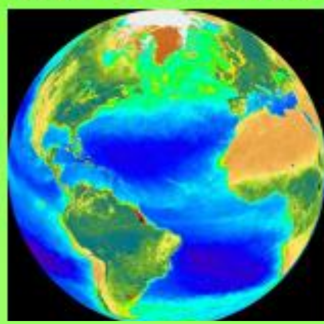
UNIT THREE

3. Vegetation Organization

Levels of Organization in ecology

- Ecologists study organisms and their environments at different levels of organization:
  - Biosphere: consists of all organisms on Earth



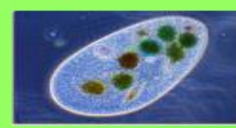
  - Community: consists of populations of different species that live in the same area and interact together.

  - Population: organisms of the same species that live in the same area, interact with one another, and *produce fertile offspring*.

  - Biome: group of ecosystems that have the same climate and dominant communities.

  - Ecosystem: consists of living things and their environment.

  - Organisms: are individual living things.



This is the lowest level of organization that ecologists study. Biologists study organisms, organ systems, organs, tissues, cells, organelles, and molecules.

What is a Community?

- A community is a group of populations that coexist in space and time and interact directly or indirectly.
- By "interact", we mean affect each others' population dynamics.
- is inclusive, and pertains to all plants, animals, fungi, bacteria, etc.

What is a Plant Community?

- A plant community is the vegetative subset of the community (excluding herbivores, decomposers, pollinators, etc.).
- The plant community is simply all of the plants occupying an area which an ecologist has circumscribed for study.
- In many ways, the plant community is an *abstraction*.

Terminology

- **Association:** a particular community type, found in many places and with a specific species composition and physiognomy.
- **Formation:** originally used to refer to a large regional climax community.

Nature of the Plant Community

- Ecologists based in different countries, educated in different traditions, tend to view communities differently.
  - ✓ Europeans tend to see communities as distinct and discrete entities.
  - ✓ North Americans tend to see communities as entities that blend together continuously.

A History of Controversy

- The *nature* of the plant community remains today as one of the biggest controversies to ever occur in ecology.

- Our current view of plant communities "evolved" over almost 100 years and can be discretely categorized in to three historical eras or paradigms:
  - ✓ Clementsian Paradigm (Organismal (or discrete or holistic) concept)
  - ✓ Gleasonian Challenge (Individualistic (or continuum) concept)
  - ✓ Modern Synthesis

The Clementsian Paradigm

Clements (1904) picked up on the work of Cowles and crystallized it in to a broader theory of vegetation dynamics.

Clements used the Organismal Metaphor (communities are "superorganisms") to demonstrate that communities changed over time in very discrete ways (like human development) ultimately culminating in a predictable endpoint or "climax".

In this view, the climax community was a static developmental endpoint of great stability.

Two themes are prevalent in this viewpoint:

(1) there are very tight linkages among species
(2) there is cooperation among species for the benefit of the community.

Frederick E. Clements (1874-1945)

Clement's view of the community was intransigent: communities were distinct spatial entities and developed with one superorganism complex giving way to another (either in space or time).

Clements did acknowledge the role of competition, mutualism, and predation in influencing community structure; and he did recognize the role of environment, soils, and history.

BUT, his focus was on the idealized nature of communities.

Ecotones are boundary areas between adjacent communities and often share a mix of species.

Organismic (Holistic) concept: Distribution of species is discrete (associations)

Association: a type of community with

1. relative consistent species evolved together;
2. a uniform general appearance;
3. a distribution that is characteristics of a particular habitats such as hilltop or valley.

- Transitional between communities are narrow, with few species in common (Ecotone).
- Suggest a common evolutional history and similar foundational response and tolerances for component species.
- Mutualism and coevolution play important roles in the species that make up association.

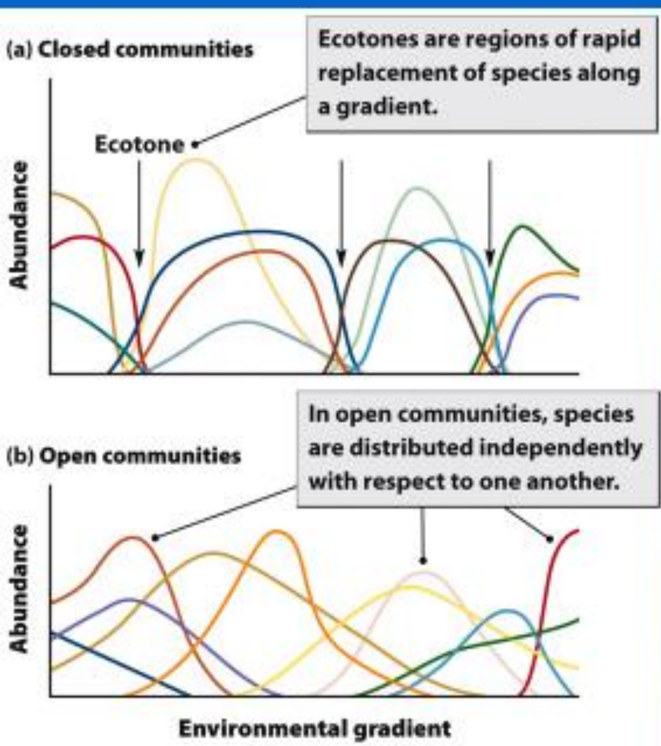
- Clement's view of the nature of the community dominated the science of ecology well in to the early 1960s.
- His perception of the community was simple, palatable, and easy to relate to (*human metaphor*).
- However, some ecologists of the day were less accepting of this neatly packaged, developmentally predictable, view of the plant community.

Gleasonian Challenge

- Henry Allen Gleason, in a series of papers (1917, 1926, 1939), argued that communities were the result of interactions between individual species and the environment (biotic and abiotic) in combination with chance historical events.
- Each species has its own environmental tolerance and responds *individualistically* to the environment.

Henry Allen Gleason
(1882-1975)

- Gleason's view of the plant community became known as the Individualistic Concept (Continuum View) and opposed Clement's Organismic View in virtually all aspects.
- The implication of Gleason's view was that species were distributed along environmental gradients, with their boundaries determined by their tolerances to the environment.
- Communities were *not* tightly linked superorganisms, but rather arbitrarily circumscribed by humans.
- Relationship among co-existing species is the result of similarities in their requirements and tolerances, not the result of strong interactions or common evolutionary history.
- Gradual change in species abundance along environmental gradient (no associations).
- Transitions are gradual and difficult to detect.



Two views of community

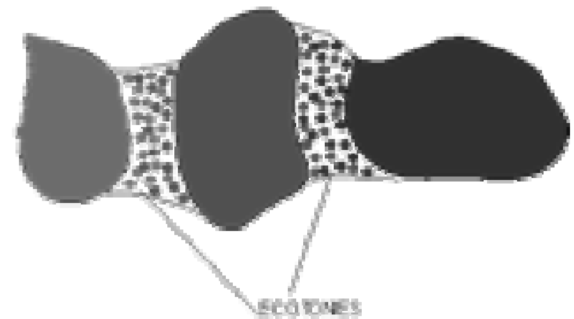
Organismic and individualistic views

Holistic (discrete) or continuum

Ecotones

Closed or open communities

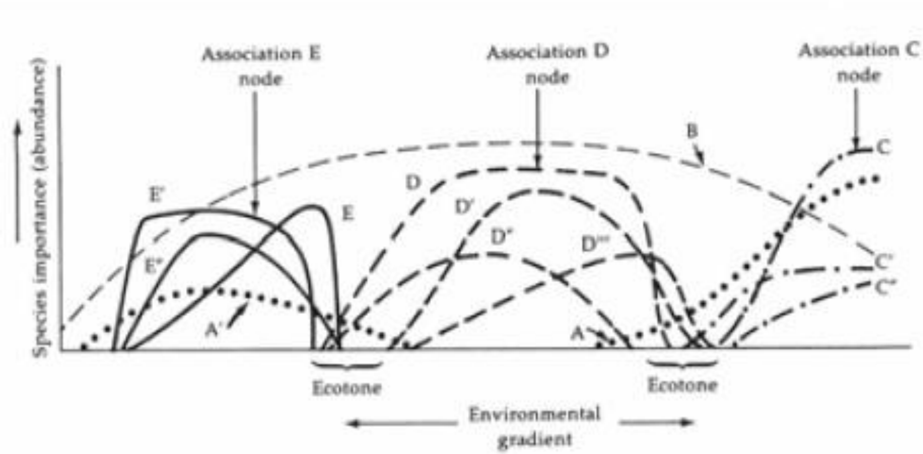
Ecotones



Ecotones are boundary areas between adjacent communities and often share a mix of species.

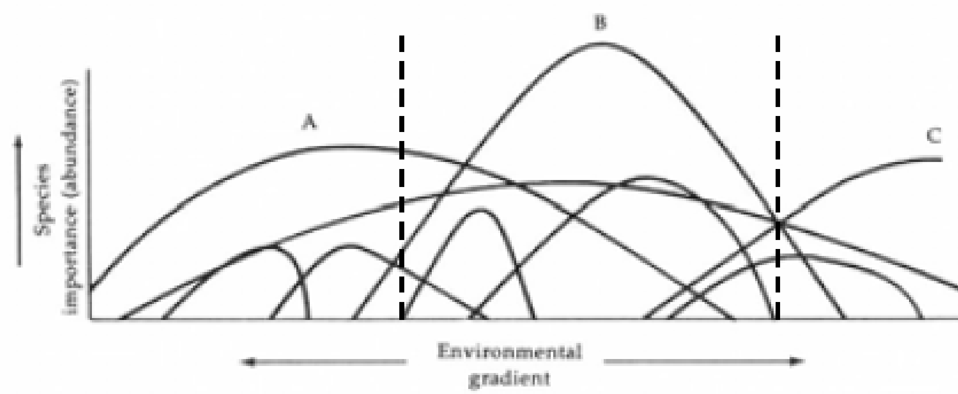
Clement's *Organismic View* of Communities

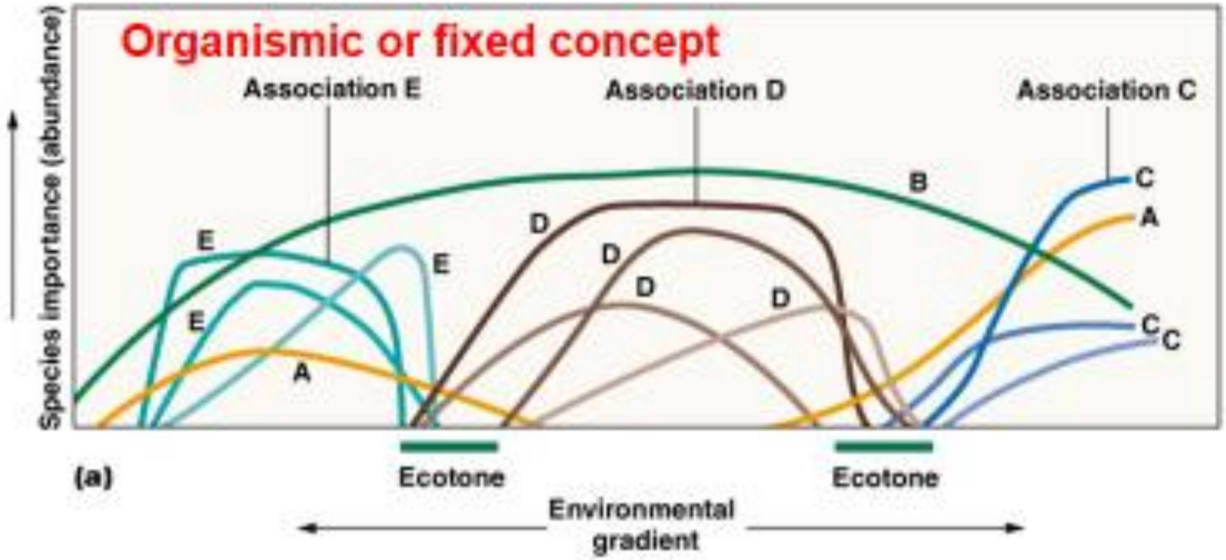
Each community (association) is a "node"

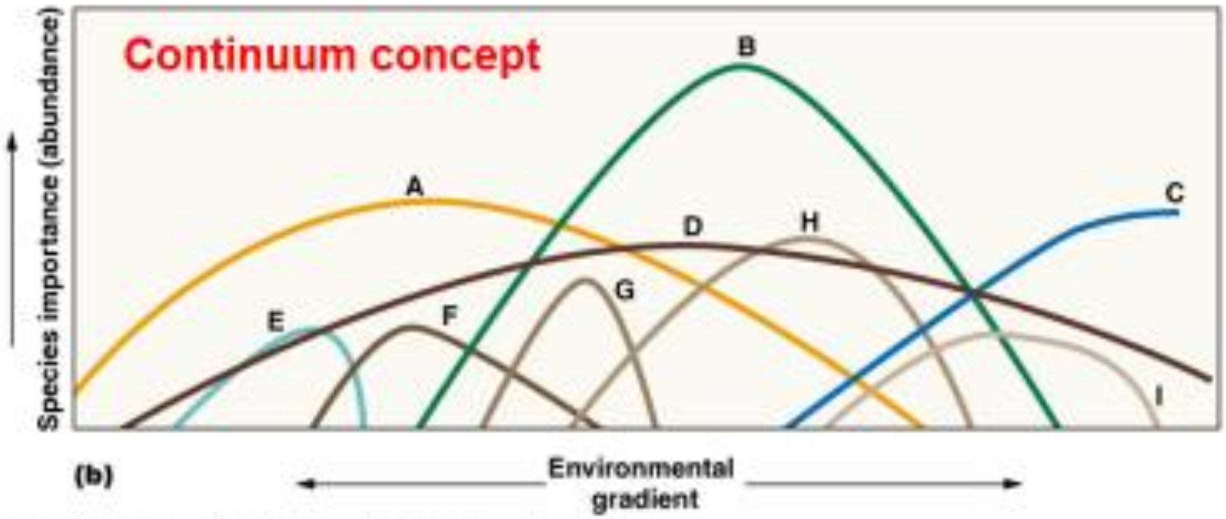


Gleason's *Continuum View* of Communities

Each community (A, B, C) is an arbitrary section




Organismic or fixed concept
Association E
Association D
Association C
Species importance (abundance)
B
C
A
E
D
E
D
D
E
D
C
C
A
(a)
Ecotone
Ecotone
Environmental gradient


Continuum concept
Species importance (abundance)
B
A
C
D
H
G
E
F
I
(b)
Environmental gradient

The Modern Synthesis

- The primary issues surrounding the nature of plant communities divide roughly into those of pattern and process.

- The issues of *pattern* focus on how species and communities are distributed over the landscape. Are boundaries abrupt or gradual? How predictable are the patterns?

- The issues of *process* focus on what processes (e.g., competition, herbivory, history) actually function in natural communities and which of these are most important in determining the observed patterns.

  - ✓ Do some processes predominate? Do processes vary among communities? Are communities static or dynamic?

The Modern Synthesis - Major Elements -

1. Communities structure is a population process

2. Communities are sections of continuous gradients

3. Communities show some directionality & predictability

4. Communities are strongly influenced by historical effects

5. Communities do not develop to a stable climax

6. Communities are dynamic & influenced by disturbance

Analysis of communities (Analytical and Synthetic Characters Seen in Plant Community Structure)

- Structure of plant communities can be determined by analytical characters and synthetic characters.

I. Analytical characters:

- These are of two types:

a) quantitative, which are expressed in quantitative terms and

b) qualitative, which are expressed only in qualitative way.

a) Quantitative characters:

These include such characters as frequency, density, cover, basal area and abundance etc.

i) Frequency:

✓ Frequency is the number of sampling units (as %) in which a particular species occurs.

✓ Thus, frequency of each species is calculated as follows:

Frequency (%) = Number of sampling units in which the species occurred / Total no. of sampling units studied x 100

ii) Density:

- Density represents the numerical strength of a species in the community.
- The number of individuals of the species in any unit area is its density.
- Density gives an idea of degree of competition.
- It is calculated as follows:

Density = Total no of individuals of the species in all the sampling units / Total no. of sampling units identified

iii) Cover and Basal area:

- The above ground parts (such as leaves, stems and inflorescence) cover a certain area
- if this area is demarcated by vertical projections, the area of the ground covered by the plant canopy is called foliage cover or herbage cover or canopy cover.
- Basal area refers to the ground actually penetrated by the stems and is readily seen when the leaves and stems are clipped at the ground surface.
- It is one of the chief characteristics to determine dominance.

iv) Abundance:

- This is the number of individuals of any species per sampling unit of occurrence. It is calculated as follows:
- Abundance = Total no. of individuals of the species in all the sampling units. / No. of sampling units in which the species occurred.
- But, abundance thus obtained in quantitative terms gives little idea of the distribution of the species.

b) Qualitative characters:

- These include physiognomy, phenology, stratification, abundance, sociability, vitality and life, life form (growth form), etc.

i) Physiognomy:

- This is the general appearance of vegetation as determined by the growth form of dominant species.
- Such a characteristic appearance can be expressed by single term.
- For example, on the basis of appearance of a community having trees and some shrubs as the dominants, it can be concluded that it is a forest.

ii) Phenology:

- It is the scientific study of seasonal change i.e., the periodic phenomenon of organisms in relation to their climate.
- Different species have different periods of seed germination, vegetative growth, flowering and fruiting, leaf fall, seed and fruit dispersal, etc.
- Such data for individual species are recorded.
- A study of the date and time of these events is phenology.
- In other words phenology is the calendar of events in the life history of the plant.
- Environmental factors tend to influence the phenological behavior of a species population.

iii) Stratification:

- Stratification of communities is the way in which plants of different species are arranged in different vertical layers in order to make full use of the available physical and physiological requirements.

iv) Abundance:

- Plants are not found uniformly distributed in an area.
- They are found in smaller patches or groups, differing in number at each place.
- Abundance is divided in five arbitrary groups depending upon the number of plants.
- The groups are very rare, rare, common, frequent and very much frequent.

v) Sociability:

- Sociability or gregariousness expresses the degree of association between species.
- It denotes the proximity of plants to one another.
- Braun-Blanquet (1932) classified plants into the following five sociability groups:
- S_1 – Plants found quite separately from each other, growing singly
- S_2 – Plants growing in small groups (4 to 6 plants)
- S_3 – Plants growing in small scattered patches.
- S_4 – Several bigger groups of many plants at one place
- S_5 – A large group occupying larger area.

vi) Vitality:

- It is the capacity of normal growth and reproduction which are important for successful survival of species.
- In plants, stem height, root length, leaf area, leaf number, number and weight of flowers, fruits, seeds, etc., determine the vitality.

vii) Life form (growth form):

- Ecologists generally use Christen Raunkiaer's classification (1934) of plant life forms.
- Refer chapter 2

II. Synthetic characters:

- These are determined after computing the data on the quantitative and qualitative characters of the community.
- For comparing the vegetation of different areas, community comparison needs the calculation of their synthetic characters.
- Synthetic characters are determined in terms of the following parameters:

i) Presence and Constance:

- It expresses the extent of occurrence of the individuals of a particular species in the community, i.e., how uniformly a species occurs in a number of stands of the same type of community.
- The species on the basis of its percentage frequency may belong to any of following five presence classes that were first proposed by Braun-Blanquet.
- (a) Rare—present in 1 to 20% of the sampling units.
- (b) Seldom present—present in 21-40% of the sampling units.
- (c) Often present—present in 41-60% of the sampling units.
- (d) Mostly present—present in 61-80% of the sampling units.
- (e) Constantly present—present in 81-100% of the sampling units.

ii) Fidelity:

- Fidelity or "Faithfulness" is the degree with which a species is restricted in distribution to one kind of community.
- Such species are sometimes known as indicators.
- The species have been grouped into five fidelity classes which were first formulated by Braun Blanquet:

a) Fidelity 1: Plants appearing accidentally (Strangers)

b) Fidelity 2: Indifferent plants may occur in any community (Indifferents).

c) Fidelity 3: Species which occur in several kinds of communities but are predominant in one (Preferentials).

d) Fidelity 4: Specially present in one community but may occasionally occur in other communities as well (Selectives).

e) Fidelity 5: Occur only in one particular community and not in others (Exclusives).

iii) Dominance:

- It is used as a synthetic as well as analytical characters.
- cover is included as an important character in dominance.
- Relative dominance (cover; RDO) is calculated as follows:
- Relative Dominance (cover) = Dominance (cover) of the species / Total dominance (cover) of all the species x 100

iv) Importance Value Index (IVI):

- This index is used to determine the overall importance of each species in the community structure.
- For IV, values of relative density, relative frequency and relative dominance are obtained as follows:

$$\text{Relative density (RD)} = \frac{\text{Number of individual of a species}}{\text{Total number of individual of all species}} \times 100$$

$$\text{Relative frequency (RF)} = \frac{\text{Number of occurrences of a species}}{\text{Total number of occurrences of all species}} \times 100$$

$$\text{Relative dominance (RDo)} = \frac{\text{Total basal cover of individual species}}{\text{Total basal cover of all species}} \times 100$$

$$\text{Importance Value Index} = \text{RD} + \text{RF} + \text{RDo}.$$

Basal Area (BA) can calculated using DBH as follows:-

Basal Area (BA) = $\pi d_2/4$, where, $\pi = 3.14$; d = DBH (cm)

Other components of community analysis

- **Species diversity**
- Species diversity relates to the number of the different species and the number of individuals of each species within any one community.
- A number of objective measures have been created in order to measure species diversity.
- Diversity is a combination of two factors; the number of species present - **species richness**, and the distribution of individuals among the species are referred to as **evenness or equitability**.
- Whittaker distinguishes three types of diversity.

1. **alpha diversity** - diversity within a particular area or ecosystem,
2. **beta-diversity** - the change in diversity between ecosystems, and
3. **gamma diversity -** the overall diversity of a landscape comprising of several ecosystems.

- **Species richness**
- Species richness is the number of different species present in an area.
- The more species present in a sample the 'richer' the area.
- **Species evenness**
- the extent to which a group of species is uniform in number
- **Simpson's diversity index**
- Species richness as a measure on its own takes no account of the number of individuals of each species present.
- It gives equal weight to those species with very few individuals and those with many individuals.
- A better measure of diversity should take into account the abundance of each species.

- Simpson's index (**D**) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present.
- In essence it measures the probability that two individuals randomly selected from an area will belong to the same species.
- The formula for calculating D is presented as:

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

where n_i = the total number of organisms of each individual species
N = the total number of organisms of all species

- The value of **D** ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. That is, the bigger the value the lower the diversity.

- **<u>Using Simpson's index to measure biodiversity – a worked example</u>**
- Consider three communities, each made up of a total of 100 organisms, drawn from combinations of ten species, A to J.

Table 1 *Species composition of three different communities*

Species	Community 1	Community 2	Community 3
A	10	72	35
B	9	6	34
C	11	3	31
D	10	3	0
E	8	1	0
F	12	3	0
G	10	4	0
H	11	3	0
I	10	2	0
J	9	3	0
Total	100	100	100

- Community 1 has the highest diversity. It has the joint highest species richness (10) and each species has a similar relative abundance.
- Community 2 has the same species richness as community 1, but is dominated by one species (A) so that the diversity of this community is lower than in community 1.
- Community 3 has a lower diversity than community 1, due to its lower species richness.

Table 2 *Data for calculation of Simpson's index for community 1.*

Community 1			
Species	**n_i**	**$n_i - 1$**	**$n_i(n_i - 1)$**
A	10	9	90
B	9	8	72
C	11	10	110
D	10	9	90
E	8	7	56
F	12	11	132
G	10	9	90
H	11	10	110
I	10	9	90
J	9	8	72
Total	N = 100		$\Sigma n_i(n_i - 1) = 912$

So for community 1:

$$D = \frac{912}{100 \times 99}$$

$$= 0.09 \text{ (high diversity)}$$

- By the same method calculate the diversity for community 2 & 3.

- **Shannon-Wiener Diversity Index (H') -** Can be determined by using the following formula.

$$H' = -\sum_{i=1}^{s} pi(\ln(pi)) \text{ Whereby,}$$

H'= Shannon diversity index

Σ= Summation symbol;

S = the number of species;

Pi= the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of the total cover in the sample;

ln = natural logarithm to base n ($\log_n$)

Shannon's evenness (J) or equitability were calculated by applying the following formula:

$$J = \frac{H'}{H'max} \text{ Whereby,}$$

J = the species evenness
H' = Shannon-Wiener Diversity Index
H'max = Maximum Diversity Index of species in the sample

Similarity measures (Coeficients)

- Once data are collected, we may be interested in the similarity (or absence thereof) between different samples, quadrats, or communities
- Numerous similarity indices have been proposed to measure the degree to which species composition of quadrats is alike (conversely, dissimilarity coefficients assess the degree to which quadrats differ in composition).

Jaccard coefficient

Simplest index, developed to compare regional floras; widely used to assess similarity of quadrats/communities.

Uses presence/absence data (i.e., ignores info about abundance)

$S_J = a/(a + b + c)$, where

S_J = Jaccard similarity coefficient,

a = number of species common to (shared by) quadrats,

b = number of species unique to the first quadrat, and

c = number of species unique to the second quadrat

<u>Sørensen coefficient</u> (syn. coefficient of community, CC)

A very simple index, similar to Jaccard's index

Give greater "weight" to species common to the quadrats than to those found in only one quadrat.

- Uses presence/absence data:

$$Ss = \frac{2a}{(2a + b + c)} \text{ where,}$$

Ss = Sørensen's similarity coefficient

a = Number of species common to both communities

b = Number of species in community 1 only;

c = Number of species in community 2 only.

Ordination vs. classification

- The main purpose of both multivariate methods is to interpret patterns in species composition
- Complementary approaches
- Classification is used for grouping ecological communities.
- Ordination (from German, *ordnung*) is used for arranging data along gradients i.e. multivariate gradient analysis.
- **Ordination** displays the major axes of variation while **classification** identifies clusters of sites and outliers.

Ordination

✓ Ordination involves reduction of dimensionality.

✓ The basic objective of reducing dimensionality in analyzing multi-response data is to obtain simplicity for:

- ➢ better understanding,
- ➢ visualization and
- ➢ interpretation.

- In ordination two distinctly different approaches exist: **direct** and **indirect gradient analysis**.

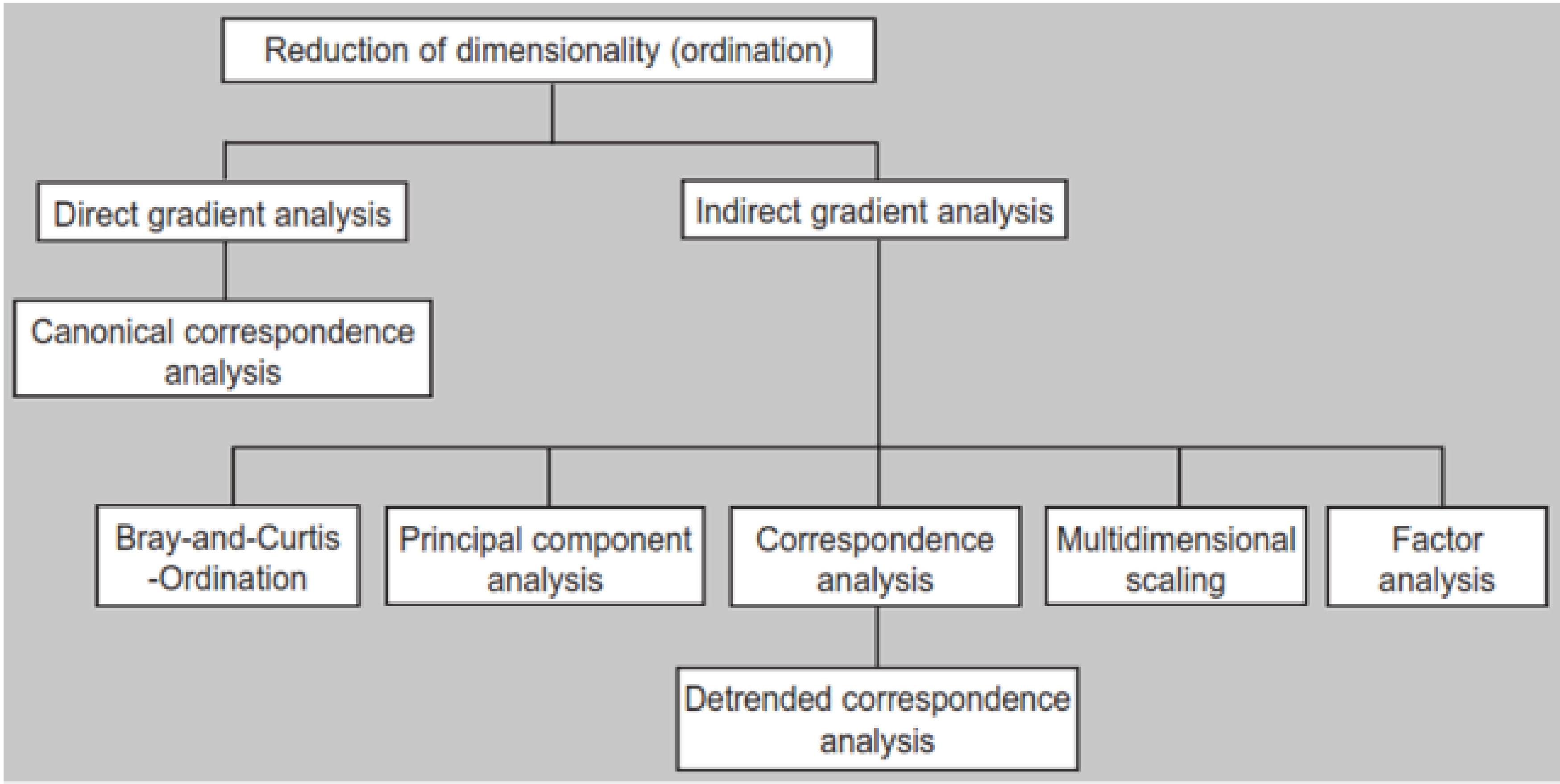


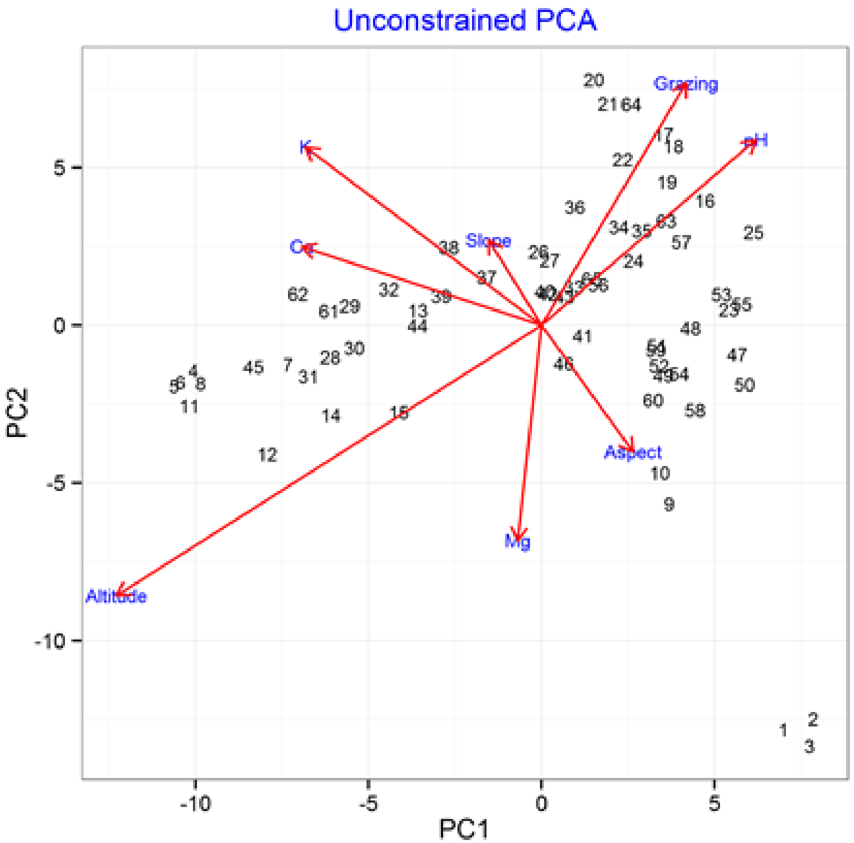
Figure. Classification of ordination methods

Direct ordination

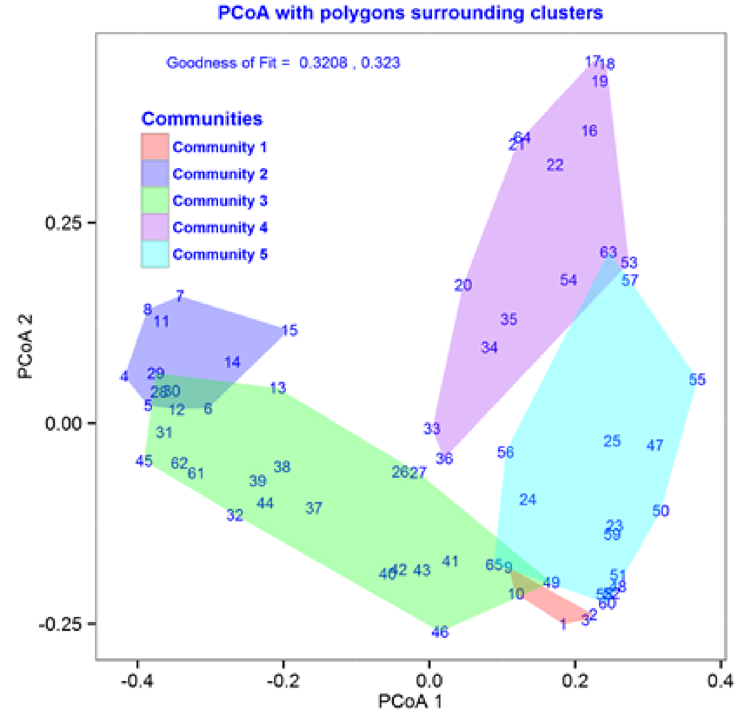
- Originally termed as direct gradient analysis by Whittaker (1956),
  - ✓ is the analysis of species distributions (presence/absence or abundance data) and collective properties (e.g. species richness) in relation to environmental variables conventionally referred to as environmental gradients.
- In direct gradient analysis, vegetation relevés are arranged in an ecological space along axes of moisture, nutrients, altitude, etc. and the influence of the respective factors on the vegetation is determined.

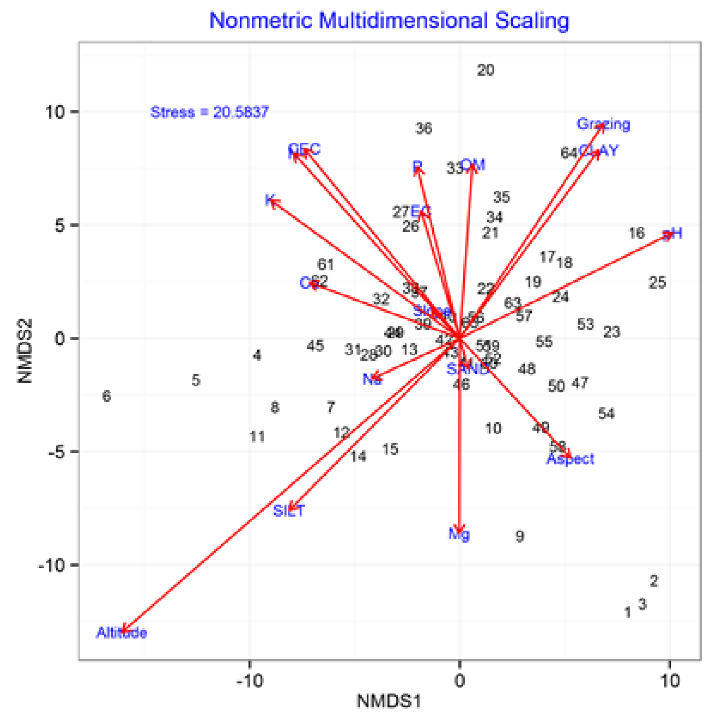
Indirect ordination

- ✓A graphical representation of the variation in vegetation across all sites can be constructed by measuring the similarity between each site based on the species composition.
- ✓The indirect gradient analysis, in contrast to direct gradient analysis, focuses on the floristic composition.



PCA with environmental variable

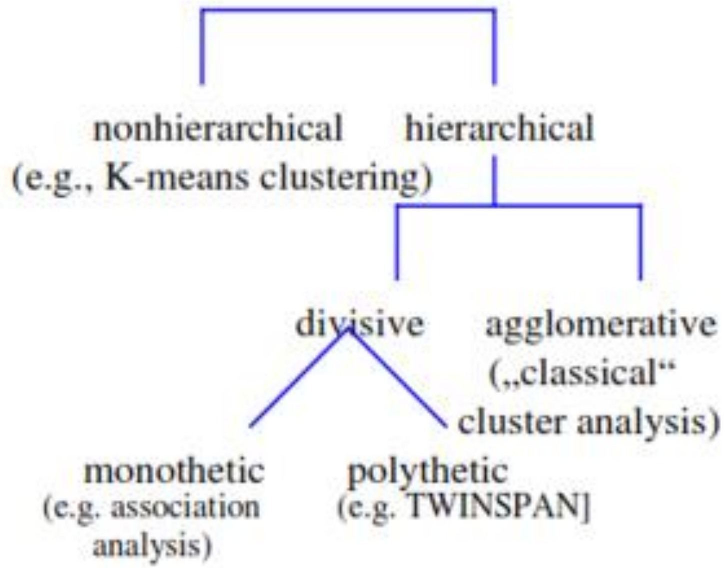




NMDS (nmds) with environmental variables

Numerical classification

- Numerical methods were developed to provide objective procedures.
- They were based on use of a similarity or association measure between plots of vegetation, grouping together those plots, which were most similar.
- Numerous methods of classification were developed with various similarity measures and different strategies for grouping plots together.



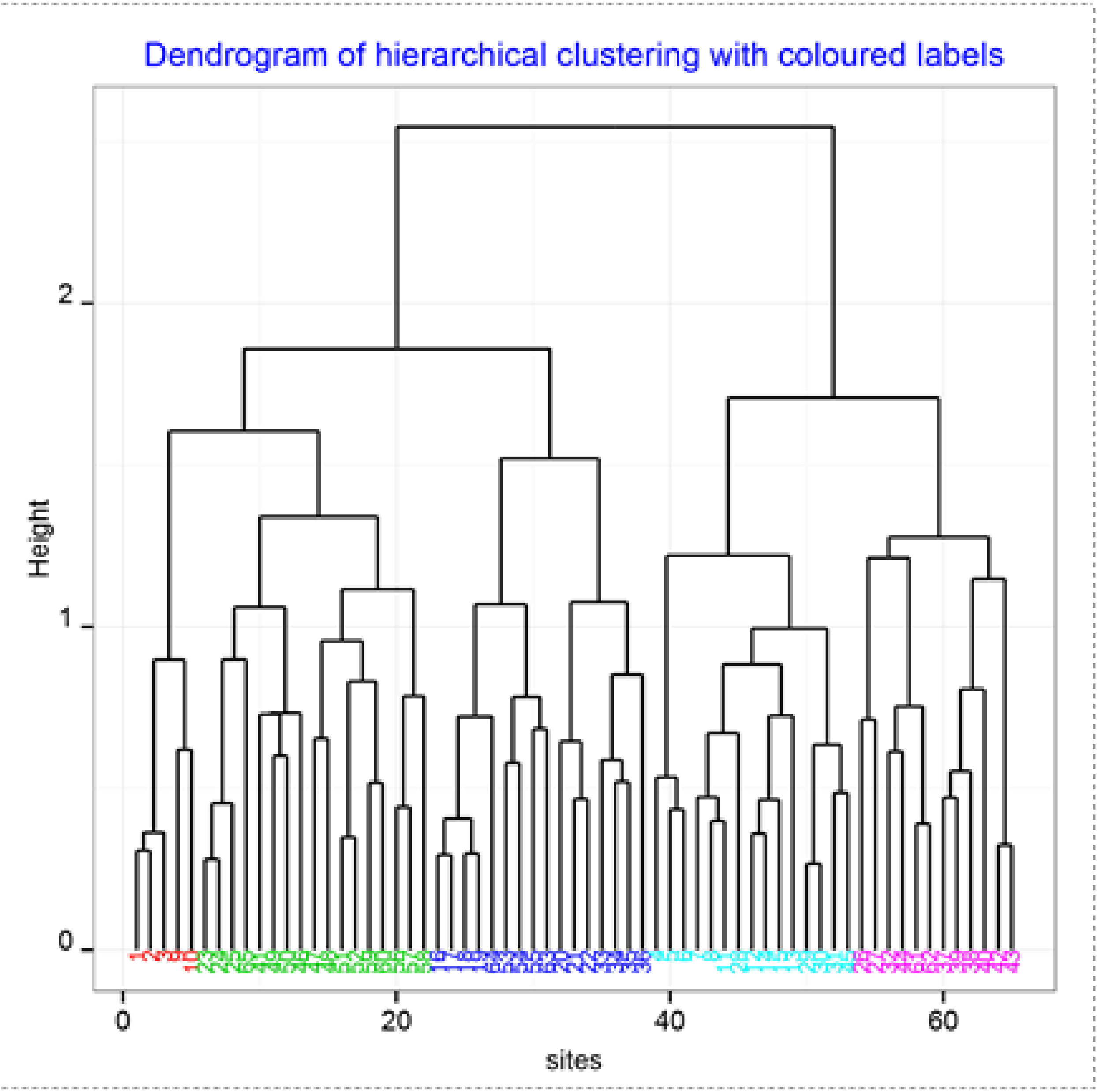
Type of classification methods

Non-hierarchical classification (K-means clustering)

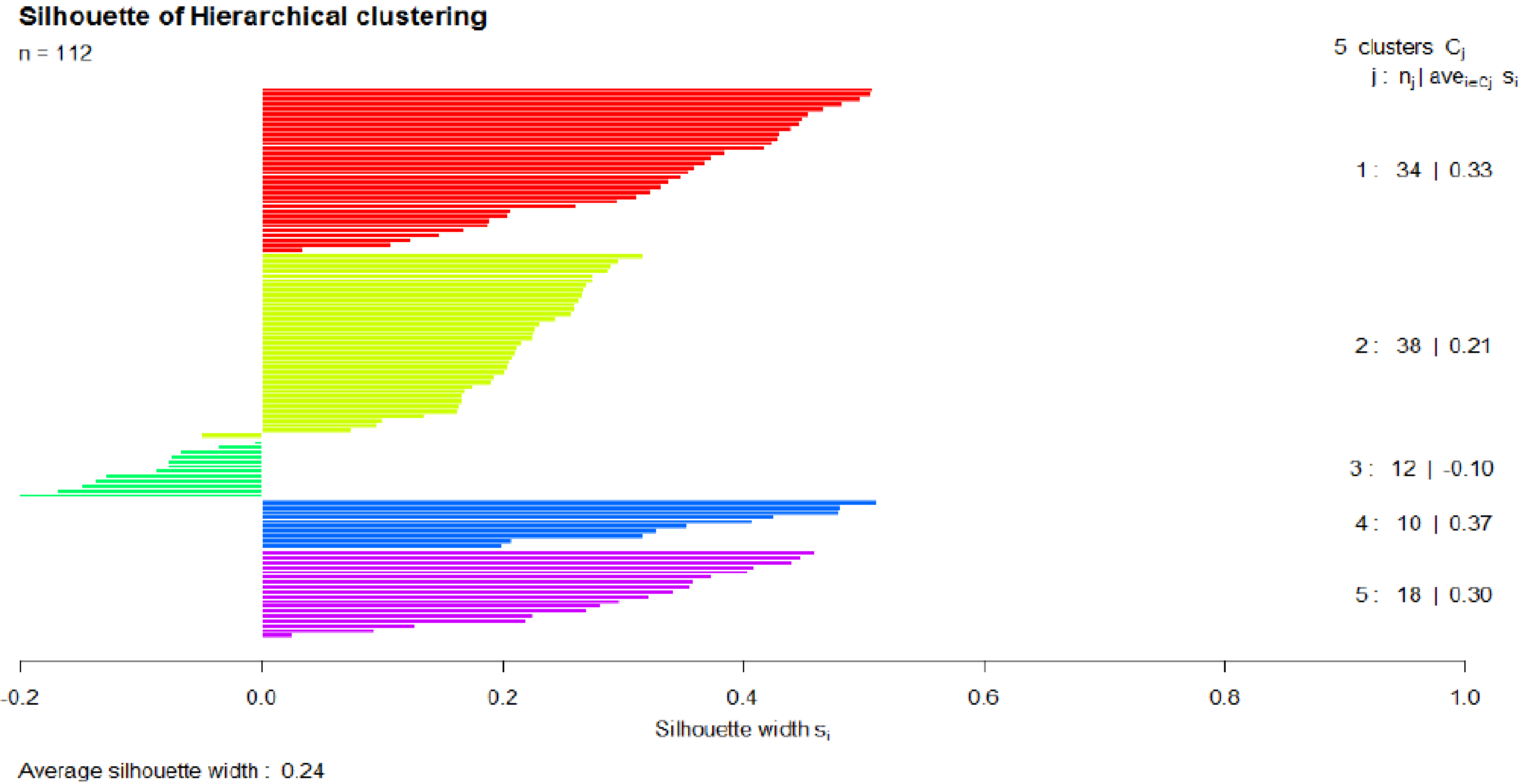
- The goal of the method is to form (predetermined number) of groups of objects (clusters);
  - ✓ the groups should be internally homogenous and different from each other.
- All the groups are of the same level, there is no hierarchy.

Hierarchical classifications

- In hierarchical classifications, the groups are formed that contain subgroups, so there is a hierarchy of levels.
- When the groups are formed from the bottom (i.e. the method starts with joining the two most similar objects), then the classifications are called **agglomerative**.
- When the classification starts with the whole data set, which is first divided into two groups and those are further divided, the classification is called **divisive**.
- The term “Cluster analysis” is often used for the agglomerative methods only.



Agglomerative Hierarchical clustering using euclidean distance



3. Silhouette of hierarchical clustering using libraries vegan, cluster and glus

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Key: A = Association 1

Con = constant species

B = Association 2

The ordered two-way table from TWINSPAN showing the association of plants

- # Interspecific Interactions

Relationship	**Effect on species 1**	**Effect on species 2**
Competition	- (competitor)	- (competitor)
Predation	+ (predator)	- (prey)
Mutualism	+ (partner)	+ (partner)
Commensualism	+ (epiphyte)	O (host)
Amensalism	+ (secretor)	- (other)
Parasitism	+ (parasite)	- (host)

- **Competition:** tends to have a negative effect on both interacting species.
- **Predation:** here, one party (the predator) benefits, while the other party (the prey), being consumed, clearly does not.
- **Mutualism:** in a mutualistic relation, both interactors benefit.
- **Commensalism:** in a commensualistic relationship, one interactor benefits, while the other is basically unaffected.
- **Amensalism:** In this kind of relationship, one (the secretor) benefits, while the other is harmed.
- **Parasitism:** In this interaction, the parasite benefits, while the host suffers.

COMPETITION

- Competition: happens when two species use the same resource and the resource is in short supply
- Might compete for food, nesting sites, living space, light, mineral nutrients, water, mates
- Each organism has less access to the resource so they are both harmed by the competition.

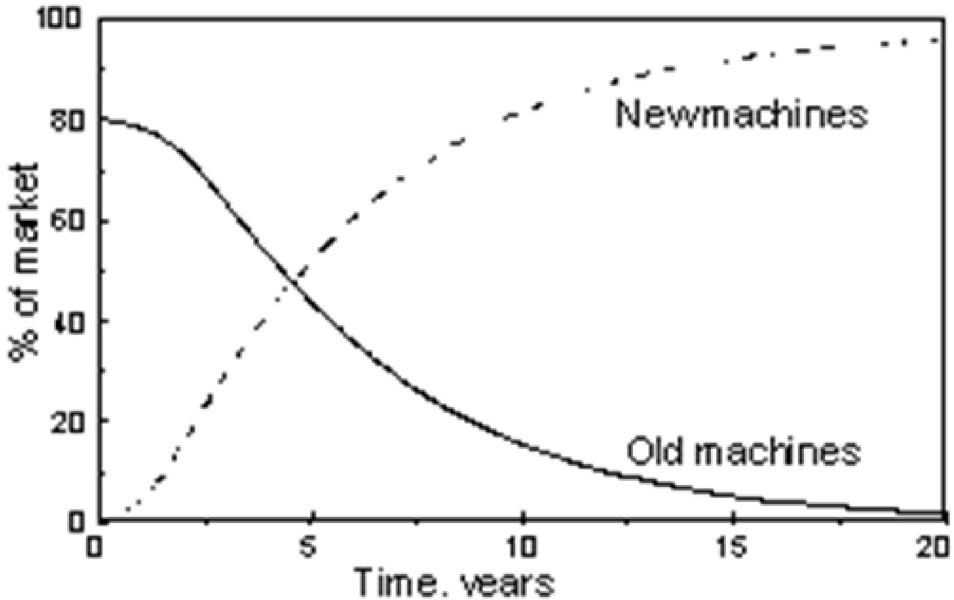
Types of Competition

1. Interspecific competition: 2 different species compete for the same resource
2. Intraspecific competition: members of the same species compete

Competition can cause:

- **Niche Restriction**
  - The competitors will each only use part of their potential niche. They divide it up in space or time. That way they can coexist in the same area.
- **Competitive Exclusion**
  - One species out competes and eliminates the other species (will leave the area or die off)

- **Laboratory experiments demonstrate that two species cannot coexist if they require similar resources.**



- Closely related species rarely coexist for long in the laboratory.
- If two species are forced to live off the same resource, inevitably one persists and the other dies out.
- The competitive exclusion principle holds that two species cannot coexist on the same limiting resource.
- Only resources that limit population growth can provide the basis for competition.
- Non-limiting resources are superabundant compared to the needs of organisms.

PREDATION

- **Predation**: process by which one organism captures and feeds upon another.
- Predator benefits and prey is harmed.
- Both evolve adaptations to help them survive.

Predator/Prey Dynamics

- When prey is plentiful, predator numbers can increase.
- But predators have an obvious adverse effect on prey population numbers.
- Individual predators tend to be larger than their prey, and also less abundant.

• Herbivores and Plants

- The nature of the plant has profound effects on the evolution of its herbivores.
- Plants also adapt to the pressures of herbivory, and develop strategies to escape predation.
- Plants and herbivores are locked in a coevolutionary arms race.

- Plant defenses against herbivores
  - Thorns, spines, prickles
  - Secondary compounds – defensive chemicals that are toxic
- Herbivores overcome plant defenses
  - Larvae may not be affected by toxic defensive chemicals

Bull Thistle
kaweahoaks.com

SYMBIOTIC SPECIES

- **Symbiosis:** two or more species live together in a close, long-term association
- May have coevolved together.
- Three types of Symbiosis:
  - Parasitism
  - Mutualism
  - Commensalism

PARASITISM

- Parasitism: parasite benefits, host is harmed
  - One organism lives in or on another organism
  - Host provides food, place to live, spreads the parasite's offspring

Tick in dog fur

Caterpillar covered with wasp pupae

aphids on a plant

MUTUALISM

- **Mutualism:** both participating species benefit

  Example: aphids and ants

✓ Aphids extract fluids from sugar conducting vessels of plants, make honeydew

✓ Ants get honeydew from the aphids that they use as food. In turn, they protect the aphids.

The bee gathers pollen from the flowers to make honey.
The flowers get pollinated.

COMMENSALISM

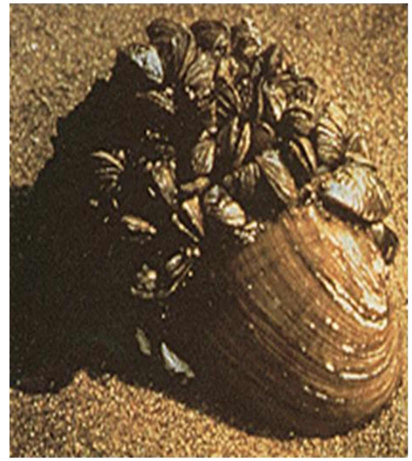
- **Commensalism:** one species benefits and the other is neither harmed nor helped

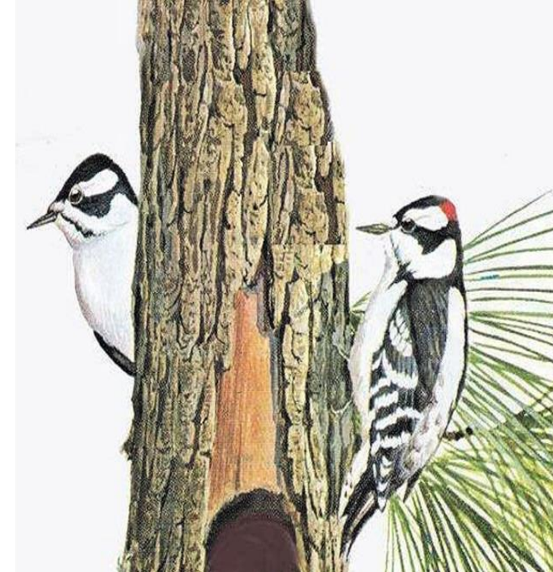
  Example: clown fish and anemones

✓ Anemones have stinging tentacles that can paralyze other fish. Clown fish live in the tentacles of anemones and are protected from predators. Clown fish benefit, and the anemone is neither helped nor harmed.

Ecosystem Components

- **Niches**
- **Habitats**
- **Competitive Exclusion Principle**

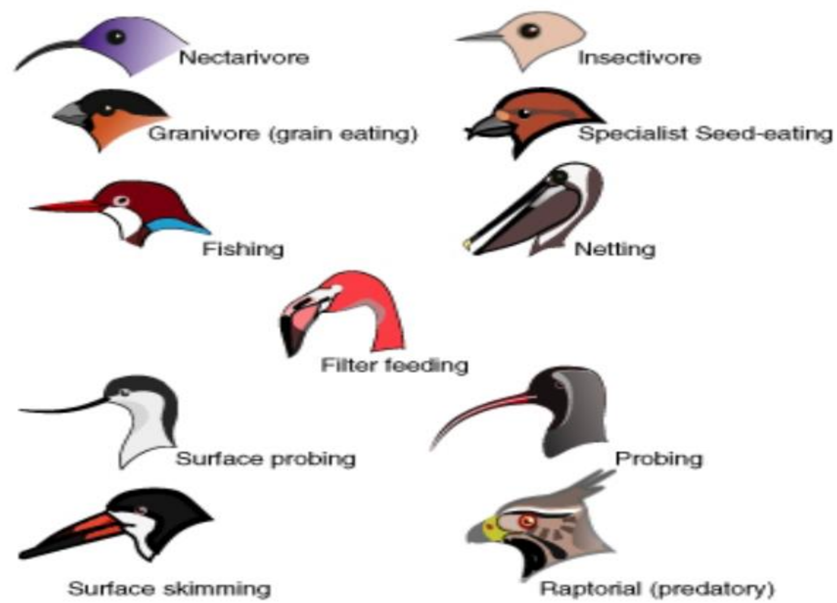




The Niche

Niche→ organism's occupation (role), where it lives, and way in which organism's use conditions they exist in

- Food it eats
- Place in food web
- How it gets food
- Range of temperatures needed for survival
- When and how it reproduces



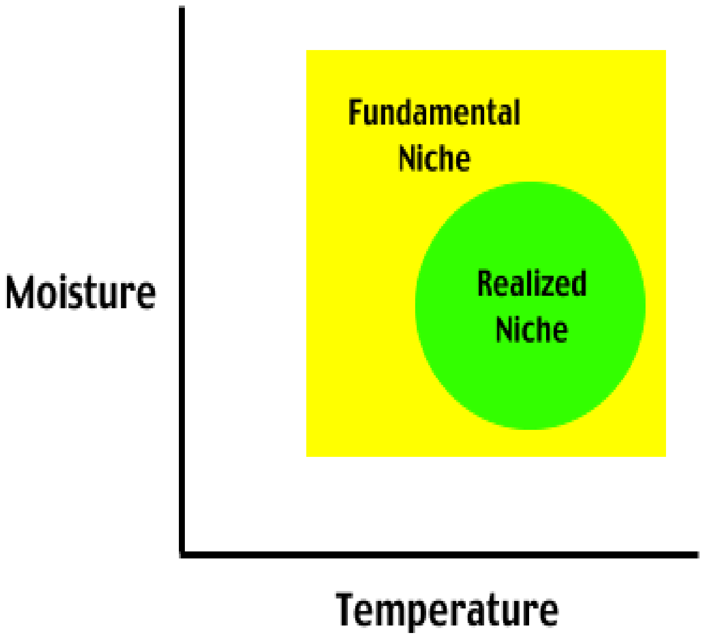
Niches

- **Fundamental niche**

  * The niche that an organism could theoretically occupy.

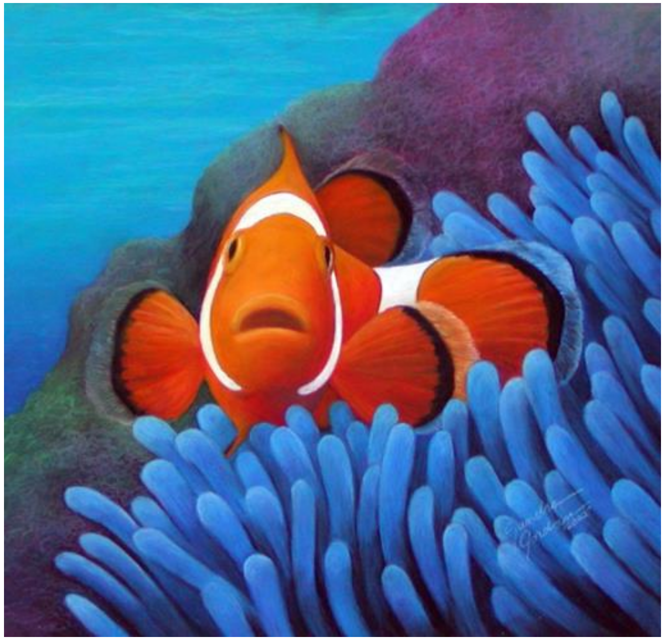
- **Realized niche**

  * The niche that an organism actually occupies which could be less extensive (smaller) than the fundamental niche.



The Habitat

- Physical environment to which an organisms has become adapted and survives in.

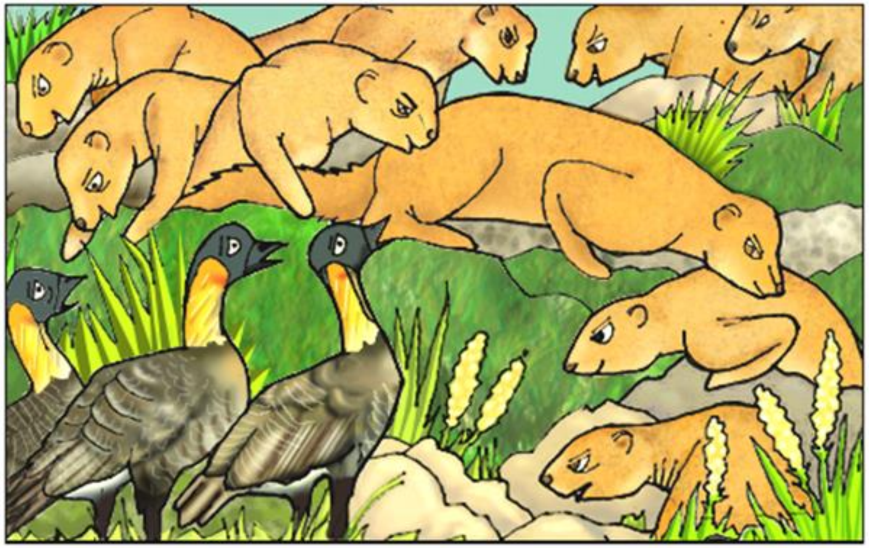


Competitive Exclusion Principle

- Two different species cannot occupy the same niche in the same geographic area.

- If they do they will compete with one another for the same food and other resources.

➢ Eventually, one species will out compete the other.



UNIT FOUR

4. Vegetation development