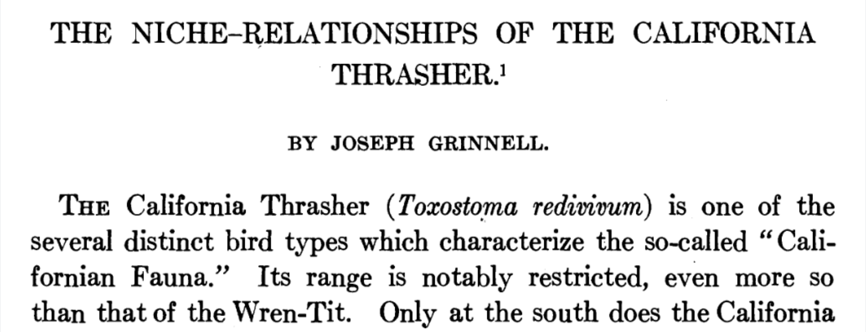
7. Trait-based Ecology

Jasper Slingsby, BIO2014F

2024-04-26

Why haven't we been talking about traits?

The Grinnellian Niche


THE NICHE-RELATIONSHIPS OF THE CALIFORNIA THRASHER.[1]

BY JOSEPH GRINNELL.

The California Thrasher (*Toxostoma redivivum*) is one of the several distinct bird types which characterize the so-called "Californian Fauna." Its range is notably restricted, even more so than that of the Wren-Tit. Only at the south does the California

> *"An explanation of this restricted distribution is probably to be found in the* ***close adjustment of the bird in various physiological and psychological respects*** *to a narrow range of environmental conditions. The nature of these critical conditions is to be learned through an examination of the bird's habitat."*

Grinnell 1917

Photo: Leslie Cavaliere, iNaturalist

The Eltonian Niche

> *"what [it] is doing in its community,... its place in the* ***biotic*** *environment, its relations to food and enemies"* - **Elton 1927**
>
> *"used in ecology in the sense that we speak of trades or professions or jobs in a human community"* - **Elton 1933**

Focuses on the organism's role or **function** in the ecosystem, often in relation to trophic position (consumers, predators, etc) and **resource use**.

Often considers the **attributes or traits** of species that allow them to fulfill their role.

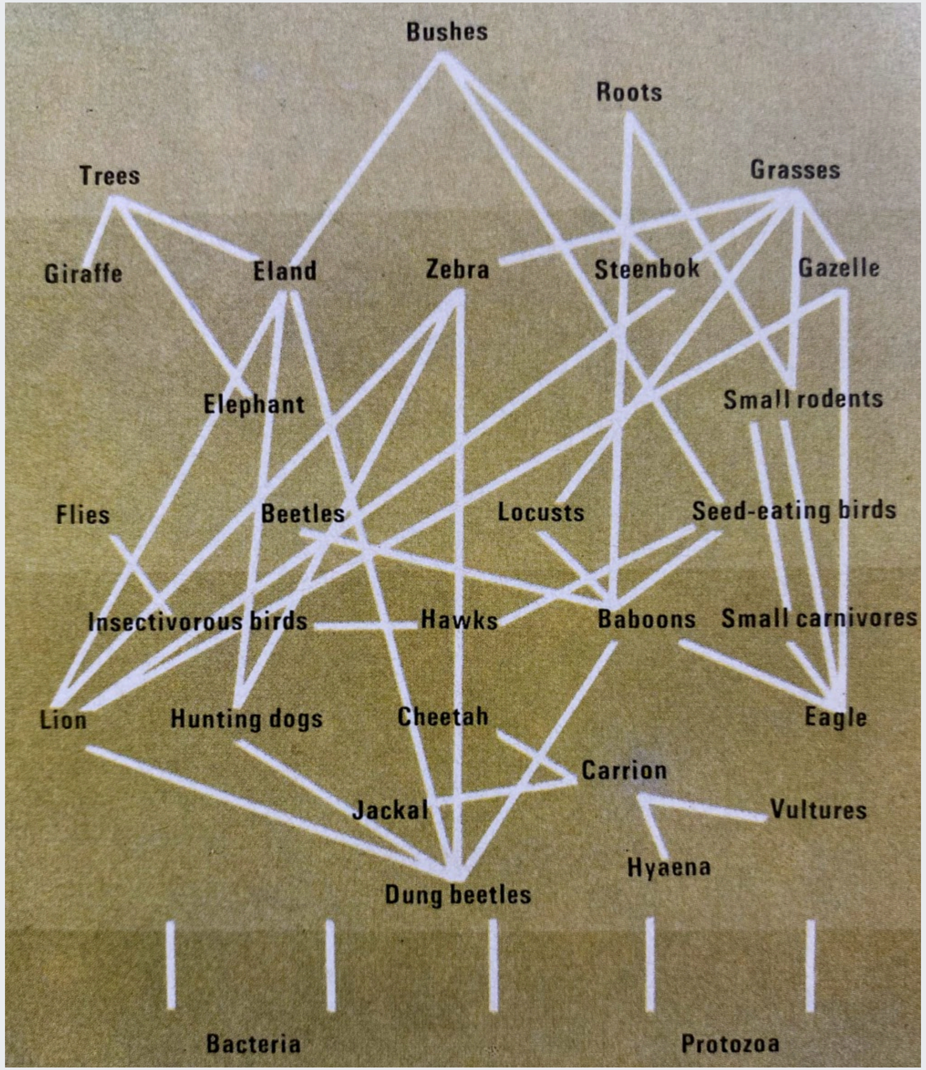


image: *The Atlas of World Wildlife* 1973

Eltonian Niche Traits

Honeycreepers evolved a range of bill forms in response to available food sources on the Hawaiian archipelago.

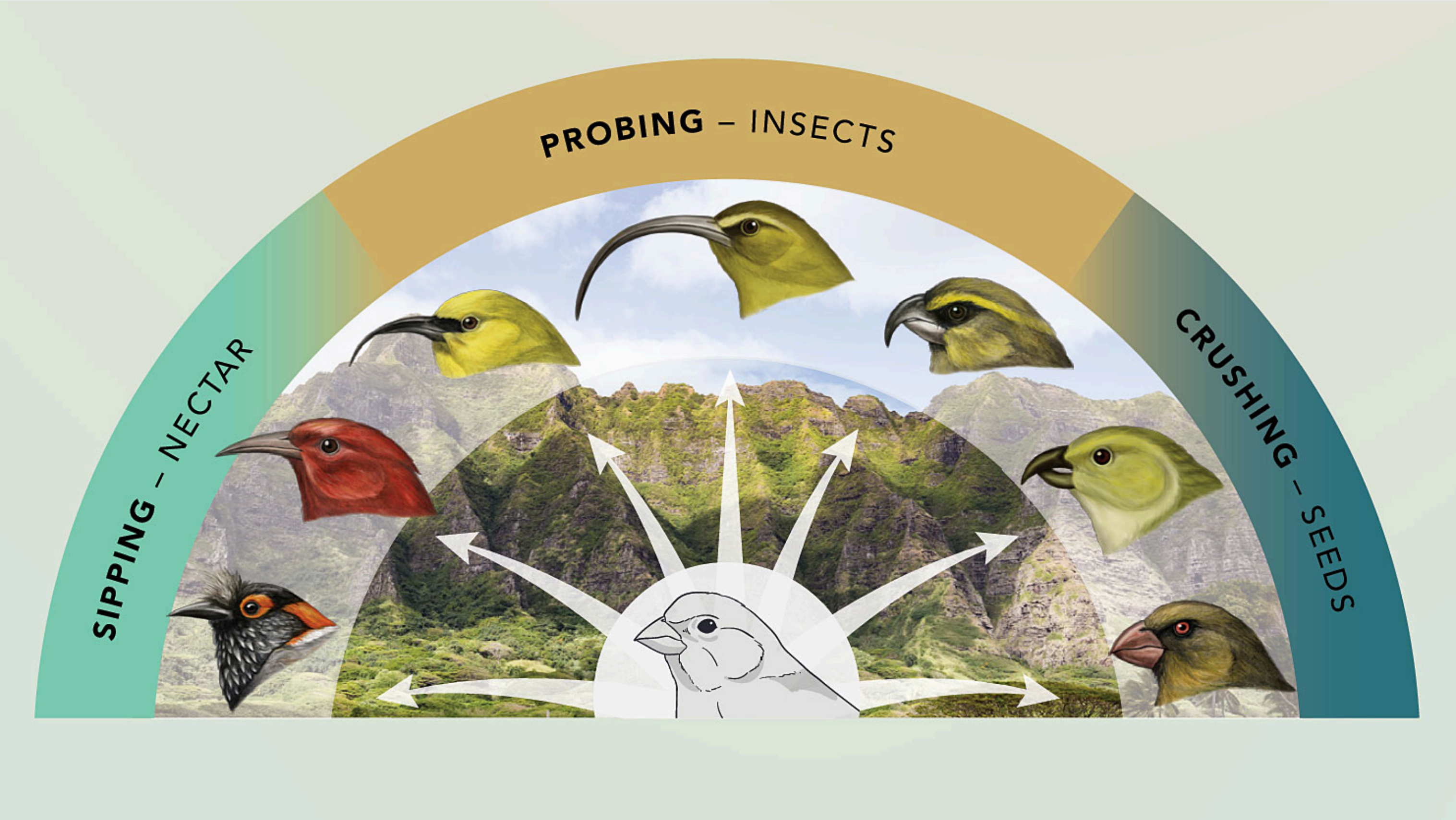


Illustration by Jillian Ditner, photo by Ashlyn Gehrett

Eltonian and Grinnellian Niche Traits?

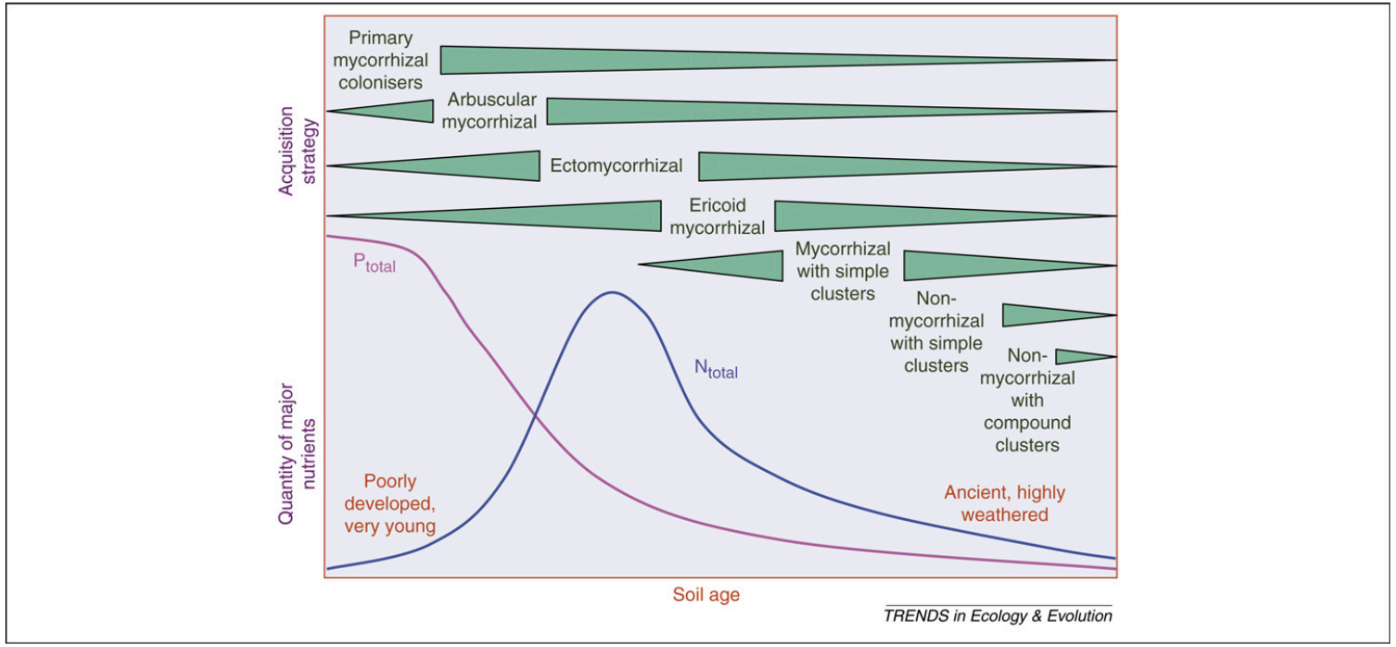
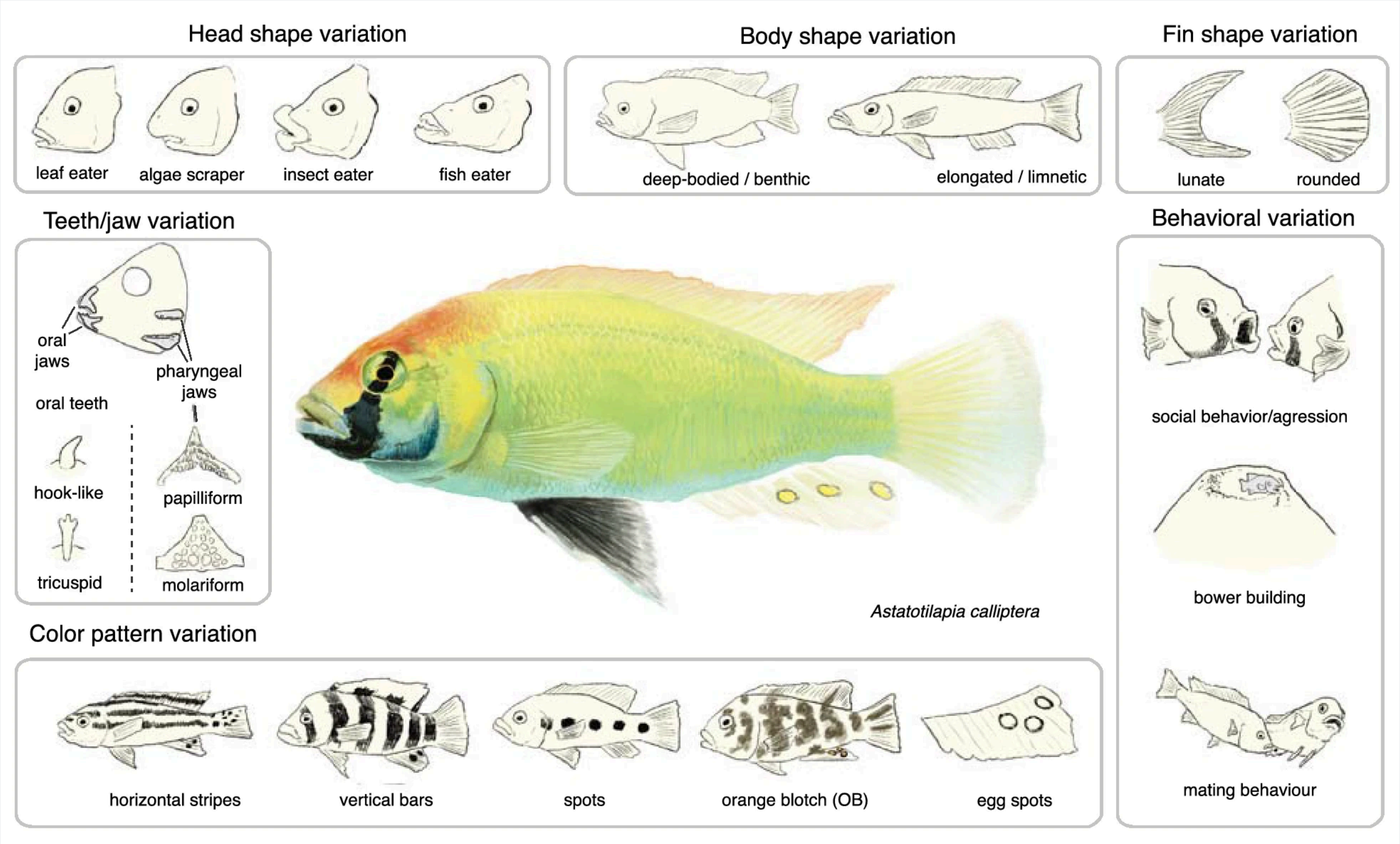


Figure 1. Changes in total soil P (purple) and N (blue) and in plant nutrient-acquisition strategies (green) as dependent on soil age, based on data in various studies [5,11,36]. 'Poorly developed, very young soils' refers to soils that result from recent volcanic eruptions; 'ancient, highly weathered soils' refers to soils that have been above sea level and have not been glaciated for millions of years. Although never becoming dominant in severely P-impoverished soils, some mycorrhizal species do co-occur with non-mycorrhizal cluster-bearing species. The highest and lowest total P levels in young and ancient soils are ~800 mg kg^{-1} soil and 30 mg kg^{-1} soil, respectively. Peak total N levels are 8 000 mg kg^{-1} soil, whereas total N levels in the very youngest soils shown here are <5 mg kg^{-1}. The width of the triangles referring to the different ecological strategies provides a (relative) measurement of the abundance of these strategies as dependent on soil age.

Plants have a range of nutrient-acquisition strategies that affect both their ability to compete for (or partition) nutrients and the soil environmental conditions where they are most likely to occur (**Lambers et al. 2008**).

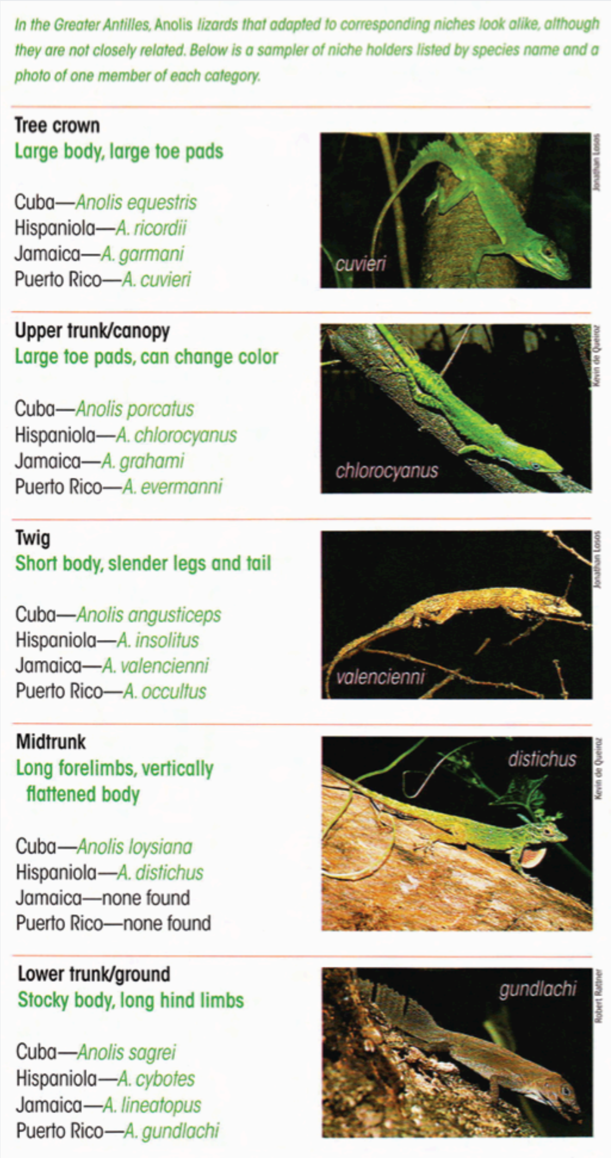
Eltonian and Grinnellian Niche Traits?



East African cichlid fishes have diverged in traits relating diet, mating behaviour, competition and habitat.
Santos et al. 2023

Grinnellian Niche Traits?

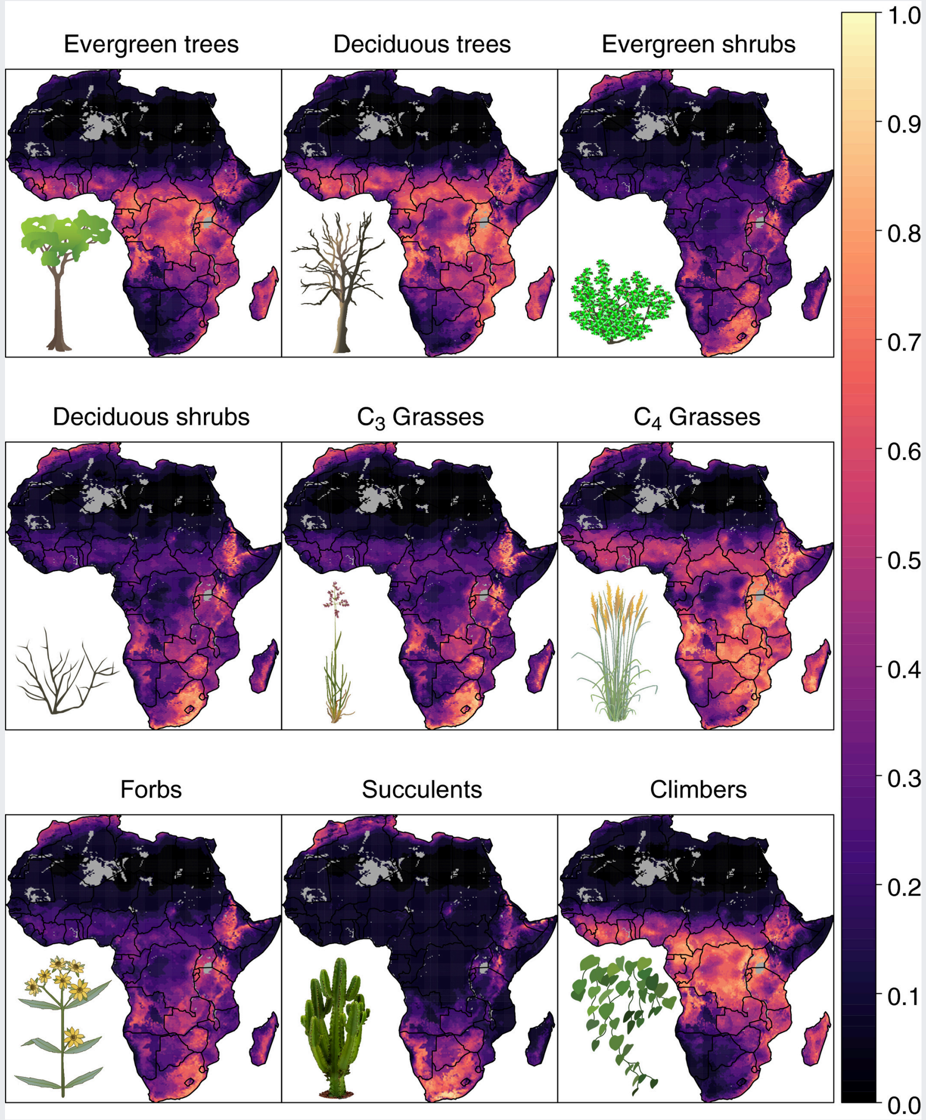
Not only have *Anolis* lizard species of the Greater Antilles specialised to use different parts of the trees they live in (niche partitioning), but these niches are filled by different species on each island and unrelated species have converged to similar morphology for each habitat type!



Losos and de Queiroz 1997

Grinnellian Niche Traits

There are clear climatic preferences among plant functional types in Africa.



Conradi et al. 2021

Opinion — TRENDS in Ecology and Evolution Vol.21 No.4 April 2006

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Rebuilding community ecology from functional traits

Brian J. McGill[1], Brian J. Enquist[2], Evan Weiher[3] and Mark Westoby[4]

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> *"...this can be achieved [,but] community ecology has lost its way by focusing on pairwise species interactions independent of the environment."*
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> [1.] *how the fundamental niche is governed by functional traits within the context of abiotic environmental gradients; and*
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> [2.] *how the interaction between traits and fundamental niches maps onto the realized niche in the context of a biotic interaction milieu.*
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> [1.] *how the fundamental niche is governed by functional traits within the context of abiotic environmental gradients; and* [**Traits and the Fundamental Niche**]
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Traits and the fundamental niche

Can traits be used to predict the fundamental niche of species?

Traits and the fundamental niche

An example from serotinous Cape Proteaceae…

RESEARCH PAPER

Global Ecology and Biogeography — A Journal of Macroecology
WILEY

Functional traits explain the Hutchinsonian niches of plant species

Martina Treurnicht[1,2,3] | Jörn Pagel[1] | Jeanne Tonnabel[4] | Karen J. Esler[2,5] | Jasper A. Slingsby[3,6] | Frank M. Schurr[1]

Related inter- and intraspecific variation in 11 functional traits to measures of the fundamental Hutchinsonian niches of 26 Proteaceae species in the Cape Floristic Region.

Treurnicht et al. 2020

image: Roets et al 2006

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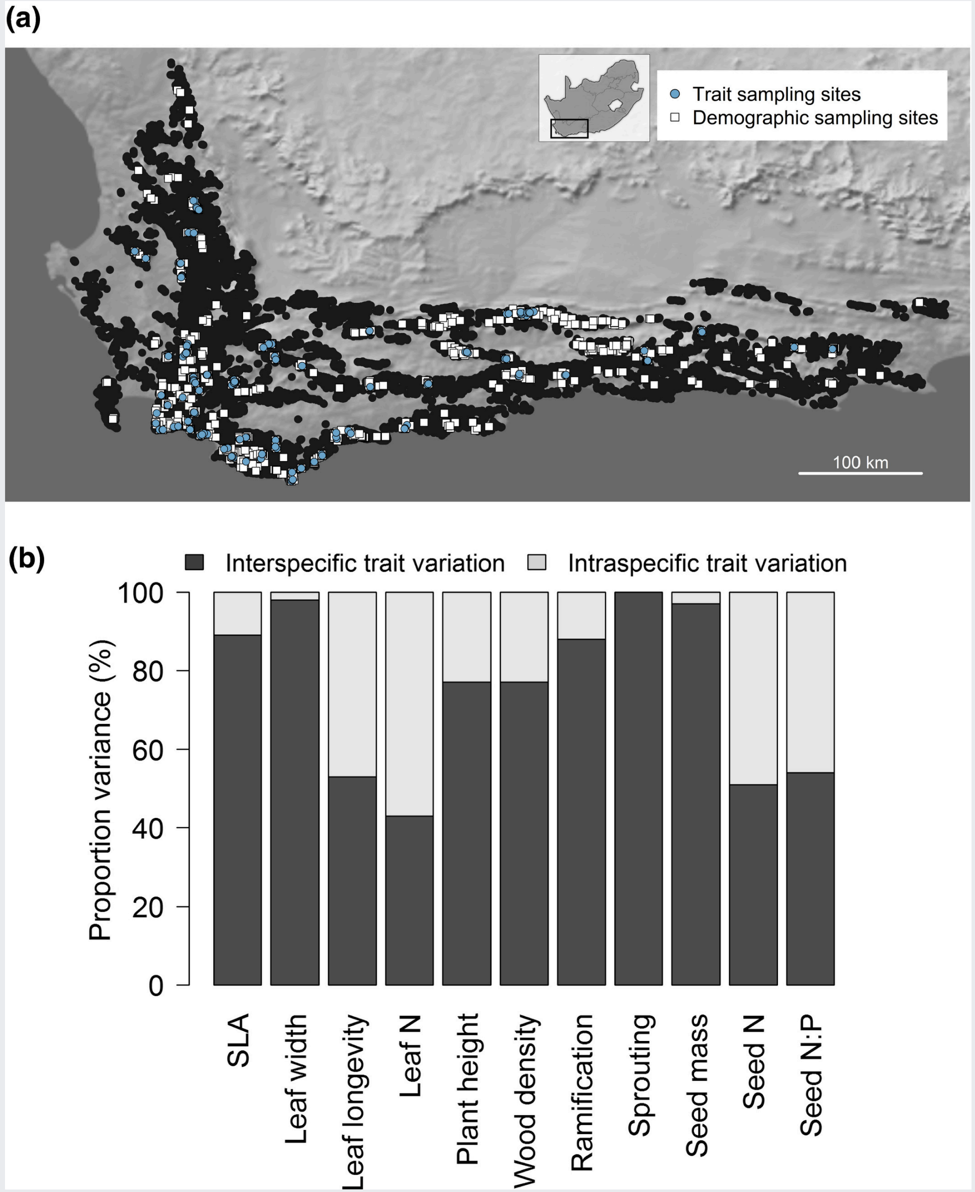
Sampled traits and demographic parameters (fecundity, recruitment and adult fire survival) for the 26 species from across their ranges.

Most of the variation in traits was between species, but some (e.g. leaf and seed N) showed high intraspecific variability.

Treurnicht et al. 2020



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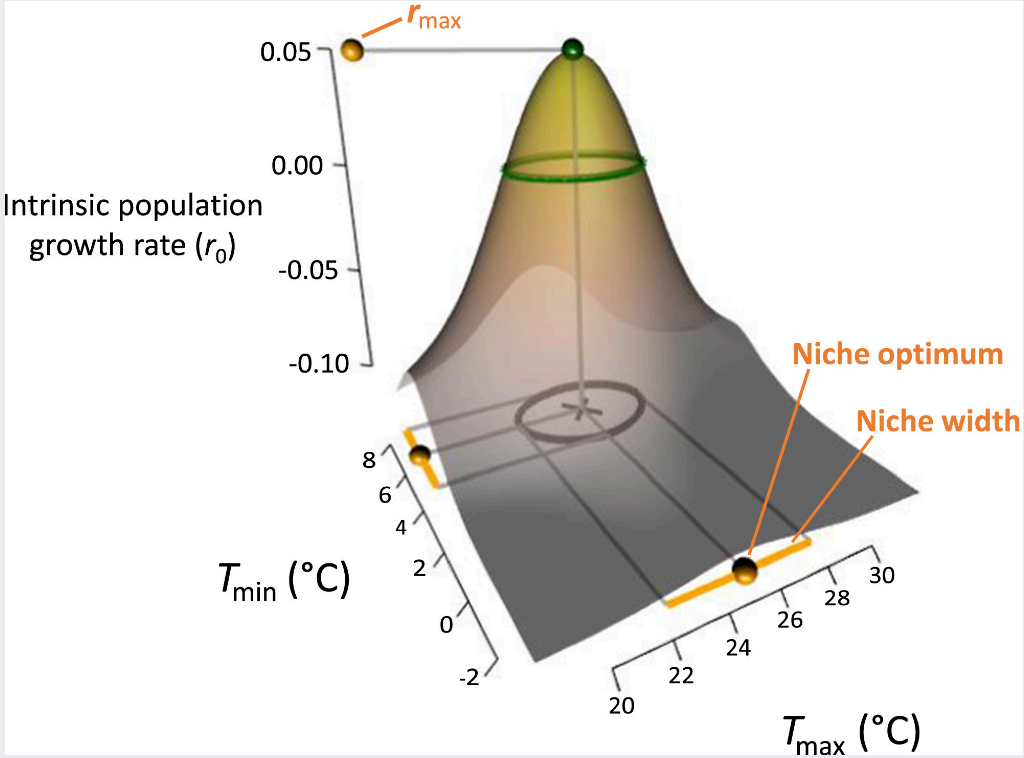

Built demographic models to estimate measures of the fundamental Hutchinsonian niche for the 26 species. These were the niche optimum and niche width for each of 5 environmental variables (aridity, minimum and maximum temperature, soil fertility and fire interval) and the r_{max} (which integrates across all variables).

Treurnicht et al. 2020

RESEARCH PAPER

Global Ecology and Biogeography — A Journal of Macroecology

WILEY

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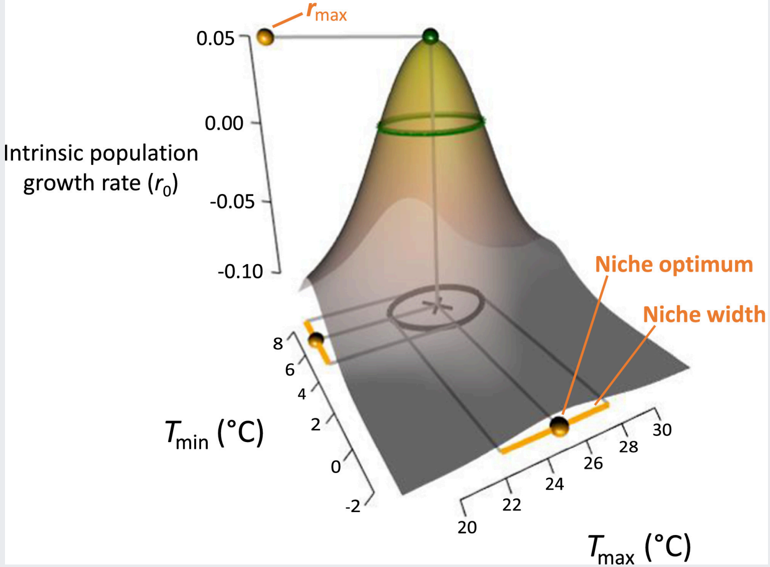
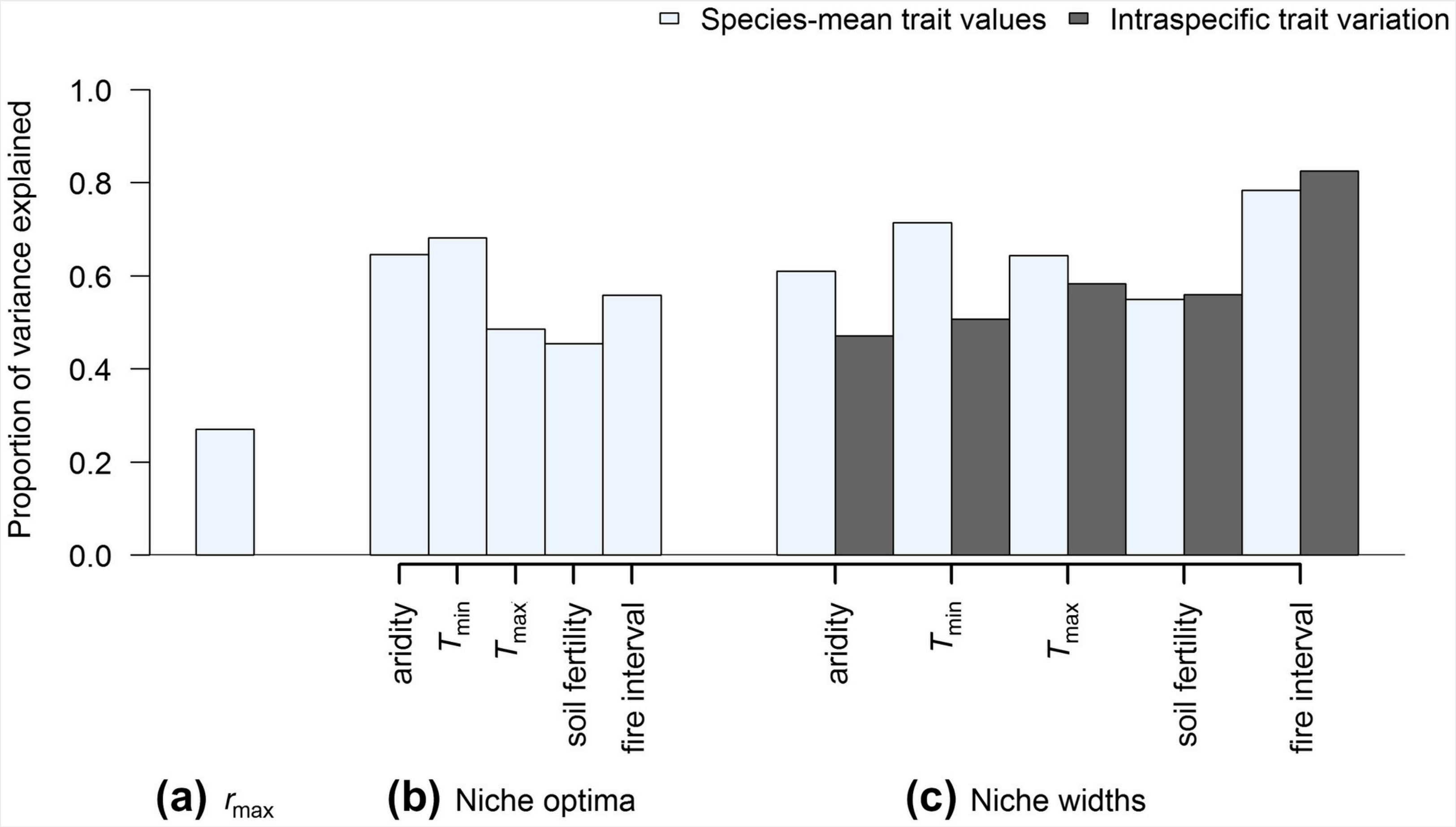
Built statistical models to predict the Hutchinsonian niche parameters as a function of the 11 functional traits.



Treurnicht et al. 2020

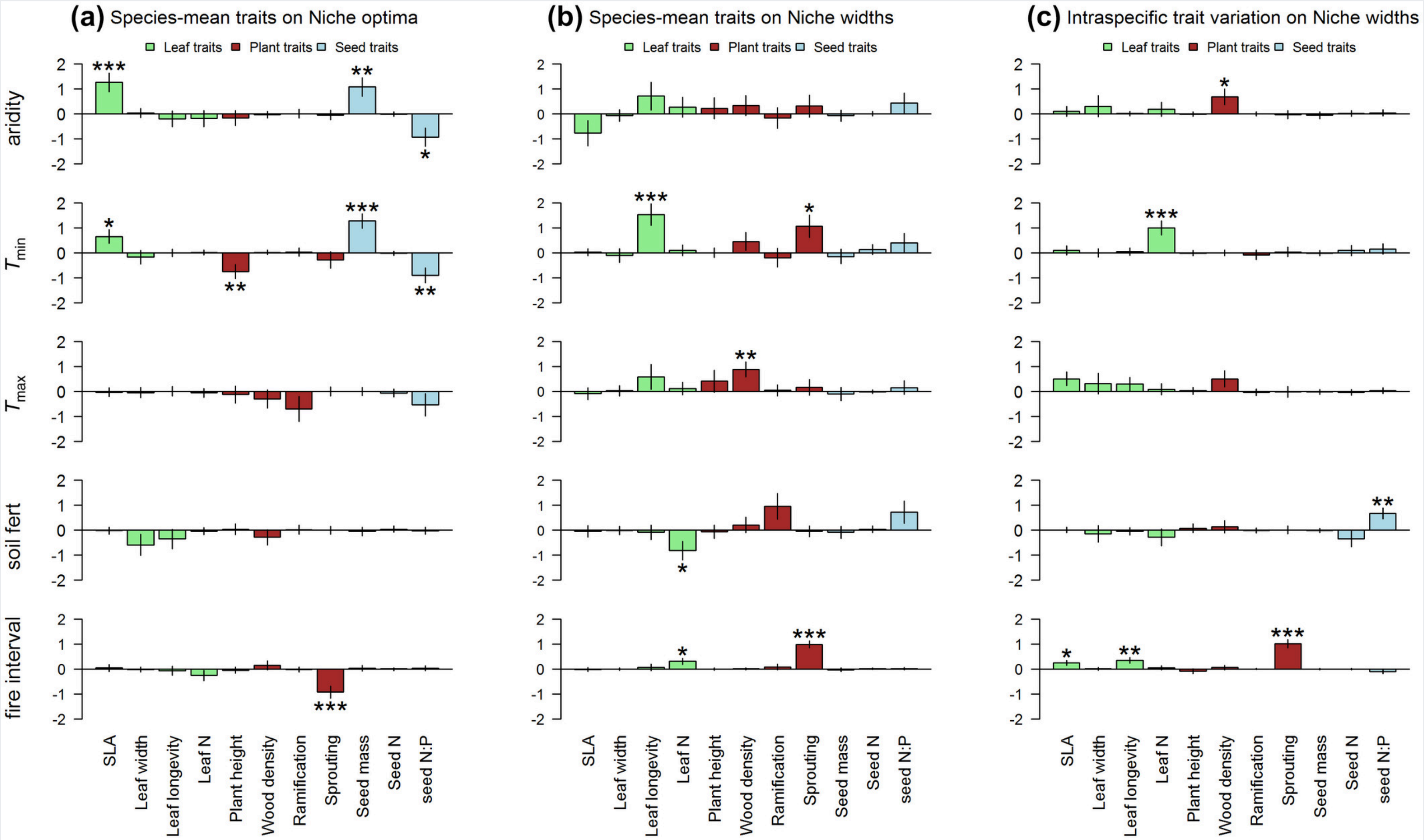
The models could explain 30% of the variance in r_{max} and >50% of the variance in the niche optima and widths!

P.S. This is good...



Treurnicht et al. 2020

Several of the traits were significant predictors of the niche optima and widths for the 5 environmental variables.



Treurnicht et al. 2020

Traits and Community Assembly

What can traits reveal about community assembly?

Traits and Community Assembly

How would you expect traits to relate to the community assembly process?

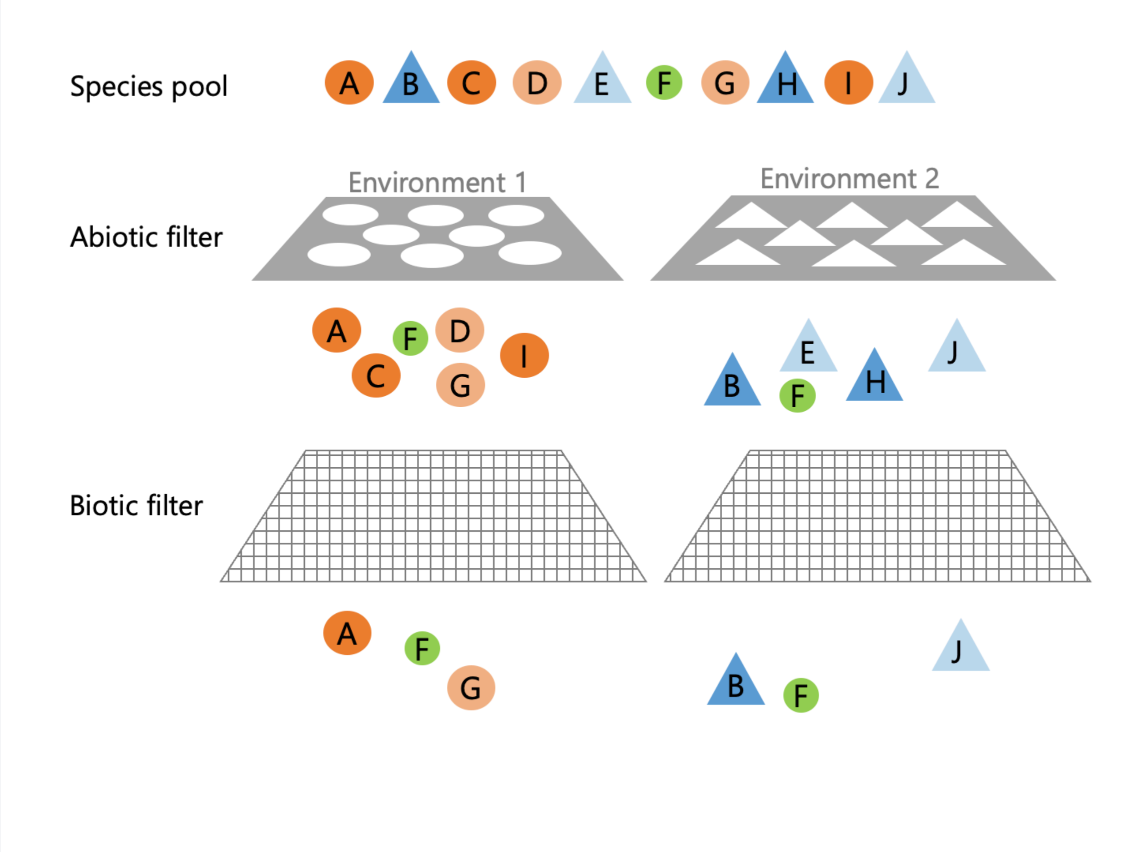


image: Tony Verboom

Traits and Community Assembly

Environmental filtering should select for species with the traits needed to survive in that environment, usually reducing the variation in traits.

Biotic interactions can have two outcomes. Competition should drive trait divergence. Conversely, a common limiting factor (e.g. a resource or shared predator) should drive convergence.

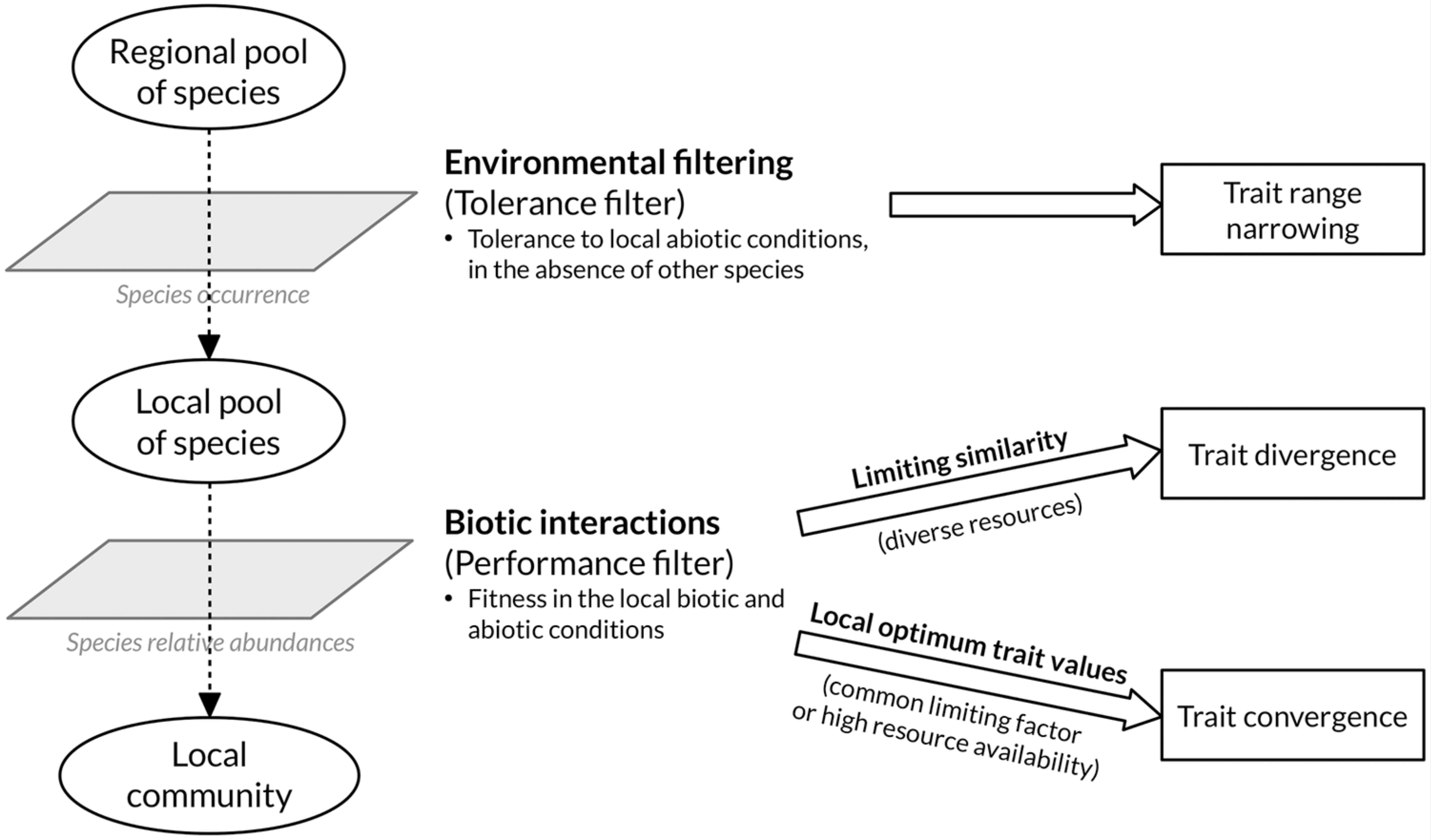


Figure from **Lechene et al 2018**

Examples?

Traits and Community Assembly

Just a note that these things are complex to measure though.

For example, limiting similarity may result in a greater range of traits, but there's a lot going on within that range too. Only species with overlapping niches should compete, so many species within the range should be competitively excluded...

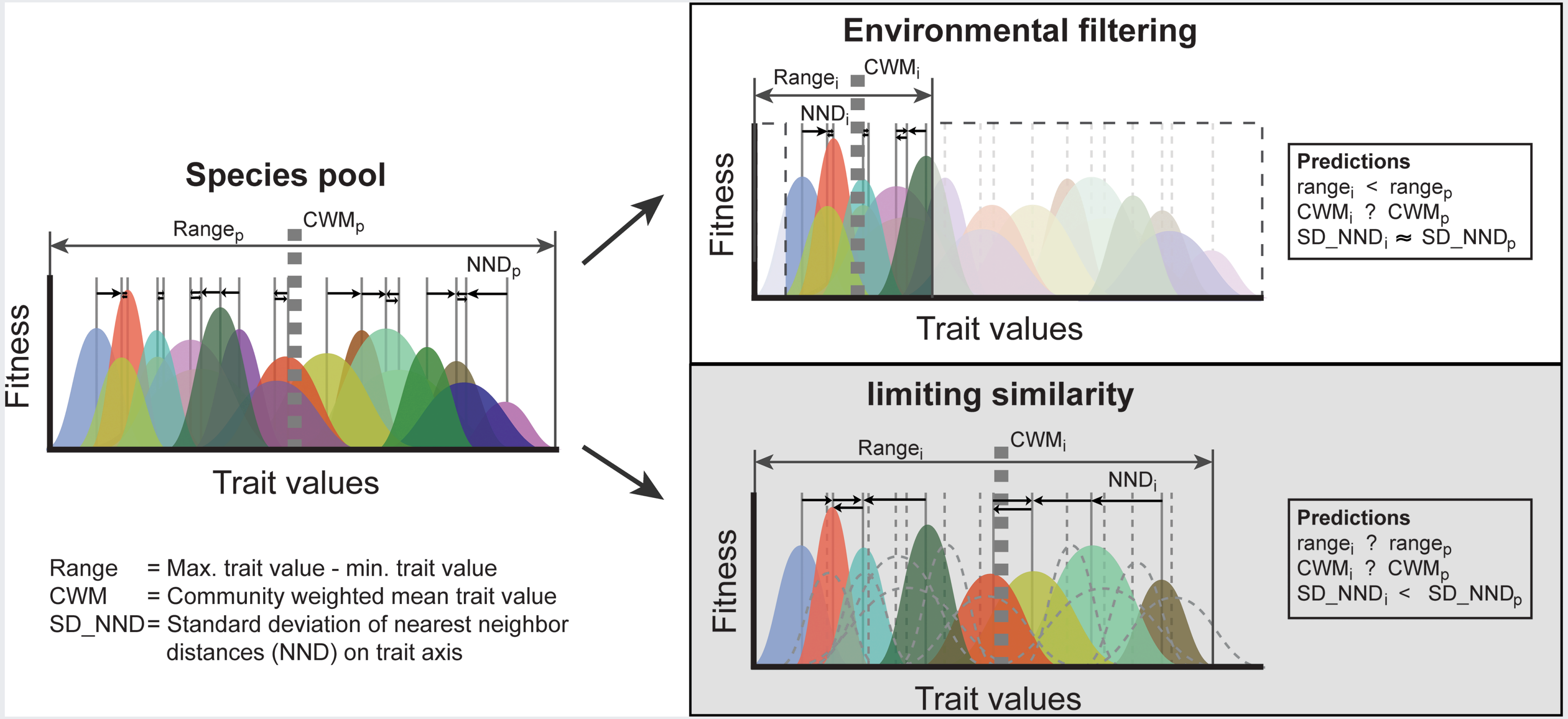


Figure from **Luo et al 2016**

But how do we know these are the right traits?

Traits and Community Assembly

If one has a clear understanding of the system and necessary traits, you could be more specific in your predictions than just changes in trait convergence or divergence.

e.g. This example shows the need for plants to have aerenchyma to survive in inundated wetlands, because otherwise their roots would rot.

Unfortunately, it is rare to have this detailed an understanding of the biology *a priori*. It is also difficult to generalise this rule beyond wetland plants...

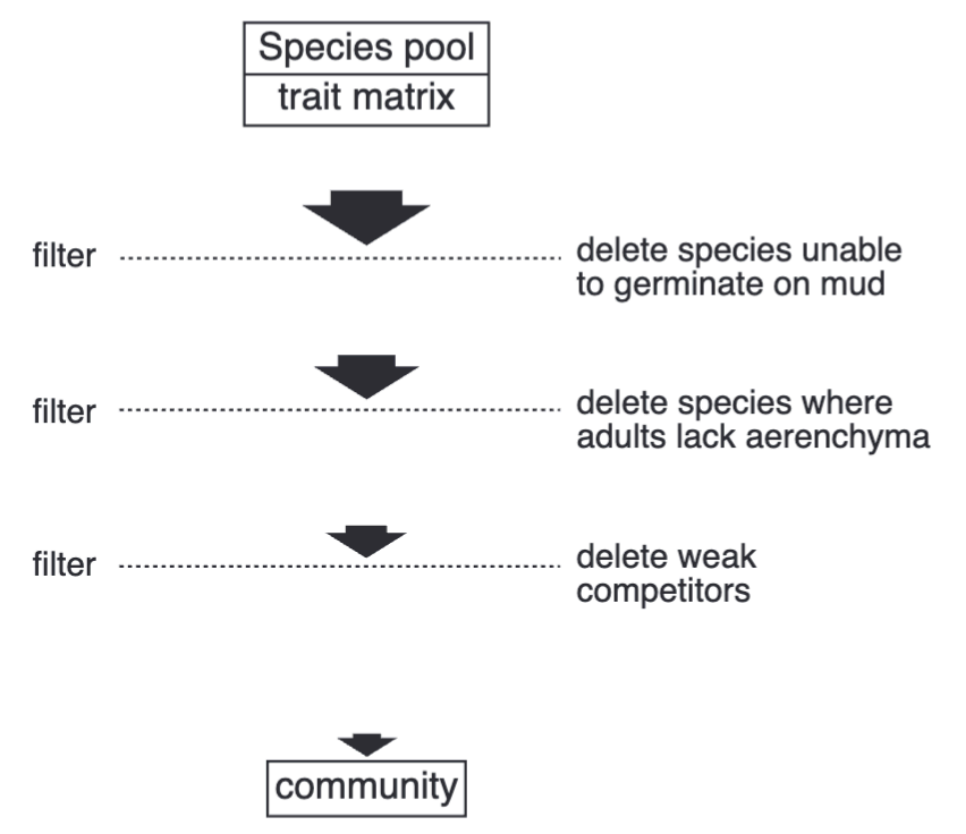
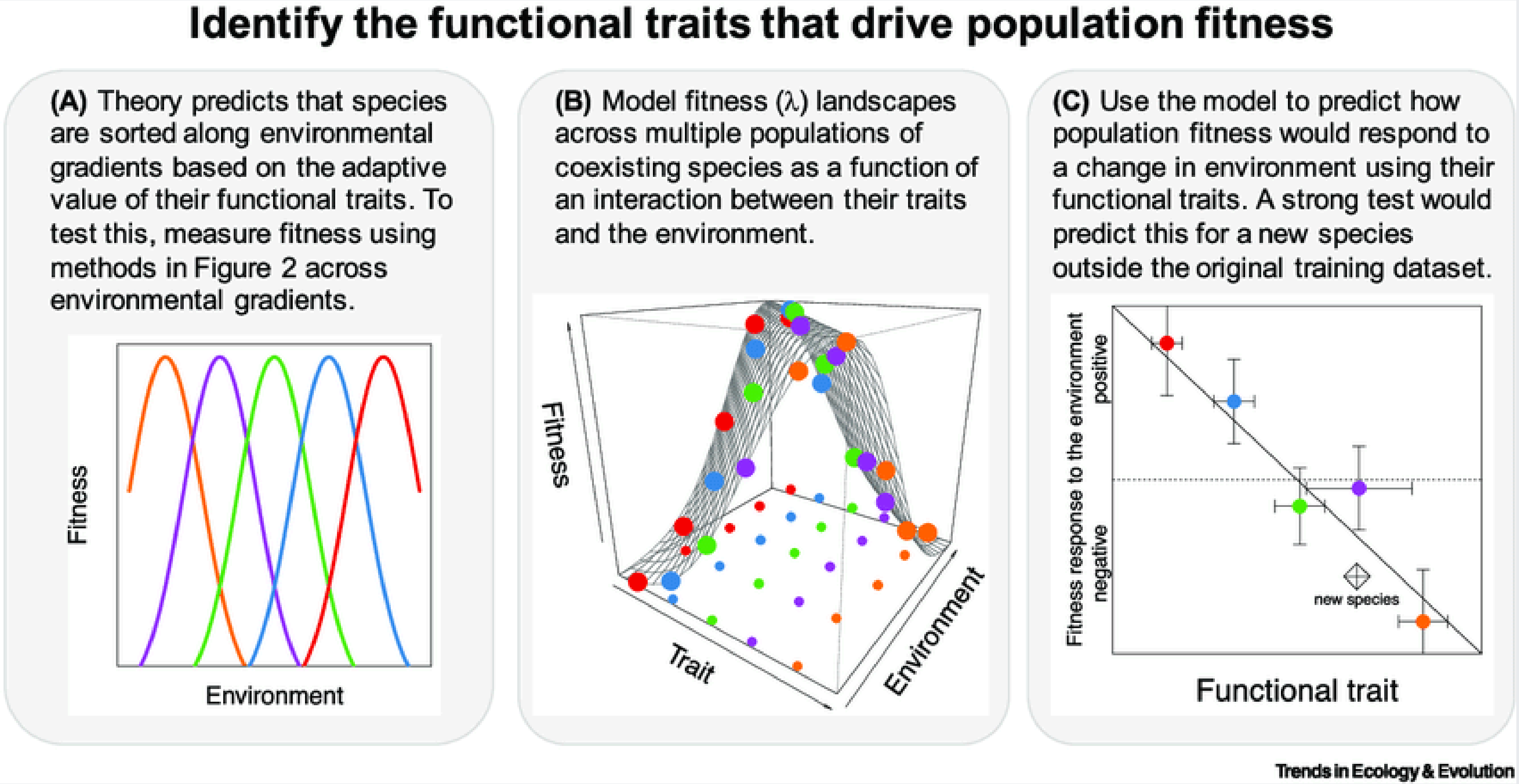


Figure from **Keddy 1992**

But how do we know these are the right traits?

This is why step 1 is looking at the relationship between traits and fundamental niches!

Selecting the right traits



This is essentially the process we followed in **Treurnicht et al. 2020**. Figure from **Laughlin et al. 2020**.

Other considerations and advantages of trait-based ecology?

There are often trade-offs among traits

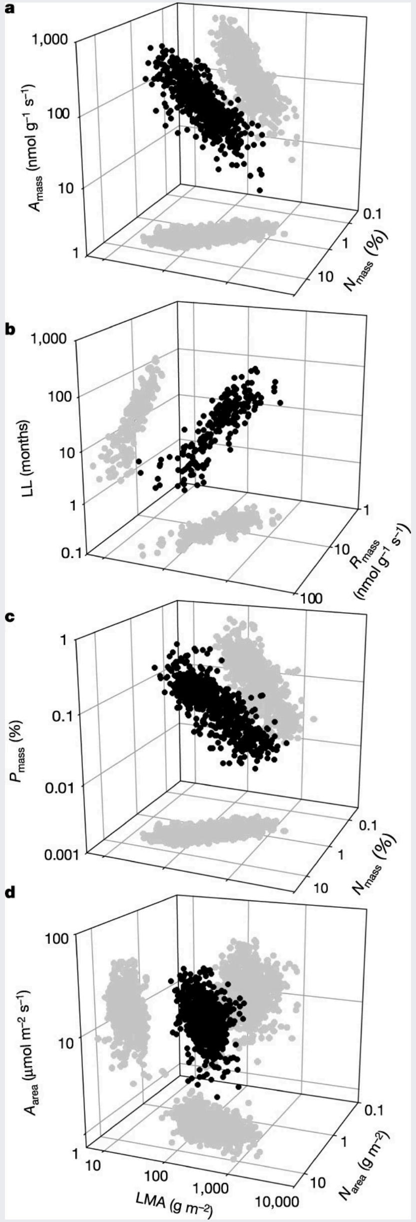
Leaf dry mass per unit area (LMA) predicts

- Nitrogen content
- photosynthetic capacity
- relative growth rate

But

- Trades off against leaf longevity

The leaf economics spectrum (LES) - Wright et al. 2004

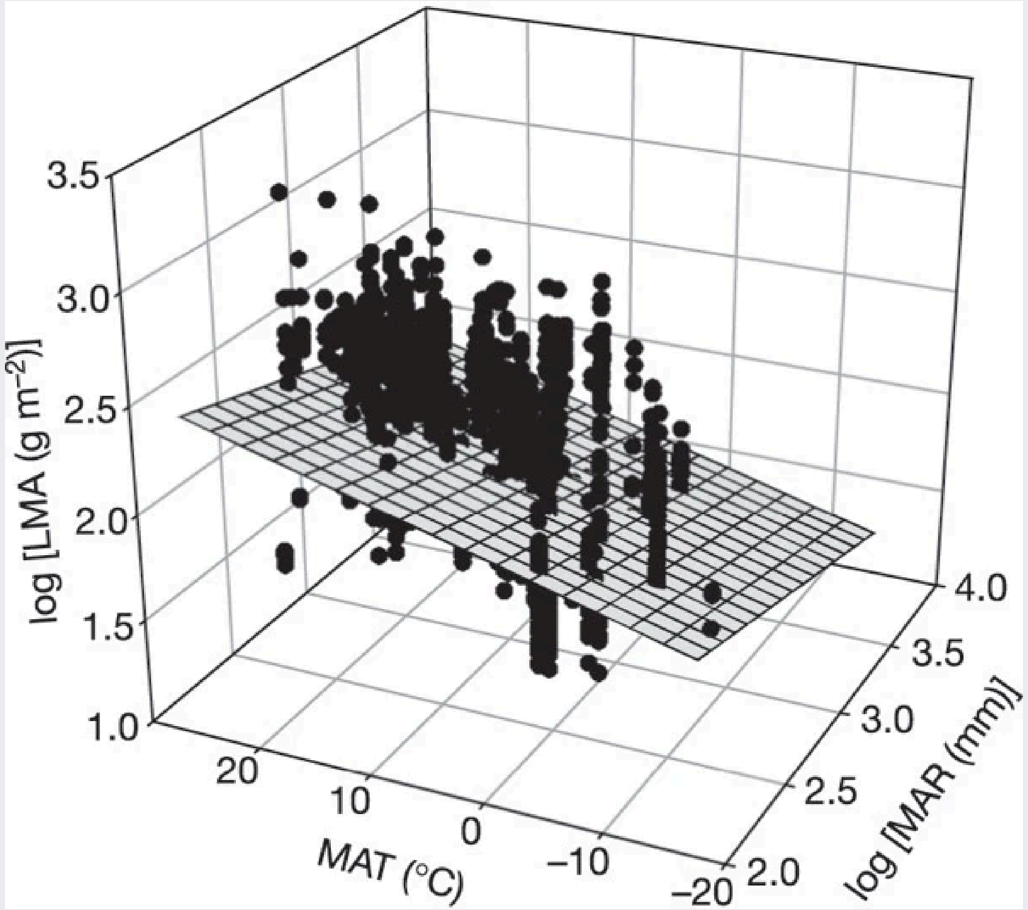


There are often trade-offs among traits

LMA correlates with environment (temp and rainfall)

- Higher LMA in hot, dry places

This also represents a trade-off in that specific traits can limit species to specific resource/habitat requirements (water, light, nutrients). i.e. these trade-offs have a direct effect on species niches!



The leaf economics spectrum (LES) - Wright et al. 2004

Traits and scaling

Example traits	Organismal processes	Community processes	Ecosystem processes
Leaf chemistry and longevity	Carbon balance Disease resistance Growth rate	Competition Herbivory Succession	Decomposition Nutrient cycling Productivity
Leaf and stem hydraulic traits	Drought tolerance	Competition and facilitation	Hydrology Precipitation patterns
Fine root traits	Soil resource uptake Growth rate	Competition and facilitation Community invasibility	Decomposition Soil development

Fig. 1. Functional traits can be used to understand a wide range of ecological processes occurring at organismal, community, and ecosystem scales. Examples are given here of how leaf, stem, and fine root traits influence a variety of ecological processes.

Traits affect processes from the organism to ecosystem and should help us scale across the hierarchy or ecology

Funk et al. 2017

Traits and ecosystem function

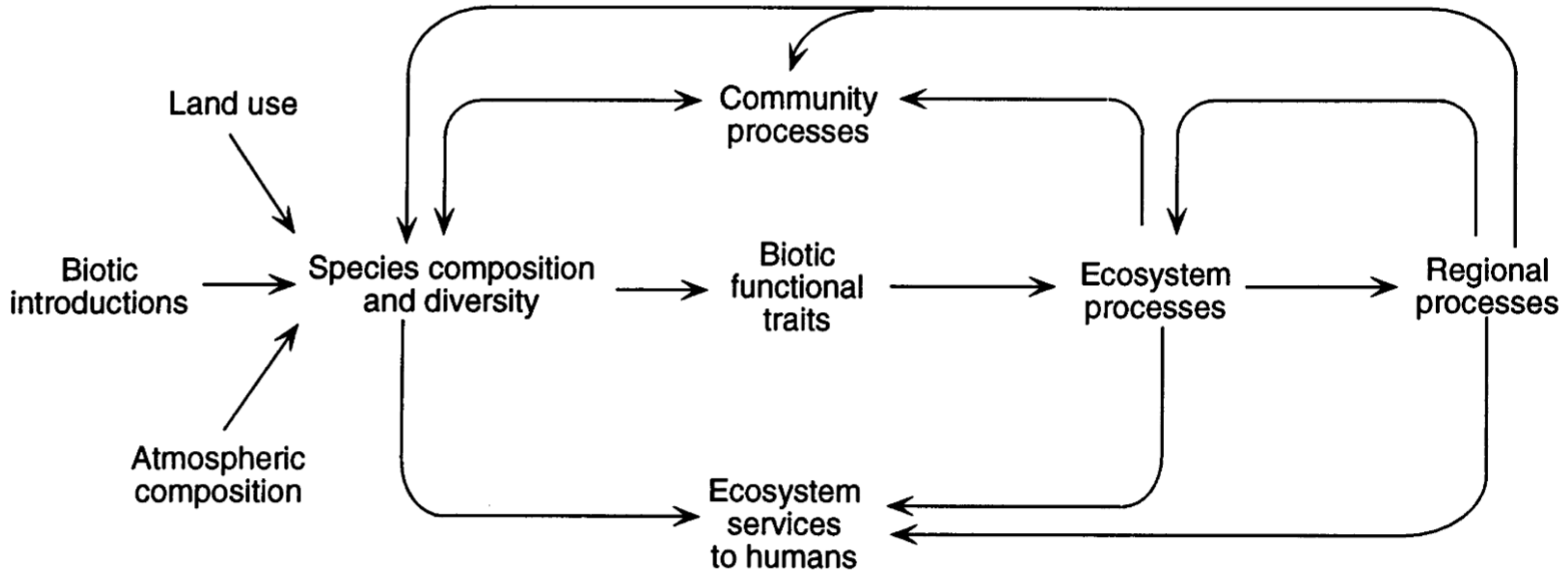


Fig. 1. Linkages involving species composition and diversity and ecosystem processes. Ecosystem processes include productivity and nutrient cycling. Regional processes include trace gas fluxes to the atmosphere and nutrient fluxes from terrestrial to aquatic systems. Community processes include competition and predation. Ecosystem services are the benefits derived by humans from ecological processes.

A focus on traits allows us to link community assembly and outcomes for ecosystem function, **Chapin et al 1997**

> "Opinions regarding the relative importance of the niche, and hence traits, to community dynamics fall loosely into three camps.
>
> - The first argues that trait differences among individuals are largely irrelevant at the community level compared to factors such as demographic stochasticity (e.g. Neutral Theory: Hubbell, 2001).
> - The second argues that traits are relevant to individuals, but the complexity of biotic and abiotic interactions precludes us from scaling individual processes to the community level (e.g. Lawton, 1999).
> - The final camp argues that traits provide a path forward to a unified theory of community ecology by providing a taxon-independent means for generalizing the structure and/or functioning of communities that is based on functional traits rather than species identity (e.g. Westoby & Wright, 2006; McGill et al., 2006a)."

- **Funk et al. 2017**

Take-home

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> **

Thanks!

Slides created via the R packages:

xaringan
gadenbuie/xaringanthemer

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