

The Measure of Biodiversity



Ariane MIRABEL, November 2015



Biodiversity

The variety of plants, animals, fungi and micro-organisms on earth

Their genotypic and phenotypic variation

Their communities and ecosystems

Tropical forests biodiversity

Productivity and stability of ecosystems

(Darwin and Wallace, 1858)

Timber and non-timber interrests *(FAO, 2009)*



Need to estimate, compare and anticipate
biodiversity

Notions

- What to measure?
- Richness and evenness
- Alpha Diversity
- Gamma Diversity
- Beta Diversity
- Decomposition

What to measure ?

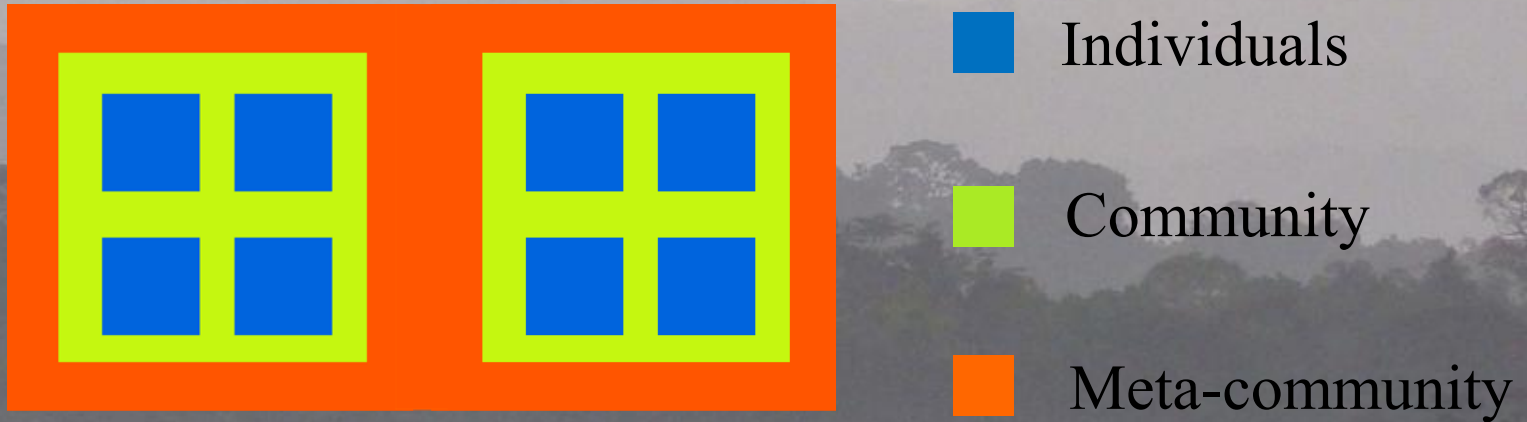


Figure 1 : Succession of studied objects



Species diversity

Diversity of an object in
its environment

Richness and evenness

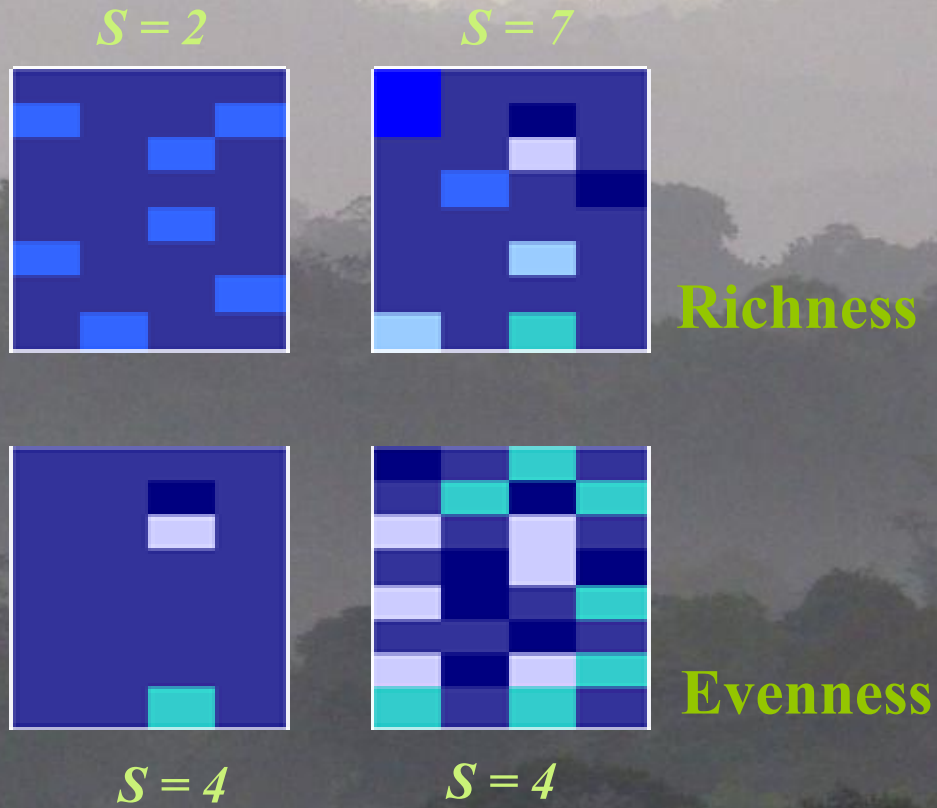


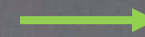
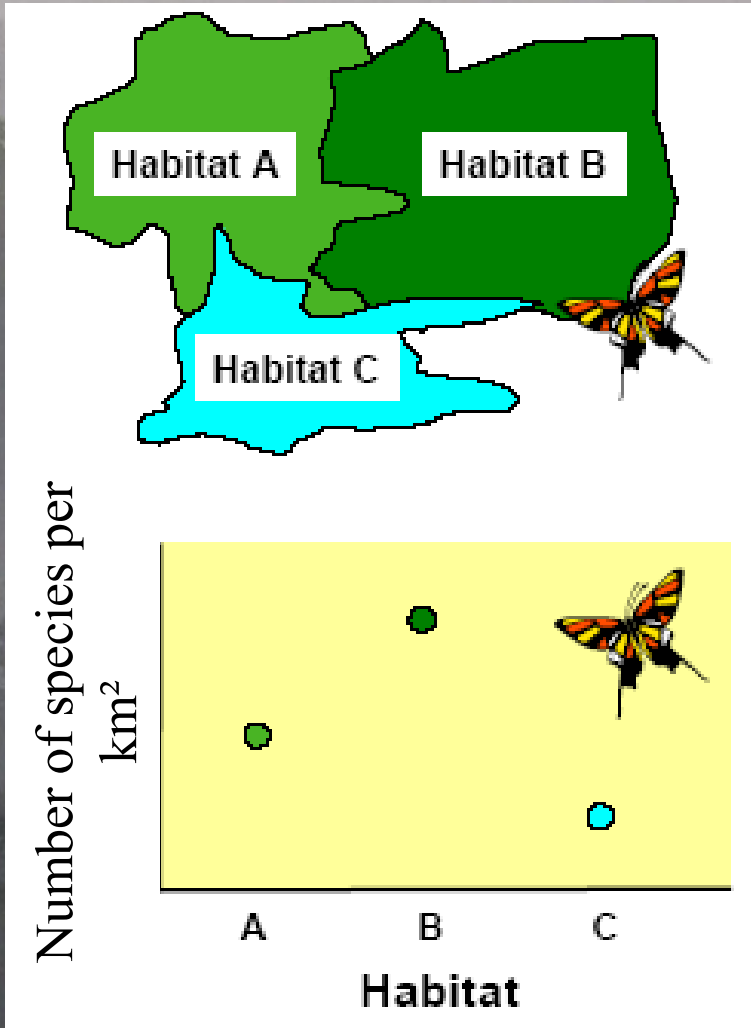
Figure 2 : Richness and evenness

Difficulty to guess the species of a random individual:

Information - Uncertainty

Alpha Diversity

α

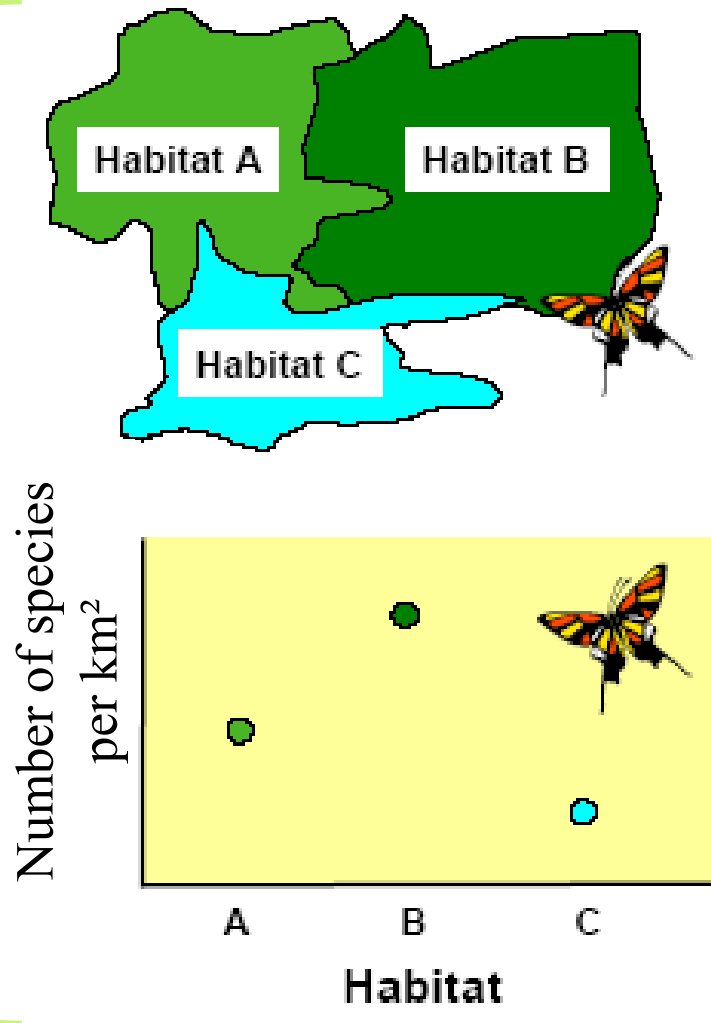


Number of species per hectar in each Habitat

Figure 3 : α Diversity, assessed through species richness
(from *Morin and Findlay, 2001*)

Gamma Diversity

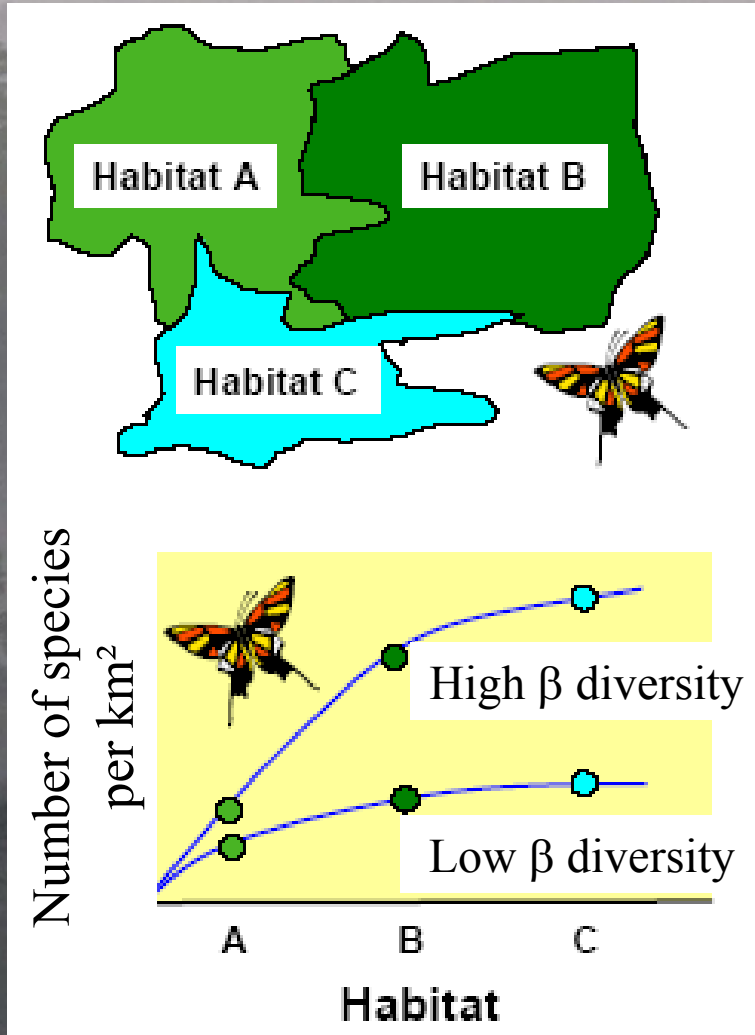
γ



Number of species /ha
in each habitat

Beta Diversity

β

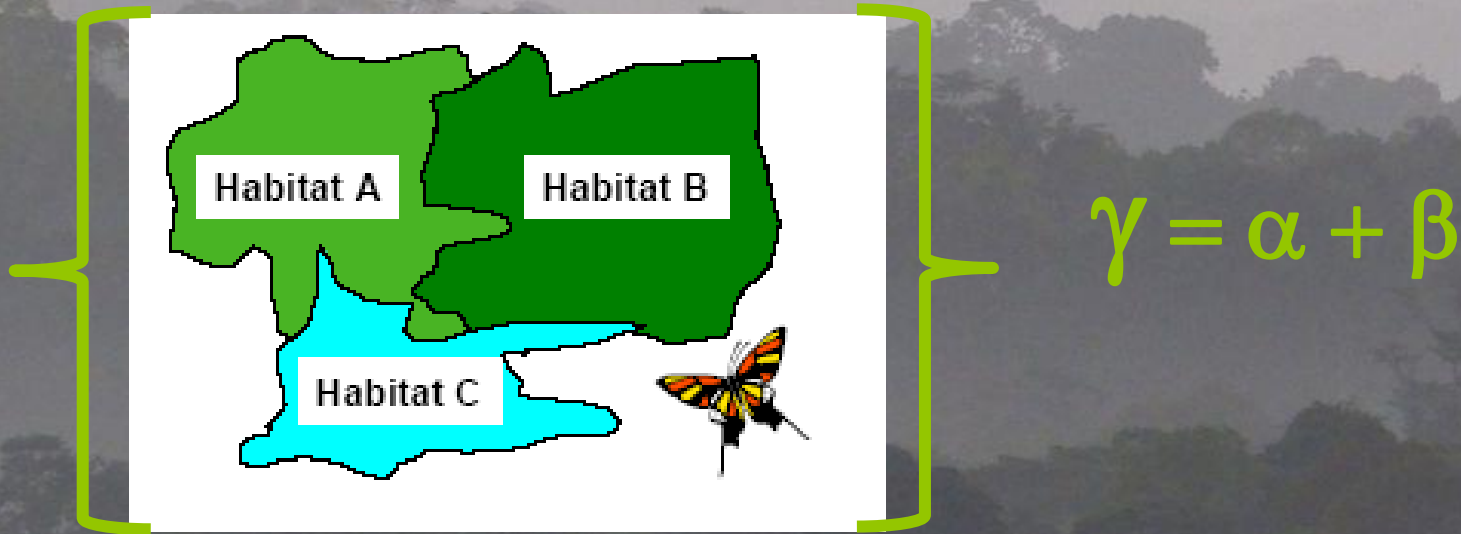


- *Variations*
Variations within a Meta-community

- *Turnover*
Changes in composition along a gradient

Figure 4 : β Diversity, species richness
(from Morin and Findlay, 2001)

Beta Diversity



Decomposition

- Derived from α and γ
- Through average dissimilarity

Diversity measurement

- Entropy
- Richness, Simpson and Shannon indices
- Hill numbers
- Rao index
- Bias correction
- Decomposition

Entropy

Summarises the various aspects of diversity

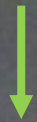
- Average uncertainty in a community
- Weight the individuals \rightarrow Order q

$${}^q H = \frac{1}{q-1} \left(1 - \sum_{s=1}^S p_s^q \right)$$

Entropy

Summarises the various aspects of diversity

- Average uncertainty in a community
- Weight the individuals \rightarrow Order q



Diversity profiles



Particular indices

- Species richness
- Shannon index
- Simpson index

Species richness

S

No evenness notion

- Number of species
- Estimation
 - Extrapolate the species-area relationship
 - Model frequencies distributions
 - Non-parametric estimations

Shannon index

H

Richness and equity

Measurement of uncertainty



Number of combinations using characters with set frequencies

$$H = - \sum_{i=1}^x p_i \ln p_i$$

Simpson index

E

Weights of individuals

Probability that two randomly drawn individuals
are of different species

$$E_s = 1 - \sum_{i=1}^x p_i^2$$

Hill numbers

D

From indices to *real diversity*

Number of *equivalent species*,
stable and understandable measure



- Number of species : unchanged
- General : Hill = \exp_q^{qH}

Rao index

Account for similarity between species

- Distance matrix
 - Species frequencies
- ↓
- Average distance between two individuals



Bias correction

Missed species

Non linear function of probabilities



Correct the richness
and adjust \hat{p}



Estimators to correct
formulas according to
coverage

Decomposition

Assess the diversity of a Meta-community

- Decomposition of indices as a sum:

$$H_{\gamma} = H_{\alpha} + H_{\beta}$$

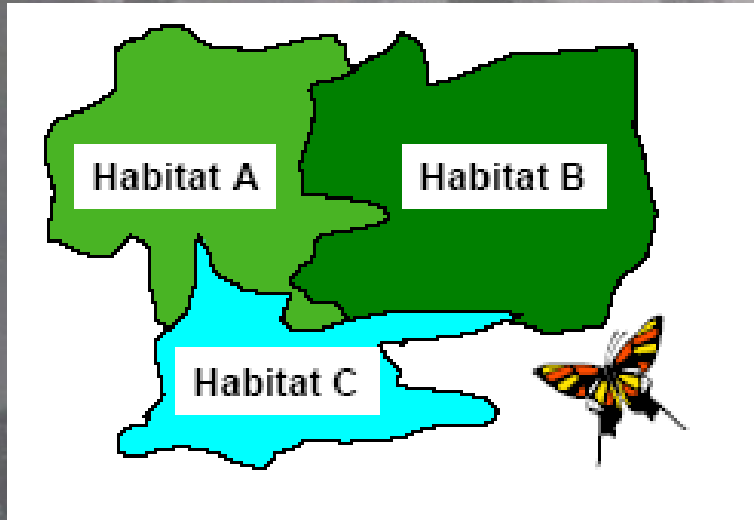
- Then relate to a diversity:

$$\exp^{H_{\gamma}} = \exp^{H_{\alpha}} \cdot \underbrace{\exp^{H_{\beta}}}_{\downarrow}$$

Equivalent number of communities

Decomposition

Characteristics of communities



Difference to the average

- Richness → Number of species
- Shannon → Frequencies distribution
- Simpson → Variance

A misty, layered forest landscape with rolling hills and dense green trees, creating a sense of depth and atmosphere. The text is overlaid on this background.

Entropart

An R package to measure and
partition Diversity

The Paracou experience

(Marcon & Hérault, 2014)

Entropart

- Data structure
- Paracou datasets
- Calculation of diversity indices
 - Single community
 - Metacommunity
- Phylogenetic and functional diversities

Communities
And
Meta-communities

Abundance or probability vectors

as.AbdVector

as.ProbaVector

Weight of the sub-communities

MetaCommunity

Coverage of the inventory

Coverage

Random communities

rCommunity

Size and number of species of the communities

Distribution and sd of probabilities:
lognormal, geometric, broken stick

Possible to input abundance/proba vectors

Paracou datasets

Paracou618

Inventories of plots 6 and 18 (1ha)

Paracou618.Taxonomy

Corresponding taxonomy *family, Genus, species*

Paracou618.Functional & Paracou618.dist

Traits on leaf, height, stem and seed traits

Entropy

Entropy of order q with default bias correction

bcTsallis

Usual indices also available

bcRichness

bcShannon

bcSimpson

Diversity

Conversion of entropies into Hill numbers

bcDiversity

expq(bcTsallis(...))

Meta-Community

Details the α , β , γ diversity for a community

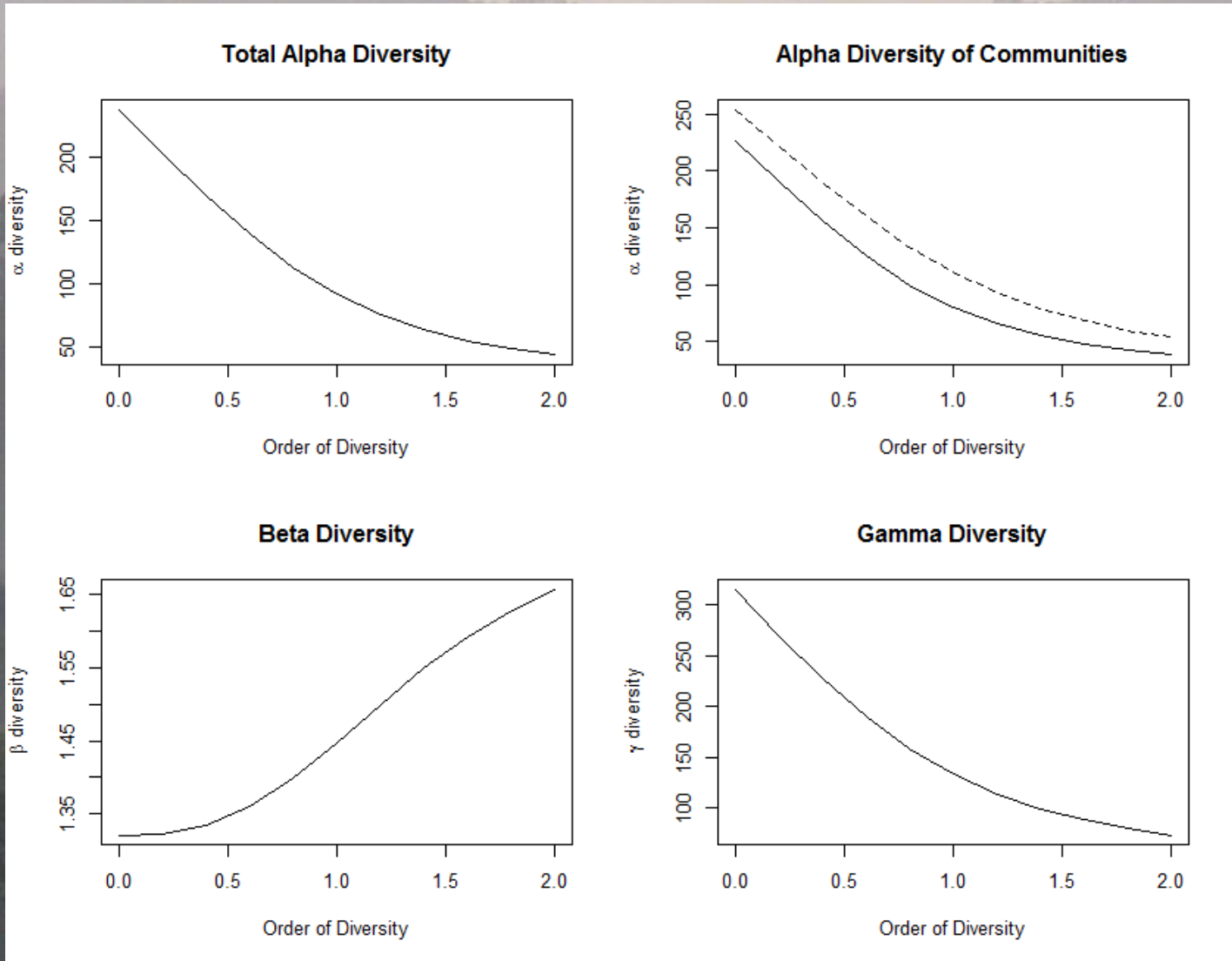
AlphaDiversity / BetaDiversity / GammaDiversity

expq(bcTsallis(...))

All at once:

DivPart / DivEst

Meta-Community



Diversity profiles: *DivProfile*

Phylogenetic diversity

DivPart / DivEst / DivProfile

Similar with additional input of the tree

Similarity-based diversity

bcDqz

With a distance matrix between individuals

Probability vector

Order q



Application in R