Site Description

1. Diversity indices
2. Species abundance models
3. Species – area relationship

Shannon diversity

$$H = -\sum_{j=1}^{S} p_j \log_b p_j$$

Originally information theory with base $b = 2$: Average length in bits of code with shortest possible unique coding

- The limit reached when code length is $-\log_2 p_i$: longer codes for rare species.

Biologists use natural logarithms (base $b = \mathrm{e}$), and call it H'

Information theory makes no sense in ecology: Better to see only as a variance measure for class data.

Simpson diversity

The probability that two randomly picked individuals belong to the same species in an infinite community is $P = \sum_{i=1}^{S} p_i^2$.

Can be changed to a diversity measure (= increases with complexity):

1. Probability that two individuals belong to *different* species: $1 - P$.
2. Number of species in a community with the same probability P, but all species with equal abundances: $1/P$.

Claimed to be ecologically more meaningful than Shannon diversity, but usually very similar.

Hill numbers

Common measures of diversity are special cases of Rényi entropy;

$$H_a = \frac{1}{1-a} \log \sum_{i=1}^{S} p_i^a$$

Mark Hill proposed using $N_a = \exp(H_a)$ or the “Hill number”:

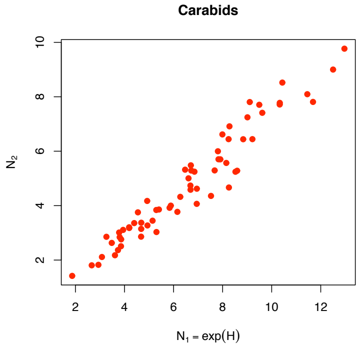
$$\begin{array}{lllllll} H_0 & = & \log(S) & N_0 & = & S & \text{Number of species} \\ H_1 & = & -\sum_{i=1}^{S} p_i \log p_1 & N_1 & = & \exp(H_1) & \text{exp Shannon} \\ H_2 & = & -\log \sum_{i=1}^{S} p_i^2 & N_2 & = & 1/\sum_{i=1}^{S} p_i^2 & \text{Inverse Simpson} \end{array}$$

Sensitivity to rare species decreases with increasing a: N_1 and N_2 are little influenced and nearly linearly related.

All Hill numbers in same units: “virtual species”.

Choice of index

- Diversity indices are only variances of species abundances.
- It is not so important which index is used, since all sensible indices are very similar.



Evenness

"If everything else remains constant", diversity increases when

1. Number of species S increases, or
2. Species abundances p_i become more equal.

Evenness: Hidden agenda to separate these two components

For a given number of species S, diversity is maximal when all probabilities $p_i = 1/S$: in Shannon index $H'_{\max} = \log(S)$

Pielou's evenness is the proportion of observed and maximal diversity

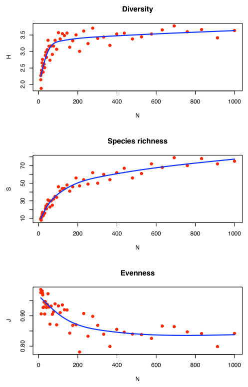
$$J' = \frac{H'}{H'_{\max}}$$

Sample size and diversity

With increasing sample size

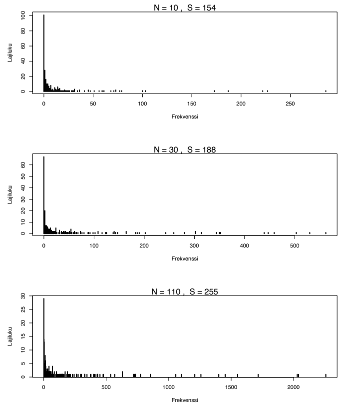
- Number of species S increases
- Diversity (N_1 or N_2) stabilizes
- Evenness decreases

Diversity little influenced by rare species: a variance measure.
Evenness based on twisted idea.



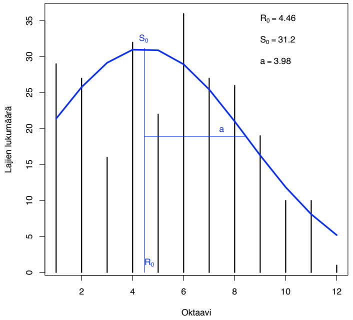
Logarithmic series

- R.A. Fisher in 1940's
- Most species are rare, and species found only once are the largest group
- In larger samples, you may find more individuals of rare species, but you find new rare species



Log-Normal model

- Preston did not accept Fisher's log-series, but assumed that rare species end with sampling
- Plotted number of species against 'octaves': doubling classes of abundance
- Modal class in higher octaves, and not so many rare species
- Canonical standard model of our times

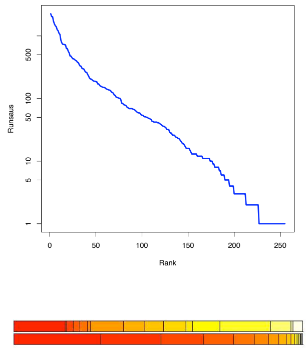


Ranked abundance diagrams

- Horizontal axis: ranked species
- Vertical axis: Logarithmic abundance

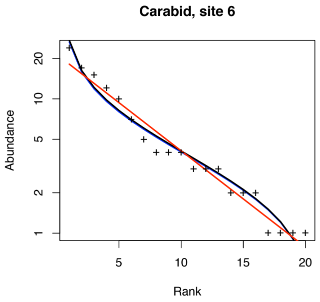
The shape of abundance distribution clearly visible:

- Linear: Pre-emption model
- Sigmoid: Log-normal or broken-stick



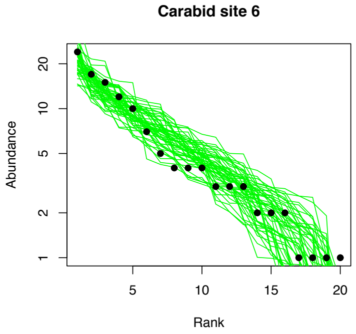
Fitting RAD models

- Pre-emption model
  - Species abundances decay by constant proportion.
  - A line in the ranked abundance diagram.
- Log-normal model
  - Species abundances distributed Normally
  - Sigmoid: excess of both abundant and rare species to pre-emption model.



Broken Stick

- Species 'break' a community ('stick') simultaneously in S pieces.
- No real hierarchy, but chips arranged in rank order:
- Result looks sigmoid, and can be fitted with log-Normal model.

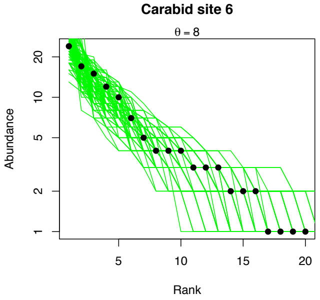


Hubbell's abundance model

Ultimate diversity parameter θ

- $\theta = 2J_M\nu$, where J_M is meta-community size and ν evolution speed
- θ and J define the abundance distribution
- Simulations can be used for estimating θ.

Species generator $\theta/(\theta+j-1)$ gives the probability that jth individual is a new species for the community.



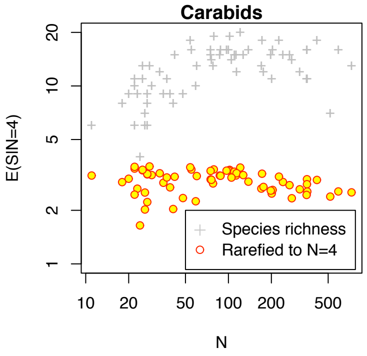
Species richness: The trouble begins

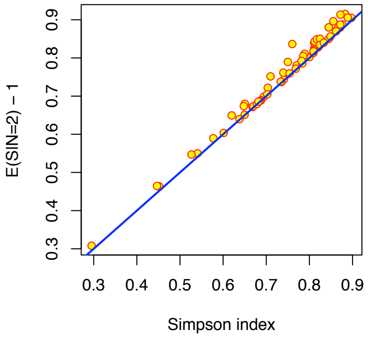
- Species richness increases with sample size: can be compared only with the same size.
- Rare species have a huge impact in species richness.
- Rarefaction: Removing the effects of varying sample size.
- Sample size must be known in individuals: Equal area does not imply equal number of individuals.
- Plants often difficult to count.

Rarefaction

Rarefy to a lower, equal number of individuals

Only a variant of Simpson's index



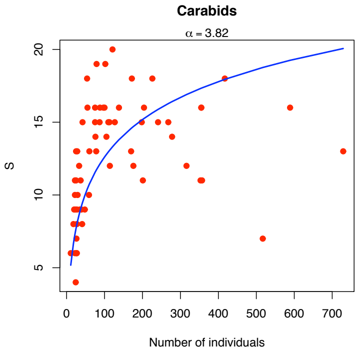


Species richness and sample size

Fisher log-series predicts:

$$S = \alpha \ln\left(1 + \frac{N}{\alpha}\right)$$

Species never end, but the rate of increase slows down.



Species – Area models

- Island biogeography: $S = cA^z$.
- Parameter c is uninteresting, but z should describe island isolation.
- Regarded as universally good: Often the only model studied, so no alternatives inspected.
- Assuming that doubling area A brings along a constant number of new species fits often better.