BIOL 410 Population and Community Ecology

Community composition

Ecological communities

Species richness (number of species)

Questions of ecological communities

- For a given community, how many species are present and what are their relative abundances?
- How many species are rare?
- How many species are common?
- How can the species in the community be grouped
- What type of interactions occur between the species groups (guilds)?

Community structure

- Diversity
  - Does a community contain a divers range of species or few
- Relative Abundance
  - What can we learn from the relative abundance of species within a community?
- Dominance
  - Is a community dominated (numerically of functionally) by some species?
- Trophic structure
  - How is the community organized and how does energy (food) flow through it?

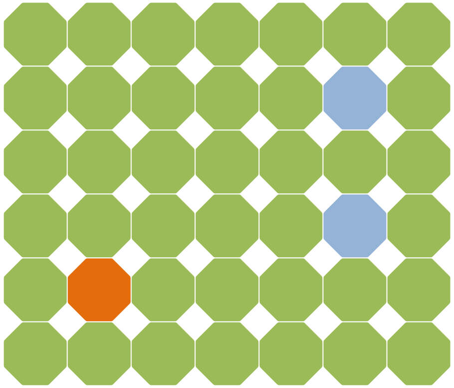
Species diversity

- What determines the number and kinds of species that occur in a particular place?
- Why do number and kinds of species vary from place to place?

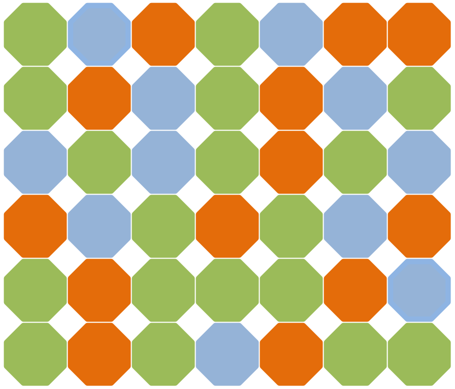
Species diversity

- Species diversity consists of two components

1. Species Richness
    - The total number of species in an area
    - Simple summation



2. Species Evenness
    - How evenly the species are represented in the area
    - E.g. do most of the individuals belong to one species?

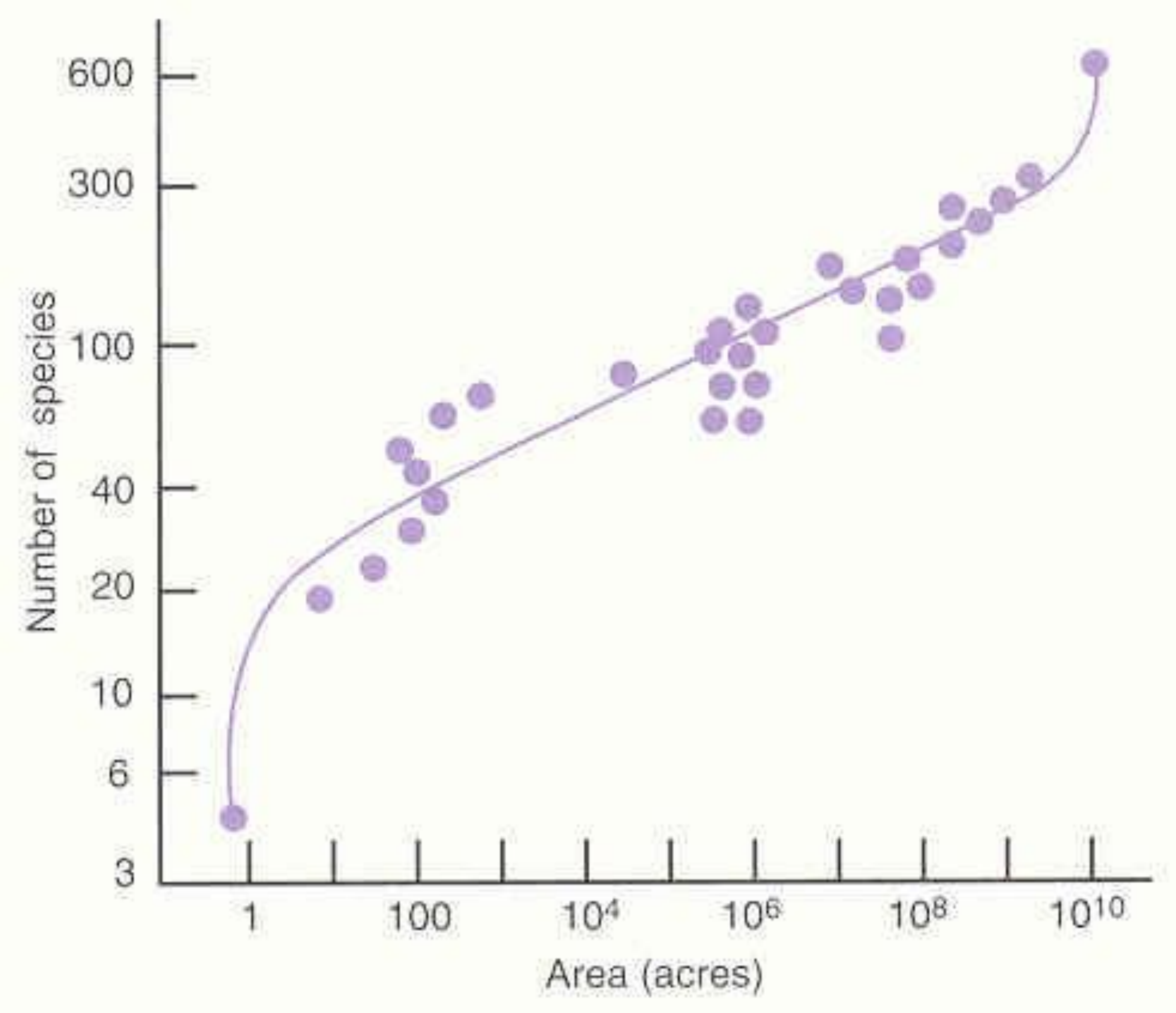


Species richness

Just count the number of species

- Detection bias between species?
  - Within habitat types?
  - Between habitat types?
- Sample effort (size) bias?

Species richness



Relationship between sampling area and bird species richness in North America

Species richness

Margalef's index

$$I_{Margalef} = \frac{S-1}{\ln(N)}$$

S: total number of species in area sampled
N: total number of individuals observed

Menhinick's index

$$I_{Menhinick} = \frac{S}{\sqrt{N}}$$

- Attempts to estimate species richness independent of sample size
- Index will be independent of the number of individuals in the sample only if the relationship between S (or S-1) and ln(N) or sqrt(N) is linear
  - This is seldom the case

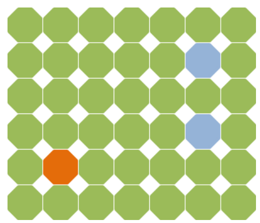
Species Richness

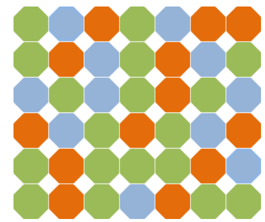
Margalef's and Menhinick's index

- Interpretation
  - The higher the index the greater the richness
  - E.g.
    - S = 6 and N = 50
      - Margalef index = 1.28, Mehinick index = 0.85
    - S = 6 and N = 20
      - Margalef index = 1.67, Mehinick index = 1.34

Species diversity

species diversity = f(species richness, species evenness)





- Many calculations use species proportions (not absolute numbers)

$$p_i = x_i / \sum_{i=1}^{s} x_i$$

- X is observed abundance of species I (numbers, biomass, cover etc.)
- S is the number of species
- P_i is the proportion of individuals belonging to species I

Species richness

$$D_0 = \sum_{i}^{s} {p_i}^0$$

Simpson's Index

- Edward Simpson, British Statistician
  - Developed index to measure the degree of concentration when individuals are classified by types (i.e. a measure of the degree of dominance)
  - Asked: "if I draw two individuals at random from this community, what is the probability that they will belong to the same species?"
    - Probability of drawing species i is p_i
    - Probability of drawing species I twice is p_i^2
    - Sum of the value for all species is the Simpson's index of dominance

$$D_{Simpson} = \sum {p_i}^2$$

Simpson's index of dominance

- In small samples, the probability of drawing species i the second time is not the same as the first since there are now fewer individuals

- In small populations the index is:

$$D_{Simpson} = \frac{\sum n_i(n_i - 1)}{N(N - 1)}$$

- n total number of organisms of a particular species
- N total number of organisms of all species

Simpson's index of diversity

- Species diversity is given as the counter to dominance and calculated as either:

$$I_{CompSimp} = 1 - D_{Simpson}$$

Gini-Simpson index

$$I_{InvSimp} = 1/D_{Simpson}$$

- Range 0 to 1
- The higher the index the greater the diversity

Simpson's Index

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

$$\sum n(n-1) = 264$$

	n	n(n - 1)
Species A	12	132
Species B	3	6
Species C	7	42
Species D	4	12
Species E	9	72
$\sum n(n-1)$		**264**

N = total number of all individuals = 35

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

$$D = \frac{264}{1190} = 0.22184$$

Shannon's index

- Measure of the entropy (disorder) of a sample
  - Measures the "information content" of a sample unit
    - Field of information theory
    - i.e. have a string of letters (r,e,f,r,f,f,e,a), and want to predict which letter will be next in the string
      - More letters = more difficult
      - More even the letters = more difficult

  - Degree of uncertainty associated with predicting the species of an individual picked at random from a community
    - i.e. if diversity is high, you have a poor chance of correctly predicting the species of the next randomly selected individual
      - Increased species number reduces chance of correctly predicting species
      - Decreased evenness reduces chance of correctly predicting species

Shannon's diversity index

- H or H'

$$H' = -\sum_{i}^{s} p_i \ln(p_i)$$

Log 2, 10

- s = number of species
- p_i = proportion of individuals belonging to species I

- Range usually between 1.5 and 3.5
- Low value indicates low diversity
  - High information content
- High value indicates high diversity
  - Large number of species
  - Even distribution of species

Shannon's diversity index

	Sp A	Sp B	p_A	p_B
Plot 1	99	1	0.99	0.01
Plot 2	50	50	0.50	0.50

$$H' = -\sum_{i=1}^{2} p_i \log p_i$$

For plot 1

$$H' = -1\left[0.99 \cdot \log(0.99) + 0.01 \cdot \log(0.01)\right] = 0.024$$

For plot 2

$$H' = -1\left[0.5 \cdot \log(0.5) + 0.5 \cdot \log(0.5)\right] = 0.301$$

Species evenness

- How equally abundant are each of the species?
- What is the structure of species relative abundance within a community?
- Can we compare how evenly distributed two communities are

- Rarely are all species equally abundant
  - Some are better competitors, more fecund than others

- Are communities with high species evenness
  - More resilient to disturbances?
  - Harder to invade by a new species?

  - High evenness is often viewed as a sign of ecosystem health

Shannon's index of evenness

- Calculated from the diversity index
- Value of H when all species are equally abundant (i.e. perfect evenness) is ln(S)

$$E_{Shannon} = \frac{H}{\ln(S)}$$

- When the proportions of all species are the same evenness is one
- Value increases as evenness decreases

Simpson's index of evenness

$$E_{Simpson} = \frac{I_{InvSimp}}{S}$$

S = number of species

$$I_{InvSimp} = 1/D_{Simpson}$$

Community diversity metrics

Table 1
Indices quantifying diameter diversity within stands

Index	Influenced by	Theoretical index value range	Reference
Margalef index, $D_{Mg} = (S-1)/\ln(BA)$	Range	$[0, \infty]$	Clifford and Stephenson (1975)
Shannon index, $H' = -\sum_{i=1}^{s} p_i \ln(p_i)$	Range	$[0, \ln(S)]$	Shannon (1948)
Gini coefficient, $GC = \frac{\sum_{j=1}^{n} (2j-n-1)ba_j}{\sum_{j=1}^{n} ba_j(n-1)}$	Range	$[0, 1]$	Gini (1912)
Simpson index, $D_{Si} = 1 - \sum_{i=1}^{s} p_i^2$	Dominance	$[0, 1]$	Simpson (1949)
McIntosh index, $D_{MI} = \frac{BA - \sqrt{\sum_{i=1}^{s} ba_i^2}}{BA - \sqrt{BA}}$	Dominance	$[-\infty, \infty]$	McIntosh (1967)
Berger–Parker index, $D_{BP} = 1 - ba_{max}/BA$	Dominance	$[0, 1]$	Berger and Parker (1970)
Shannon evenness (*E*), $E_{Sh} = H'/\ln(S)$	Evenness	$[0, 1]$	Pielou (1969)
McIntosh evenness (*E*), $E_{MI} = \frac{BA - \sqrt{\sum_{i=1}^{s} ba_i^2}}{BA - BA/\sqrt{S}}$	Evenness	$[0, 1]$	Pielou (1969)

S, number of diameter classes; BA, basal area ($m^2\ ha^{-1}$); ba_i, basal area in size class i; p_i, proportion of basal area in size class i ($m^2\ ha^{-1}$); ba_j, basal area for tree with rank j ($m^2\ ha^{-1}$); j, the rank of a tree in ascending order from $1, \ldots, n$; n, total number of trees; ba_{max}, basal area in the size class with largest basal area ($m^2\ ha^{-1}$).

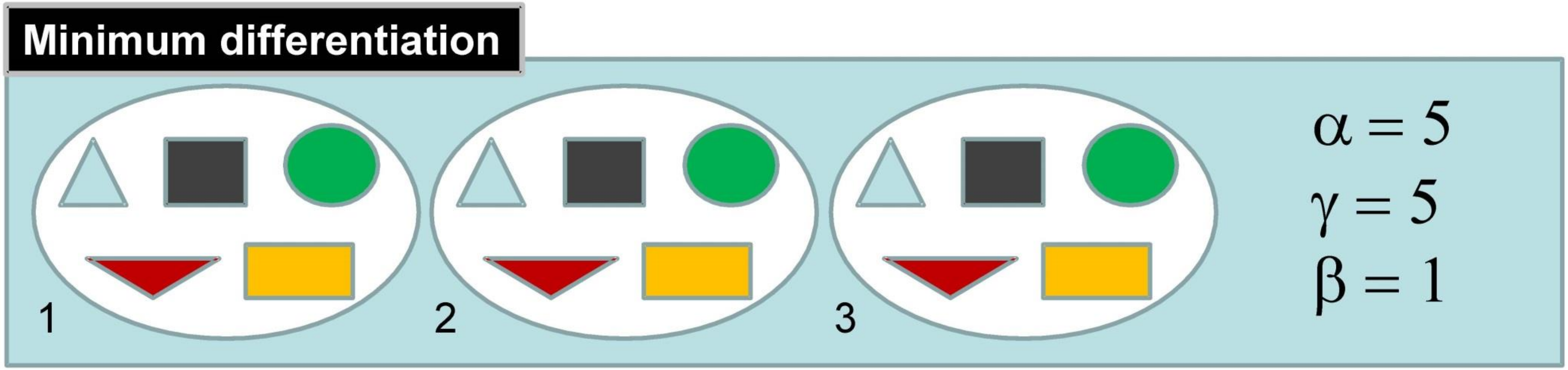
Species and community diversity

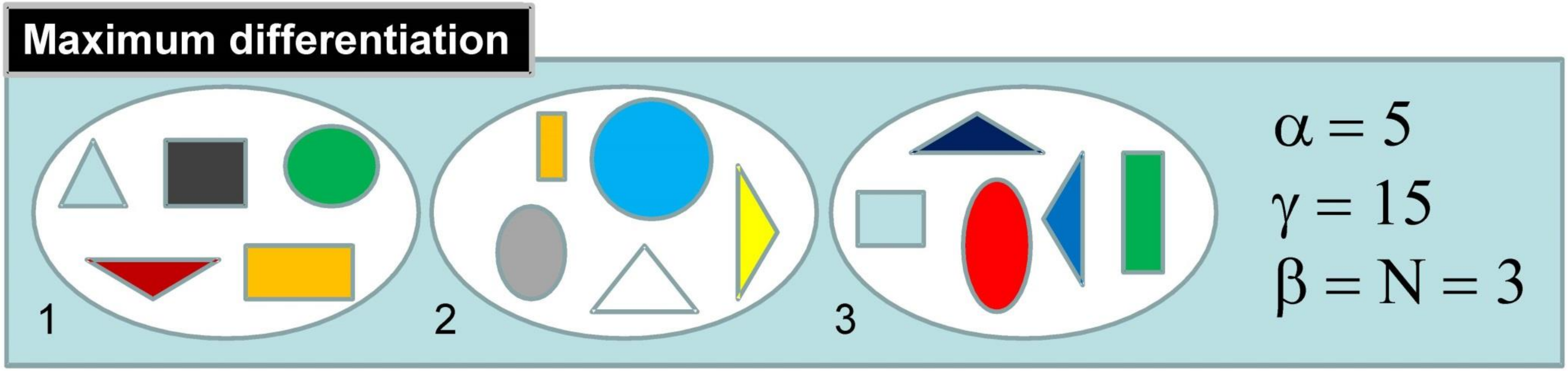
- Estimates of species diversity are scale dependent
  - Species area curves
  - Habitat type differences?

Scales of diversity

- Alpha diversity
  - Within patch diversity
- Beta diversity
  - Between patch diversity
  - Rate of species change between two areas
  - Spatial (but calculation can also be applied to temporal changes)
- Gama diversity
  - Landscape level diversity

Scales of diversity





Andres Baselga 2015

Beta diversity

- R.H. Whittaker (1960)
  - "the extent of change in community composition, or degree of community differentiation, in relation to a complex-gradient of environment, or a pattern of environments"

- Why is beta diversity important?
  - Biodiversity is not evenly distributed around the world
  - Quantifying the differences among biological communities is often a first step towards understanding how biodiversity is distributed

Beta diversity

- Rate of change between two habitats
- Dissimilarity between habitats
  - Normally based on species presence-absence data
  - Dissimilarity indexes

Habitat	Spec. A	Spec. B	Spec. C	Spec. D
1	1	1	0	0
2	1	1	1	0
3	1	0	0	1
4	0	0	1	1
5	1	0	0	0

  - Which habitats are most similar
  - Which habitats are least similar

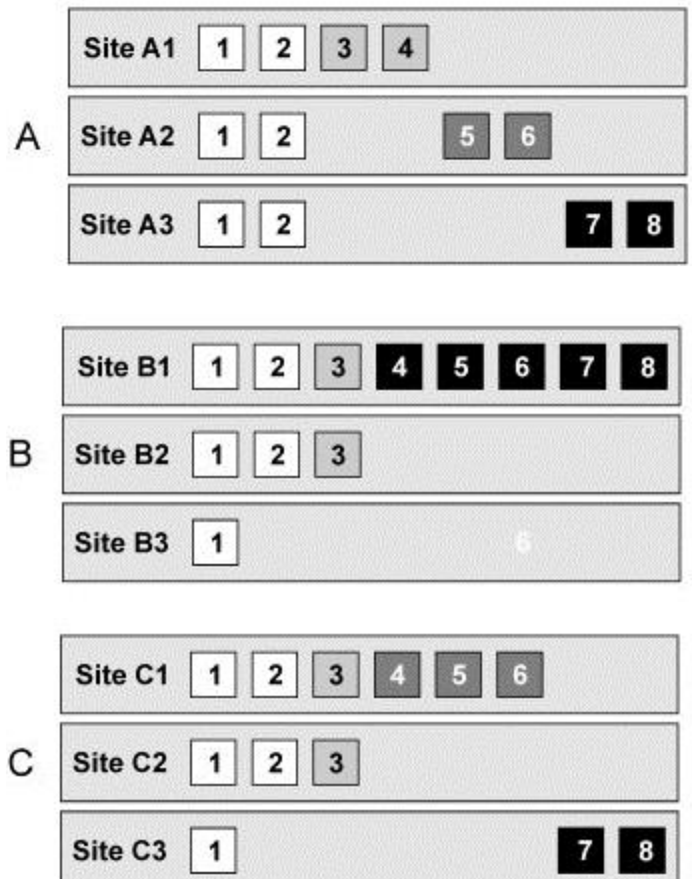
Beta diversity

- Beta diversity can be quantified in a couple of ways
  1. Beta diversity defined as the ratio between gamma diversity and alpha diversity
     - Multiplicative beta diversity
     - $\beta = \gamma/\alpha$ $(\gamma = \alpha\ \beta)$
     - α is the mean α diversity across all sites

https://methodsblog.wordpress.com/2015/05/27/beta_diversity/

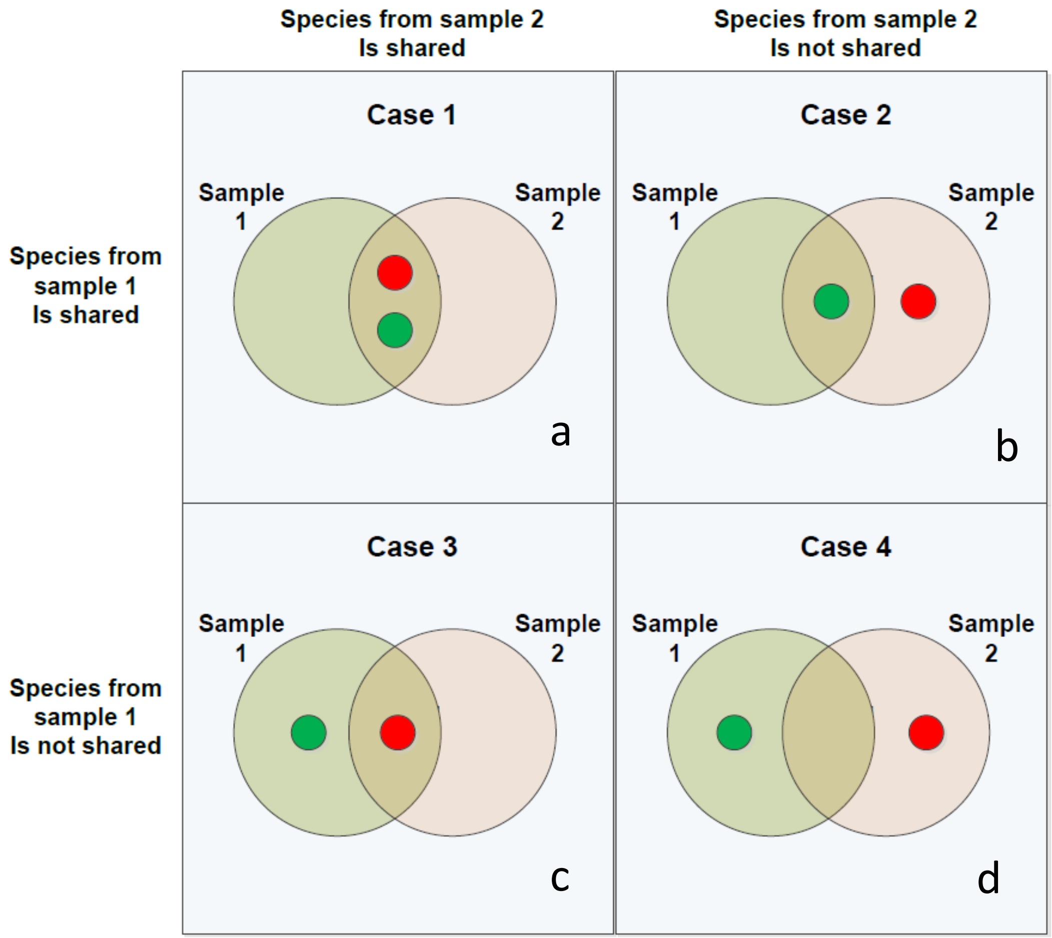
Beta diversity

- Evaluating “difference” in biological communities



α	γ
4,4,4 4	8
8,3,1 4	8
6,3,3 4	8

Similarity, dissimilarity

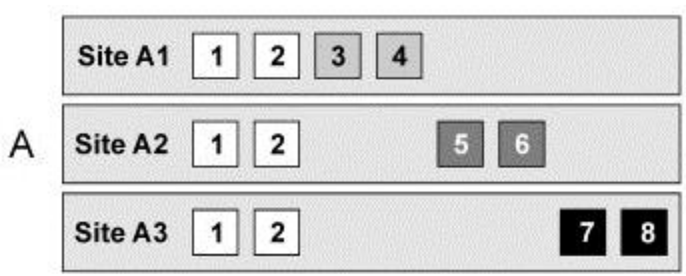


a = Number of species in sample A and sample B (joint occurences)
b = Number of species in sample B but not in sample A
c = Number of species in sample A but not in sample B
d = Number of species absent in both samples (zero-zero matches)

Jacard’s dissimilarity index

$$D_j = 1 - \frac{a}{a + b + c}$$

a = number of species common to both areas
b = number of species unique to the first area
c = number of species unique to the second area

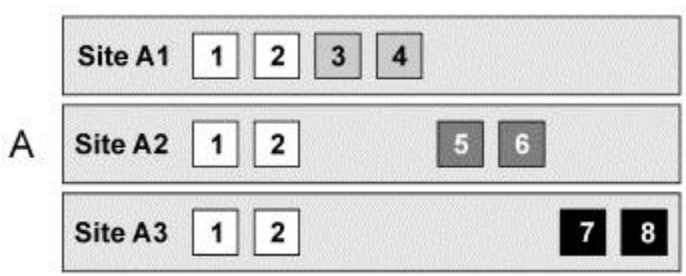


$$D_{j12} = 1 - \frac{2}{2 + 2 + 2} = 0.33$$

Sorensen dissimilarity index

$$D_s = 1 - \frac{2a}{(2a + b + c)}$$

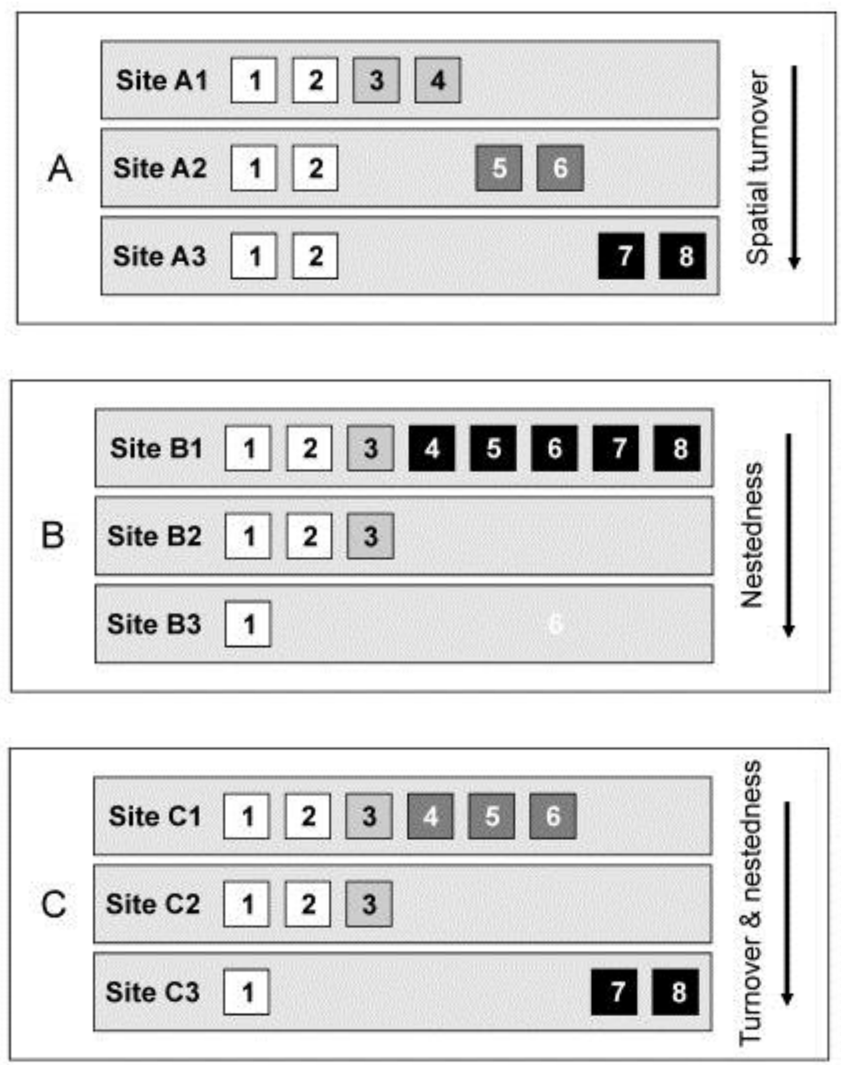
a = number of species common to both areas
b = number of species unique to the first area
c = number of species unique to the second area



$$D_{s12} = 1 - \frac{2(2)}{(2(2) + 2 + 2)} = 0.5$$

Beta diversity

- Evaluating “difference” in biological communities



$\beta = 8/4 = 2$

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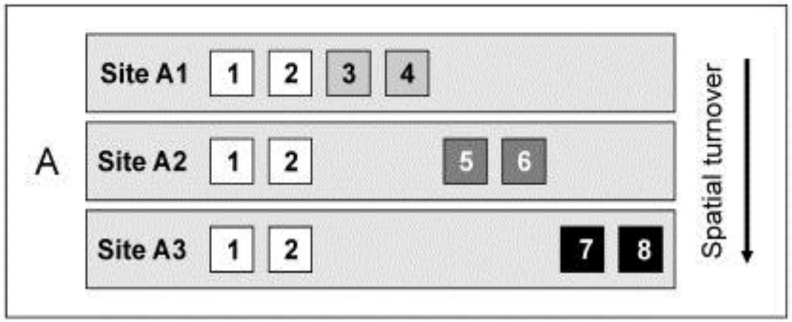
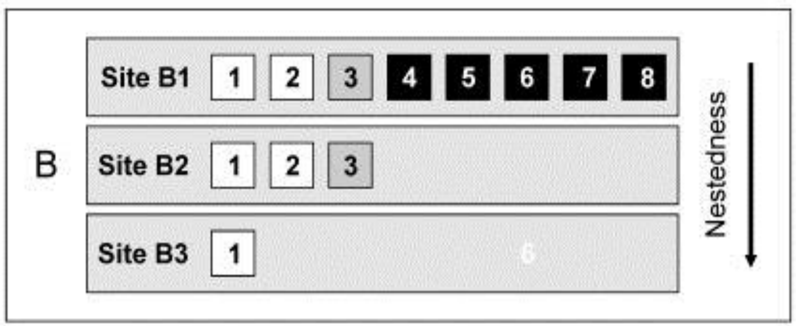
Beta diversity

$$D_s = 1 - \frac{2a}{(2a + b + c)}$$



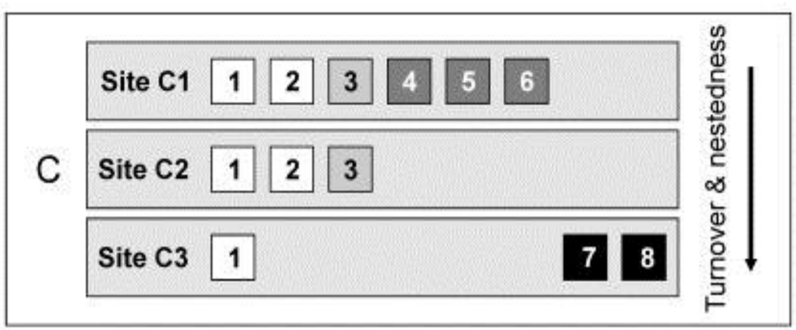
β=8/4=2

	a	b	c	Sorenson	Jacard
A1-A2	2.00	2.00	2.00	0.50	0.33
A1-A3	2.00	2.00	2.00	0.50	0.33
A2-A3	2.00	2.00	2.00	0.50	0.33
				0.50	0.33



β=8/4=2

	a	b	c	Sorenson	Jacard
A1-A2	3.00	5.00	0.00	0.55	0.38
A1-A3	1.00	7.00	0.00	0.22	0.13
A2-A3	1.00	2.00	0.00	0.50	0.33
				0.42	0.28



β=8/4=2

	a	b	c	Sorenson	Jacard
A1-A2	3.00	3.00	0.00	0.67	0.50
A1-A3	1.00	5.00	2.00	0.22	0.13
A2-A3	1.00	1.00	1.00	0.50	0.33
				0.46	0.32