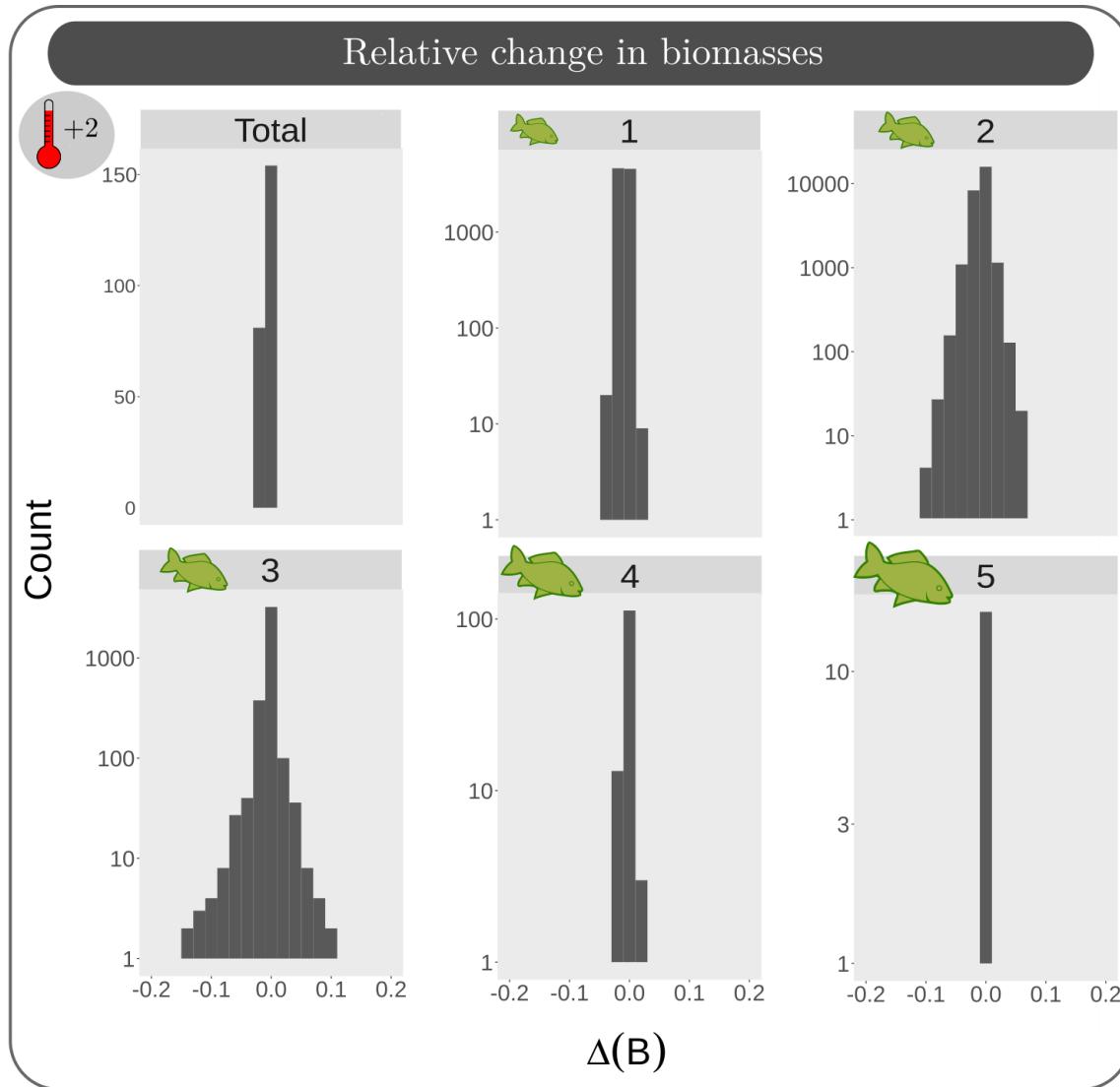
# Results

# Moderate effect on community properties

Relative change in the metrics of community dynamics



# Strong effect at the species level



# To conclude

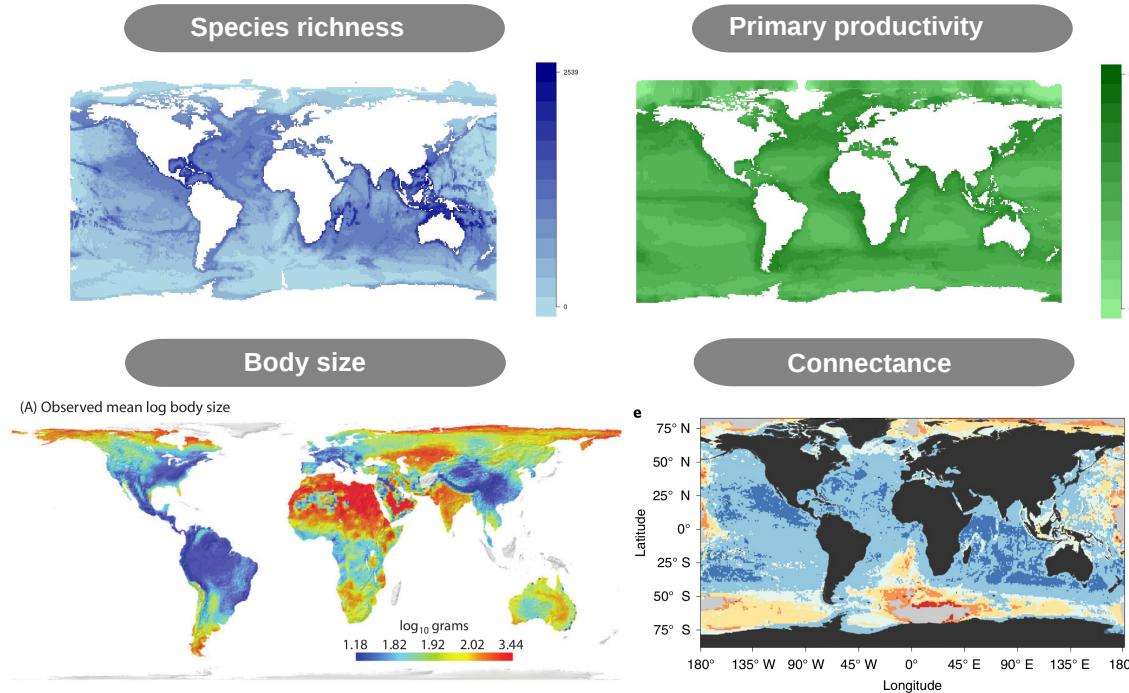
Warming affects individual species more significantly than communities as an entity

- Moderate increase in top-down control and collectivity and decrease in variability
- Stronger variation in species biomass, especially species from trophic levels 2 and 3

Focus on direct effect of temperature on biological rates and interactions

# Entangled effects of temperature

Apply the framework to identify latitudinal variation in trophic control, variability and collectivity



Other variables drive variation in community dynamics  
Indirect effects of warming

Stronger impact of warming at the species level than at the community level



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FOR BIODIVERSITY  
SCIENCE



Special thanks to

- You for listening
- My collaborators and supervisors
- Will for the nice template