Boyd Orr Centre
for Population and
Ecosystem Health

DIVERSITY

Sonia Mitchell
Richard Reeve
Louise Matthews
Christina Cobbold
Tom Leinster

LOTS OF TYPES OF DIVERSITY

Alpha

Beta

Gamma

AND LOTS OF MEASURES OF DIVERSITY

Species richness

Shannon entropy

Simpson's index

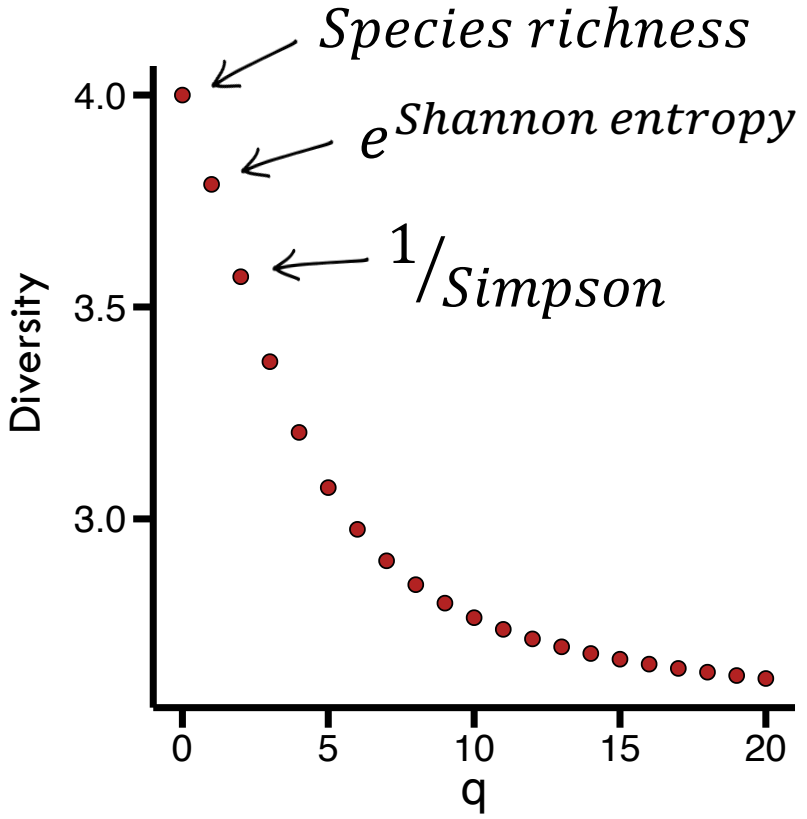
Berger-Parker

Hill, M. (1973) Diversity and evenness... *Ecology* (54) 2: 427-32.

Jost, L. (2006) Entropy and diversity. *Oikos* (2) 2: 363-75.

HILL NUMBERS

$$^{q}D(\boldsymbol{p}) = \mathrm{M}_{1-q}(\boldsymbol{p}, \boldsymbol{p}^{-1})$$



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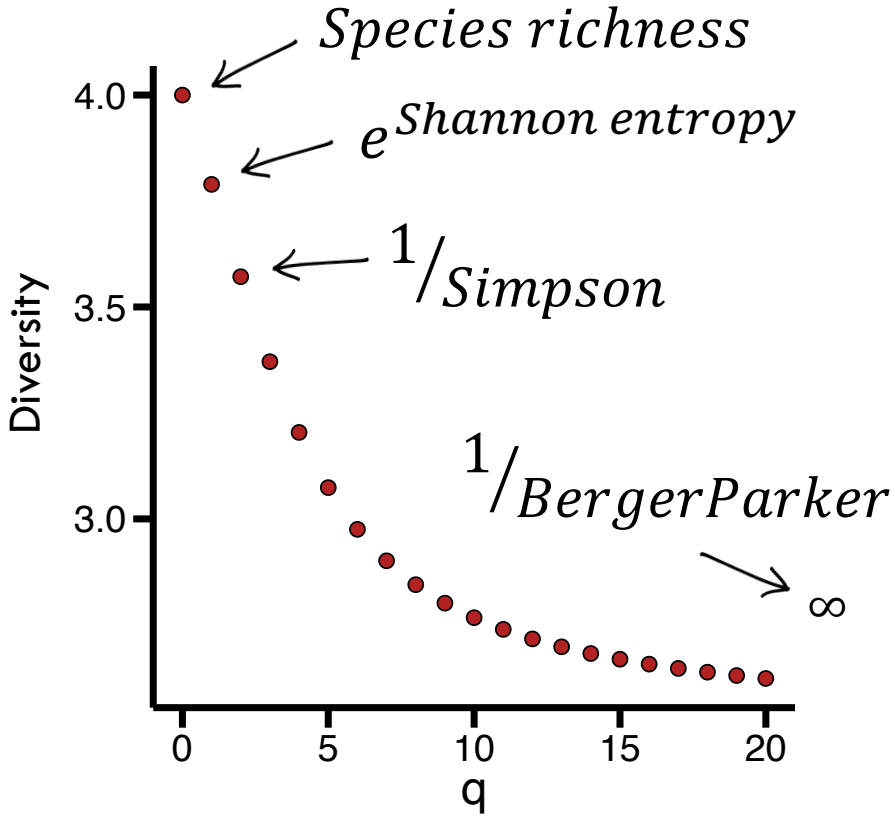

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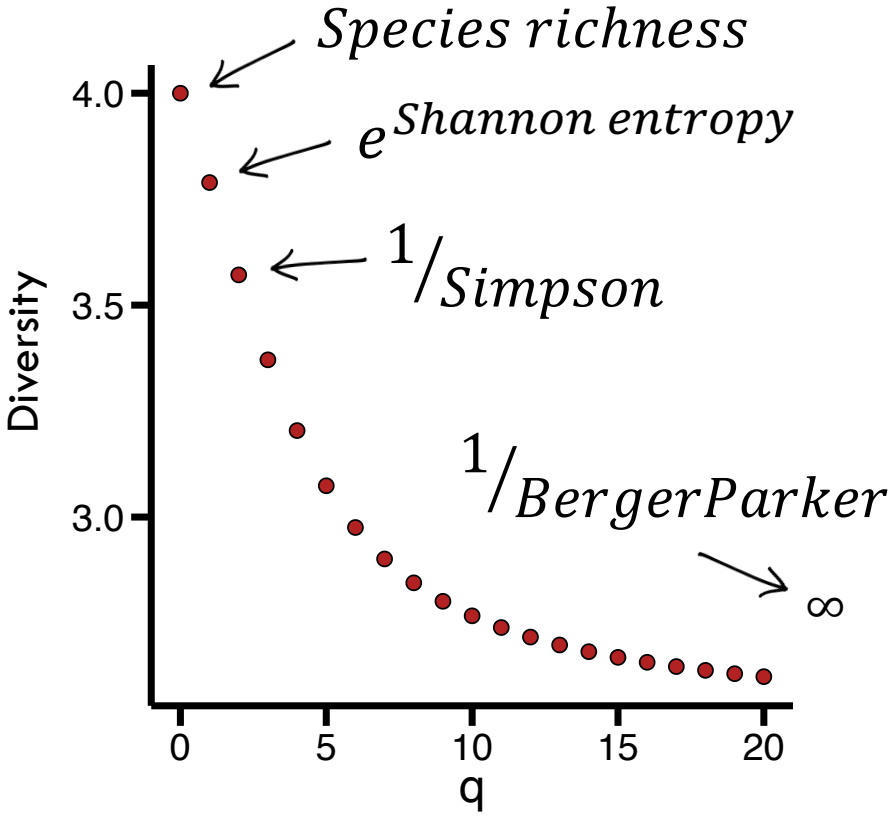
Jost, L. (2006) Entropy and diversity. *Oikos* (2) 2: 363-75.

HILL NUMBERS

$$ {}^{q}D(\boldsymbol{p}) = \mathrm{M}_{1-q}(\boldsymbol{p}, \boldsymbol{p}^{-1}) $$

'a diversity index is not necessarily itself "diversity"'

– Hill, 1973



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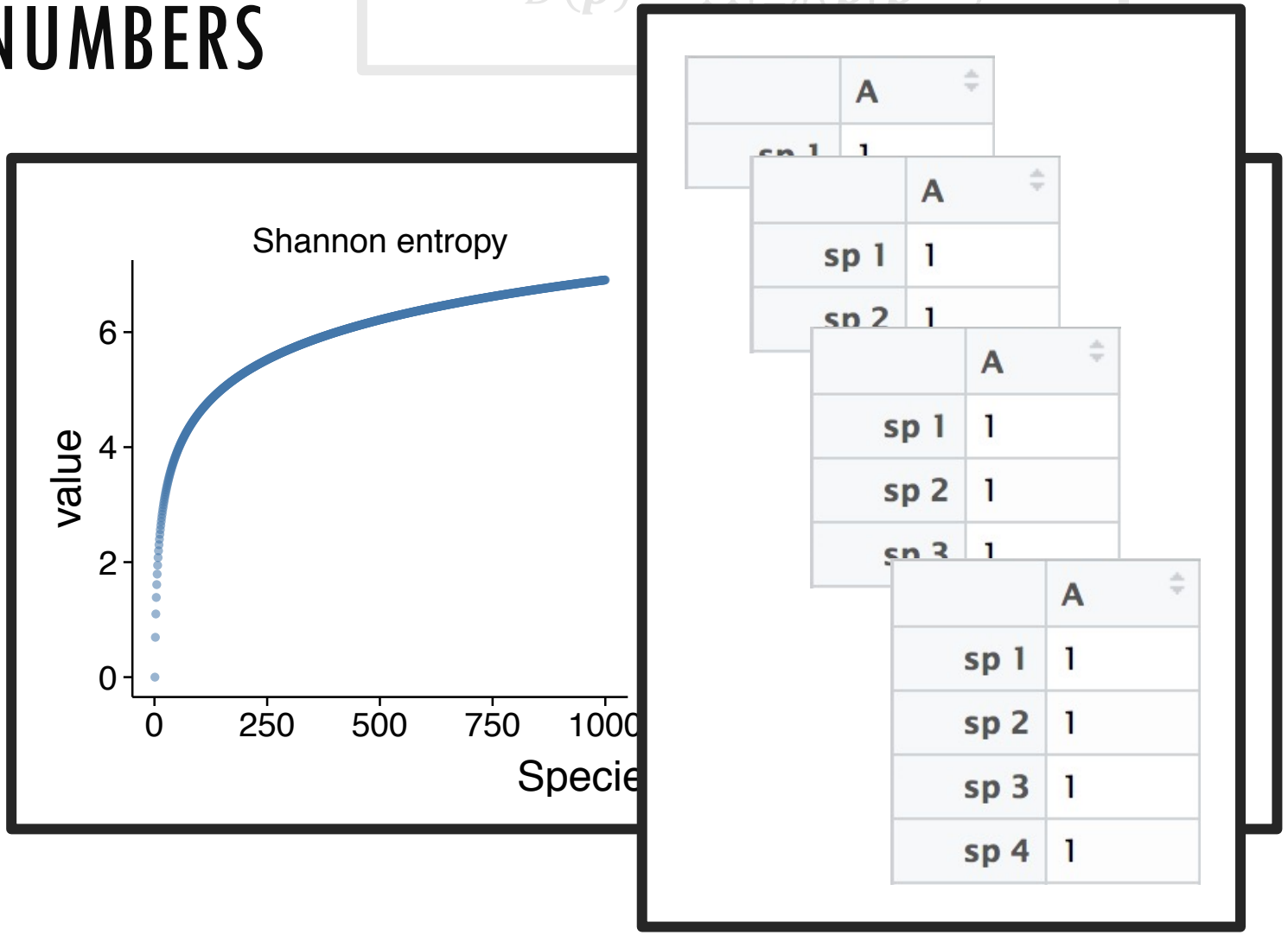
EFFECTIVE NUMBERS

$$^{q}D(\boldsymbol{p}) = \mathrm{M}_{1-q}(\boldsymbol{p}, \boldsymbol{p}^{-1})$$



Hill, M. (1973) Diversity and evenness... *Ecology* (54) 2: 427-32.
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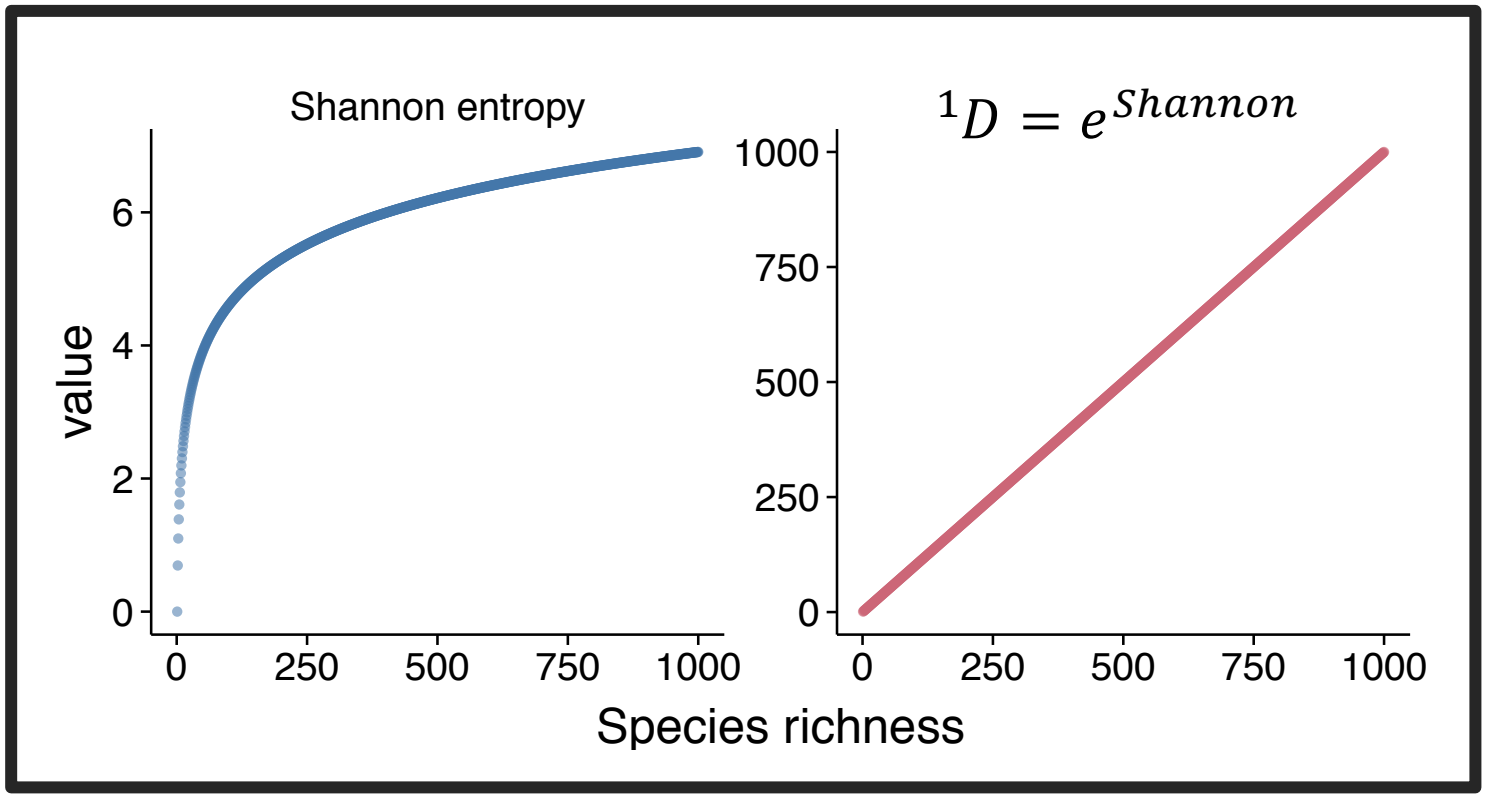
EFFECTIVE NUMBERS

$$^{q}D(\boldsymbol{p}) = \mathrm{M}_{1-q}(\boldsymbol{p}, \boldsymbol{p}^{-1})$$

Equivalent to the amount of **information gained in observing its result**



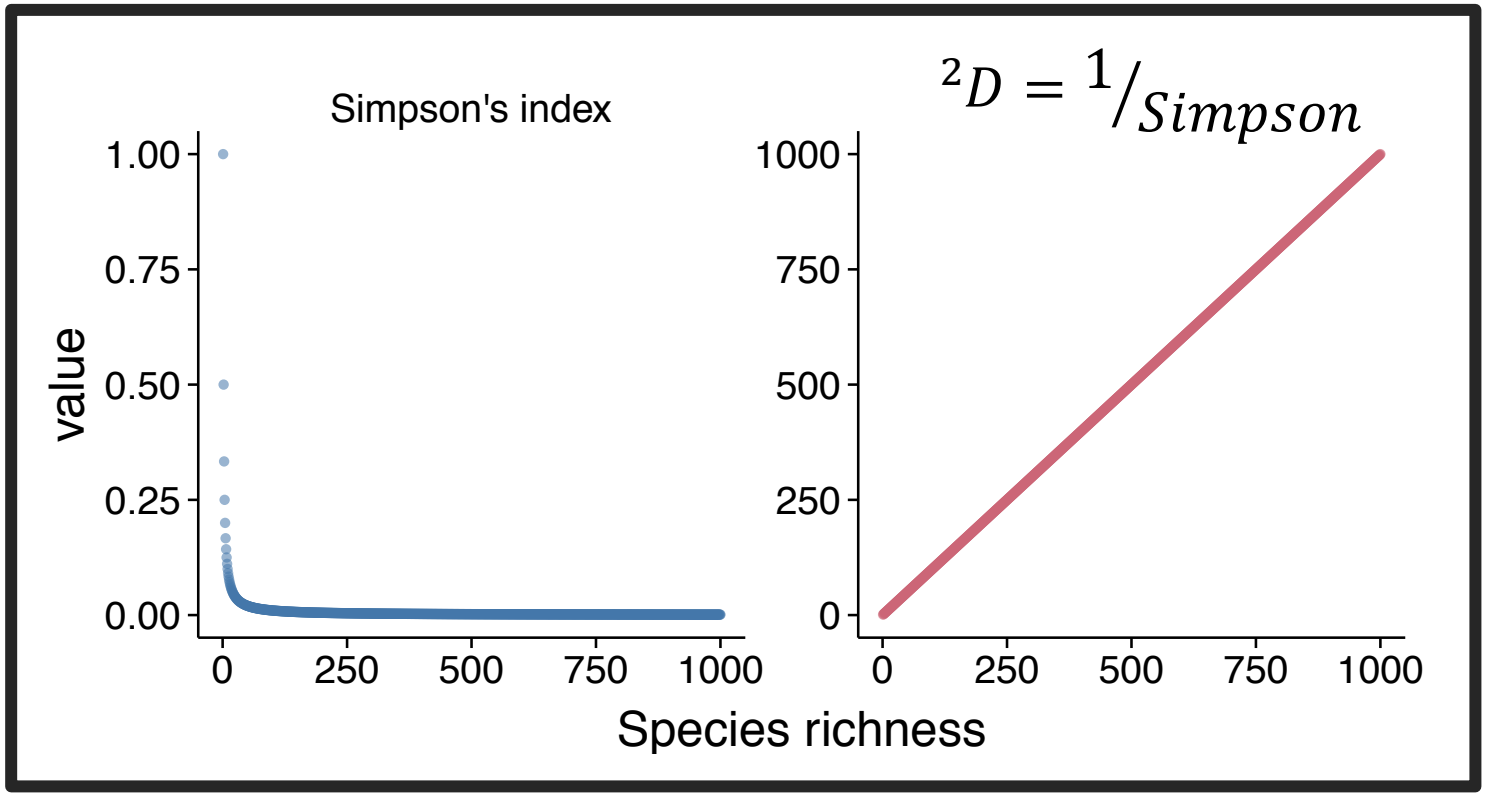
The **average uncertainty associated with predicting the species-identity of a single individual** in a sampling process

Hill, M. (1973) Diversity and evenness... *Ecology* (54) 2: 427-32.
Jost, L. (2006) Entropy and diversity. *Oikos* (2) 2: 363-75.

EFFECTIVE NUMBERS

$$^{q}D(\boldsymbol{p}) = \mathrm{M}_{1-q}(\boldsymbol{p}, \boldsymbol{p}^{-1})$$

The number of equally common species in an equivalent community of equal diversity



The **probability** with which two randomly selected individuals will **belong to the same species**

Hill, M. (1973) Diversity and evenness... *Ecology* (54) 2: 427-32.
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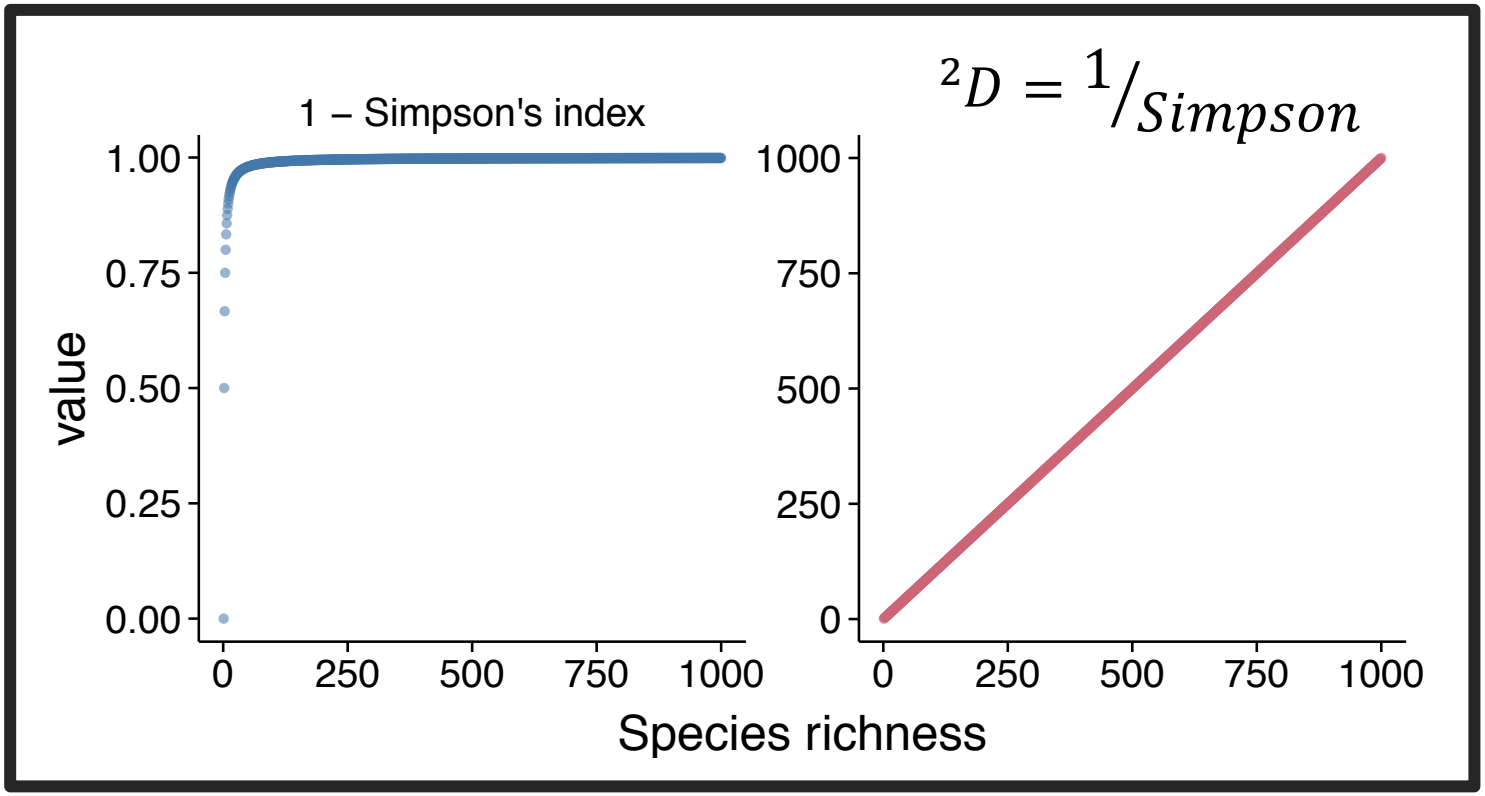


The **probability** with which two randomly selected individuals will **belong to the different species**

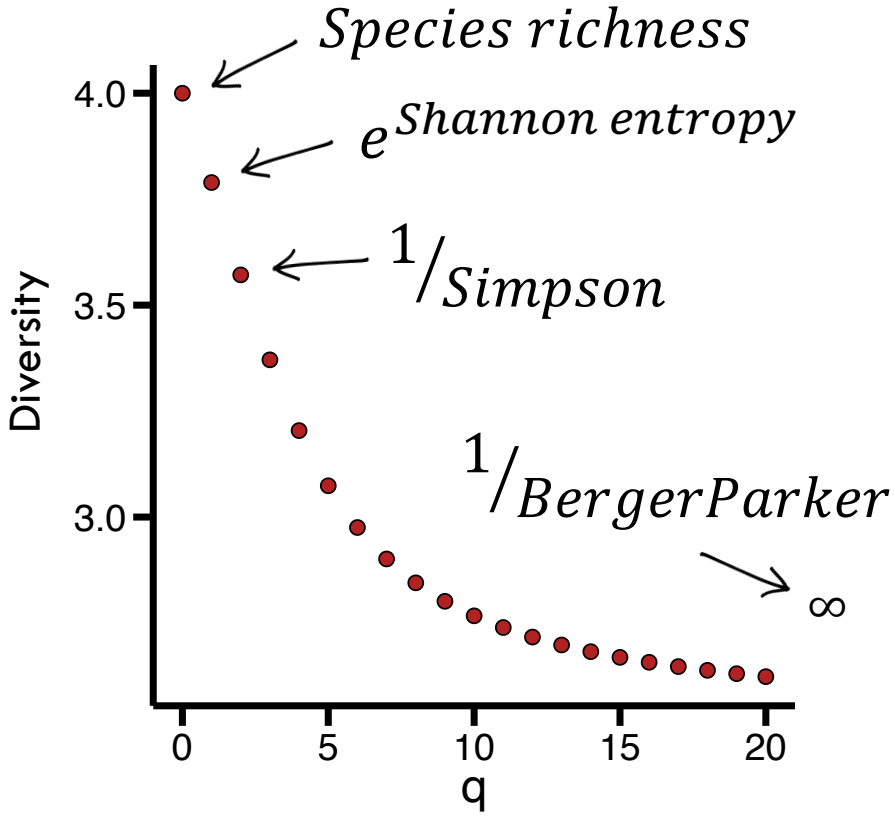
Hill, M. (1973) Diversity and evenness... *Ecology* (54) 2: 427-32.
Jost, L. (2006) Entropy and diversity. *Oikos* (2) 2: 363-75.

EFFECTIVE NUMBERS

$$ {}^{q}D(\boldsymbol{p}) = \mathrm{M}_{1-q}(\boldsymbol{p}, \boldsymbol{p}^{-1}) $$

The number of equally abundant species necessary to produce the observed value of diversity

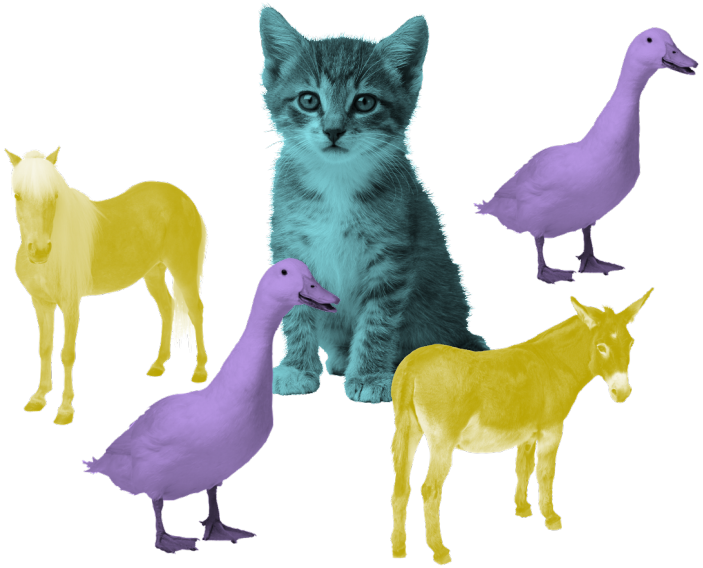
in units of "number of species"

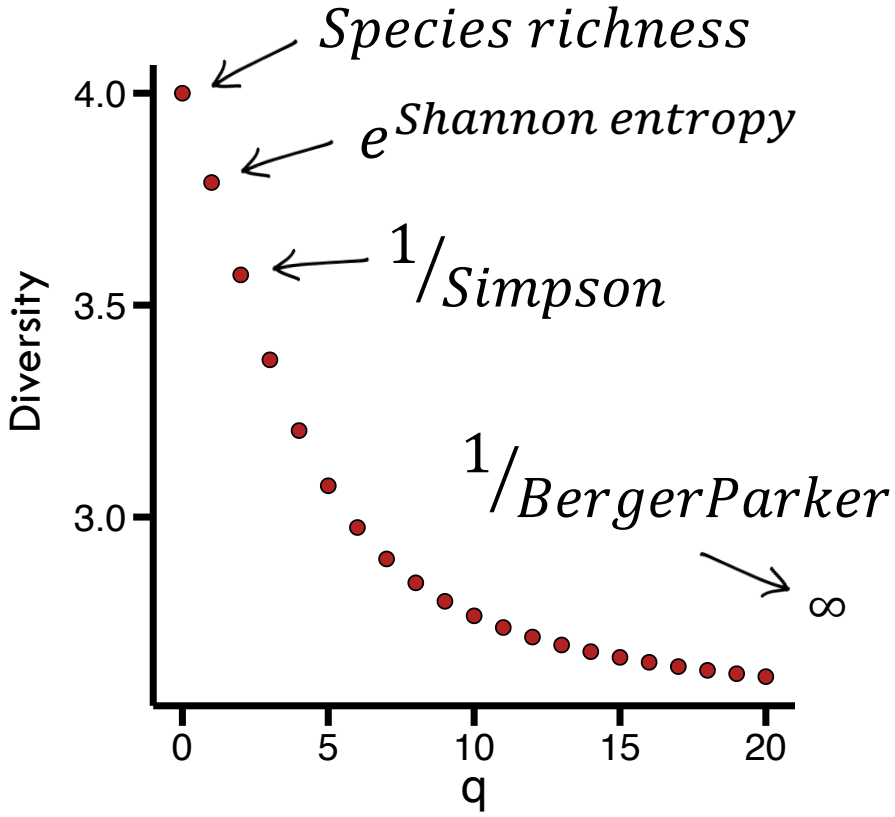


Leinster, T. and Cobbold, C. (2012) Measuring diversity: The importance of species similarity. *Ecology* (93) 3

SIMILARITY

$$ {}^{q}D(\boldsymbol{p}) = \mathrm{M}_{1-q}(\boldsymbol{p}, \boldsymbol{p}^{-1}) $$





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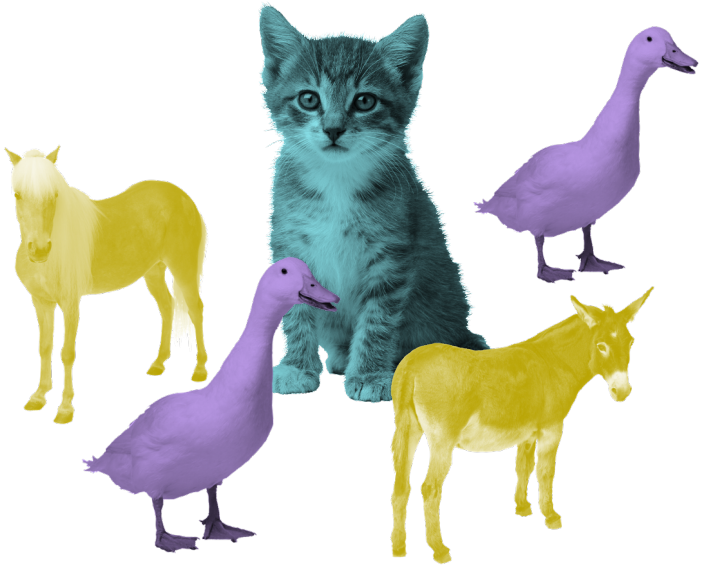
SIMILARITY

$$^{q}D(\boldsymbol{p}) = \mathrm{M}_{1-q}(\boldsymbol{p}, \boldsymbol{p}^{-1})$$

$$^{q}D(\boldsymbol{p}) = \mathrm{M}_{1-q}(\boldsymbol{p}, (\boldsymbol{Z}\boldsymbol{p})^{-1})$$



```
> Z
        ducks cats horses donkeys
ducks       1    0    0.0     0.0
cats        0    1    0.0     0.0
horses      0    0    1.0     0.9
donkeys     0    0    0.9     1.0
```

Leinster, T. and Cobbold, C. (2012) Measuring diversity: The importance of species similarity. *Ecology* (93) 3

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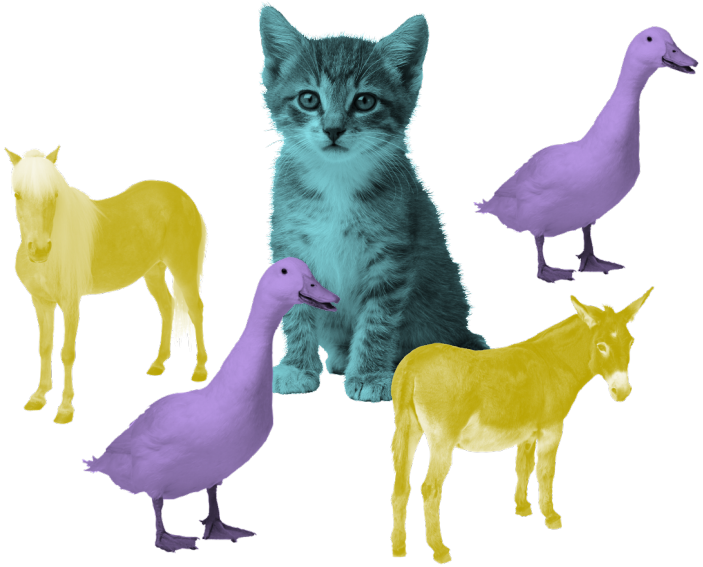

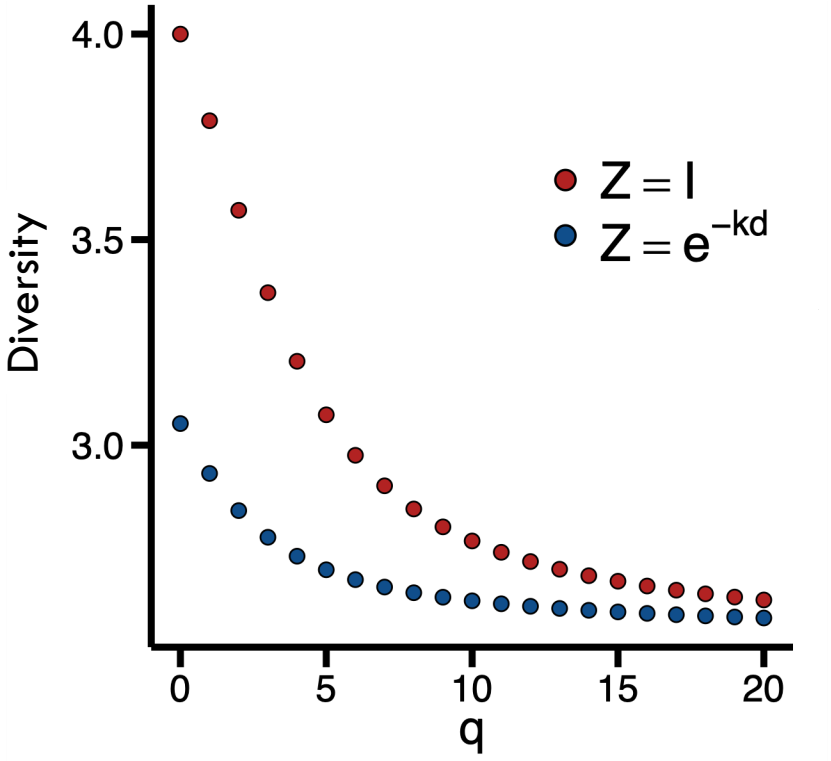

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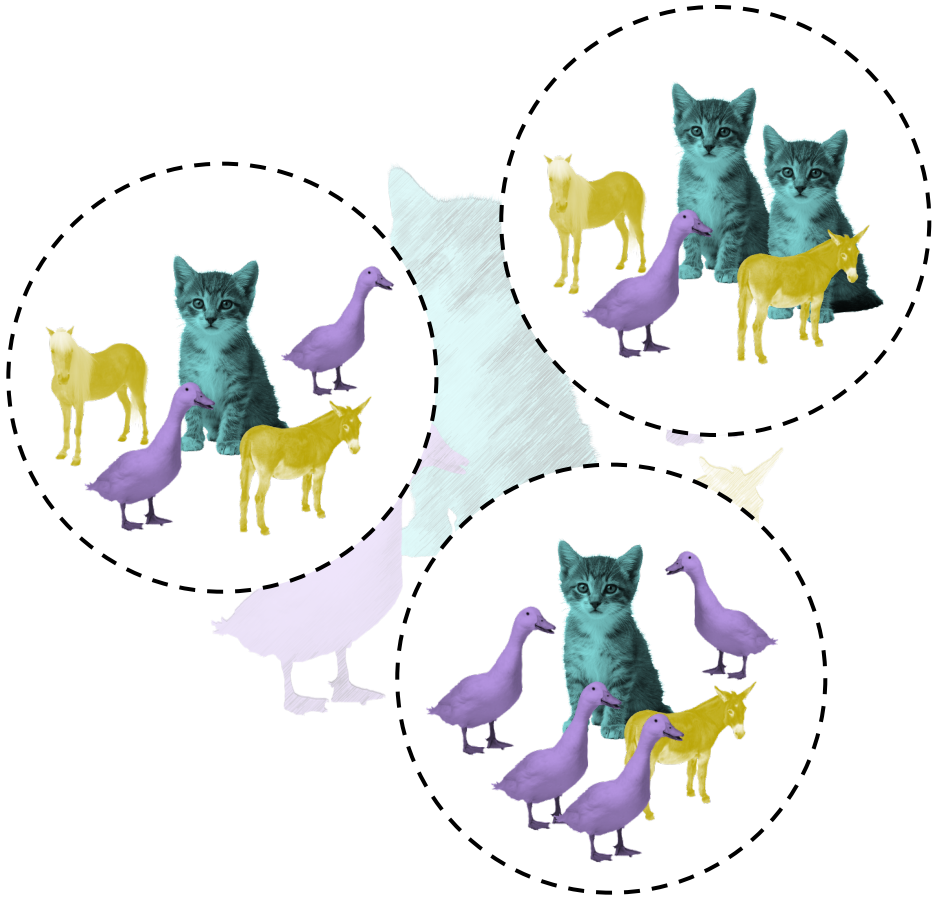
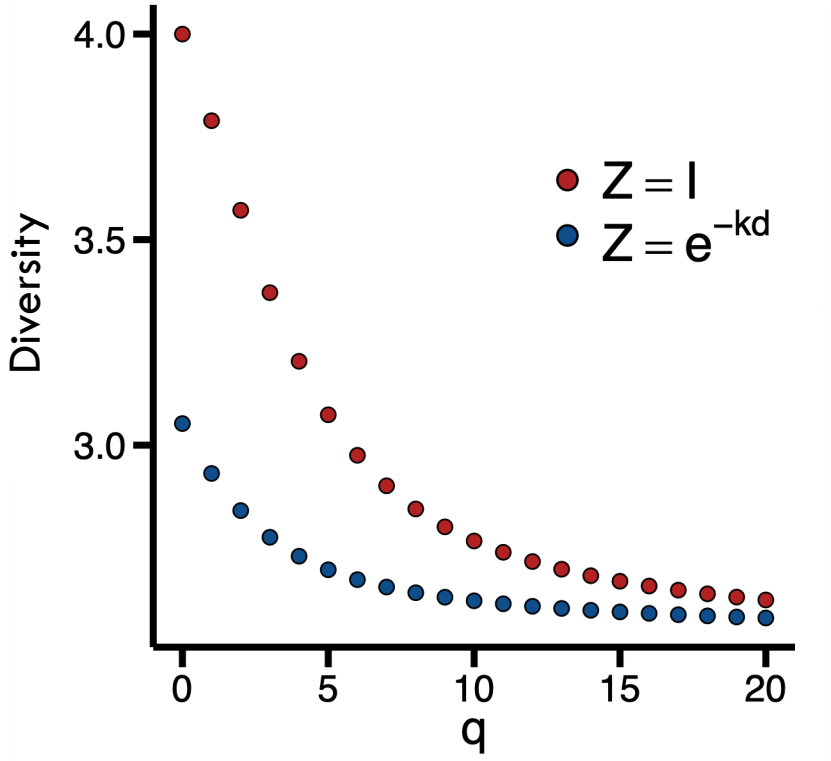




Reeve, R. et al. (2016) How to partition diversity. *arXiv:1404.6520 [q-bio.QM]*:.

PARTITIONING DIVERSITY

Metacommunity diversity

$^{q}\bar{A}^{\mathbf{Z}} = M_{1-q}\left(\boldsymbol{w}, {}^{q}\bar{\alpha}_j^{\mathbf{Z}}\right)$	Normalised alpha: average similarity-sensitive **diversity** of subcommunities (norm_meta_alpha)
$^{q}R^{\mathbf{Z}} = M_{1-q}\left(\boldsymbol{w}, {}^{q}\rho_j^{\mathbf{Z}}\right)$	Raw beta (reversed): average **redundancy** of subcommunities (raw_meta_rho)
$^{q}\bar{R}^{\mathbf{Z}} = M_{1-q}\left(\boldsymbol{w}, {}^{q}\bar{\rho}_j^{\mathbf{Z}}\right)$	Normalised beta (reversed): average **representativeness** of subcommunities (norm_meta_rho)
$^{q}B^{\mathbf{Z}} = M_{1-q}\left(\boldsymbol{w}, {}^{q}\beta_j^{\mathbf{Z}}\right)$	Raw beta: average **distinctiveness** of subcommunities (raw_meta_beta)
$^{q}\bar{B}^{\mathbf{Z}} = M_{1-q}\left(\boldsymbol{w}, {}^{q}\bar{\beta}_j^{\mathbf{Z}}\right)$	Normalised beta: **effective number of distinct subcommunities** (norm_meta_beta)
$^{q}G^{\mathbf{Z}} = M_{1-q}\left(\boldsymbol{w}, {}^{q}\gamma_j^{\mathbf{Z}}\right)$	Gamma: **metacommunity** similarity-sensitive diversity (meta_gamma)

Subcommunity diversity

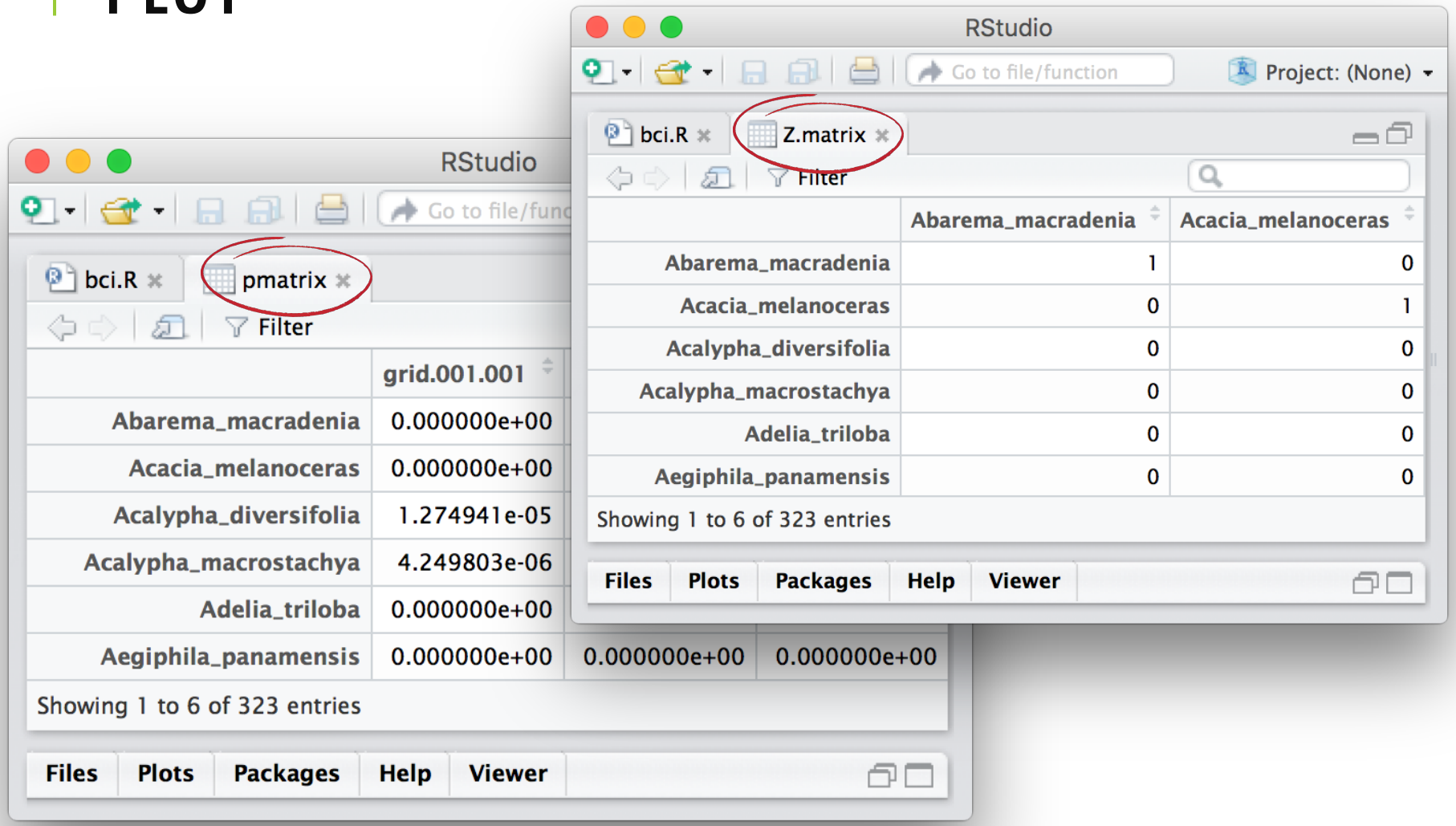
$^{q}\bar{\alpha}_j^{\mathbf{Z}} = M_{1-q}\left(\overline{\boldsymbol{P}}_{.j}, \left(\boldsymbol{Z}\overline{\boldsymbol{P}}_{.\boldsymbol{j}}\right)_i^{-1}\right)$	Normalised alpha: similarity sensitive **diversity** of subcommunity *j* in isolation (norm_sub_alpha)
$^{q}\rho_j^{\mathbf{Z}} = M_{1-q}\left(\overline{\boldsymbol{P}}_{.j}, (\boldsymbol{Zp})_i / \left(\boldsymbol{ZP}_{.\boldsymbol{j}}\right)_i\right)$	Raw beta (reversed): **redundancy** of subcommunity *j* (raw_sub_rho)
$^{q}\bar{\rho}_j^{\mathbf{Z}} = M_{1-q}\left(\overline{\boldsymbol{P}}_{.j}, (\boldsymbol{Zp})_i / \left(\boldsymbol{Z}\overline{\boldsymbol{P}}_{.\boldsymbol{j}}\right)_i\right)$	Normalised beta (reversed): **representativeness** of subcommunity *j* (norm_sub_rho)
$^{q}\beta_j^{\mathbf{Z}} = 1/{}^{q}\rho_j^{Z}$	Raw beta: **distinctiveness** of subcommunity *j* (raw_sub_beta)
$^{q}\bar{\beta}_j^{\mathbf{Z}} = 1/{}^{q}\bar{\rho}_j^{Z}$	Normalised beta: estimate of **effective number of distinct subcommunities** (norm_sub_beta)
$^{q}\gamma_j^{\mathbf{Z}} = M_{1-q}\left(\overline{\boldsymbol{P}}_{.j}, (\boldsymbol{Zp})_i^{-1}\right)$	Gamma: **contribution** per individual toward metacommunity diversity (sub_gamma)

BIODIVERSITY

Barro-Colorado Island Forest census plot

Condit, R., S. Lao, R. Pérez, S. B. Dolins, R. Foster, and S Hubbell. 2012. Barro Colorado Forest Census Plot Data (Version 2012).

BARRO-COLORADO ISLAND FOREST CENSUS PLOT



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BARRO-COLORADO ISLAND FOREST CENSUS PLOT

Metacommunity = 50 ha forest plot

Subcommunities = 1250 $[20 \times 20\ \mathrm{m}]$ quadrats

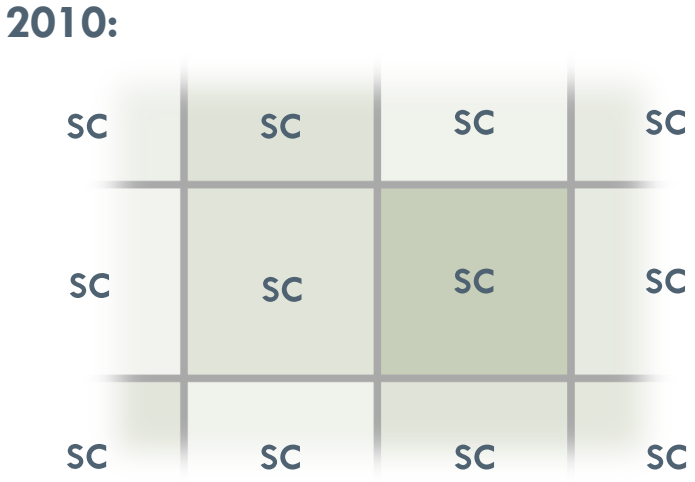
Spatial biodiversity: Seventh census (2010)

Naïve-species similarity, all species are completely distinct: $\boldsymbol{Z = I}$

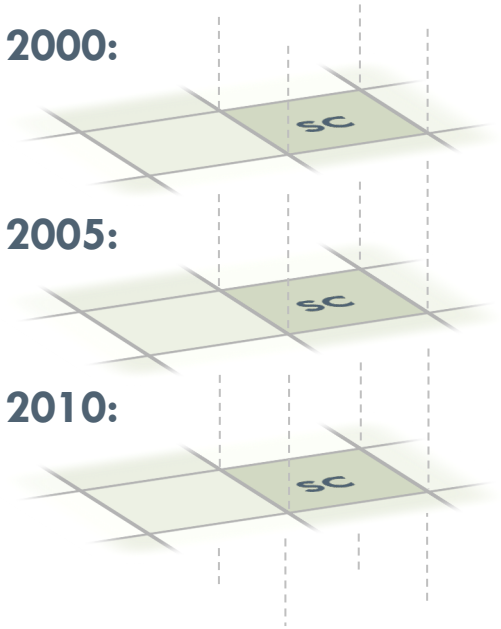
Condit, R., S. Lao, R. Pérez, S. B. Dolins, R. Foster, and S Hubbell. 2012. Barro Colorado Forest Census Plot Data (Version 2012).

BARRO-COLORADO ISLAND FOREST CENSUS PLOT

Spatial



Temporal

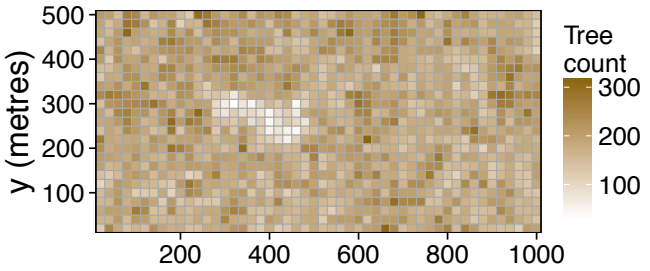


7 tree censuses

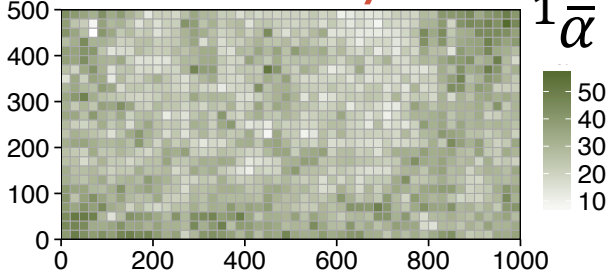
at approximately 5-year intervals from 1981-2010

Condit, R., S. Lao, R. Pérez, S. B. Dolins, R. Foster, and S Hubbell. 2012. Barro Colorado Forest Census Plot Data (Version 2012).

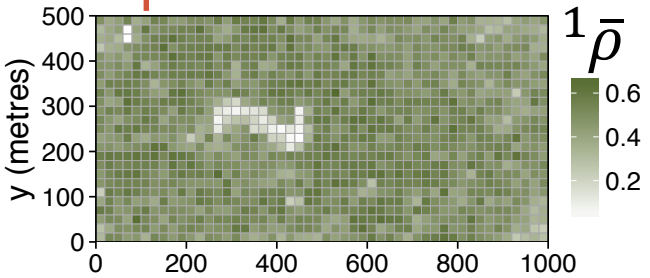
SPATIAL BIODIVERSITY



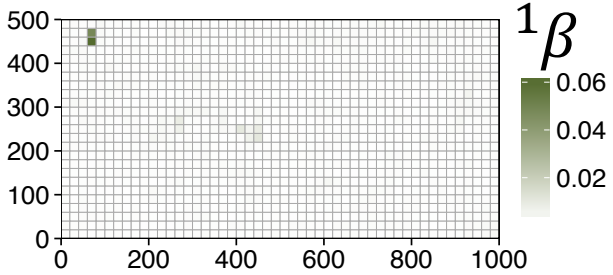
diversity



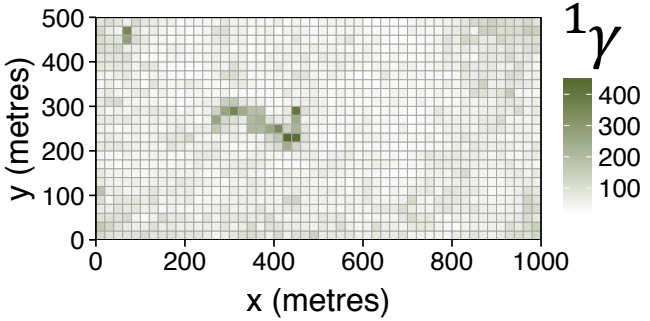
representativeness



distinctiveness



contribution

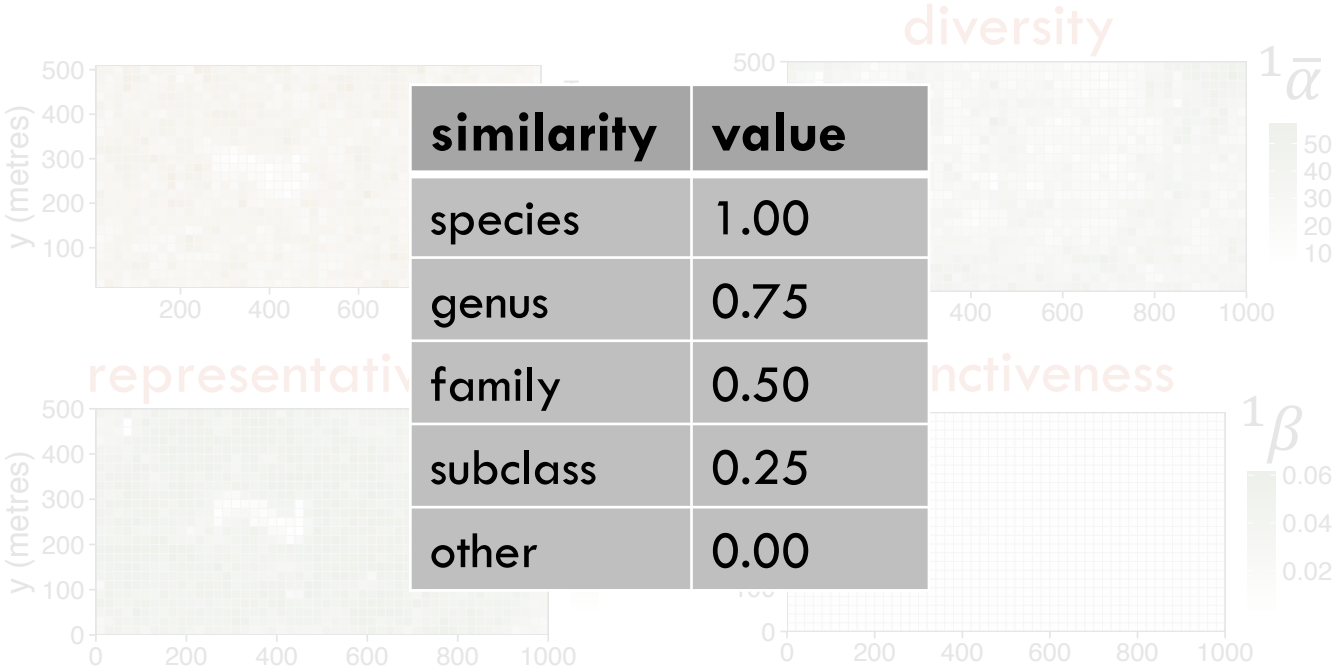


Shimatani

Shimatani, K. (2001) On the measurement of species diversity incorporating species differences. *Oikos* (93)1: 135-47

TAXONOMIC DIVERSITY

similarity	value
species	1.00
genus	0.75
family	0.50
subclass	0.25
other	0.00



Reeve, R. et al. (2016) How to partition diversity.
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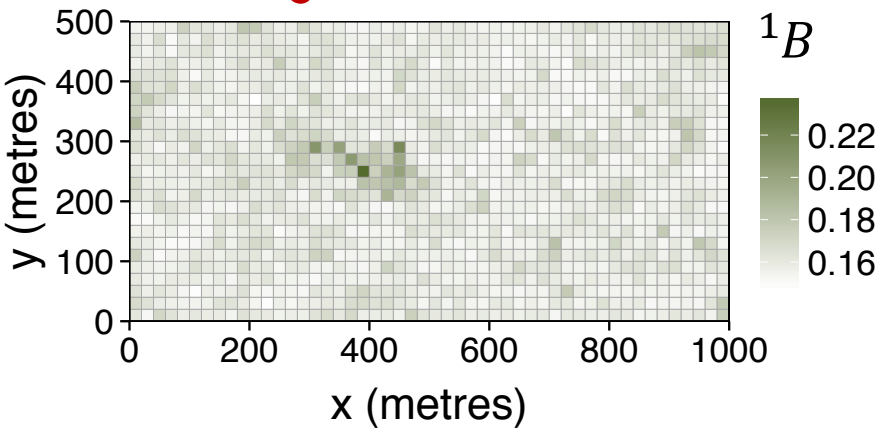
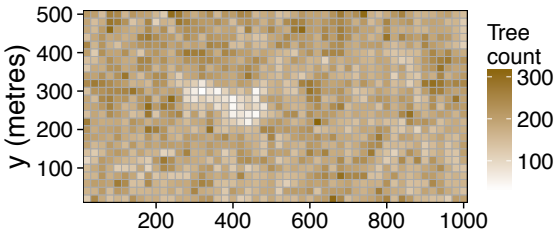
TEMPORAL BIODIVERSITY

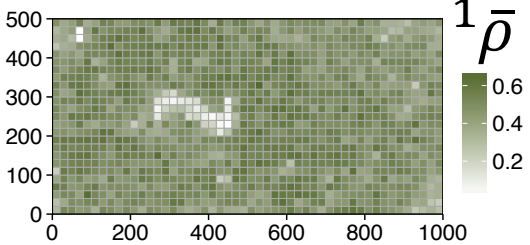
average distinctiveness



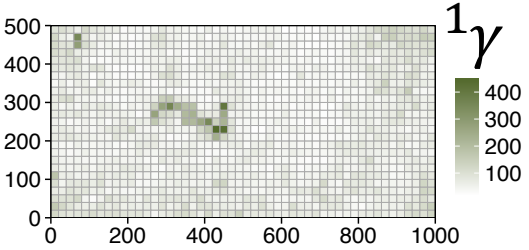
81/82



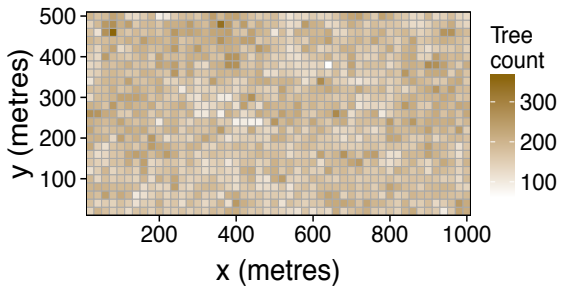
representativeness

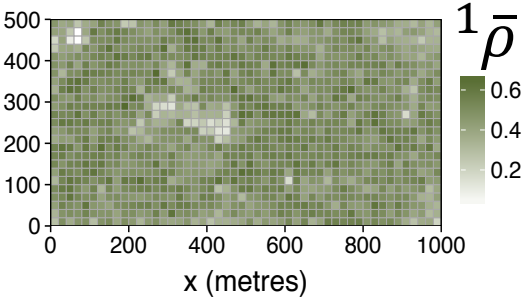


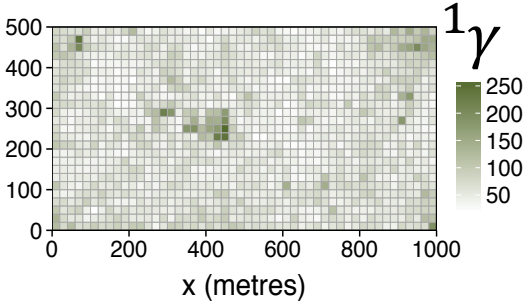
contribution



2010







R PACKAGES

- rdiversity
  - Our package for diversity measurement
  - Opinionated about the best way to measure diversity
  - https://github.com/boydorr/rdiversity
  - http://boydorr.github.io/rdiversity
  - https://cloud.r-project.org/web/packages/rdiversity/index.html
- vegan
  - The most popular R package for diversity measurement
  - A package that covers most popular ways of measuring diversity
  - https://github.com/vegandevs/vegan
  - https://cran.r-project.org/web/packages/vegan/index.html

See also:

- iNEXT