6. The Assembly of Diversity

Local Processes

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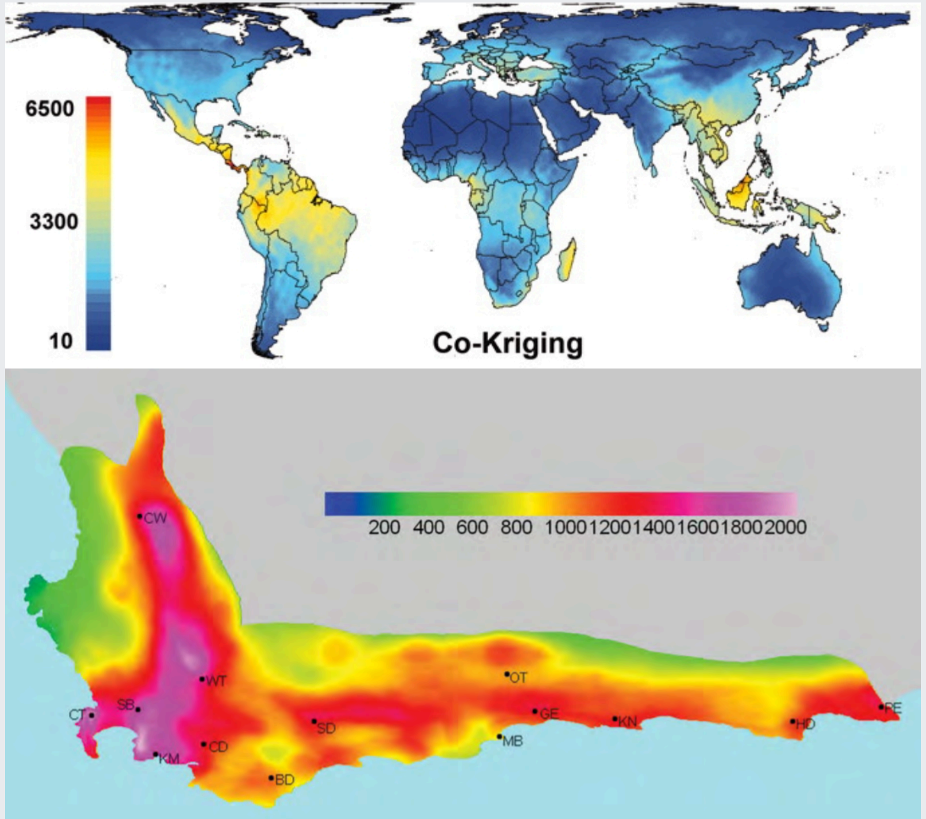
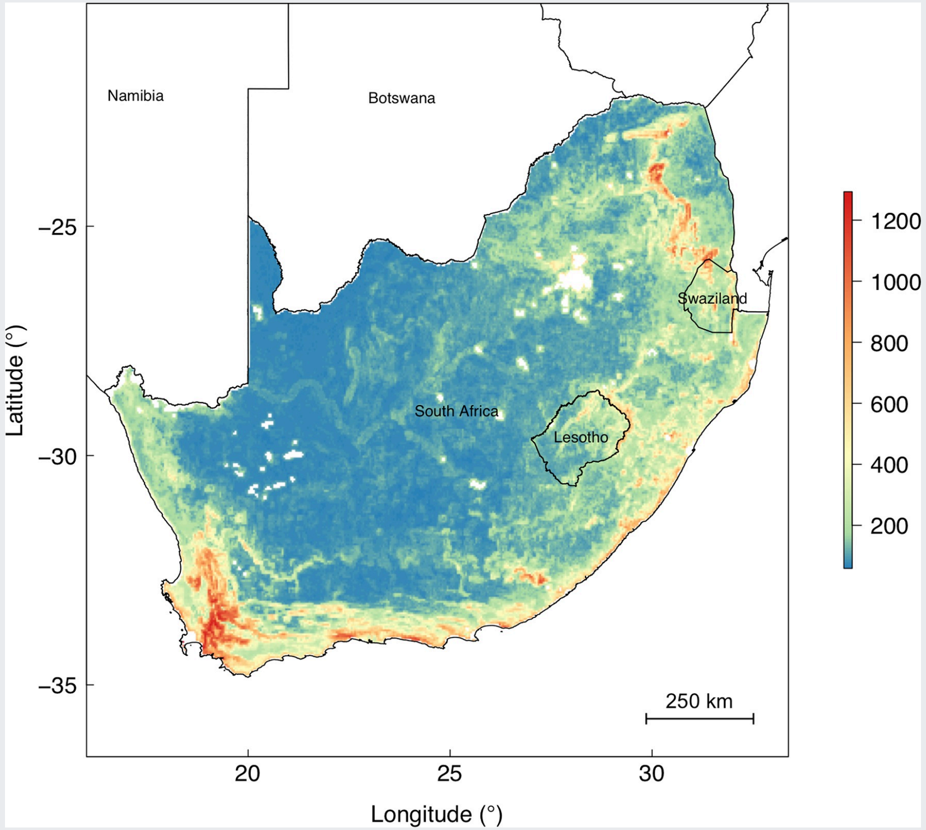
Diversity is not distributed evenly...



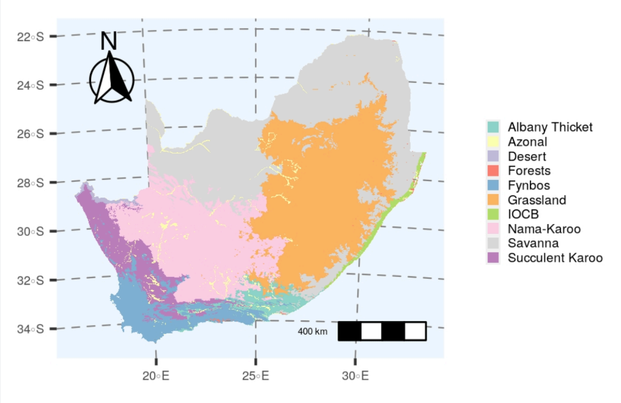
Kreft and Jetz 2007; Freiberg and Manning 2013

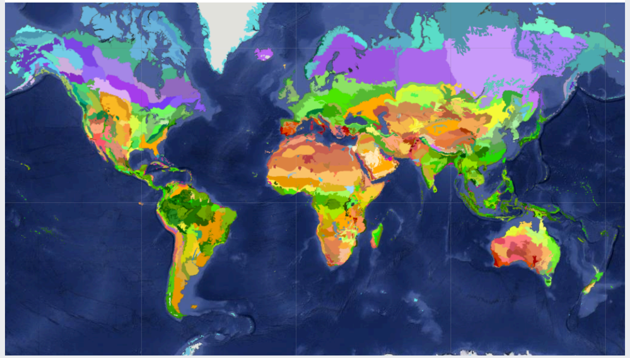


Cramer and Verboom 2017

What determines the distribution and abundance of biodiversity?

And how do these processes vary with spatial and temporal scale?



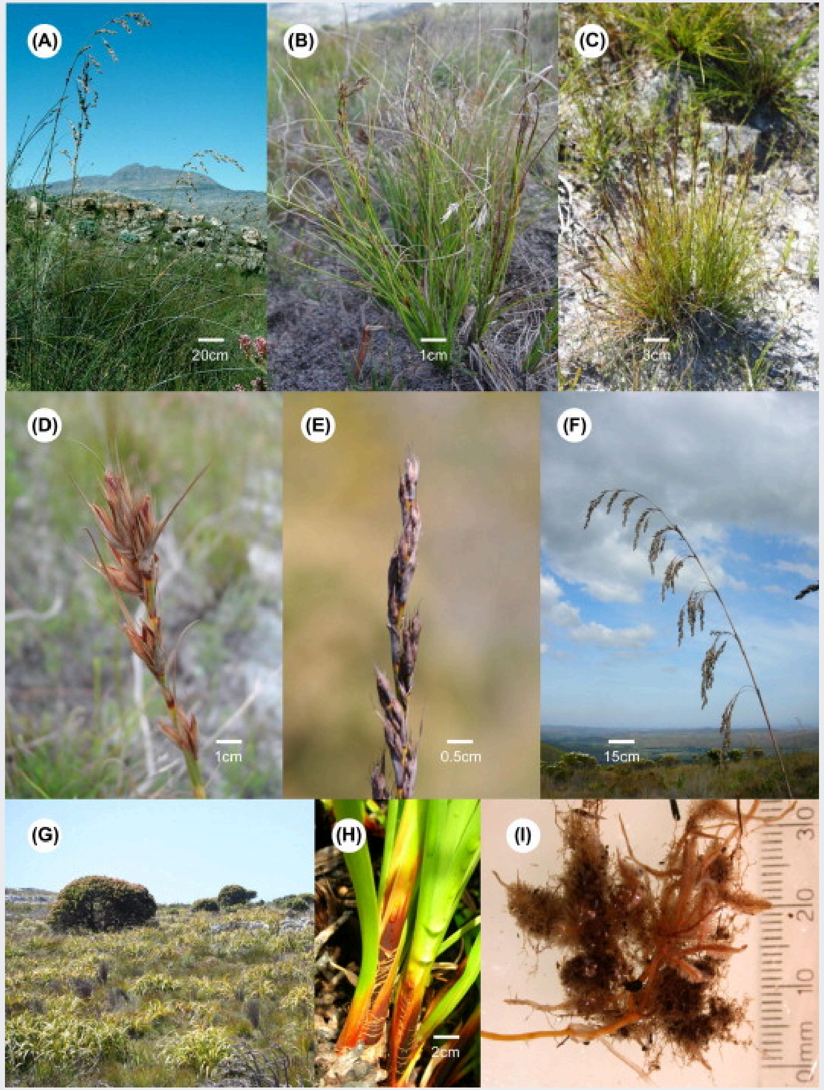


Niche theory

The niche is a multidimensional description of a species resource needs, habitat requirements, environmental tolerances and interactions[1]

- i.e. a particular set of abiotic (light, water, nutrient, shelter, etc) and biotic conditions (predators, prey, pathogens, mutualists (e.g. mycorrhizae, pollinators), competitors, etc)
- often explored by looking at where species occur in the environment, or by looking at their traits, assuming these reflect resource use strategies

[1]*In simplified terms* **(there are a few definitions)**



Using the Cape sedge genus *Tetraria* as an example

Slingsby 2011, Slingsby et al. 2014

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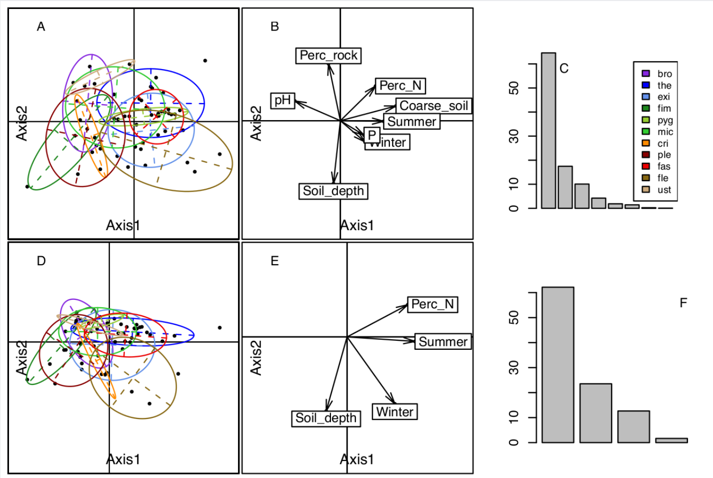
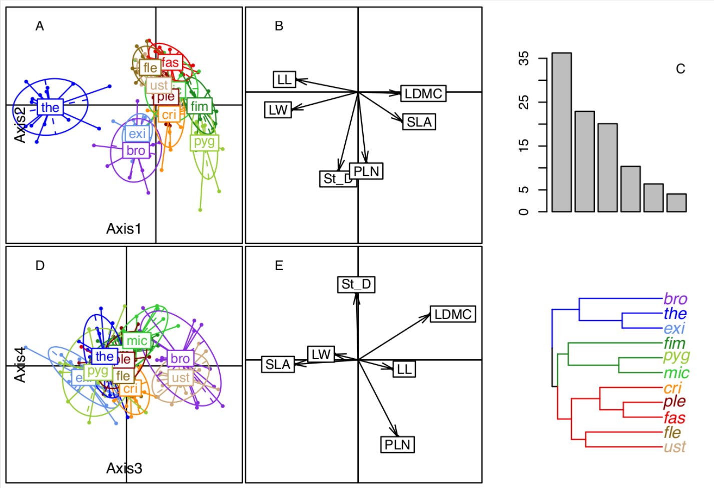


Environmental space

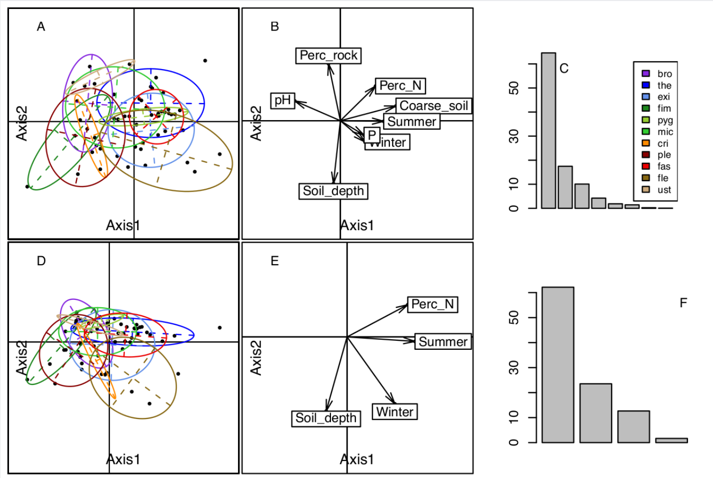


Trait space

Niche theory

Niche theory predicts local deterministic processes like habitat filtering, competition, facilitation, etc.

- These processes influence the co-occurrence/coexistence, trait/functional similarity and relatedness of species
- Thus influencing various forms of diversity (species, functional, phylogenetic)



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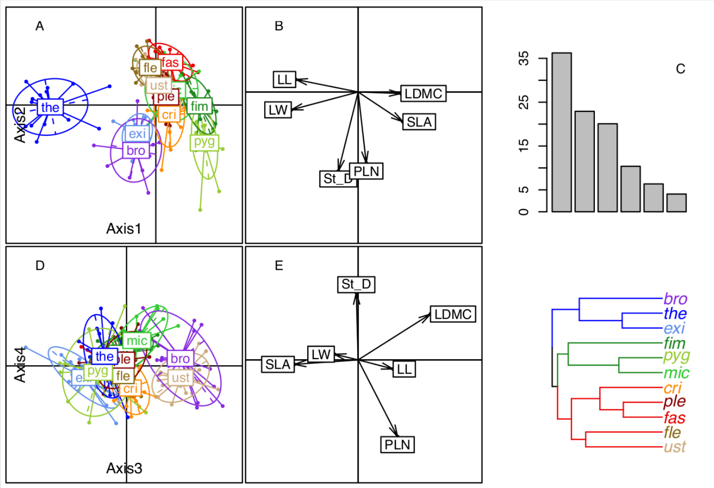


Trait space

Using the Cape sedge genus *Tetraria* as an example

Community assembly processes: local scale

Habitat filtering (or ecological sorting)

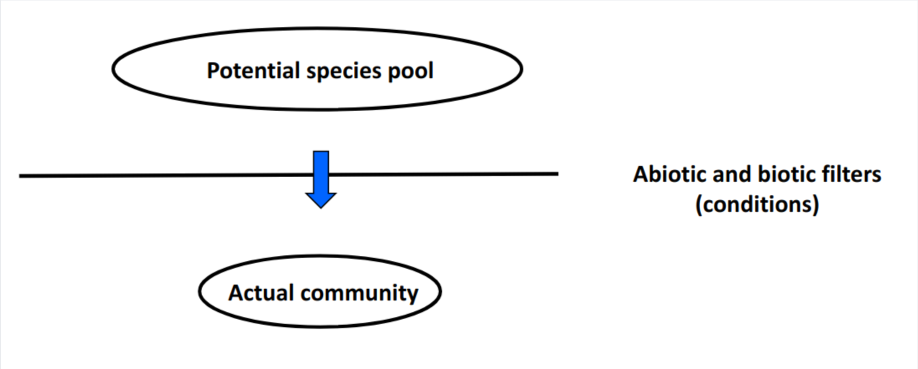
Hypothesis:

- species with similar resource requirements (or stress tolerance) will be sorted into the same environments

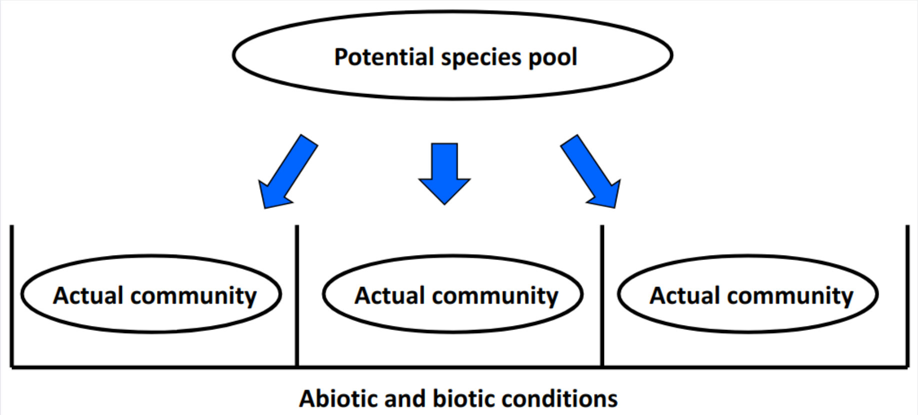
Predictions:

- co-occurring species should be more functionally ***similar*** than you'd expect by chance
- functionally similar species should co-occur ***more*** often than you'd expect by chance

Habitat filtering



Ecological sorting



Community assembly processes: local scale

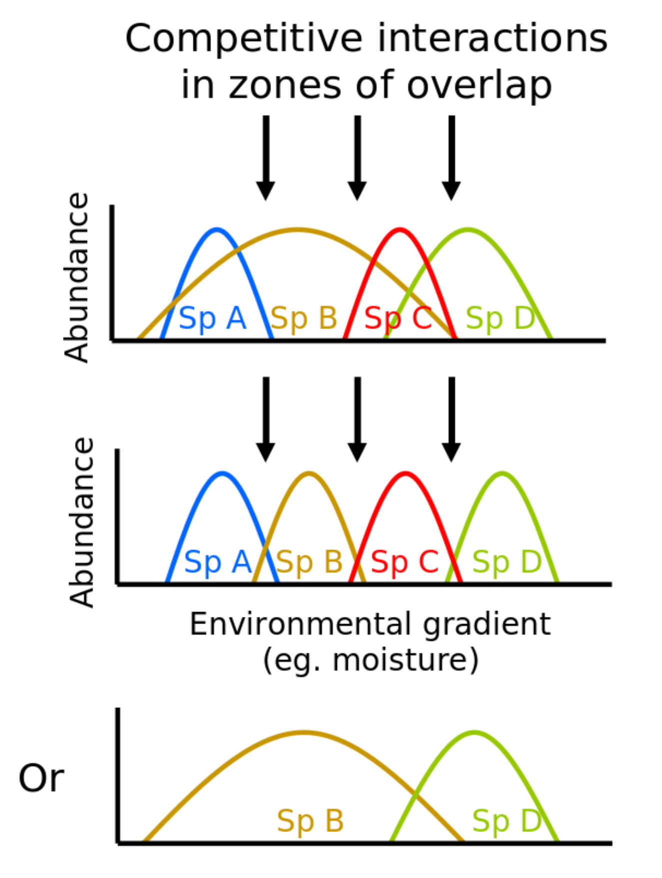
Limiting similarity **and** ***Competitive exclusion***

Hypothesis:

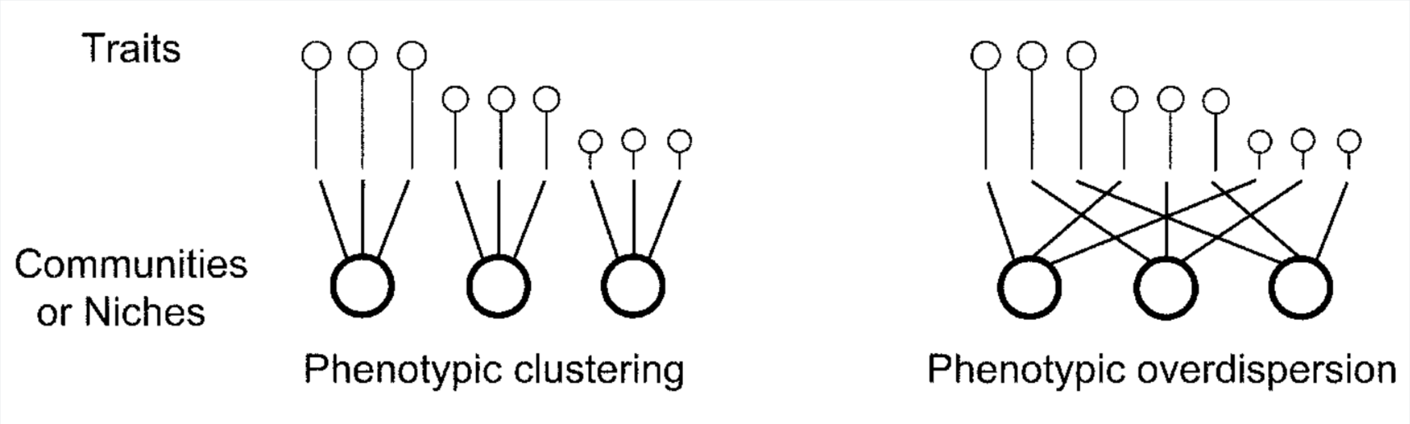
- species competing for the same resources cannot stably coexist, because the stronger competitors will exclude the others

Predictions:

- co-occurring species should be more functionally ***different*** than you'd expect by chance
- functionally similar species should co-occur ***less*** often than you'd expect by chance



We now have contrasting predictions!



Functional clustering (low Functional Diversity) = habitat filtering

Functional evenness/overdispersion (high Functional Diversity) = competition

Let's test them with null models...?

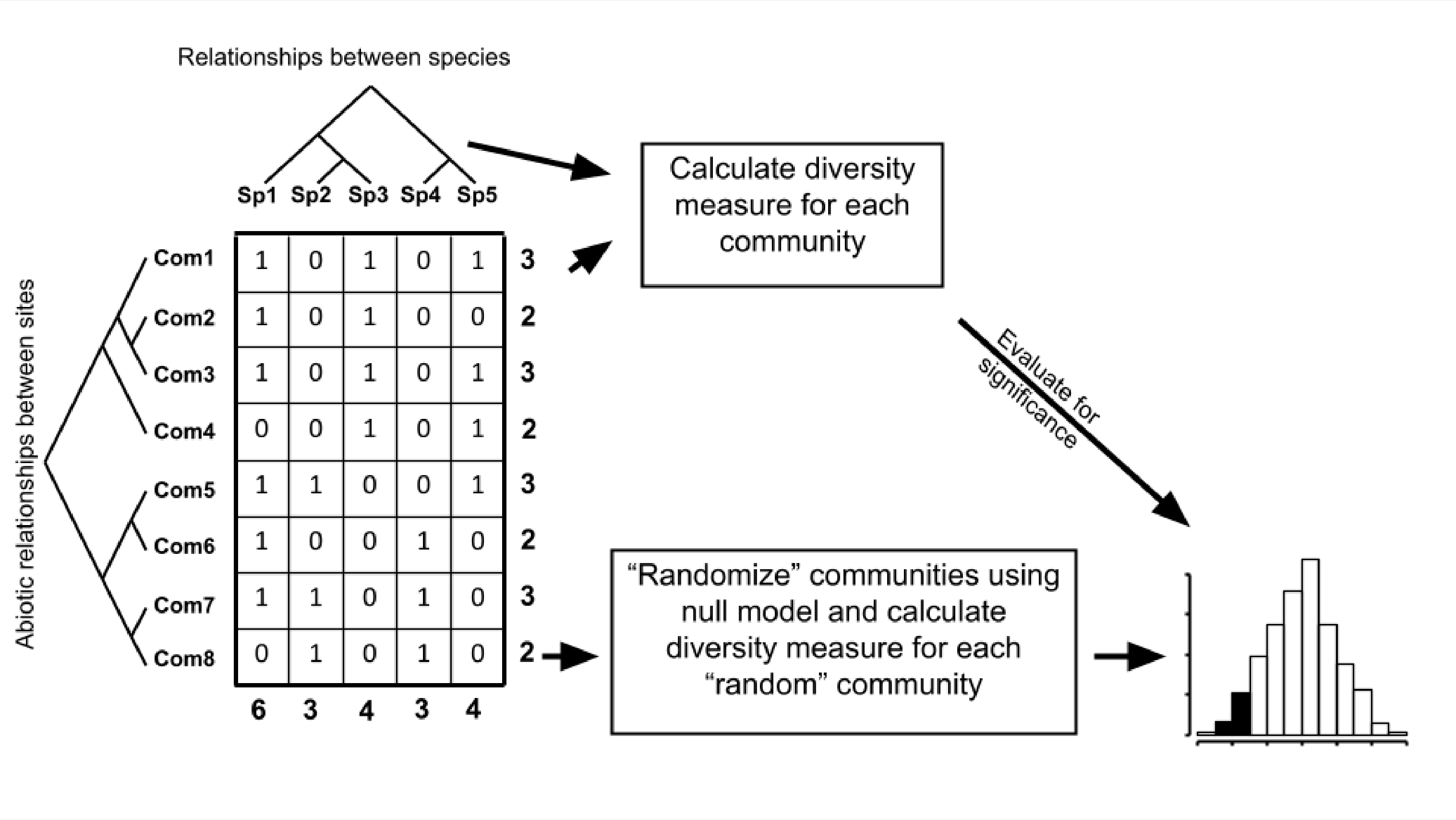


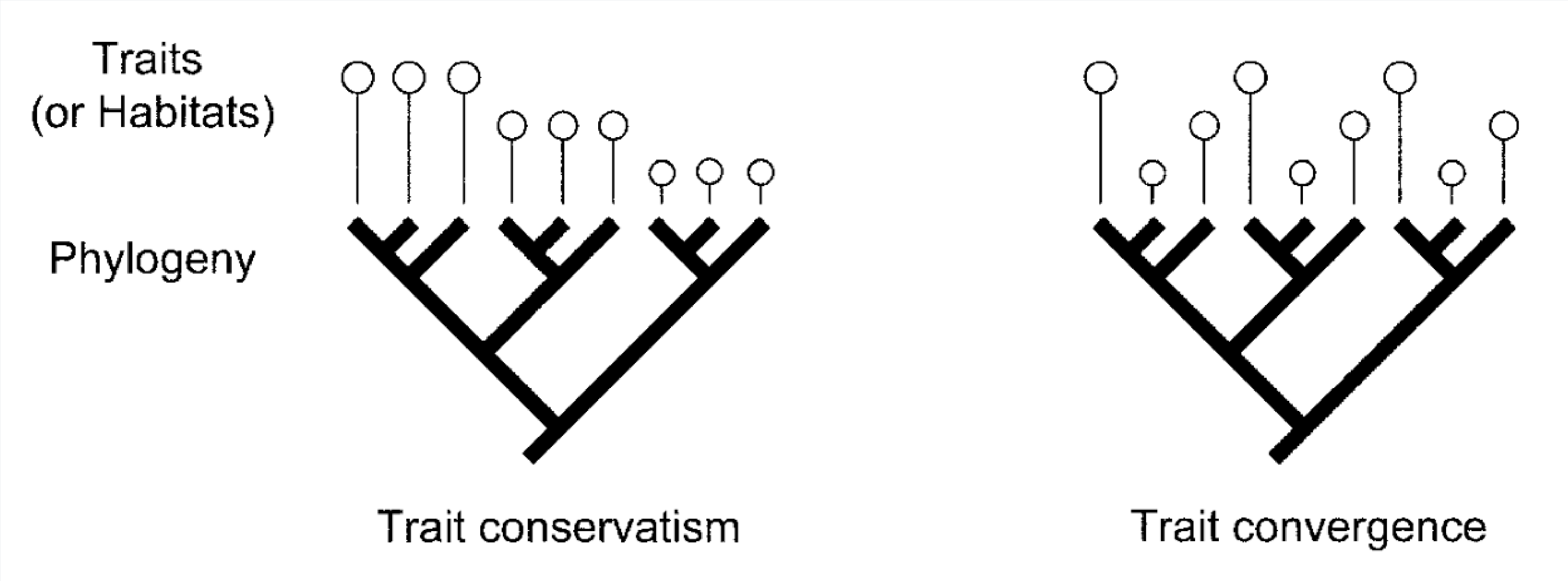
figure from Slingsby 2011, PhD

But wait!

There are other processes at play that can affect the outcomes…

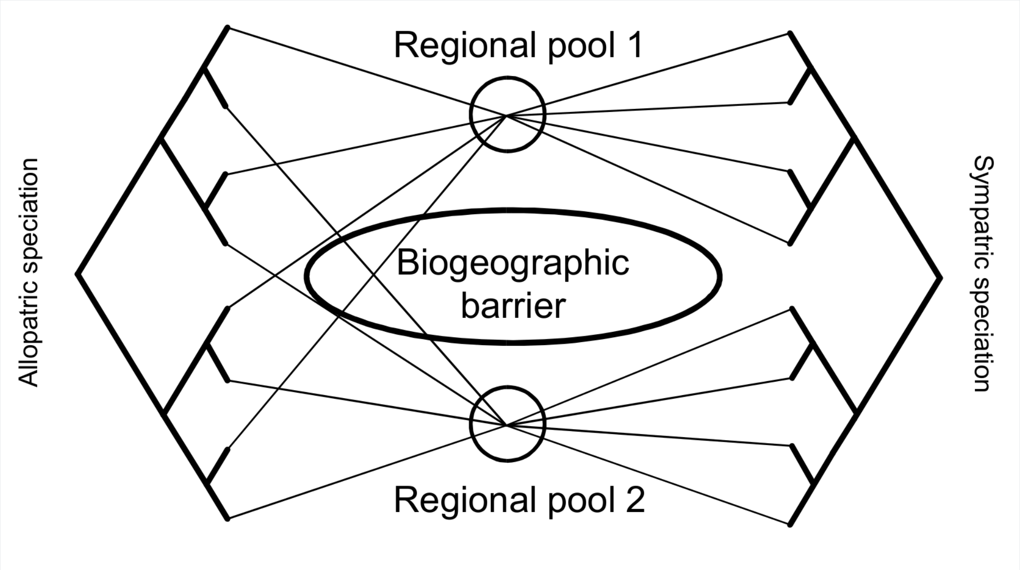
Especially when we expand the spatial and temporal scale…

Recall that traits are often constrained by phylogeny



Some degree of trait conservatism is the norm...

Mode of speciation



> Closely-related species tend to be similar, because they share a common ancestor (phylogenetic signal and niche conservatism)

Where functional similarity reflects phylogeny:

- **Sympatric speciation** (in situ speciation) = phylogenetic and functional clustering
- **Allopatric speciation** (speciation via dispersal, isolation and drift) = phylogenetic and functional evenness/overdispersion

i.e. the mode of speciation can create the same pattern as competition or habitat filtering…

Community assembly processes

Vary with spatial scale

- competition or facilitation operates between neighbouring individuals
- environmental filtering operates at a range of scales (climate > soils > microsite, etc)
- biogeographic processes (speciation, extinction, vicariance, dispersal) operate across large extents

Vary with temporal scale

- pollination, seed dispersal, herbivory, predation, etc can be near-instantaneous
- speciation or trait evolution occur over long periods of time (typically >100s of generations)

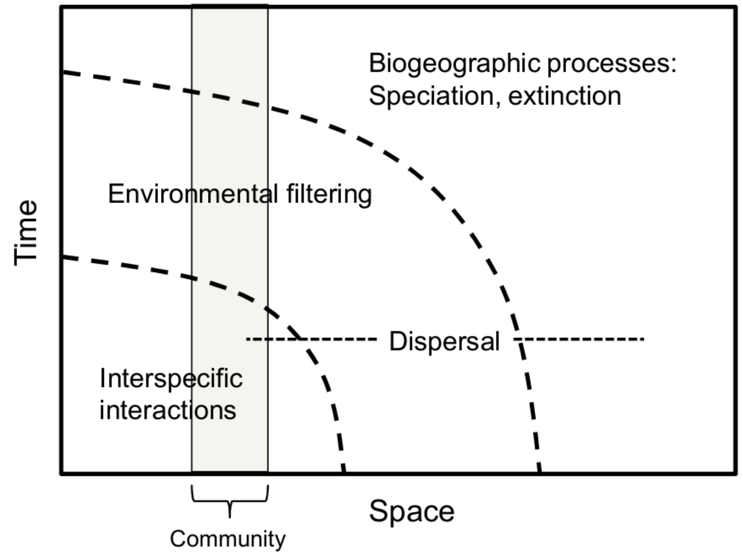
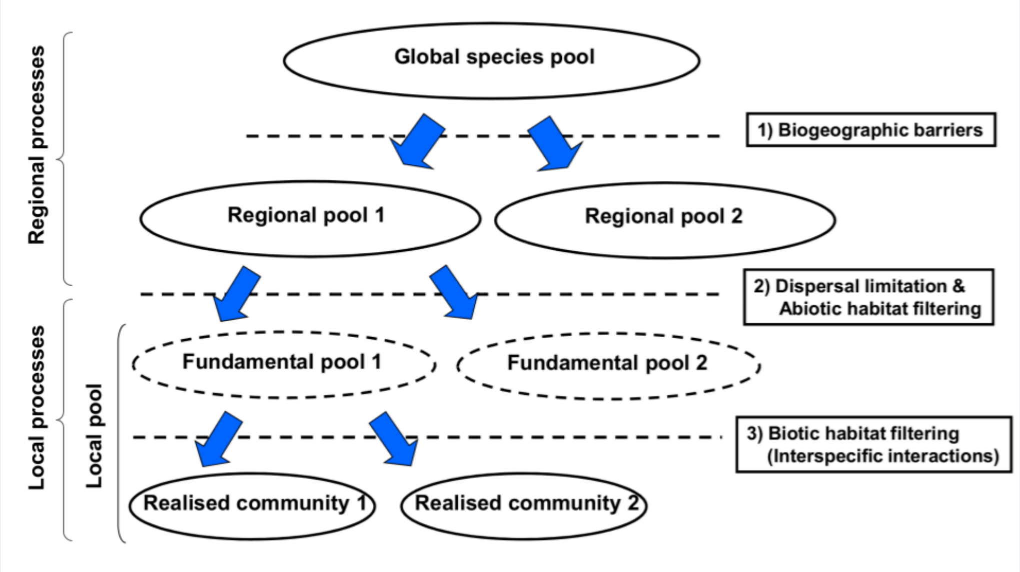


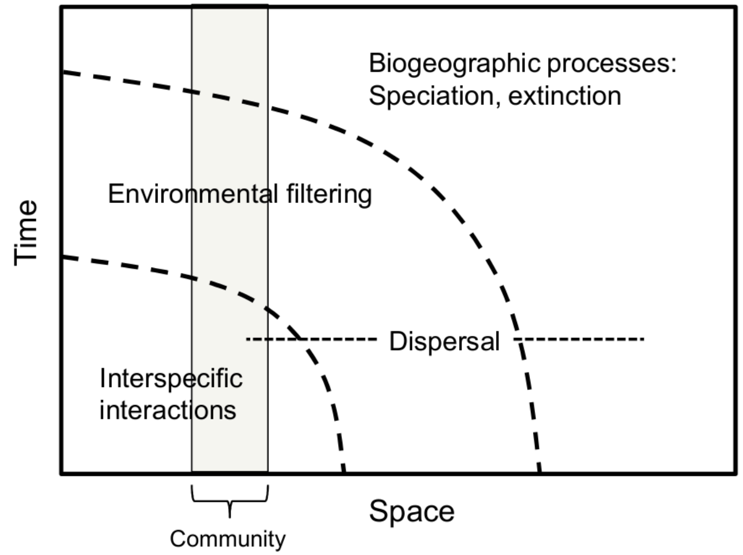
Figure 1.1: Processes that affect the assembly of communities at different spatial and temporal scales. Finer-scale processes are nested within broader scale processes. Adapted from Weiher & Keddy (1999), Cavender-Bares *et al.* (2009).

Assembly of species pools across scales

Community assembly can be thought of as the successive filtering of species pools descending in spatial (and temporal) scale from global to local



We often split it into **regional** versus **local** processes



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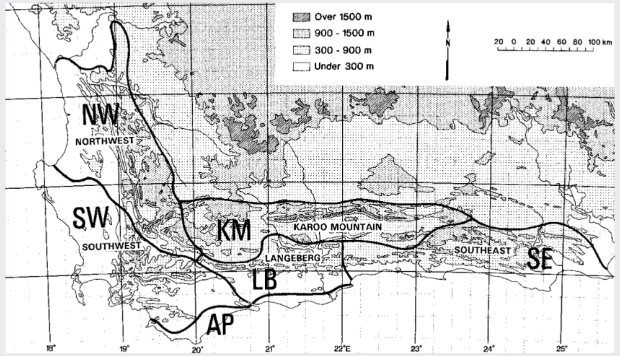
Local vs Regional scale processes

The diversity of local biological communities is a balance of regional and local processes - Ricklefs 1987

Regional scale



- speciation
- extinction
- dispersal

The phytogeographic centres of the CFR (Manning and Goldblatt 2012)

Local scale

- environmental filtering
- interspecific interactions (competition, predation, pathogens, mutualisms)
- adaptation
- stochastic variation

Dominant processes vary with the relative scale of your species pools

Community assembly can be thought of as the successive filtering of species pools descending in spatial (and temporal) scale from global to local.

The outcomes of your analyses can depend in the scale at which your communities and regional species pools are defined, because different processes are more or less important at different scales.

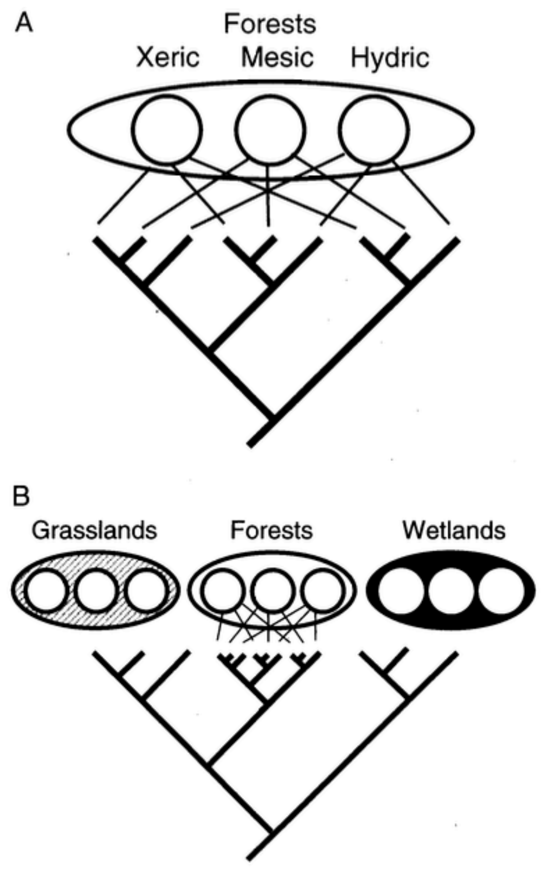
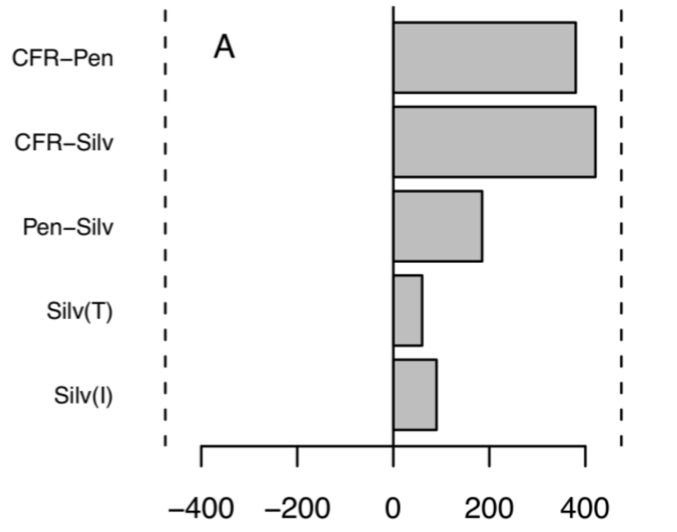


FIG. 4. The phylogenetic structure of communities is dependent on the scale at which they are defined. Apparent overdispersion within forest communities (A), for example, can appear as clustering when grassland and wetland communities are included (B). At the same time, phylogenetic structure also depends on the phylogenetic scale or taxonomic inclusiveness. Apparent overdispersion within a lineage is more likely to appear as a dominant pattern of clustering when the analysis includes many lineages.

Cavender-Bares et al. 2006

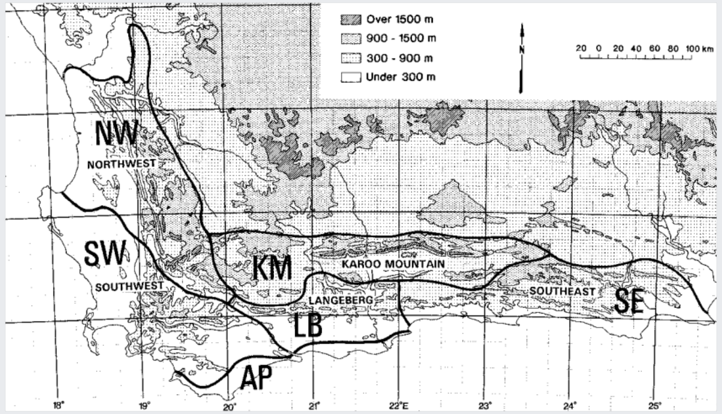
An example of inferring the assembly of *Tetraria* communities



Three scales (pools):

- Global = Cape Floristic Region (CFR)
- Regional = Cape Peninsula (Pen)
- Local = plots within Silvermine (Silv)

Slingsby 2011, PhD



The set of species on the Peninsula and in Silvermine are more dissimilar than expected relative to the CFR - ***suggests allopatric speciation***

Species at Silvermine more dissimilar than expected relative to the Peninsula - ***suggests competition***

Species within plots are more dissimilar than expected relative to all plots - ***suggests competition***

Take-home

Patterns of diversity are determined by assembly processes that operate from local to regional scales

While the distinction between local and regional processes is somewhat arbitrary (or even artificial), local scale processes are typically ecological, operating over the near term, while regional processes are typically evolutionary, operating over longer periods of time

One method for investigating these processes by exploring functional and phylogenetic diversity at different scales (species pools), often in combination with null models

References

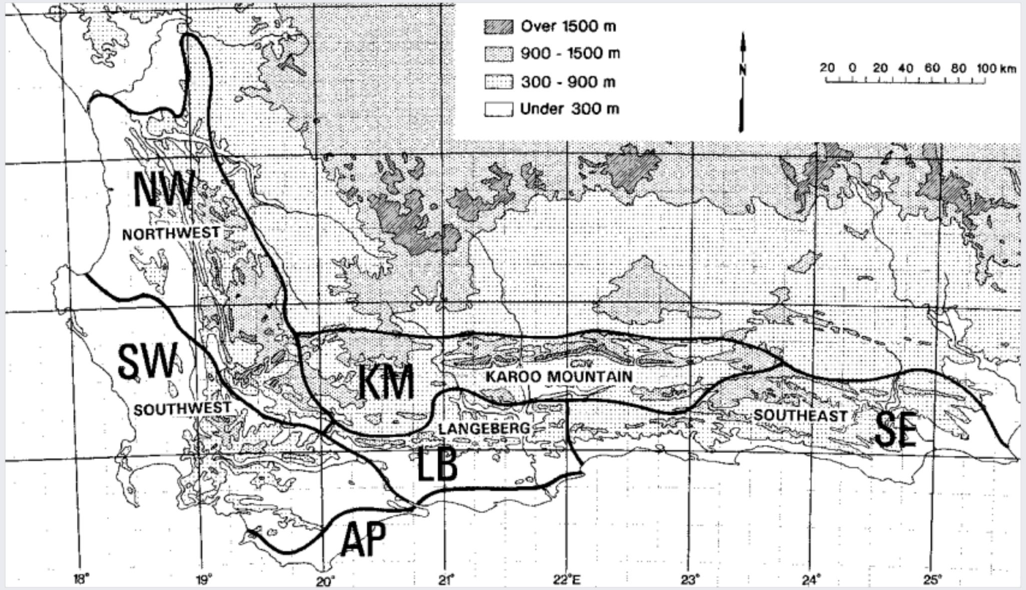
Gotelli, N. J. and R. K. Colwell (2001). "Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness". In: *Ecology letters* 4.4, pp. 379-391. ISSN: 1461-023X, 1461-0248. DOI: 10.1046/j.1461-0248.2001.00230.x.

Slingsby, J. A., C. Merow, M. Aiello-Lammens, et al. (2017). "Intensifying postfire weather and biological invasion drive species loss in a Mediterranean-type biodiversity hotspot". En. In: *Proceedings of the National Academy of Sciences of the United States of America* 114.18, pp. 4697-4702. ISSN: 0027-8424, 1091-6490. DOI: 10.1073/pnas.1619014114.

Whittaker, R. H. (1972). "Evolution and measurement of species diversity". En. In: *Taxon* 21.2-3, pp. 213-251. ISSN: 0040-0262, 1996-8175. DOI: 10.2307/1218190.

An example of regional species pools from the Cape...

The phytogeographic centres of the CFR



Data and figure from Manning and Goldblatt 2012

Region	Area (1000 km2)	Number of species	Endemism (%)
Cape Floristic Region	90.8	9381	68,3
NW	23.1	4259	25,5
SW	21.3	4864	30,5
AP	4.2	1530	13,6
KM	16.8	2336	15,3
LB	8.1	2457	11,3
SE	17.3	2938	9,4
Cape Peninsula	4.7	2250	7,5

The Cape phytochoria make good *Regional species pools*, but the regional pools used can be defined differently depending on the purposes of the study and if it can be justified, e.g. the Cape Peninsula is a relatively isolated biogeographic unit

CFR effectively = *Global species pool*, because of such high endemism

Thanks!

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gadenbuie/xaringanthemer

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