

Functional Diversity

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Biodiversity

- Includes genotypic and phenotypic variation, and evolutionary histories of organisms across space and time.
- Its quantification is challenging. Large part of this quantification deals with the number of species and their abundances:

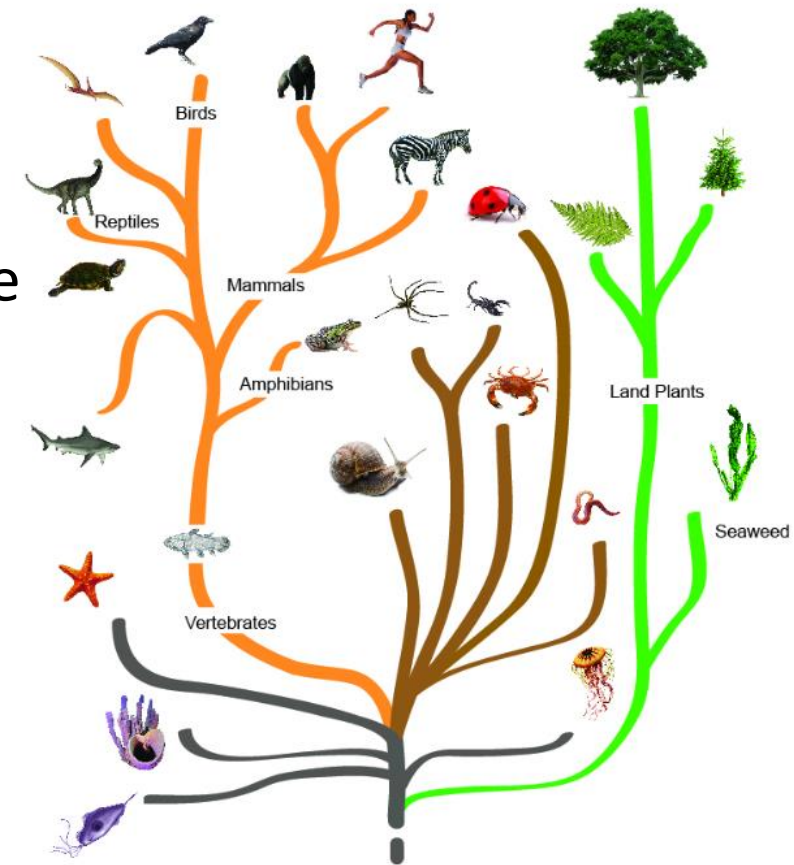
“Taxonomic facet”



Biodiversity

Other facets:

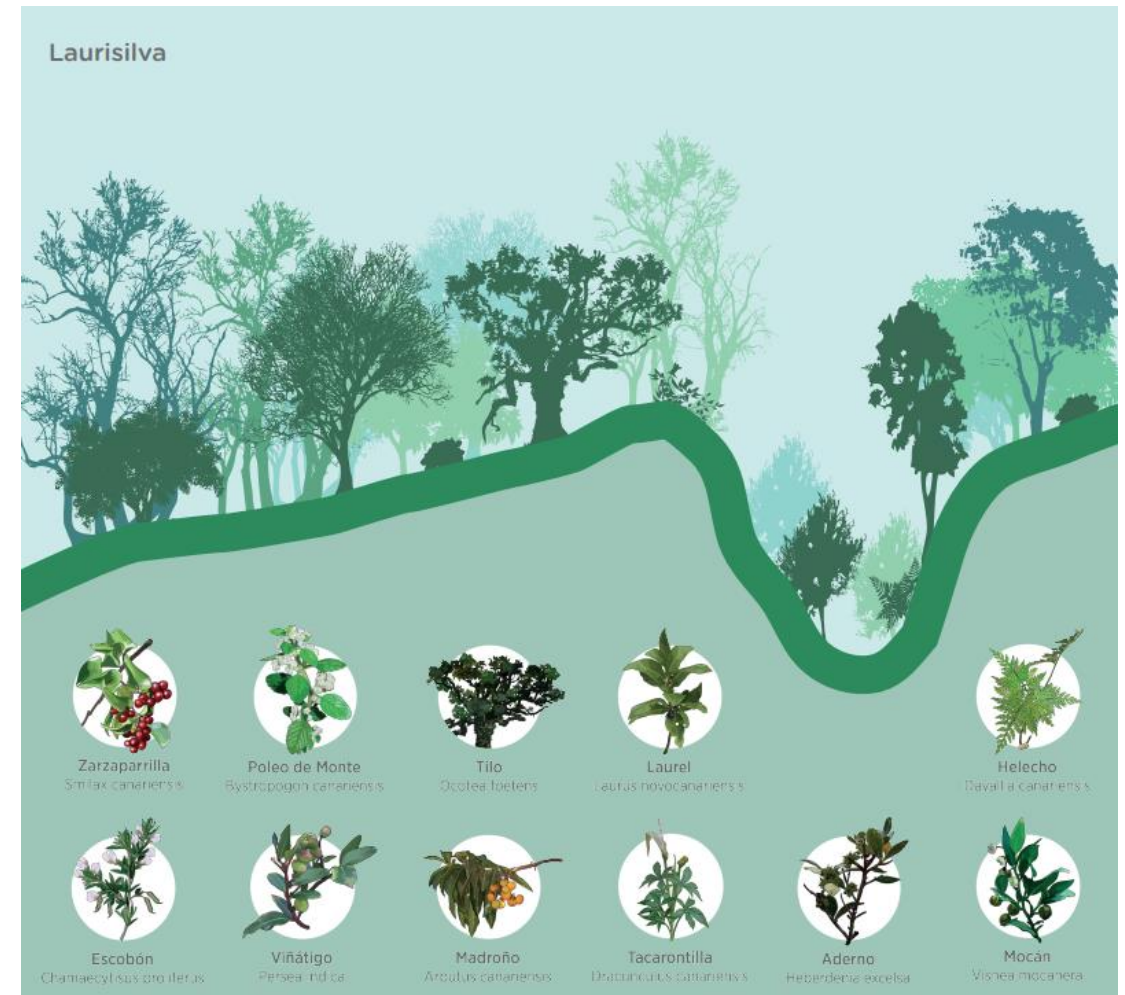
- **“Phylogenetic facet”**: reconstructs the origins of life and evolution, i.e., tree of life.
- **“Functional facet”**: deals with organisms/species functional characteristics in relation to the environment.



Biodiversity

Focus: “**Functional facet**”:

relates to species, populations, communities and ecosystems ecological performance.



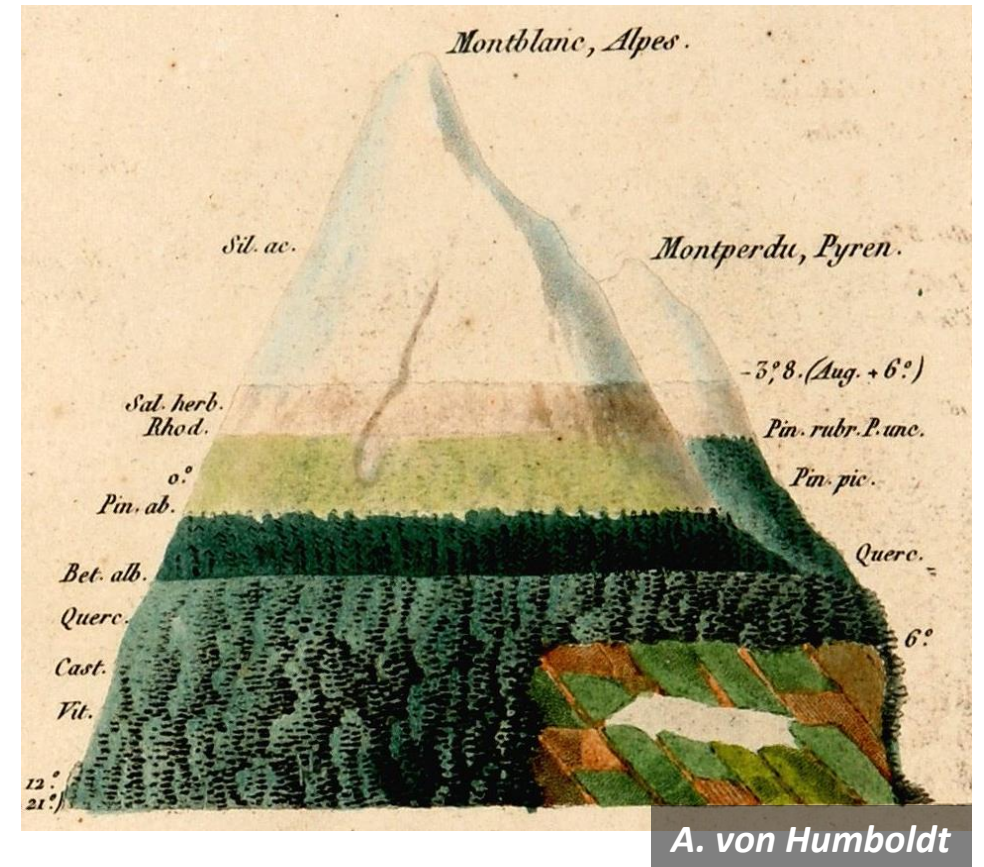
Tilman 2001

What is functional diversity?

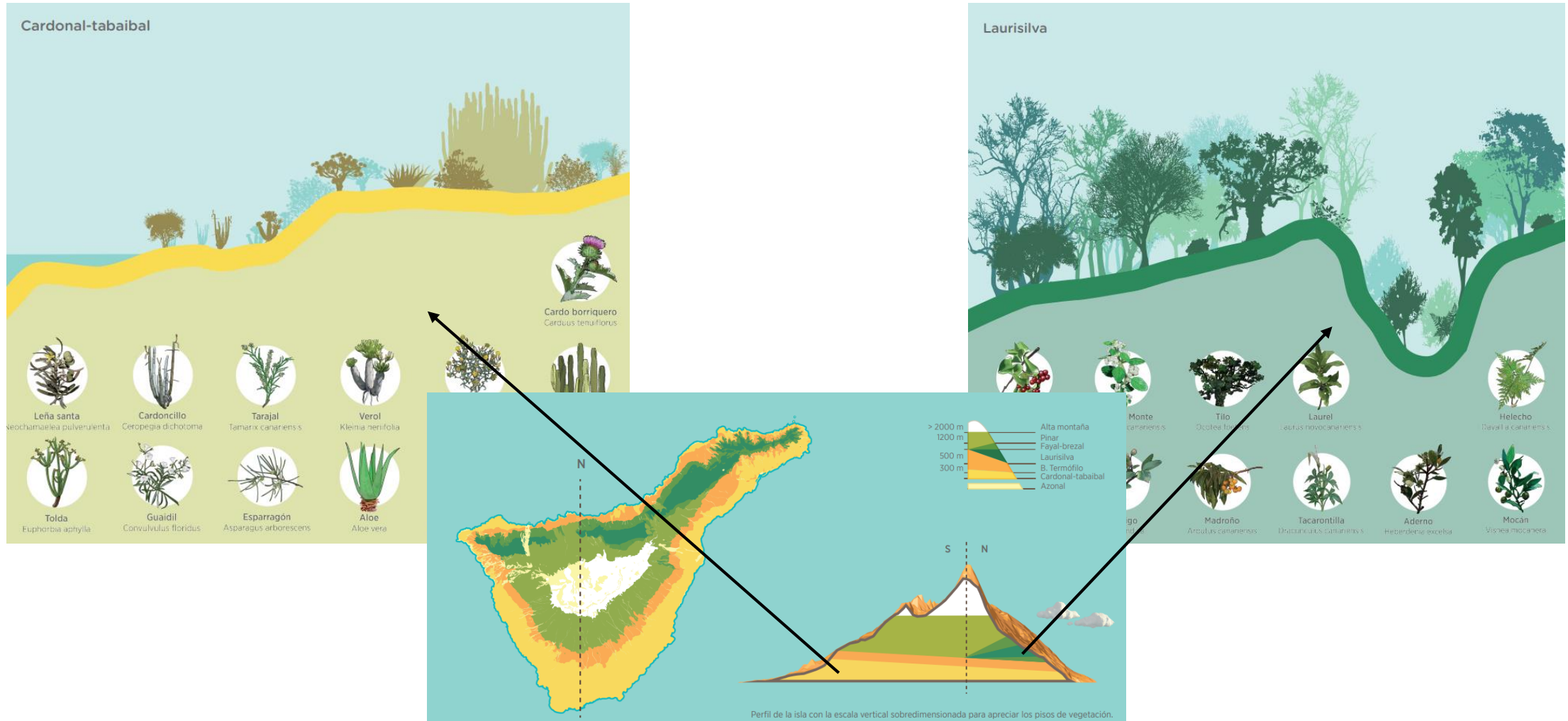
‘Schimper world’

- Certain species are more successful in different parts of the landscape than other because their attributes “traits”.
- For instance: leaf sizes, wood densities and canopy heights.

Westoby & Wright (2006)



What is functional diversity?



What is functional diversity?

- “Function” (the action of performing)
 - Relates to the role of organisms in their environment.
 - Reflects natural selection (environmental filters or competition) on an organism.
- “Function” specific activity carried out by part of a whole or by the whole itself, e.g., species and ecosystems (scale).



Calow 1987 Func. Ecol; Garnier et al 2016

Functional ecology

Differences among species are quantified using morphological and physiological characteristics (“traits”) that impact how organisms respond to environmental factors, affect other trophic levels, and influence ecosystem properties.



Lavorel and Garnier 2002 *Func. Ecol*; Violle et al 2007 *Oikos*

What are traits?

“Morphological, physiological, phenological characteristics of organisms that impact growth, reproduction and survival of individuals”

(Violle et al 2007)

“Traits affect how organism respond to environmental factors and affect ecosystem properties” (Lavorel & Garnier 2002)

Functional traits

Examples

- Plant height
- Seed mass
- Leaf area
- Pollination syndrome (categorical)



- Body size
- Beak length
- Wing length
- Diet (categorical)



Functional traits

Ecological functions

Seed mass

Plant height

Leaf size

Specific leaf area (SLA)

Root depth or root length



Fecundity

Light interception, competitive ability

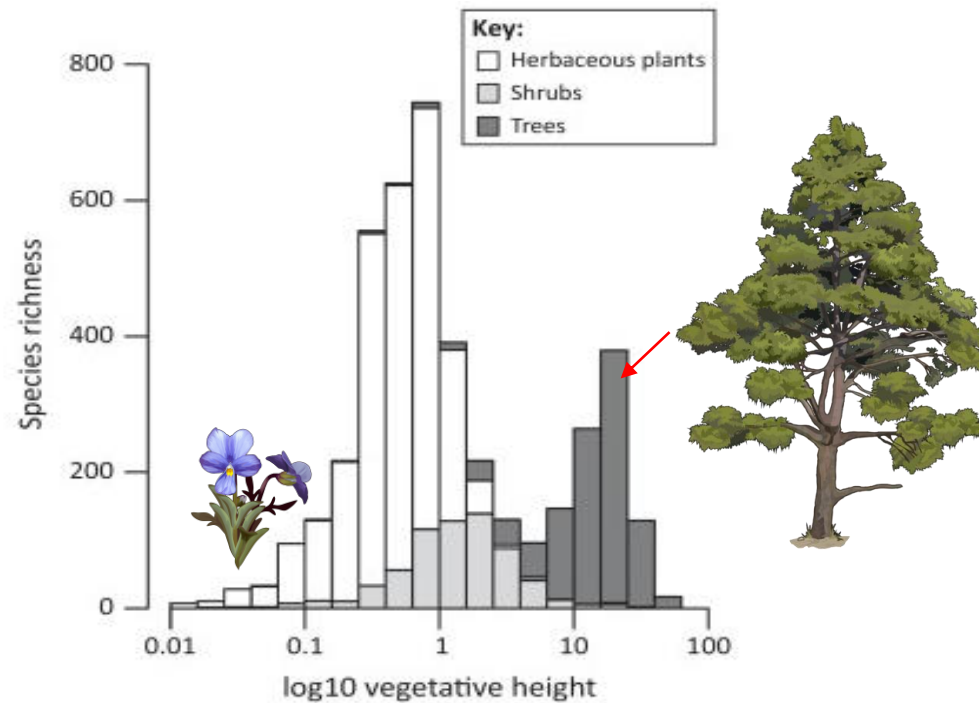
Resource acquisition. Growth (fast, slow)

Absorption (nutrients, water)

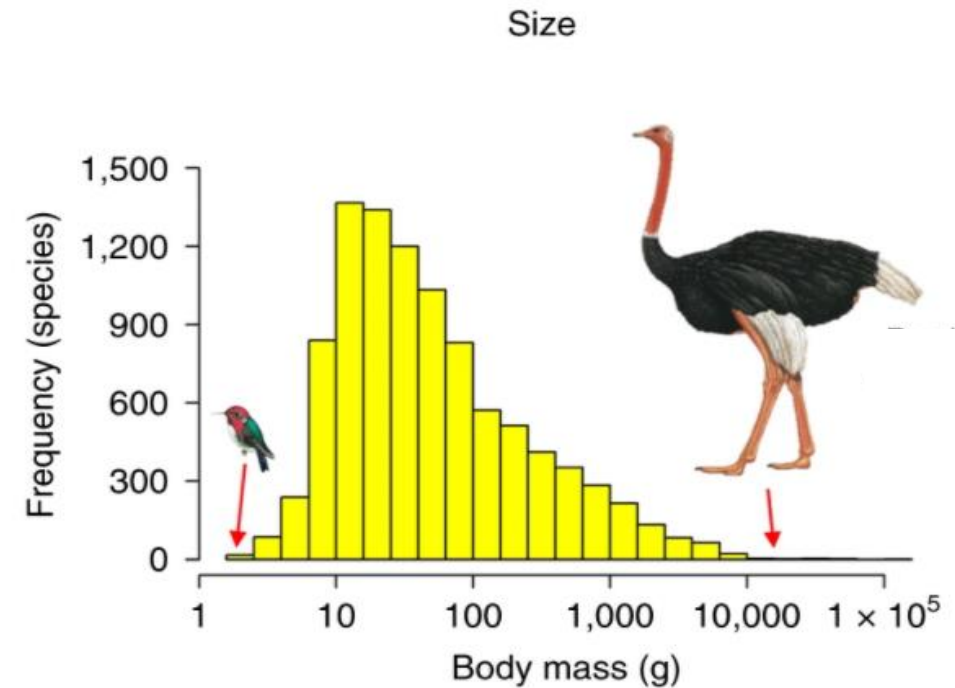
Survival under drought

Garnier et al 2016

Functional traits - univariate analysis

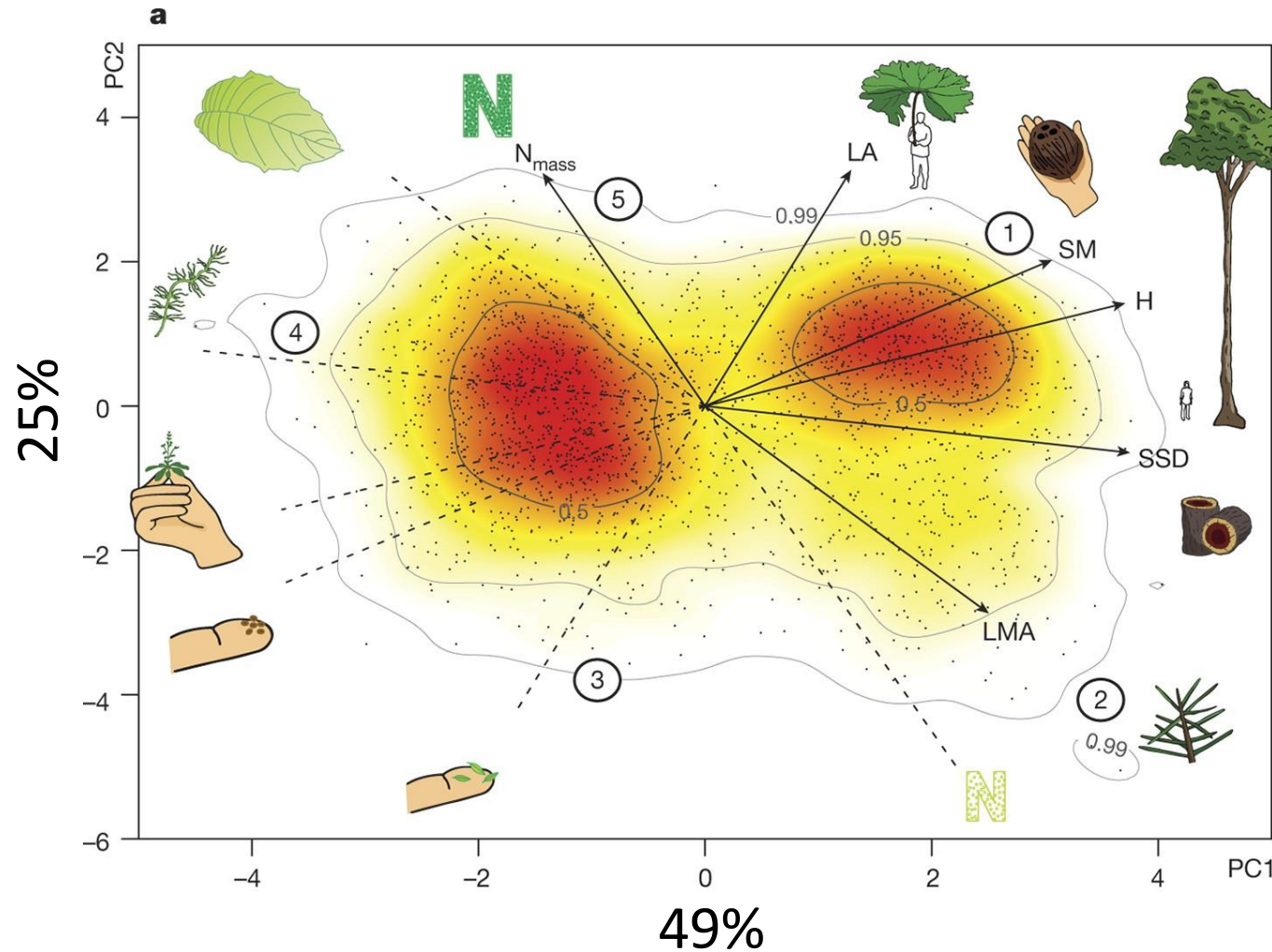


Scheffer et al 2014. Trends in Ecology & Evolution



Pigot et al 2020. Nature Ecology & Evolution

Plant ecological strategies – multivariate analysis



Díaz et al. 2016. Nature

Take home message

- Which traits should we measure?

We can start asking what are the functions that organism perform and which traits or proxies of traits most effectively measure those functions.

Three main functions:

1. Resource acquisition
2. Ability to tolerate environmental extremes
3. Ability to compete with other species

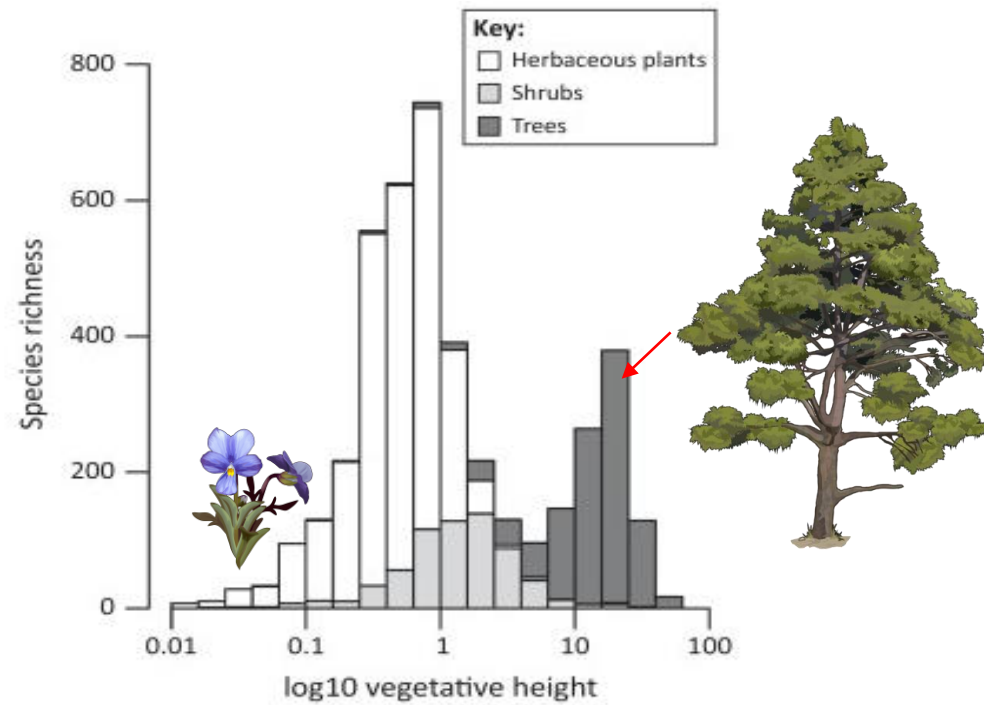
Quantification of functional trait diversity



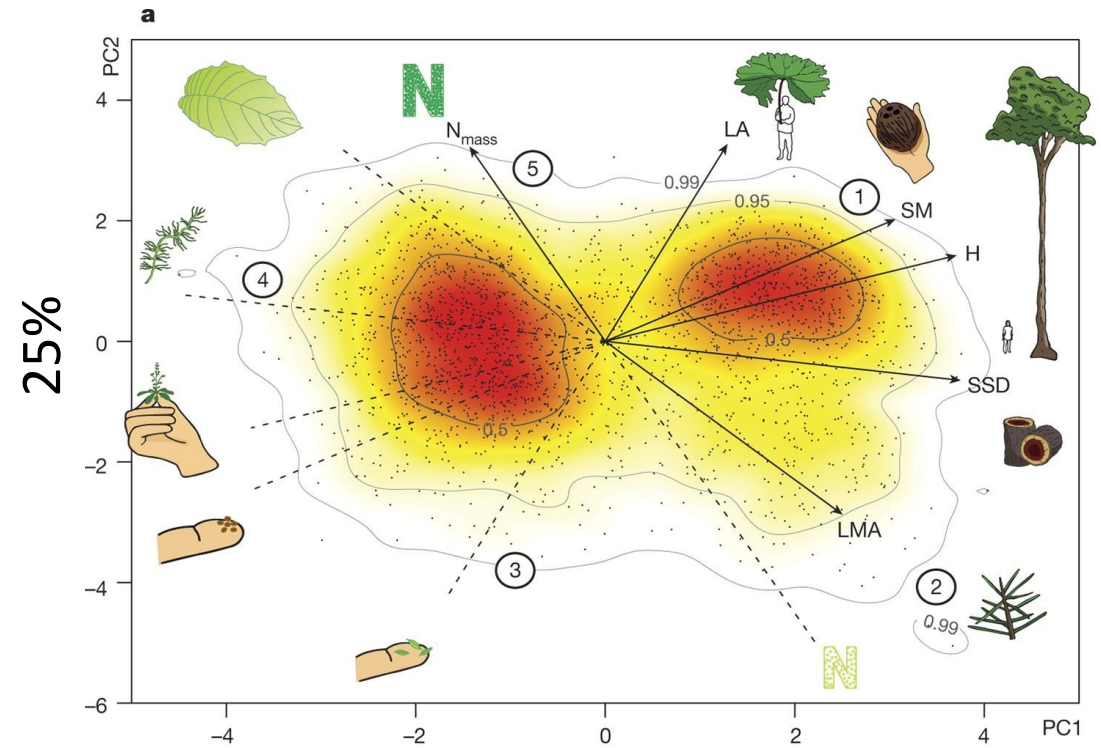
Trait-value-based approach

- Measures are calculated:
 - Species trait values directly (e.g., aggregated-trait value; Garnier et al 2004)
 - Accounting for their position in a multidimensional functional space built according to their trait values (e.g., volume occupied by species; Cornwell et al. 2006).

Species trait values - univariate analysis



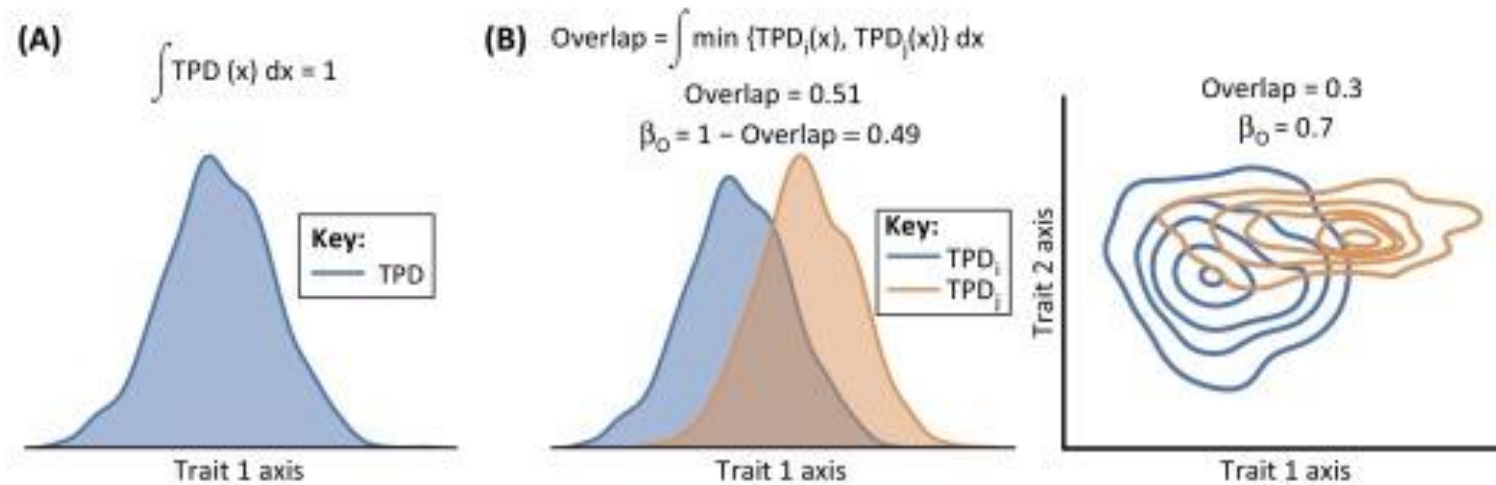
Scheffer et al 2014. Trends in Ecology & Evolution



Díaz et al. 2016. Nature

Functional diversity quantification

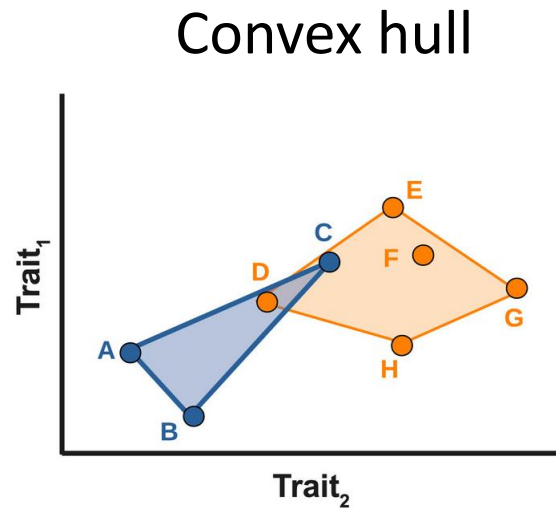
Univariate analysis



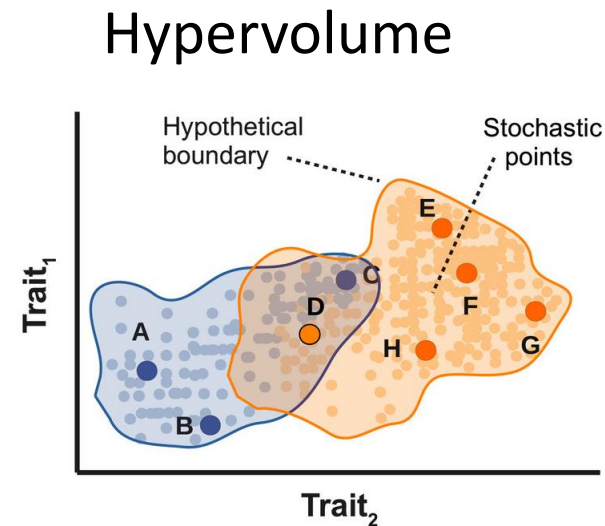
Carmona et al 2016. Trends in ecology & evolution.

Functional diversity quantification

Functional richness (volume)



Laliberté et al approach



Blonder approach

It detects possible holes in the trait space.¹⁹

Blonder 2018

Functional diversity quantification

Do hypervolumes have holes?

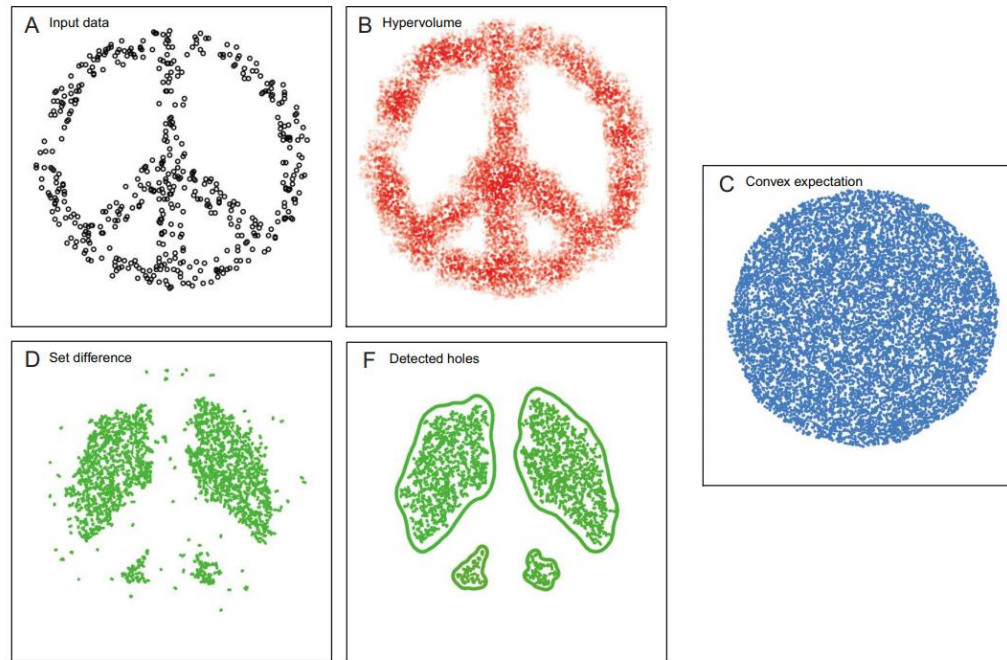


Figure 3: Major steps of the hole-detection algorithm, as illustrated in $n = 2$ dimensions. *A*, The user supplies an input data set (black circles). *B*, A hypervolume is constructed assuming that the data are sampled from an unknown probability distribution using the *hypervolume* function. The hypervolume is inferred by uniformly randomly sampling from a thresholded

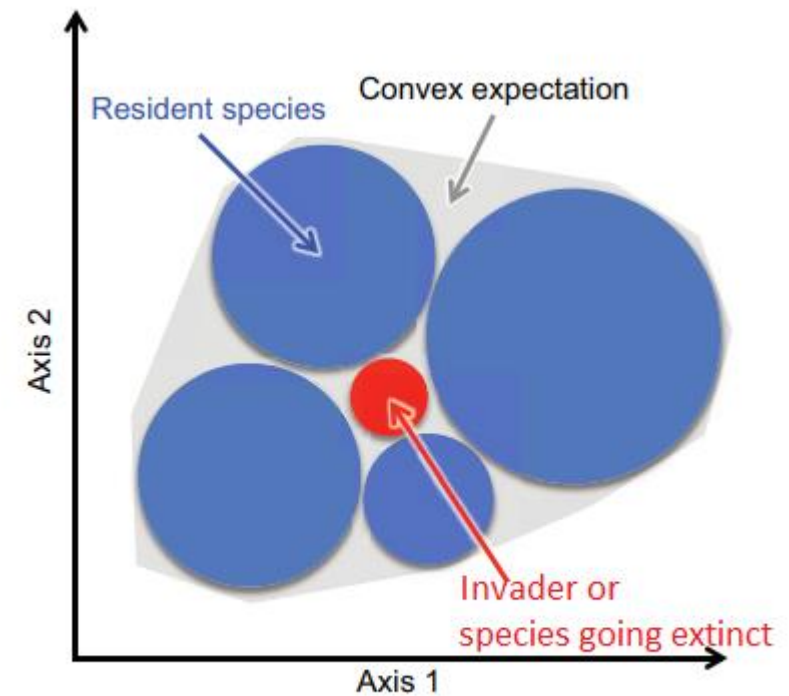


Figure 5: Cartoon example of holes mediating invasion. Consider a