The diversity – stability relationship: from theory to natural communities

Théophile Olivier

Elisa Thébault

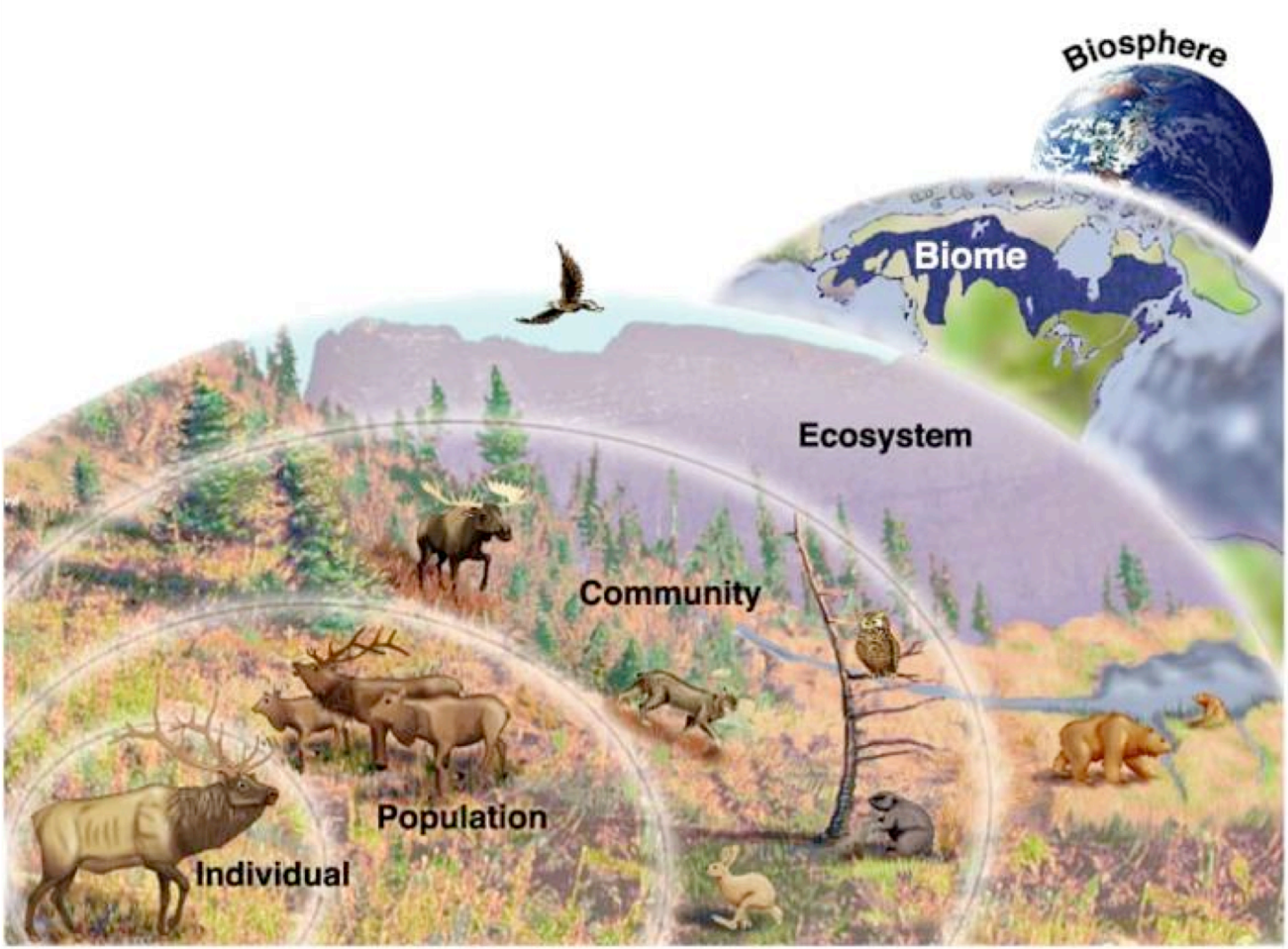
Benoit Fontaine

Marianne Elias

Colin Fontaine

theophile.olivier@gmail.com

Several organisation levels in ecology



Population

- Individuals of a same species that interbreed and live a the same place at a same time.

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Aptenodytes forsteri

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Aptenodytes forsteri

Felis silvestris « loly » catus

Community

- Populations of different species coexisting in a habitat over a particular time, with interactions affecting each other's abundance, distribution, adaptation and existence.

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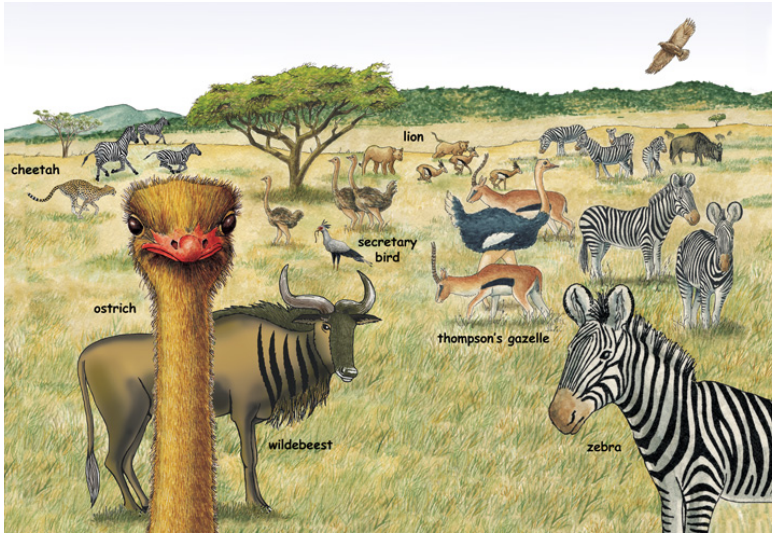

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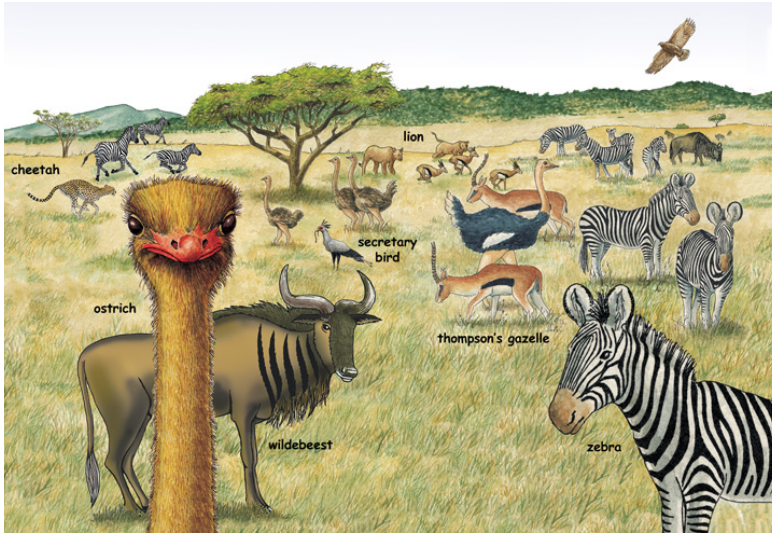


Diversity

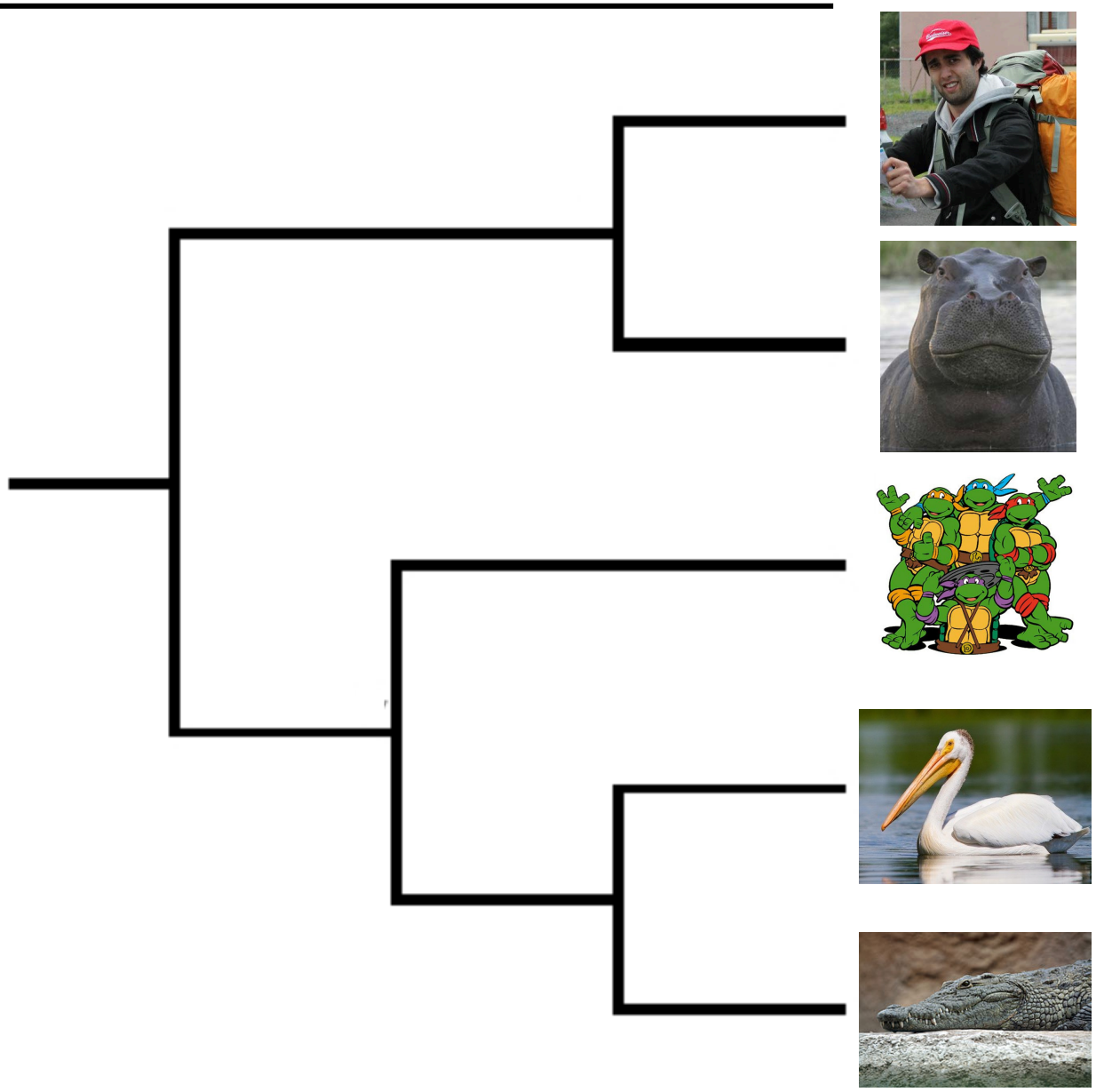
➔ Species richness

– Number of species in a community

➔ Phylogenetic diversity

– Phylogenetic differences between species of a community due to the evolutionary history of species

Phylogenetic diversity



Stability

- Temporal invariability of a component
  - Abundance
  - Biomass

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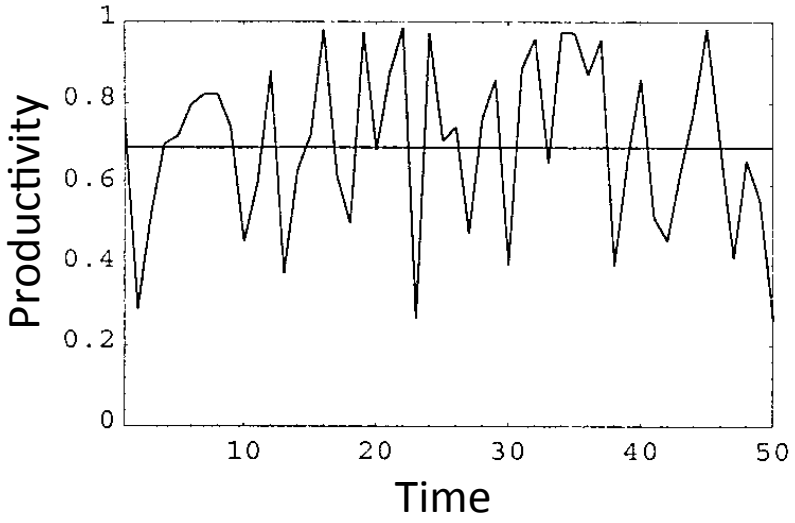
Low stability



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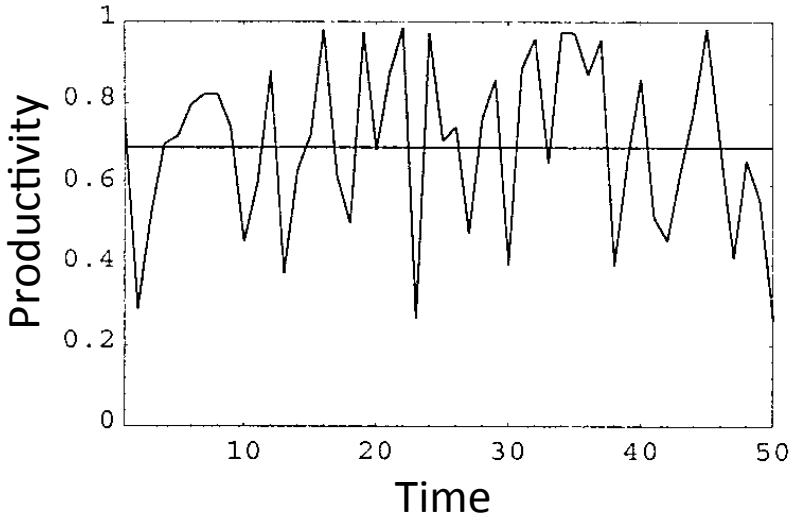
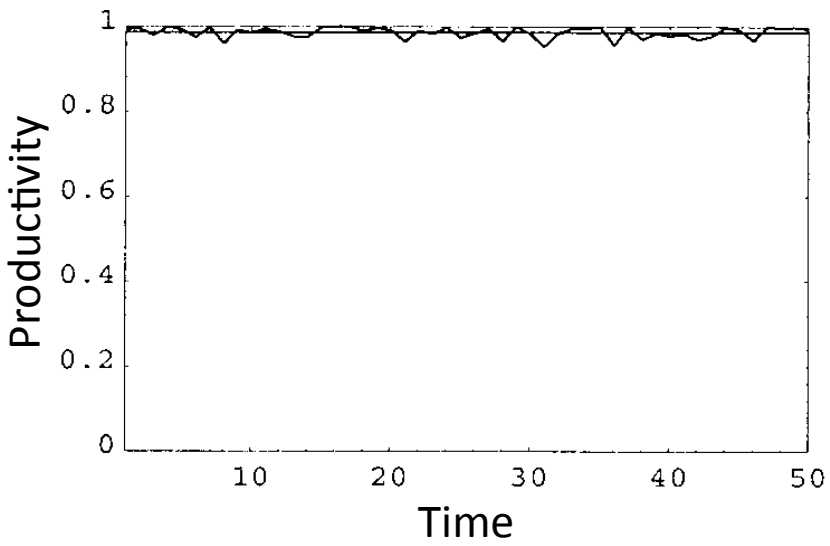


High stability



Relationship

- Dependance between two variables (or two human beings), with a significancy and an estimated strength

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« Ça s'en va et ça revient, c'est fait d'un tout petit rien »

Claude François, 1973

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The diversity – stability relationship in natural communities of butterflies, birds and bats

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Diversity – stability relationship

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

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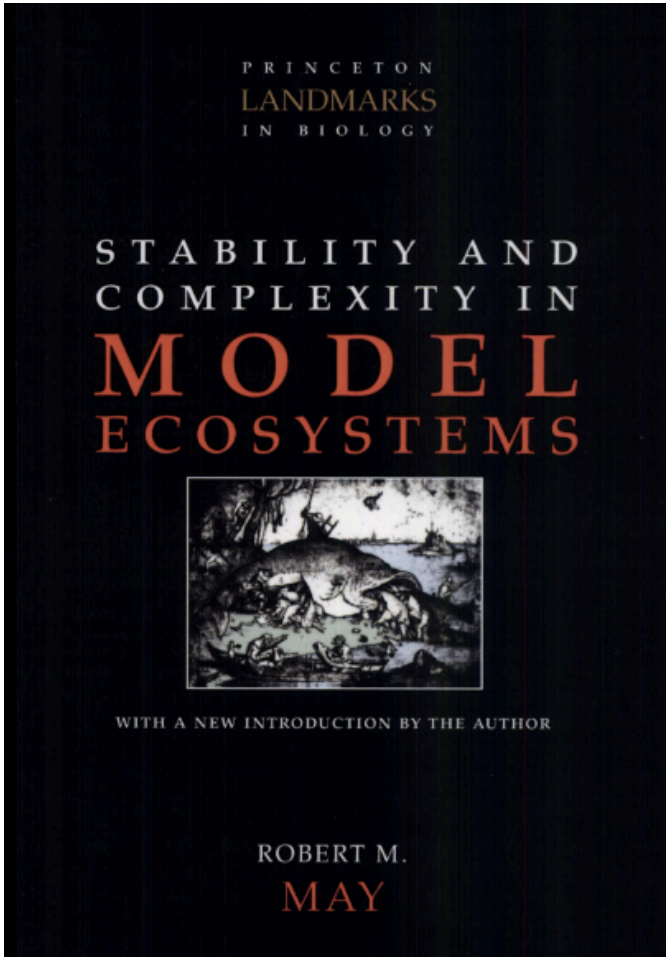

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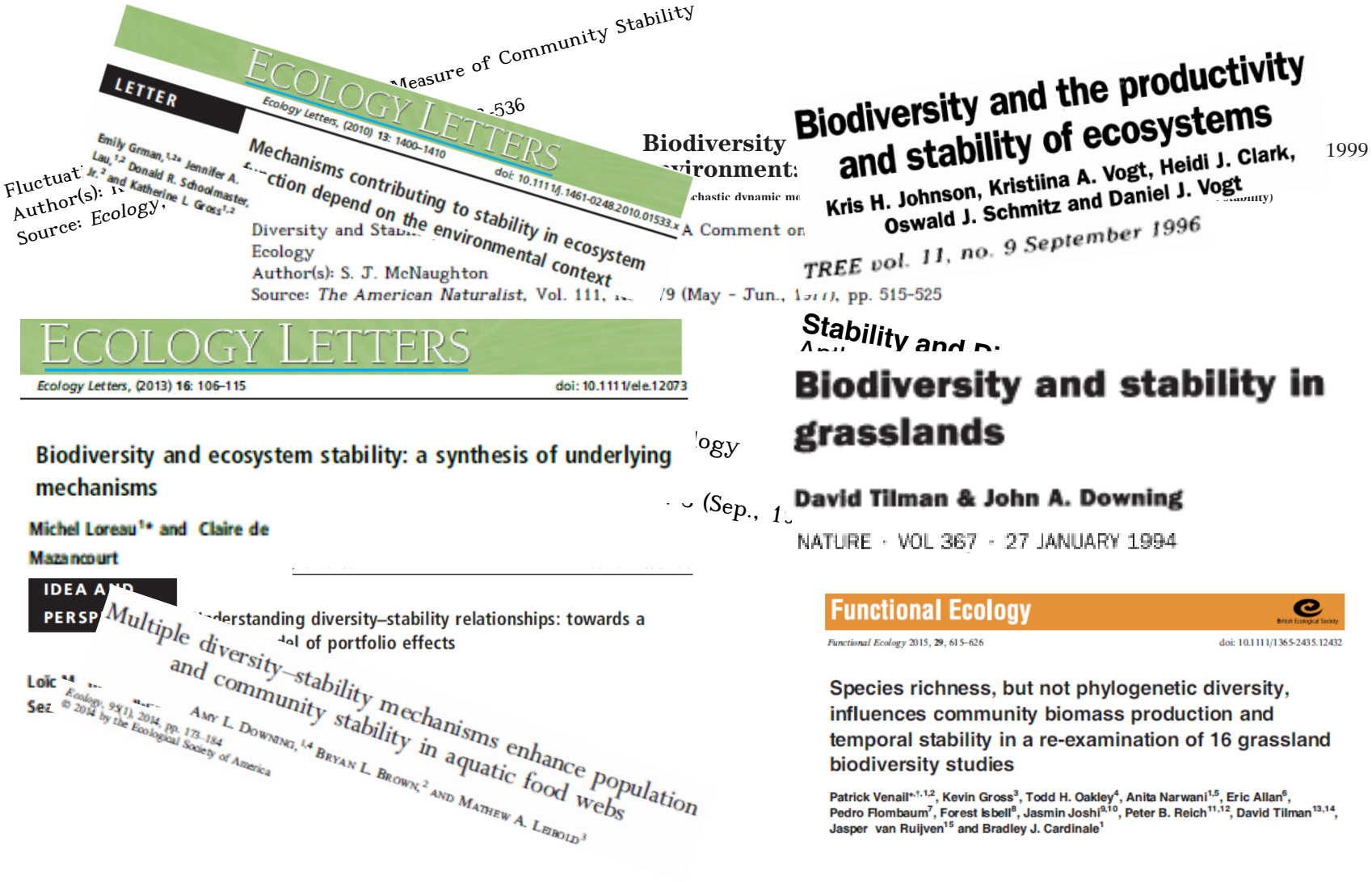

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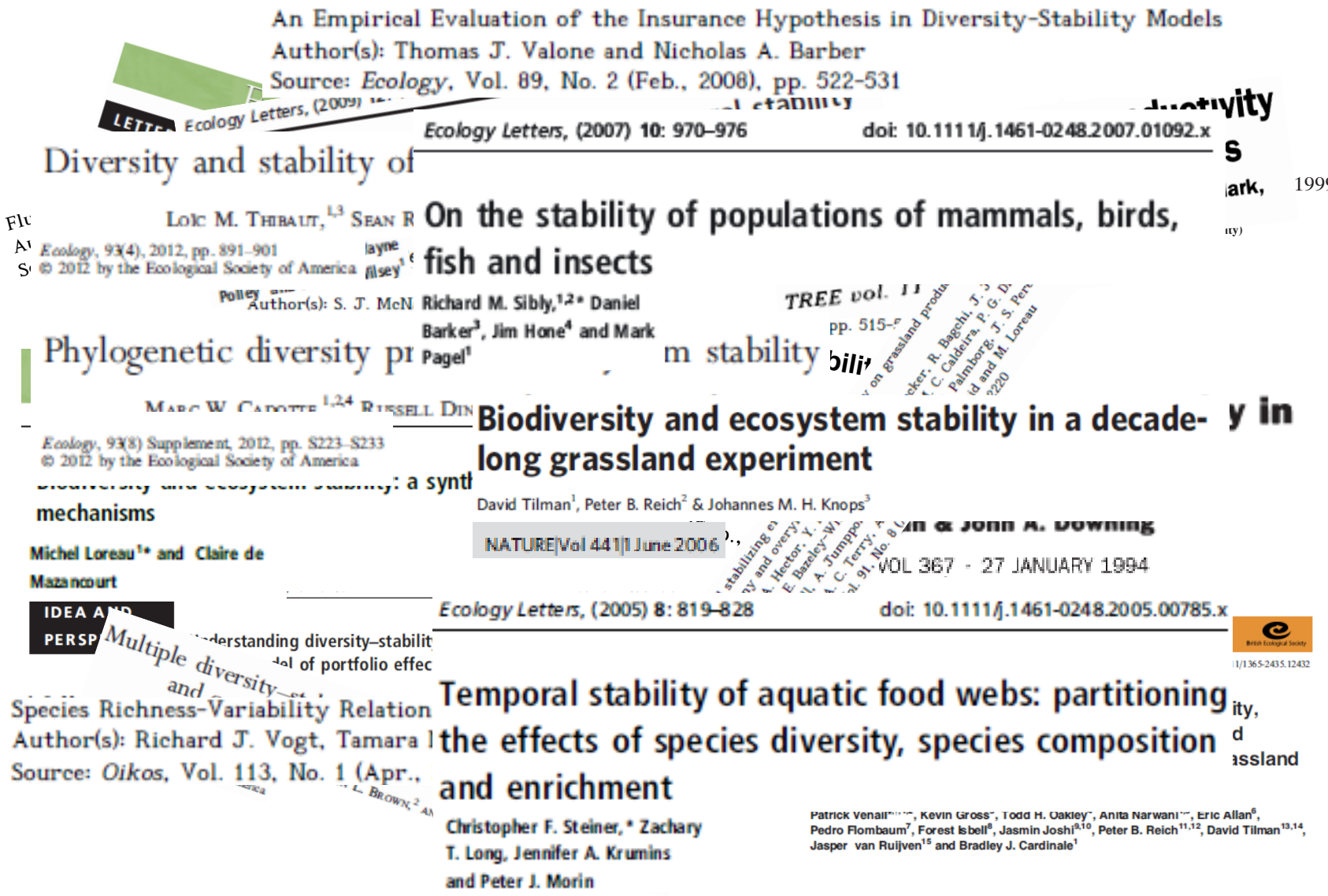
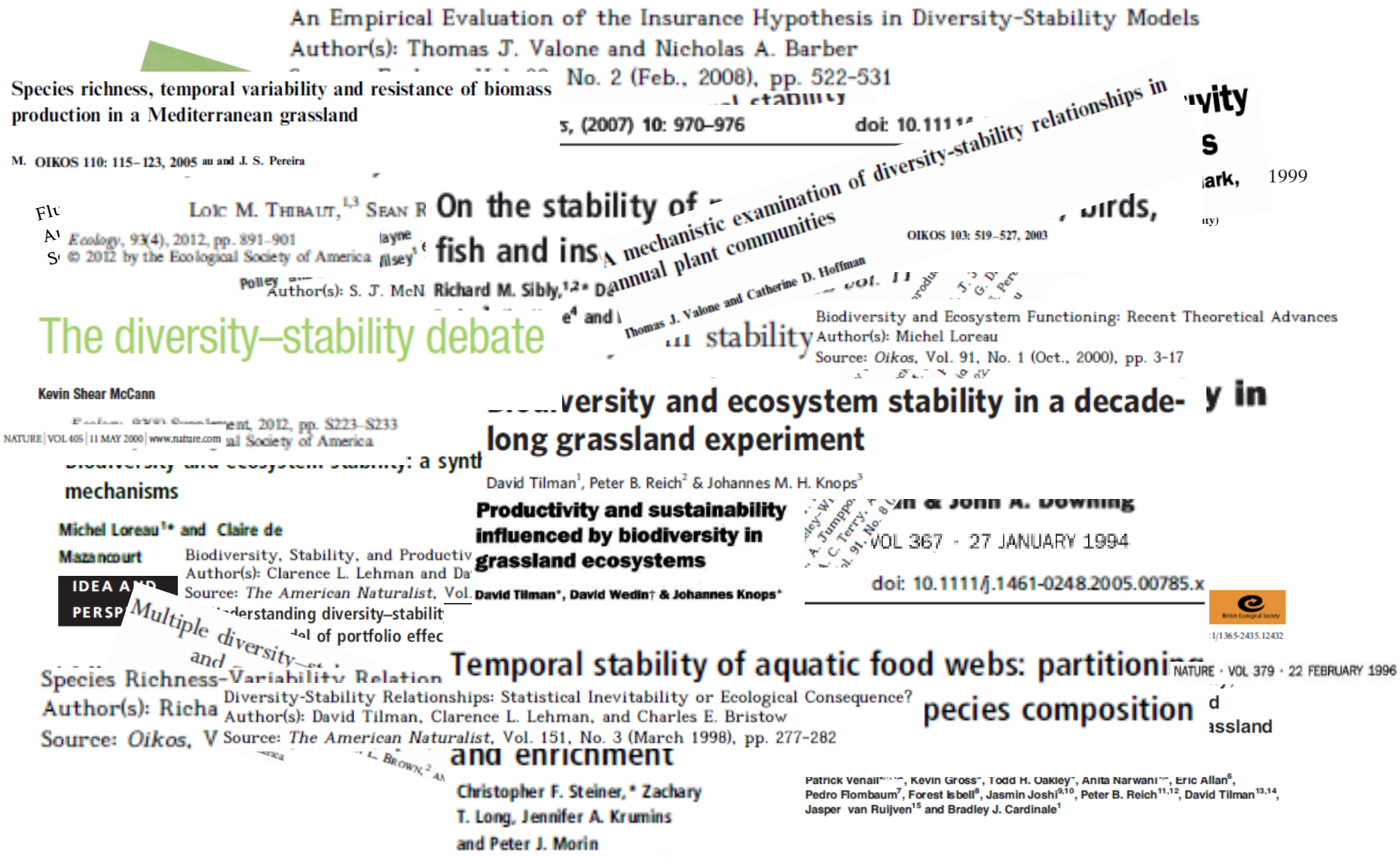


1999

Diversity – stability relationship



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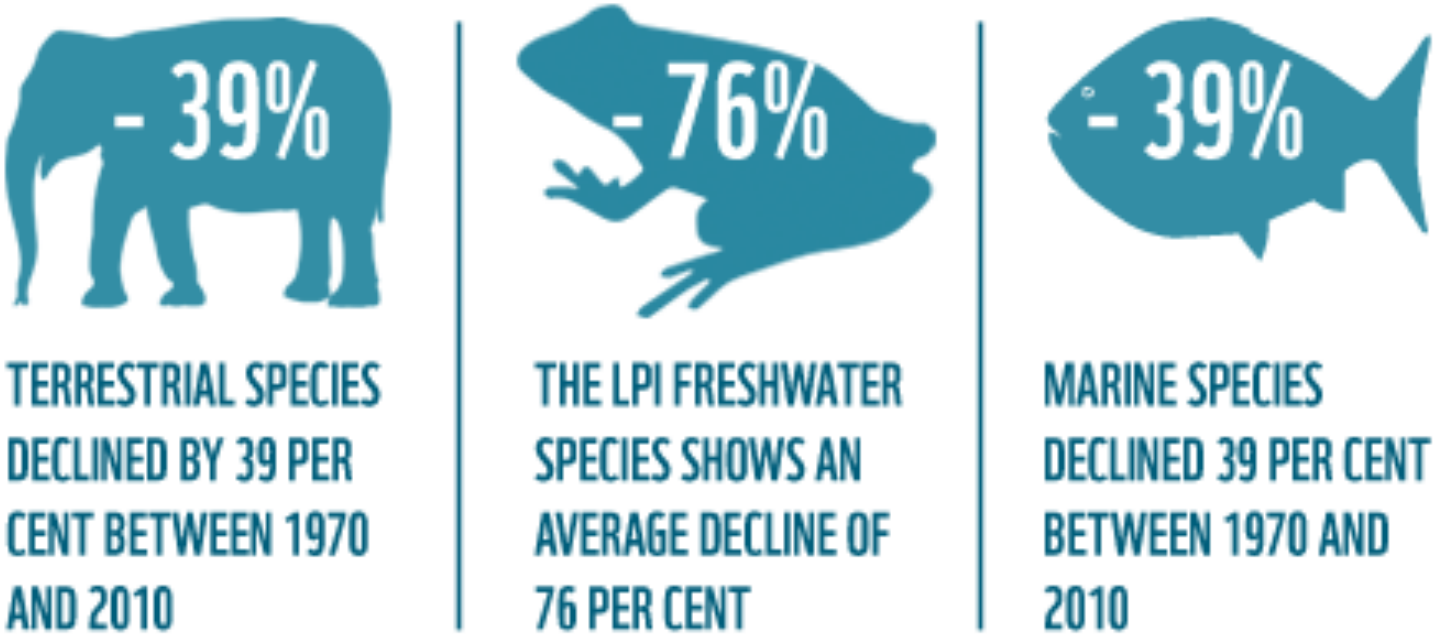

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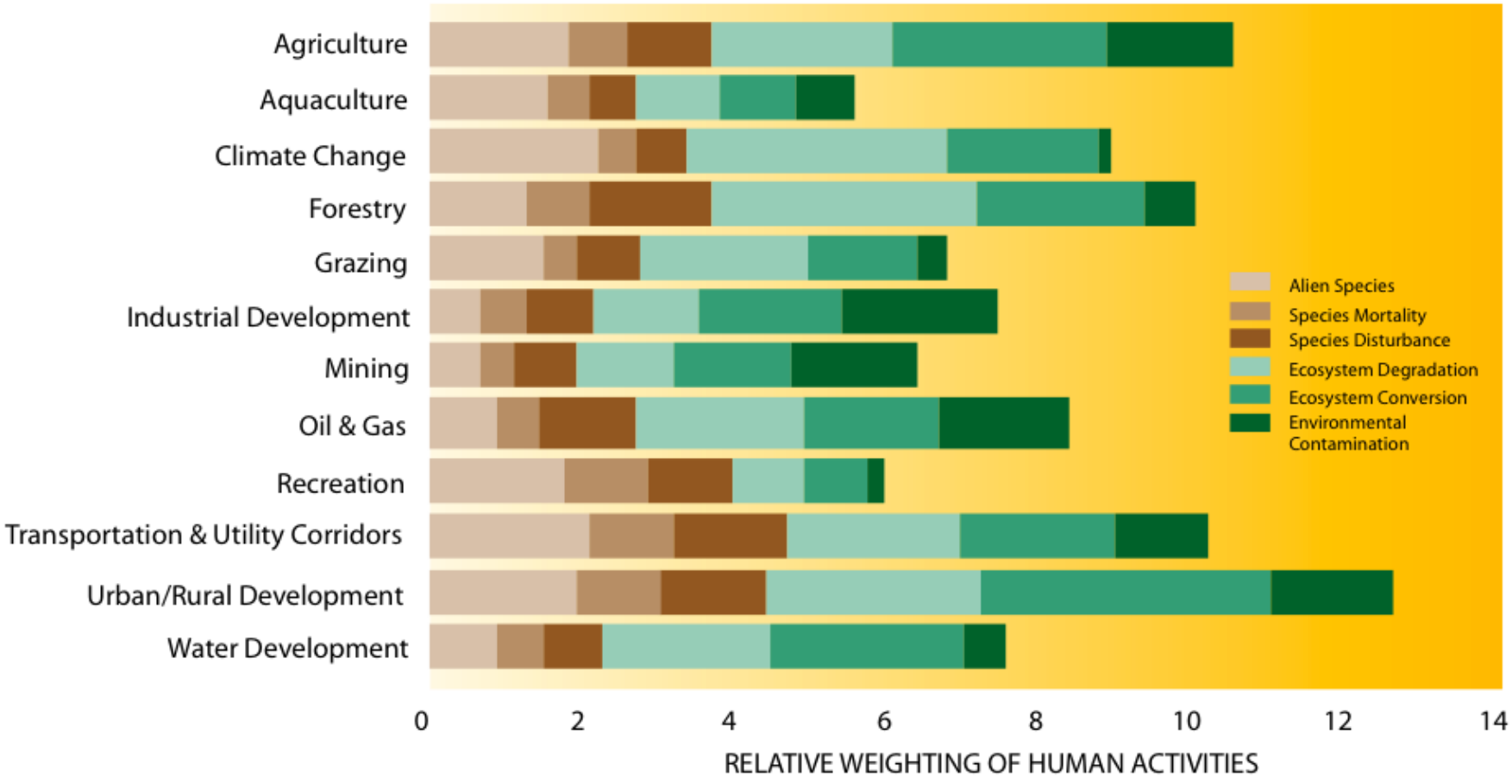
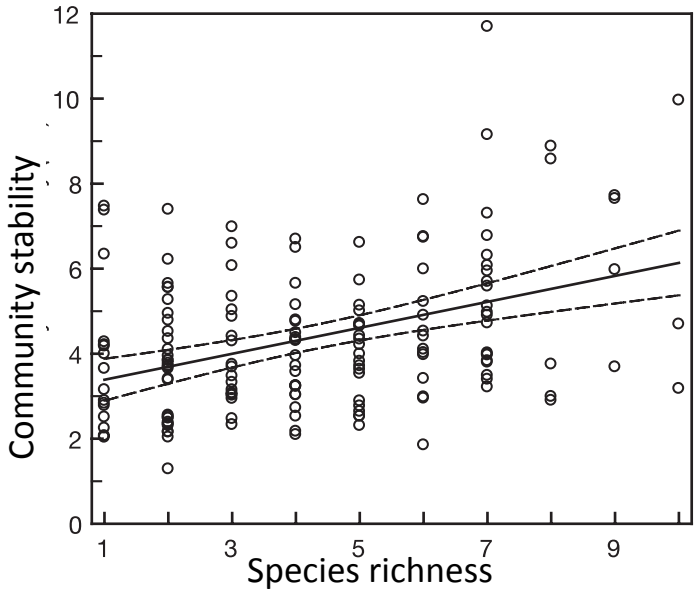
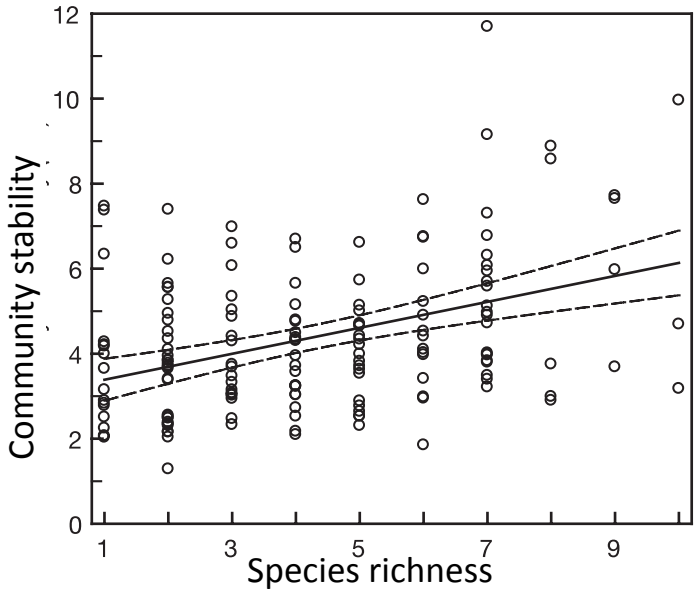


Experimental studies



(Tilman et al., 2006)

Experimental studies



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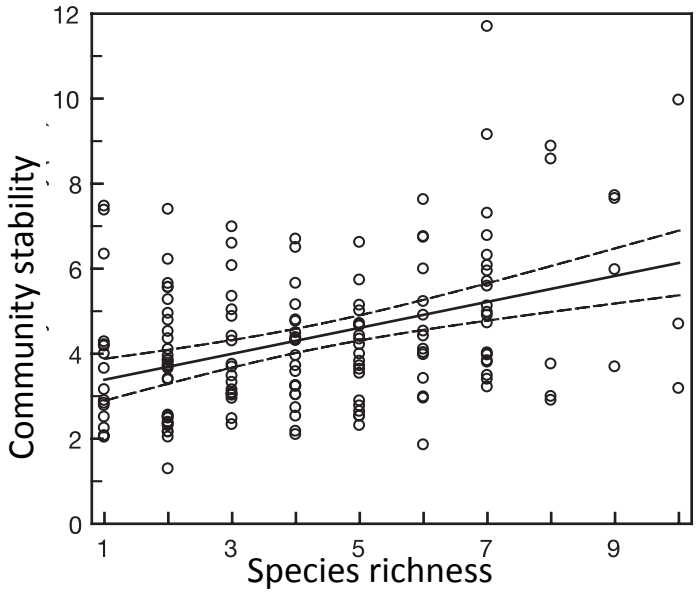

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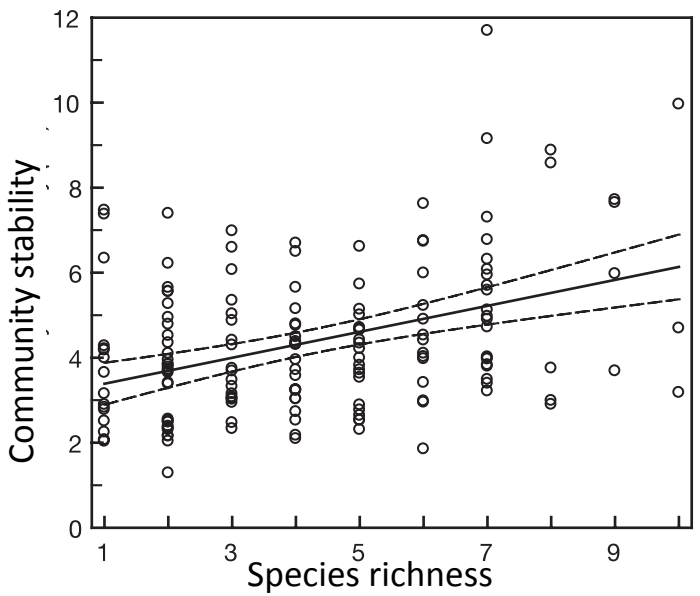
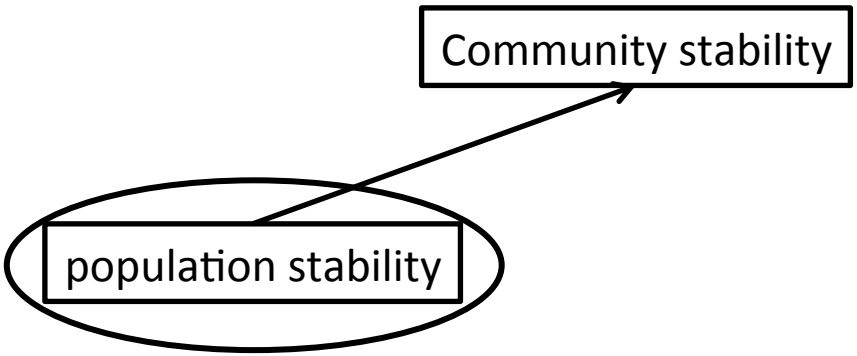


Which mechanisms ?

(Tilman et al., 2006)

Population stability



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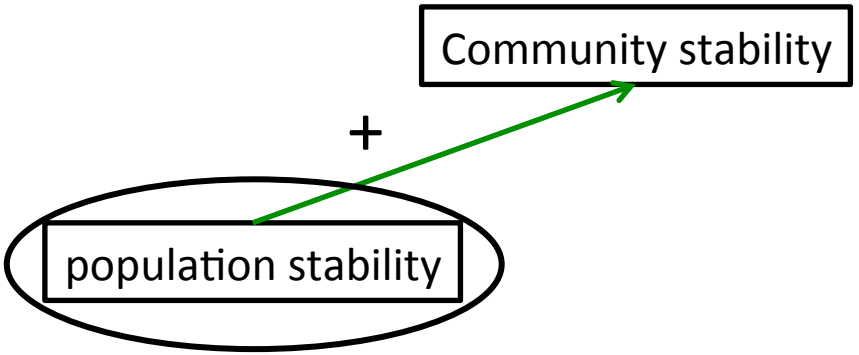
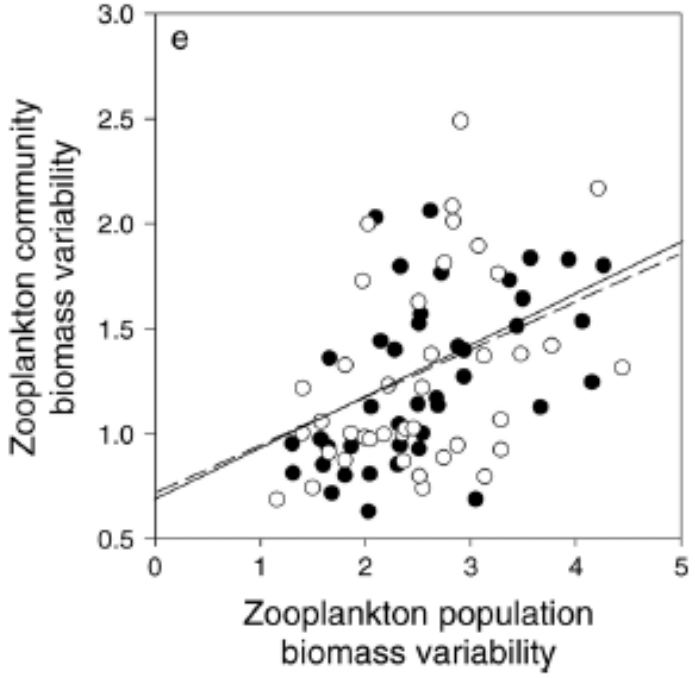
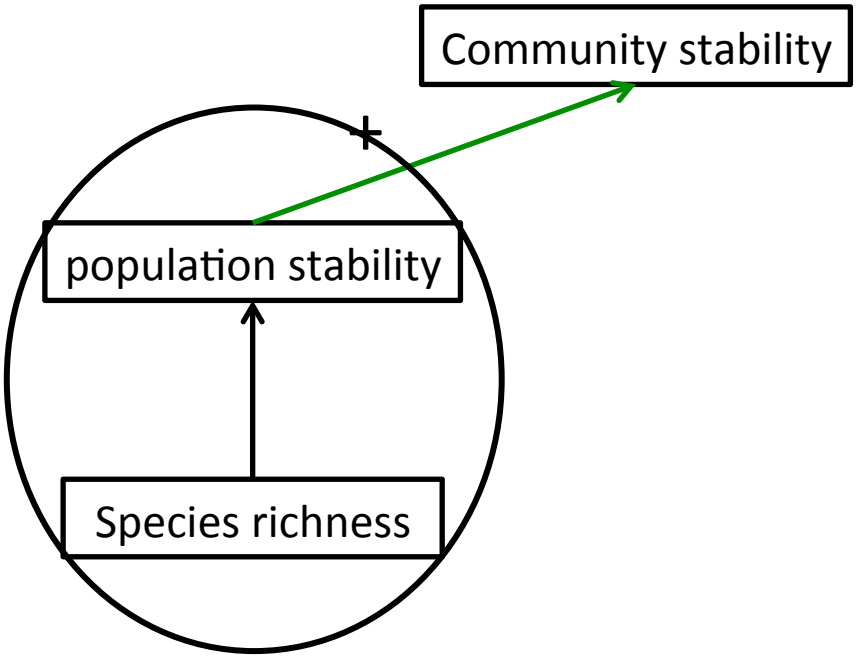




(Downing et al., 2014)

Population stability



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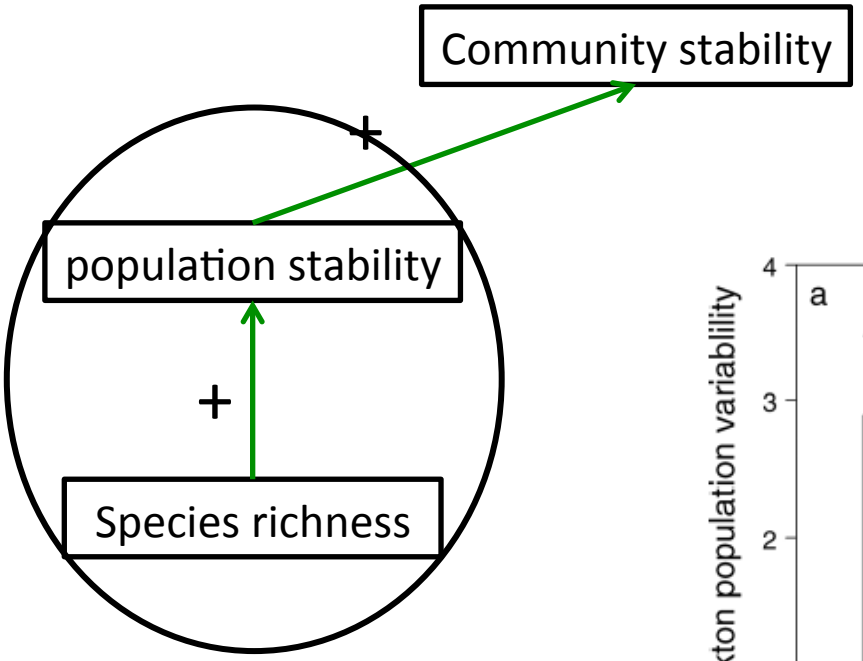

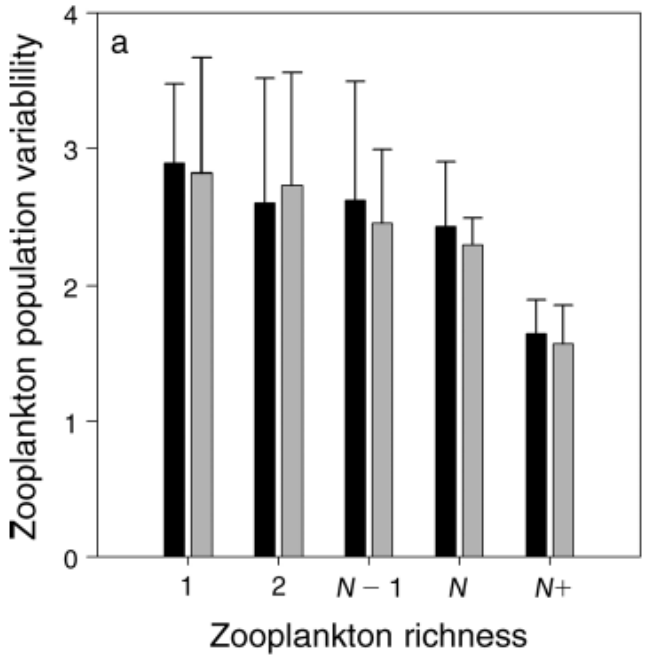

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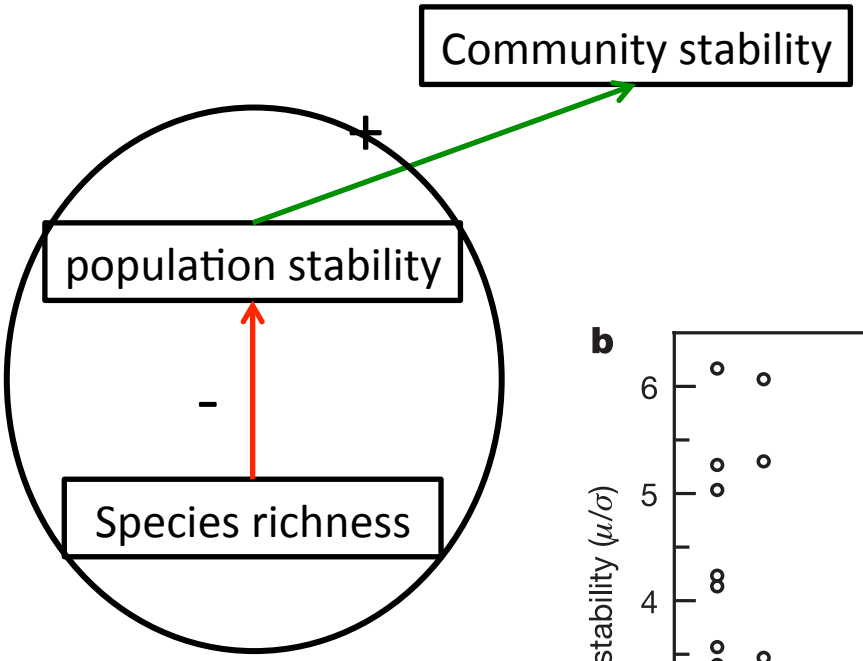

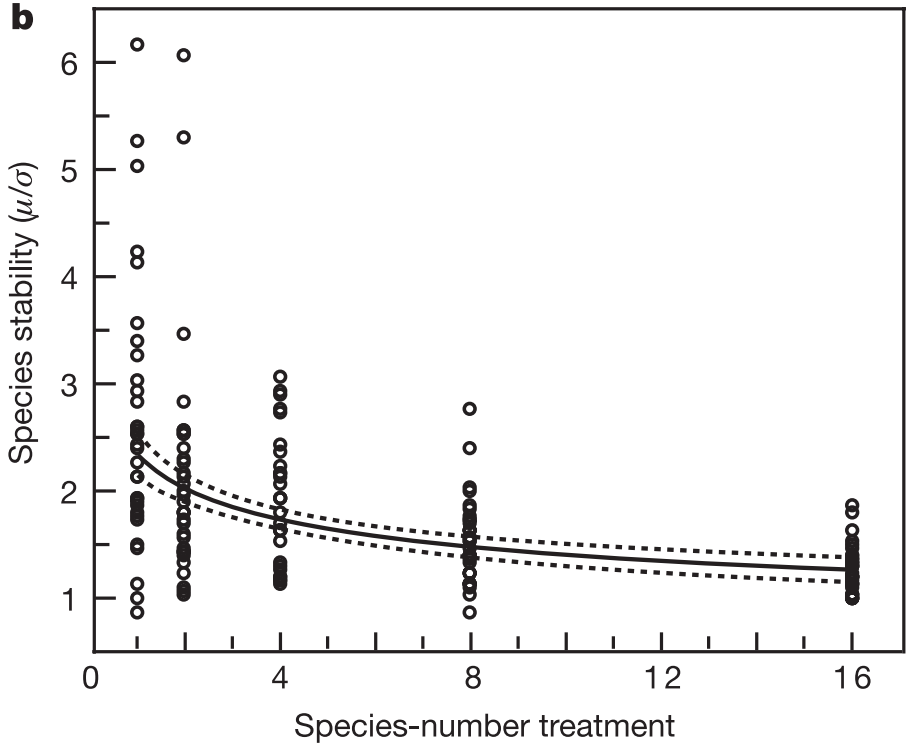

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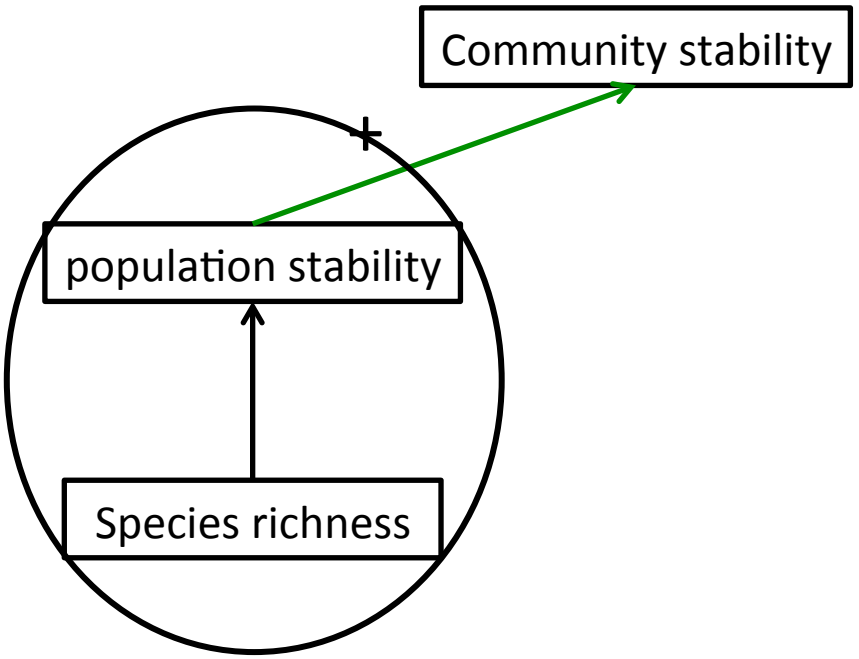
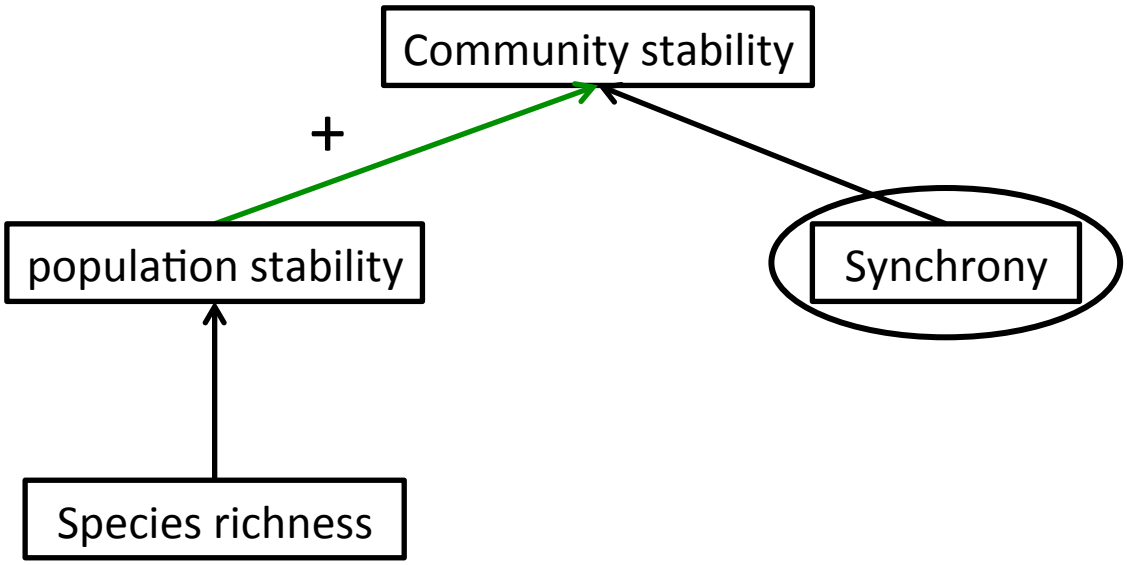


Abundance VS biomass

Animals VS plants

Population synchrony



Population synchrony

- Correlation between temporal population's fluctuations

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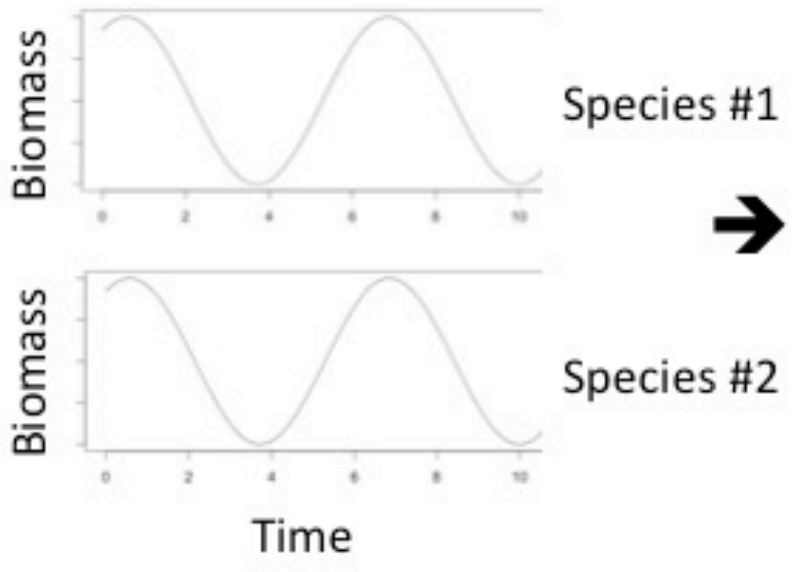
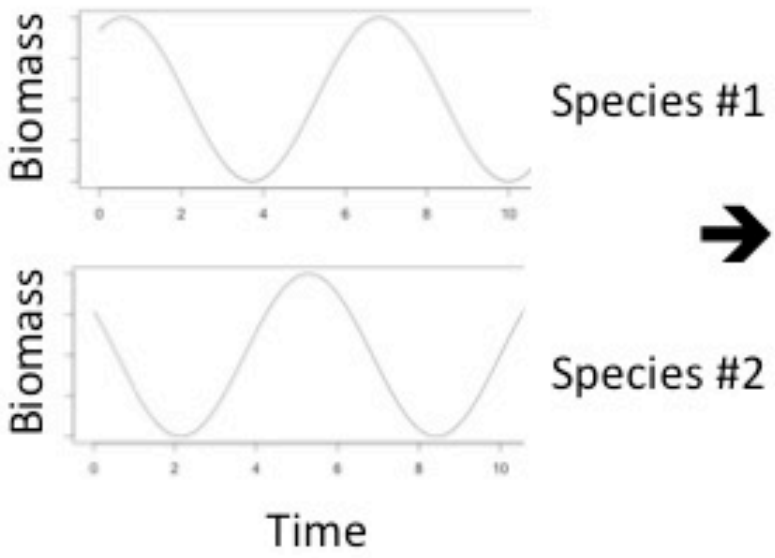


➔ Synchronous populations

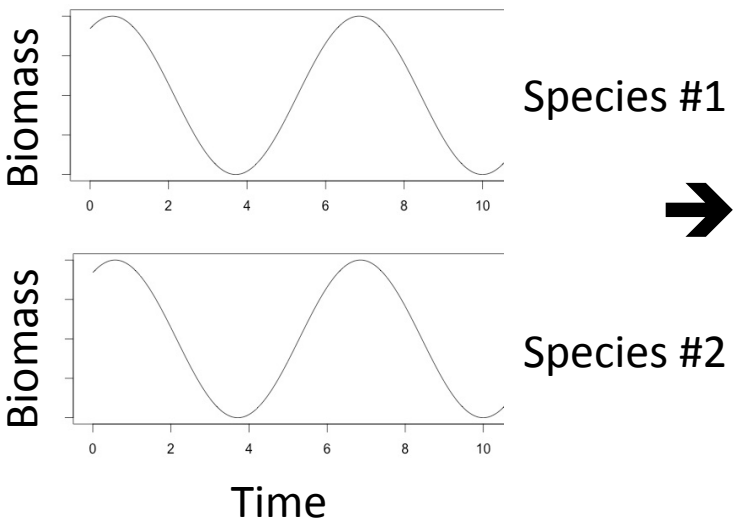
Population synchrony

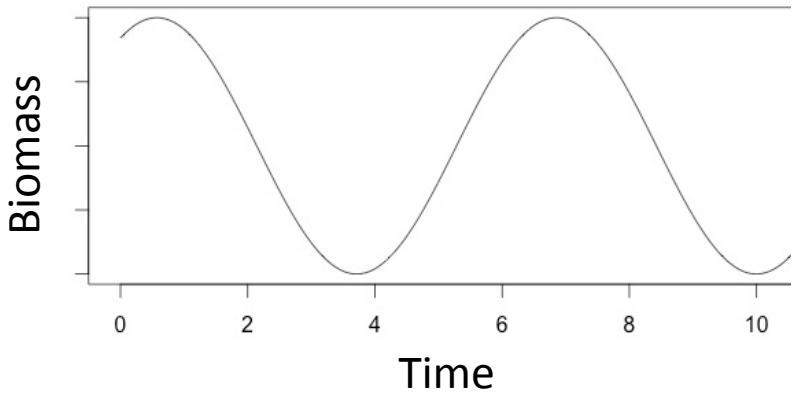
- Correlation between temporal population's fluctuations

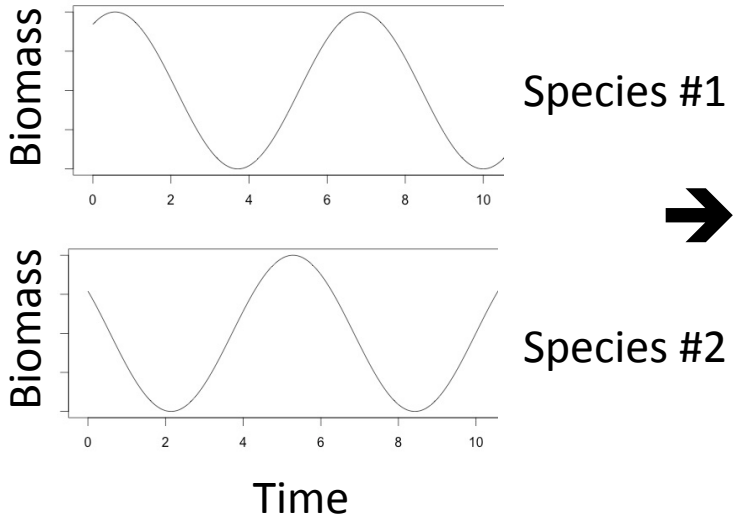


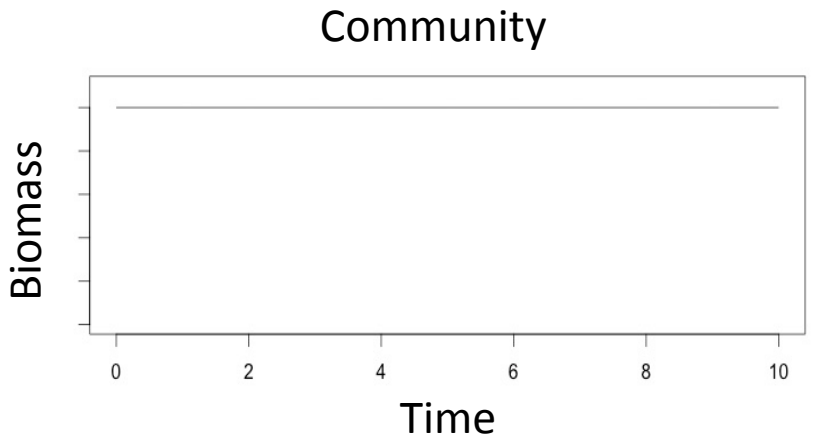
→ Asynchronous populations

Population synchrony









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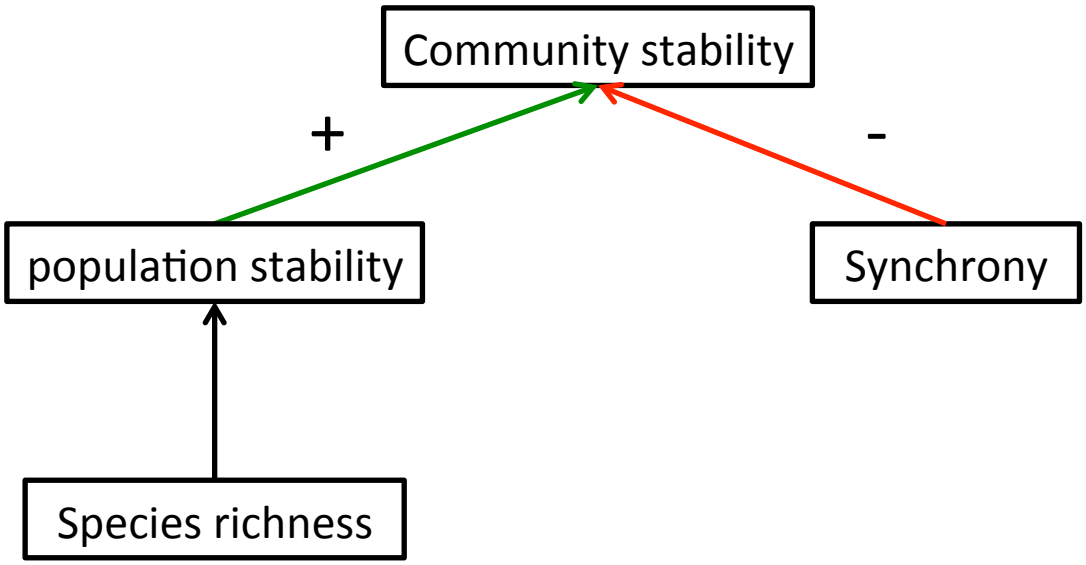

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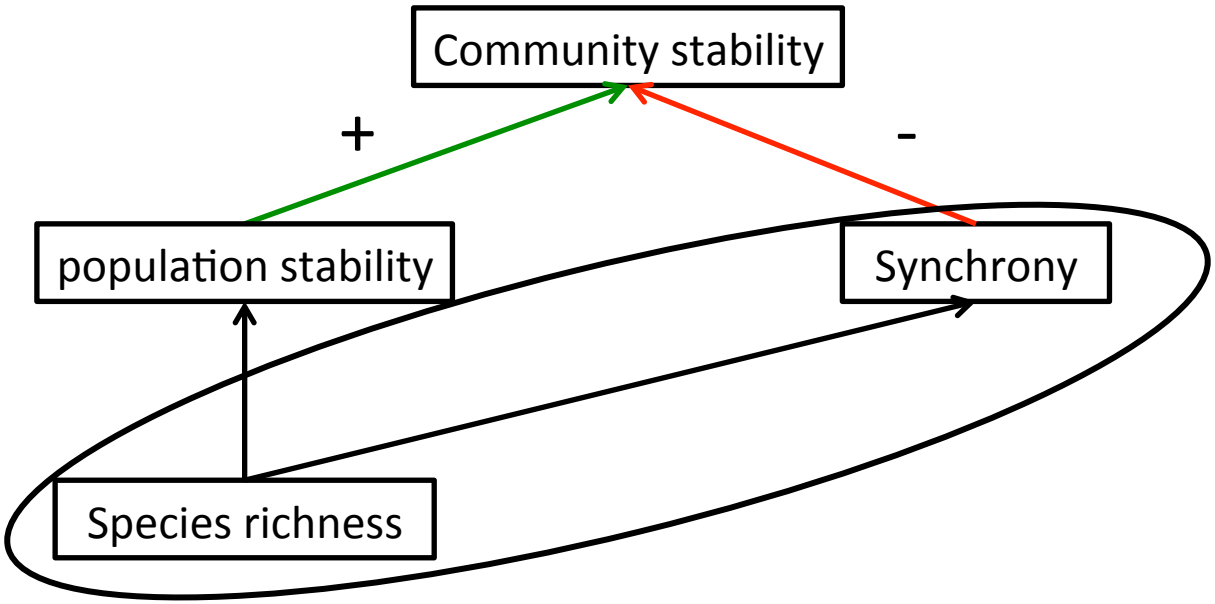

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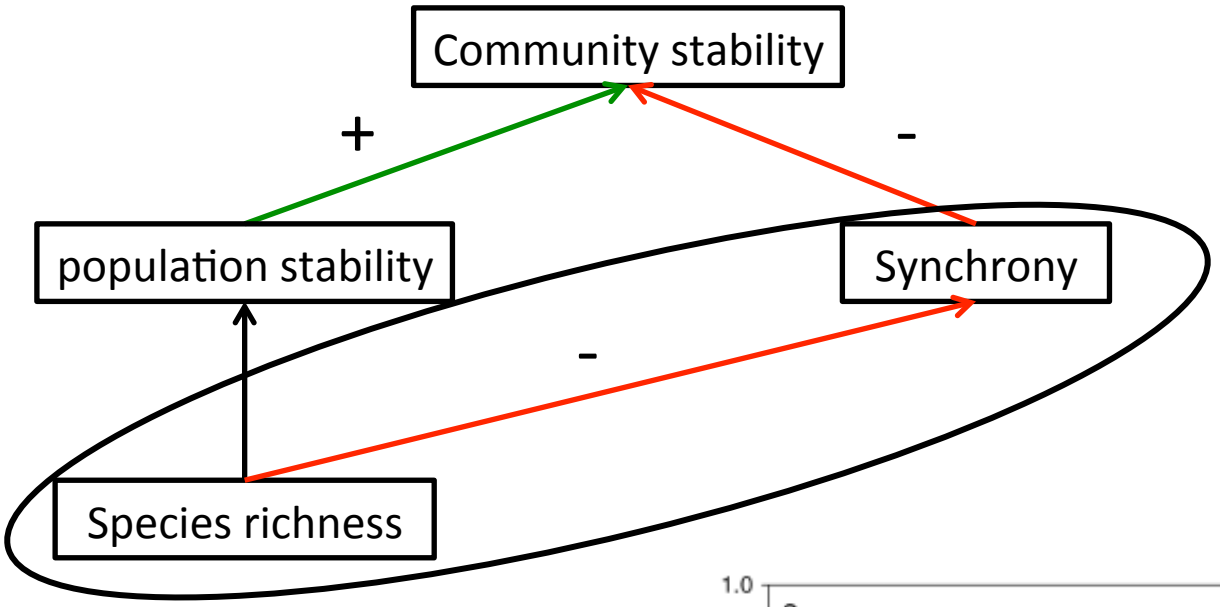
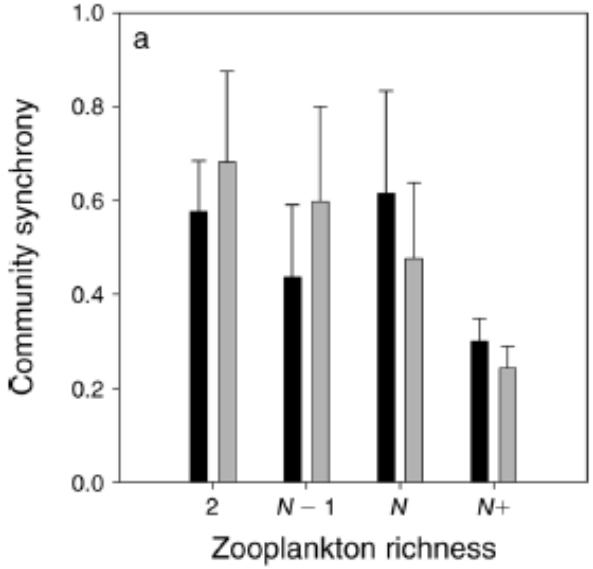
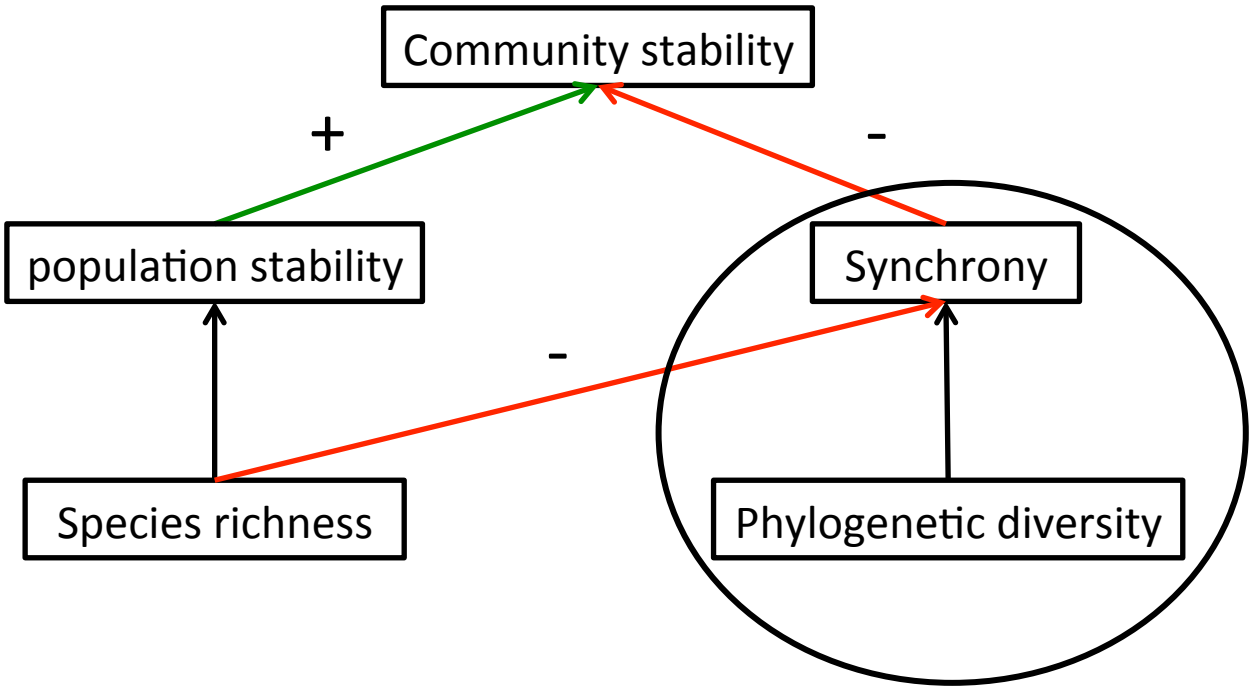




(Downing et al., 2014)

Phylogenetic diversity



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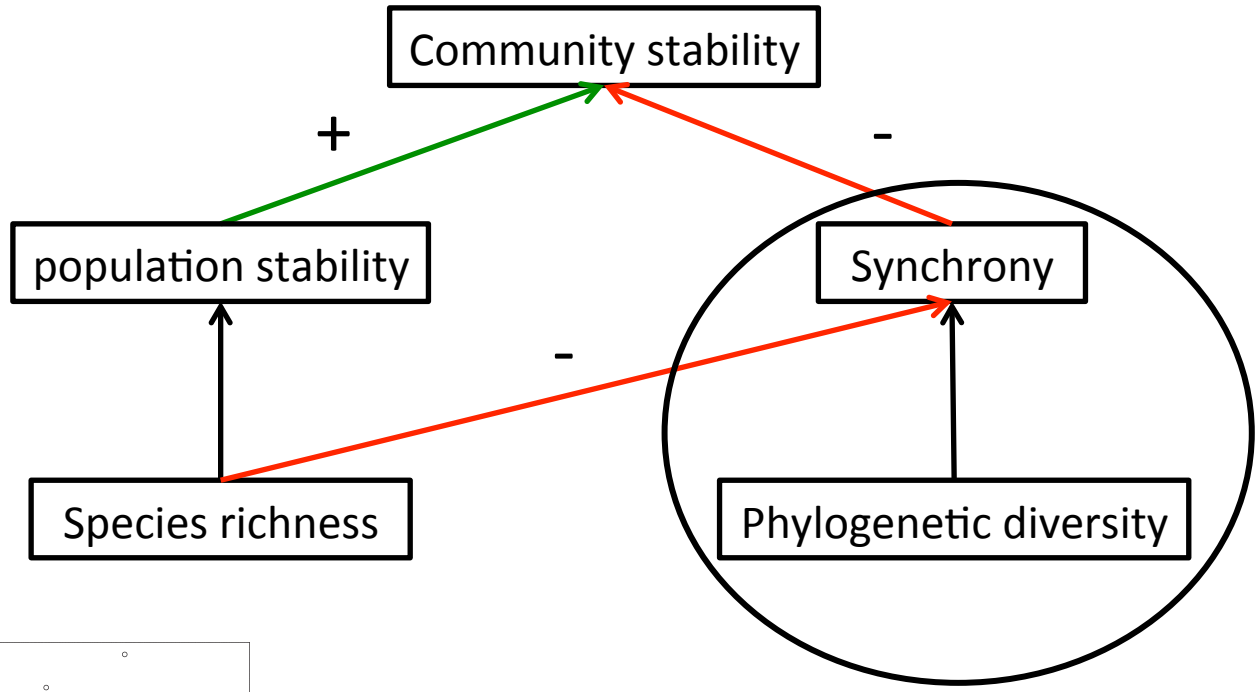
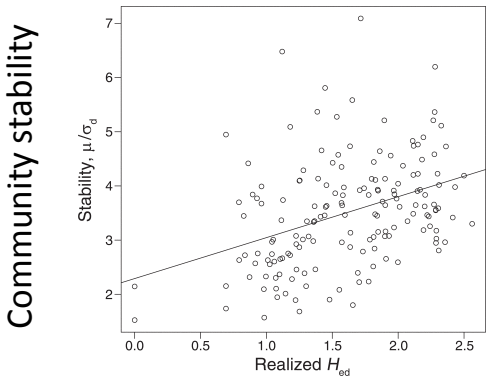




But

Functional Ecology

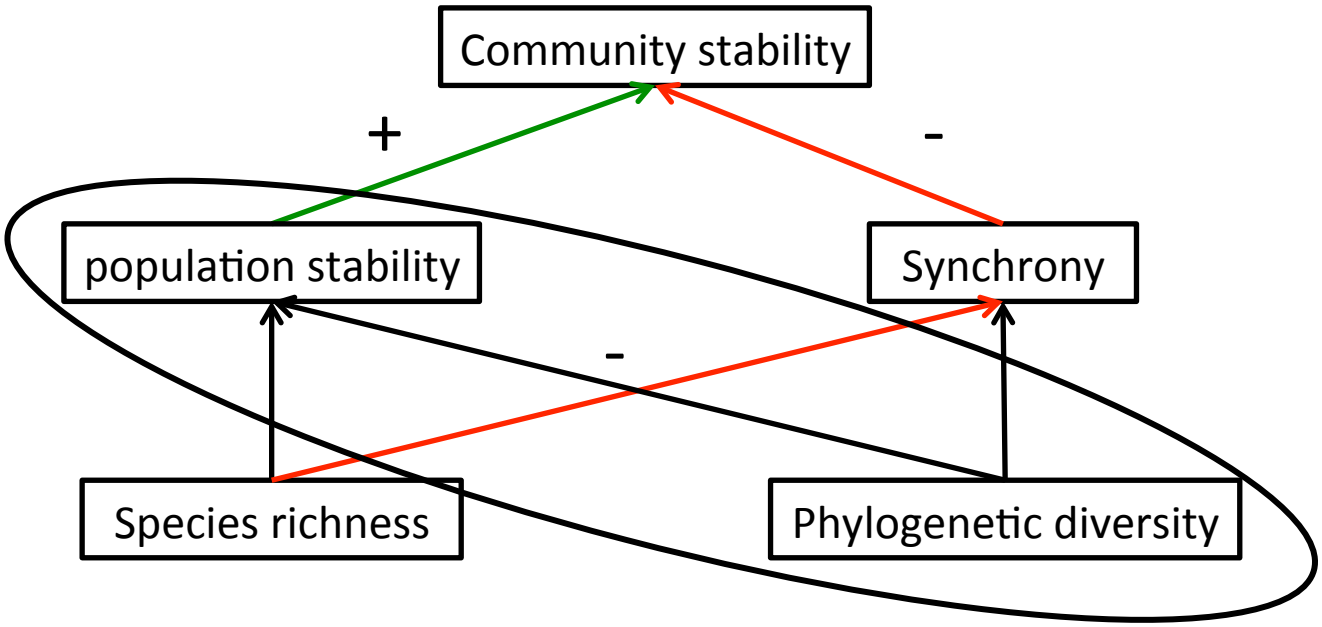
Functional Ecology 2015, 29, 615-626 doi: 10.1111/1365-2435.12432

Species richness, but not phylogenetic diversity, influences community biomass production and temporal stability in a re-examination of 16 grassland biodiversity studies

Patrick Venail[*,†,1,2], Kevin Gross[3], Todd H. Oakley[4], Anita Narwani[1,5], Eric Allan[6], Pedro Flombaum[7], Forest Isbell[8], Jasmin Joshi[9,10], Peter B. Reich[11,12], David Tilman[13,14], Jasper van Ruijven[15] and Bradley J. Cardinale[1]

(Cadotte et al., 2012)

Phylogenetic diversity



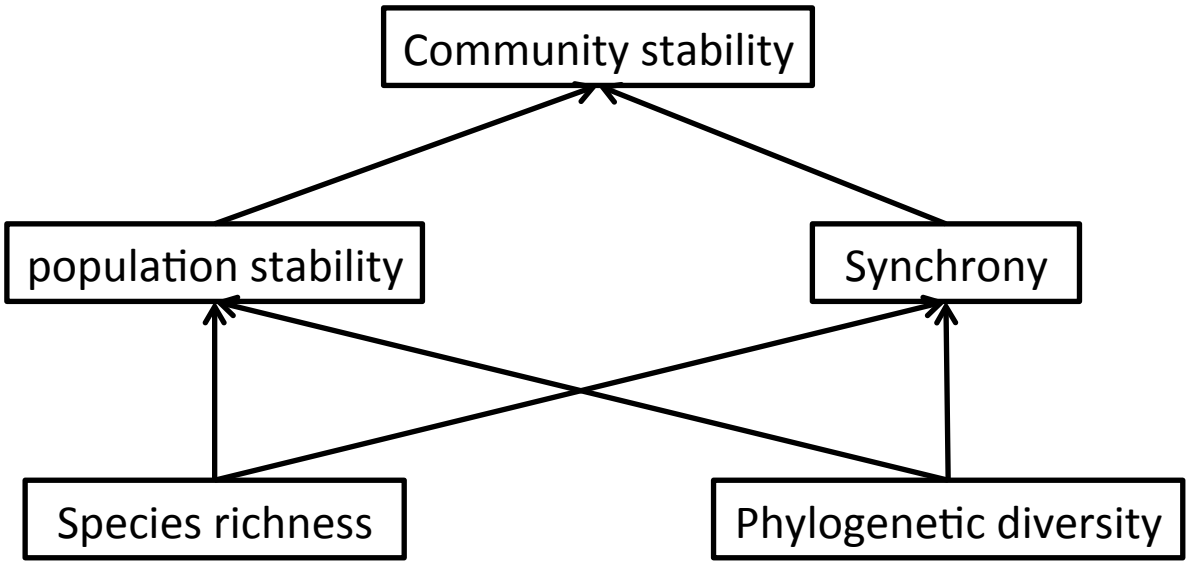
Once upon a time…

Experimental communities

Experimental communities

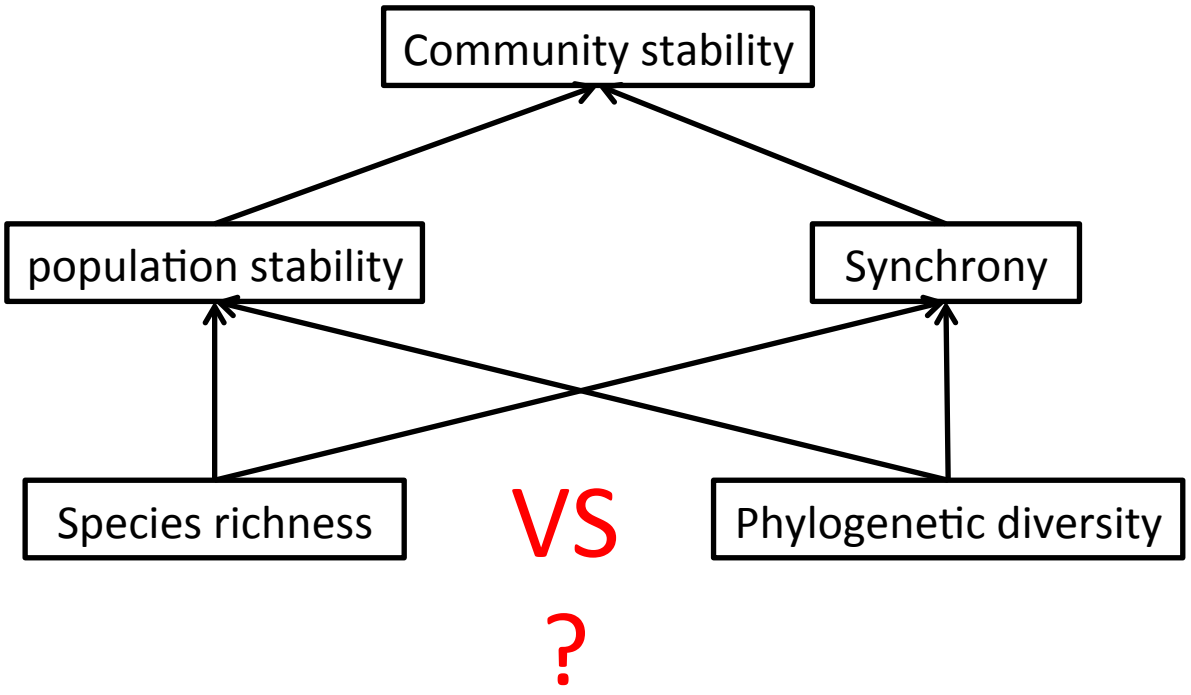
Controlled species richness
and
Random species assemblages

What happens in natural communities ?

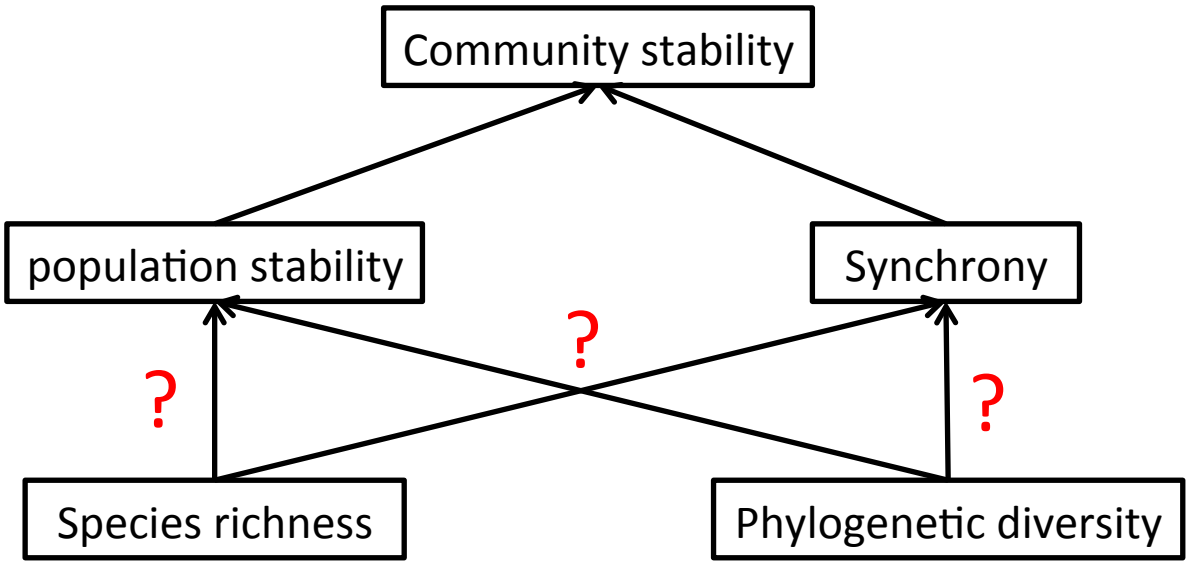


?

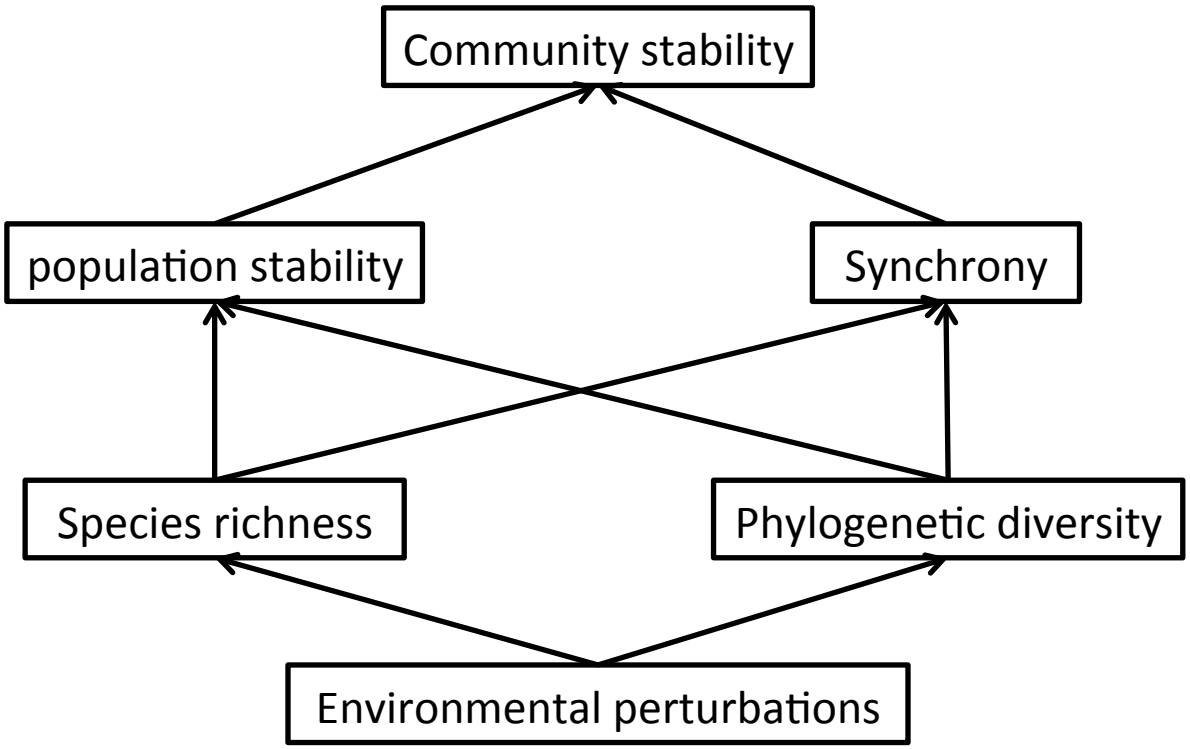
What drives this relationship ?



Through which mechanisms ?



What is the effect of environmental perturbations ?



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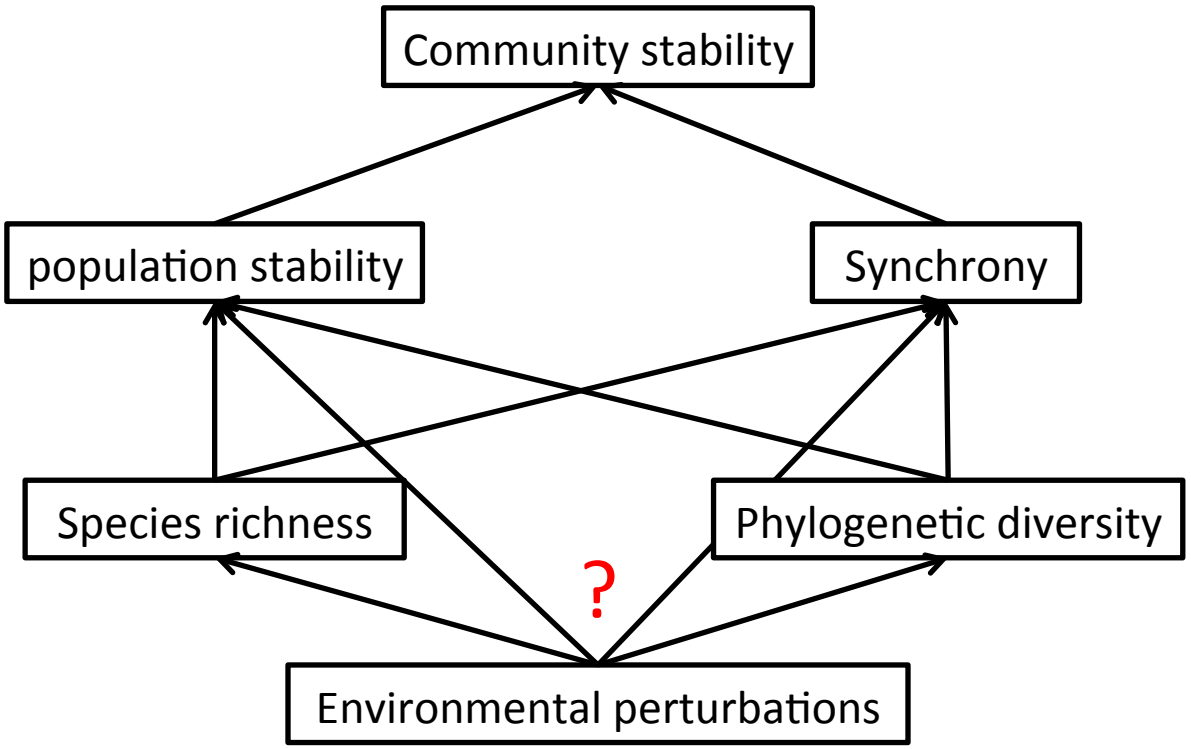

Datasets

Highly replicated time series

➔ Lot of diversity levels

➔ Wide environmental range

(http://vigienature.mnhn.fr/)

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VIGIENATURE

Un réseau de citoyens qui fait avancer la science

Citizen science programs

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SUIVI TEMPOREL DES OISEAUX COMMUNS

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Observatoire de la Biodiversité des Jardins

OPÉRATION PAPILLONS

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STOC

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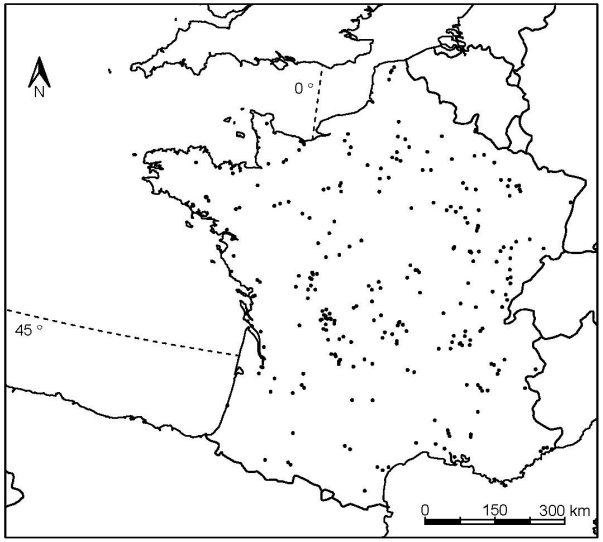
OPÉRATION PAPILLONS

Vigie-Chiro

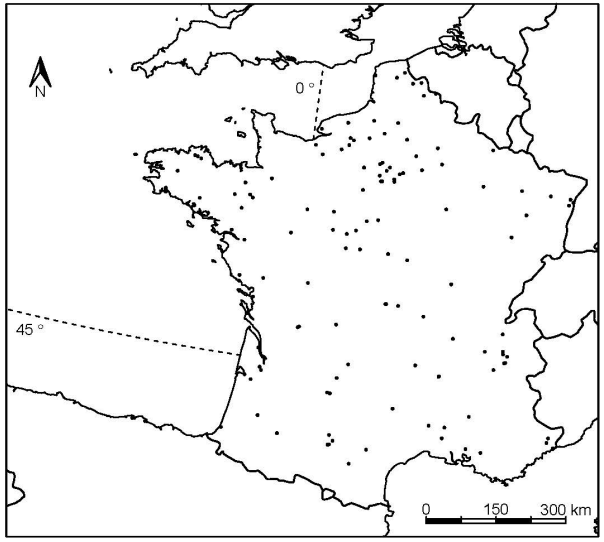
Suivi des chauves-souris

(http://vigienature.mnhn.fr/)

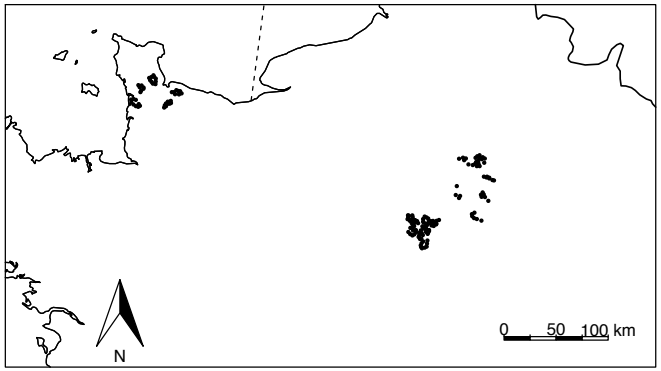
Datasets



Birds
→ 269 communities
→ 75 species
→ 8 years



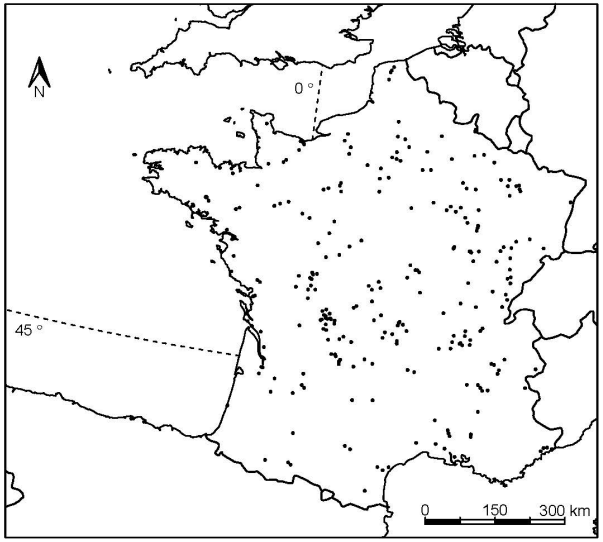
Butterflies
→ 131 communities
→ 14 species
→ 7 years

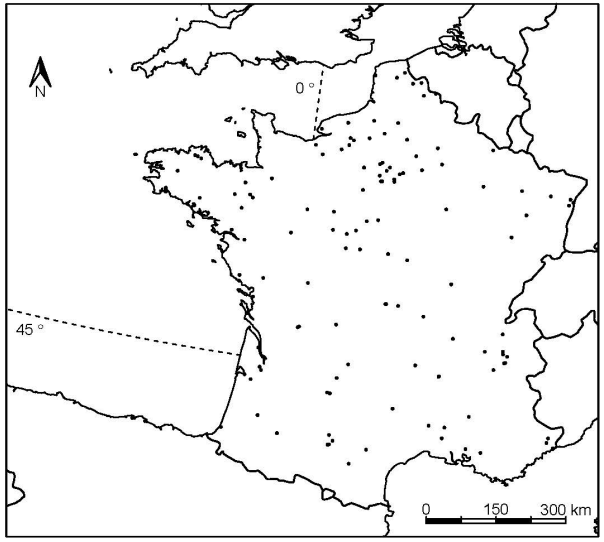


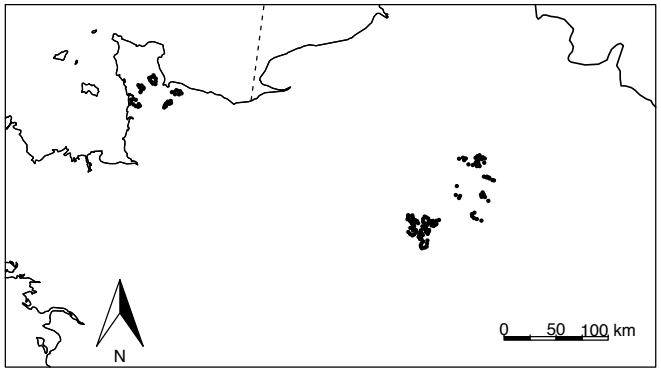
Bats
→ 162 communities
→ 7 species
→ 4 years

Annual survey
Same volunteer
Standardized protocol
Common species

Datasets







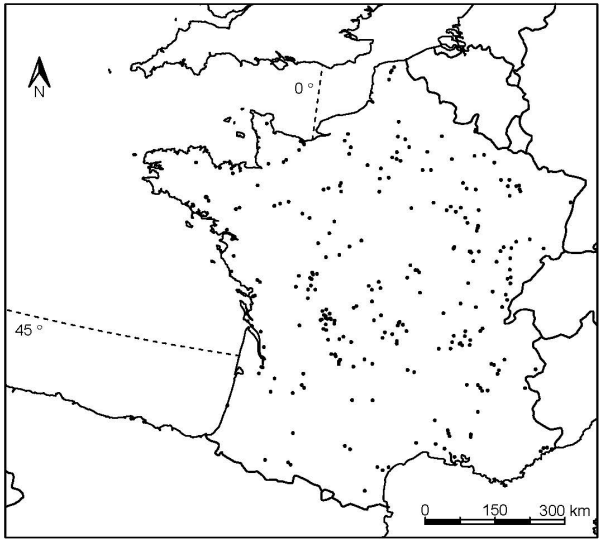
Birds
→ 269 communities
→ 75 species
→ 8 years

Butterflies
→ 131 communities
→ 14 species
→ 7 years

Bats
→ 162 communities
→ 7 species
→ 4 years

1 abundance value / species / community / year

Datasets



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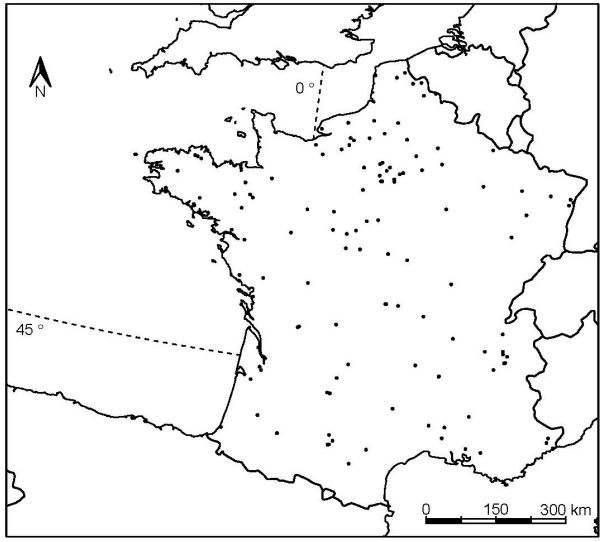

Butterflies
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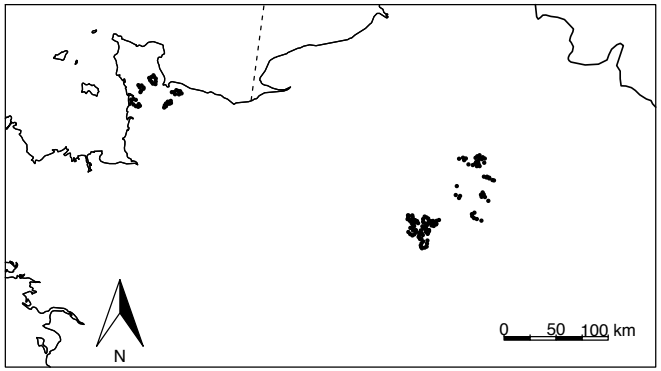


Bats
→ 162 communities
→ 7 species
→ 4 years

Stability of community's abundance

Stability measure

Community stability

$$\frac{1}{CV} = \frac{\mu}{\sigma}$$

Stability measure

Community stability

$$\frac{1}{CV_{community}} = \frac{1}{\overline{CV}_{populations}} x \frac{1}{\sqrt{\varphi}}$$

(Loreau & de Mazancourt, 2008; Thibault & Connolly, 2013)

Weighted mean population stability

Community stability

$$\frac{1}{CV_{community}} = \frac{1}{\sqrt{CV_{populations}}} x \frac{1}{\sqrt{\varphi}}$$

Weighted population stability

$$CV_i^w = \frac{\mu_i}{\mu_{community}} x CV_i$$

(Loreau & de Mazancourt, 2008; Thibault & Connolly, 2013)

Synchrony index

Community stability

$$\frac{1}{CV_{community}} = \frac{1}{\overline{CV}_{populations}} x \frac{1}{\sqrt{\varphi}}$$

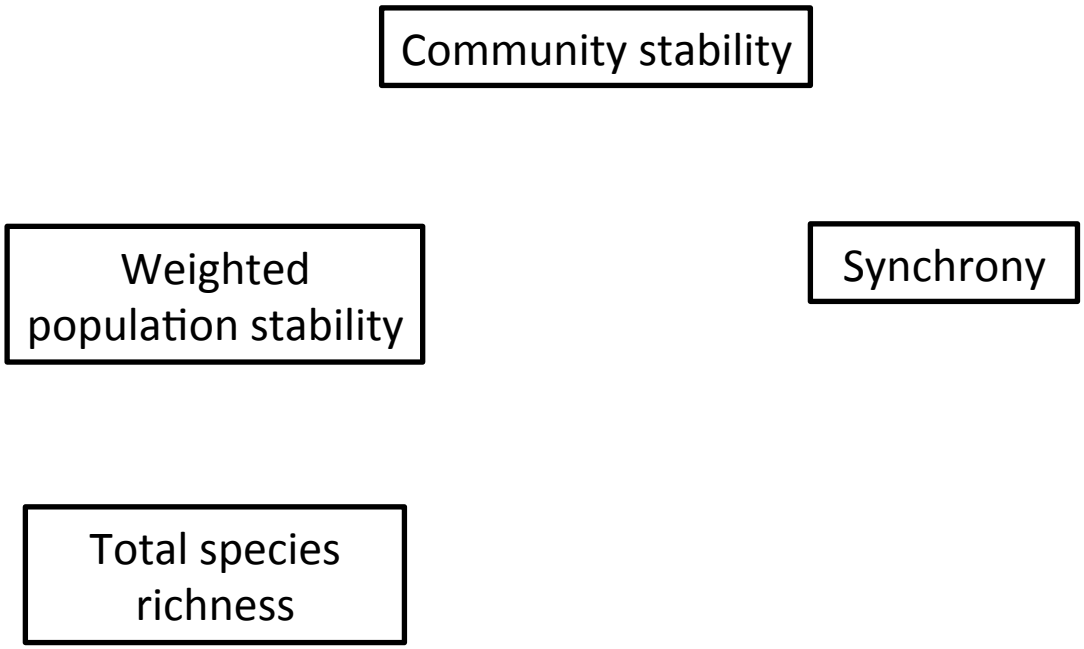
Weighted population stability

Synchrony

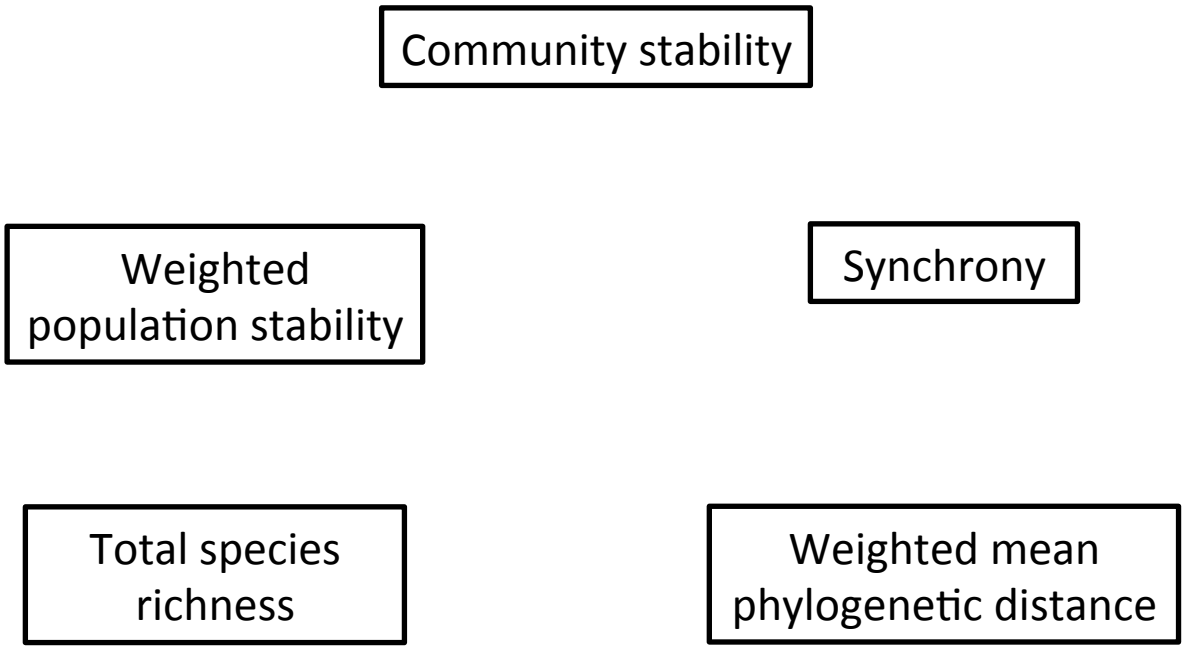
$$\varphi = \frac{\sigma^2_{community}}{(\Sigma_i \sigma_i)^2}$$

(Loreau & de Mazancourt, 2008; Thibault & Connolly, 2013)

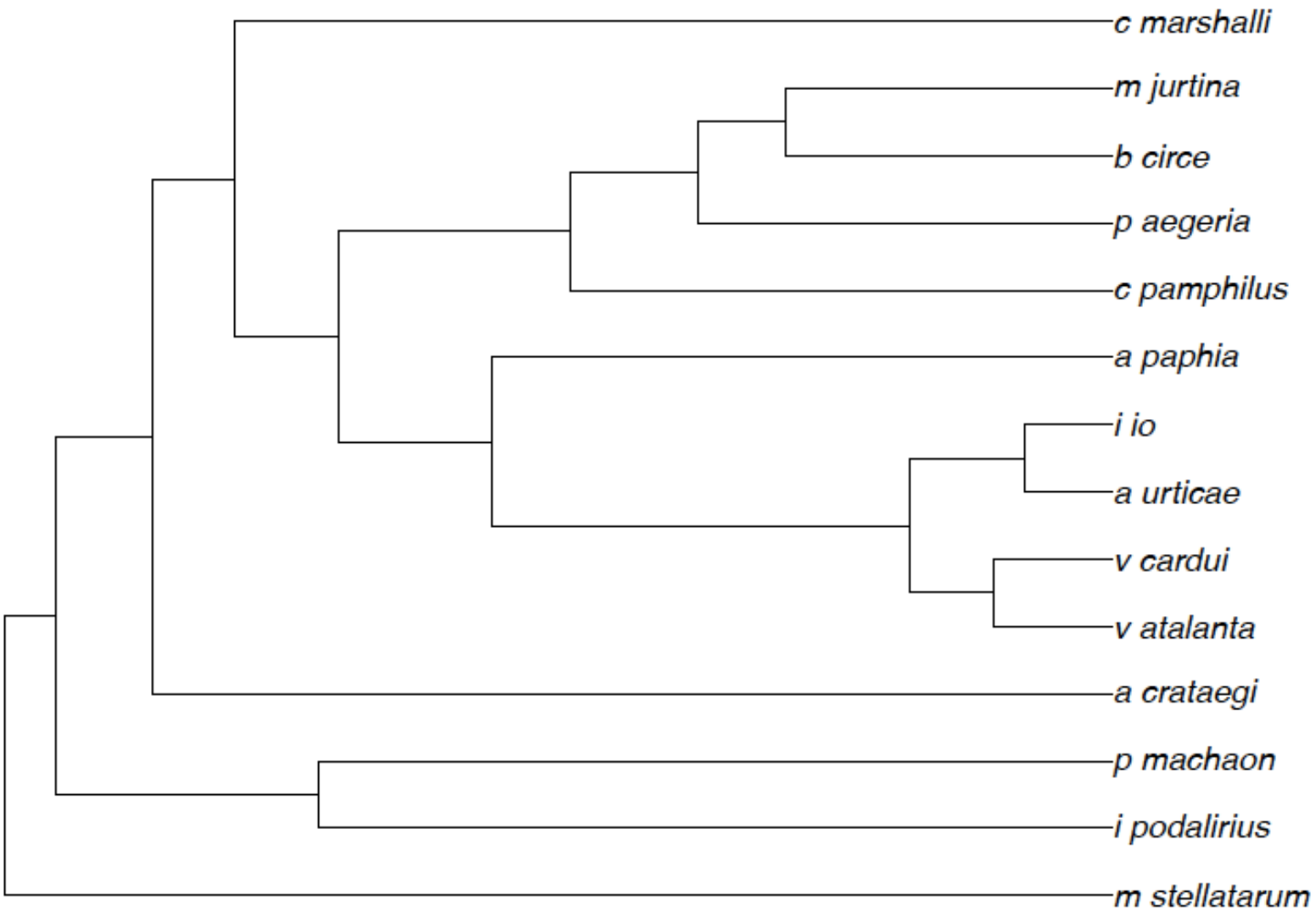
Community composition



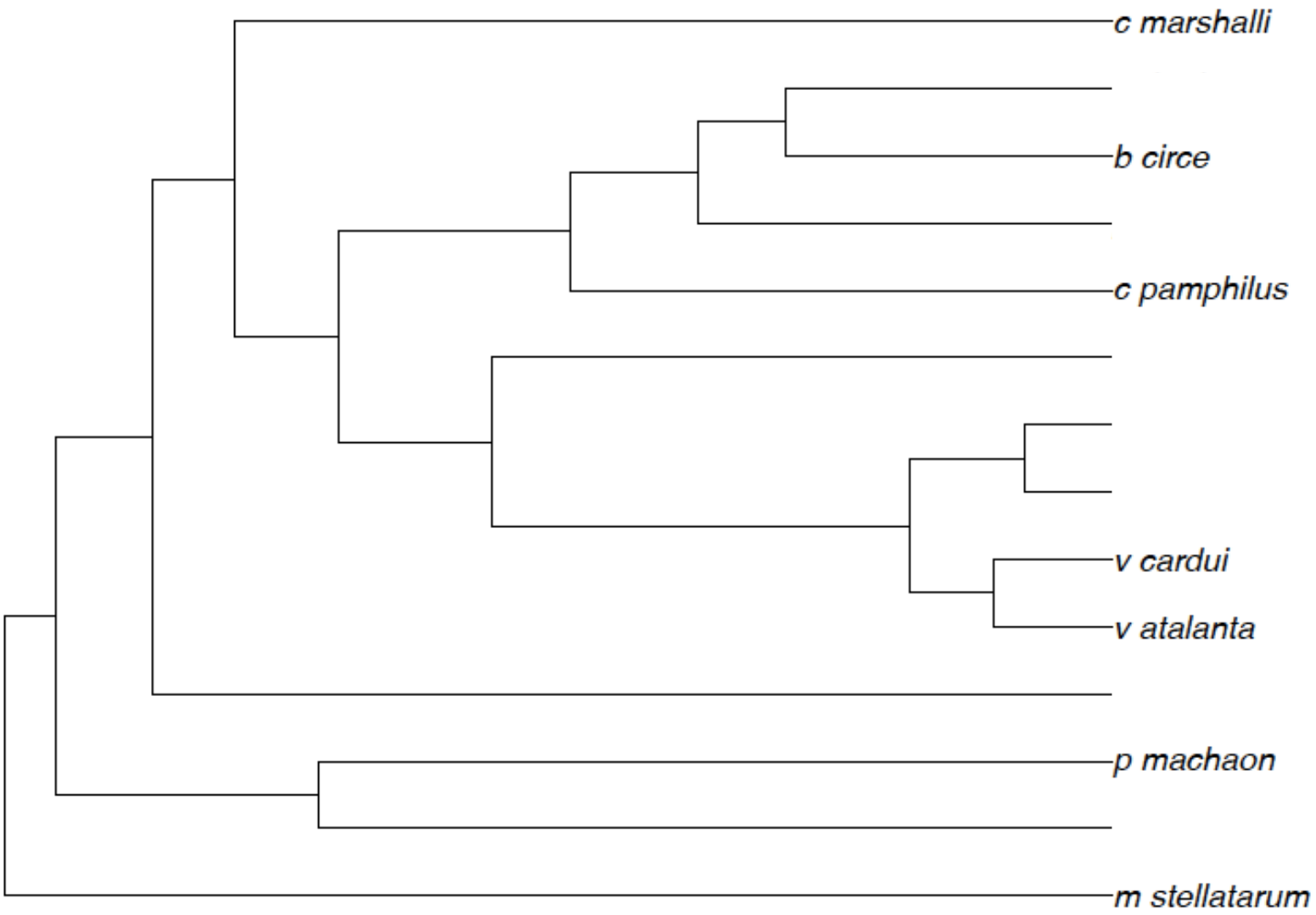
Community composition



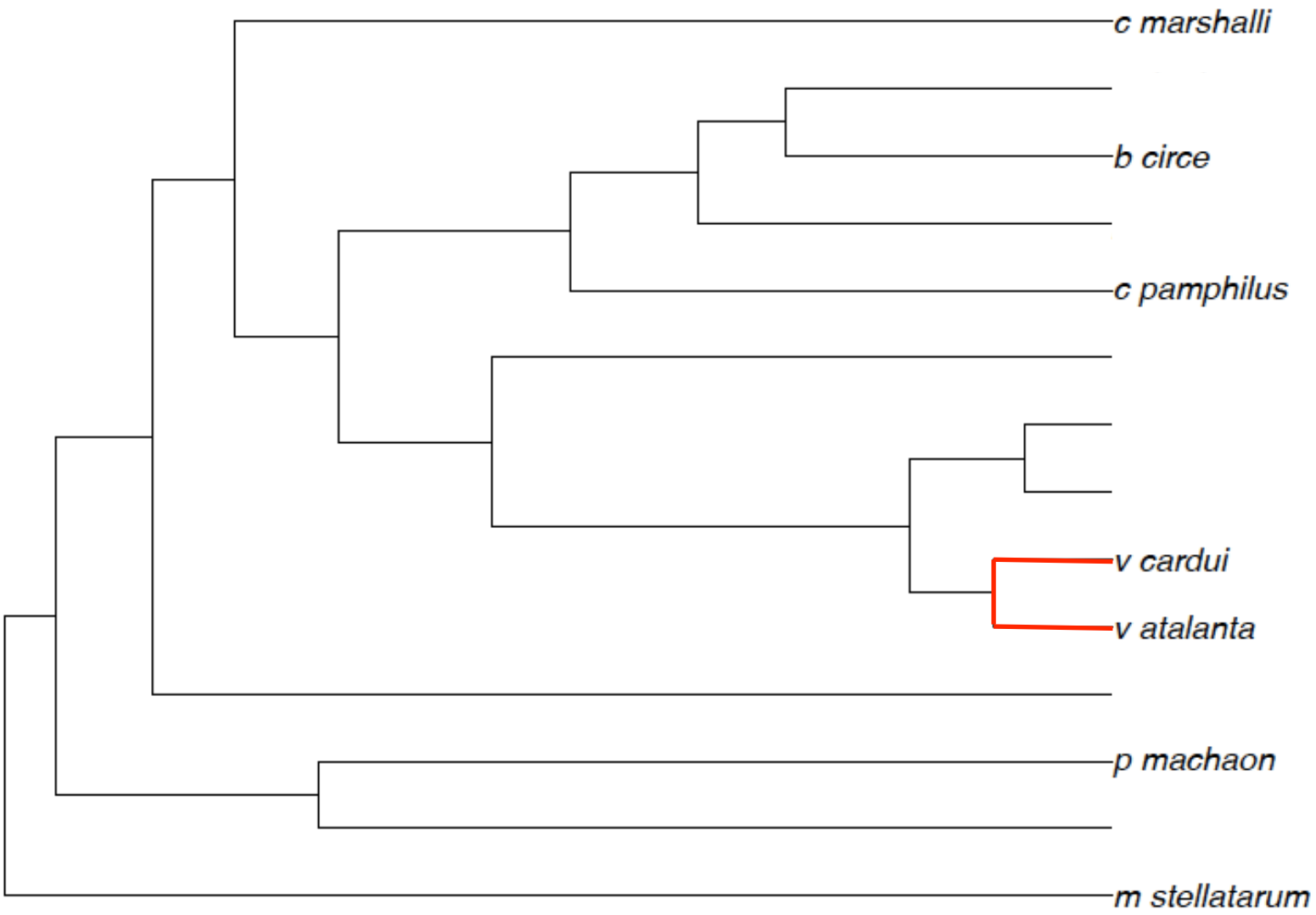
Weighted mean phylogenetic distance



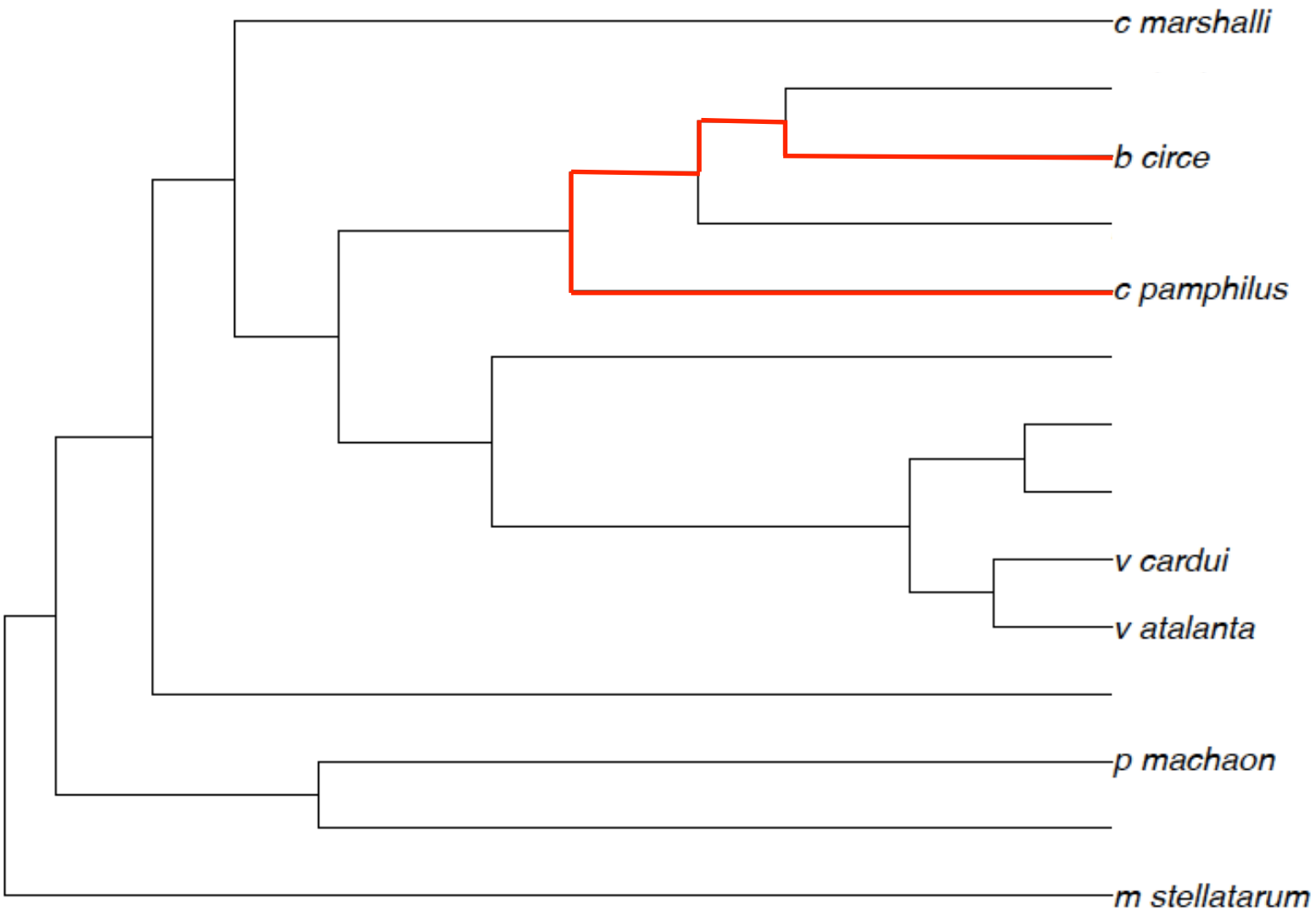
Weighted mean phylogenetic distance



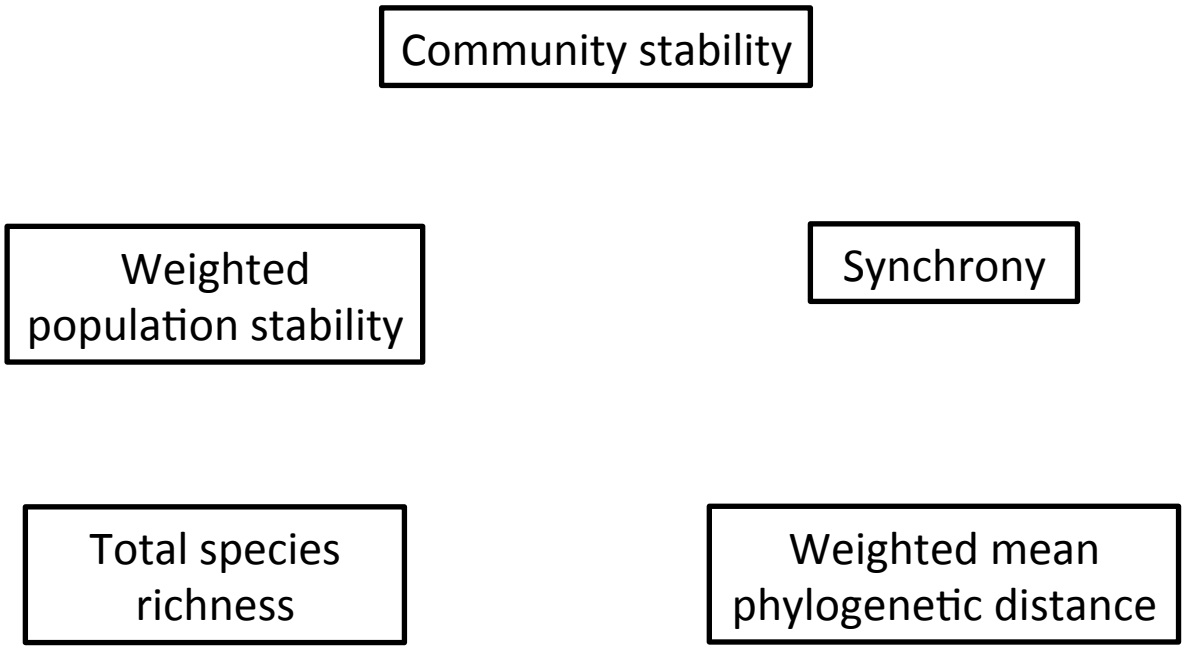
Weighted mean phylogenetic distance



Weighted mean phylogenetic distance



Community composition



Landscape perturbations

Urban area

Arable lands

Grasslands

Woodlands

Landscape perturbations

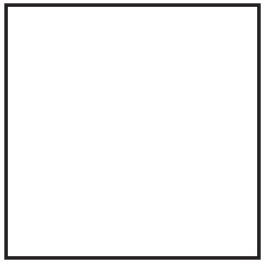
Urban area

Arable lands

Grasslands

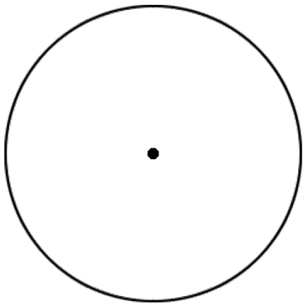
Woodlands

Birds



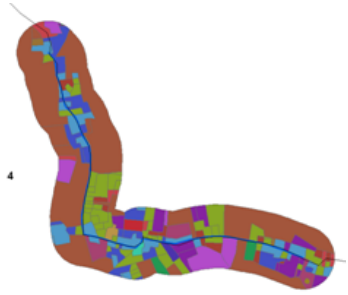
2km squares

Butterflies



1000m buffers

Bats



250m buffers

Landscape perturbations

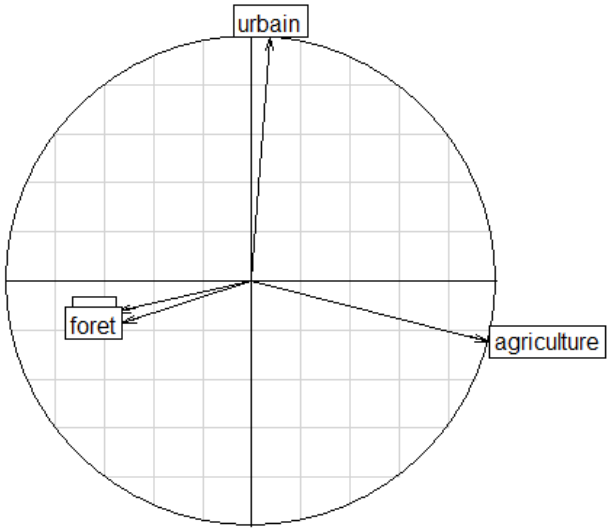
Urban area

Arable lands

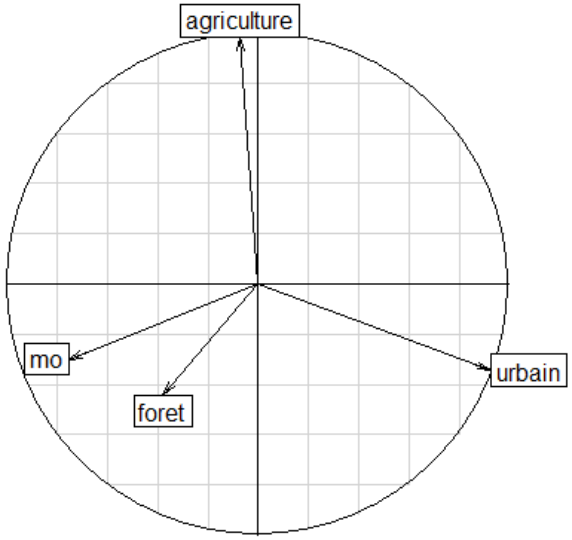
Grasslands

Woodlands

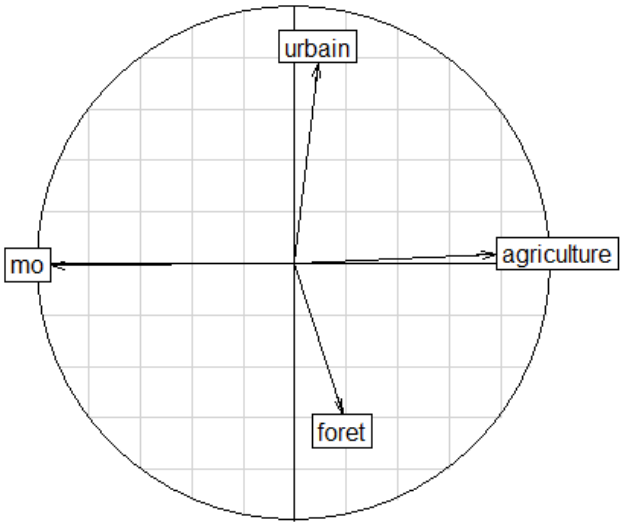
birds



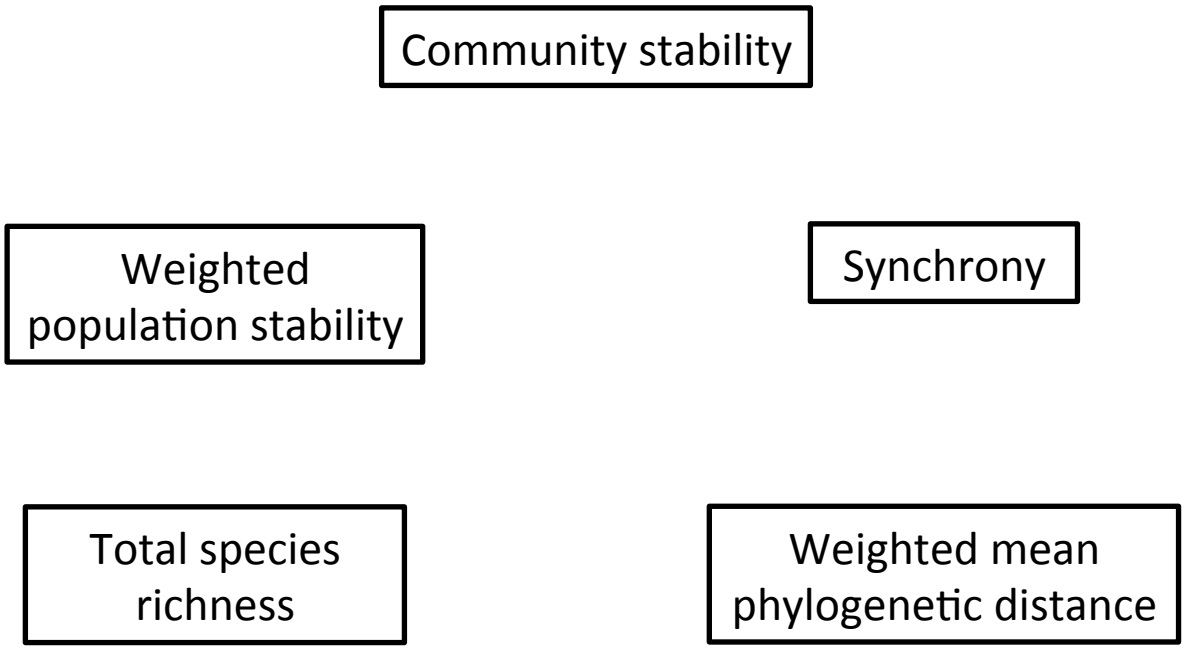
butterflies



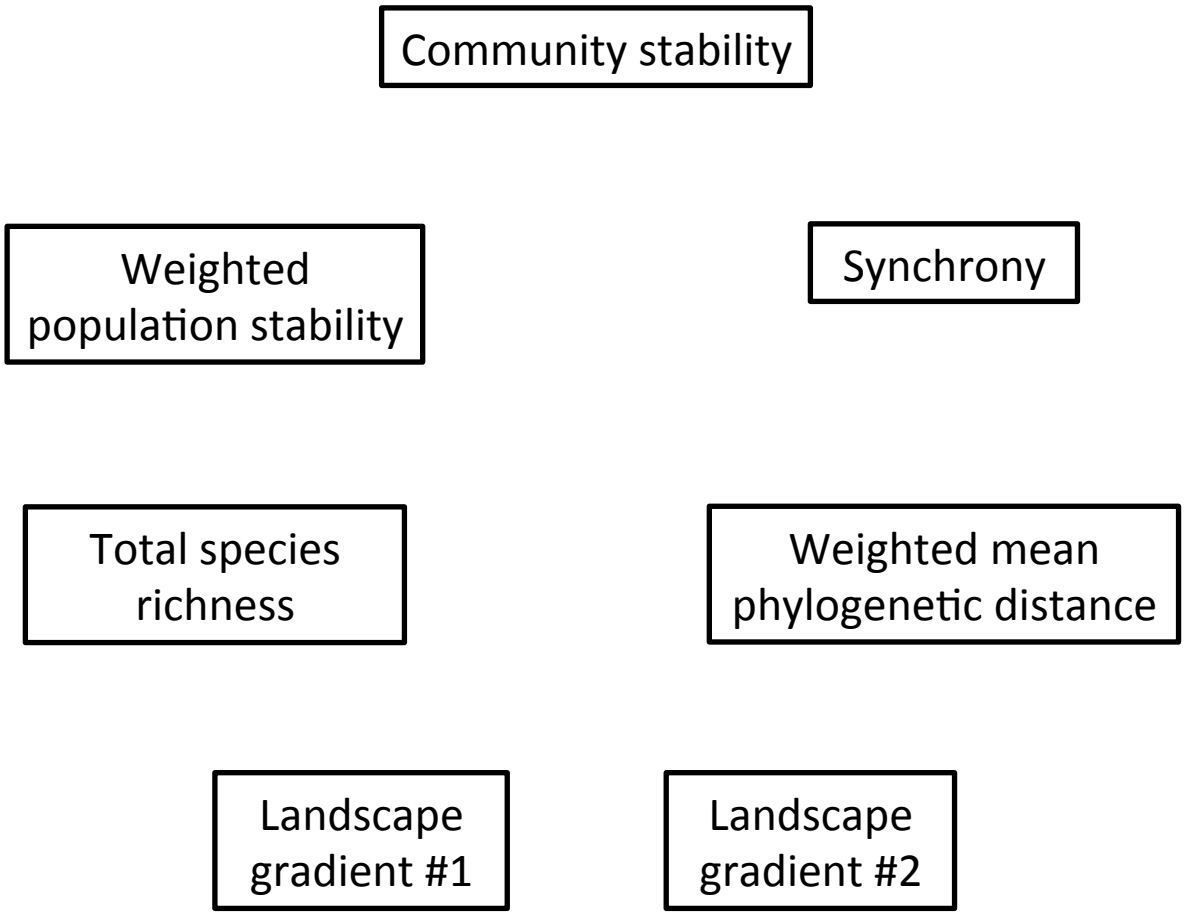
bats



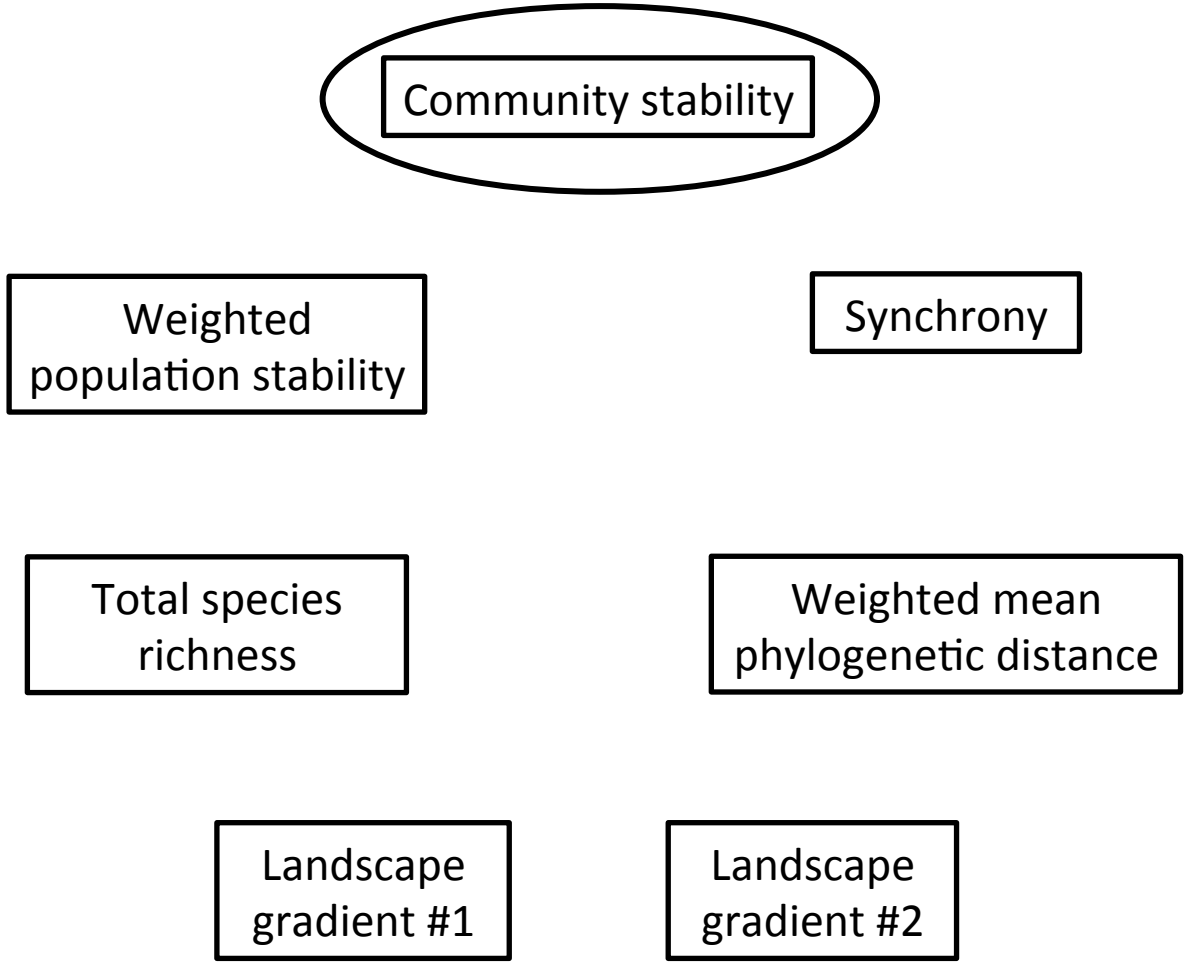
Landscape perturbations



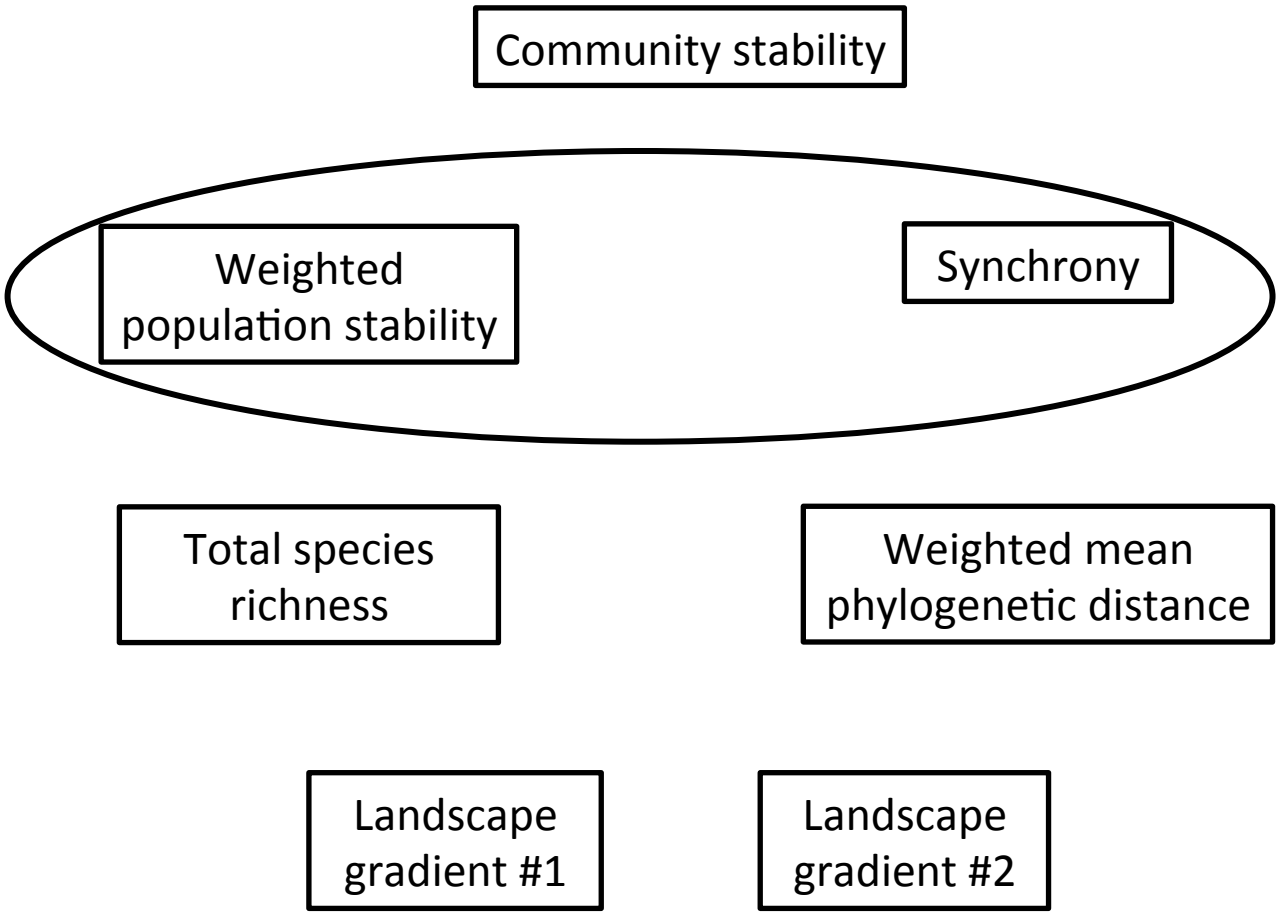
Landscape perturbations



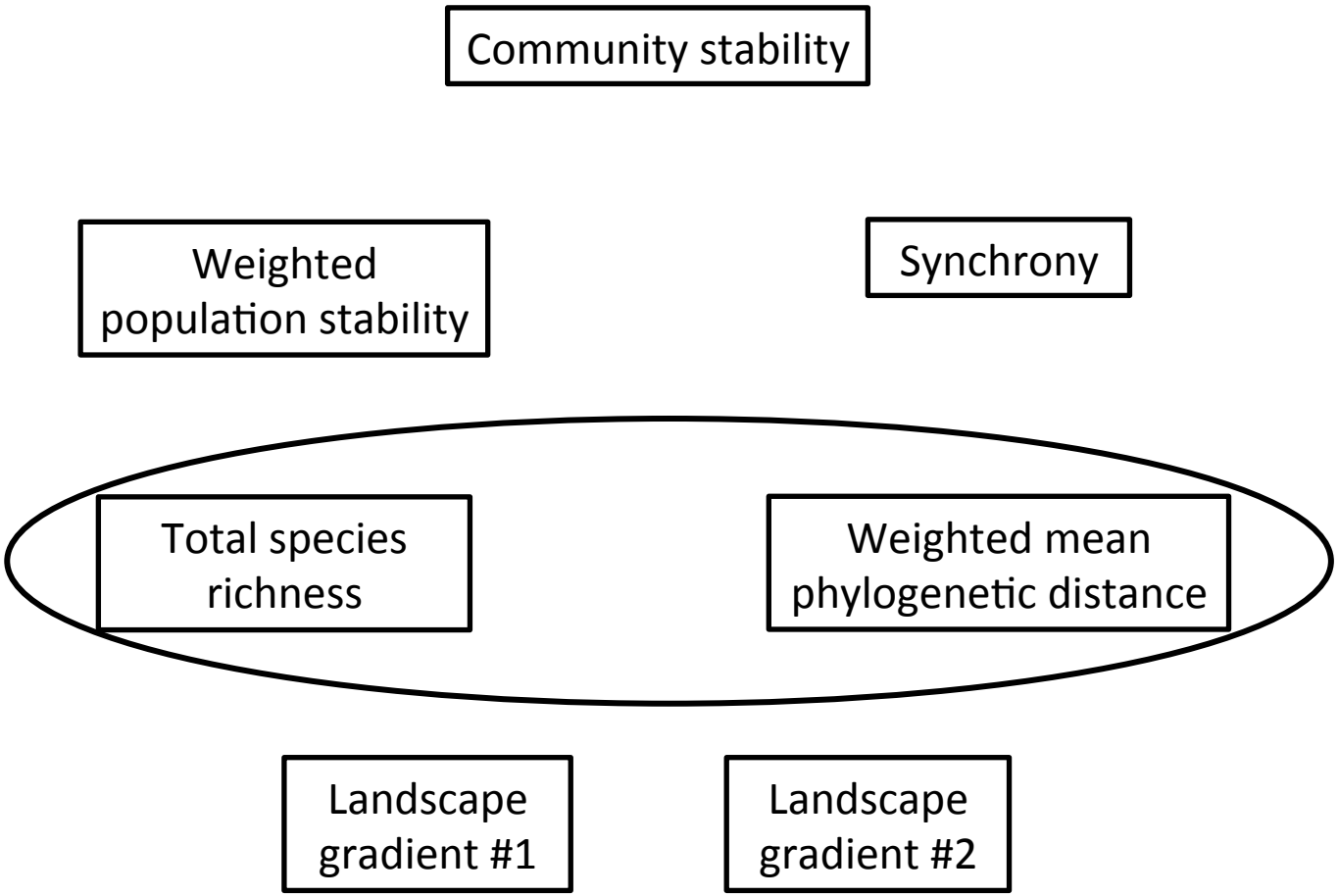
Community stability



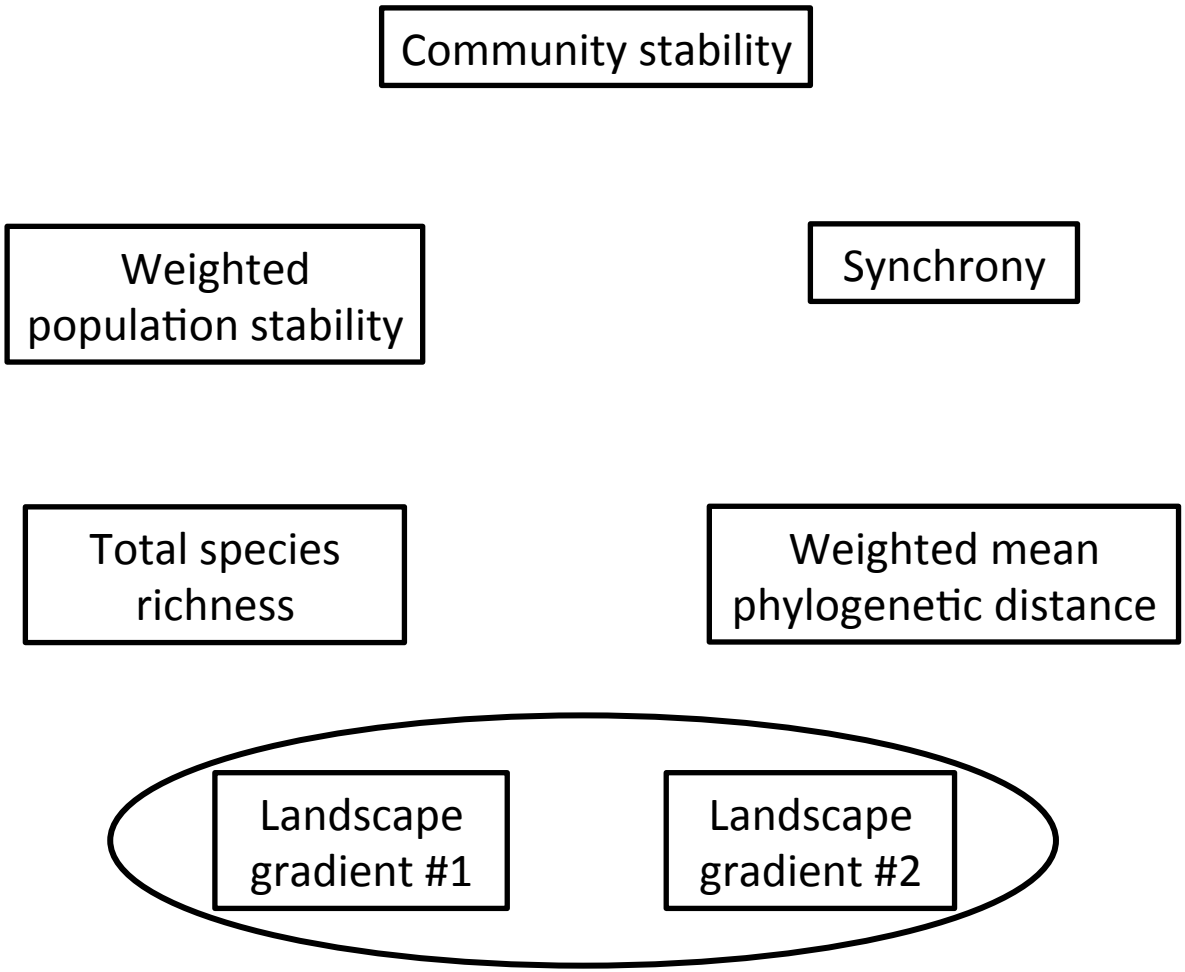
Community dynamics level



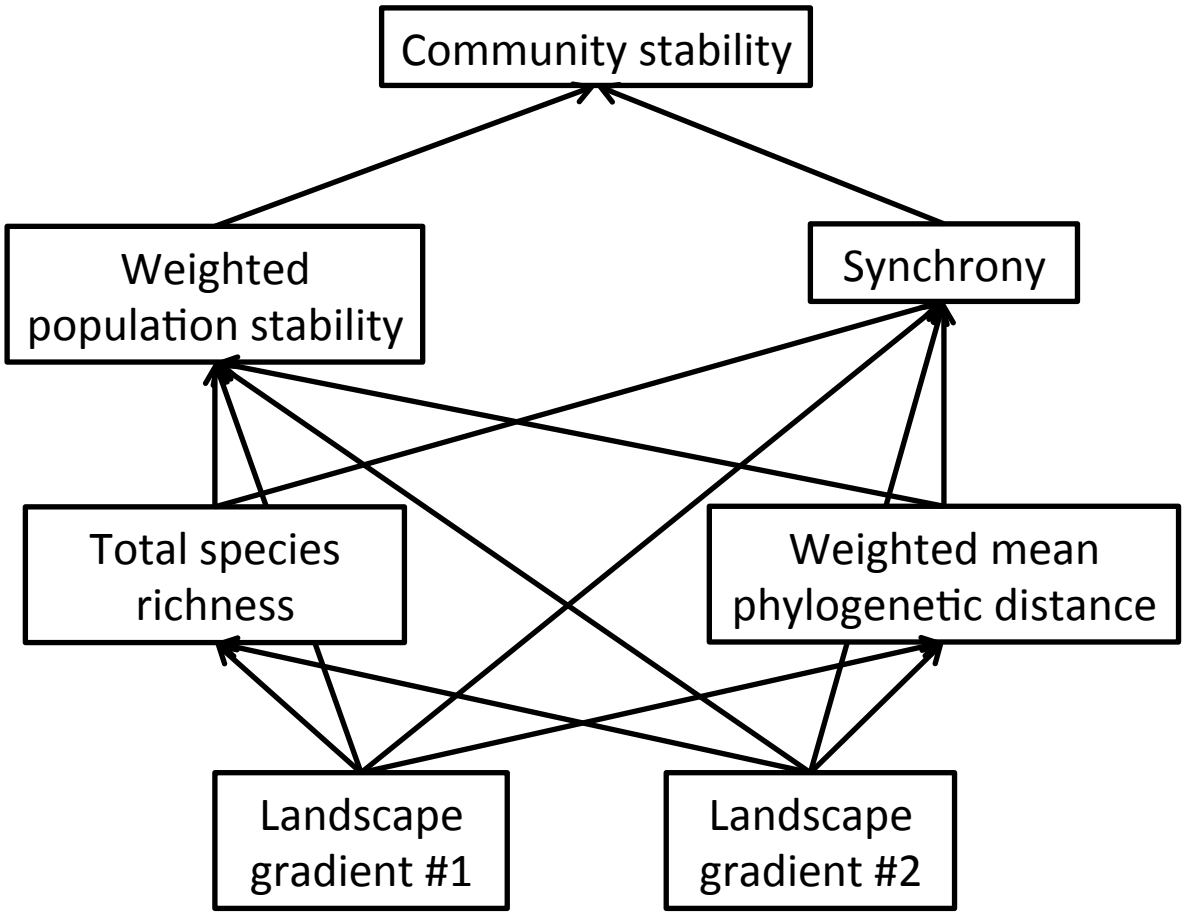
Community composition level



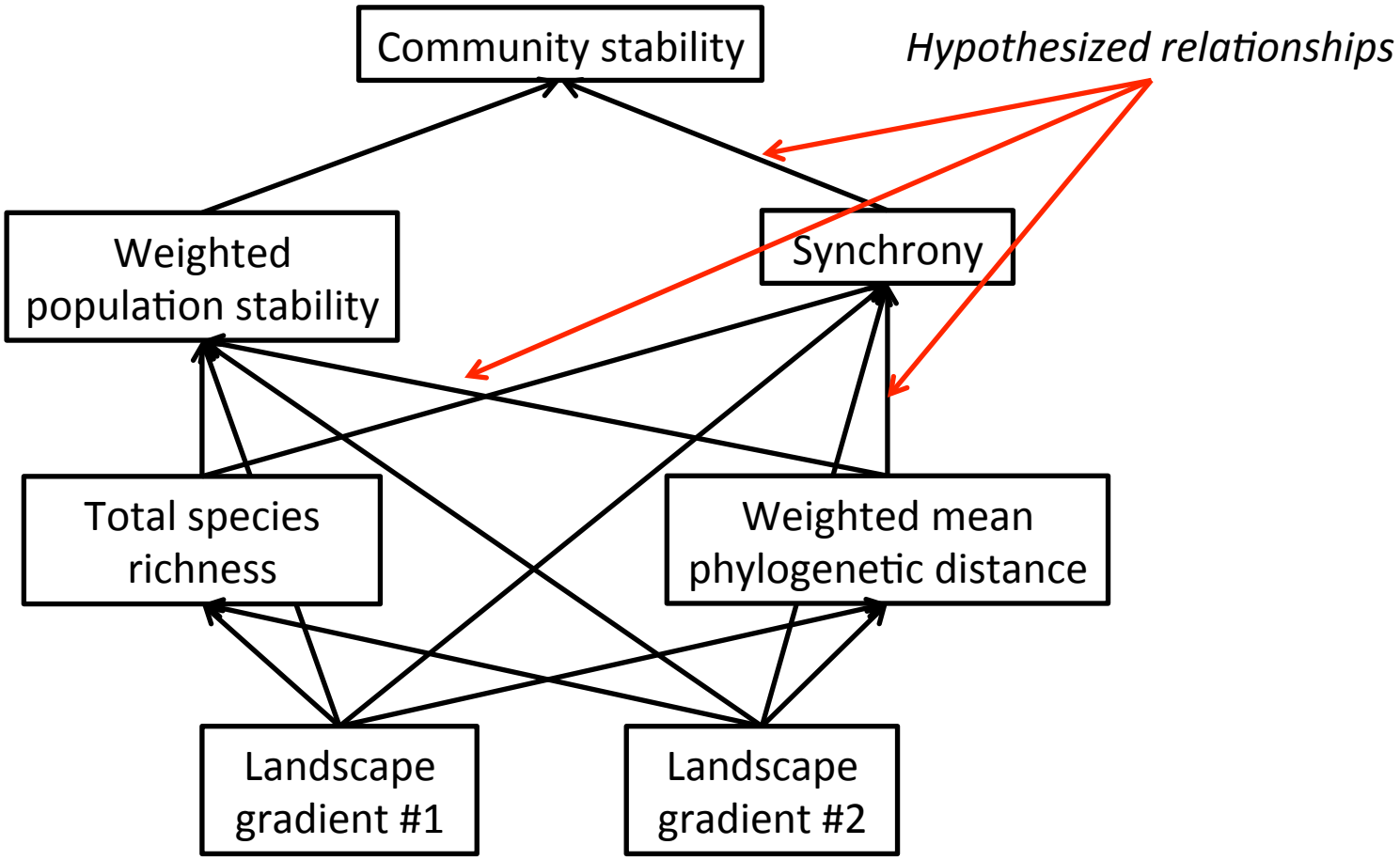
Environmental perturbations level



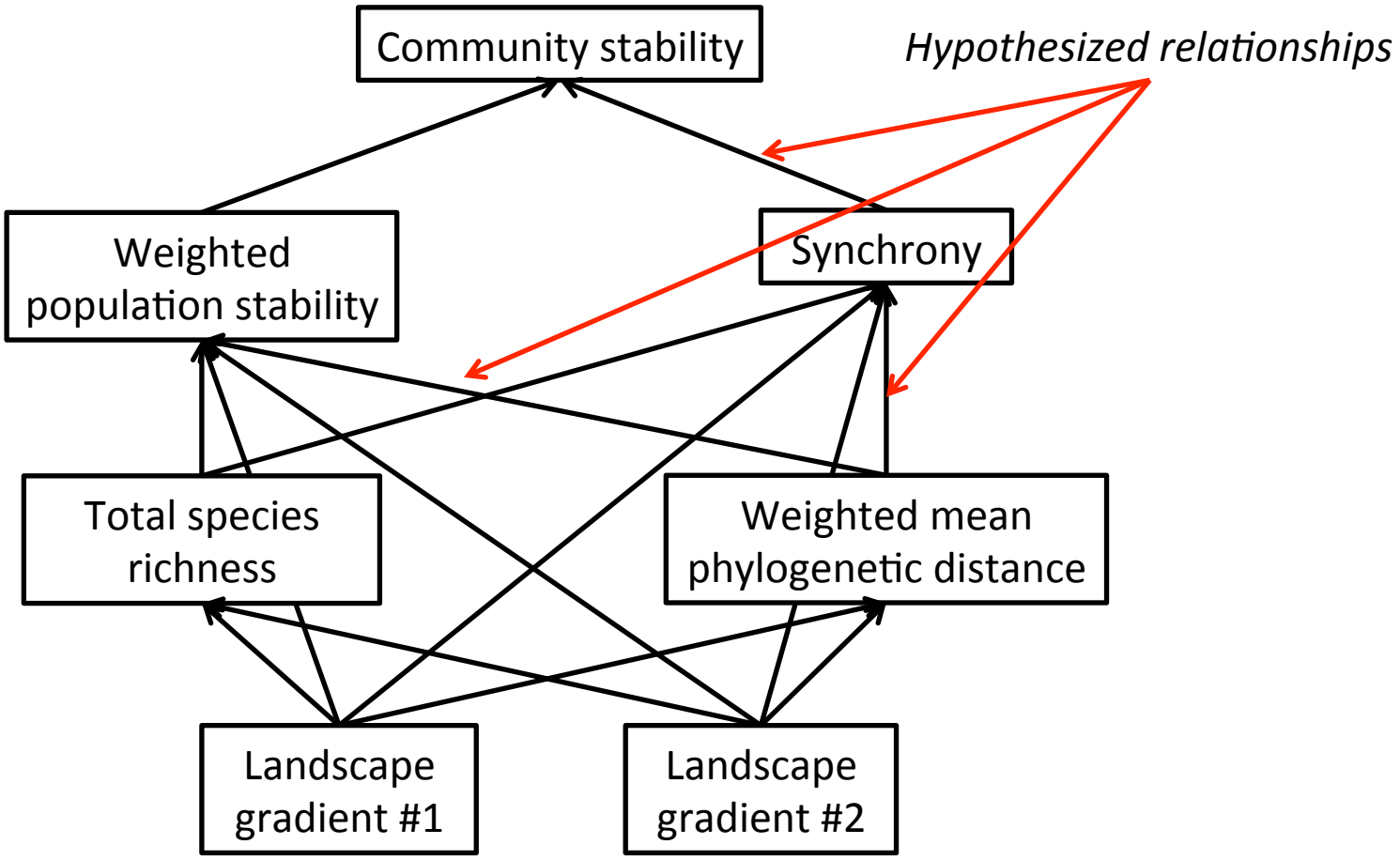
Path analysis



Path analysis

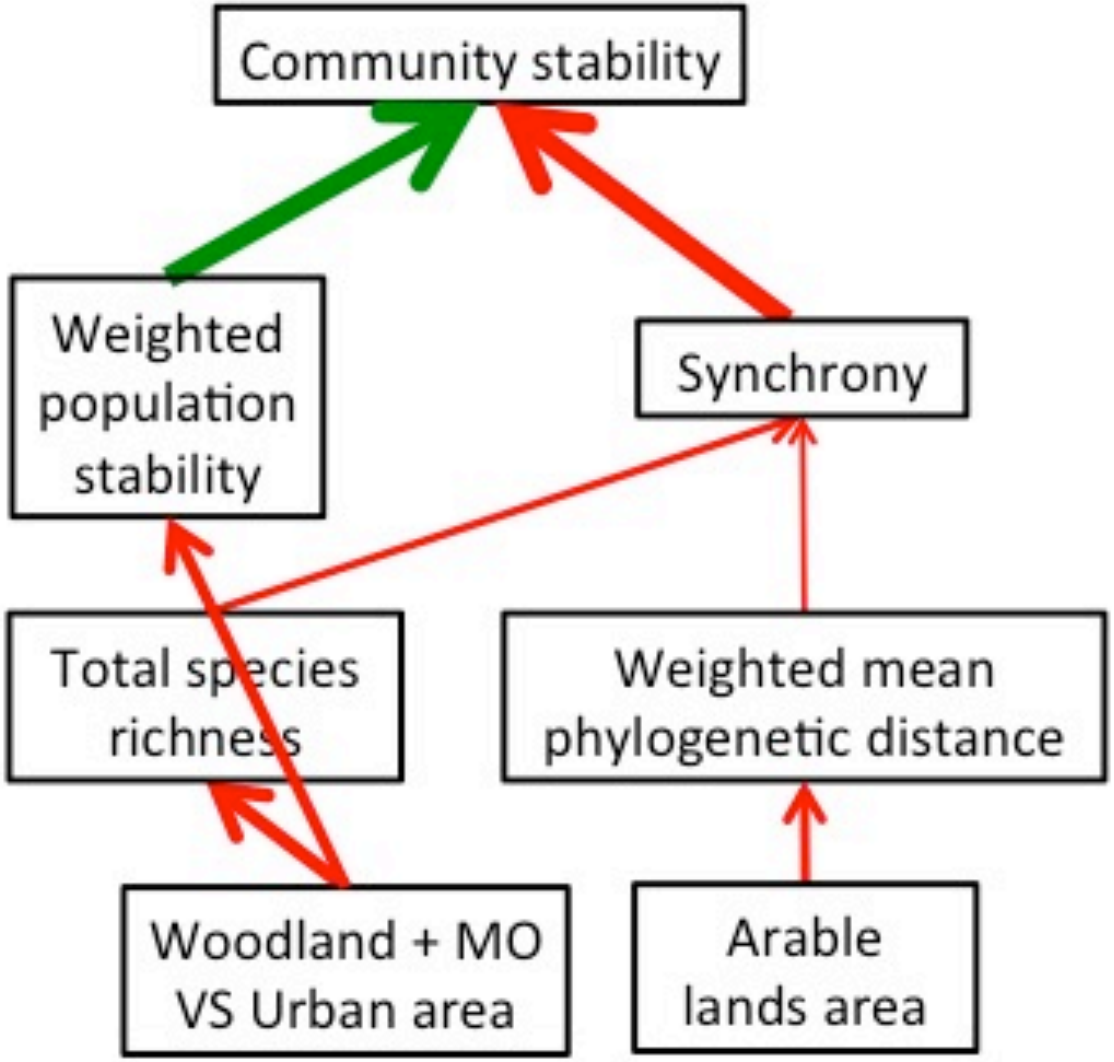


Path analysis

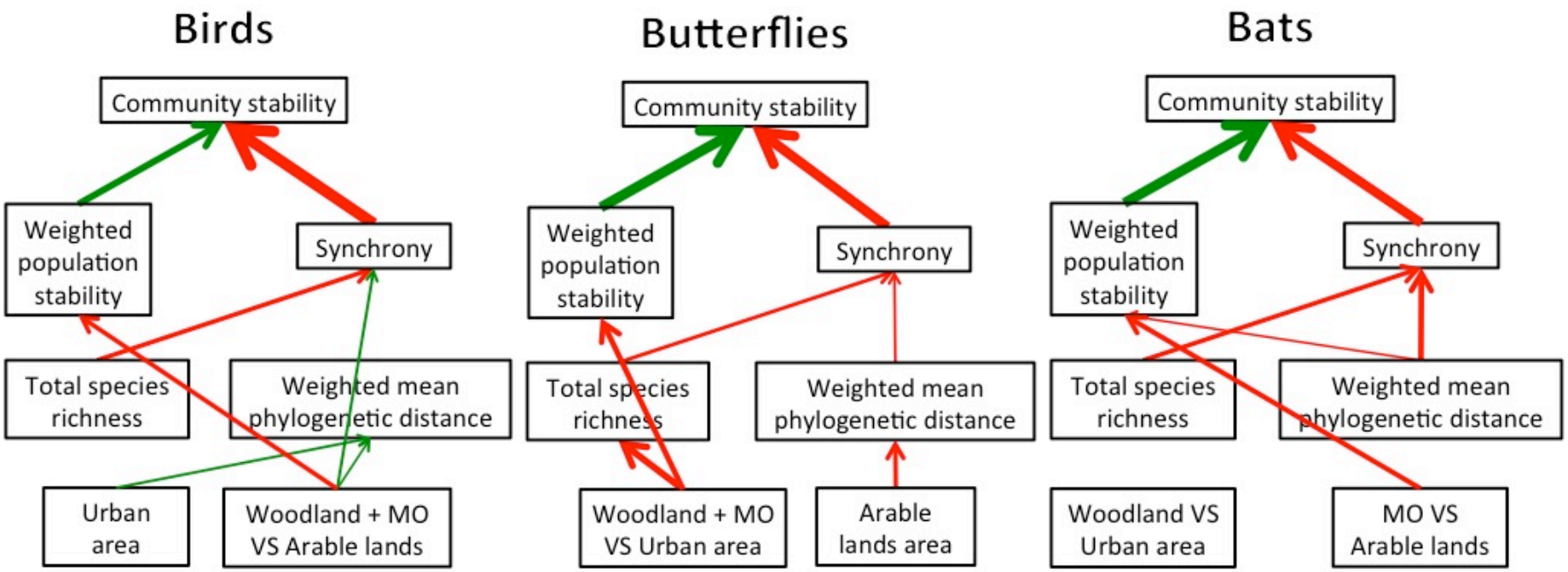


Standardized estimates

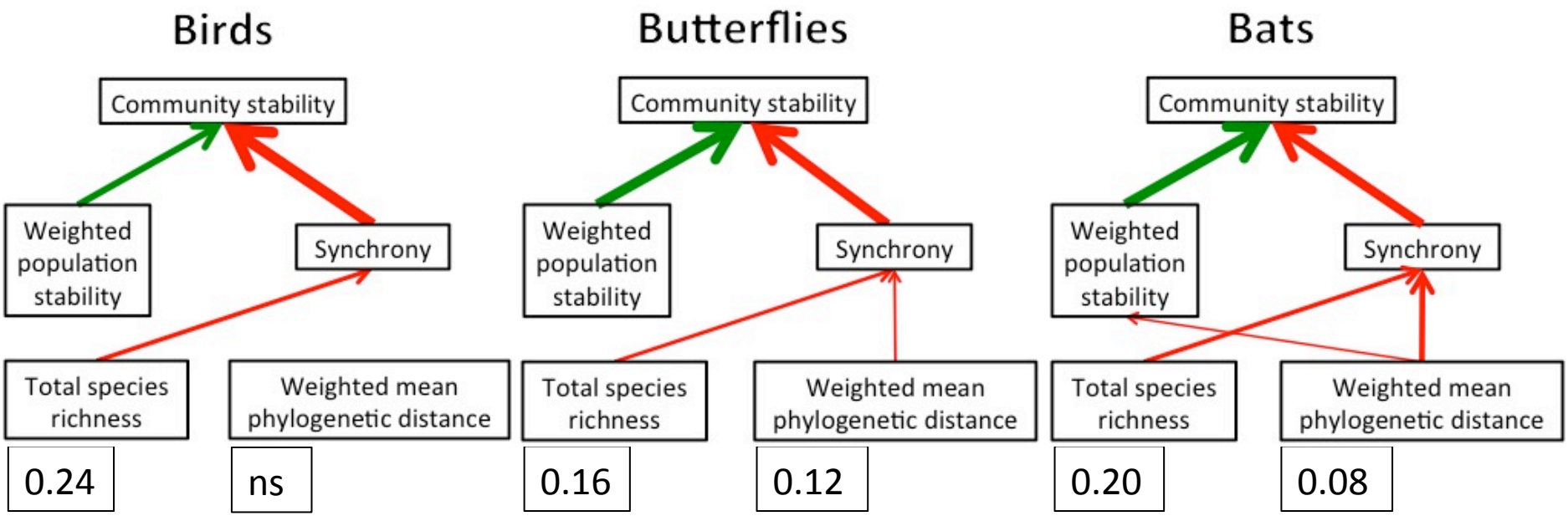
Results


Community stability
Weighted population stability
Synchrony
Total species richness
Weighted mean phylogenetic distance
Woodland + MO VS Urban area
Arable lands area

Results


Birds
Community stability
Weighted population stability
Synchrony
Total species richness
Weighted mean phylogenetic distance
Urban area
Woodland + MO VS Arable lands
Butterflies
Community stability
Weighted population stability
Synchrony
Total species richness
Weighted mean phylogenetic distance
Woodland + MO VS Urban area
Arable lands area
Bats
Community stability
Weighted population stability
Synchrony
Total species richness
Weighted mean phylogenetic distance
Woodland VS Urban area
MO VS Arable lands

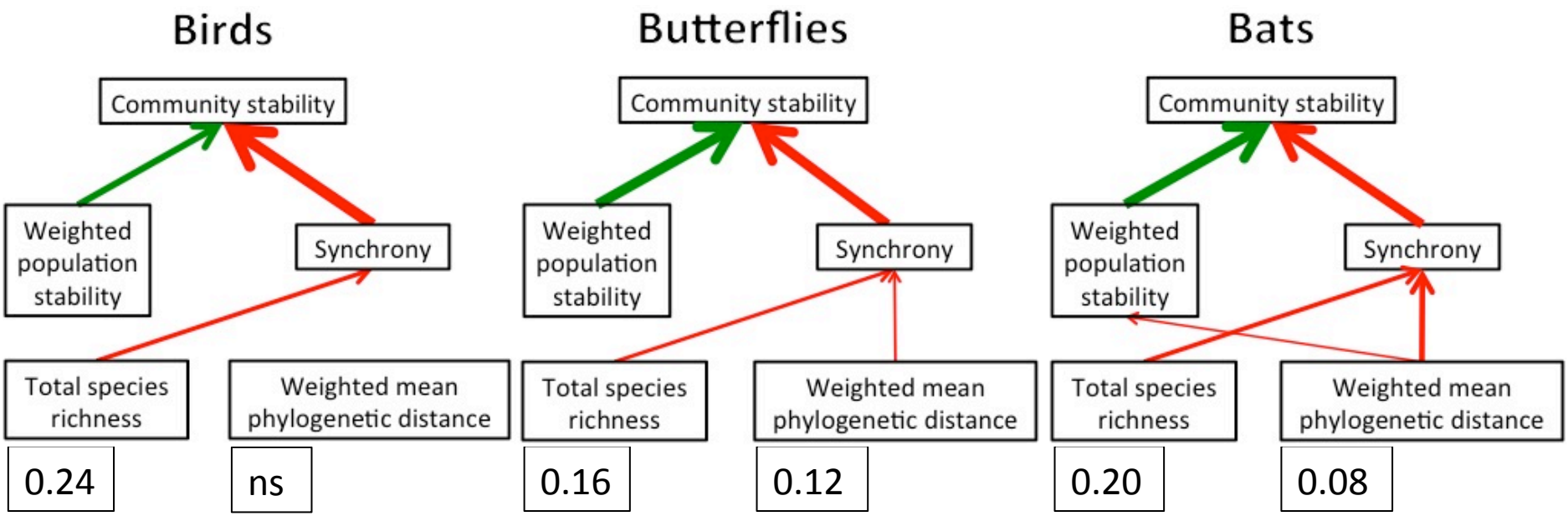
Community composition level



➔ Positive effect of Species richness and phylogenetic distance on community stability

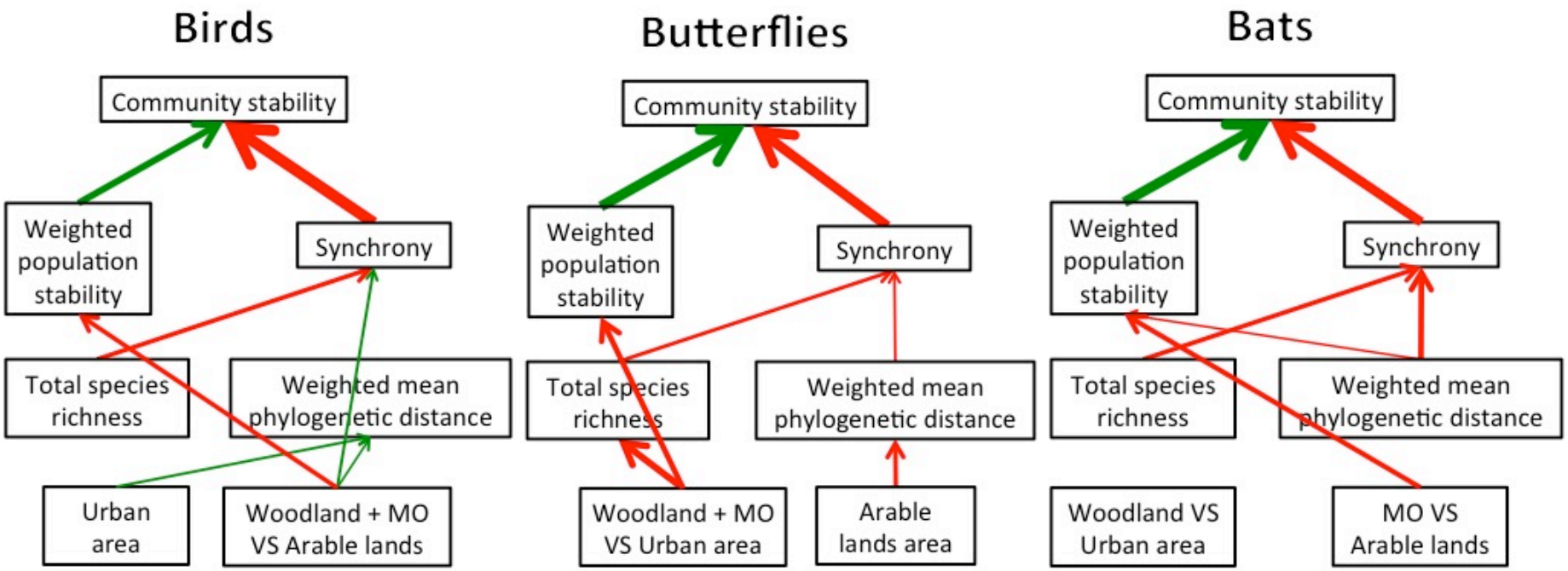
➔ Species richness effect **>** phylogenetic distance effect

Community composition level



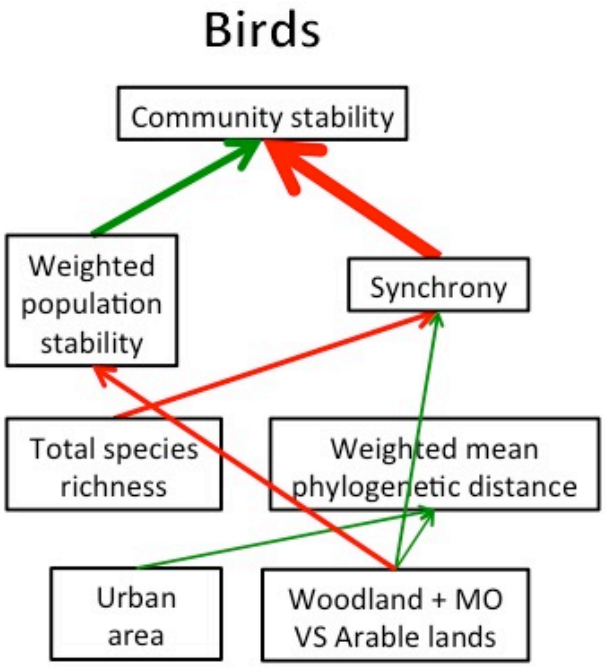
➔ Positive effect of Species richness and phylogenetic distance on community stability
➔ Species richness effect > phylogenetic distance effect
➔ Effects mostly mediated by changes in population synchrony

Landscape perturbations level



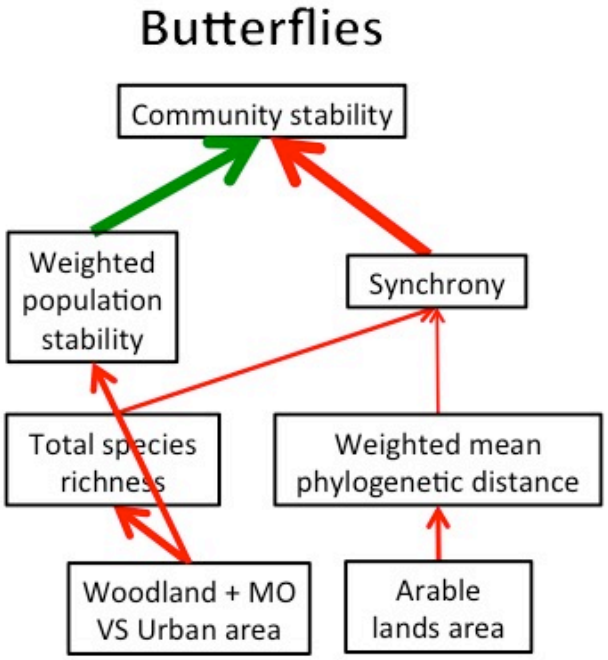
➔ Effects of landscape perturbations are variable among taxa

Landscape perturbations level



- ➔ The increase of urban area and arable lands increases the weighted mean phylogenetic distance
- ➔ The increase of arable lands increases the population's synchrony
- ➔ The increase of arable lands decreases the weighted mean population's stability

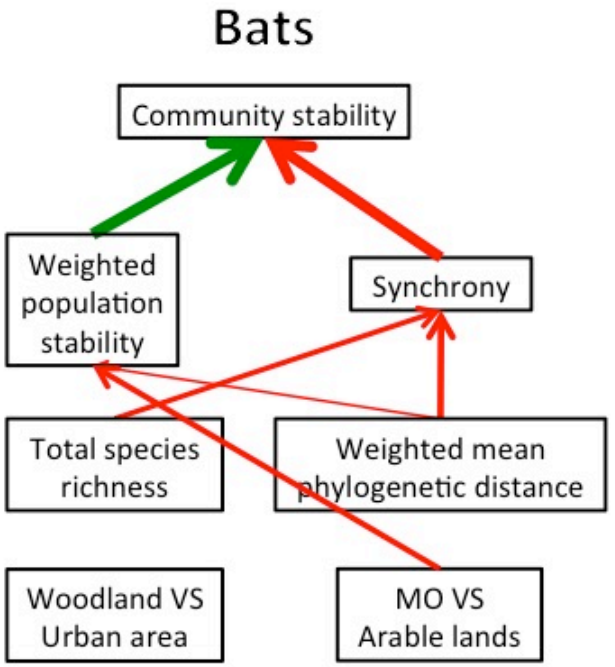
Landscape perturbations level



➔ The increase of urban area decreases the species richness and the weighted mean population's stability

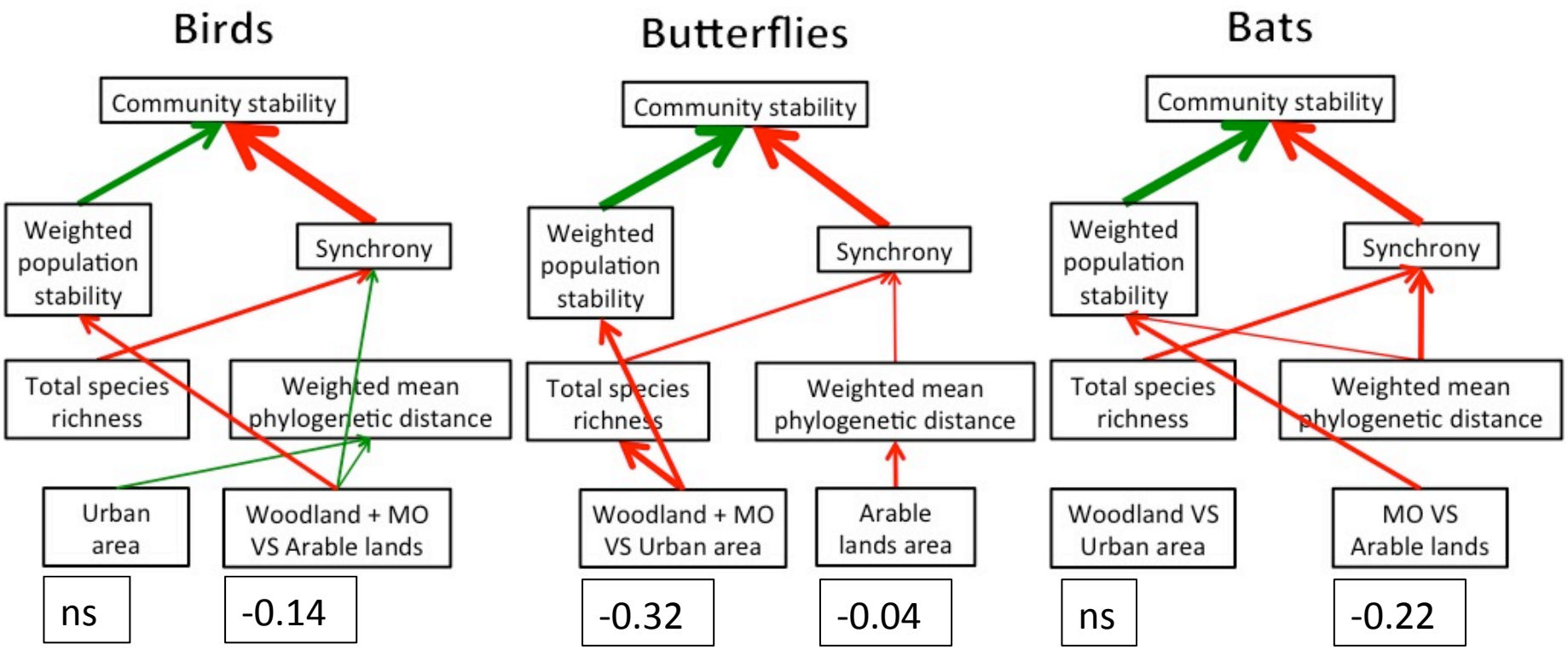
➔ The increase of arable lands decreases the weighted mean phylogenetic distance

Landscape perturbations level



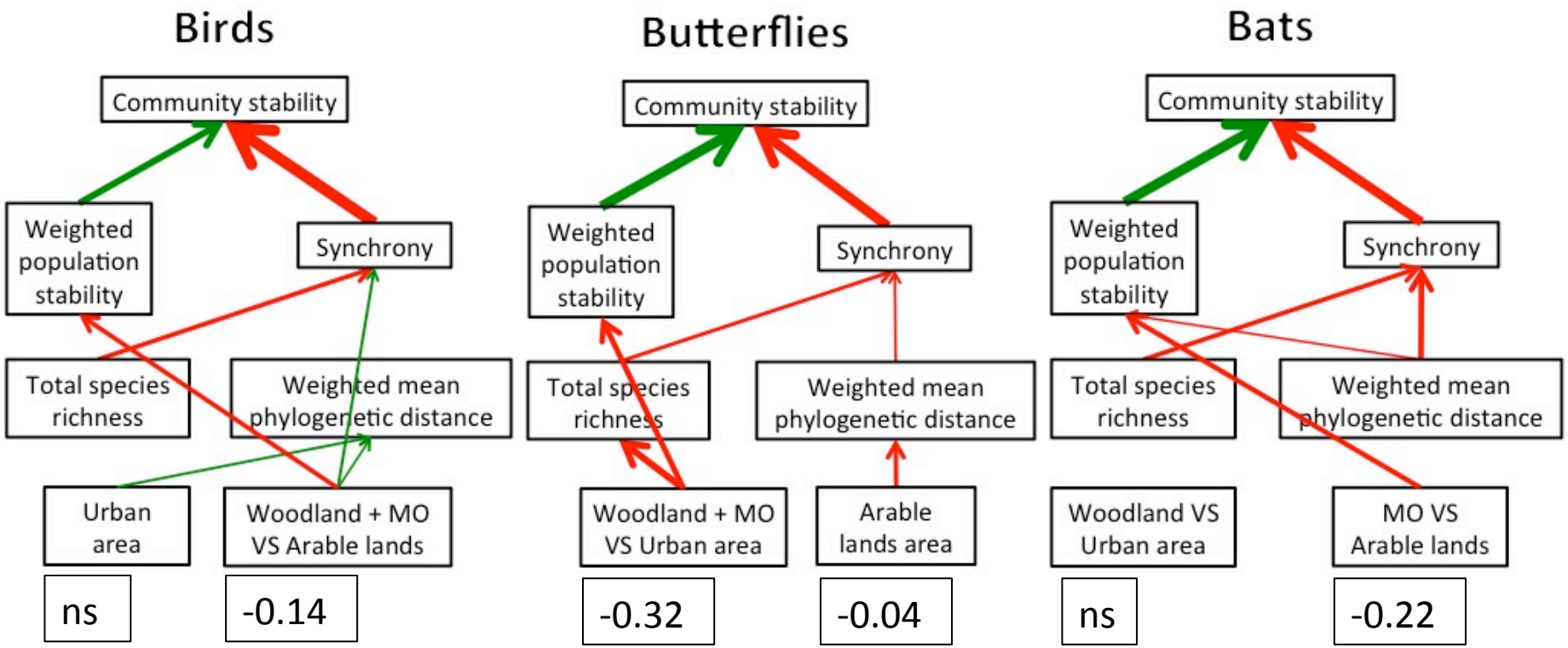
➔ The increase of arable lands decreases the weighted mean population's stability

Landscape perturbations level



➔ Negative effects of landscape perturbations

Landscape perturbations level



Birds	Butterflies	Bats
Composition effect = 0 Dynamic effect = -0.14	Composition effect = -0.11 Dynamic effect = -0.25	Composition effect = 0 Dynamic effect = -0.22

➔ Negative effects of landscape perturbations

➔ Perturbation affect community stability by impacting community composition and community dynamic

Take home message

→ There is a positive diversity – stability relationship in natural communities

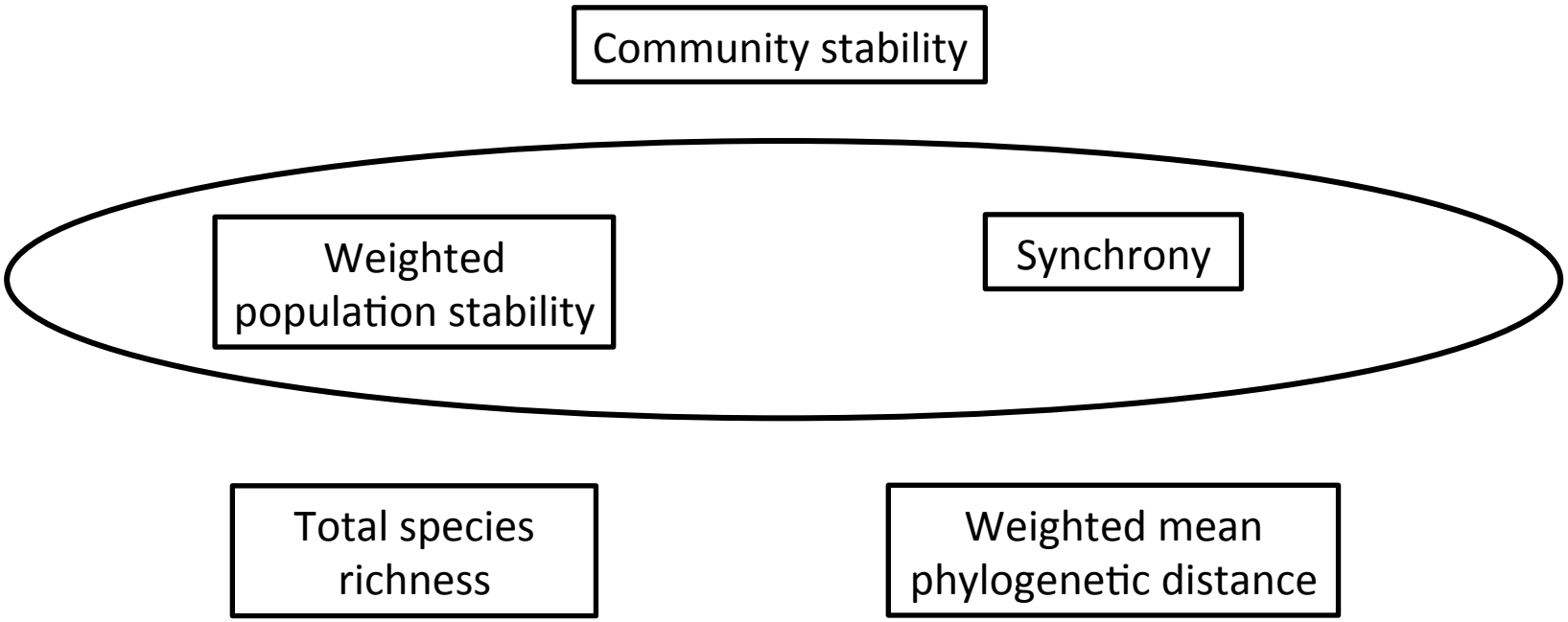
→ The population synchrony appears to be the main mechanism of the diversity-stability relationship in natural communities

- Why is there no stronger effect of phylogenetic distance among species?

→ Environmental perturbations have a direct impact on community dynamic, and in particular population stability

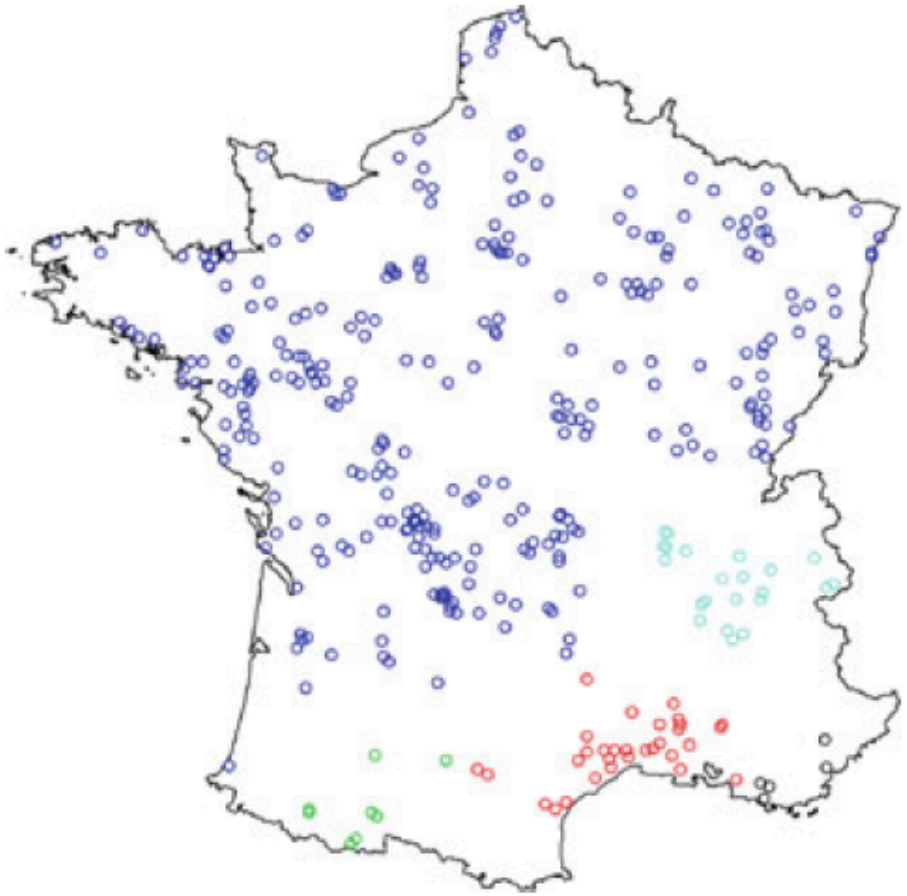
- Need for a better understanding of the determinants of the mean – variance scaling of natural population densities

Perspectives



Perspectives

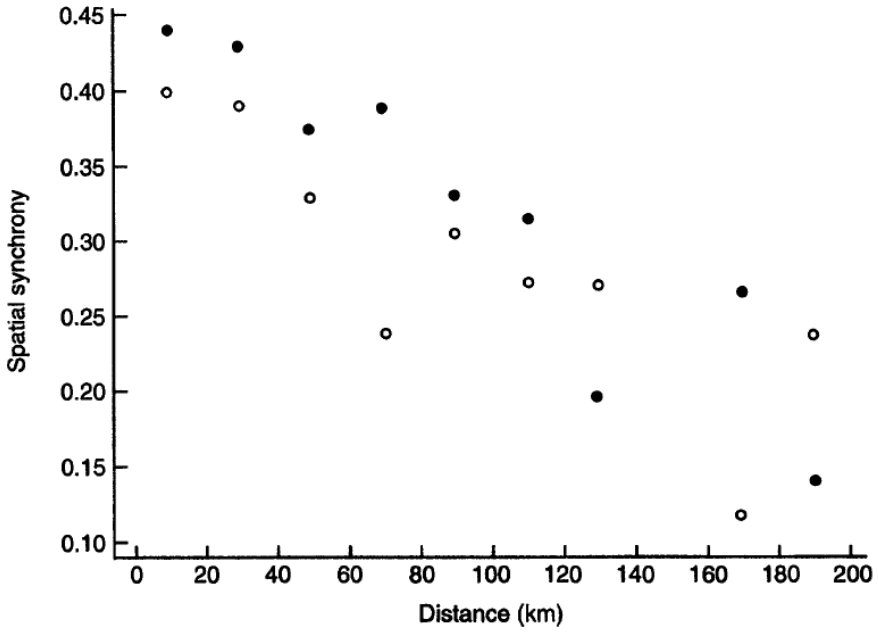
Synchrony

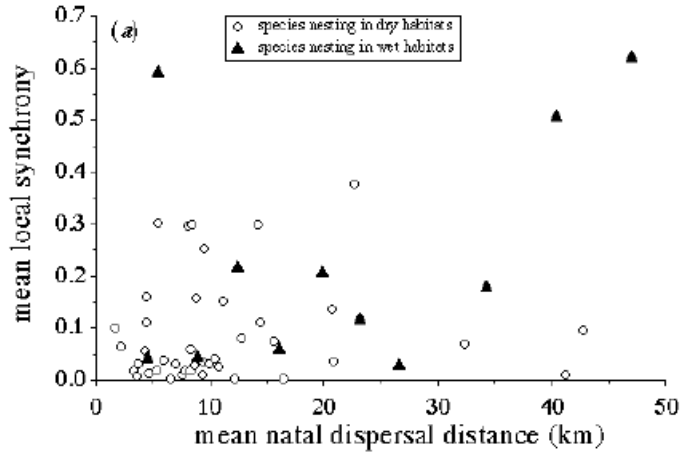


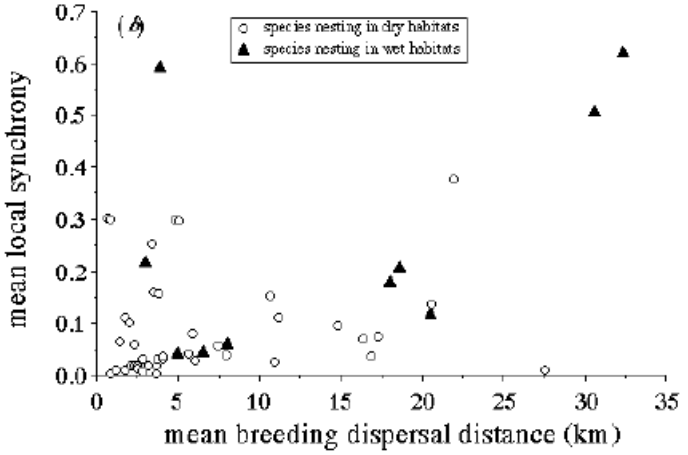
(Giraud et al., 2013)

Perspectives

Synchrony







(Sutcliffe et al., 1996 ; Paradis et al., 1999 ; Kendall et al., 2000)

Perspectives

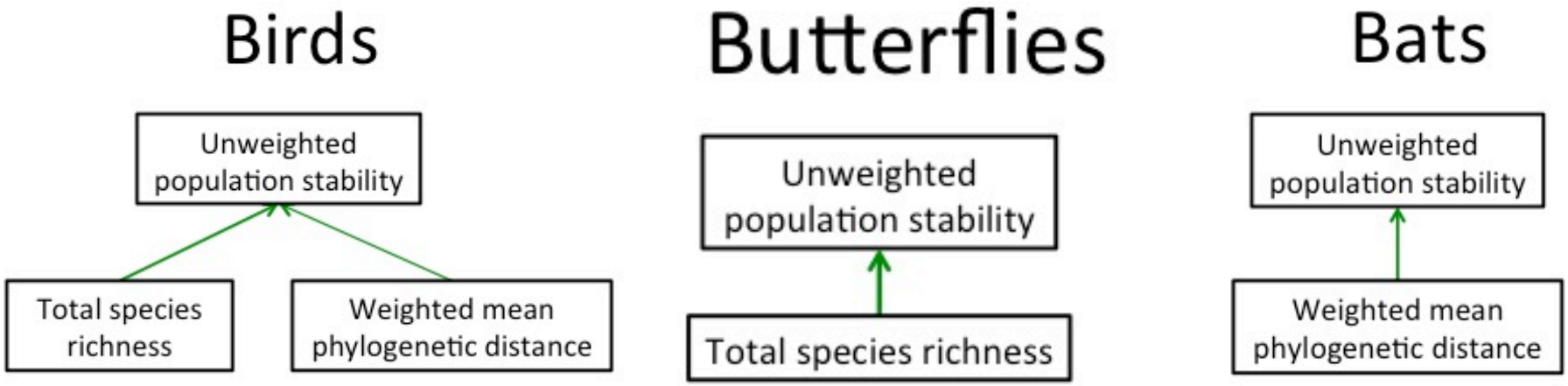
Synchrony

→ Are groups of species showing synchrony locally consistent across region?

→ Can we identify bio-geographical regions where groups of species are synchronous ?

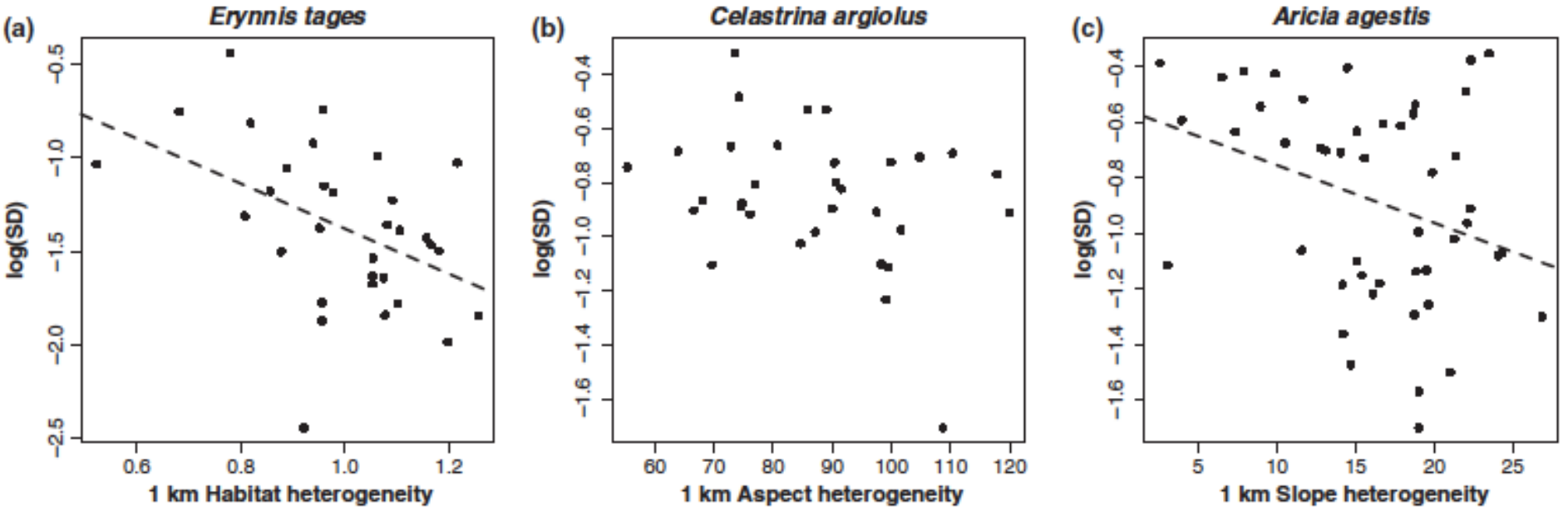
Perspectives

Population stability



Perspectives

Population stability



(Oliver et al., 2010)

Perspectives

Population stability

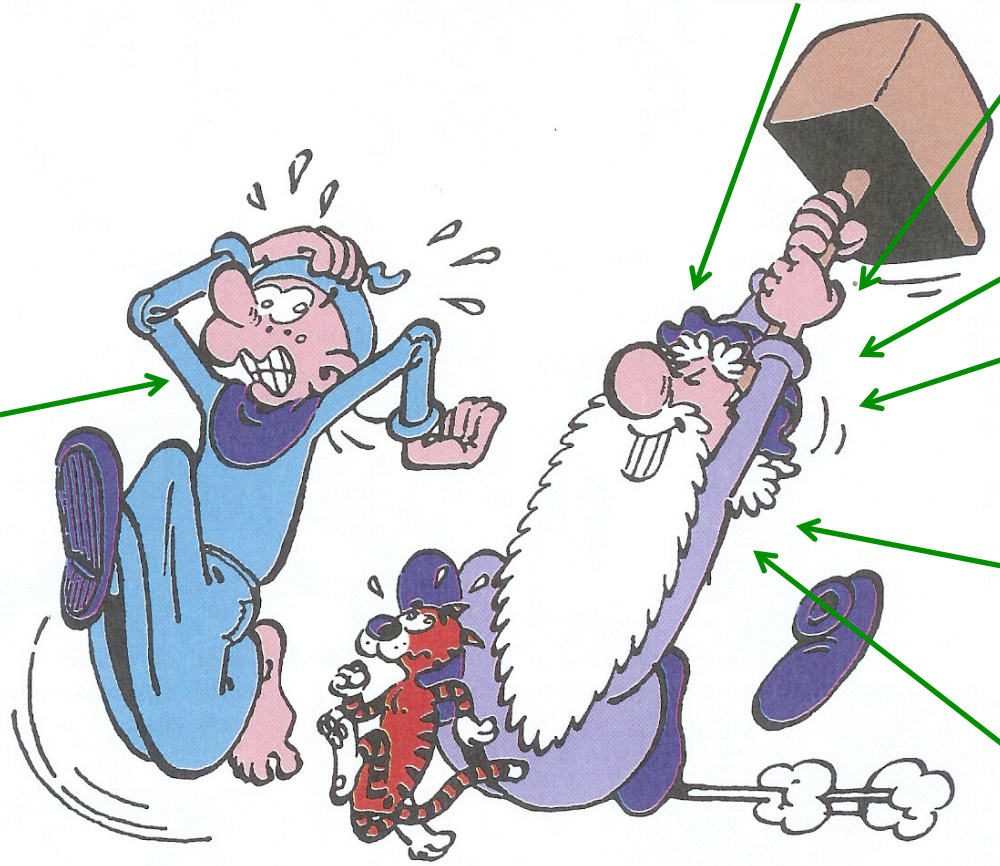
→ Which kind of species have their population stability impacted by the species richness of the community ?

→ Is the impact of landscape perturbations on population stability related to species' relative abundance or functional traits?

Thank you for your attention








« Je sers la science et c'est ma joie »

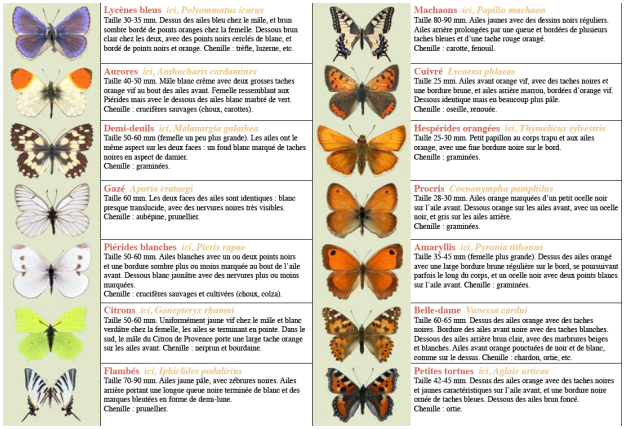
Basile Landouye, disciple de Léonard le Génie

theophile.olivier@gmail.com

Butterfly data

Observatoire de la Biodiversité des Jardins

OPÉRATION PAPILLONS



→Abundance of 28 butterfly species and species groups in private gardens

→Between March and October

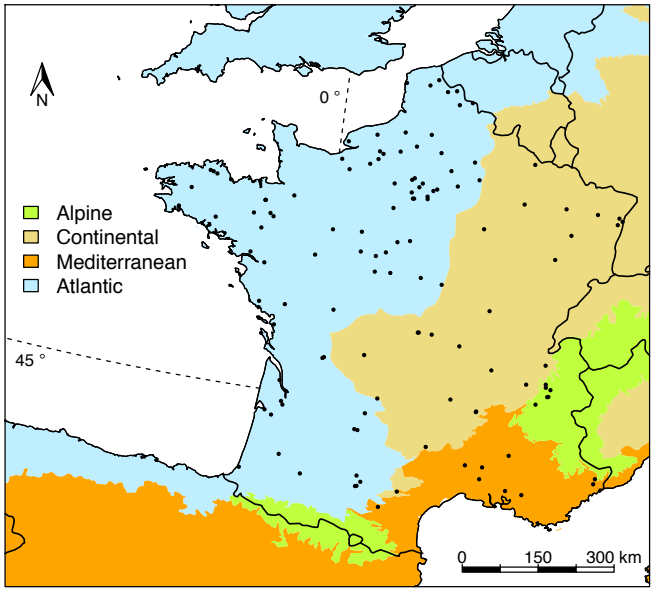
→1 data per month of observation

→Max number of individuals seen simultaneously

→Frequency of visits

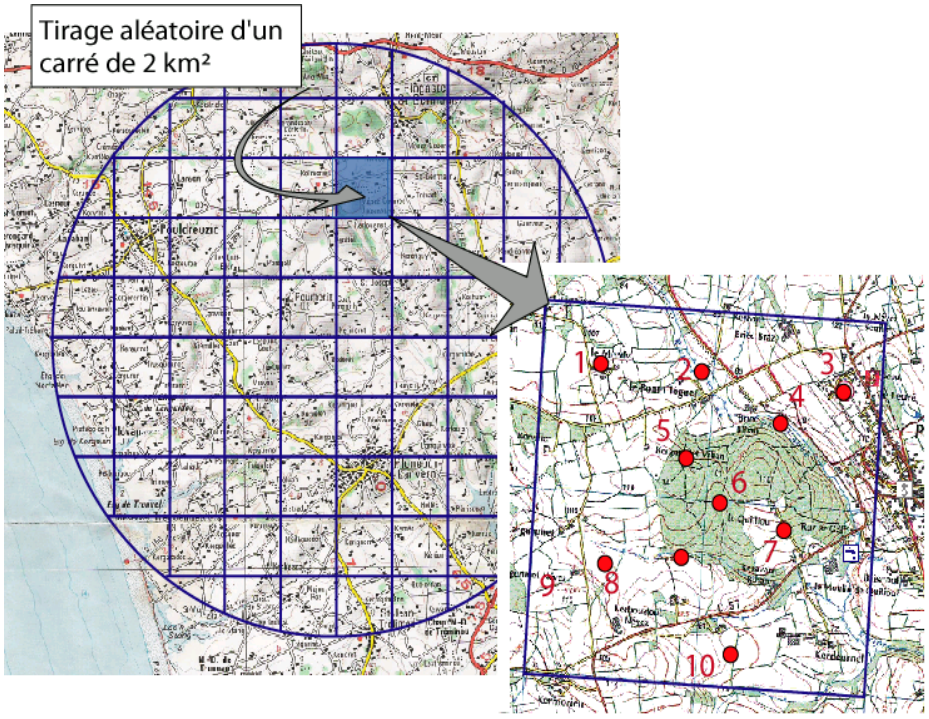
Butterfly data

- 131 residential gardens across France
- Butterfly abundance in July
- 8 continuous years of observations
- 14 species



Bird data

STOC
SUIVI TEMPOREL DES OISEAUX COMMUNS



Squares of 2km / 2km
Randomly selected

http://www.vigie-plume.fr/

Bird data

→ 10 points / square

→ Standardized habitat description

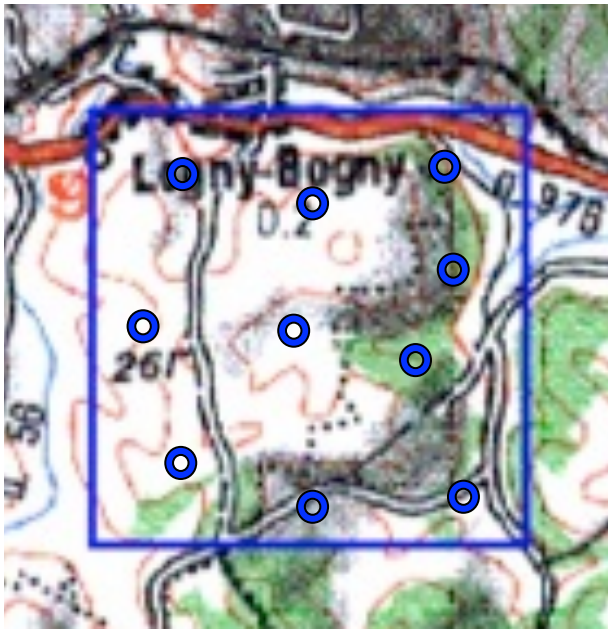
→ Two observation events / year (spring)

→ 5 minutes (1h after the sunrise)

→ Same place

→ Same date

→ Same volunteer



Bird data

- 269 squares
- Mean abundance / year / square
- 8 continuous years of observations
- 75 common species

Bat data

→ Since 2006

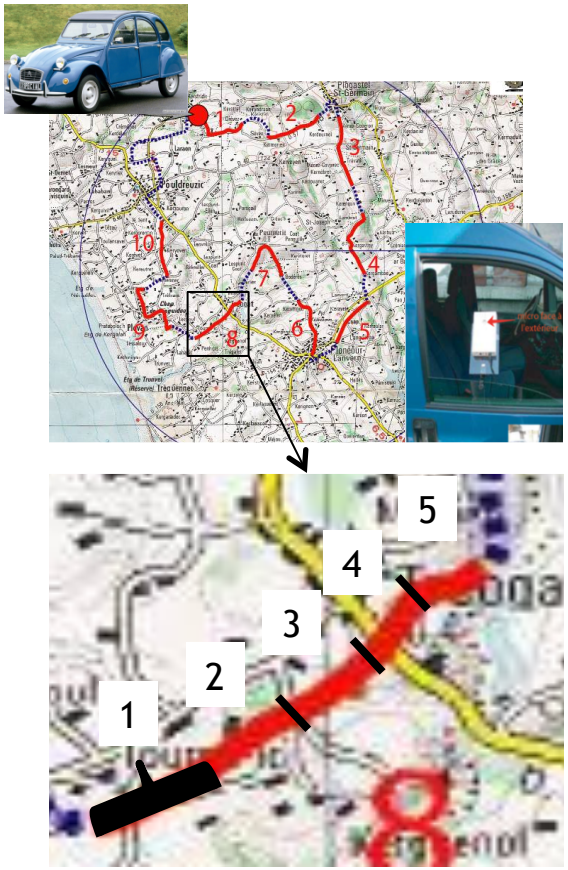
→ Survey by car

→ Acoustic signals

→ 2 times / year

→ 10 tracks of 2km

→ 5 transects of 400m / track



Vigie-Chiro
Suivi des chauves-souris

http://vigienature.mnhn.fr/page/vigie-chiro

Bat data

- 162 transects
- Mean abundance / year / transect
- 4 continuous years of observations
- 7 species