Warming impacts in fish food web dynamics

Econet 2021

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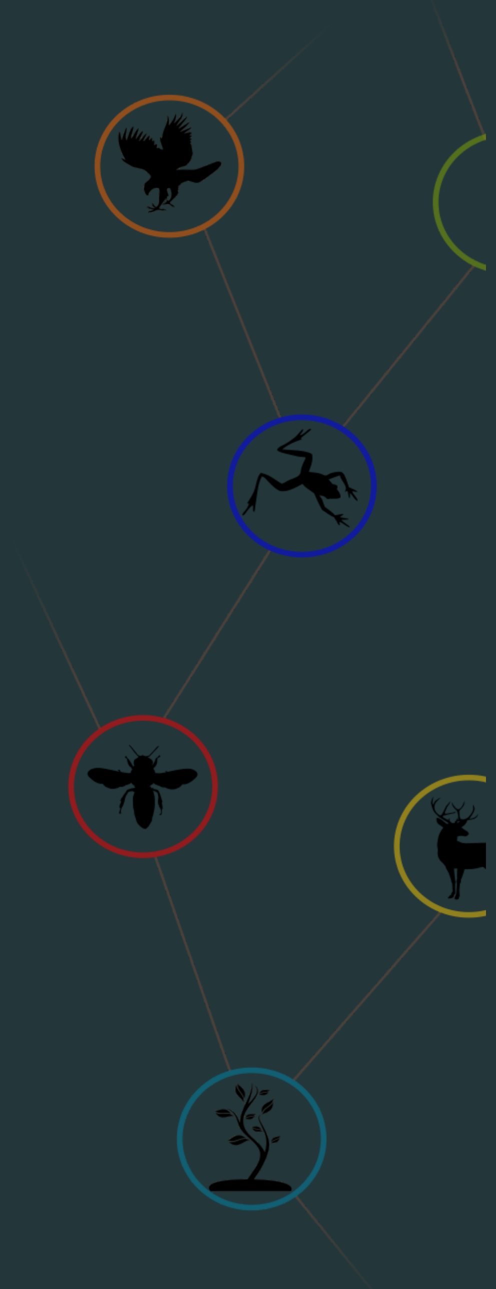
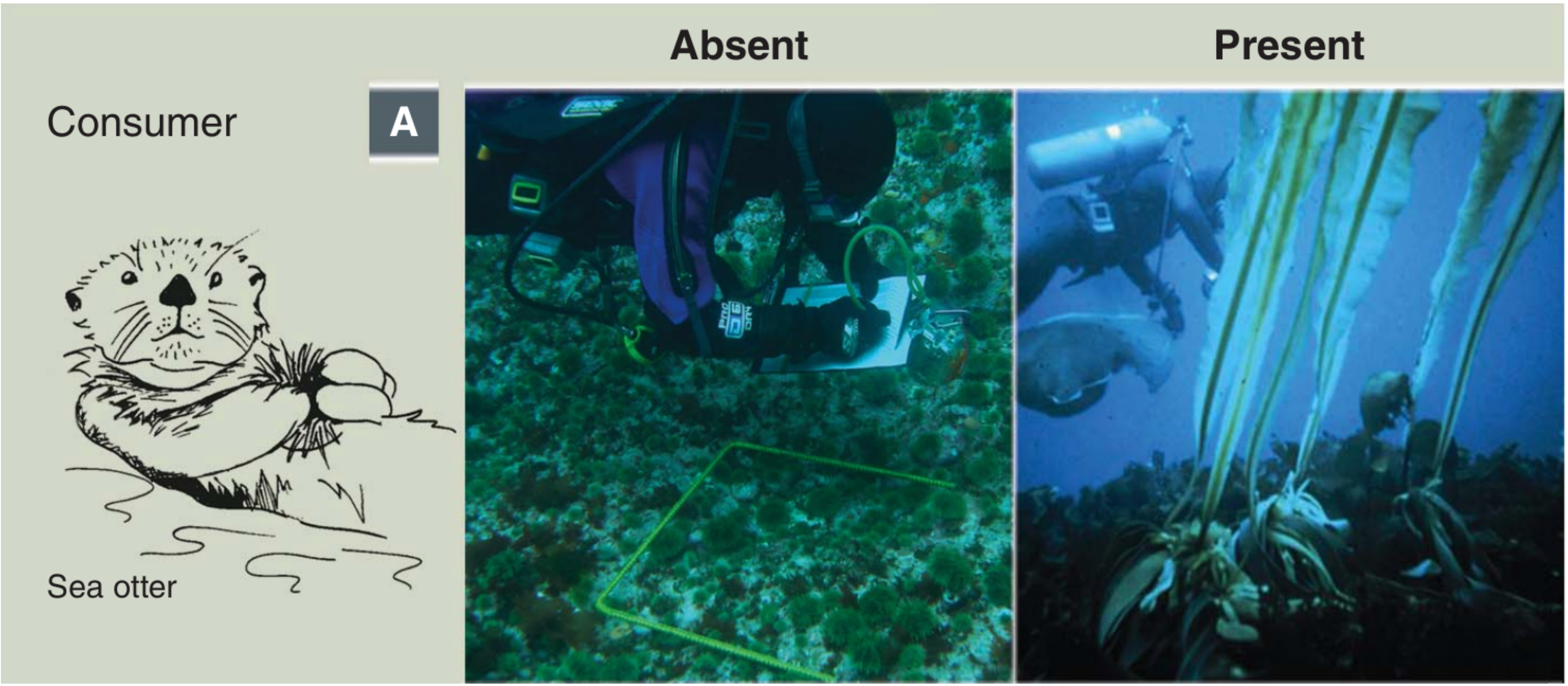
Azenor/talk_Econet2021

@Azenor_Bideault



Trophic interactions

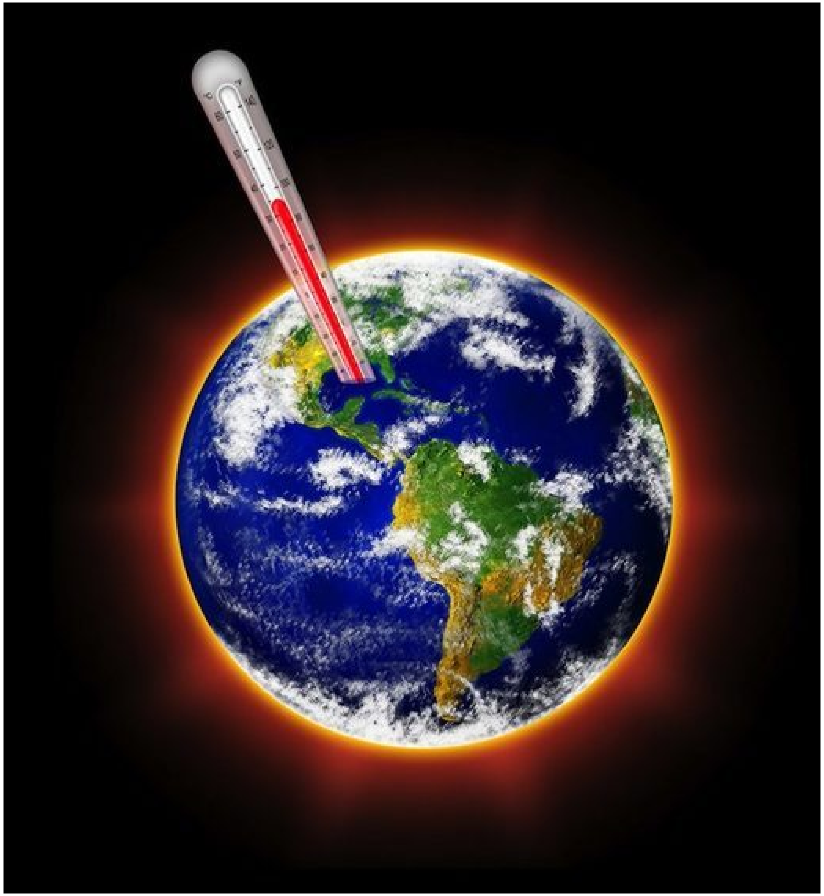
Are at the core of ecological systems



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

Temperature

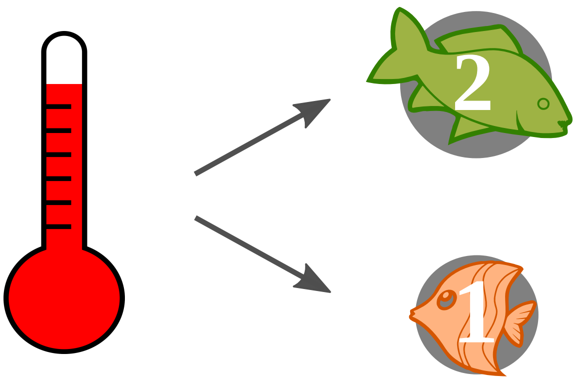
Climate change

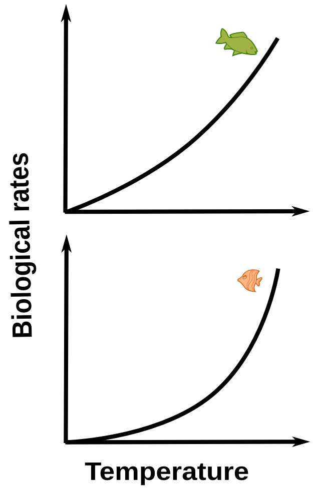


What are the effects of temperature ?

Direct effect of temperature

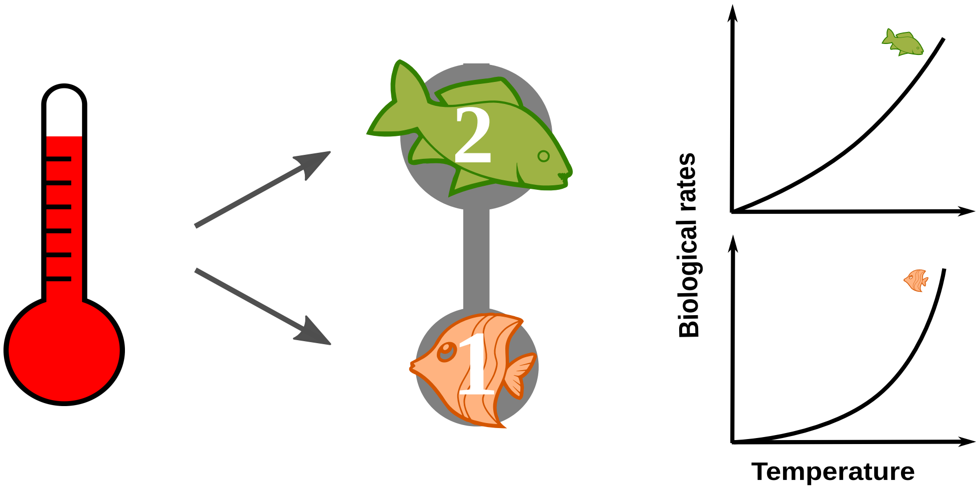
On populations





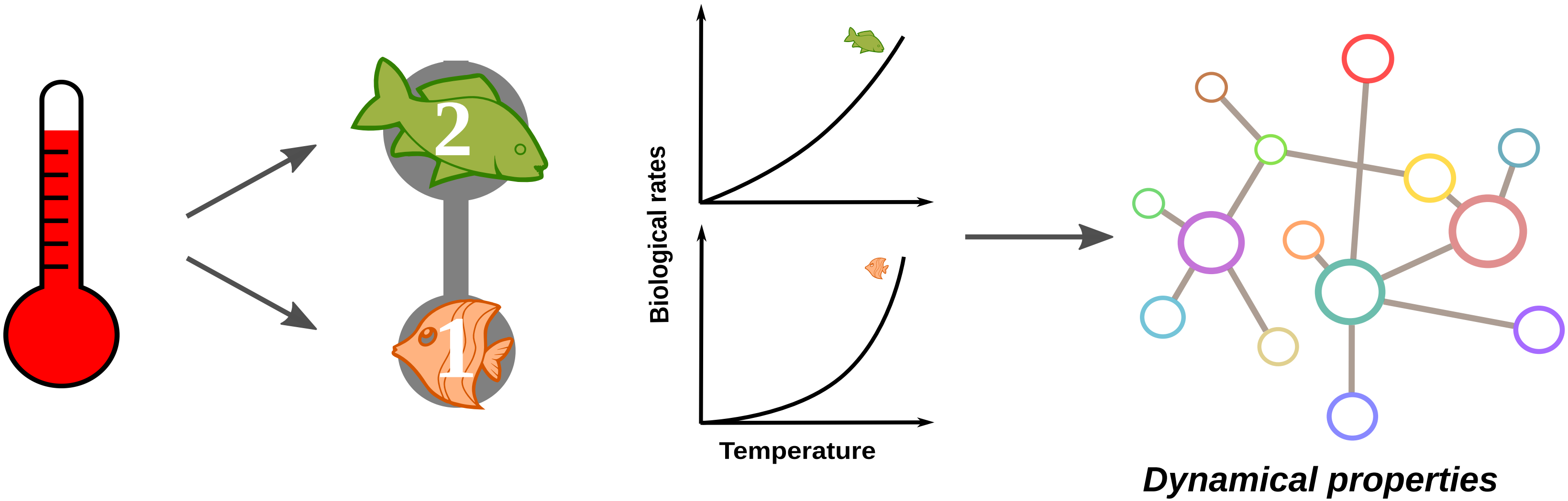
Direct effect of temperature

On their interactions



Effect of temperature

On the dynamics of food webs



- Alter trophic control
- Decrease stability
- Trigger extinctions

No synthetic understanding yet

Most studies explore :

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

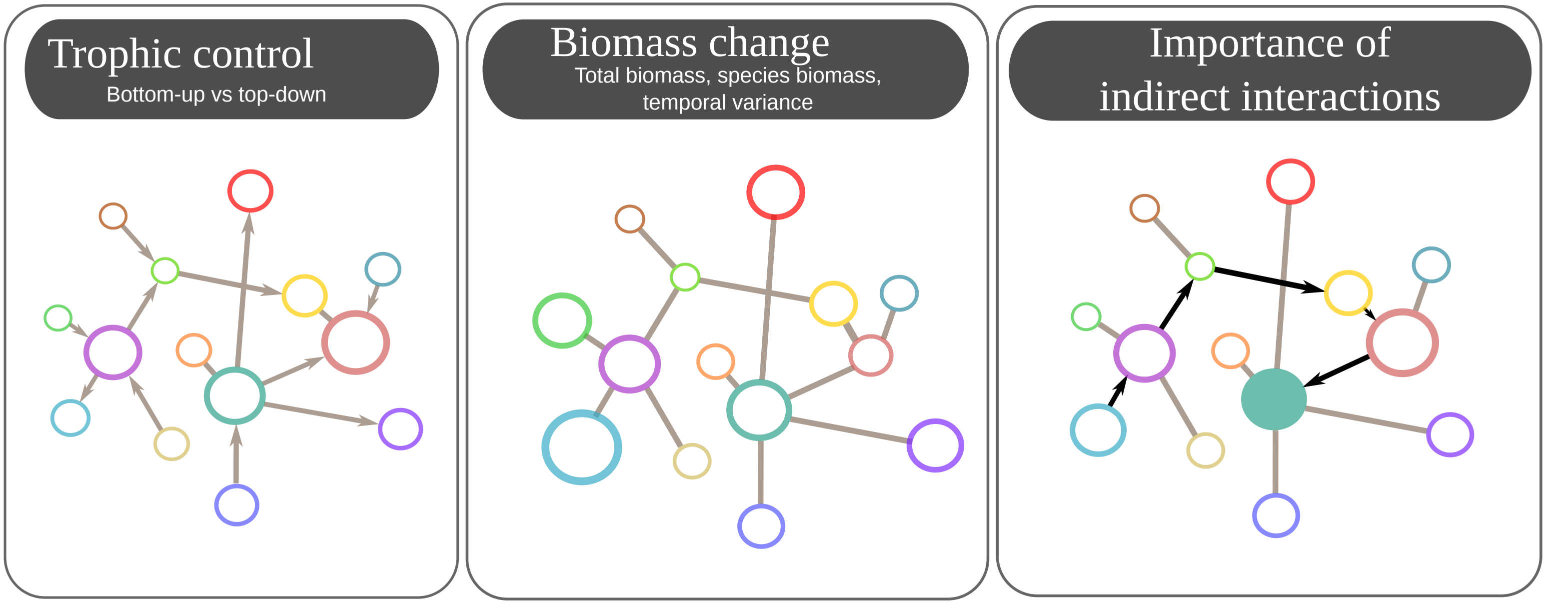
with different

- 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?

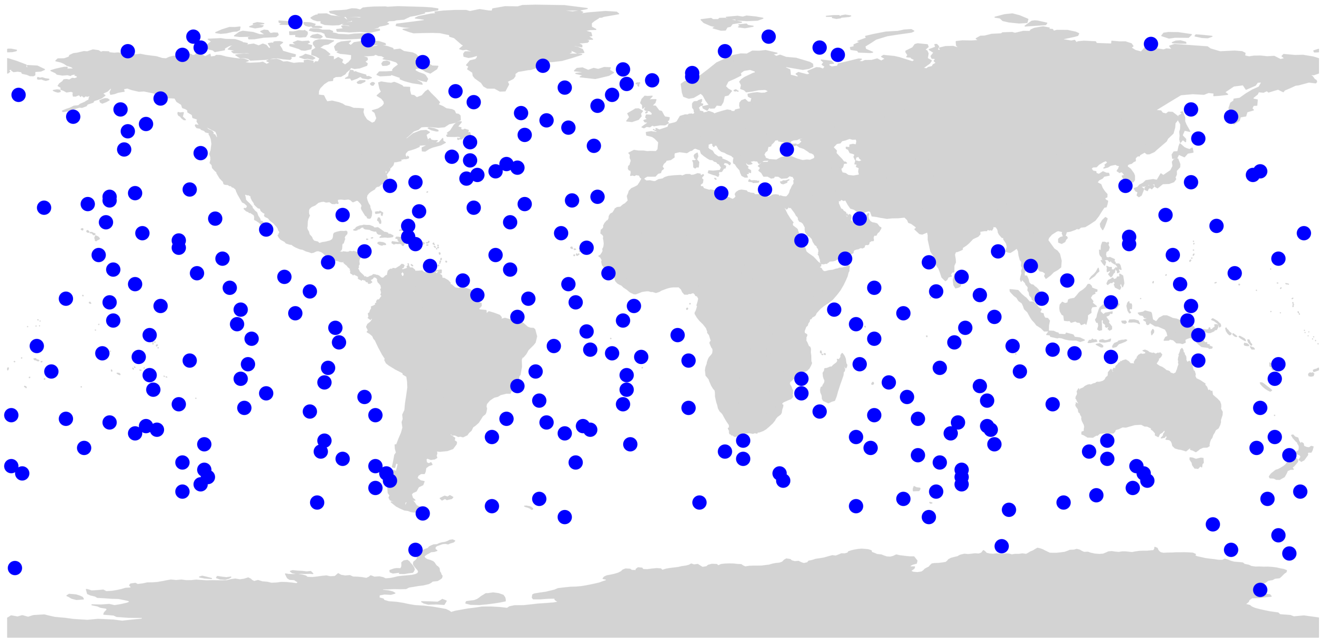
Food webs dynamical properties



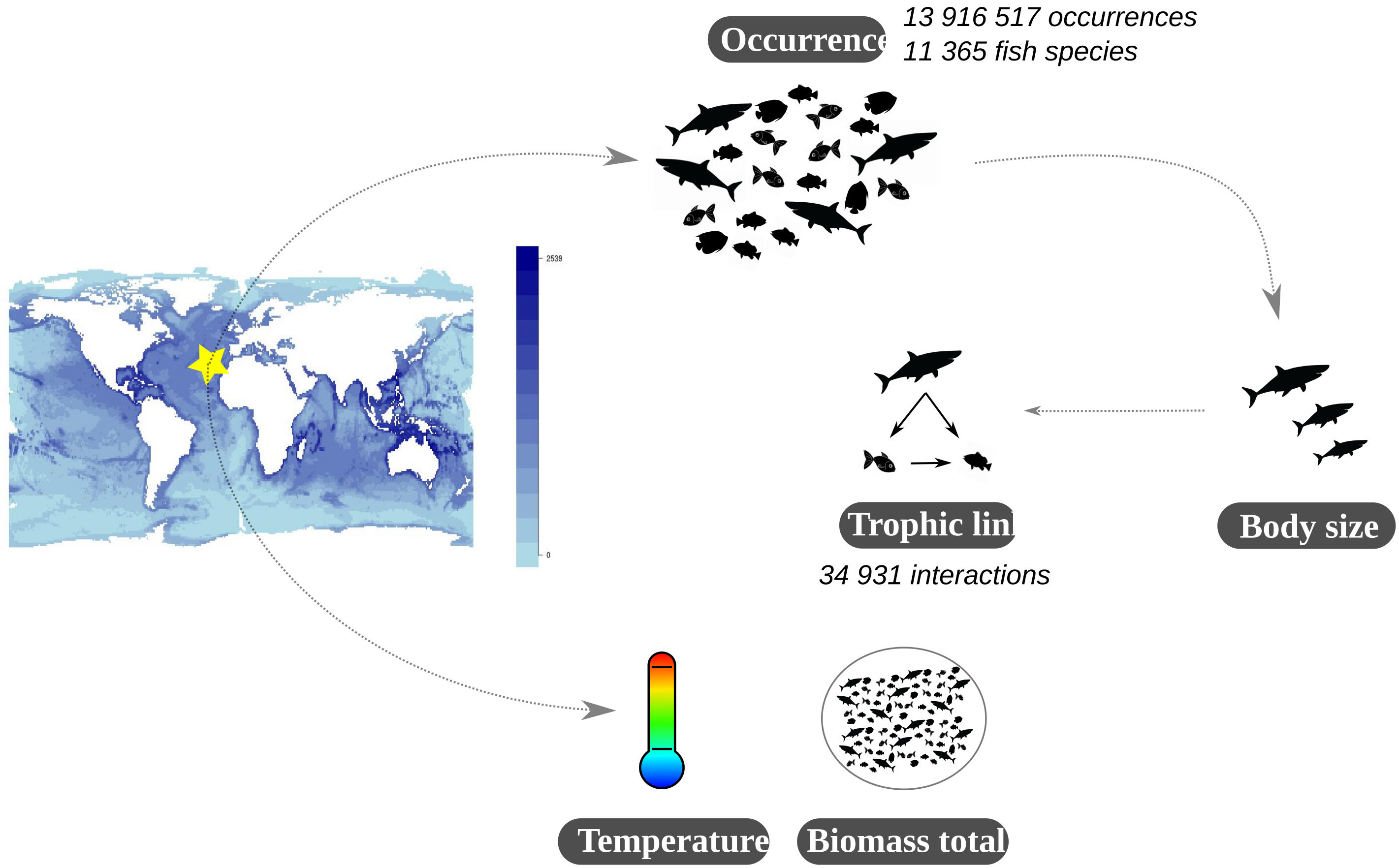
Effects of warming : compare changes in the dynamics at the community and species levels

Method

Fish food webs at large scale



Data



Occurrence
13 916 517 occurrences
11 365 fish species
2539
0
Trophic lin
34 931 interactions
Body size
Temperature
Biomass total

Theoretical approach

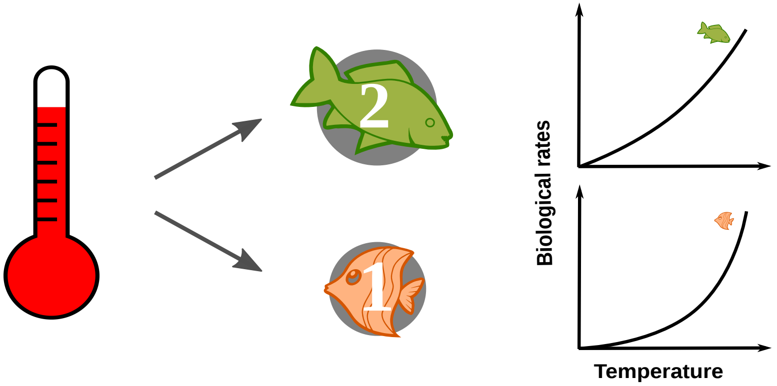
Modelling communities to infer their structural and dynamical properties

Lotka-Volterra system

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

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

Temperature and body-mass dependence of biological rates



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

- m body mass
- β exponent
- b_0, k constants
- T temperature
- E activation energy

Growth and attack rate

Savage et al [2004], Li et al [2018]

Theoretical approach

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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

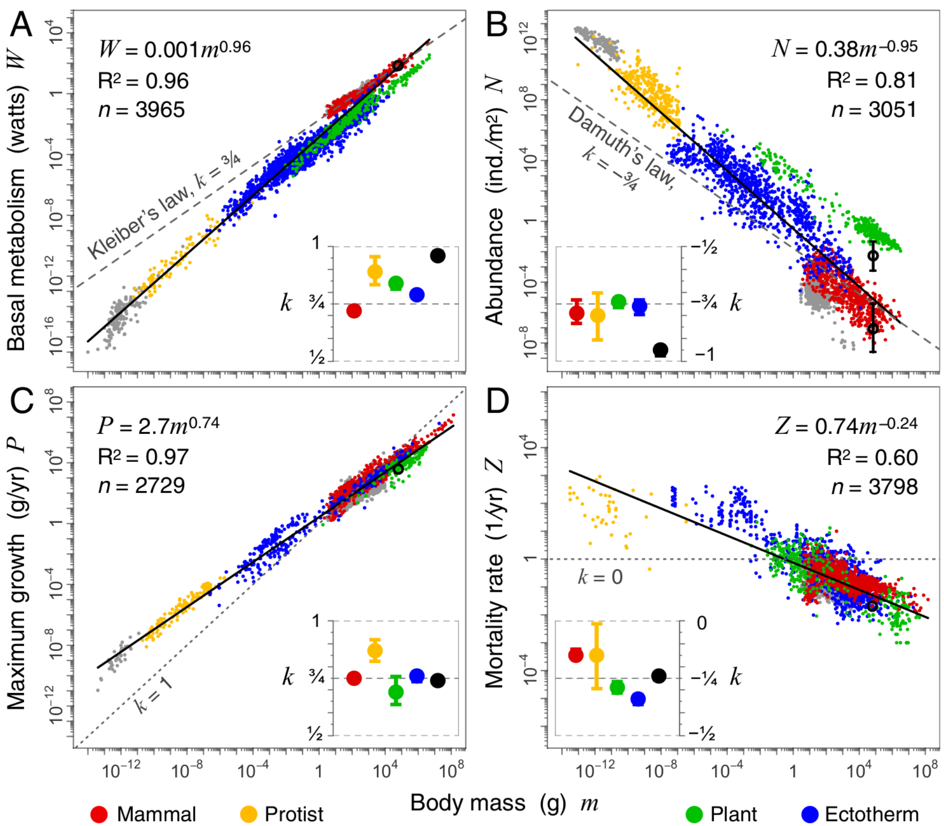
Examples :

- 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



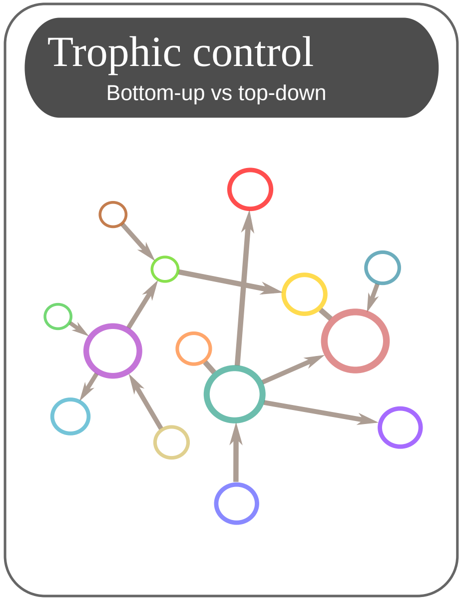
Method to estimate self-regulation

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

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

Simulate the dynamics of communities and measure some dynamical properties

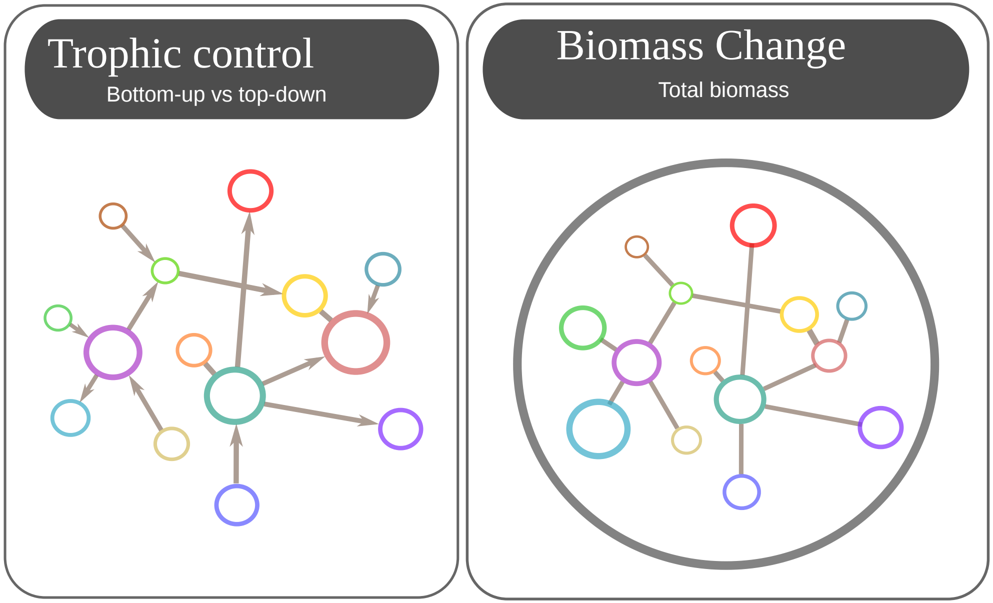
Metrics of community dynamics



Trophic control (bottom-up vs top-down)

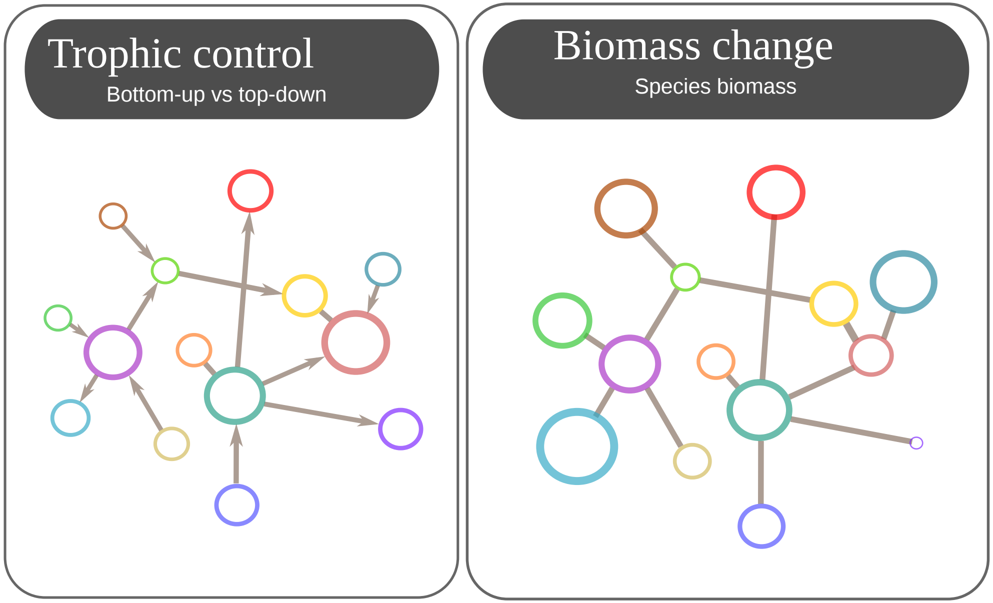
$$\lambda = \frac{\epsilon A_{21}^2}{D_1 D_2}$$

Metrics of community dynamics



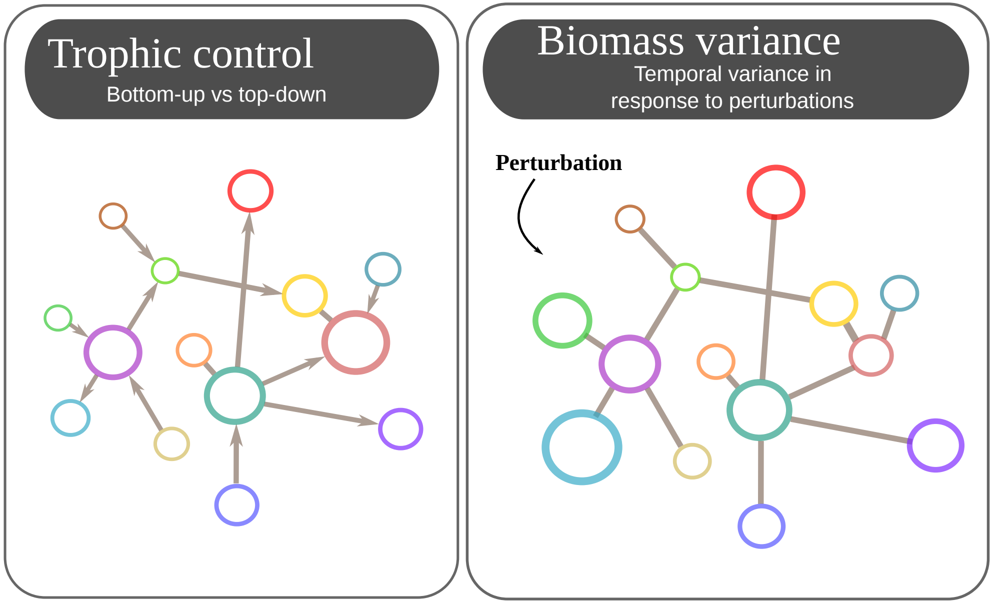
Sum species biomass

Metrics of species dynamics



Relative change in species biomass

Metrics of community dynamics



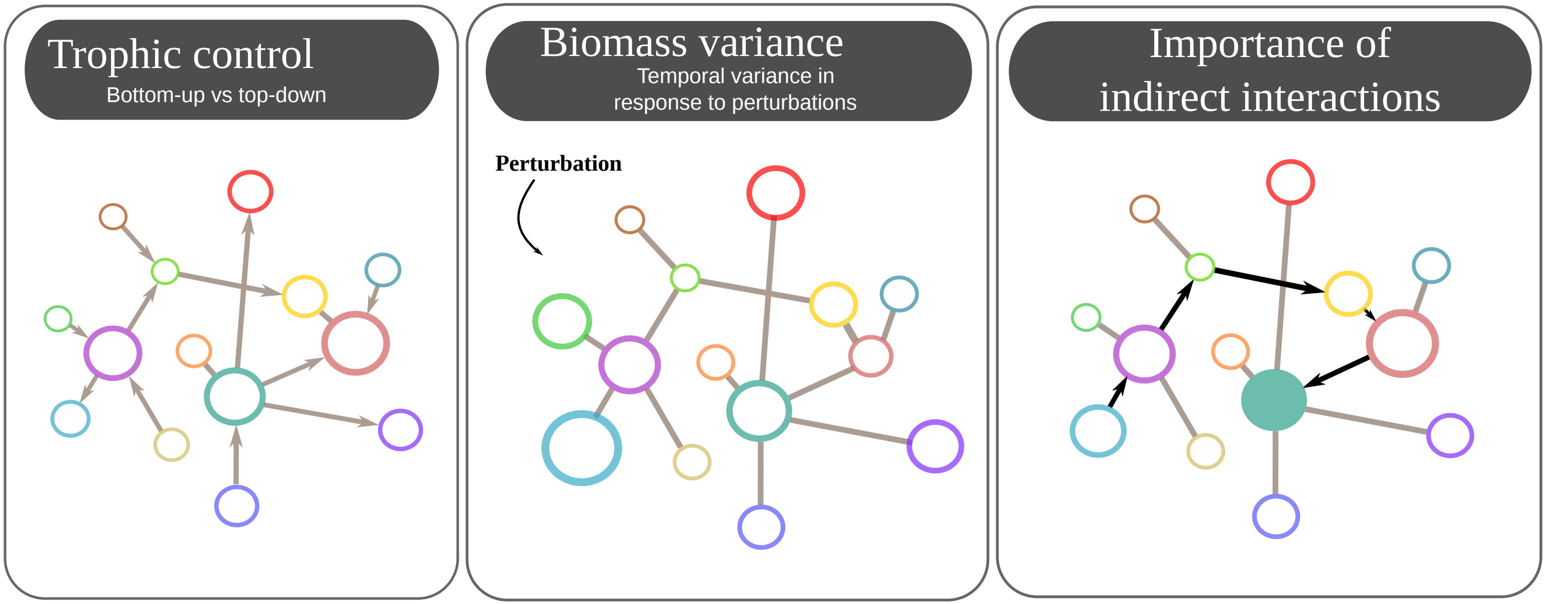
Variability : temporal biomass variance in response to stochastic pertubations (community average)

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

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

Arnoldi et al [2019]

Measures of community dynamics



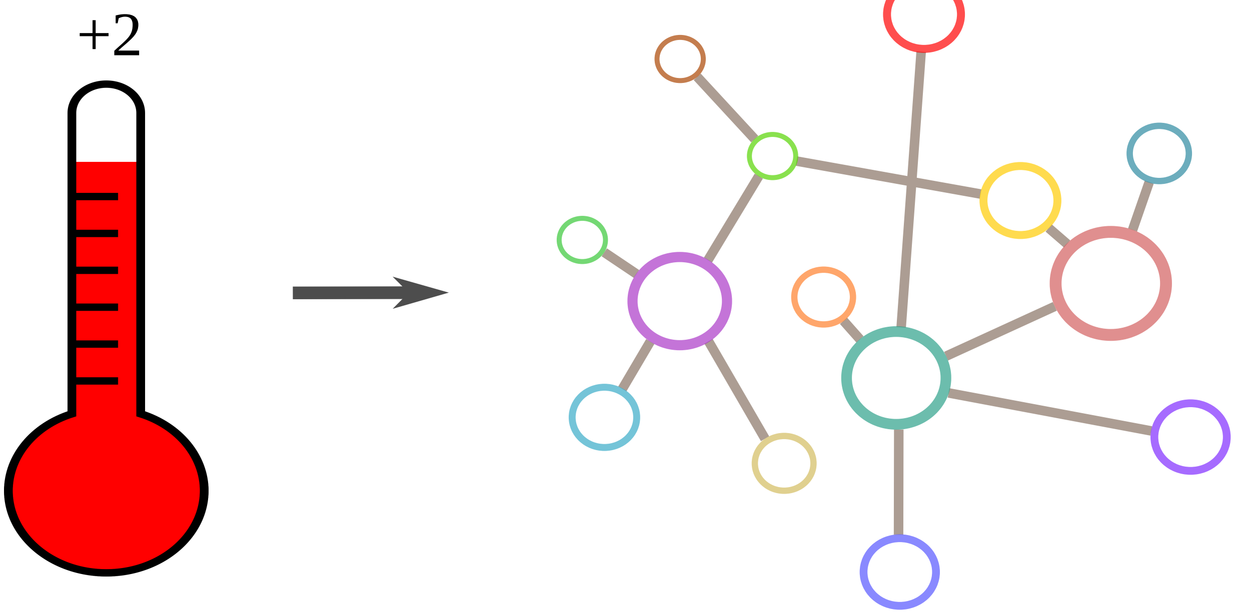
Collectivity : importance of indirect interactions (collectivity = 1, a change in species abundance affect other species far in the network)

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

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

Arnoldi et al [in prep]

Simulate warming



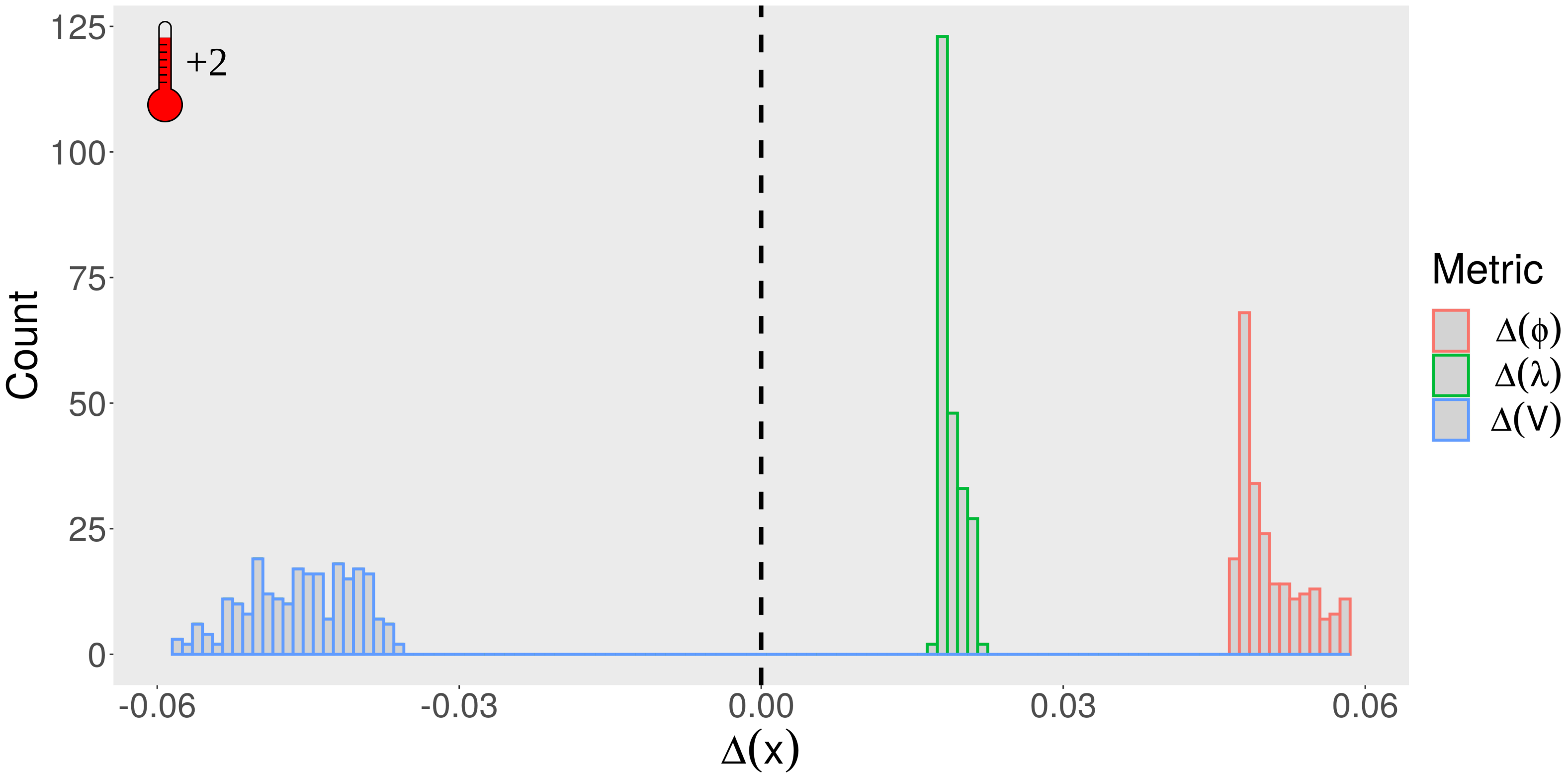
- Direct effect of warming on species biological rates
- Compute the relative change in community metrics

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

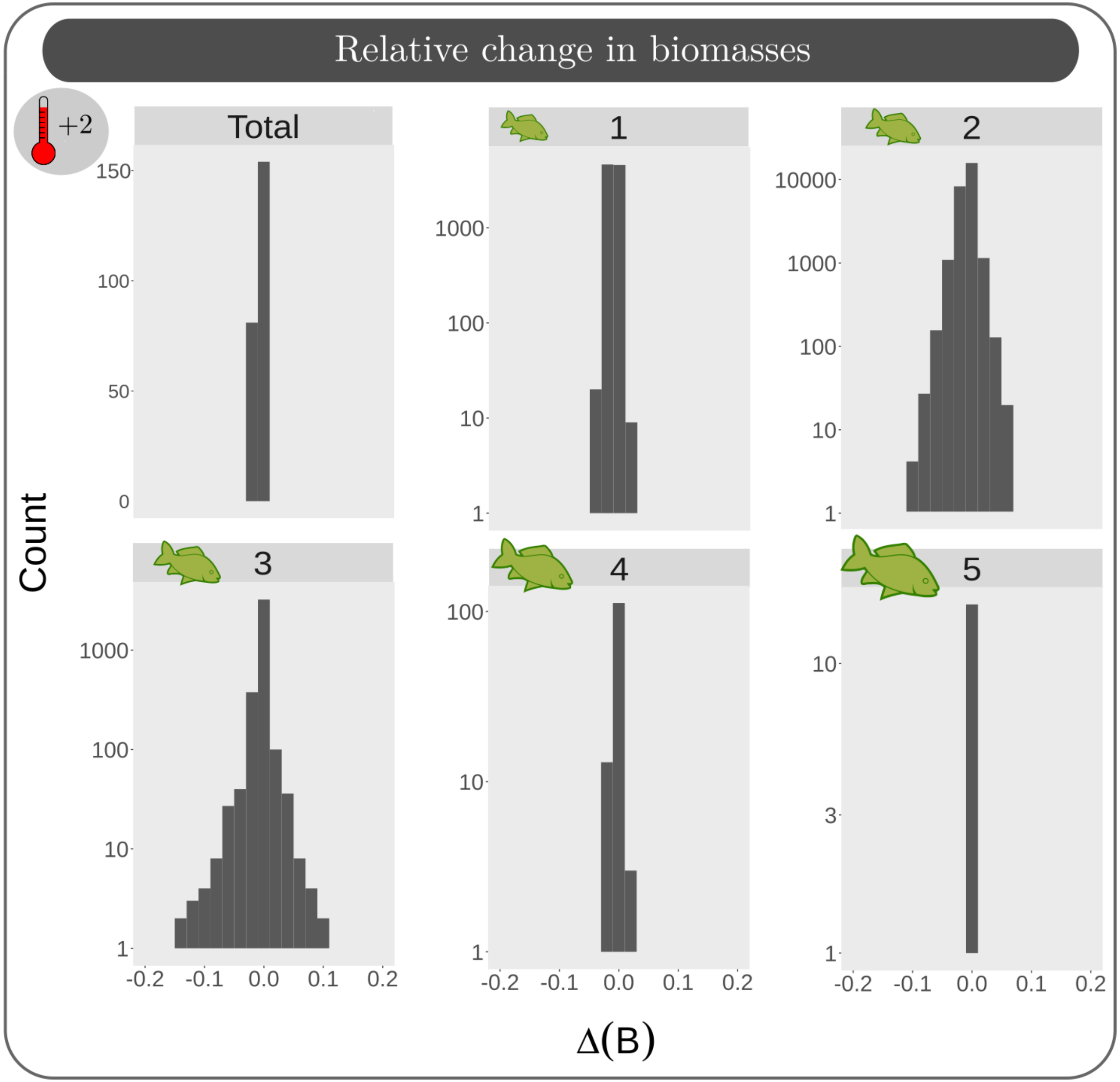
Results

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

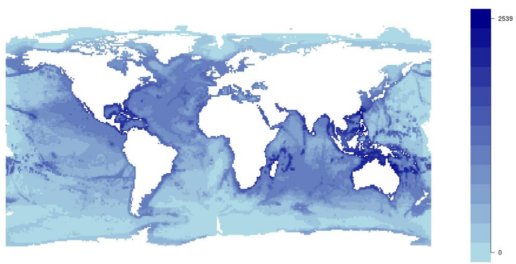
- Moderate increase in top-down control and collectivity and decrease in variability
- Stronger variation in species biomass, especially species from trophic levels 2 and 3

Focus on direct effect of temperature on biological rates and interactions

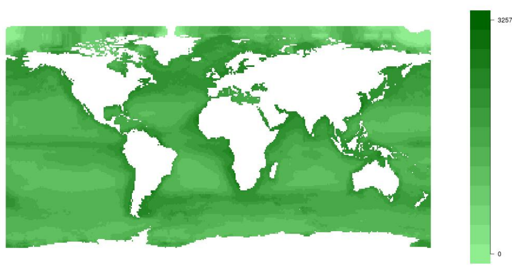
Entangled effects of temperature

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

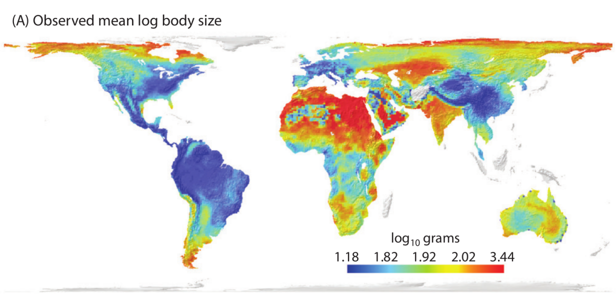
Species richness



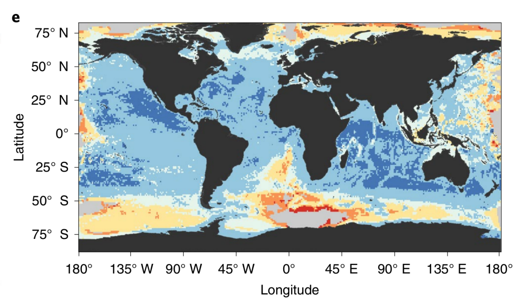
Primary productivity



Body size



Connectance



Other variables drive variation in community dynamics
Indirect effects of warming

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

Special thanks to

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