

# Species diversity, food web structure and the temporal stability of ecosystems: bridging the gap between theory and data?

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# The links between diversity, food web complexity and stability: a long standing interest in theoretical ecology

## ➤ Diversity, connectance and stability

Fluctuations of Animal Populations and a Measure of Community Stability

Author(s): Robert MacArthur

Source: *Ecology*, Vol. 36, No. 3 (Jul., 1955), pp. 533-536

### **Will a Large Complex System be Stable?**

[ROBERT M. MAY](#)

[Nature](#) **238**, 413–414 (1972) | [Cite this article](#)

### **Foraging Adaptation and the Relationship Between Food-Web Complexity and Stability**

Michio Kondoh


*Science* **299**. 1388 (2003):

### **Generalized Models Reveal Stabilizing Factors in Food Webs**

Thilo Gross, *et al.*

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## ➤ Food chain length and stability

### Number of trophic levels in ecological communities

[S. L. PIMM](#) & [J. H. LAWTON](#)

[Nature](#) **268**, 329–331 (1977) | [Cite this article](#)

### Structural asymmetry and the stability of diverse food webs

Neil Rooney<sup>1</sup>, Kevin McCann<sup>1</sup>, Gabriel Gellner<sup>1</sup> & John C. Moore<sup>2</sup>

### Stability trophic cascades in food chains

David W. Shanafelt<sup>1,2</sup> and Michel Loreau<sup>1</sup>

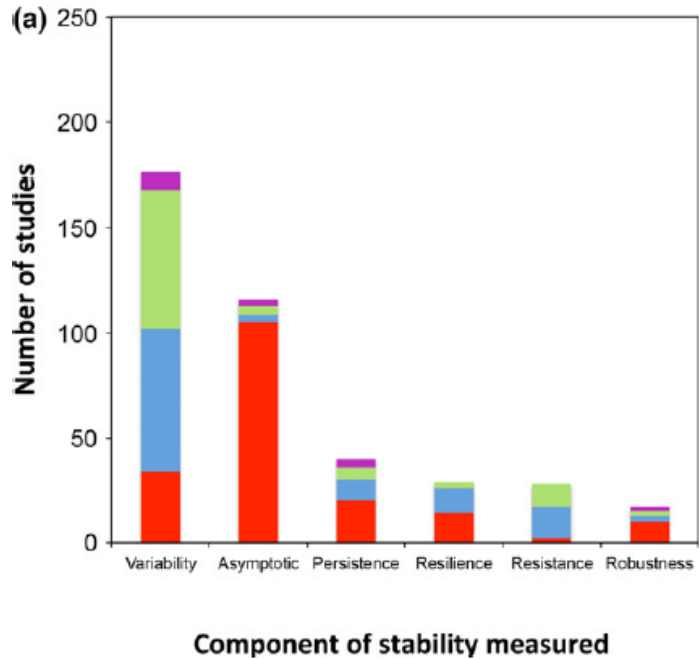
*Ecology Letters*, (2019) **22**: 1152–1162

doi: 10.1111/ele.13282

### Horizontal and vertical diversity jointly shape food web stability against small and large perturbations

Zhao et al.

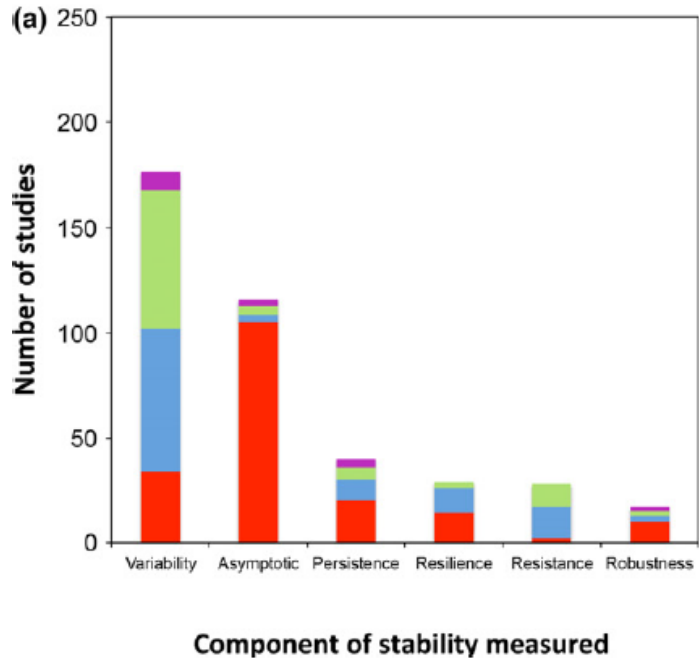
# Many definitions of stability & disconnection between theory and experiments/observations



■ Studies combining theory and an empirical component  
■ Observational studies ■ Experimental studies ■ Theoretical studies

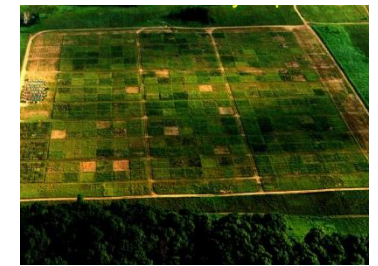
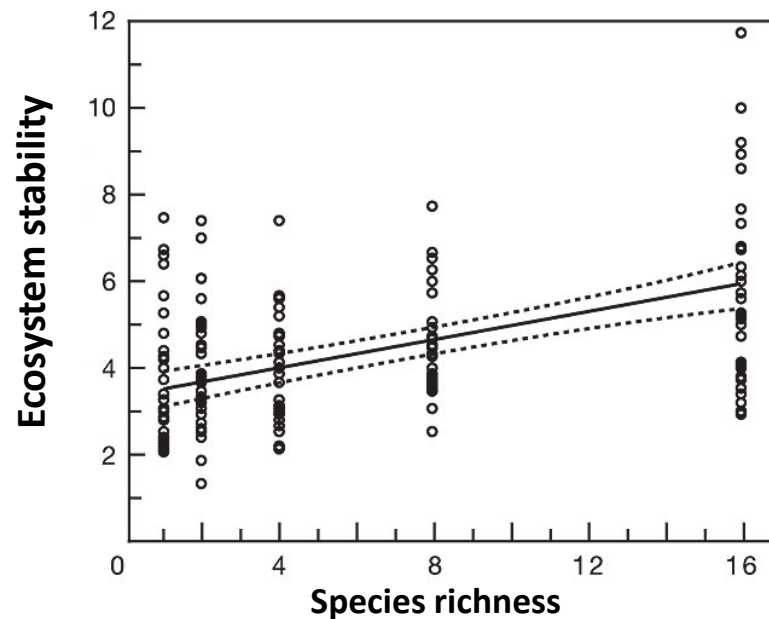
Donohue et al. (2016)

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Donohue et al. (2016)



Tilman et al. (2006)

**Biodiversity and ecosystem stability: a synthesis of underlying mechanisms**

Michel Loreau ✉ Claire de Mazancourt

First published: 24 January 2013 | <https://doi.org/10.1111/ele.12073> | Citations: 758

# Biodiversity and ecosystem stability: still a need to develop the food web perspective?

- The relationship between diversity and ecosystem functioning often focus on plant communities and taxa within a trophic level, ignoring food web structure
- Recent advances to include food web perspective on the links between diversity and ecosystem functions, but less so for stability of ecosystem functions

## Towards an Integration of Biodiversity–Ecosystem Functioning and Food Web Theory to Evaluate Relationships between Multiple Ecosystem Services

Jes Hines<sup>\*,†,1</sup>, Wim H. van der Putten<sup>‡,§</sup>, Gerlinde B. De Deyn<sup>†</sup>, Cameron Wagg<sup>||</sup>, Winfried Voigt<sup>†</sup>, Christian Mulder<sup>†\*</sup>, Wolfgang W. Weisser<sup>††</sup>, Jan Engel<sup>††</sup>, Carlos Melian<sup>††</sup>, Stefan Scheu<sup>§§</sup>, Klaus Birkhofer<sup>†\*</sup>, Anne Ebeling<sup>†</sup>, Christoph Scherber<sup>||,##</sup>, Nico Eisenhauer<sup>\*,†</sup>

Hines et al. (2015)

## Opinion

### Energy Flux: The Link between Multitrophic Biodiversity and Ecosystem Functioning

Andrew D. Barnes<sup>1,2,3,\*</sup>, Malte Jochum<sup>4</sup>, Jonathan S. Lefcheck<sup>5</sup>, Nico Eisenhauer<sup>1,2</sup>, Christoph Scherber<sup>3</sup>, Mary I. O'Connor<sup>6</sup>, Peter de Ruiter<sup>7,8</sup> and Ulrich Brose<sup>1,9</sup>

Barnes et al. (2017)

## ARTICLE

Received 17 Nov 2014 | Accepted 27 Jul 2016 | Published 5 Oct 2016

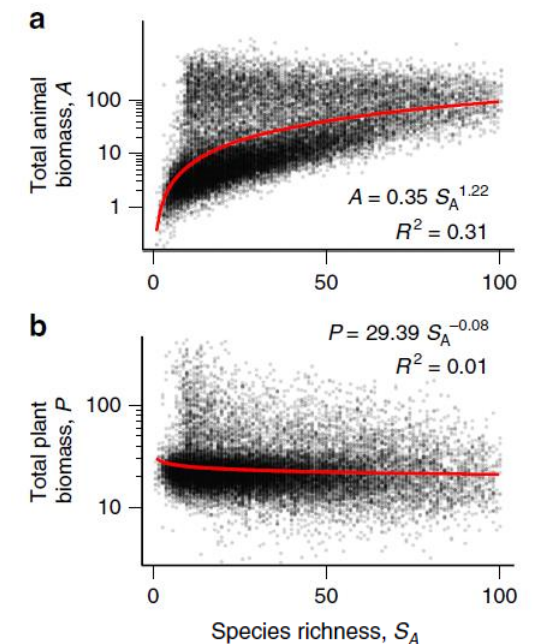
DOI: 10.1038/ncomms12718

OPEN

### Animal diversity and ecosystem functioning in dynamic food webs

Florian D. Schneider<sup>1,2</sup>, Ulrich Brose<sup>3,4</sup>, Björn C. Rall<sup>3,4</sup> & Christian Guill<sup>5,6</sup>

Schneider et al. (2016)



# Biodiversity and ecosystem stability: still a need to develop the food web perspective?

- A modelling approach



Jérôme Eschenbrenner

- Empirical relations using long-term data on stream fishes



Alain Danet



Maud Mouchet

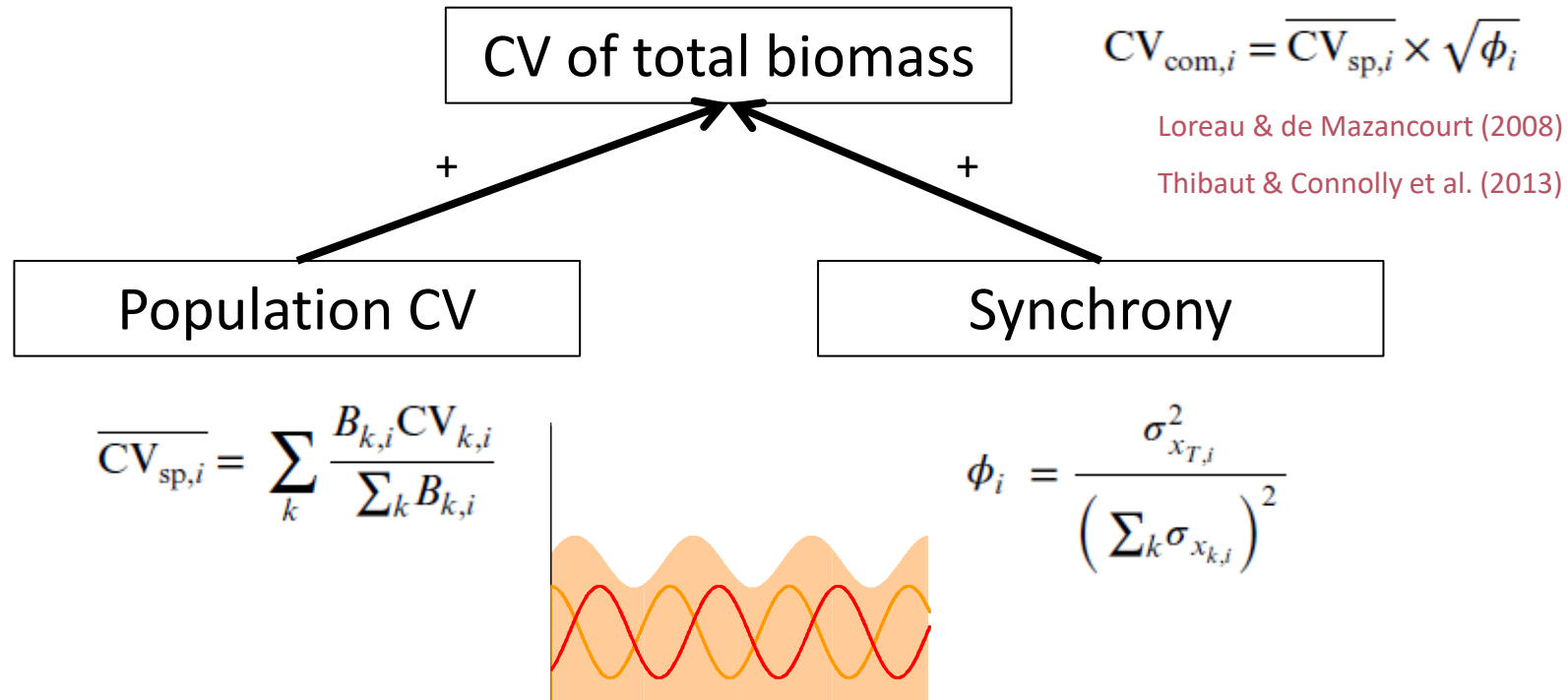


Willem Bonnaffé



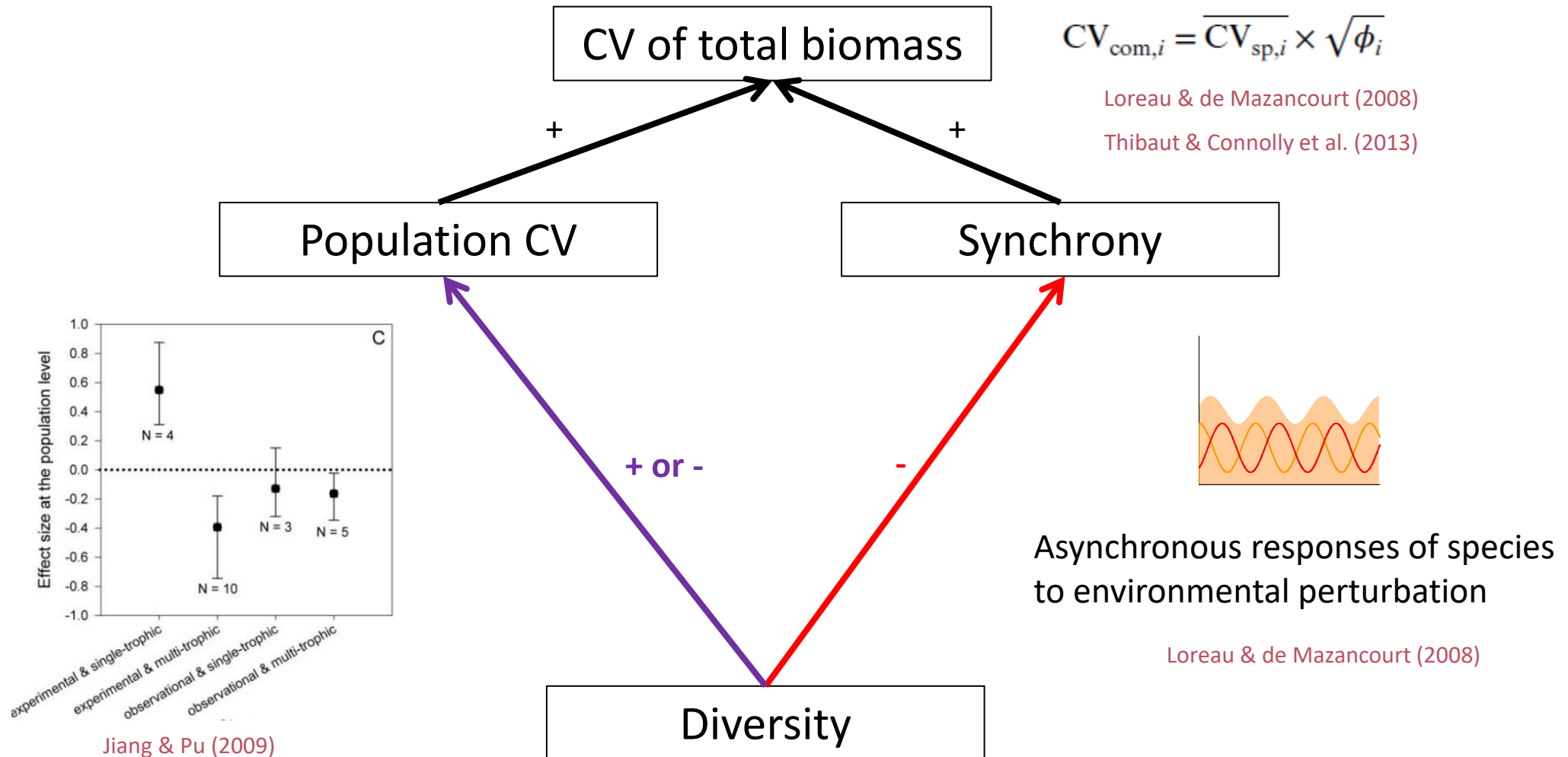
Colin Fontaine

# Assessing the links between diversity, food web structure and ecosystem stability?

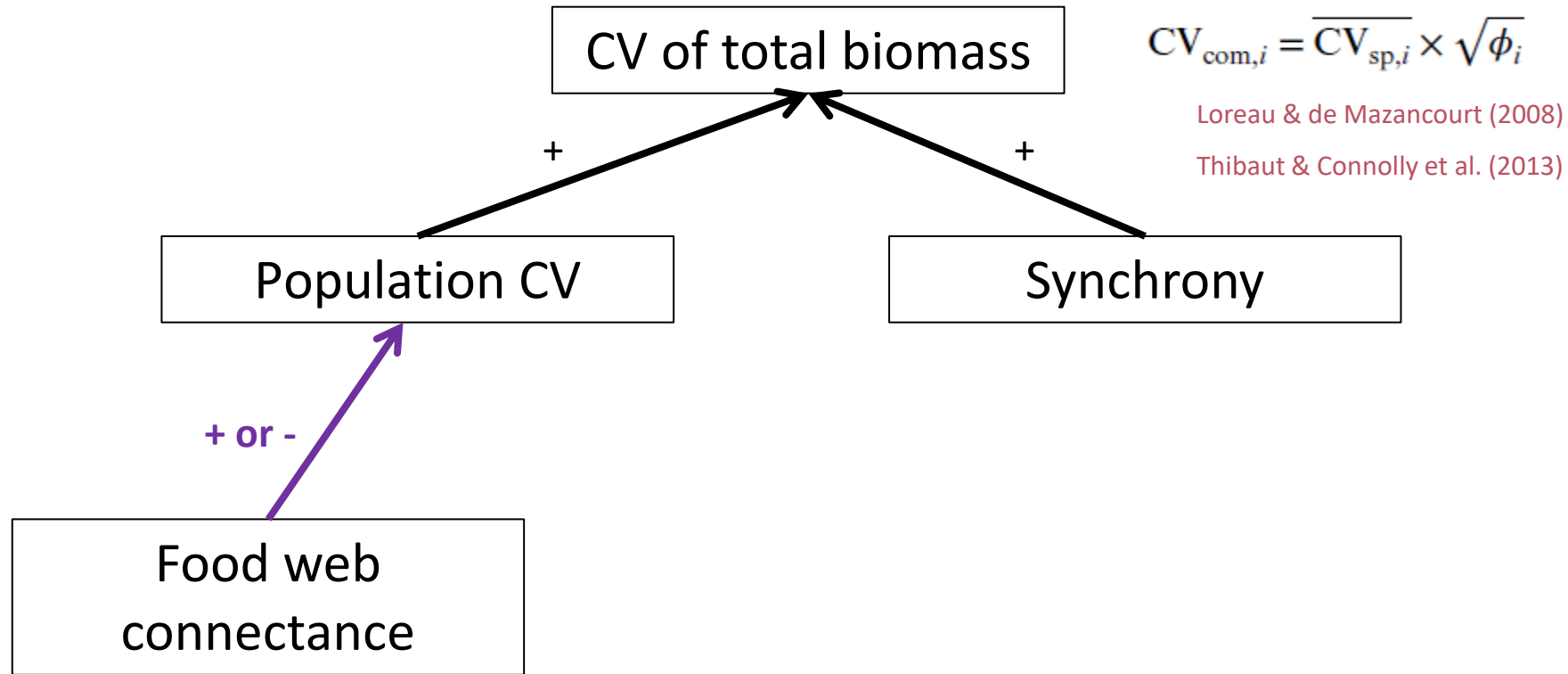




# Assessing the links between diversity, food web structure and ecosystem stability?



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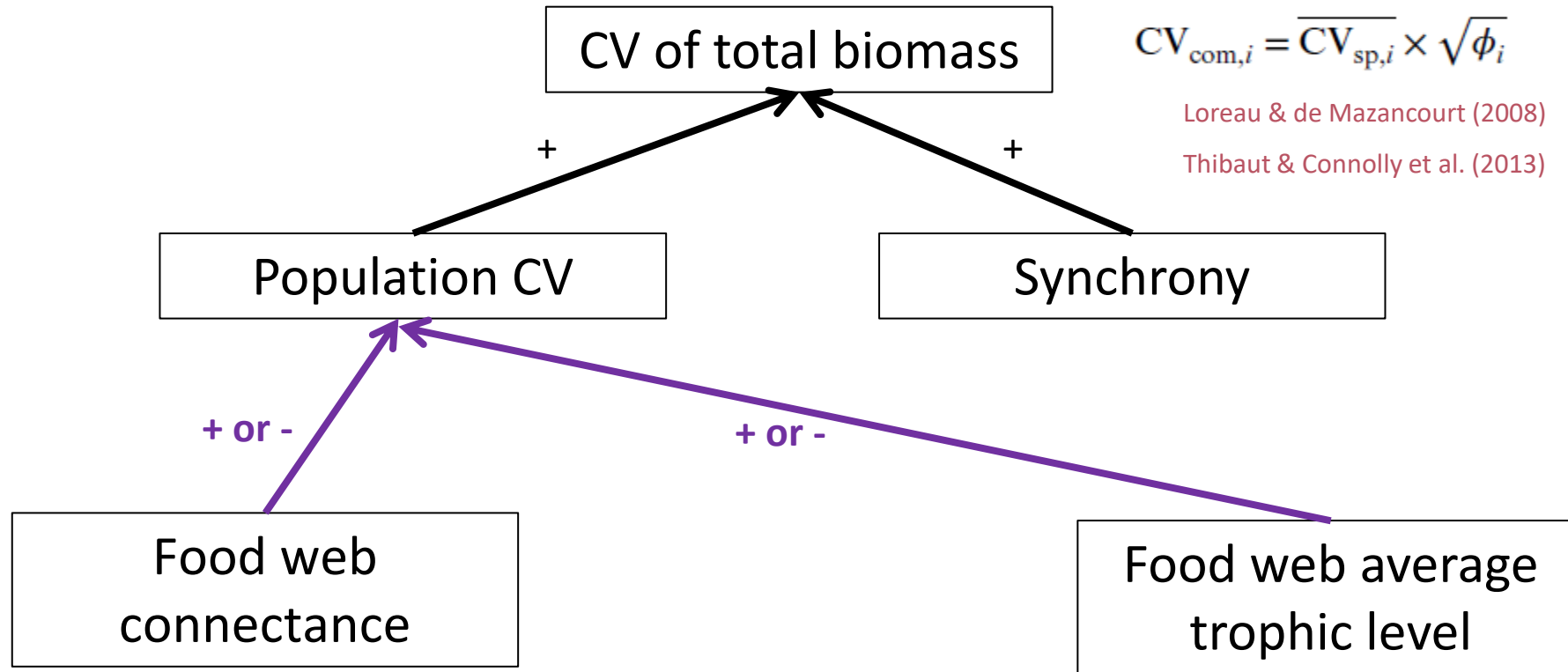
Decrease probability of local stability

e.g. Gross et al. (2009)

Generalist consumers have more stable dynamics than specialists

e.g. Thébault & Loreau (2005)

# Assessing the links between diversity, food web structure and ecosystem stability?



$$CV_{com,i} = \overline{CV_{sp,i}} \times \sqrt{\phi_i}$$

Loreau & de Mazancourt (2008)

Thibaut & Connolly et al. (2013)

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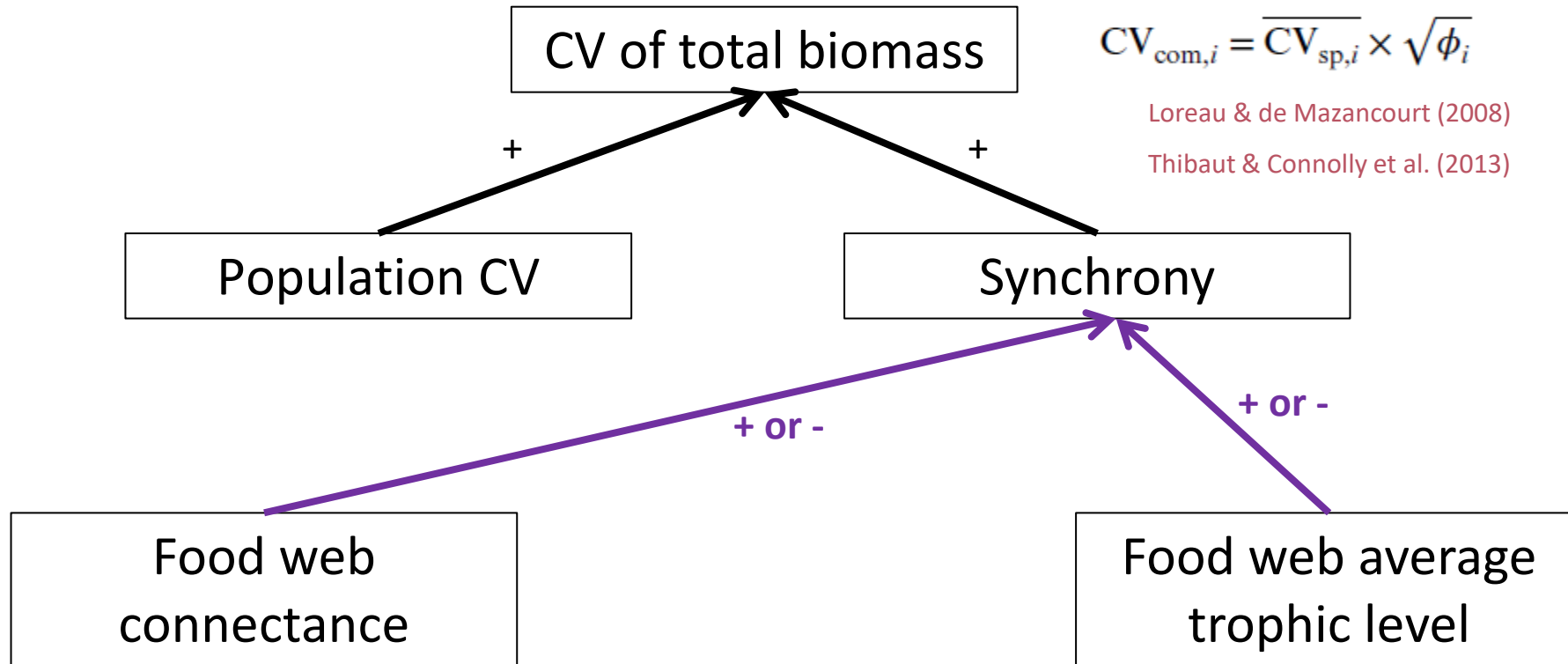
Predator has destabilizing effects on prey

e.g. Shanafelt & Loreau (2018)

Stabilizing effects of predators coupling different energy channels

Rooney & McCann (2008)

# Assessing the links between diversity, food web structure and ecosystem stability?



$$CV_{com,i} = \overline{CV_{sp,i}} \times \sqrt{\phi_i}$$

Loreau & de Mazancourt (2008)

Thibaut & Connolly et al. (2013)

Generalist consumers sharing the same prey are more synchronous than specialist consumers

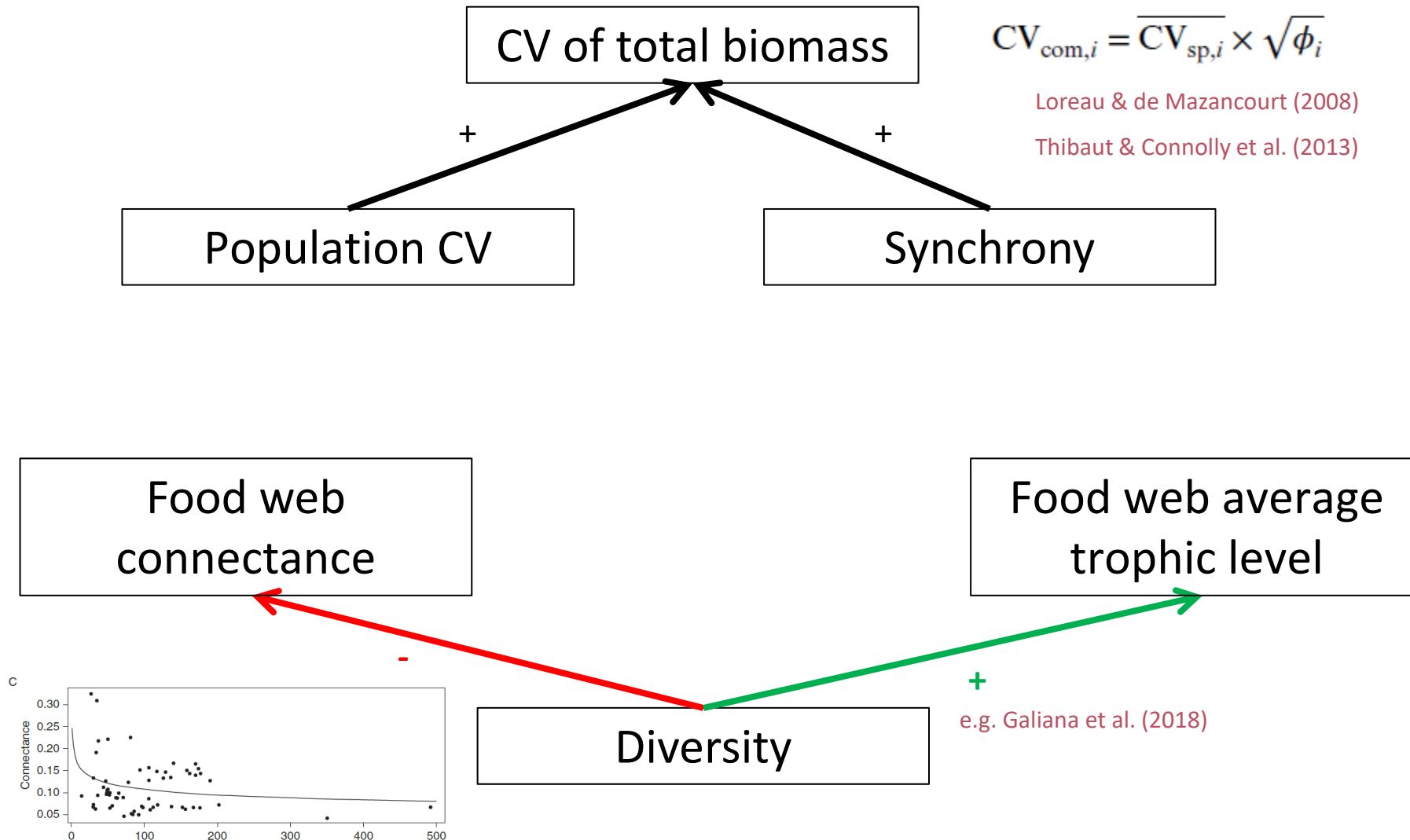
Thébault & Loreau (2005)

Predator might increase or decrease synchrony of its prey populations

Raimondo et al. (2004)

McCann (2000)

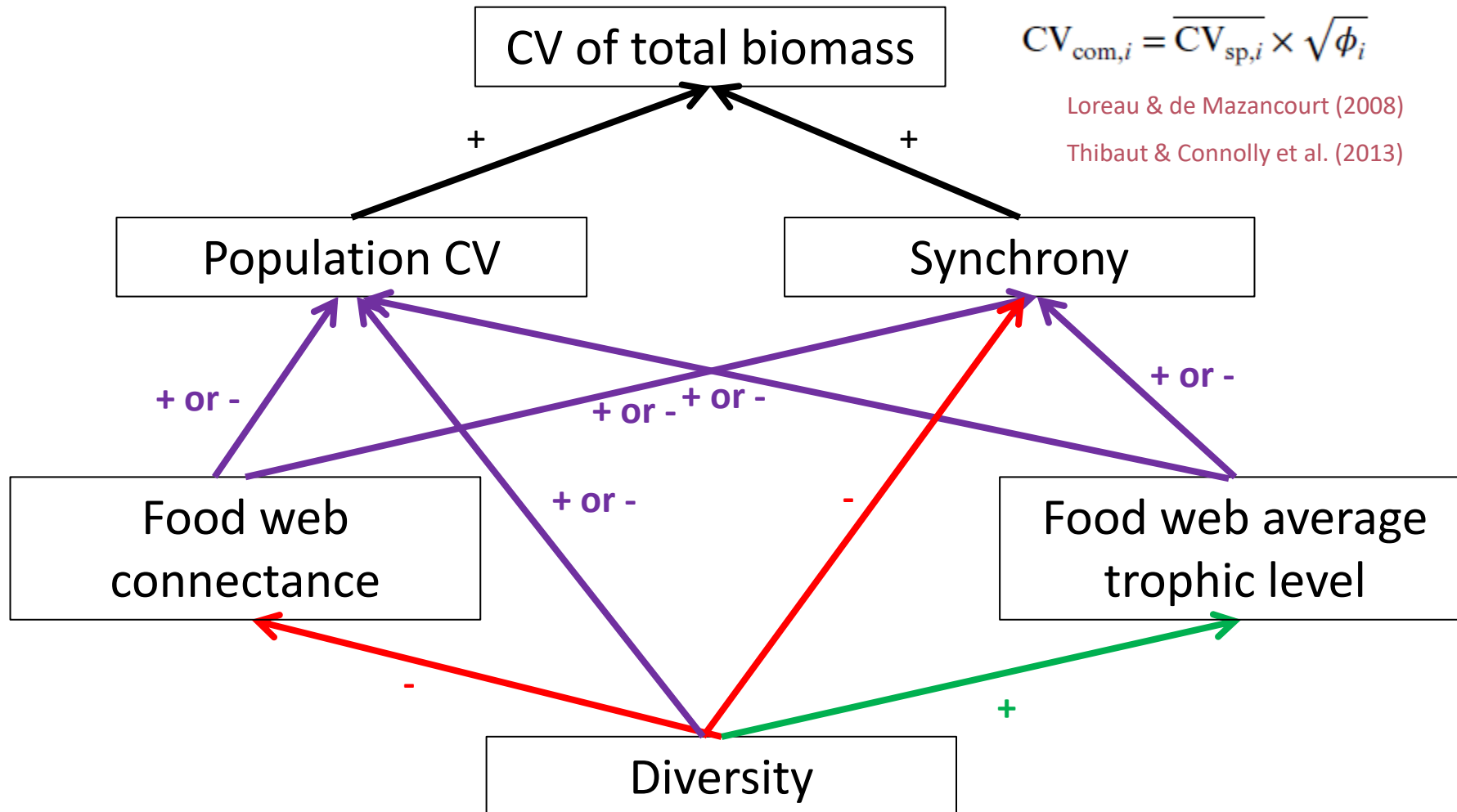
# Assessing the links between diversity, food web structure and ecosystem stability?



e.g. Riede et al. (2010)

e.g. Galiana et al. (2018)

# Assessing the links between diversity, food web structure and ecosystem stability?



**Assessing the links between diversity, food web structure and  
ecosystem stability?**  
*a modelling approach*



Jérôme Eschenbrenner

# Allometric food web model

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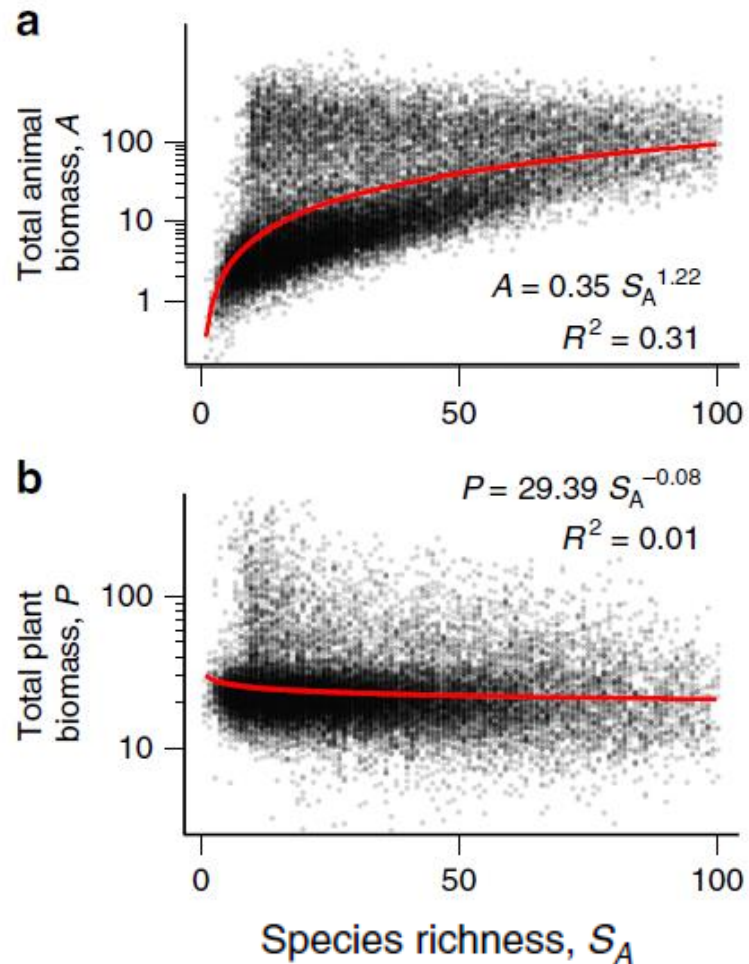
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## Animal diversity and ecosystem functioning in dynamic food webs

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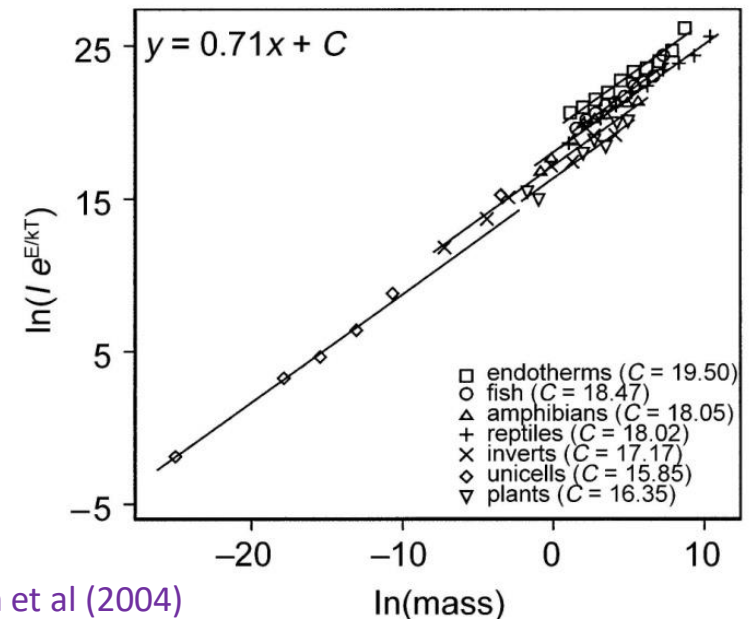
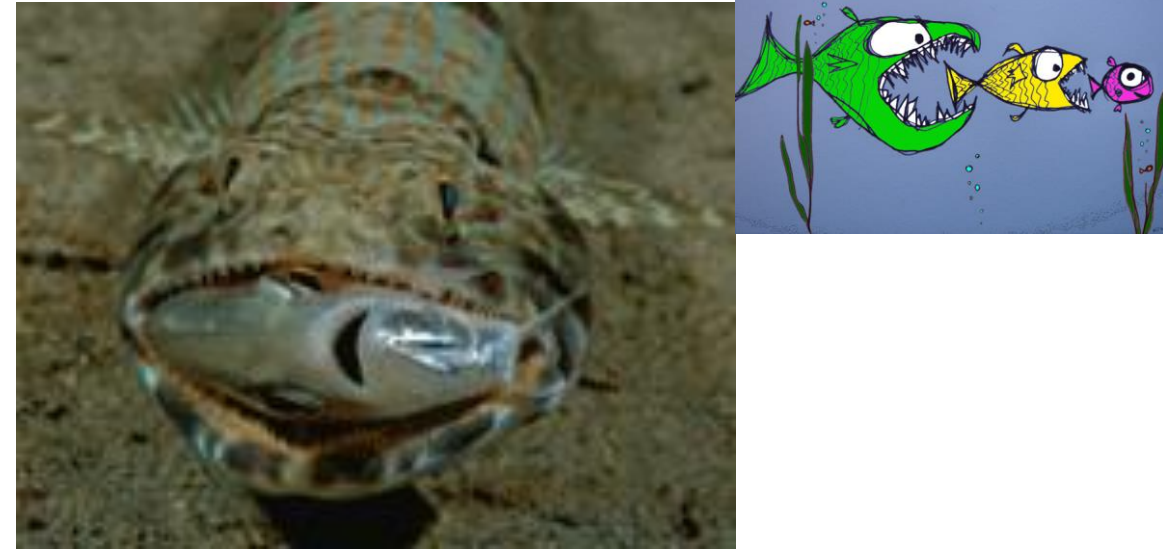
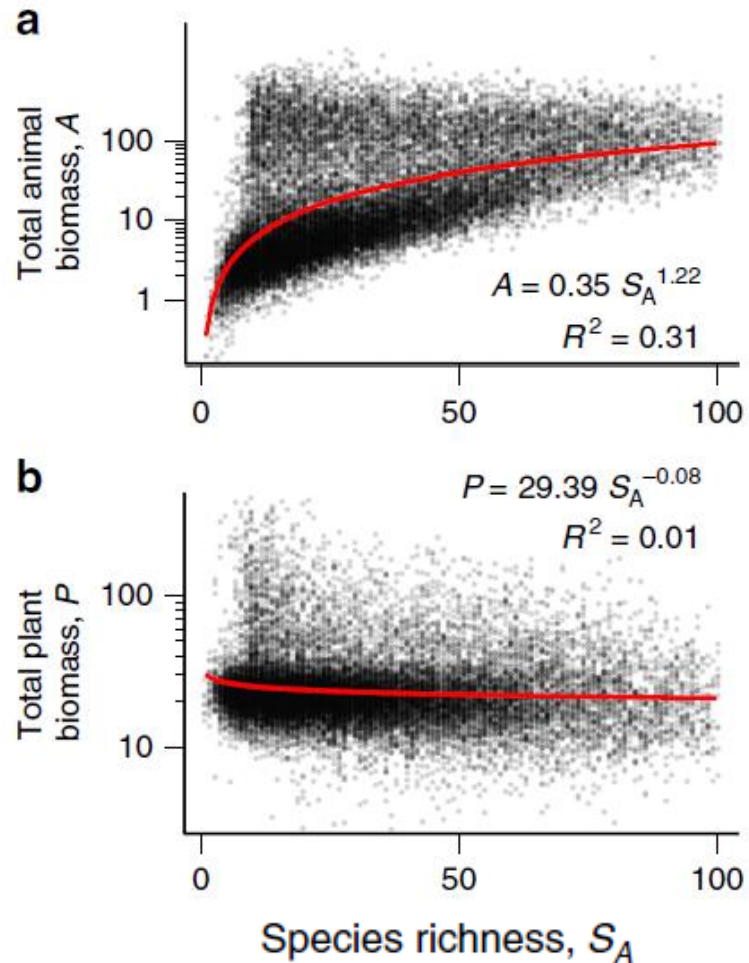
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Schneider et al. (2016)



Brown et al (2004)

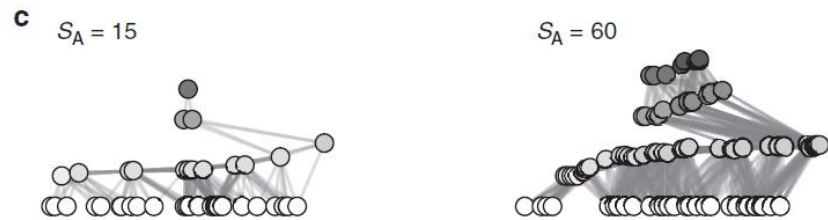
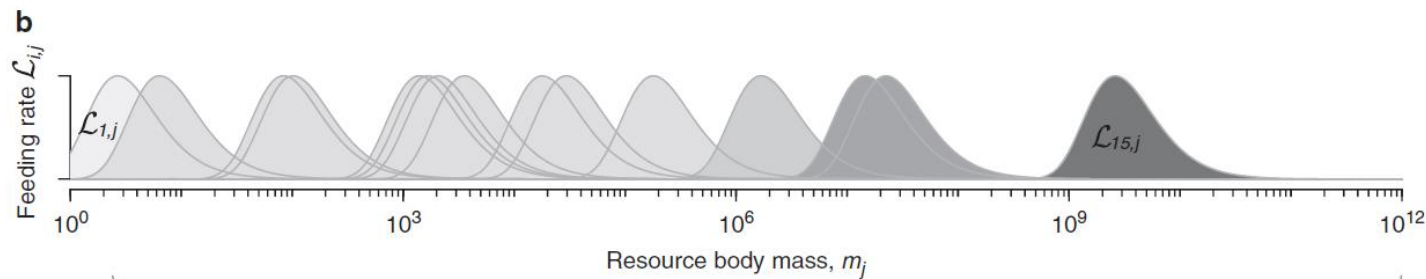
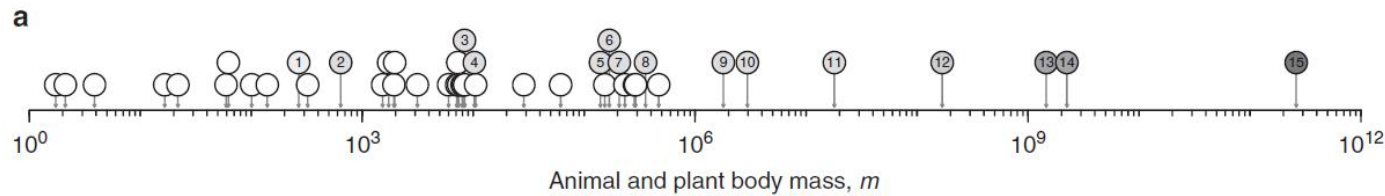
# Allometric food web model

$$\frac{dA_i}{dt} = e_p A_i \sum_j F_{ij} + e_A A_i \sum_k F_{ik} - \sum_k A_k F_{ki} - x_i A_i$$

$$\frac{dP_i}{dt} = r_i G_i P_i - \sum_k A_k F_{ki} - x_i P_i$$

$$\frac{dN_l}{dt} = D(S_l - N_l) - v_l \sum_i r_i G_i P_i$$

$$F_{ij} = \frac{\omega_i b_{ij} R_j^{1+q}}{1 + cA_i + \omega_i h_i \sum_k b_{ik} R_k^{1+q}} \cdot \frac{1}{m_i}$$



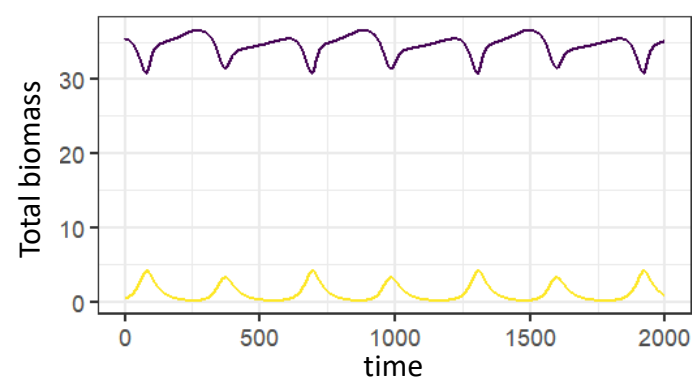
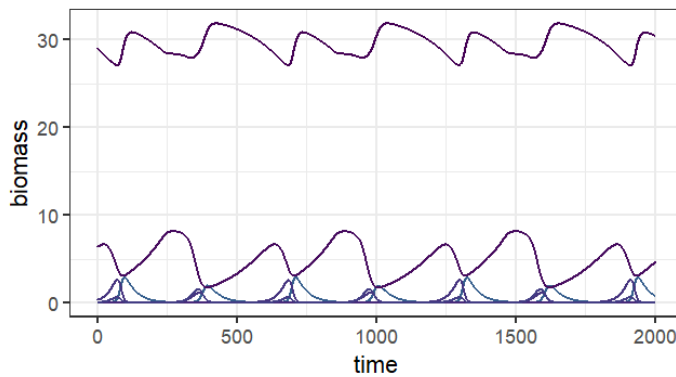
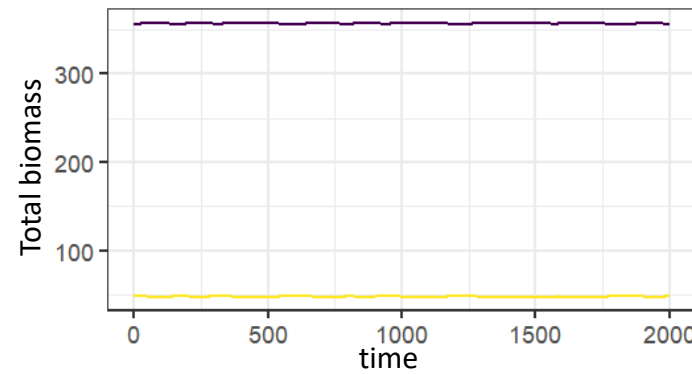
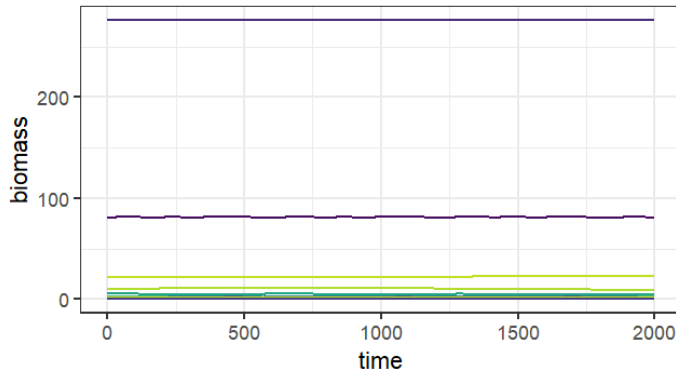
Schneider et al. (2016)

# Simulations: relations between diversity, food web structure and temporal variability of total biomass

Run simulations with varying initial diversity of plants and animals

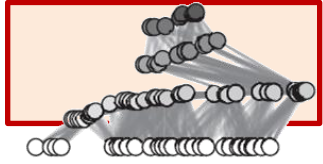


Measure food web properties at the end of simulations when transient dynamics are over

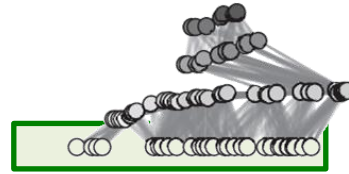


- Diversity of remaining plants and animals
- Connectance and average trophic level of species in food webs
- CV of total plant biomass and of total animal biomass
- Synchrony and population CV for plants and for animals

# Results

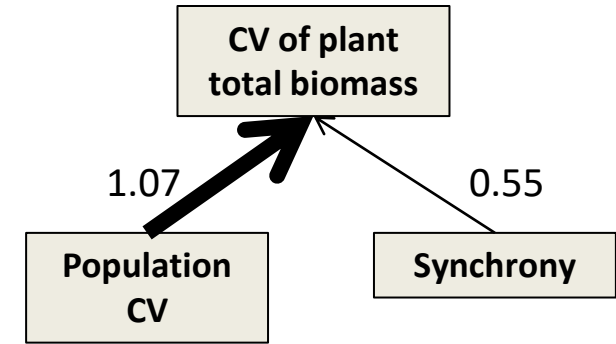
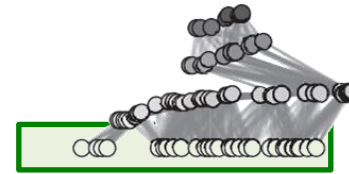
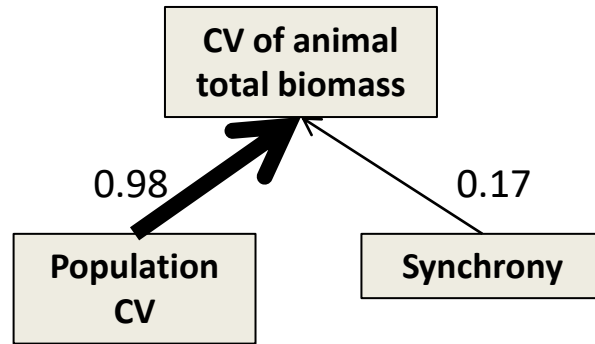
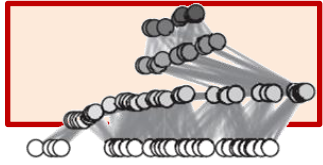


**CV of animal  
total biomass**

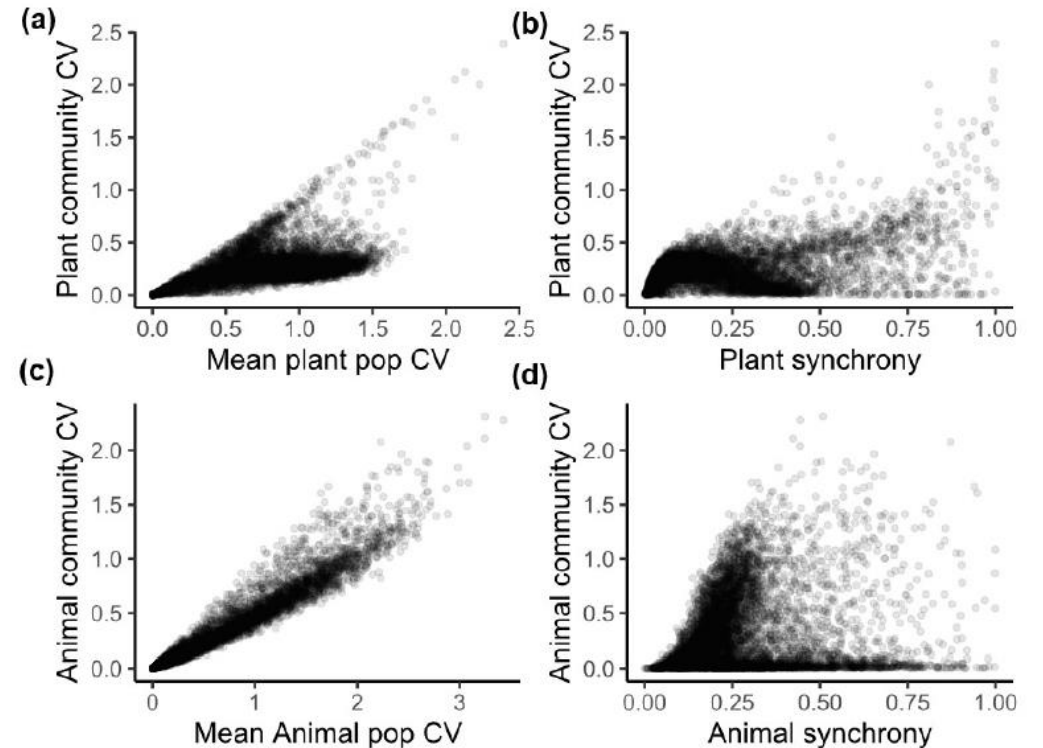


**CV of plant  
total biomass**

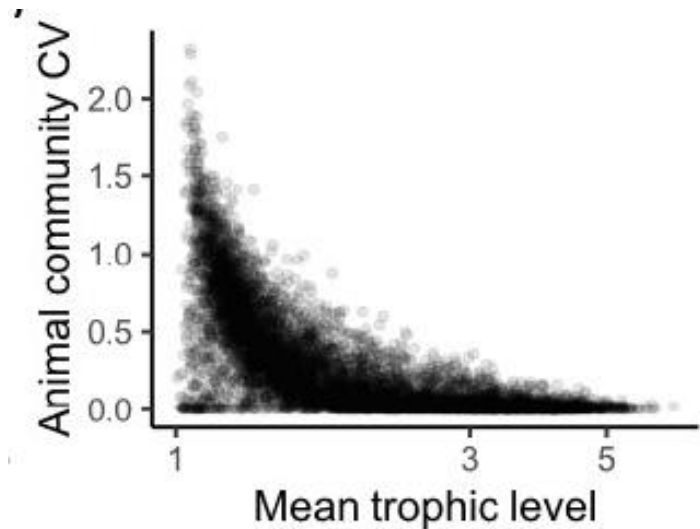
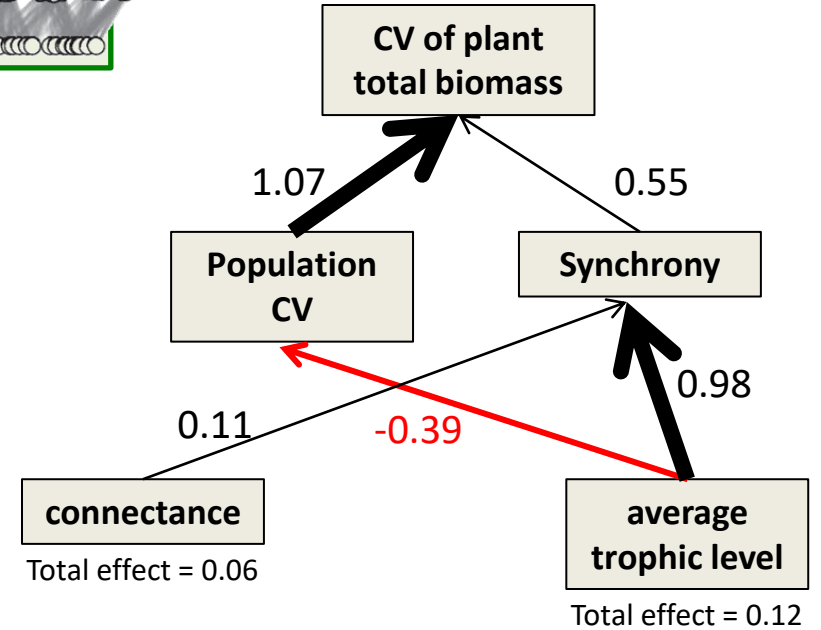
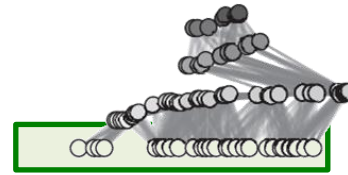
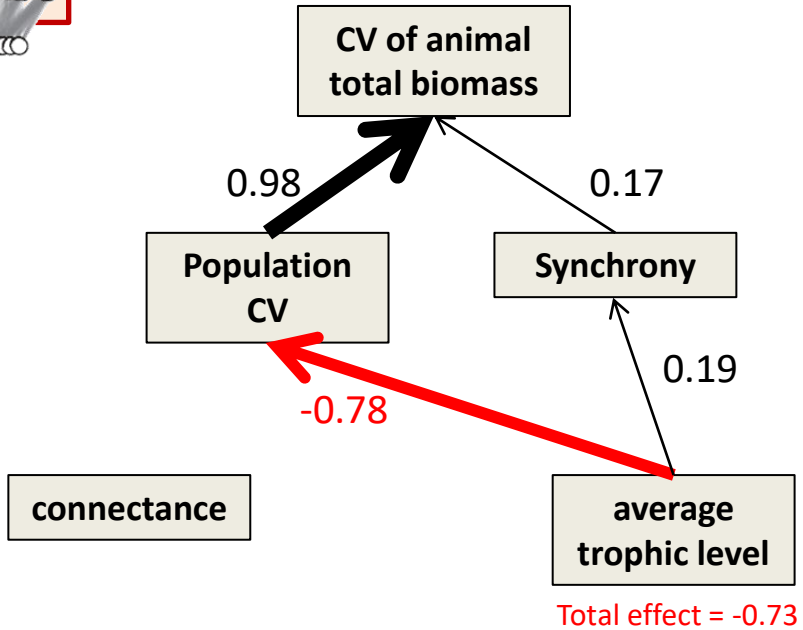
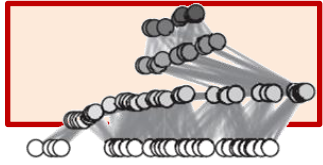
# Results



➤ Variations in CV of animal total biomass among food webs is explained by greater variations in population CV than synchrony among food webs

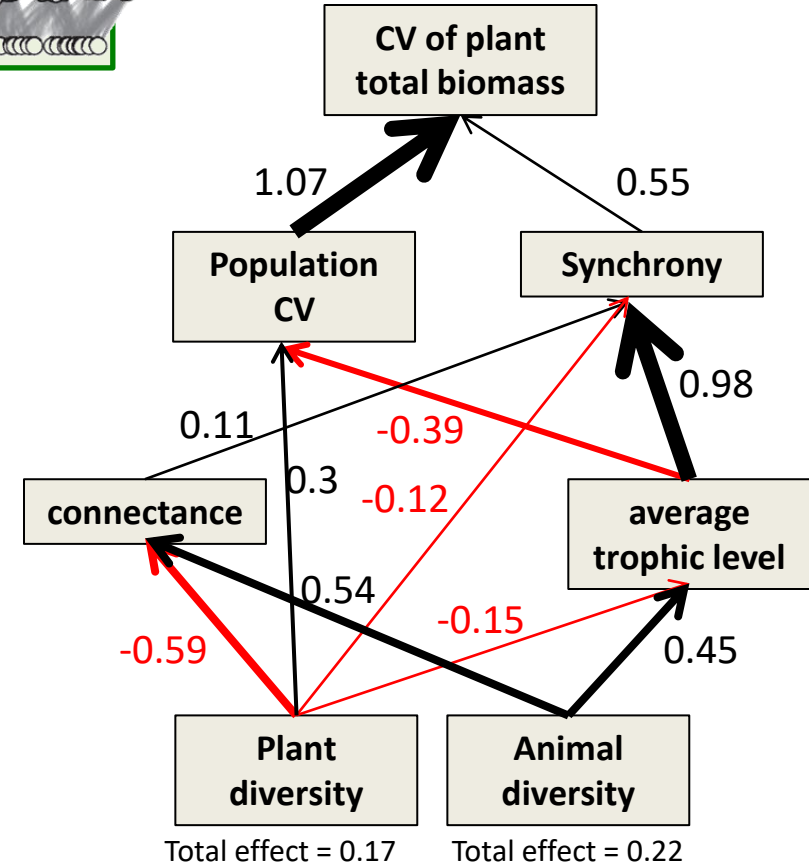
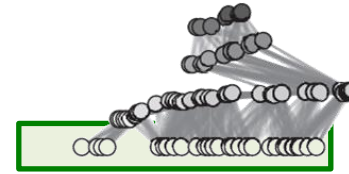
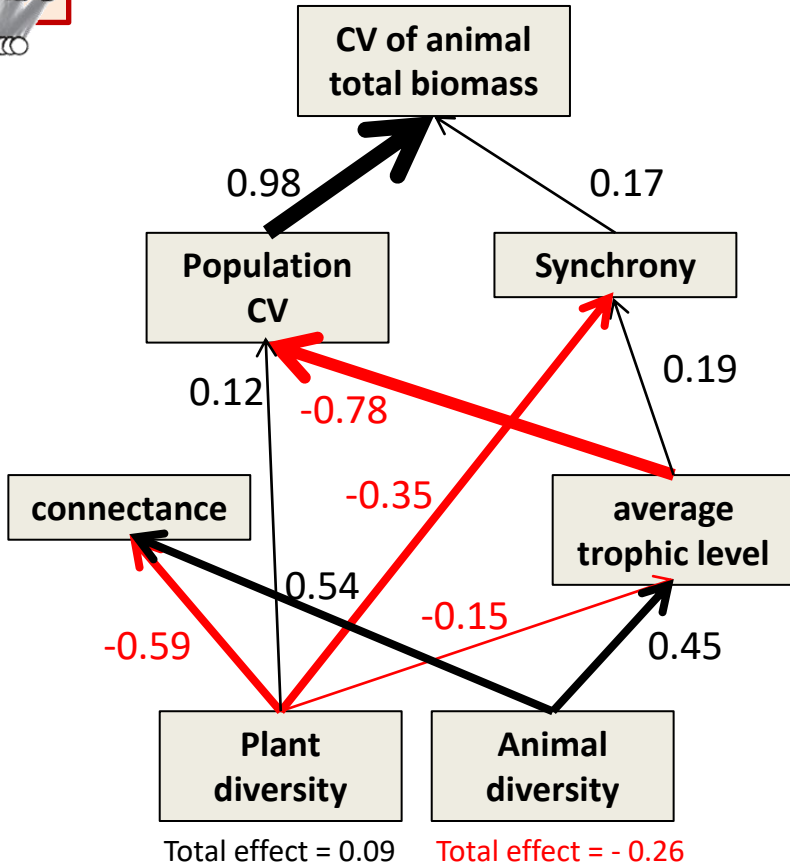
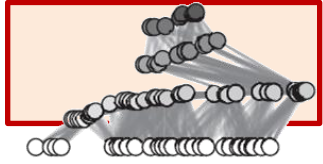


# Results



- Almost no relation between connectance and stability of total biomass
- Food webs with high species average trophic level are related with lower population CV and greater synchrony

# Results



- Effects of animal diversity related to changes in average trophic level of species in food webs
- Direct effects of plant diversity on the two components of CV of total biomass

# A few conclusions from the modelling approach

- Higher average trophic level stabilizes population CV but leads to higher synchrony
- Food webs with more biomass at higher trophic levels are characterized by more stable animal biomass
- No effect of connectance
- Inconsistent and overall weak effects of species richness: destabilising effects on temporal stability of total plant biomass, stabilising effect of animal diversity on total animal biomass



# Assessing the links between diversity, food web structure and ecosystem stability? *an empirical approach*



Alain Danet



Maud Mouchet



Willem Bonnaffé

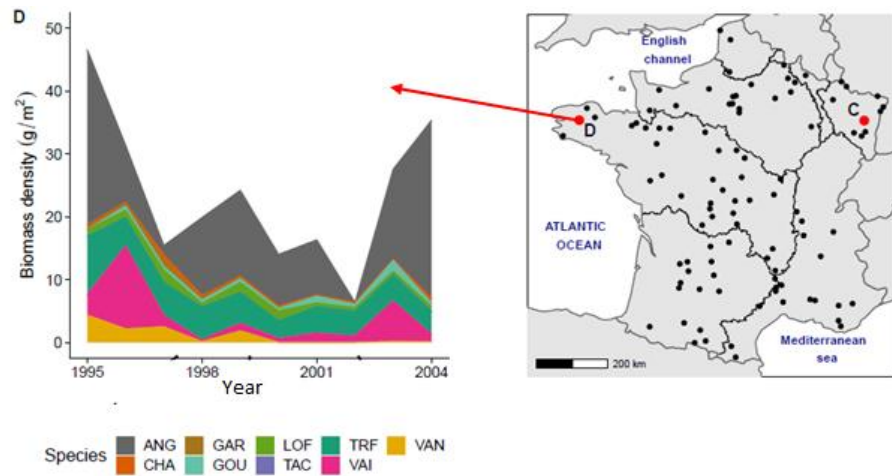


Colin Fontaine

# Assessing the links between diversity, food web structure and ecosystem stability?

## *an empirical approach*

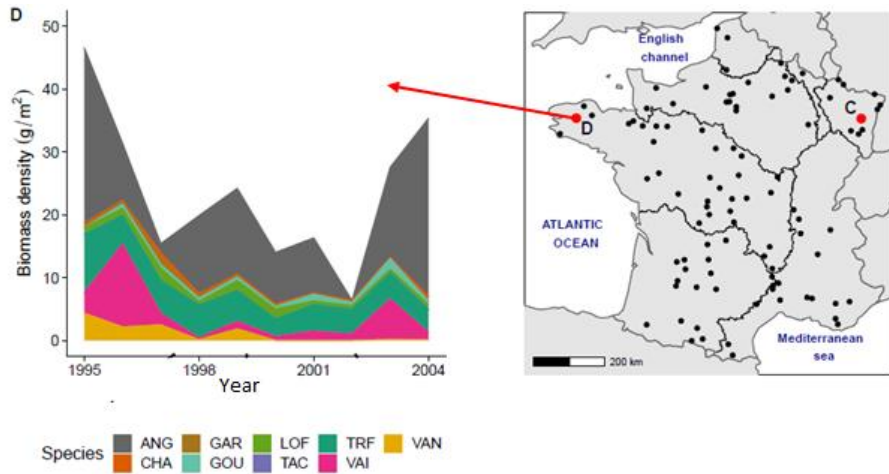
- Long-term dataset on fish communities in streams



Select sites monitored for more than 10 years  
with no temporal trends in community biomass  
-> 99 sites

# Assessing the links between diversity, food web structure and ecosystem stability? *an empirical approach*

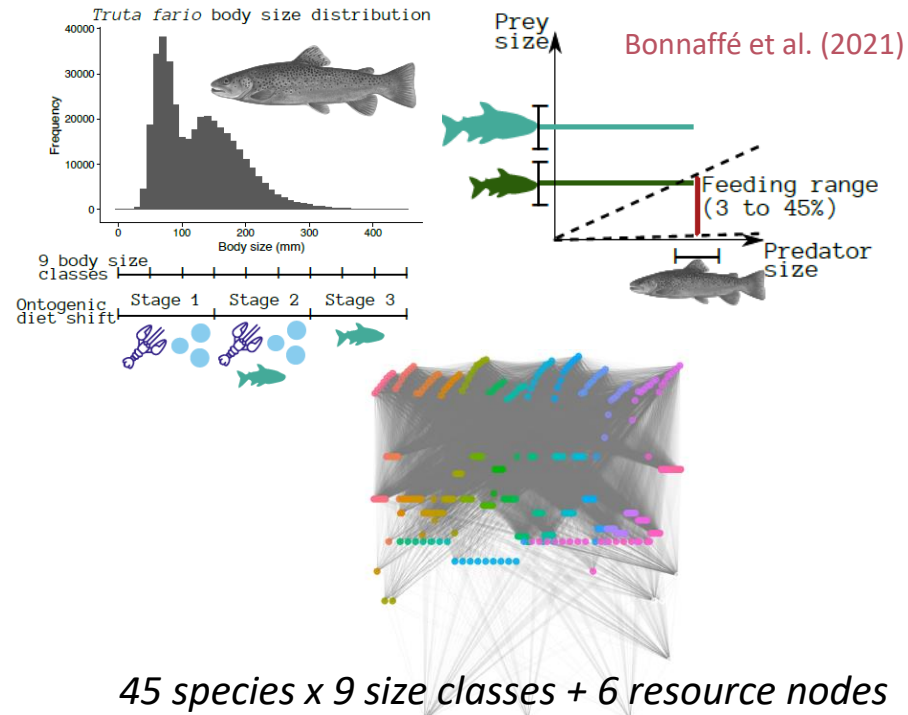
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Select sites monitored for more than 10 years with no temporal trends in community biomass  
-> 99 sites

- Food web inference of fish communities

Use data on species identity and body size of caught individuals to construct metaweb

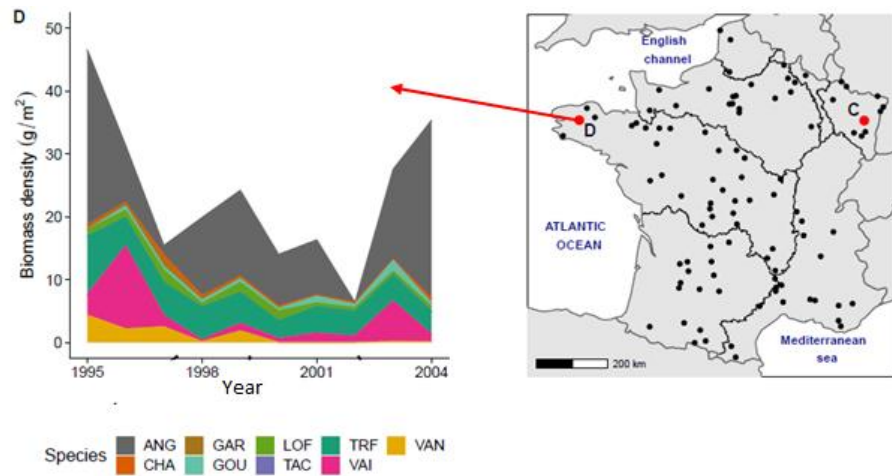


45 species x 9 size classes + 6 resource nodes

# Assessing the links between diversity, food web structure and ecosystem stability?

## *an empirical approach*

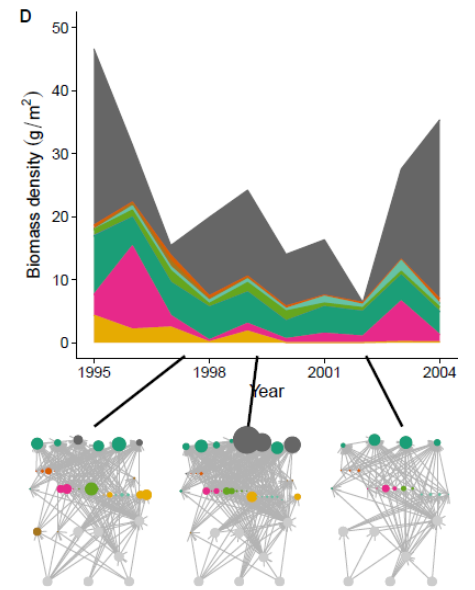
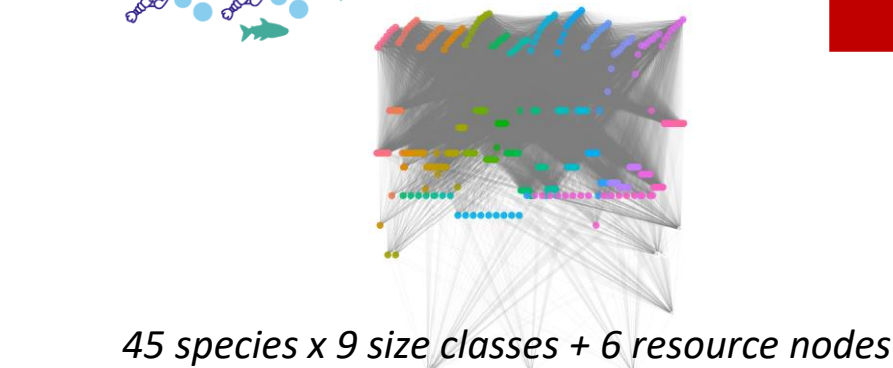
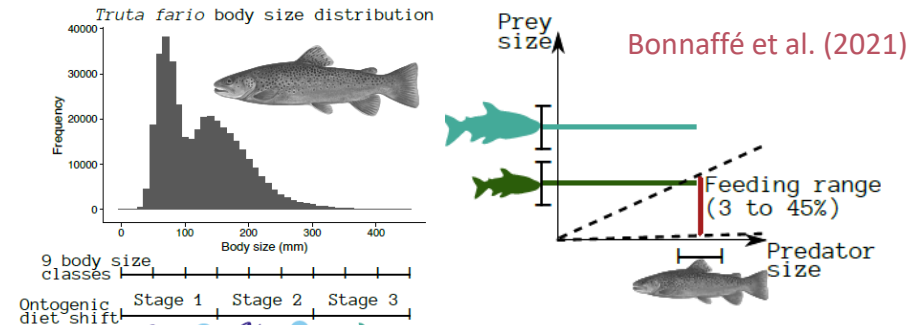
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Select sites monitored for more than 10 years with no temporal trends in community biomass -> 99 sites

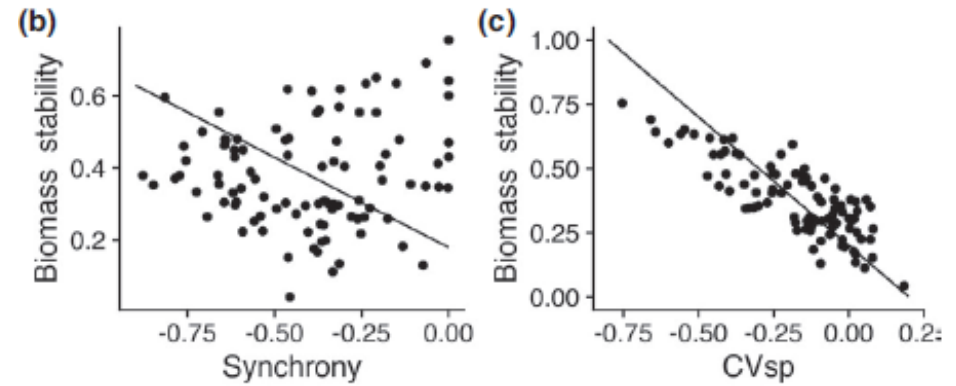
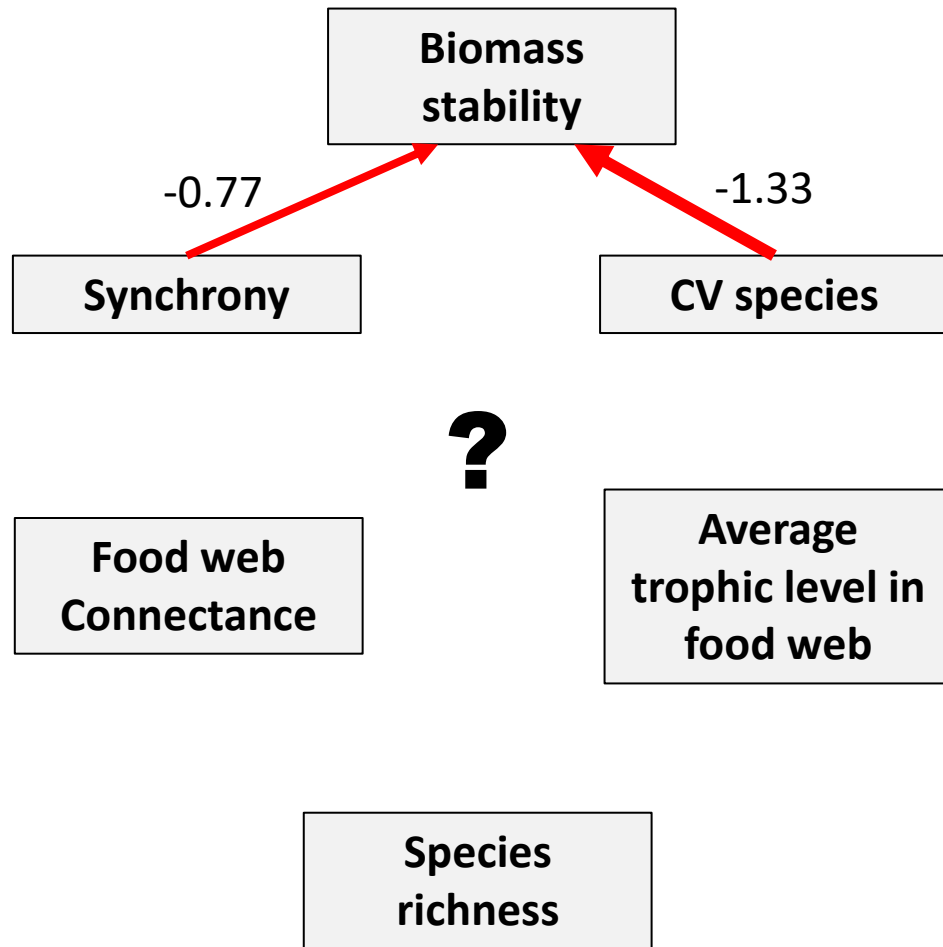
- Food web inference of fish communities

Use data on species identity and body size of caught individuals to construct metaweb and local food webs

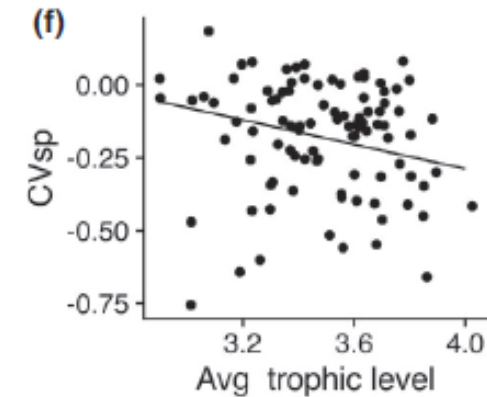
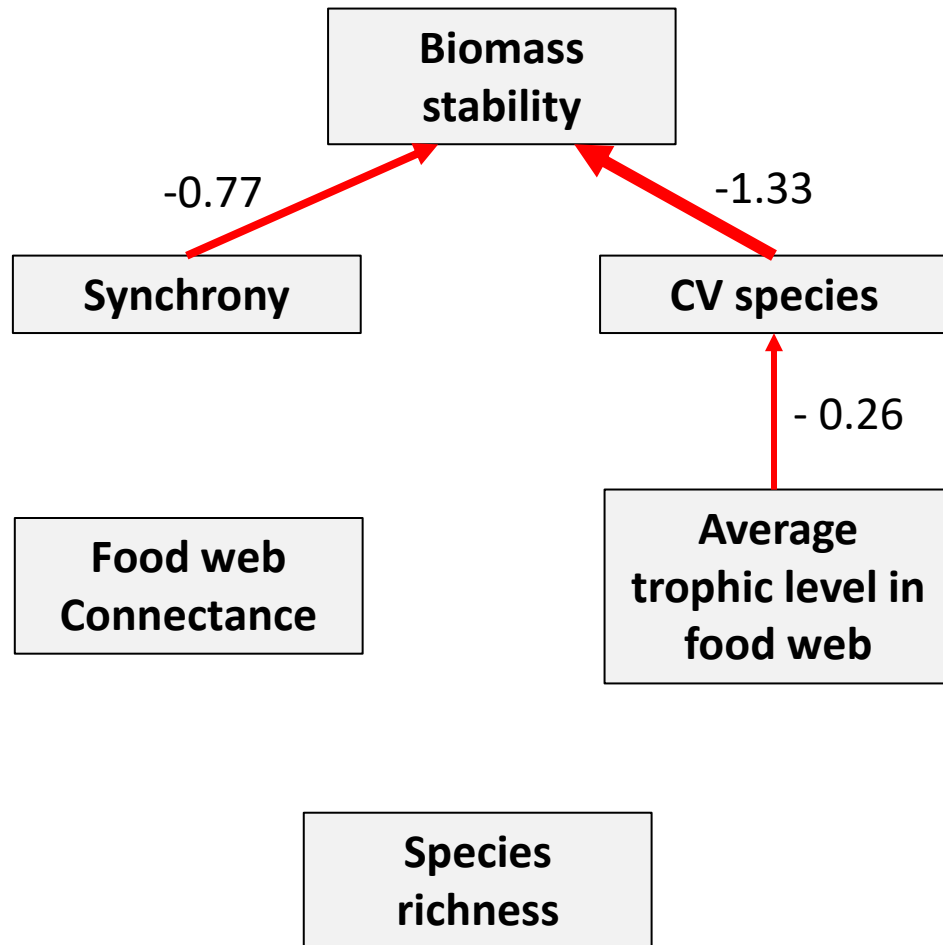


45 species x 9 size classes + 6 resource nodes

# Results: what are the relations between food web structure and biomass stability?

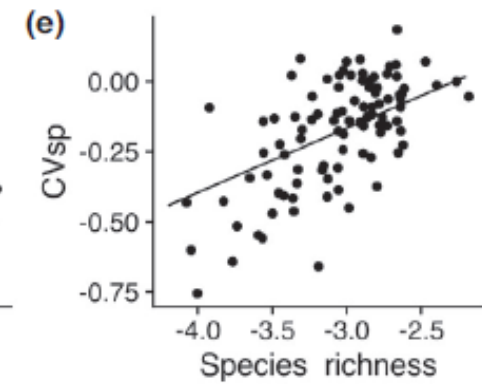
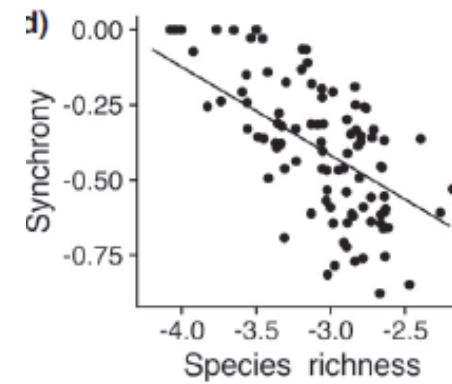
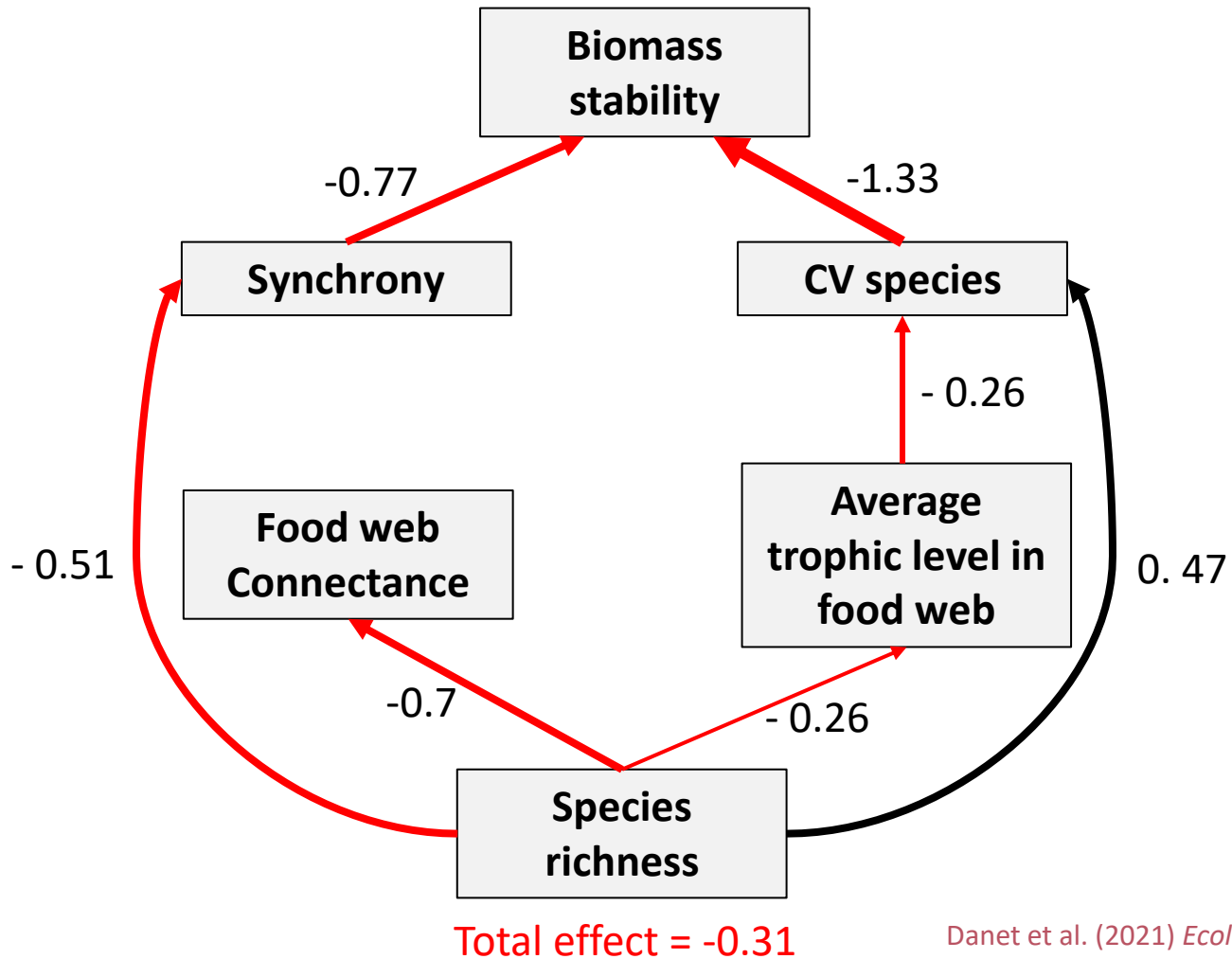


# Results: what are the relations between food web structure and biomass stability?



- No relation between connectance and stability of total biomass
- Food web average trophic level is related with lower population CV and greater stability of total biomass

# Results: what are the relations between diversity and biomass stability?

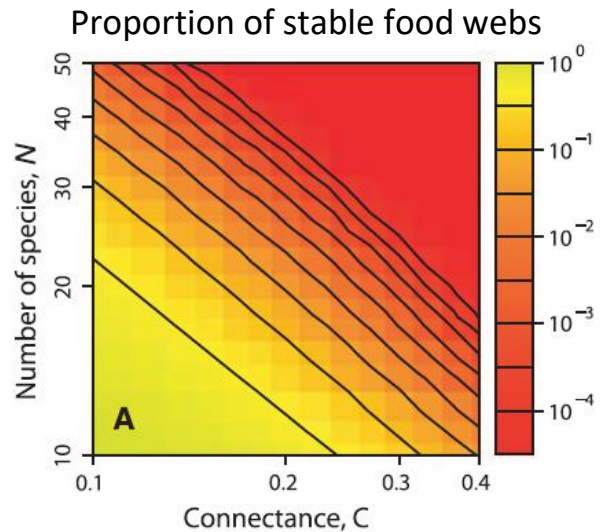


- Lower synchrony at higher species richness
- Destabilising effect of species richness on population biomass and total biomass

# Discussion and perspectives

## How these results relate with theoretical predictions?

- No correlation between connectance and biomass stability



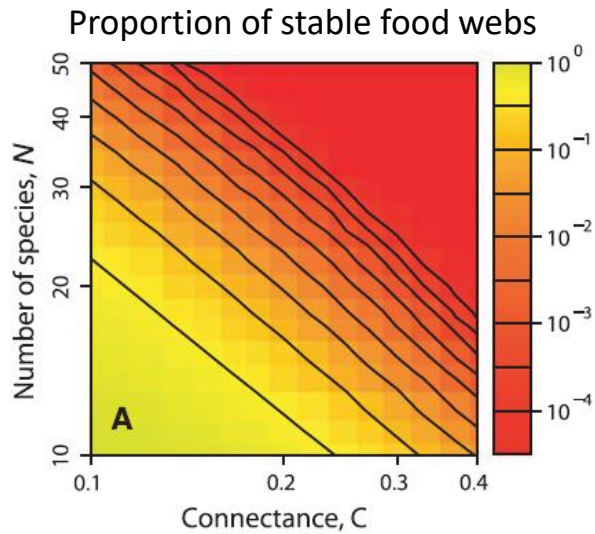
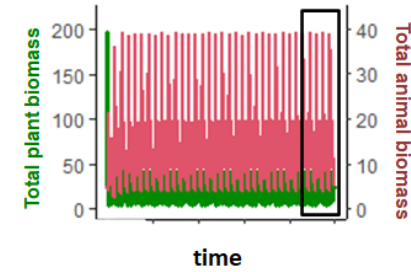
Gross et al. (2009)



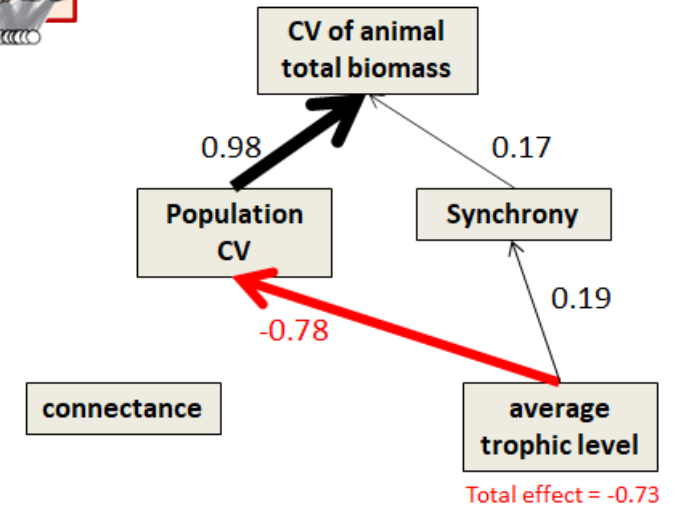
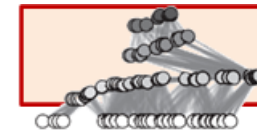
# Discussion and perspectives

## How these results relate with theoretical predictions?

- No correlation between connectance and biomass stability



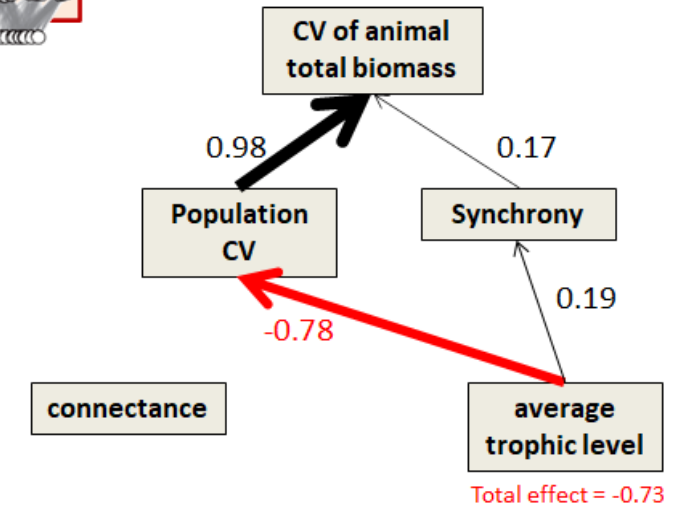
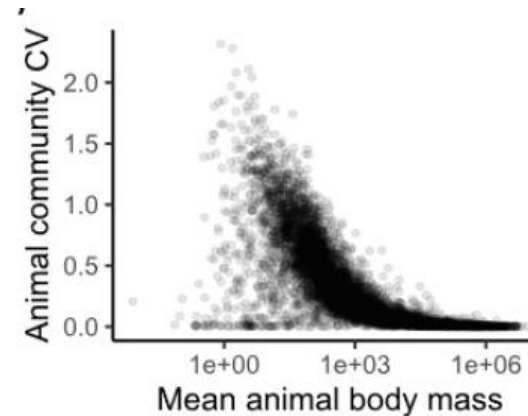
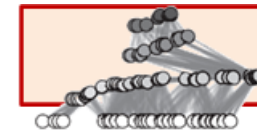
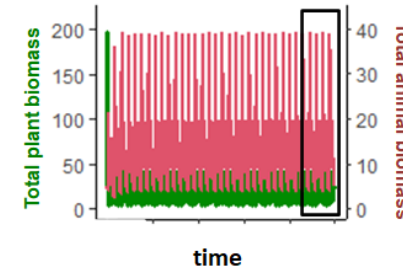
Gross et al. (2009)



# Discussion and perspectives

## How these results relate with theoretical predictions?

- Importance of mean trophic level on stability of total biomass ?



# Discussion and perspectives

## How these results relate with theoretical predictions?

- Relation between diversity and stability of total biomass in food webs?
- Consistent with experiments on plant communities



Tilman et al. (2006)

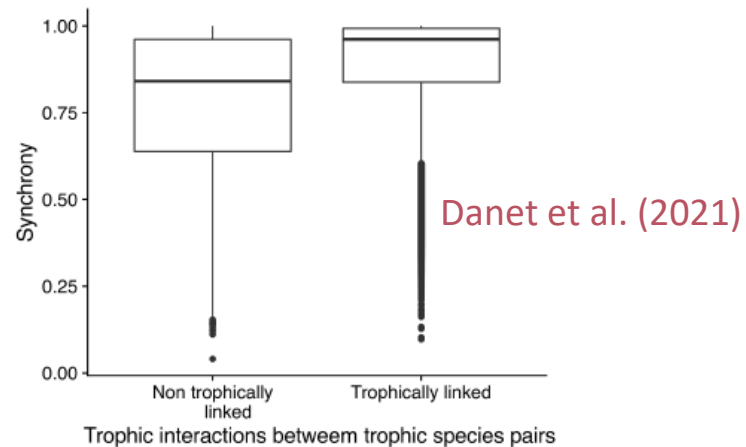
# Discussion and perspectives

## How these results relate with theoretical predictions?

- Relation between diversity and stability of total biomass in food webs?
- Consistent with experiments on plant communities



Tilman et al. (2006)



# Discussion and perspectives

## How these results relate with theoretical predictions?

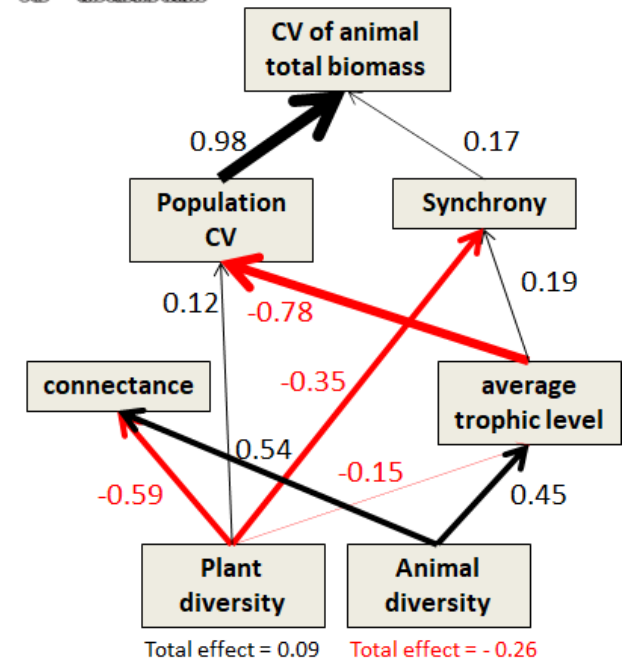
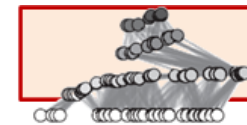
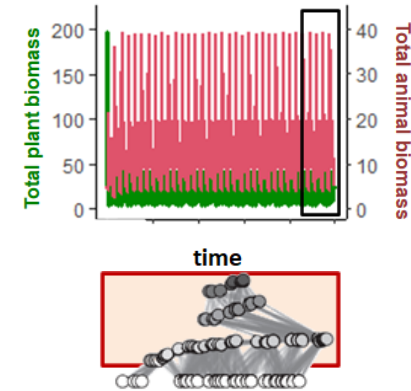
➤ Relation between diversity and stability of total biomass in food webs?

➤ Consistent with experiments on plant communities



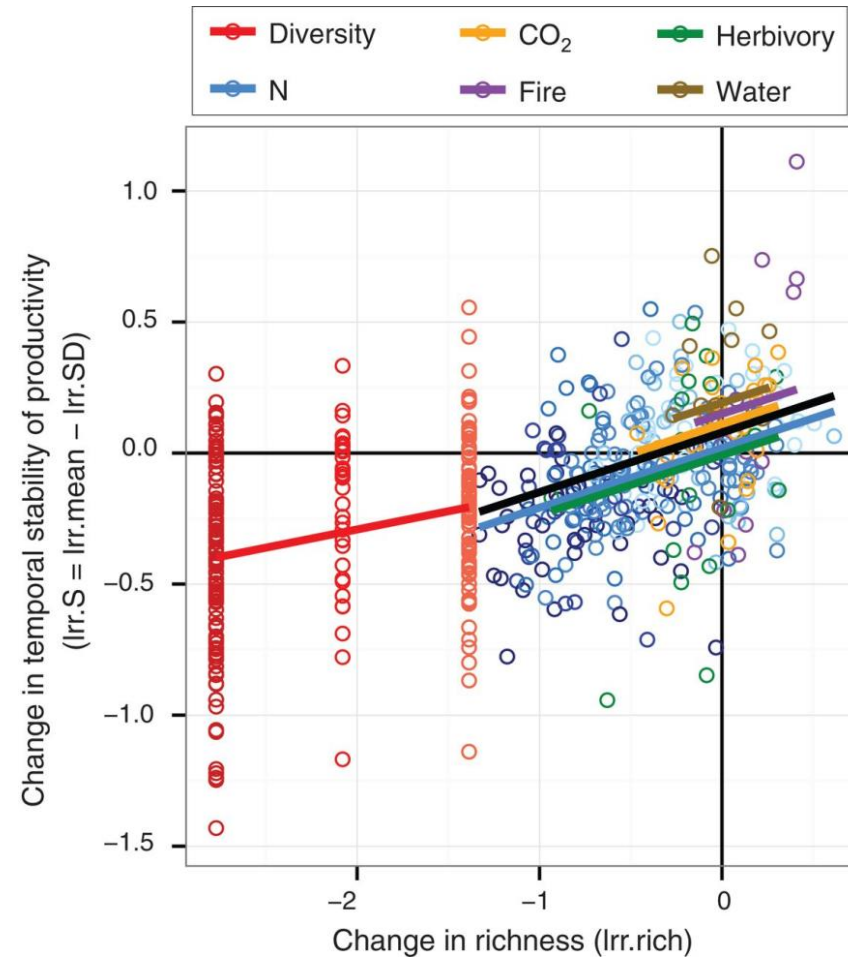
Tilman et al. (2006)

➤ But synchronizing effect of animal diversity in the food web model



# Discussion and perspectives

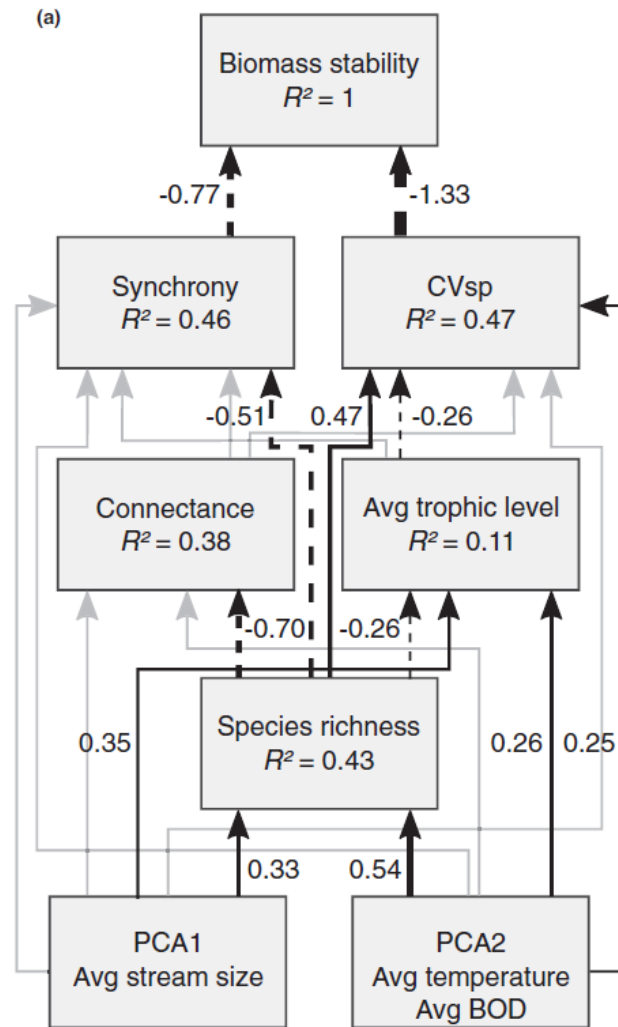
- Importance of considering environmental conditions and perturbations?



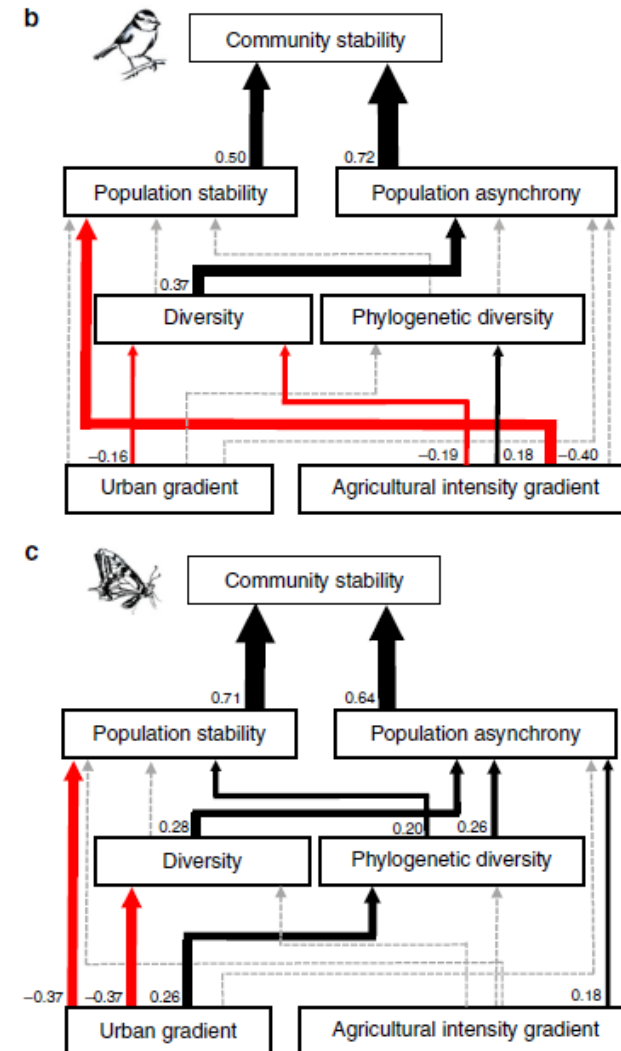
Hautier et al. (2015)

# Discussion and perspectives

- Importance of considering environmental conditions and perturbations?



Danet et al. (2021)



Olivier et al. (2020)

# Thank you for your attention



**Alain Danet**



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**Maud Mouchet**



**Willem Bonraffé**

