Phylogenies, functional traits and communities under global change

Ingo Grass
Agroecology - Department of Crop Sciences
Georg-August-Universität Göttingen

Workshop on land use and climate change in the Brazilian Caatinga
Maria Rosenberg, 21.-22. October 2014

Global change

Up: crop loss due to drought in Tanzania
Left: deforestation in South Africa

Global change

How can we predict responses of species communities & ecosystem processes ?

Up: crop loss due to drought in Tanzania
Left: deforestation in South Africa

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Functional traits, the phylogeny of function, and ecosystem service vulnerability

Sandra Díaz[1,a], Andy Purvis[2,a], Johannes H. C. Cornelissen[3], Georgina M. Mace[2,4], Michael J. Donoghue[5], Robert M. Ewers[2], Pedro Jordano[6] & William D. Pearse[2]

[1]Instituto Multidisciplinario de Biología Vegetal (CONICET-UNC) and FCEFyN, Universidad Nacional de Córdoba, Argentina
[2]Department of Life Sciences, Imperial College London, Silwood Park, SL5 7PY, United Kingdom
[3]Systems Ecology, Department of Ecological Science, Faculty of Earth and Life Sciences, VU University, Amsterdam, The Netherlands
[4]Department of Genetics, Evolution and Environment, University College London, Gower Street, London, WC1E 6BT, United Kingdom
[5]Department of Ecology and Evolutionary Biology, Yale University, New Haven, Connecticut
[6]Integrative Ecology Group, Estación Biológica Doñana, CSIC, Sevilla, Spain

Keywords
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Correspondence
Sandra Díaz, Instituto Multidisciplinario de Biología Vegetal, Casilla de Correo 495, 5000 Córdoba, Argentina. Tel: + 54 351 4331097; Fax: + 54 351 4331056; E-mail: sdiaz@efn.uncor.edu
Andy Purvis, Department of Life Sciences, Imperial College London, Silwood Park, SL5 7PY, United Kingdom. Tel: +44 207 594 2327; Fax: +44 207 594 2339; Email: a.purvis@imperial.ac.uk

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Abstract

People depend on benefits provided by ecological systems. Understanding how these ecosystem services – and the ecosystem properties underpinning them – respond to drivers of change is therefore an urgent priority. We address this challenge through developing a novel risk-assessment framework that integrates ecological and evolutionary perspectives on functional traits to determine species' effects on ecosystems and their tolerance of environmental changes. We define Specific Effect Function (SEF) as the per-gram or per capita capacity of a species to affect an ecosystem property, and Specific Response Function (SRF) as the ability of a species to maintain or enhance its population as the environment changes. Our risk assessment is based on the idea that the security of ecosystem services depends on how effects (SEFs) and tolerances (SRFs) of organisms – which both depend on combinations of functional traits – correlate across species and how they are arranged on the species' phylogeny. Four extreme situations are theoretically possible, from minimum concern when SEF and SRF are neither correlated nor show a phylogenetic signal, to maximum concern when they are negatively correlated (i.e., the most important species are the least tolerant) and phylogenetically patterned (lacking independent backup). We illustrate the assessment with five case studies, involving both plant and animal examples. However, the extent to which the frequency of the

Vive la différence: plant functional diversity matters to ecosystem processes

Sandra Díaz and Marcelo Cabido

The links between plant diversity and ecosystem functioning remain highly controversial. There is a growing consensus, however, that functional diversity, or the value and range of species traits, rather than species numbers *per se*, strongly determines ecosystem functioning. Despite its importance, and the fact that species diversity is often an inadequate surrogate, functional diversity has been studied in relatively few cases. Approaches based on species richness on the one hand, and on functional traits and types on the other, have been extremely productive in recent years, but attempts to connect their findings have been rare. Crossfertilization between these two approaches is a promising way of gaining mechanistic insight into the links between plant diversity and ecosystem processes and

ecosystem processes and the ECOSYSTEM SERVICES (see Glossary) that humans derive from them[1]. The issue of whether plant diversity influences ecosystem processes has received increasing attention in the past five years, as a consequence of the publication of several groundbreaking theoretical developments and experiments[2–13].

There is now general agreement that diversity (a synonym of biodiversity and biological diversity) includes both number and composition of the genotypes, species, functional types and landscape

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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]

[1]Department of Biology, McGill University, Montreal, QC, Canada, H3A 1B1
[2]Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ 85721, USA
[3]Department of Biology, University of Wisconsin – Eau Claire, Eau Claire, WI 54702, USA
[4]Department of Biological Sciences, Macquarie University, NSW 2109, Australia

There is considerable debate about whether community ecology will ever produce general principles. We suggest here that this can be achieved but that community ecology has lost its way by focusing on pairwise species interactions independent of the environment. We assert that community ecology should return to an emphasis on four themes that are tied together by a two-step process: how the fundamental niche is governed by functional traits within the context of abiotic environmental gradients; and how the interaction between traits and fundamental niches maps onto the realized niche in the context of a biotic interaction milieu. We suggest this approach can create a more quantitative and predictive science that can more readily address issues of global change.

Whither community ecology?

Community ecology is the study of a set of species co-occurring at a given time and place. MacArthur suggested that the goal of community ecology (as of all science) is to find general rules [1], whereas Lawton [2] suggested that ‘community ecology is a mess’ with respect to this search. Simberloff [3] countered that general rules cannot be achieved owing to the complex nature of communities. We disagree with Simberloff's view and suggest that there is hope for general rules in community ecology. Much (but not all, e.g. [4–7]) of community ecology from the 1960s onwards has pursued a program based on studying the population dynamics of pairs of species [8–10] and building this up into models of communities. This has had some success in explaining one- or few-species systems, but rarely in providing general principles about many species communities [2,3]. In response to this shortcoming, a variety of fresh approaches to community ecology have emerged recently [11–13]. We suggest that a focus on four research themes can clean up the ‘mess’, bringing general patterns to community ecology.

Corresponding author: McGill, B.J. (mail@brianmcgill.org).
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Functional traits research program

The four themes that we suggest are traits, environmental gradients, the interaction milieu and performance currencies. These themes are linked by taking a more physiological approach, by using concepts that are

Glossary

Community matrix: a square (S×S) matrix describing interactions in a community with *S* species. The community matrix, together with a vector of intrinsic rates of increase (***r***), specifies the parameters of the generalized (*S* species) Lotka–Volterra differential equations, which can be solved for equilibrium abundances (*N*).
Distinct preference niche: a model of a niche in which each closely related species has a performance optimum at a different point along an environmental gradient (Figure 1c, main text). This model is assumed correct in most of community ecology, but might be less common than shared preferences.
Fundamental niche: the subset of *n*-dimensional environmental space of all possible conditions in which a species can maintain itself in the absence of competition (Figure 1c,d, main text).
Gradient analysis: the measurement of the abundance of different species either in the field along an indirect gradient, such as elevation, or in the laboratory along a direct gradient, such as moisture or pH (Figure 1b, main text).
Habitat modeling: the development of a regression model (usually nonlinear) that predicts the abundance (or presence versus absence) of a species given a set of environmental conditions by estimating model parameters from observations of abundance versus environment in the field.
Performance currency: a measurable quantity with physical units that enables the comparison of performance (the capacity of an organism to maintain biomass over many generations) between species and across environmental gradients. The appropriate currency should be chosen based on the organisms and can vary depending on the question (e.g. fundamental versus realized niche processes), but is usually related to the acquisition and allocation of energy and nutrients.
Physiological response curve (i.e. environmental response curve): a relationship giving fitness (or a component of fitness) as a function of one (occasionally several) environmental variables (Figure 1a, main text).
Population dynamics models: a differential or difference equation model of abundance (*N*) that models changes in *N* over time either primarily or exclusively as a function of *N* at previous time intervals. It has usually been assumed that community ecology is best conceptualized as the development of multispecies population dynamic models.
Realized niche: the subset of n-dimensional environmental space where a species is present. It is usually assumed that the realized niche is a subset of (smaller than) the fundamental niche (Figure 1c,d, main text).
Shared preference niche: an alternative to distinct preferences where a set of species prefer one environment (often warm, moist, nutrient-rich, sheltered conditions). Coexistence is achieved by a tradeoff between the ability to tolerate less desirable conditions and the ability to be competitively dominant (Figure 1d, main text).
Trait: a well-defined, measurable property of organisms, usually measured at the individual level and used comparatively across species. A **functional trait** is one that strongly influences organismal performance.

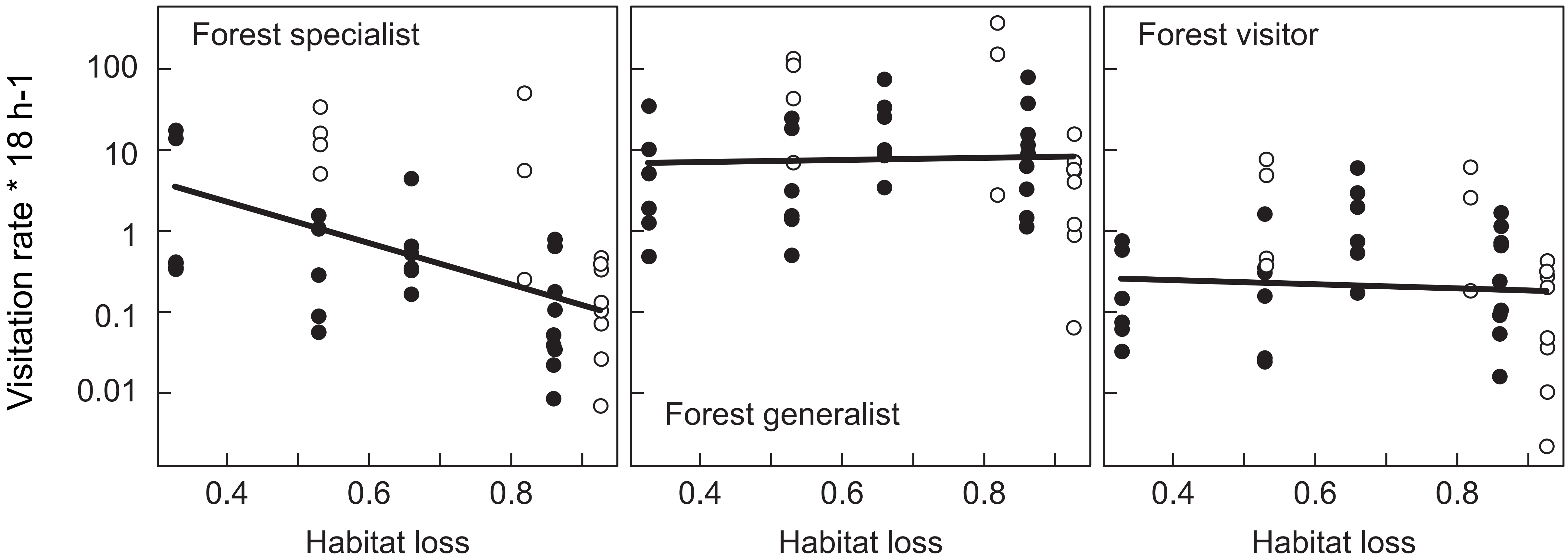
www.sciencedirect.com 0169-5347/$ - see front matter doi:10.1016/j.tree.2006.02.002

Díaz & Cabido 2001 TREE;
McGill *et al* 2006 TREE;
Díaz *et al.* 2013 Ecol. Evol.

Functional traits

- Response traits: determine responses to environmental conditions
    - e.g. drought tolerance, habitat or resource specialization

Functional traits - response traits



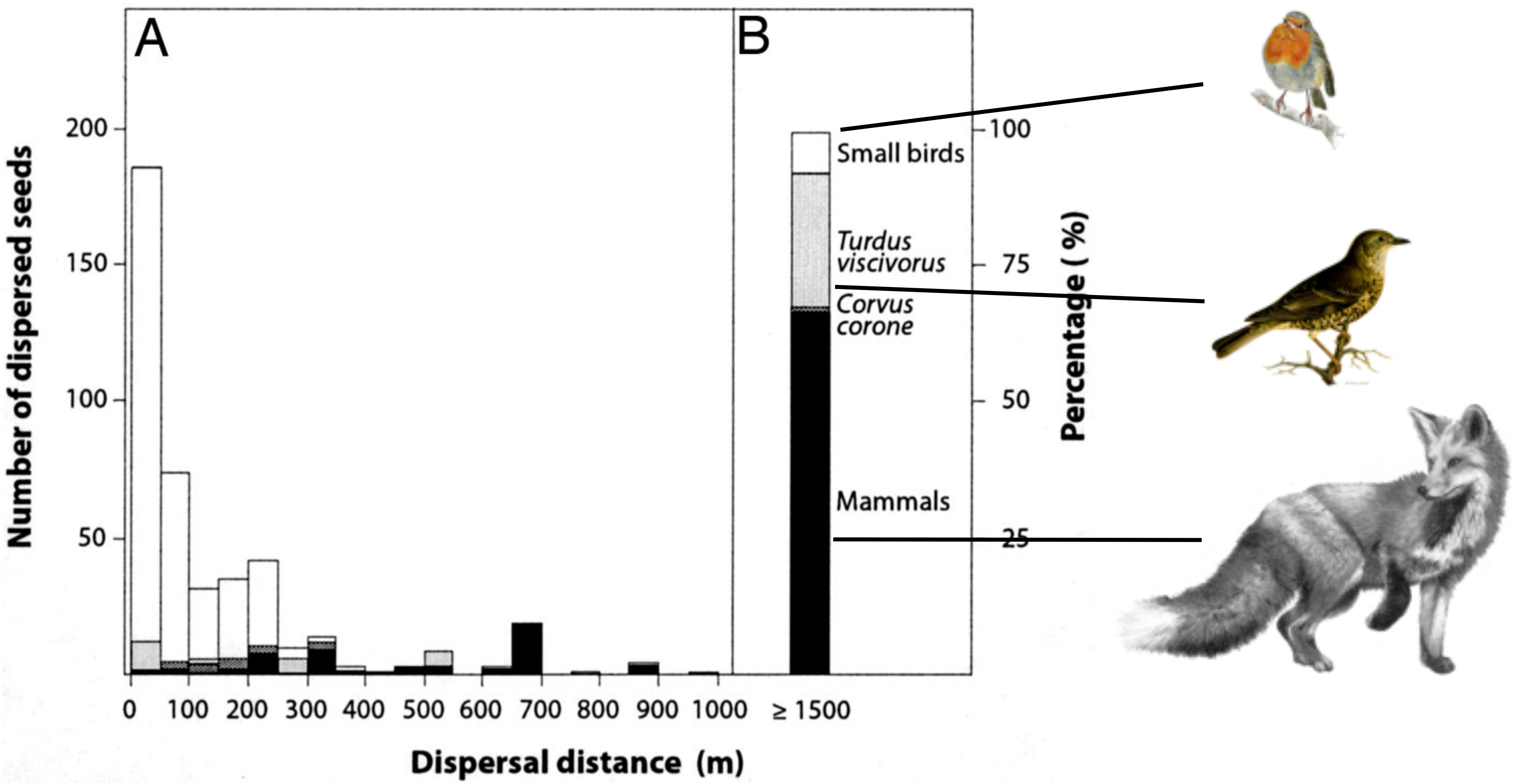
- Habitat specialization mediates vulnerability to seed disperser loss

Grass et al. 2014 Oikos

Functional traits

- Response traits: determine responses to environmental conditions
    - e.g. drought tolerance, habitat or resource specialization
- Effect traits: determine species’ effects on ecosystem processes
    - e.g. nitrogen-fixation, body size

Functional traits - effect traits



- Body size
- Seed disperser FD enhances gene flower and deposition into microhabitats

Jordano *et al.* 2007 PNAS

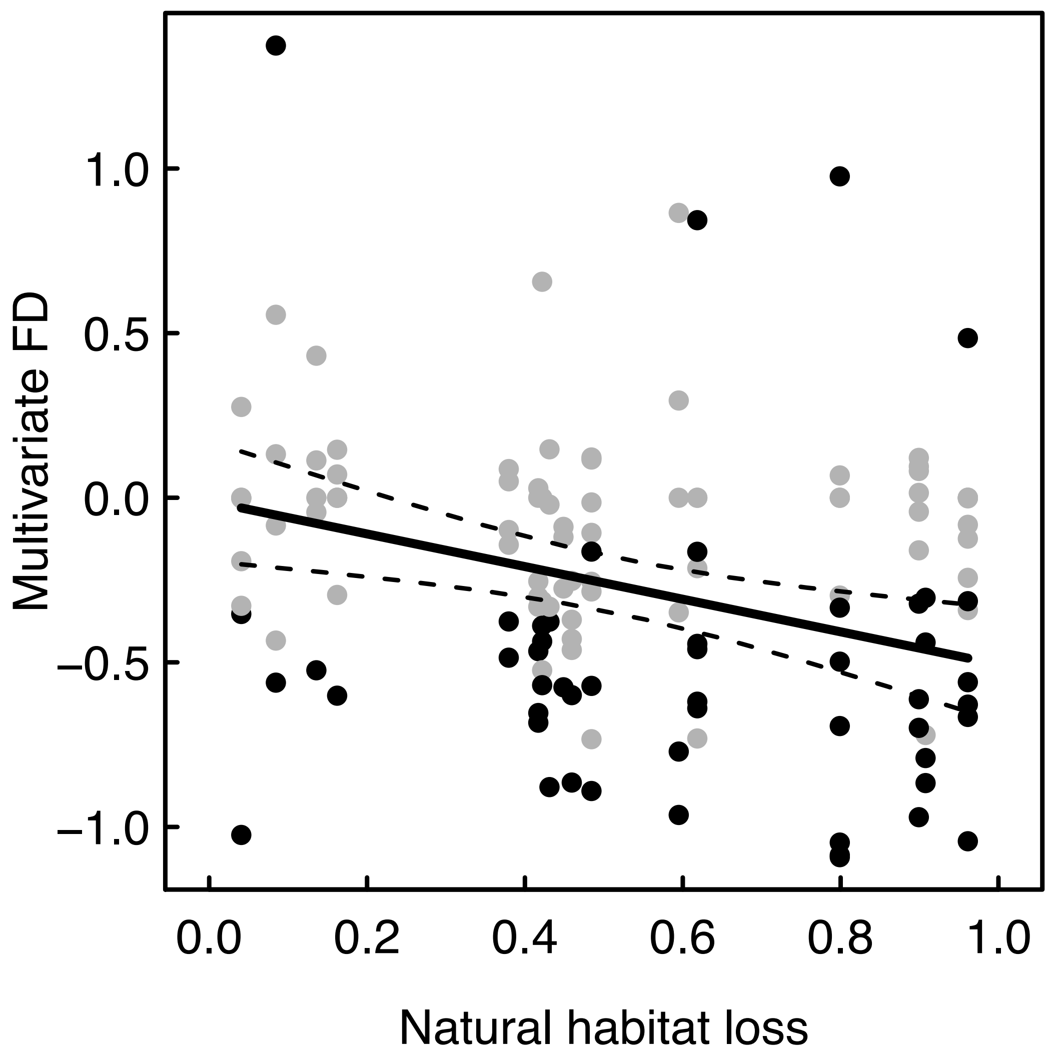
Functional traits

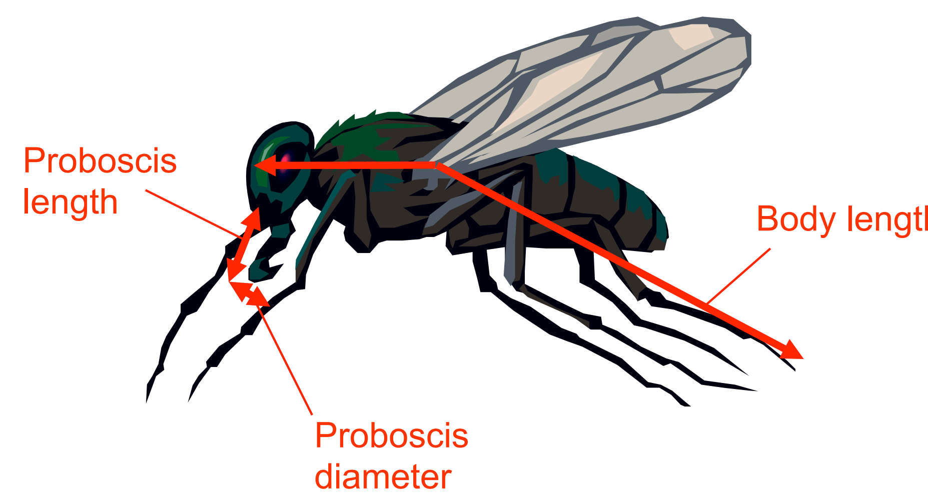
- Response traits: determine responses to environmental conditions
    - e.g [illegible] ation

Habitat changes lead to changes in functional trait diversity !

- Effect traits: determine species' effects on ecosystem processes
    - e.g. nitrogen-fixation, body size

Functional diversity - habitat changes





- Effect traits: proboscis length, proboscis diameter, body length
- Loss in pollinator functional diversity with deforestation

Grass *et al.* 2014 Funct. Ecol.

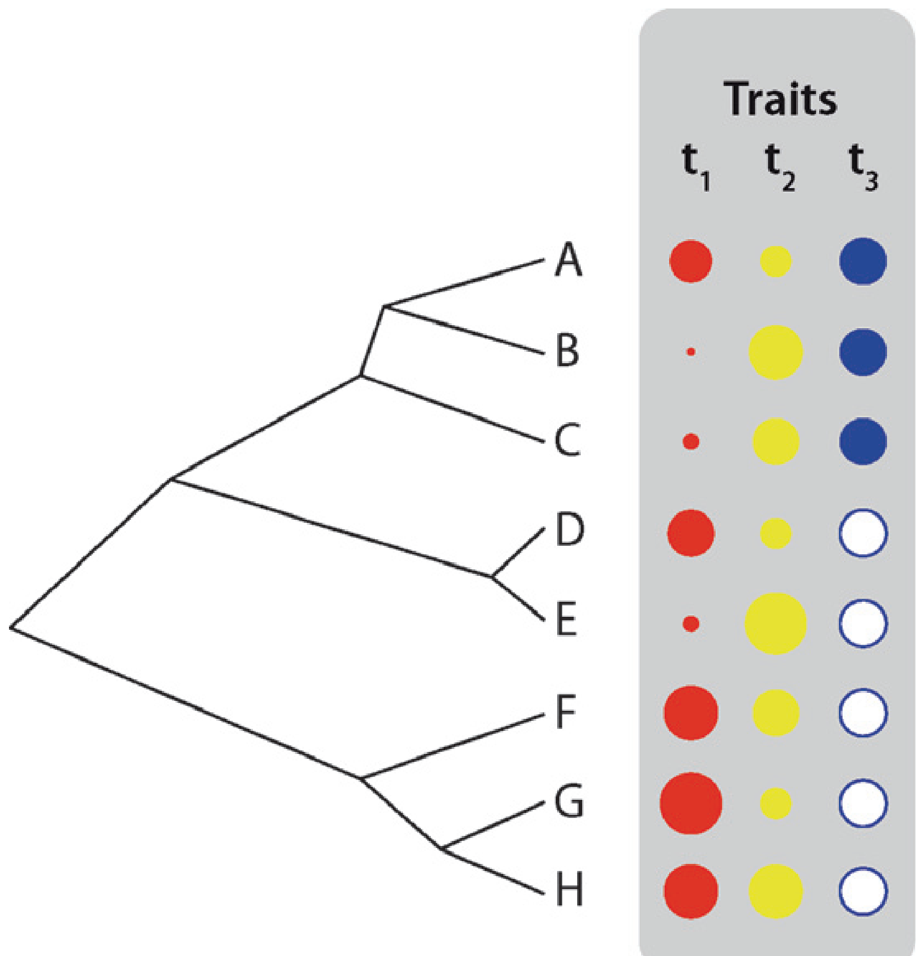
How can we

1) link response and effect traits
2) predict ecosystem functions

in changing environments ?

Functions traits - linked by phylogeny

t1 & t2: continuous
t3: categorical
(size = species values)



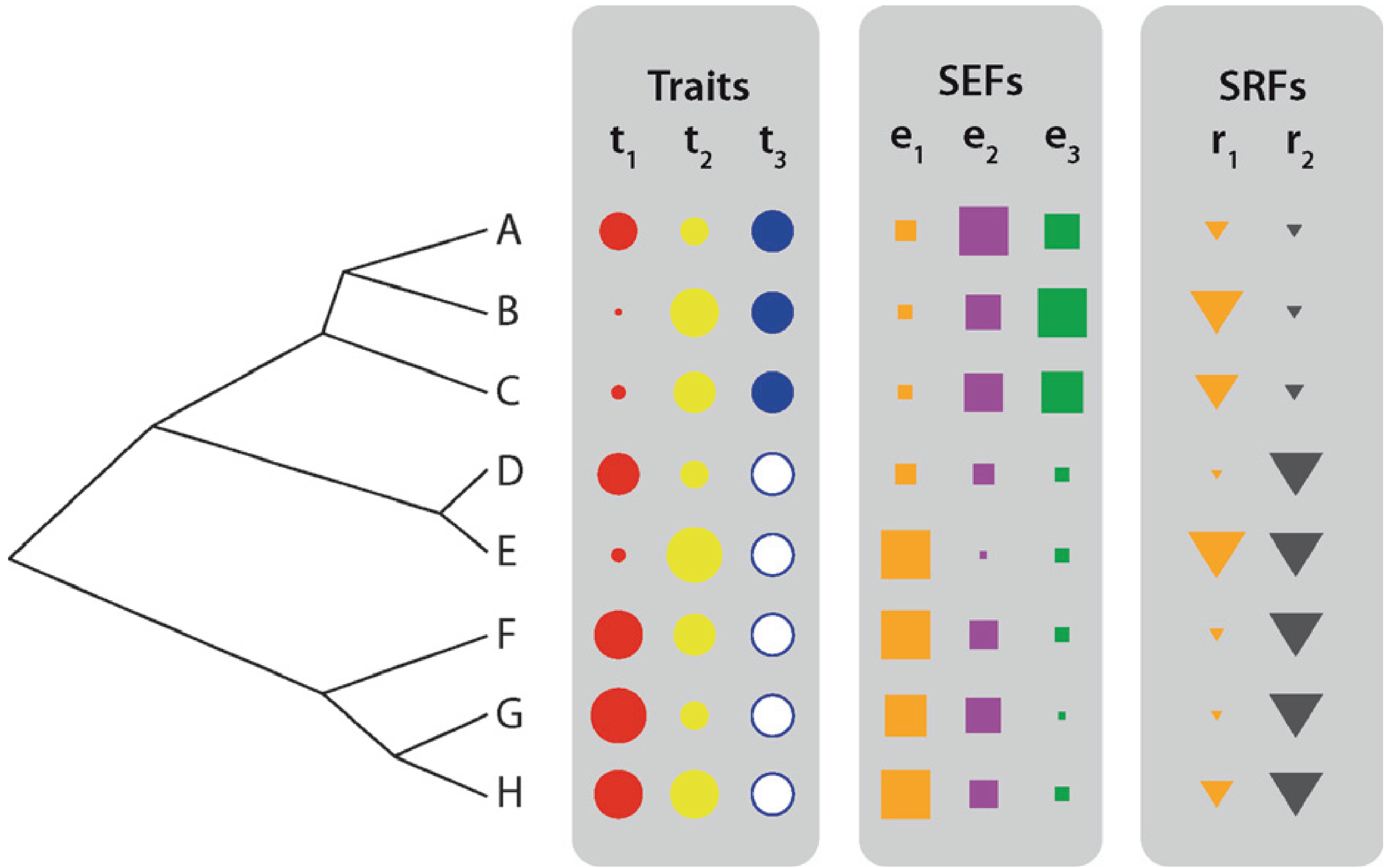
Díaz *et al.* 2013 Ecol. Evol.

Functions - trait mixtures and phylogeny

t1 & t2: continuous
t3: categorical
(size = species values)

specific effect function
which results from traits
(color mixture)

specific response function
which results from traits
(color mixture)



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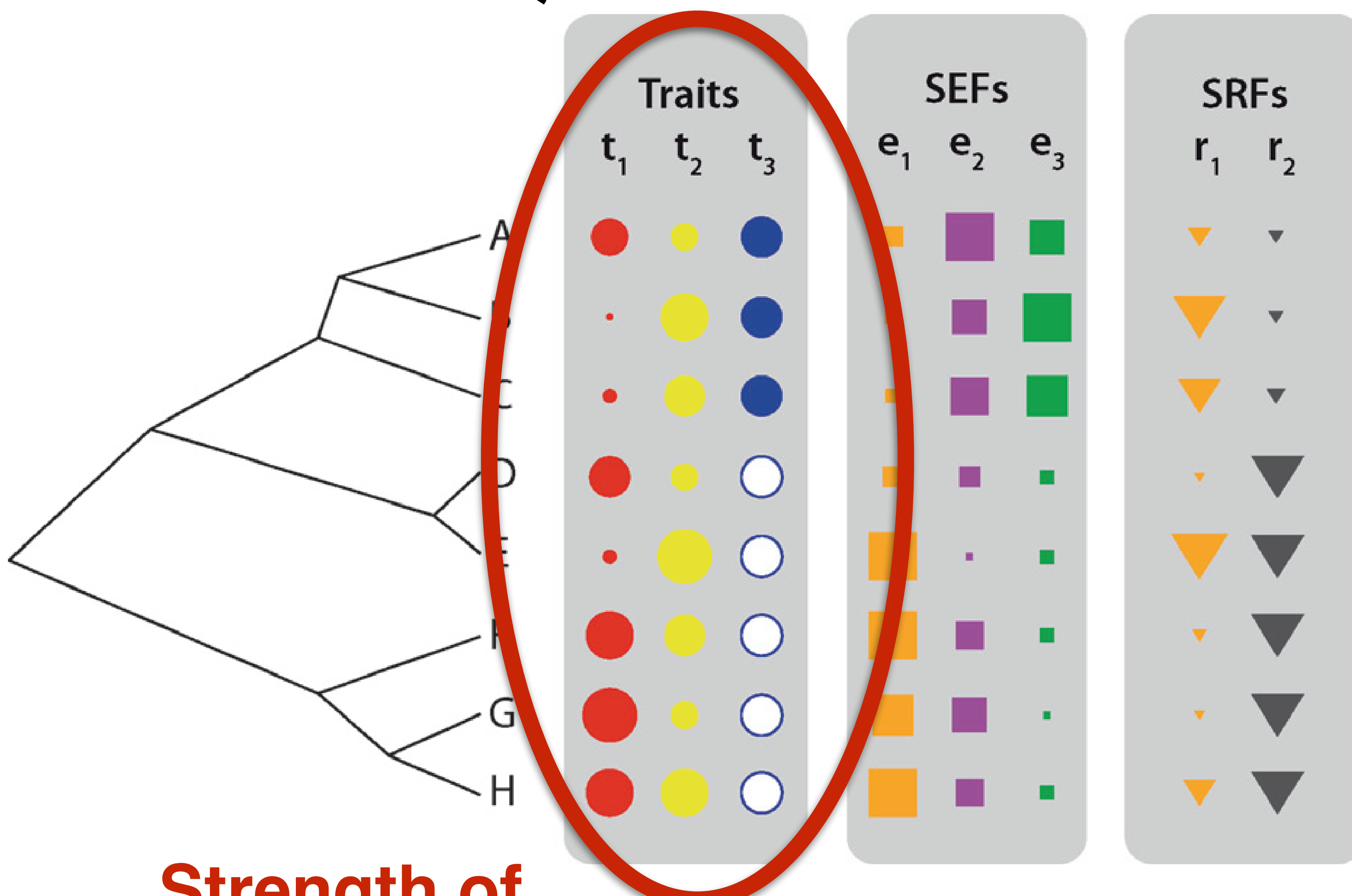

Strength of phylogenetic signal

Díaz *et al.* 2013 Ecol. Evol.

Functions - trait mixtures and phylogeny

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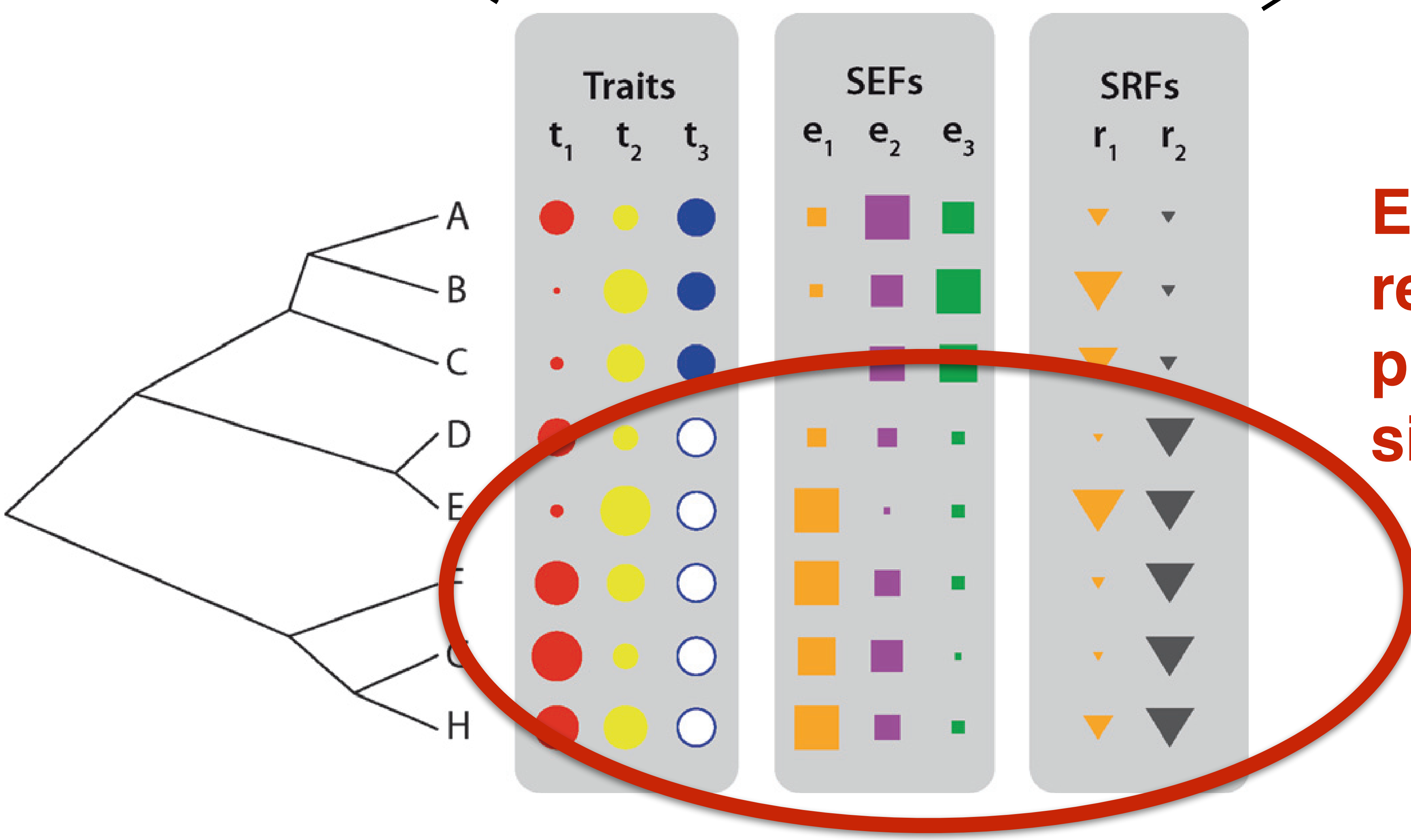
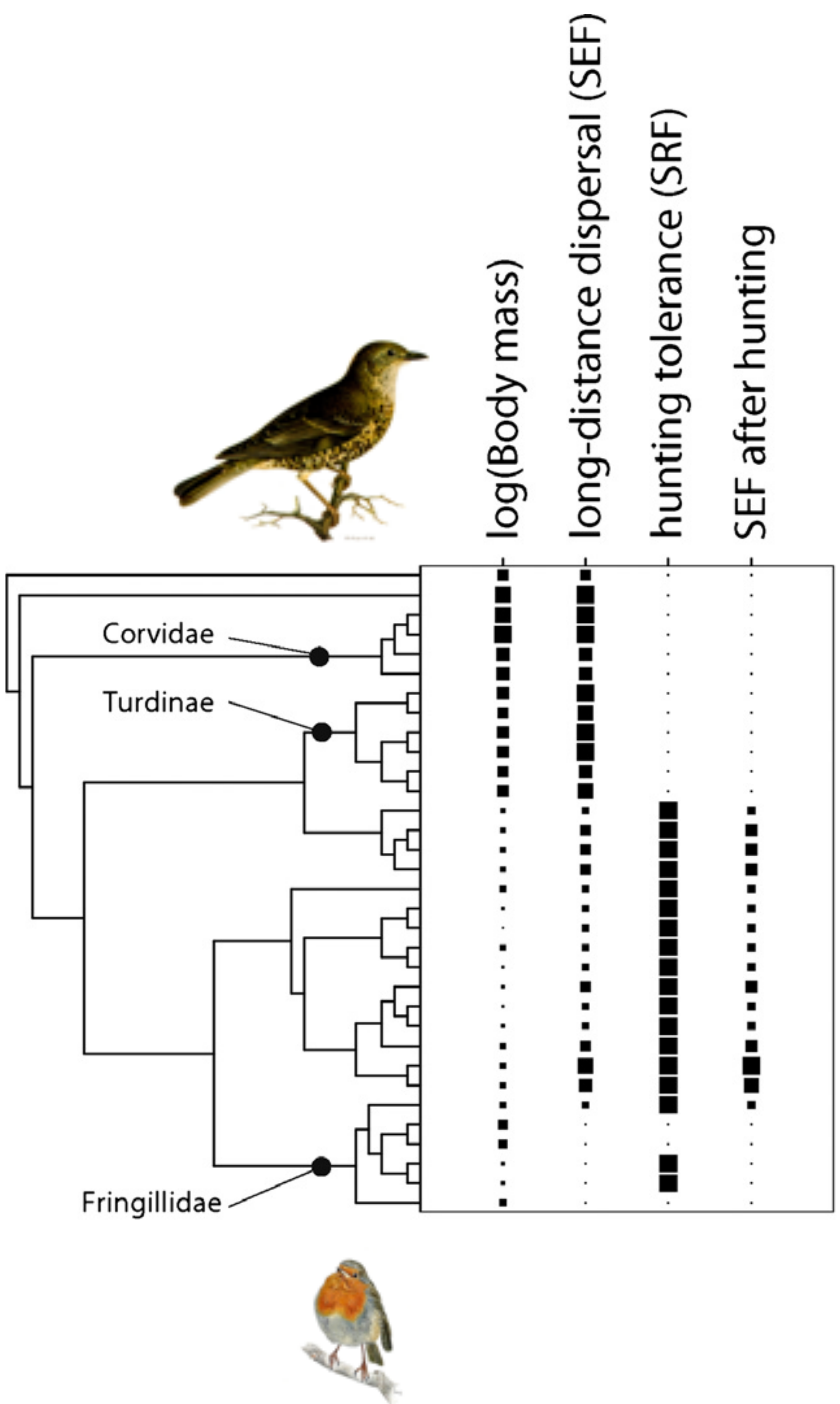
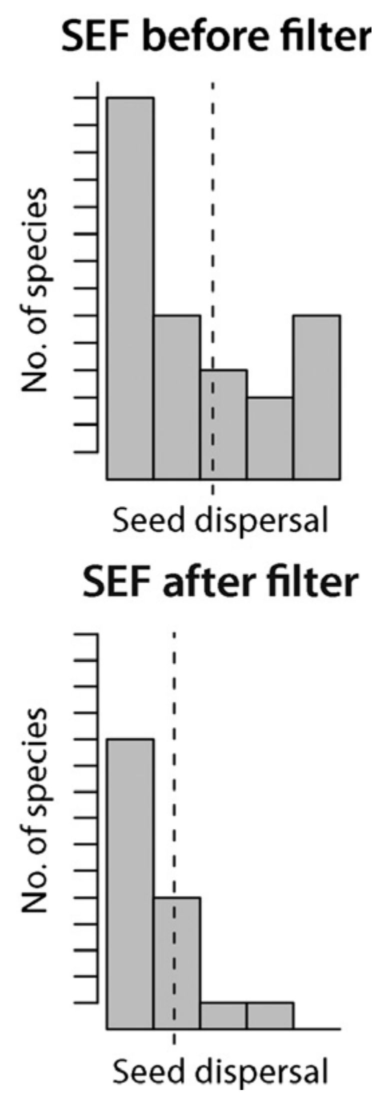


Effect and response vs. phylogenetic signal

Díaz *et al.* 2013 Ecol. Evol.

Phylogenies - an example





- SEF: long-distance seed dispersal
- Traits: body mass and hunting tolerance of birds
- SRF: hunting tolerance (mediated by body size)
- SEF and SRF strongly (phylogenetically) correlated
- Hunting of large birds leads to a loss of long-distance seed dispersal

Jordano *et al.* 2007 PNAS;
Díaz *et al.* 2013 Ecol. Evol.

Functional approaches to the Brazilian Caatinga

- SRFs of communties?
    - traits that determine vulnerability to land use & climate change
        - habitat or resource specialization
        - physiological constraints (e.g., invertebrates - ants, herbivores)
    - traits that link plants and animals (e.g., elaiosomes of plants)
- SEFs of communities?
    - herbivory, biological control, seed dispersal, …
- Correlations between SRFs and SEFs across
    - land-use & climate change gradients
    - local & regional landscape composition

Functional approaches to the Brazilian Caatinga

- SRFs of communties?
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    - ph

Thank you for your attention!

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