3. Species Richness and Diversity

Beta Diversity

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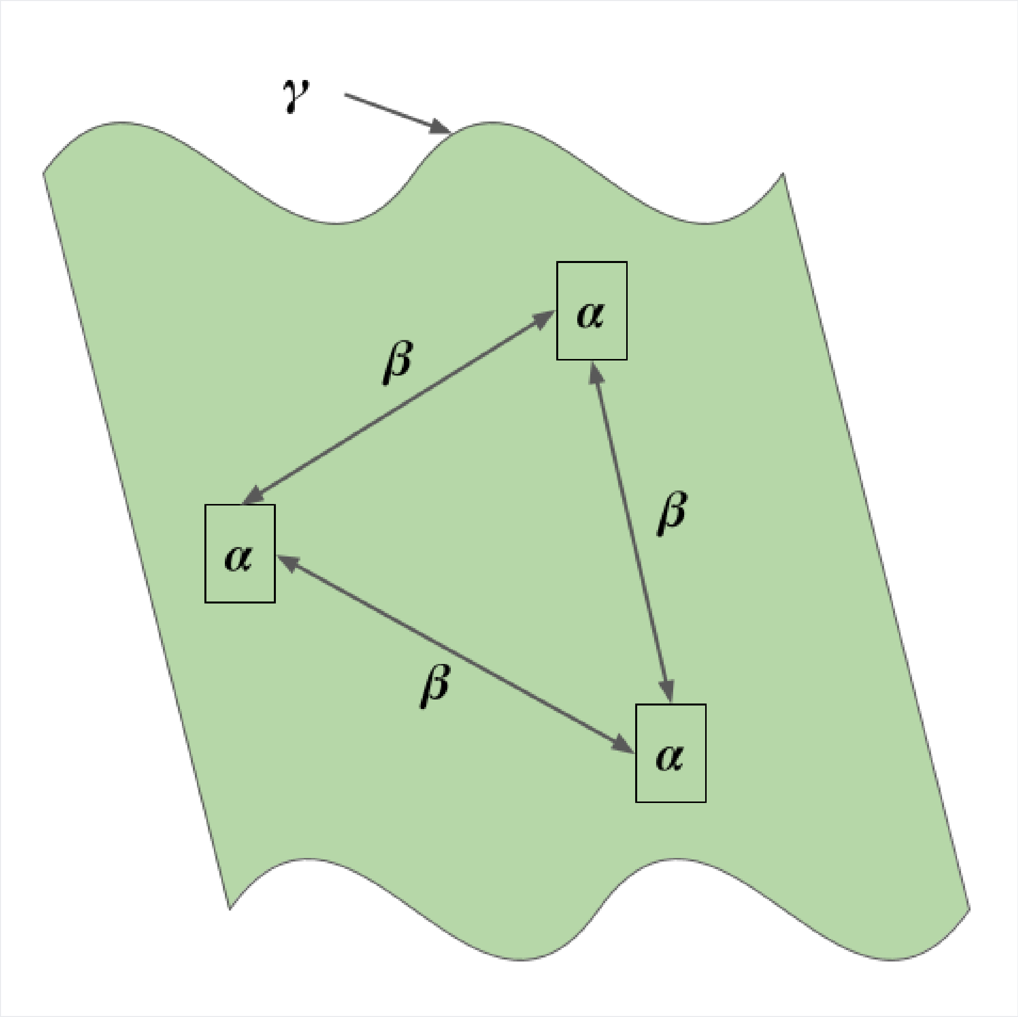
2022-02-01

The components of diversity

Alpha \((\alpha)\) = mean species diversity/richness within local-scale sites, habitats or communities (often termed "point diversity")

Beta \((\beta)\) = diversity/richness differences between sites or habitats (attributable to species "turnover" or "nestedness")

Gamma \((\gamma)\) = total landscape species diversity/richness

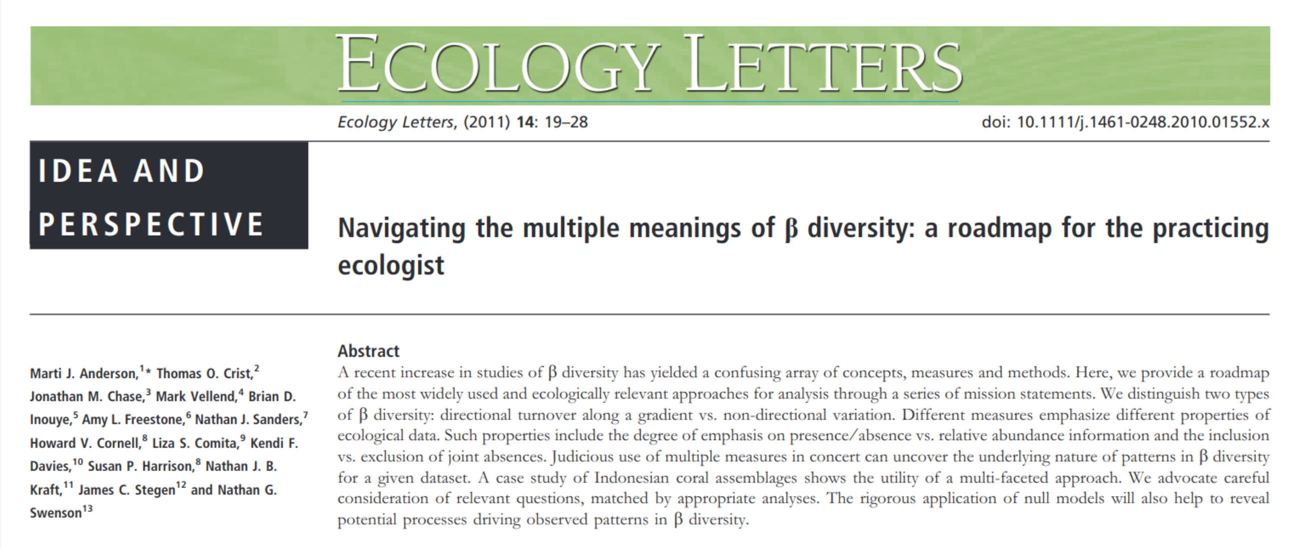


Whittaker (1972)

WARNING!

\(\beta\) diversity can get a little complicated...

There's lots of methods, and opinions often differ among experts...[1]


ECOLOGY LETTERS

Ecology Letters, (2011) **14**: 19–28 doi: 10.1111/j.1461-0248.2010.01552.x

IDEA AND PERSPECTIVE

Navigating the multiple meanings of β diversity: a roadmap for the practicing ecologist

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Abstract

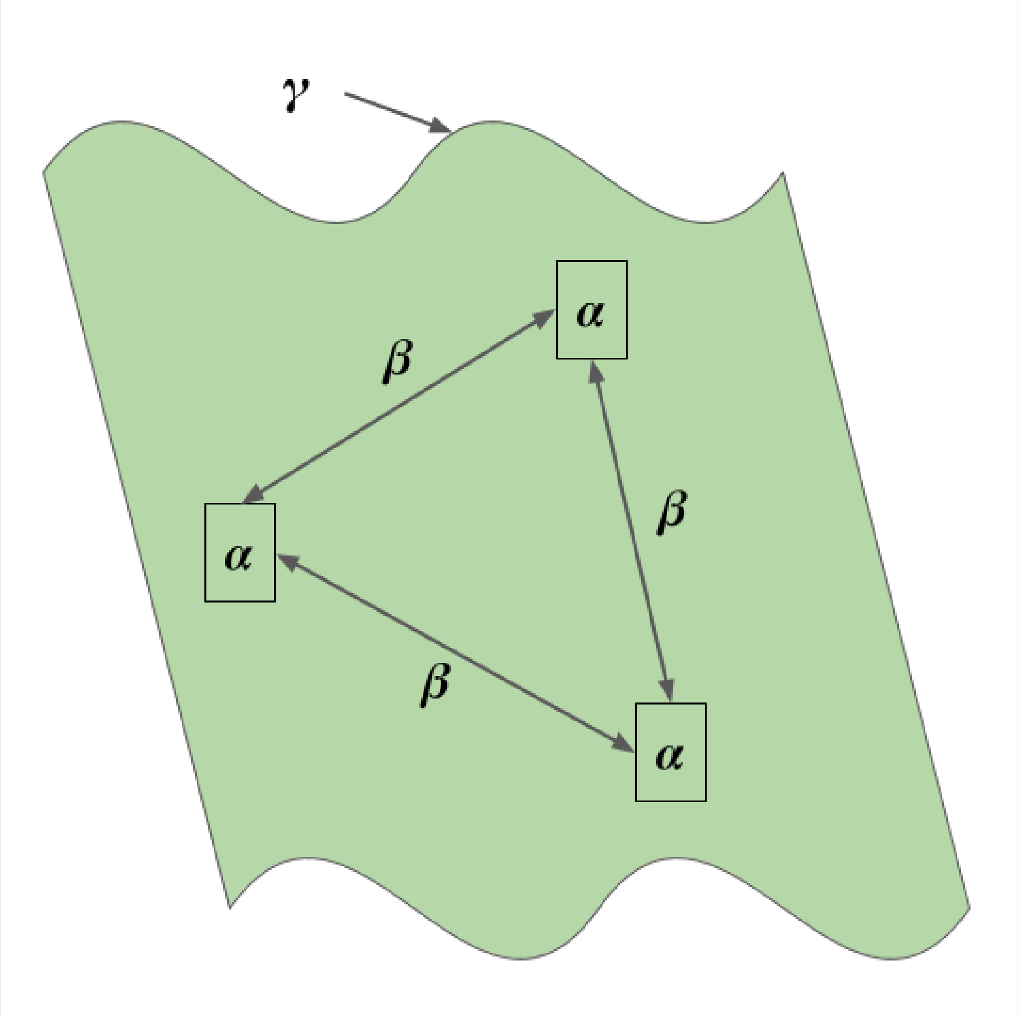
A recent increase in studies of β diversity has yielded a confusing array of concepts, measures and methods. Here, we provide a roadmap of the most widely used and ecologically relevant approaches for analysis through a series of mission statements. We distinguish two types of β diversity: directional turnover along a gradient vs. non-directional variation. Different measures emphasize different properties of ecological data. Such properties include the degree of emphasis on presence/absence vs. relative abundance information and the inclusion vs. exclusion of joint absences. Judicious use of multiple measures in concert can uncover the underlying nature of patterns in β diversity for a given dataset. A case study of Indonesian coral assemblages shows the utility of a multi-faceted approach. We advocate careful consideration of relevant questions, matched by appropriate analyses. The rigorous application of null models will also help to reveal potential processes driving observed patterns in β diversity.

[1]i.e. this is a highly active area of research...

Measuring \(\beta\) diversity

There are two major approaches:

- *"Classical" diversity metrics*, calculated directly from measures of regional \((\gamma)\) and local \((\alpha)\) diversity through additive or multiplicative decomposition
- *Multivariate measures* that calculate distances (or dissimilarities) that represent the compositional resemblance between pairs of samples



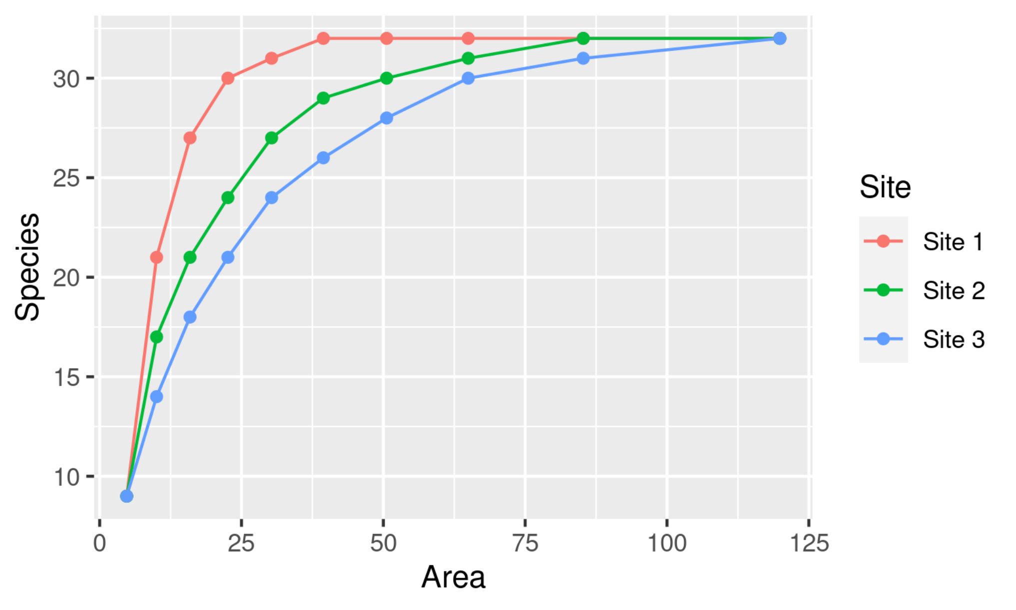
The two are related, and can even be the same thing in certain scenarios, but I'm not going to go there in this course...

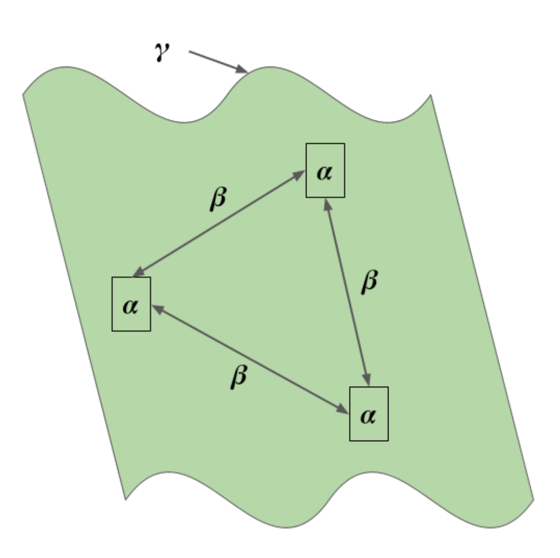
The decomposition of "classical" diversity metrics...

Consider this in the context of the species-area relationship.

If \(\gamma\) is constant (32) across sites, then

- Site 1 = higher \(\alpha\), lower \(\beta\)
- Site 2 = intermediate \(\alpha\) and \(\beta\)
- Site 3 = lower \(\alpha\), higher \(\beta\)





Comparing floras...

Fynbos has moderate to high α and very high β, resulting in high γ

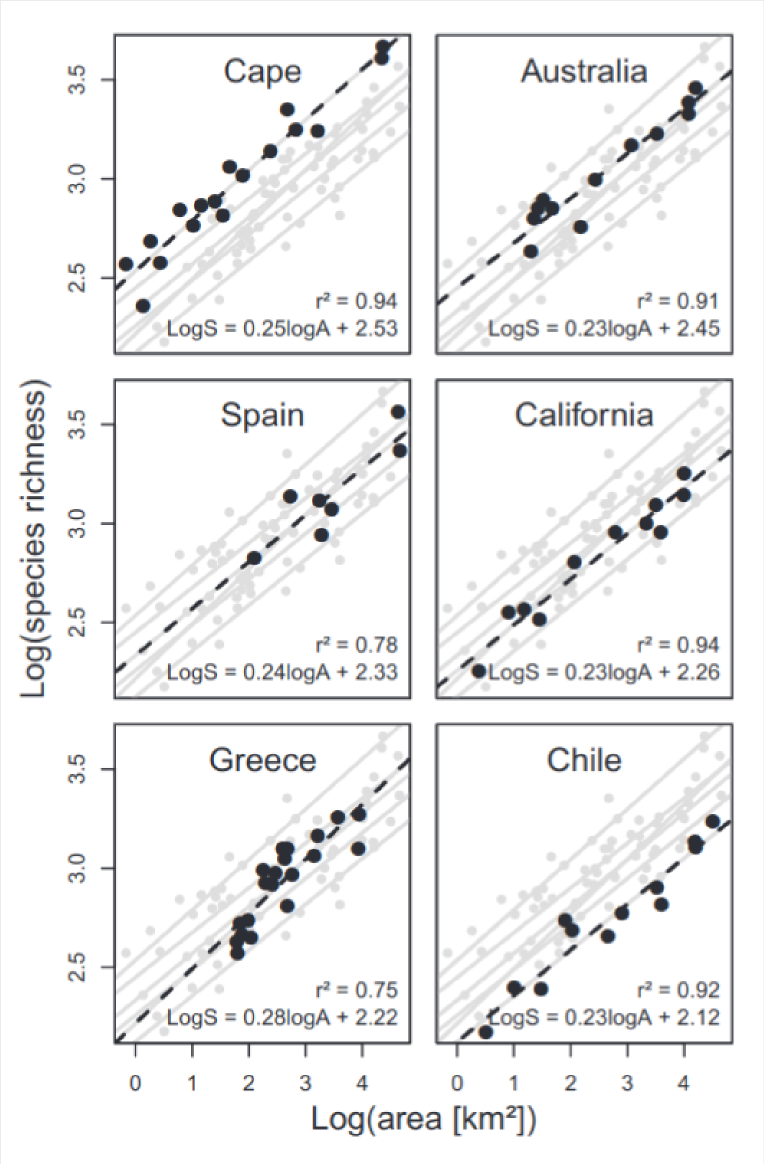
- ~9500 vascular plant species in the Cape Flora
- ~2200 native species on the Cape Peninsula alone

English meadows have very high α, but very low β, resulting in moderate to low γ

- only 1390 native species in the entire Great Britain and Ireland (~3 x the size of the CFR)

Comparing floras...

We often compare the diversity of different regions using species-area curves (usually on log-log axes so the curves are linear) - e.g. Cowling et al. 2015



The decomposition of "classical" diversity metrics...

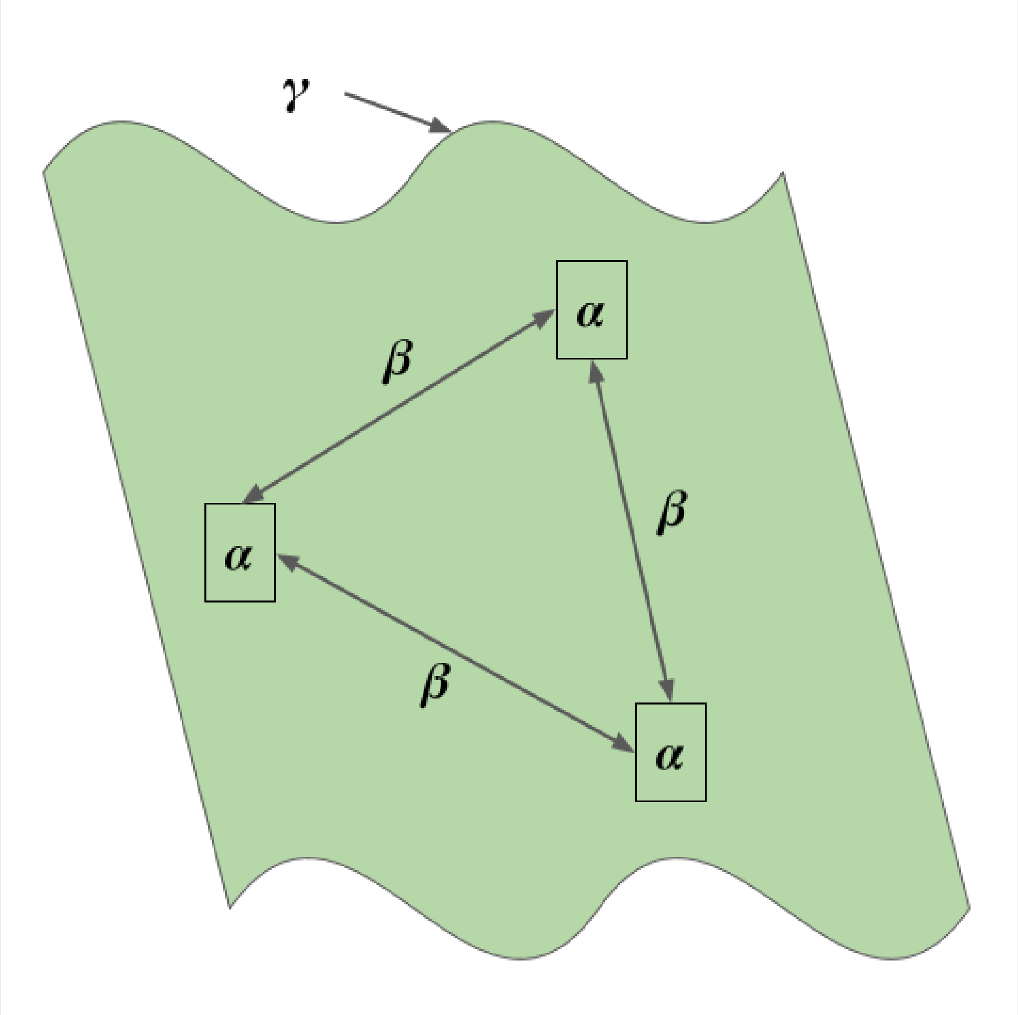
The components of biodiversity are interrelated and, depending on your preference or application, can be expressed

Multiplicatively (*sensu* Whittaker 1972):

$$\beta = \gamma/\alpha$$

Additively (*sensu* MacArthur et al. 1966, Lande 1996):

$$\beta = \gamma - \alpha$$



[1]For reviews see Veech et al. 2002 and Anderson et al. 2011.

Multiplicative "classical" diversity

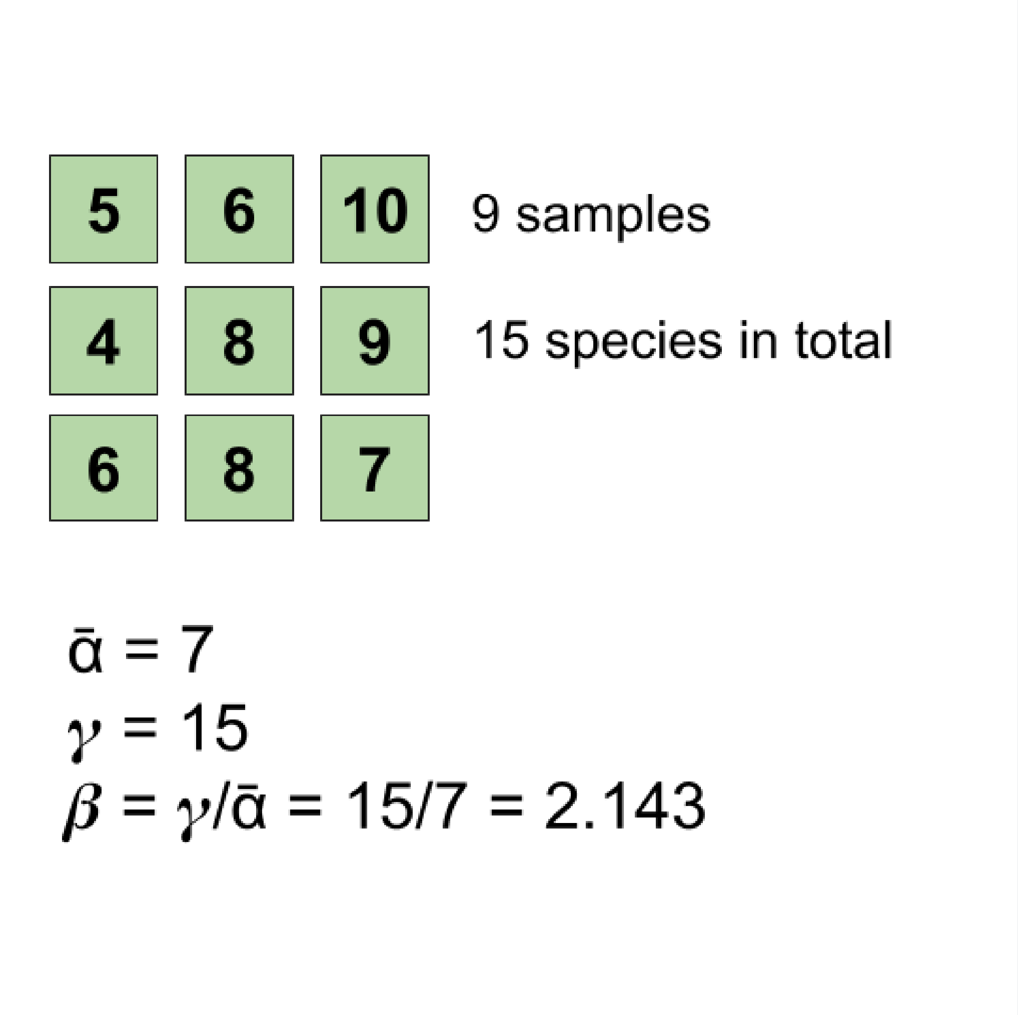
\(\beta = \gamma/\alpha\) (*sensu* Whittaker 1972)

...expresses \(\beta\) diversity as the ratio of landscape \((\gamma)\) to local \((\alpha)\) diversity (usually the mean multiple of local samples, i.e. \(\bar{\alpha}\)).

If most local \((\alpha)\) samples capture most of the landscape \((\gamma)\) diversity, then \(\beta\) diversity (i.e. differences between sites or habitats) must be low, and vv.

Disadvantages:

- the ratio is unitless
- usually need to know \((\gamma)\)



Additive "classical" diversity

$\beta = \gamma - \alpha$ (*sensu* MacArthur et al. 1966, Lande 1996)

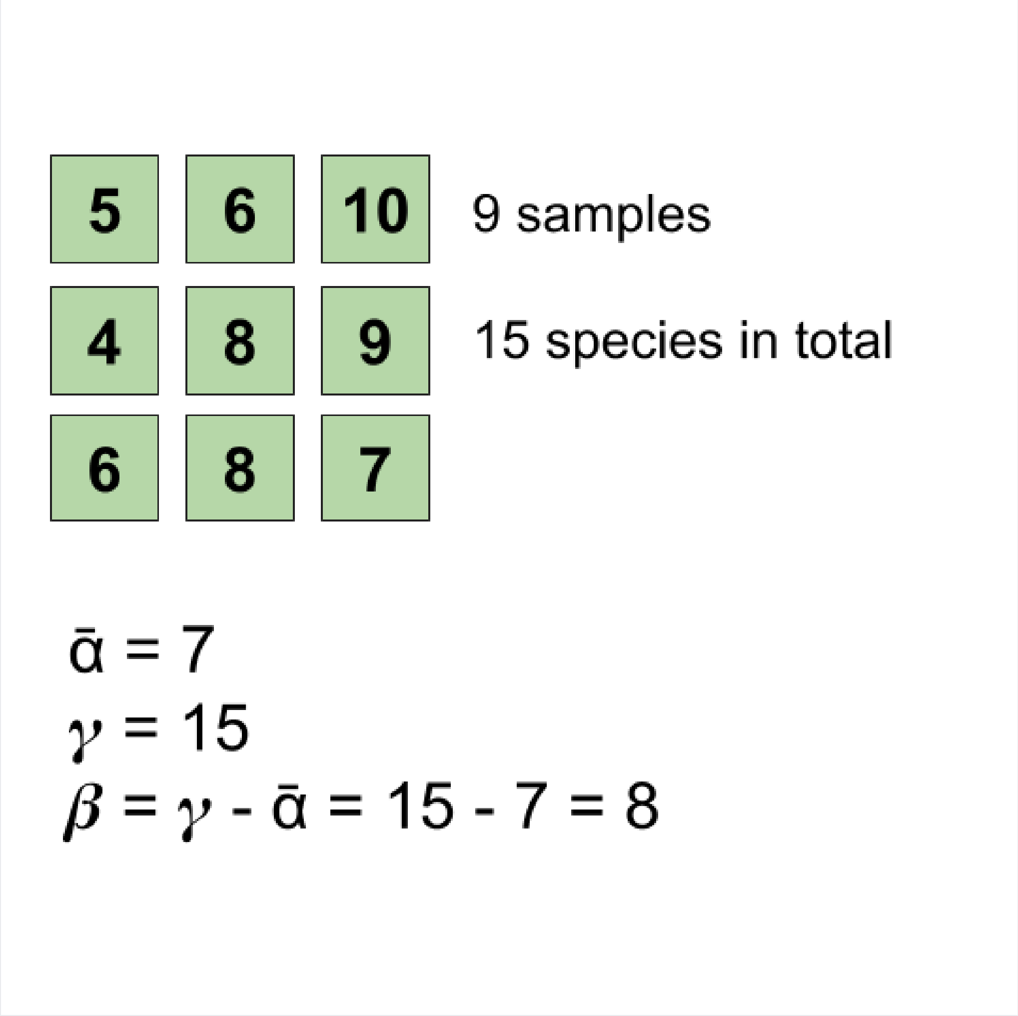
...expresses β diversity as the difference between landscape (γ) and local (α) diversity (again, usually the mean multiple of local samples, i.e. $\bar{\alpha}$).

If local (α) samples capture most of the landscape (γ) diversity, then β diversity (i.e. differences between sites or habitats) must be low, and vv.

Advantage:

- the difference is expressed as species

Disadvantage:

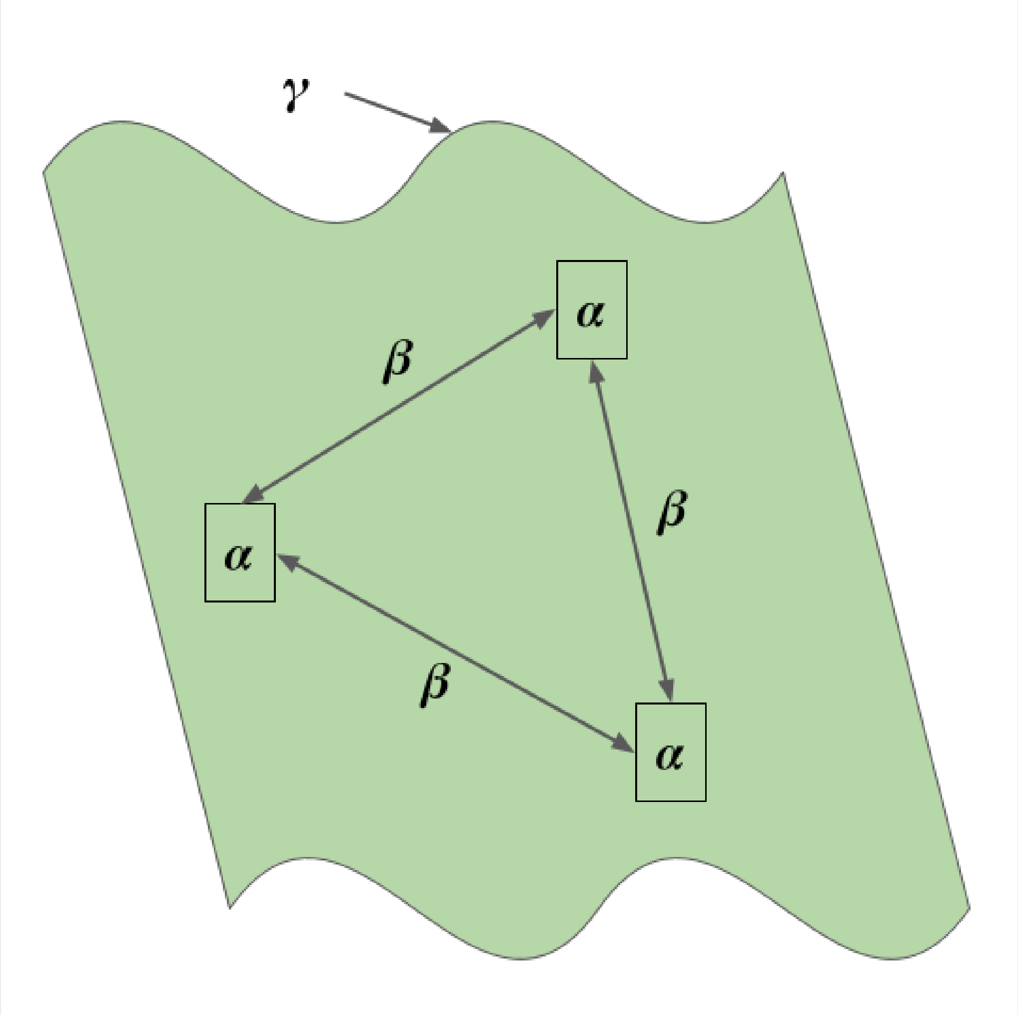


Multivariate measures...

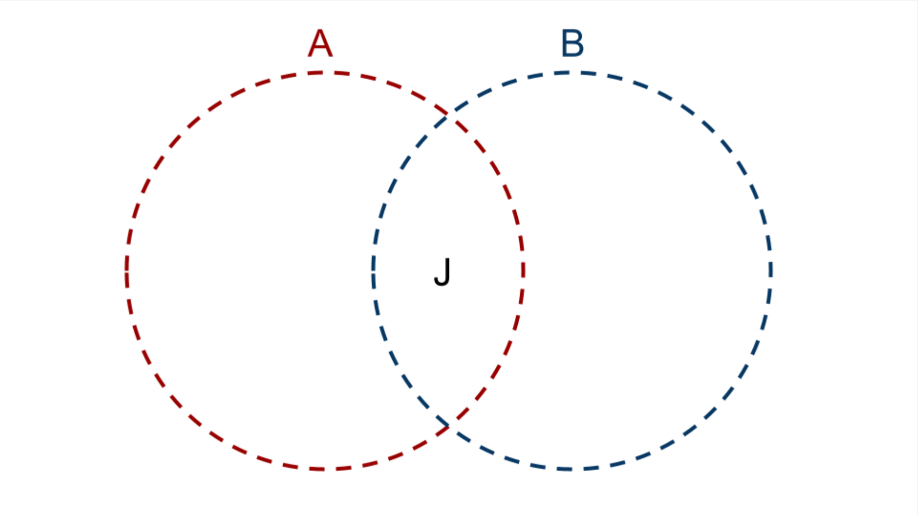
There are a large number of metrics that calculate the dissimilarity of pairs of samples based on the number of species that are shared between them or unique to each.

The metrics typically differ in whether they:

- are based on species presence/absence only, or also include abundance information
- include/exclude joint absence information
- account for differences in the \(\alpha\) diversity of samples



Multivariate measures...



e.g. the same equation, $(A+B-2*J)/(A+B)$

Where J is the shared quantity, and A and B are totals for each community,

can be...

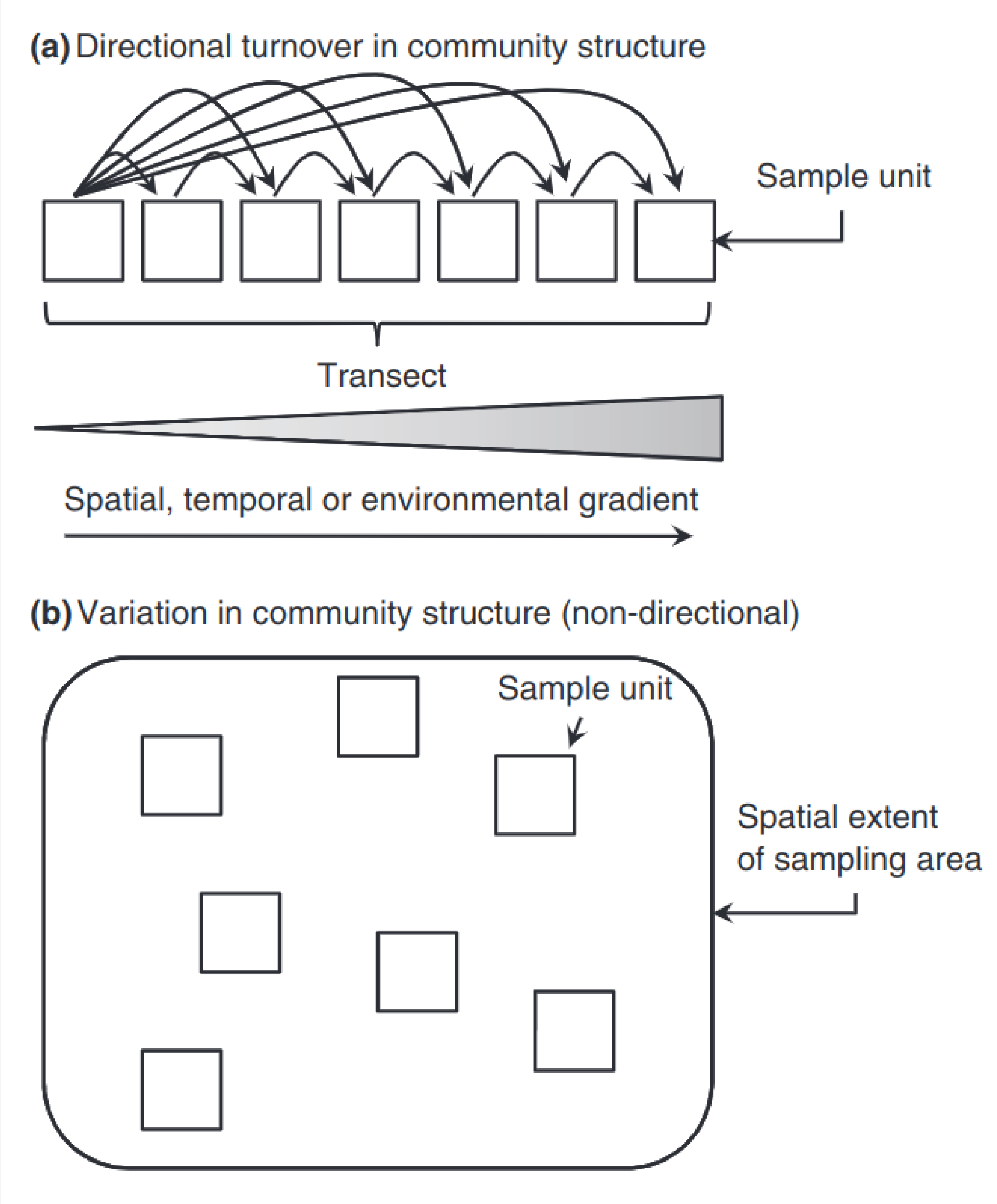
Sorenson's Index

when based on species presence/absence only

Bray-Curtis distance

when it includes abundance information

Values range from 0 (identical communities) to 1 (complete turnover).

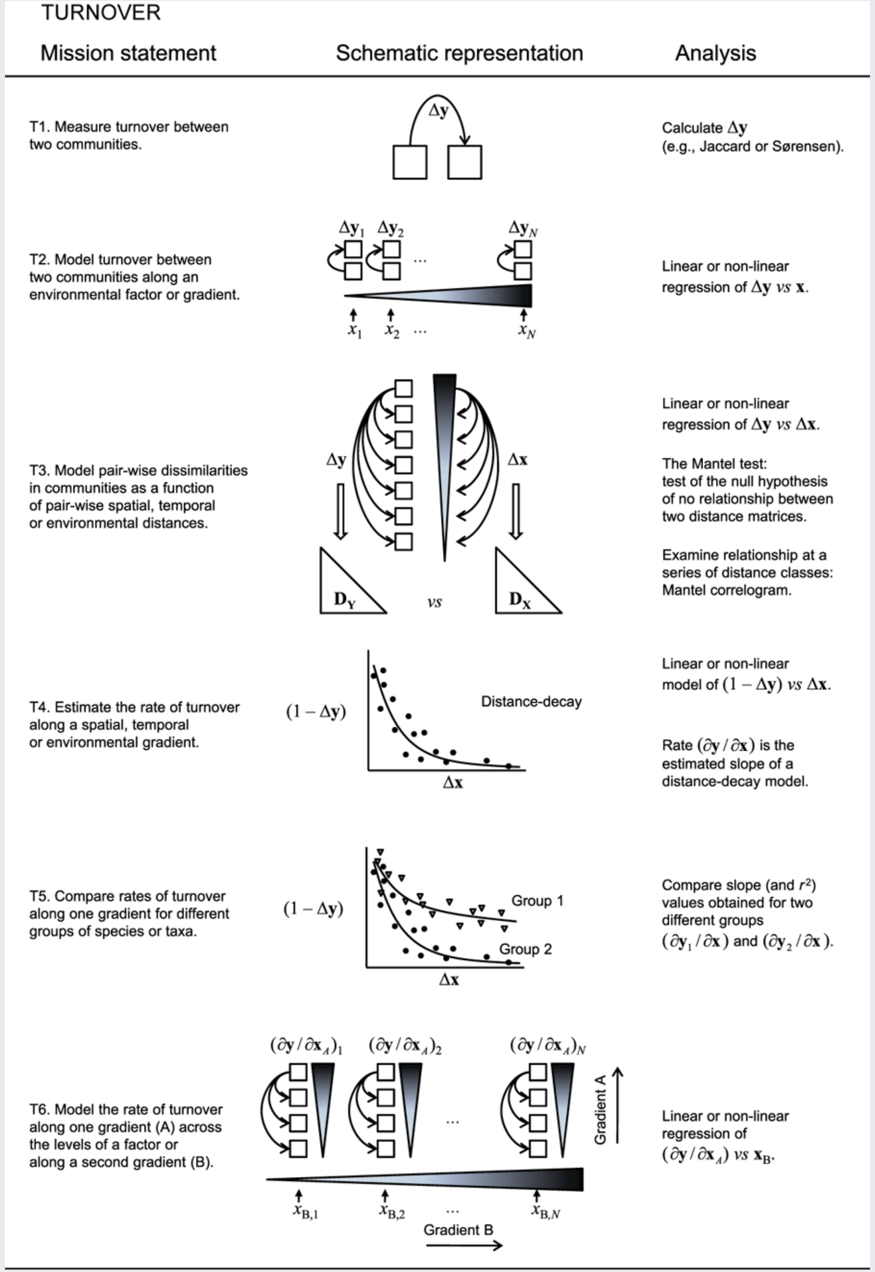


Turnover vs Variation

The application \(\beta\) diversity can be largely split into

- directional analyses, that explore *turnover* along spatial, temporal or environmental gradients, and
- non-directional analyses, that explore *variation* within or among groups.

figure from Anderson et al. 2011



"Turnover" applications

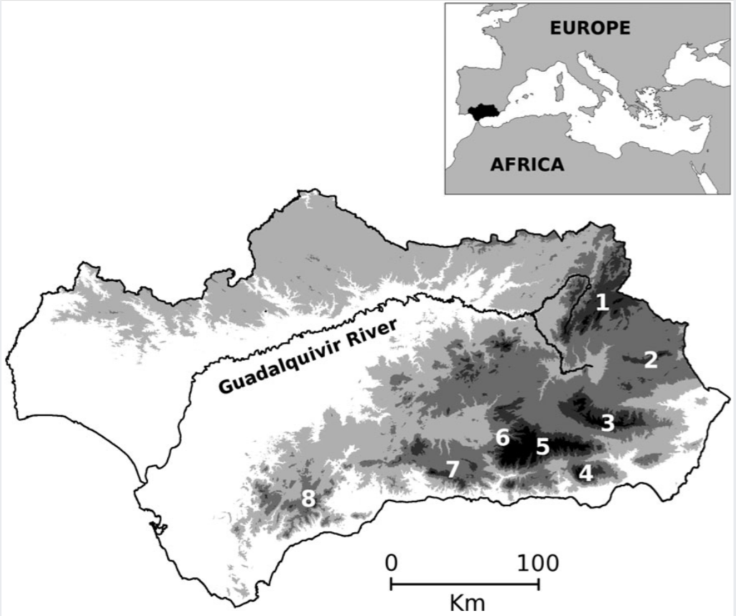
Typically explores change in community composition of one or more groups (e.g. taxa) along one or more gradients (e.g. distance, time, elevation, rainfall).

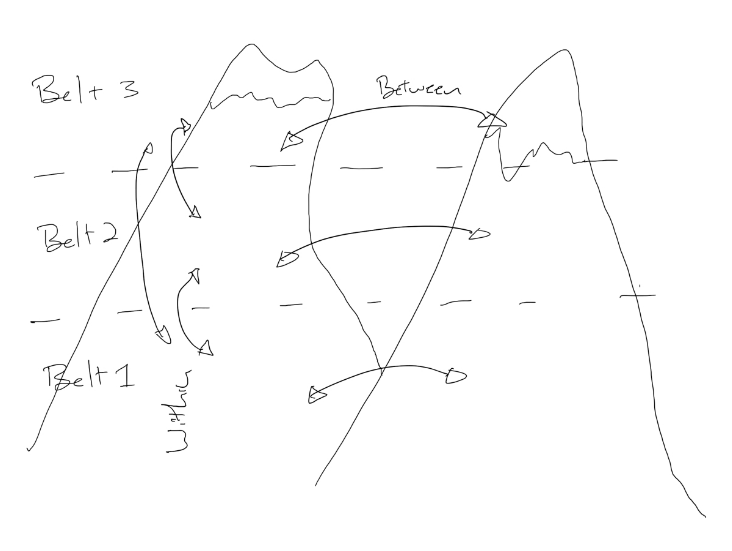
Δy = change in community composition

Δx = change in gradient

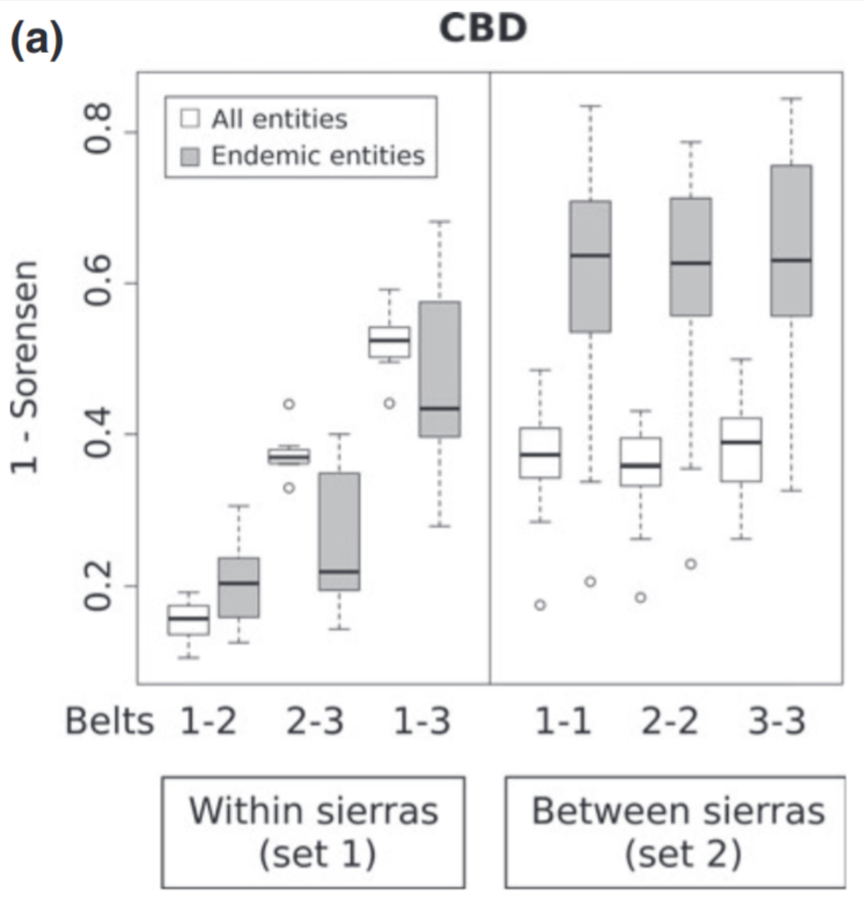
$\delta y/\delta x$ = rate of turnover along a gradient

figure from Anderson et al. 2011

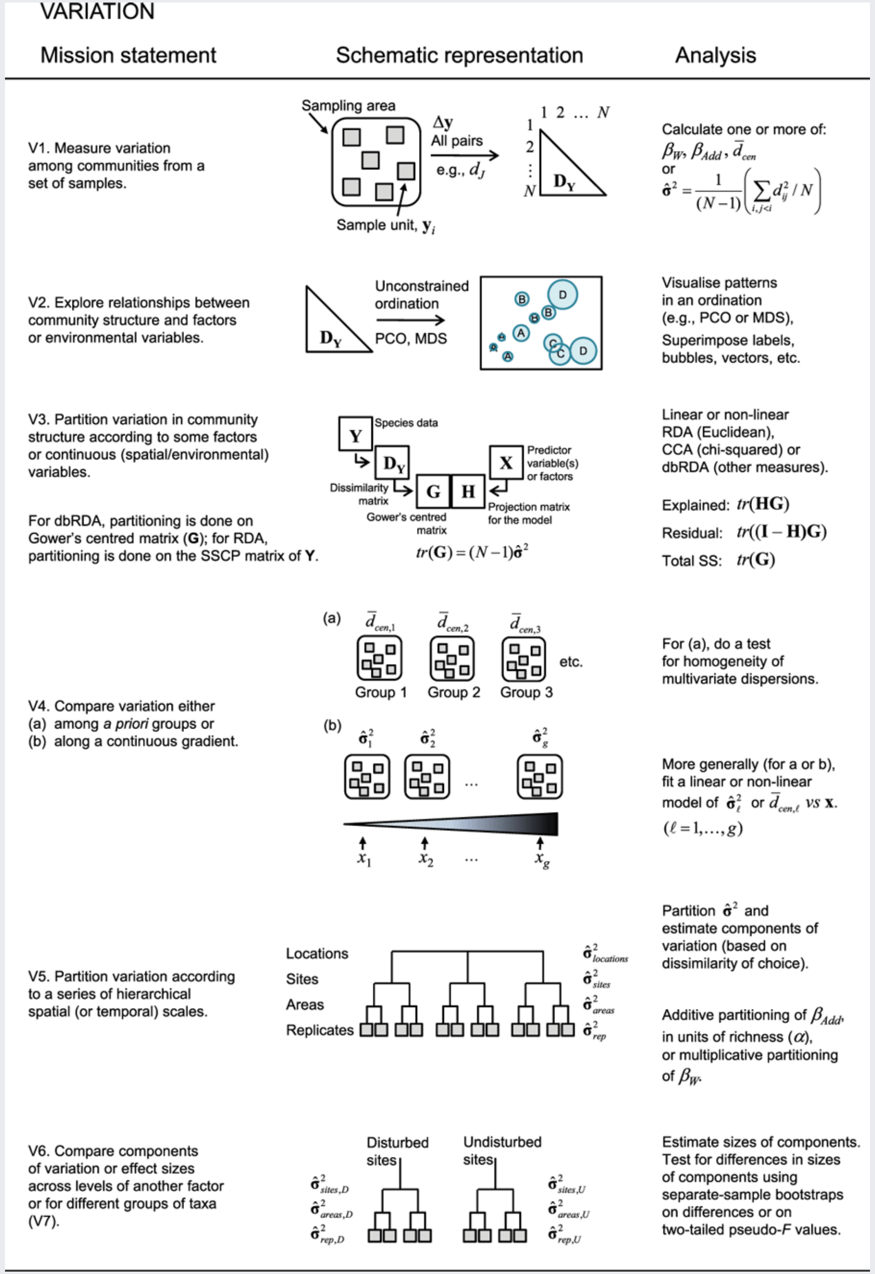




Eudicots of the Baetic mountains of Andalusia, Spain (Molina-Venegas et al. 2015)



Metric	Taxa	Temperature	Lithology	Geographical distance
CBD	All	45.5***	3.7**	8.3**
CBD	Endemic	7.2**	14.3***	27.2***



"Variation" applications

Typically explores the amount of variation in community composition among sample units across one or more groups (e.g. taxa), sometimes trying to partition the drivers of variation among factors (e.g. experimental treatments), spatial scales or environmental variables.

\(\Delta\)y = change in community composition

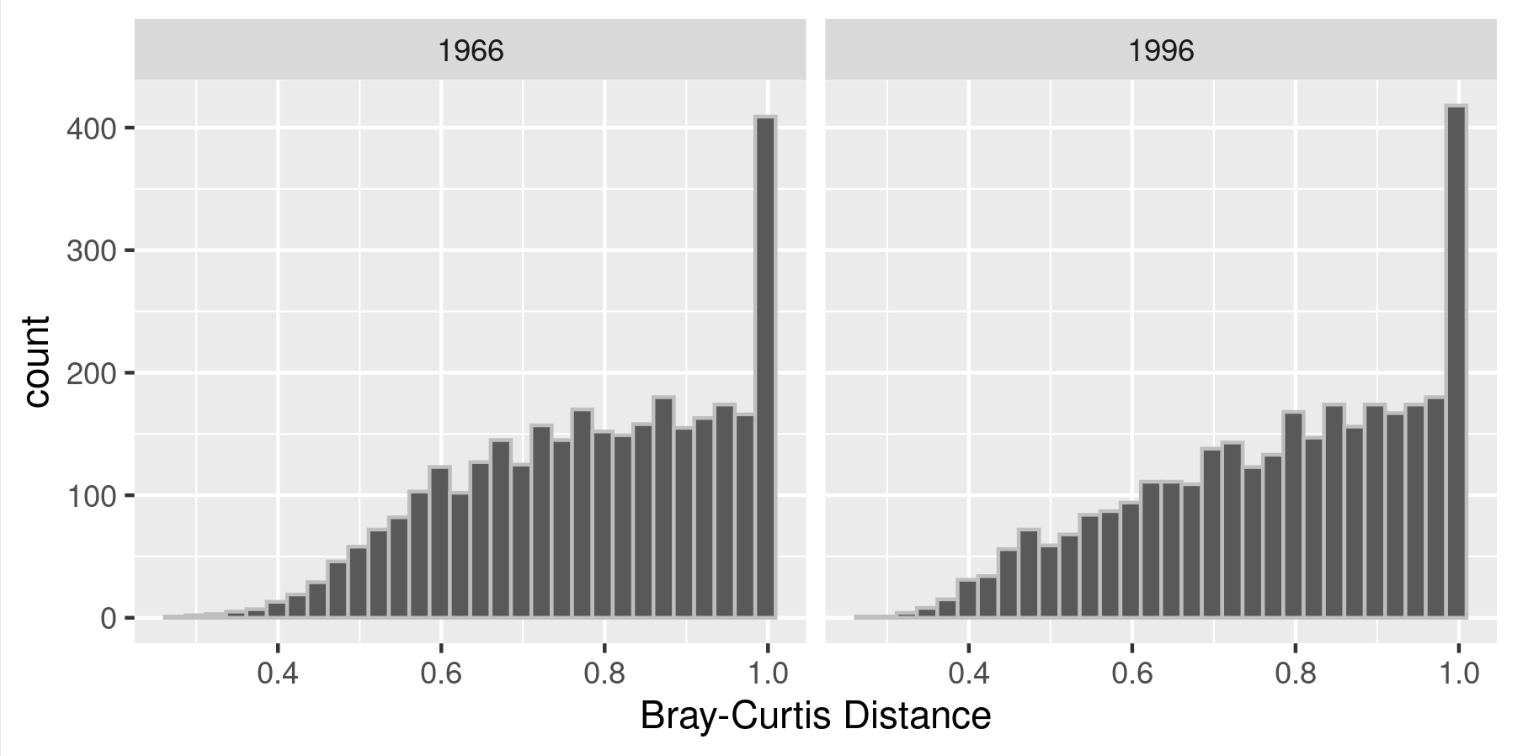
\(\hat{\sigma}\)^2 = variation in community structure among sample units

\(\bar{d}\)$_{cen}$ = average distance-to-centroid of all sample units

figure from Anderson et al. 2011

"Variation" examples

Exploring variation among samples from one or more surveys or datasets

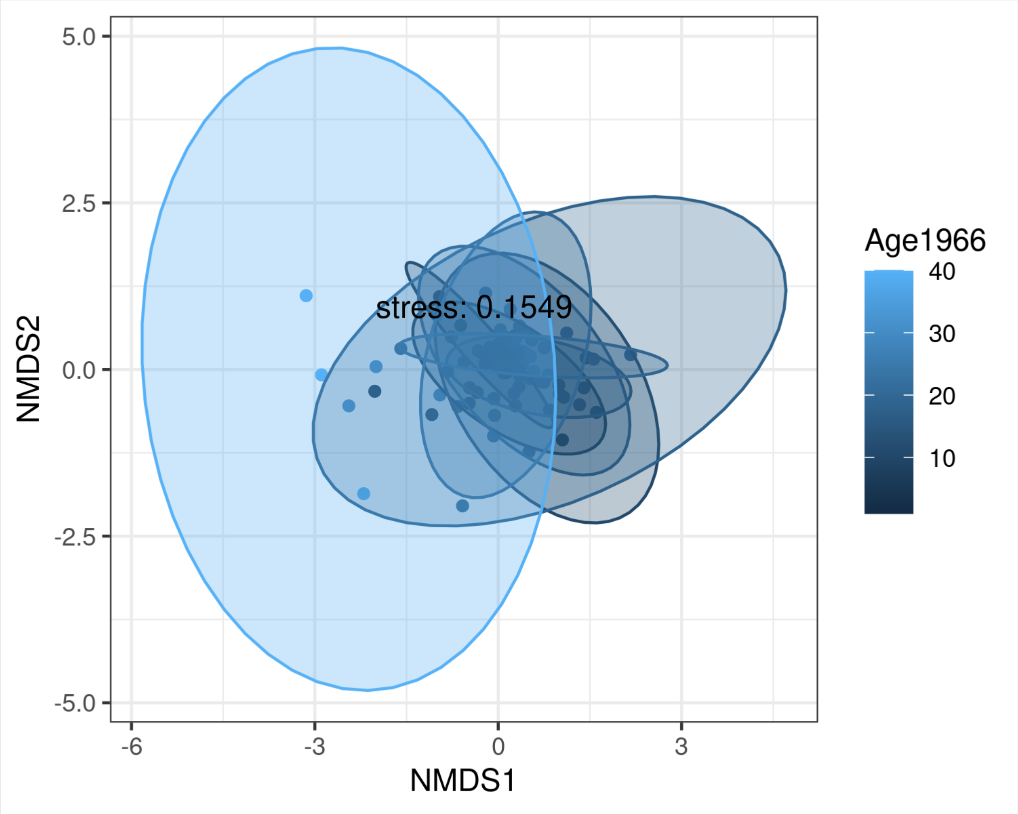


Average turnover between plots: 1966 = 0.784; 1996 = 0.780

"Variation" examples

Variation among communities in relation to an environmental variable

Community similarity in relation to age since last fire

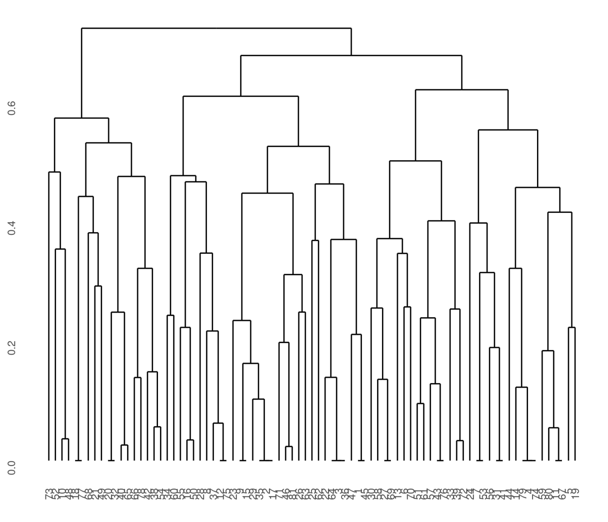


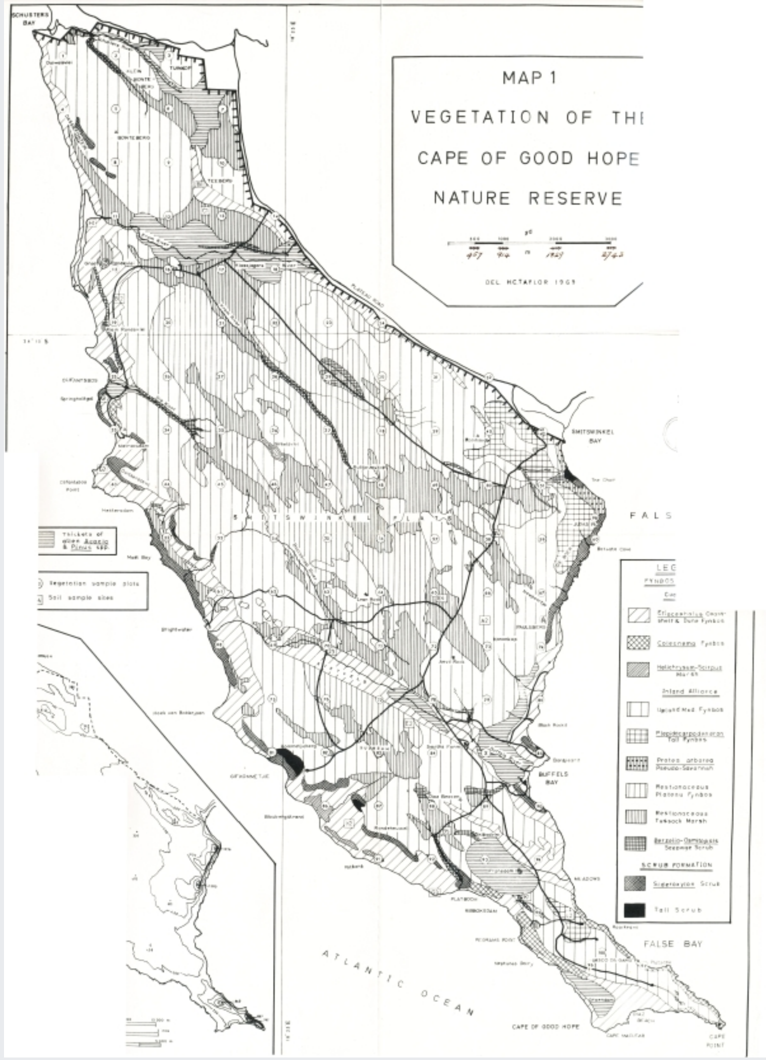
Data from Slingsby et al. 2017

"Variation" examples

Grouping samples by compositional similarity

e.g. used to identify distinct vegetation communities





Data from Slingsby et al. 2017

Map from Taylor 1983

Take-home

> *"Plurality in the concept of \(\beta\) diversity can yield important ecological insights when navigated well. By knowing the properties of the measures being used and applying more than one, the underlying ecological structures in the data generating patterns in \(\beta\) diversity can be revealed…"* - Anderson et al. 2011
>
> *"This applies to most measures of diversity…"* - Slingsby 2022

References

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Thanks!

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The chakra comes from remark.js, **knitr**, and R Markdown.