Fundamentals in Ecology

Week 4

Community ecology 1

Grossiord Charlotte

Schedule of the lectures

Room for all lectures:

ELD020

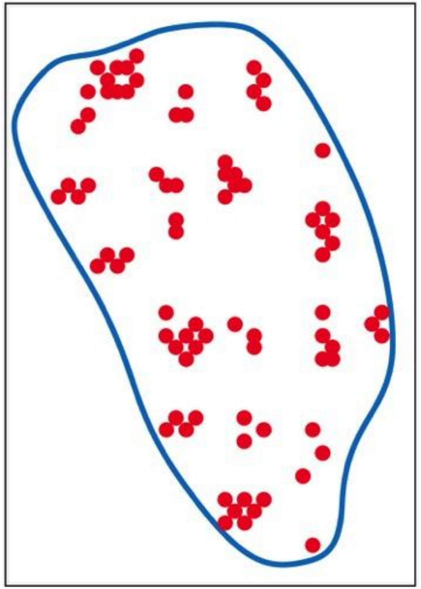
WEDNESDAY - LECTURES - ENV 220			Week	Teacher
19/2/2025	10h15-12h	The nature of ecology (introduction)	1	T. Battin
26/2/2025	10h15-12h	The physical environment	2	T. Battin
5/3/25	10h15-12h	Adaptations to the environment/Physiological ecology	3	C. Grossiord
12/3/25	10h15-12h	Population structure, dynamics, and regulation	4	C. Grossiord
19/3/25	10h15-12h	Community Ecology I	5	C. Bachofen
26/3/2026	10h15-12h	Community Ecology II	6	C. Grossiord
2/4/26	10h15-12h	Ecosystem ecology I	7	T. Battin
9/4/26	10h15-12h	Ecosystem ecology II	8	T. Battin
16/4/2026	10h15-12h	Biodiversity and conservation ecology	9	C. Grossiord
23/4/2025		Easter Holiday		
30/4/2025		ENAC Week		
7/5/24	10h15-12h	Climate Change impacts on terrestrial ecosystems	10	C. Grossiord
14/5/2024	10h15-12h	Climate Change impacts on aquatic ecosystems	11	T. Battin
21/5/2025	10h15-12h	Restoration ecology. Principles of ecosystem restoration, case studies	12	T. Battin
28/5/2025	10h15-12h	Applied ecology. Review and course wrap-up	13	C. Grossiord

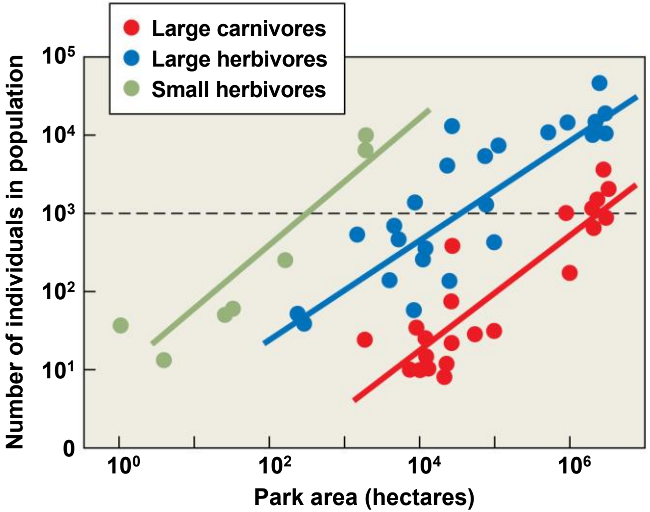
Schedule of the practicals

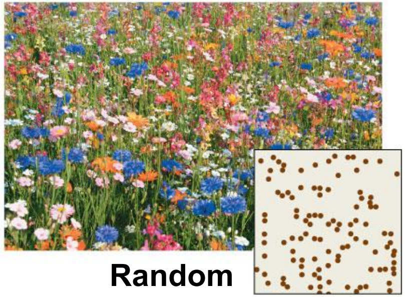
THURSDAY - PRACTICALS - ENV 220			Week	Important deadlines
20/02/25	11h15-13h	Introduction to practicals	1	
27/02/25	11h15-13h	Setting up experiments	2	**Inform the experimental setup to TAs by email by 26/02/25**
6/3/25	11h15-13h	How to write a report	3	
13/03/25	11h15-13h	Introduction to R	4	
20/03/25	11h15-13h	Field measurements 1	5	
27/03/25	11h15-13h	Data visualization in R	6	
3/4/25	11h15-13h	Field measurements 2	7	
10/4/25	11h15-13h	How to do statistical analyses	8	
17/04/25	11h15-13h	Field measurements 3	9	
24/04/25	**Easter Holiday**			
1/5/25	**ENAC Week**			
8/5/25	11h15-13h	Field measurements 4	10	
15/05/25	11h15-13h	Data Analysis/Interpretation	11	**Weighting of plant material in GR B2 423 before 15/05/25**
22/05/25	11h15-13h	Questions / Discussion	12	
REPORT SUBMITTED on MOODLE BY 06/06/25				

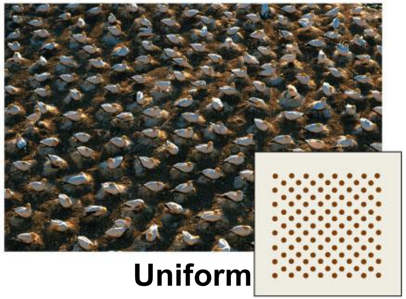
What you saw in the previous lecture

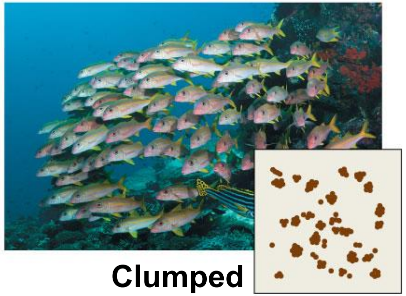
Population Ecology





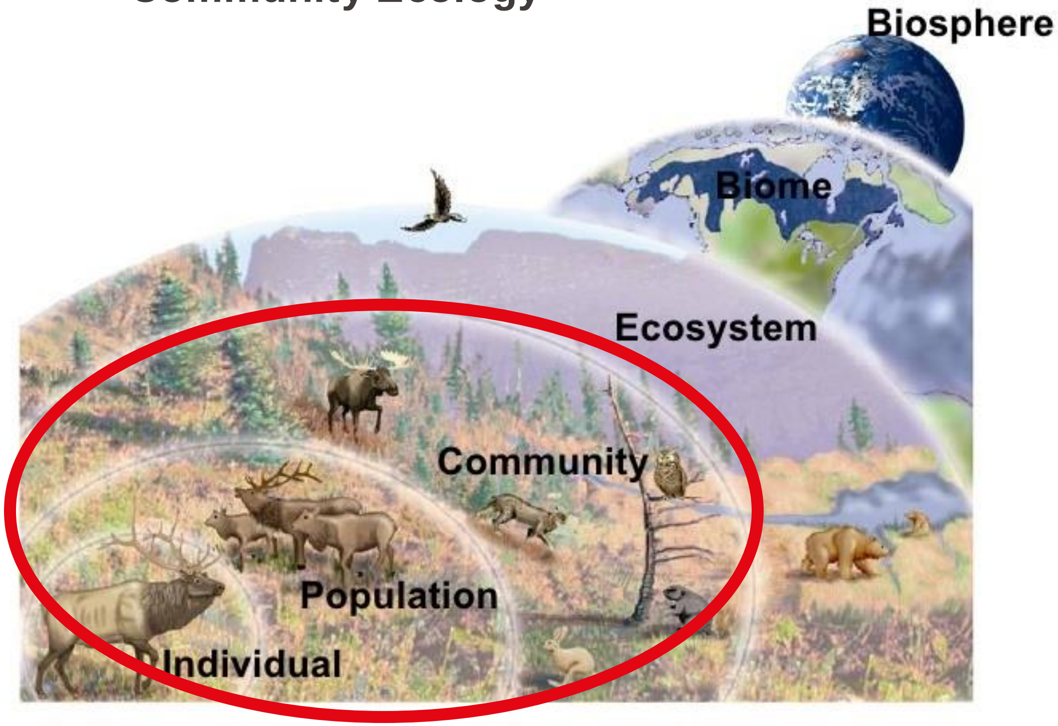






Overview of today's class

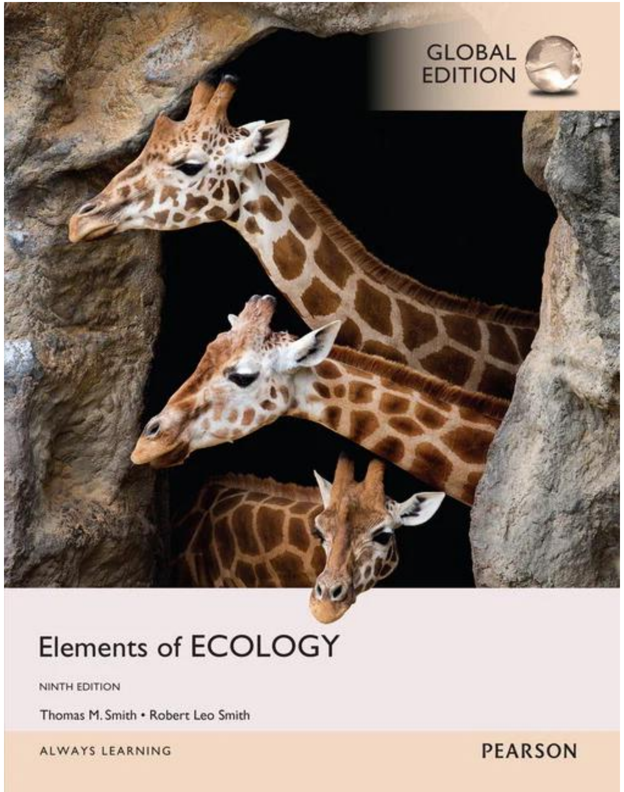
Community Ecology



I. Community Structure

II. Factors influencing the structure of communities

References to today's class



Smith, TM. & Smith RL. Elements of Ecology, Global Edition (Pearson)

1. Community structure



The concept of community is spatial - the species living <u>in a particular place with a defined boundary</u>.

A **community** is a group of species inhabiting **a given area** and interacting, directly or indirectly (e.g., competition, predation, mutualism; cf. previous class).

Attributes of a community include **(1) species number** and their **relative abundance**,

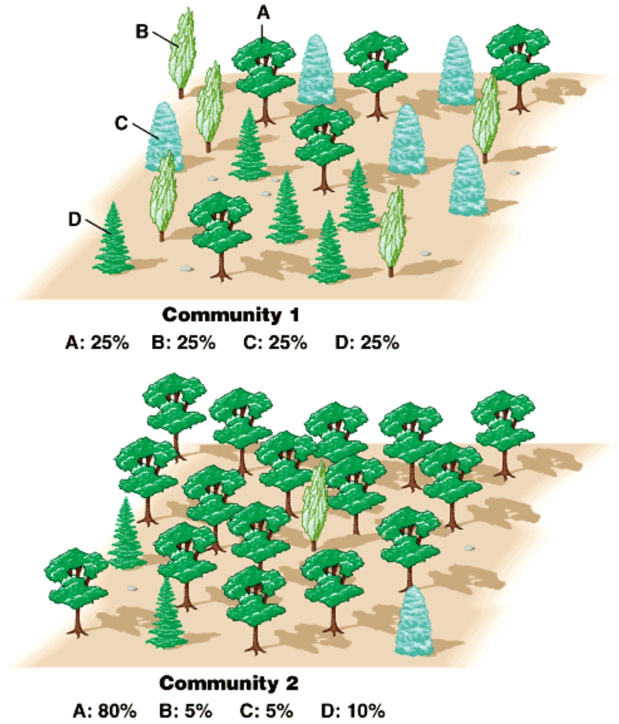
1. Community structure

(1) The **number of individuals** of each species in a community can be counted or estimated (cf. week 3).

A more meaningful measure is the **relative abundance -** the proportion of each species relative to the total number of individuals of all species living in the community:

$$p_i = n_i/N$$

p_i = proportion of individuals of species i
n_i = number of individuals of species i
N = total number of individuals of all species



1. Community structure

A common method for examining relative abundance within communities is by using **rank abundance diagram** plots.

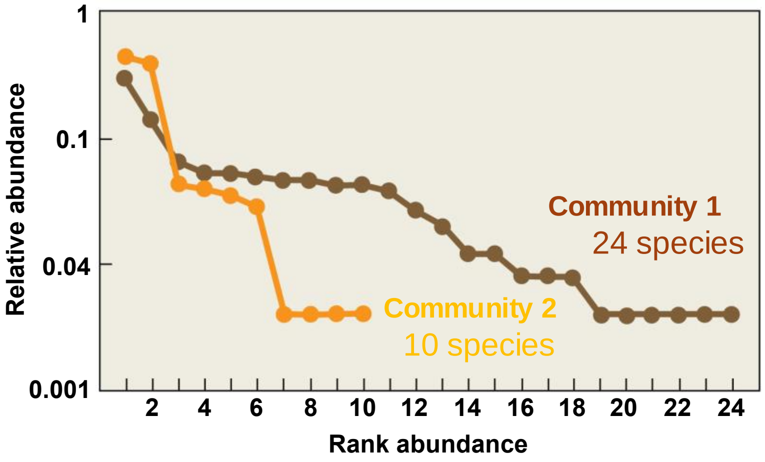
A rank abundance diagram provides information on two features of community structure :

- **Species richness (*S*)** – the number of species in the community
- **Species evenness (*E*)** – how equally individuals are distributed among the species

How to interpret rank abundance curves:

→ The longer the curve, the greater the species richness in the community

→ The more gradual the slope, the greater the species' evenness in the community



Rank-abundance curves for two communities. Rank abundance is the species ranking based on relative abundance, ranked from the most to least abundant (*x*-axis). Relative abundance (*y*-axis) is expressed on a $\log_{10}$ axis. The first community (brown line) has a higher species richness (length of curve) and evenness (slope of curve) than the second community (orange line).

1. Community structure

When a single or few species predominate within a community, those species are called **dominant species.**

However, abundance alone is not a sufficient measure of dominance. For example, in a forest, there may be more small understory trees, but the fewer large trees have most of the biomass (see example in the table).

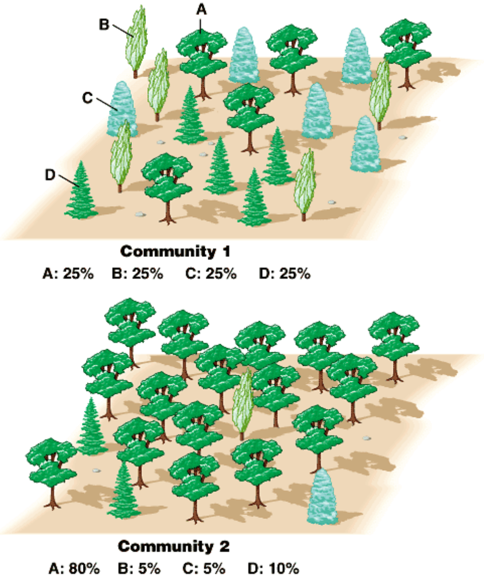


Table 16.2 Structure of Deciduous Forest Stand in Central Virginia

Species	*Number of Individuals*	*Relative Abundance*	*Relative Biomass*
Red maple *Acer rubrum*	30	33.0	6.2
Dogwood *Cornus florida*	24	26.4	4.6
White Oak *Quercus alba*	8	8.8	58.5
Tulip poplar *Liriodendron tulipifera*	6	6.6	12.3
Red Oak *Quercus rubra*	6	6.6	7.6
Mockernut hickory *Carya tomentosa*	5	5.5	2.2
Virginia pine *Pinus virginiana*	4	4.4	6.3
Cedar *Juniperus virginiana*	2	2.2	0.5
Beech *Fagus grandifolia*	2	2.2	0.9
Blackgum *Nyssa sylvatica*	1	1.1	0.2
Black cherry *Prunus serotina*	1	1.1	0.2
Sweetgum *Liquidambar styraciflua*	1	1.1	0.4
American hornbeam *Carpinus carolinia*	1	1.1	0.2
	91	**100.0**	**100.0**

1. Community structure

Abundance is a measure based on the numerical supremacy of a species' contribution to the community. However, less-abundant species may play a crucial role in the functioning of the whole community.



A **keystone species** has a disproportionate impact on the community relative to its abundance.

→ The role of a keystone species may be to create habitats or influence interactions among species.

→ The removal of a keystone species can lead to changes in community structure and lead to loss of biodiversity.

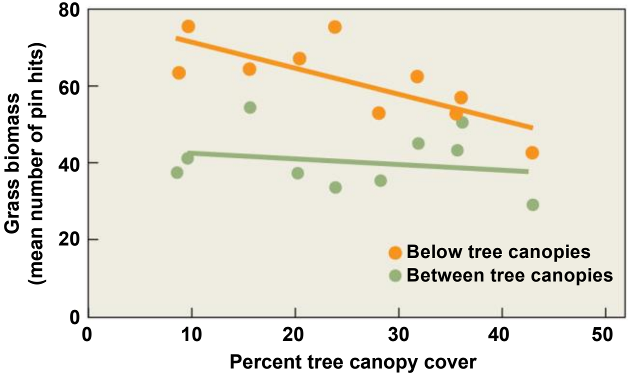

MUKKAW BAY
WASHINGTON STATE

1. Community structure

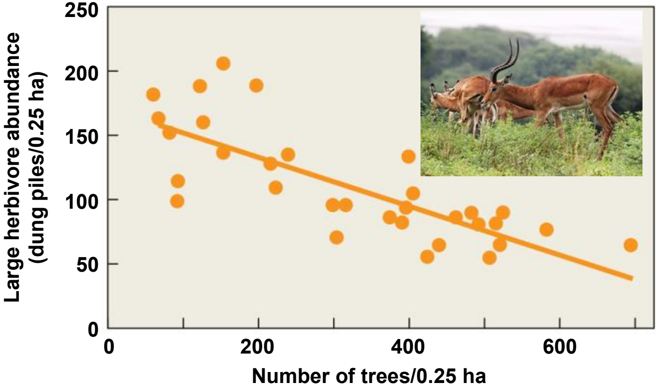
Example:

African elephants in savannas of southern Africa are keystone species that feed mainly on woody plants.

They are destructive feeders, often uprooting, breaking, and destroying the shrubs they eat. Reducing tree and shrub density favors the growth and reproduction of grasses.



(b)

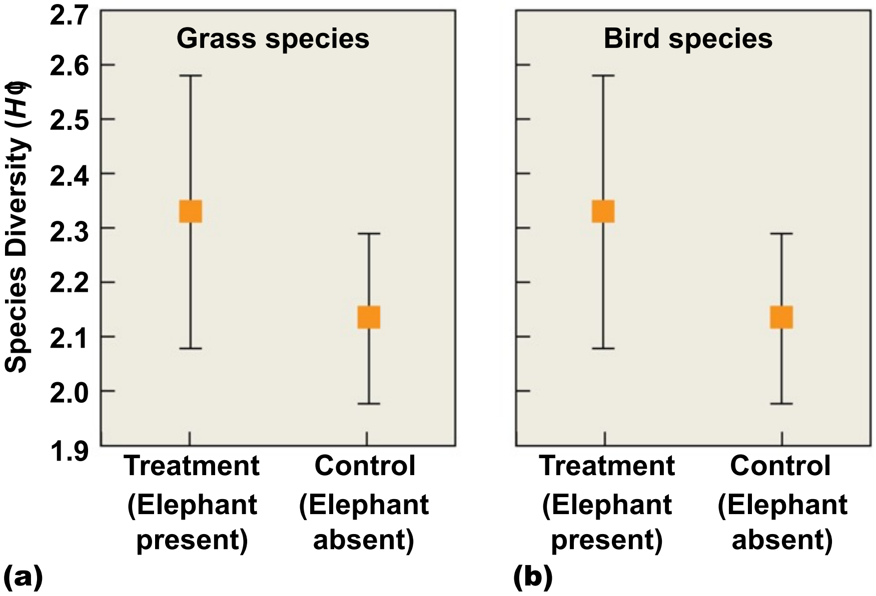


This community change benefits grazing herbivores but not elephants. Elephants' destruction of trees creates habitats for smaller vertebrates.

1. Community structure

A study in the Eastern Cape region of South Africa found a similar effect of elephant feeding on community diversity

Sites inhabited by elephants had an increase in both grass and bird species diversity compared to habitats without elephants



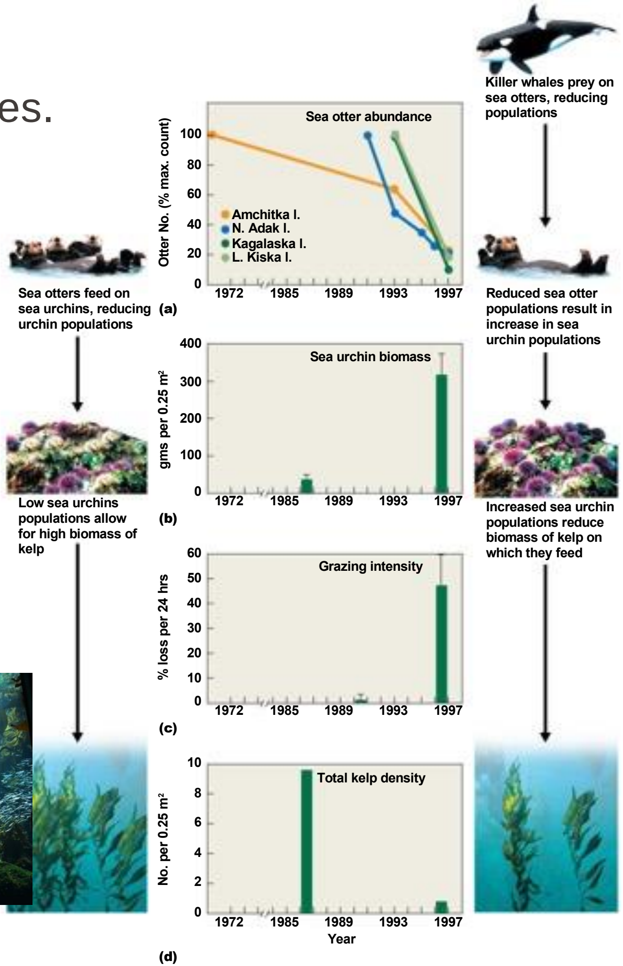
Comparison of (a) grass species diversity and (b) bird species diversity for savanna grassland sites in the Eastern Cape region of South Africa where elephants are absent (control) and where elephants are present (treatment). Species diversity is measured by the Shannon index (cf. week 10).

1. Community structure

Predators often function as keystone species in communities.

Example: The Sea otter is a keystone predator species in the coastal kelp communities of the North Pacific; however, their role as top predators has changed over the past several decades.

Increased predation of otters by whales resulted in a (a) decline in sea otter abundance and concurrent changes in (b) sea urchin biomass, (c) grazing intensity, and (d) kelp density measured from kelp forests.



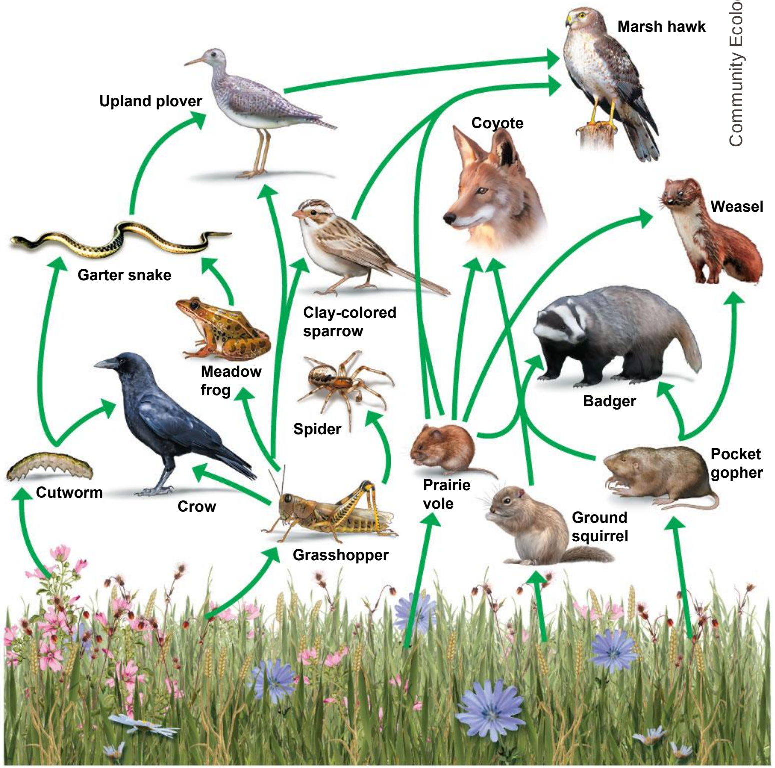
1. Community structure

(2) Ecologist studying the structure of communities often focus on the feeding relationships among the component species.

A **food chain/web** represents feeding relationships within a community.

- It is a descriptive diagram representing the flow of energy from the prey (consumed) to the predator (consumer)
- Arrows are used to represent these relationships
- The direction of the arrow goes from the prey to the predator

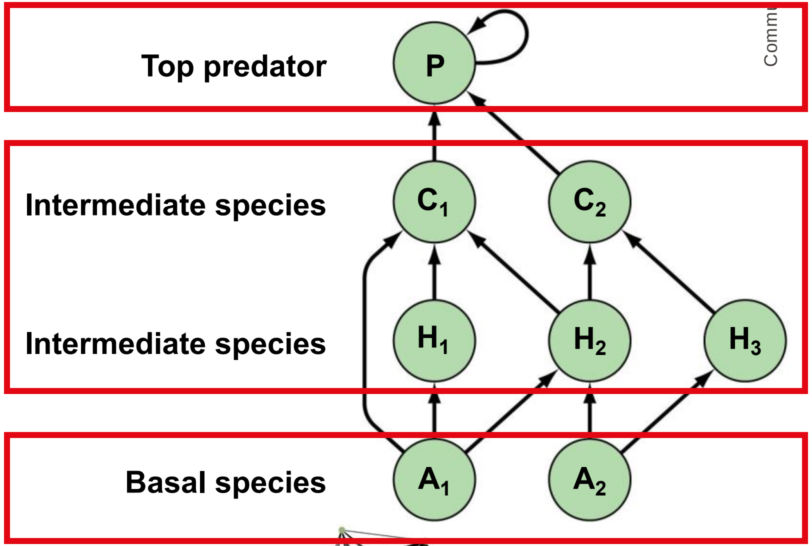
grass → grasshopper → sparrow → hawk



A food web for a prairie grassland community in the midwestern United States. Arrows flow from prey (consumed) to predator (consumer). Primary producers (photosynthetic organisms) form the base of the food web.

1. Community structure

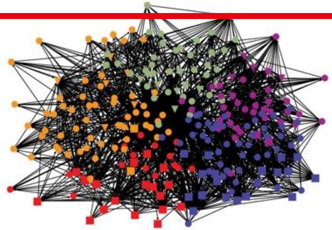
Hypothetical food web illustrating the various categories of species.



This hypothetical food web represents the basic structure of a food web and the associated terminology:

- **Basal species** – are usually autotrophs (A) that do not feed on other species
- **Intermediate species** – either herbivores (H) or carnivores (C) that feed on other species and are the prey of other species (may also be omnivores)
- **Top predators** (P) – feed on intermediate and sometimes basal species (if omnivores) but are not preyed upon themselves

Food webs can become very complex →



Compartmentalized structure of a marine food web. Symbols of different colors represent species in various compartments, whereas each link (arrow) represents a predator-prey interaction.

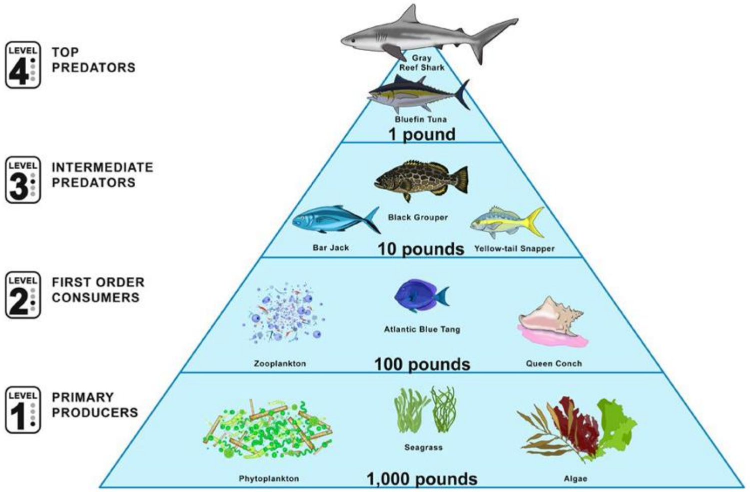
1. Community structure

The representation of a food web can be simplified by grouping species into broader categories that represent general feeding groups. For example:

- autotrophs (primary producers) – derive energy from sunlight
- heterotrophs (consumers) – derive energy from consuming plant and animal tissues.

These feeding groups are called **trophic levels.** Trophic levels are a functional classification (i.e., they define species groups that similarly acquire their energy).

Grouping species can simplify the study of communities. It creates subsets that can be more manageable for researchers to study and allow the analysis of community organizations.



The marine food pyramid displays a basic food web and the different trophic levels.

1. Community structure

This approach of grouping species has been expanded to an approach that classifies species based on **function** rather than taxonomic group.

Functional type – groups species based on their:

- common response to the environment
- life history characteristics
- role within the community

Coniferous trees

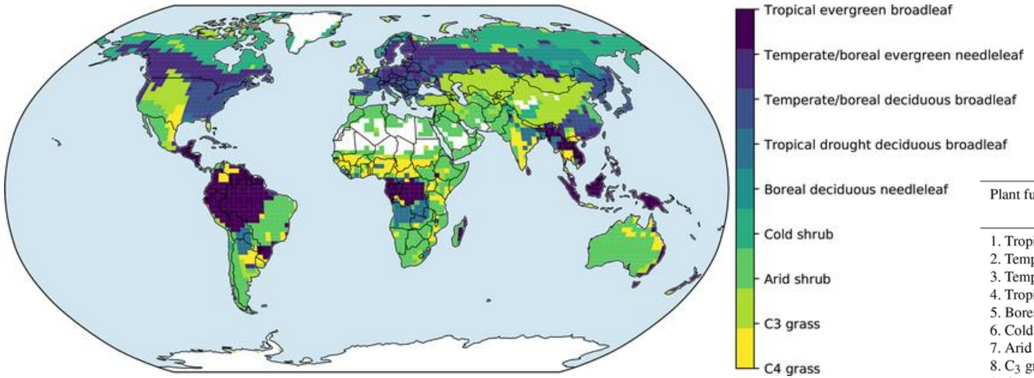
Broadleaf trees

Shrubs

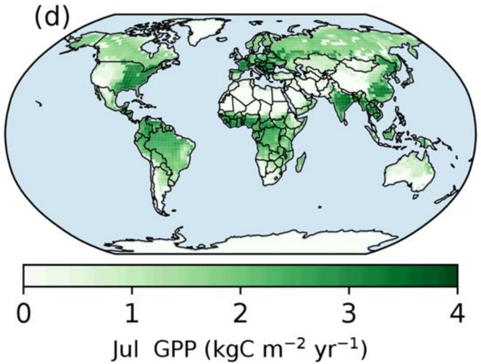
EPFL

1. Community structure

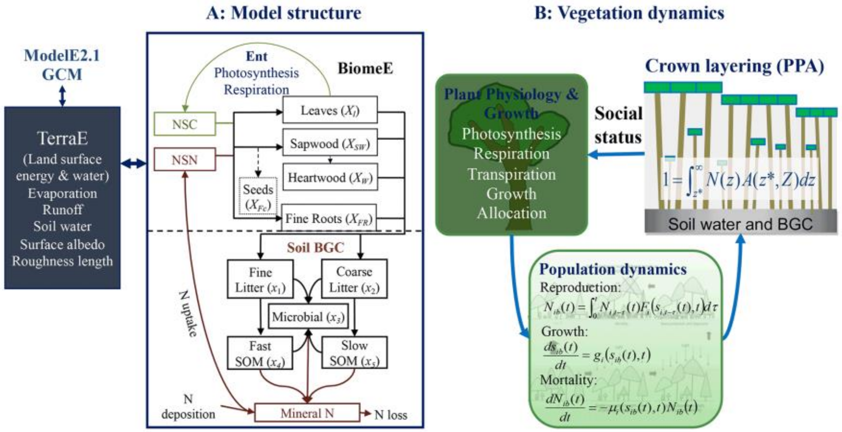
Defining functional types is key for modeling ecosystem functions



Plant functional types	V_{cmax}	LMA ($kg\,C\,m^{-2}$)	$L_{max,0}$	ρ_W ($kg\,C\,m^{-3}$)	α_Z	$T_{0,c}$	$\beta_{0,D}$	PS pathway
1. Tropical evergreen broadleaf	18	0.07	4.8	360	30	15	0	C_3
2. Temperate/boreal evergreen needleleaf	18	0.14	4.8	300	30	−80	0	C_3
3. Temperate/boreal deciduous broadleaf	22	0.025	4.5	350	30	15	0	C_3
4. Tropical drought deciduous broadleaf	20	0.03	4.5	250	30	15	0.2	C_3
5. Boreal deciduous needleleaf	20	0.03	4.0	300	30	15	0.0	C_3
6. Cold shrub	18	0.025	3.0	360	20	15	0.1	C_3
7. Arid shrub	18	0.03	3.0	360	20	15	0.1	C_3
8. C_3 grass	20	0.025	2.5	90*	10	5	0.2	C_3
9. C_4 grass	15	0.025	2.5	90*	10	5	0.2	C_4



Simulated GPP



Weng et al., 2022; Geoscientific Model Development

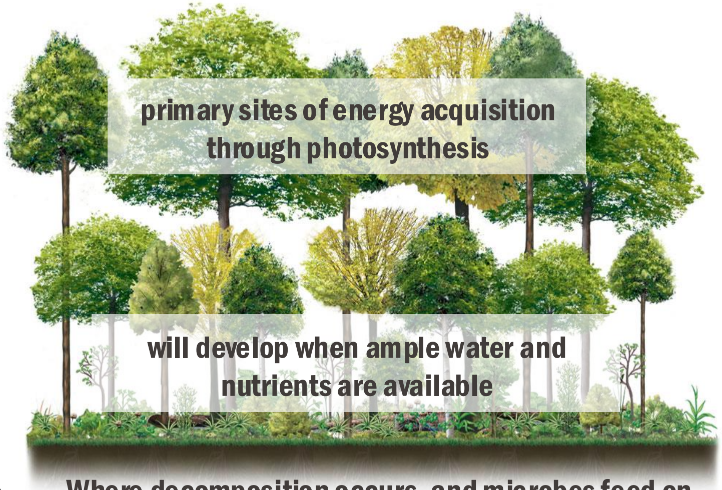
1. Community structure

(3) Communities are characterized not only by the mix of species and by the interactions among them but also by their **physical structure**.

The **physical structure** of the community reflects abiotic factors (e.g., sunlight, temperature) and biotic factors (e.g., the spatial arrangement of the organisms, their size, their density).

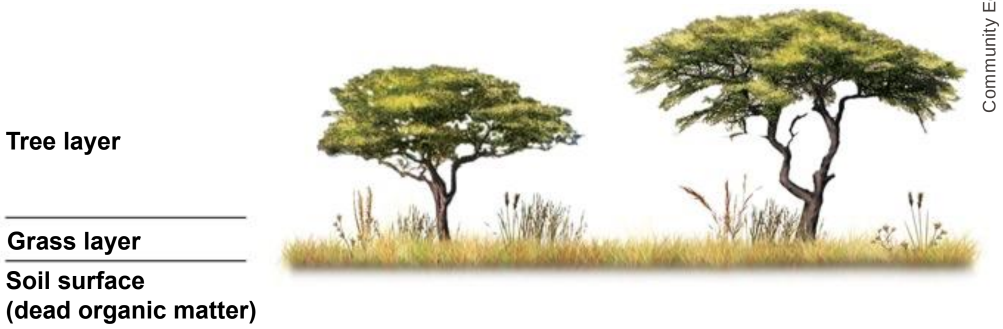
- Every community has a vertical structure: a stratification of distinct vertical layers.

- The structure influences the community (e.g., if a canopy is open, sunlight will reach the lower layers, and the understory will be well developed).

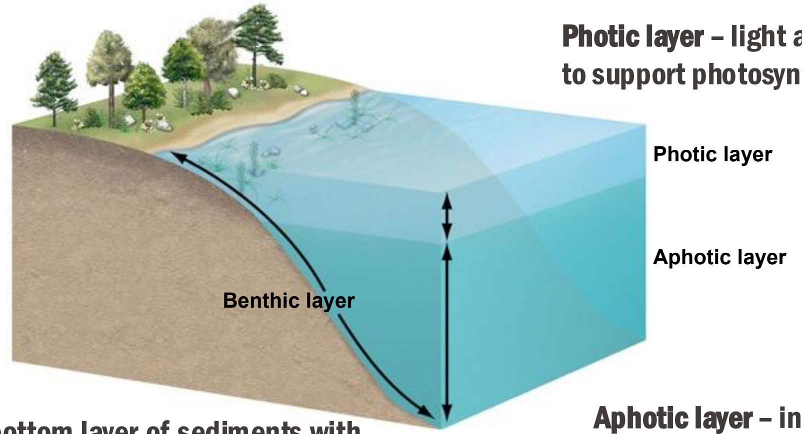


1. Community structure

Savanna communities have two distinct vegetation layers, the composition of which depends on rainfall: woody plants, such as trees and shrubs, and herbaceous plants, such as grasses.



Aquatic communities also have vertical structures, but the stratification is primarily **determined by the physical characteristics of the water column** (and not the biological characteristics)



Photic layer – light available to support photosynthesis

Aphotic layer – insufficient light for photosynthesis

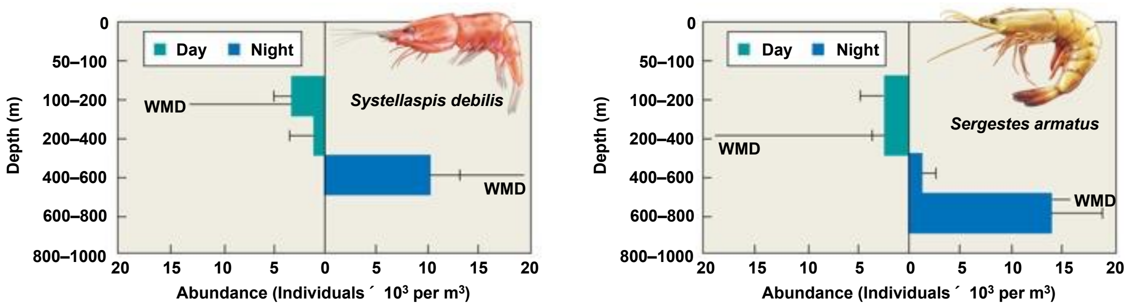
Benthic layer is the bottom layer of sediments with higher levels of decomposition

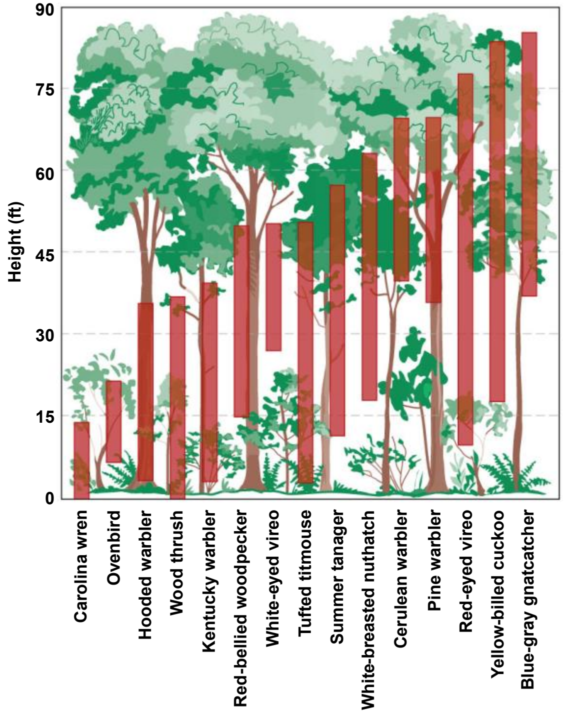
1. Community structure

Each layer contains characteristic organisms. Consumers occupy all community levels, but decomposers are more abundant on the forest floor or benthic layer.

Many mobile animals are found in a few layers, but species may move among layers daily or seasonally. This reflects variation in the physical environment, shifts in resource abundance, and changes in habitat required at different life cycle stages.

Daily vertical migration patterns of two decapod species off the coast of Namibia (Africa).

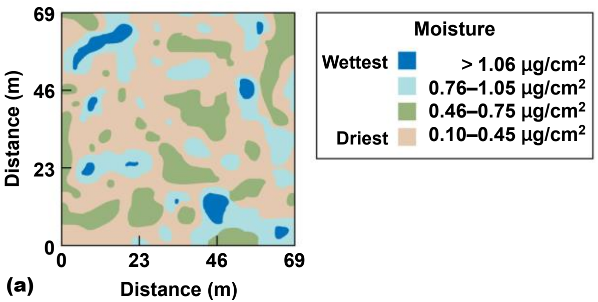




Vertical distribution of bird species within a forest community

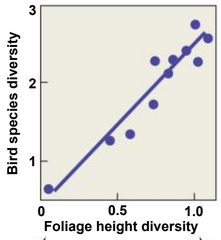
1. Community structure

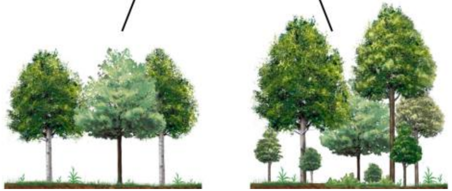
Environmental heterogeneity influences community diversity. Environmental conditions are usually not homogenous within a community.



Increased heterogeneity generally means greater diversity of potential habitats as different species have specific requirements related to food or nesting sites.

For example, deciduous forests can have multiple layers that may support 30 or more species, with different birds living at different levels (see example to the right).





Relationship between bird species diversity and foliage height diversity. Foliage height diversity is a measure of the vertical structure of the forest. The greater the number of vertical layers of vegetation, the greater the diversity of bird species in the forest.

1. Community structure

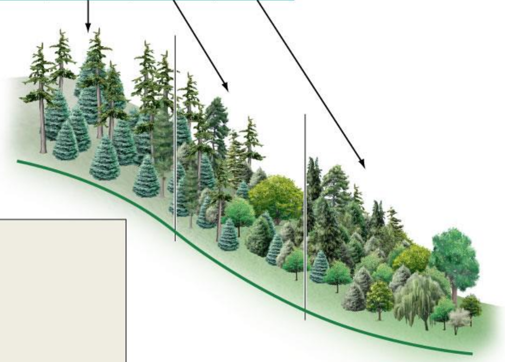
The biological and physical characteristics of a community can also change horizontally across the landscape.

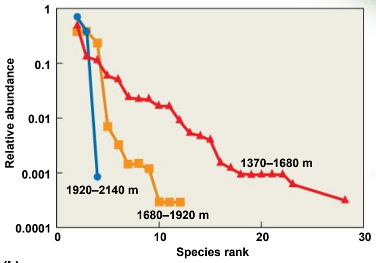
Zonation is the change in physical and biological structures of communities as seen when moving across the landscape.

From the base to the summit of the Siskiyou Mountains (see figure):
- Dominant tree species changes
- There is a decline in species richness

		Relative abundance (% Total number of individuals)		
Species	**Common name**	**1920–2140 m**	**1680–1920 m**	**1370–1680 m**
Abies nobilis	Noble Fir	64.15	40.10	2.41
Tsuga mertensiana	Mountain hemlock	35.77	18.97	0.07
Pinus monticola	Western white pine	0.08	0.03	
Pseudotsuga menziesii	Douglas fir		0.1[illegible]	14.75
Libocedrus decurrens	Incense-cedar		0.35	2.44
Abies concolor	White fir		39.50	54.32
Pinus lambertiana	Sugar pine		0.03	0.98
Corylus rostrata	Beaked hazelnut		0.13	2.64
Acer glabrum	Rocky Mountain maple		0.73	6.44
Chamaecyparis lawsoniana	Lawson cypress			12.55
Taxus brevifolia	Pacific yew			1.83
Pinus ponderosa	Ponderosa pine			0.10
Acer macrophyllum	Oregon maple			0.51
Salix spp.	Willow			0.14
Alnus spp.	Alder			0.10
Amelanchier florida	Florida juneberry			0.10
Sobrum americana	American Mountain-ash			0.[illegible]7
Castanopsis chrysophylla	Giant chinkapin			0.44

(a)





(b)

Changes in the structure of the forest communities along an elevation gradient. (a) Changes in the relative abundance of tree species for three segments of the elevation gradient: 1370–1680, 1680–2140, and 1920–2140 m. (b) Rank-abundance curves for the three forest communities corresponding to the three segments of the elevation gradient.

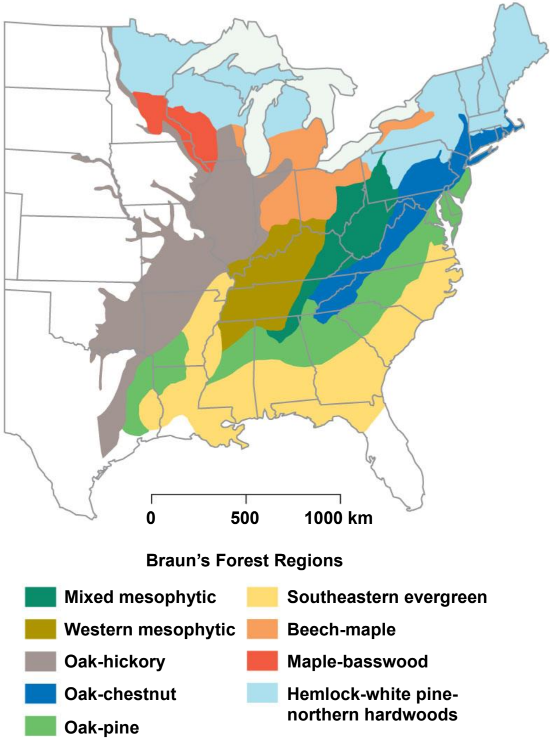
1. Community structure

How different do two adjacent communities need to be before they are distinct communities?

Adjacent communities are distinguished by differences in their physical and biological structure but:

- If the transition between two communities is abrupt, defining the boundaries may not be difficult.
- If the transition between two communities is gradual, where is the boundary between them?

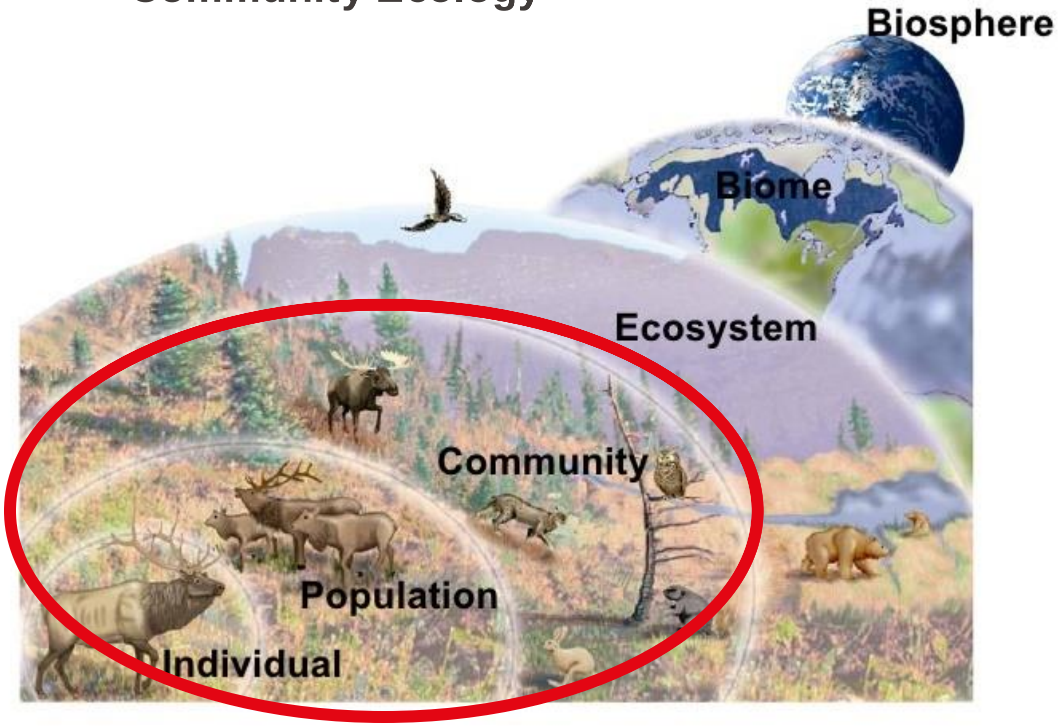
We have multiple techniques to delineate communities. All will have some measure of community similarity or difference. These classifications can include subjectivity, depending on the spatial scale and the objectives of the study.



Large-scale distribution of deciduous forest communities in the eastern United States is defined by nine regions. These examples of large-scale zonation reinforce the idea that the definition of a community is a spatial concept.

Overview of today's class

Community Ecology



I. Community Structure

II. Factors influencing the structure of communities

2. Factors influencing the structure of communities

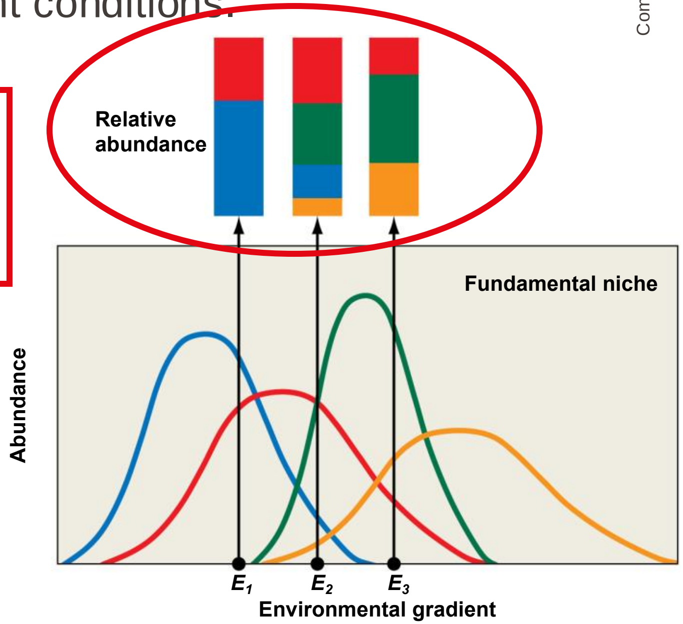
A set of adaptations that enables a species to succeed under a specific set of environmental conditions can prevent success under different conditions.

Fundamental niche: The total range of environmental conditions under which a species can survive and reproduce.

The fundamental niches of species in a community can be represented by curves along an environmental gradient plotted against abundance.

The distribution of fundamental niches along an environmental gradient represents a primary constraint on community structure:

- For a location at a particular point along the gradient, only a subset of species has the potential to be part of the community.

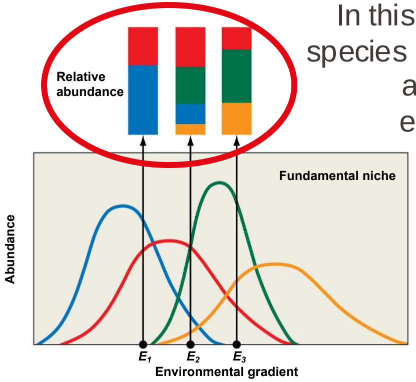


Hypothetical example of the fundamental niches of four species represented by their distributions and abundances along an environmental gradient (e.g., air temperature). Their relative abundances at any point along the gradient (E_1, E_2, and E_3) provide a first estimate of community structure.

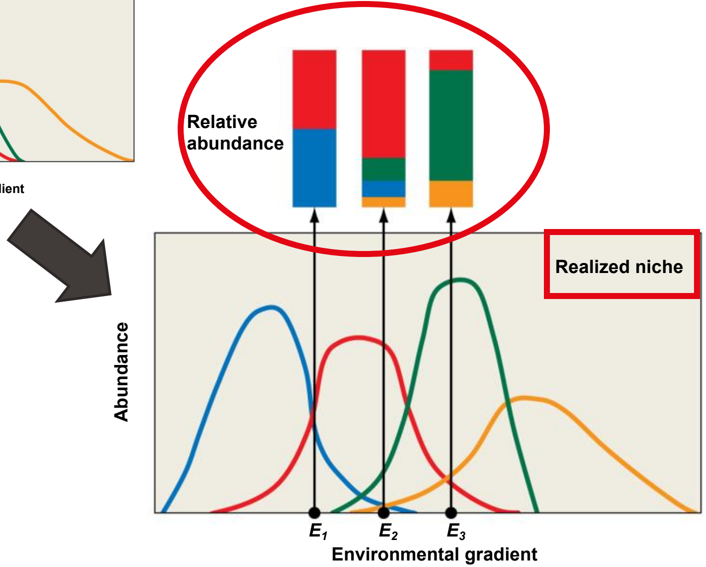
2. Factors influencing the structure of communities

Species interactions influence the presence and abundance of species within communities:

- can modify fundamental niches
- can influence relative abundances



In this example, the realized niche of the red species is reduced by competition or predation at both ends of its distribution along the environmental gradient (blue and green arrows).



Competition and predation can reduce the abundance or exclude species. Facilitation and complementarity can increase the abundance or extend the distribution of a species.

Realized niche: fundamental niche modified by interactions with other species in the community.

The actual community structure at any point along the gradient is a function of the species' realized niches—the species' potential responses (fundamental niche) as modified by their interaction with other species present.

2. Factors influencing the structure of communities

Most studies focus on direct interactions between two or a few species to examine the role of species interactions on communities. However, interactions are often involving multiple species.

Diffuse competition – describes the total competitive effects of several interspecific competitors.

- If the relative abundance of a species is affected by competitive interactions with a single competitor, removing the competitor provides information on the importance of competition for the species being studied.

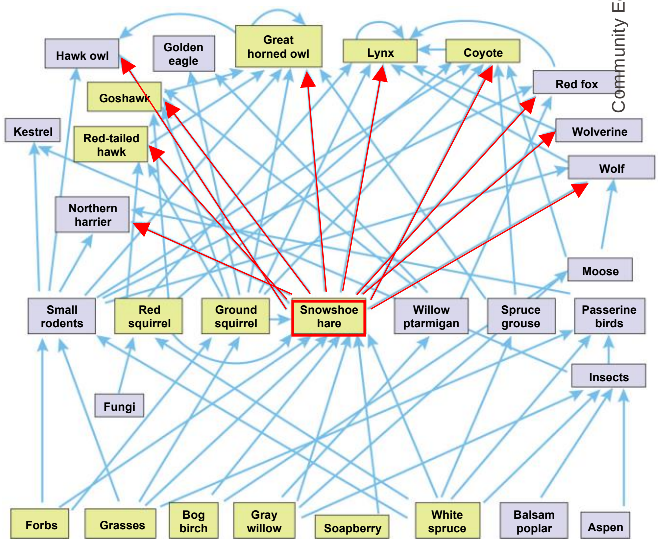
- However, if the relative abundance of a species is affected by competition with many other species in the community, removing only one or even a few competitors may have little effect on the abundance of that species.

2. Factors influencing the structure of communities

Food webs can illustrate **diffuse** species interactions (see example with the snowshoe hare in the figure).

- An **indirect interaction** occurs when species A does not interact directly with species B, but instead influences species C that directly interacts with species B. A direct interaction between two species can lead to indirect interactions across a community.

Example: Lynx do not directly interact with white spruce, but prey on snowshoe hare, which feed on white spruce. This predation can positively affect the survival of the white spruce population.



A generalized food web for a boreal forest. Dominant species within the community are shown in yellow. Arrows link predator with prey species. Arrows that loop back to the same species (box) represent cannibalism. Many predators in this community use the same prey resources – **diffuse competition**. For instance, 11 of the 12 predators prey on snowshoe hares. Any one has a limited effect on the hare population. But the combined effect of multiple predators can regulate the hare population.

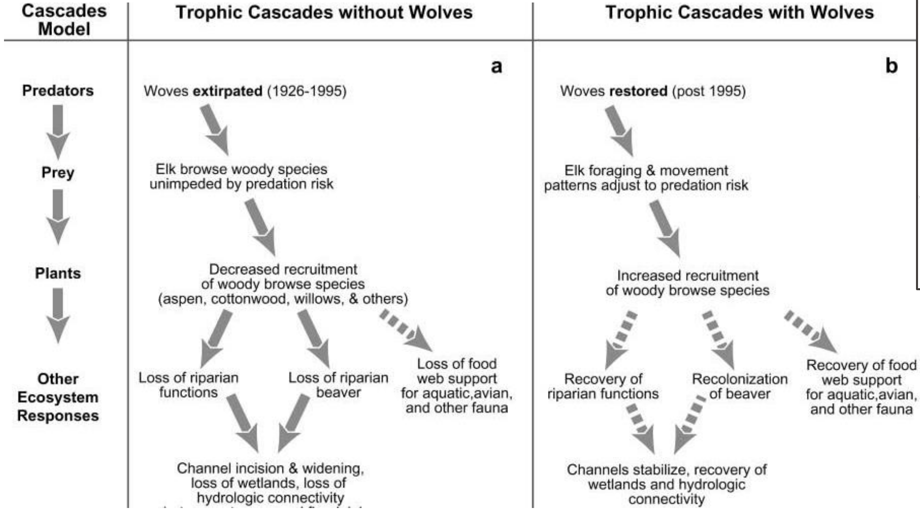
HOW WOLVES CHANGE RIVERS

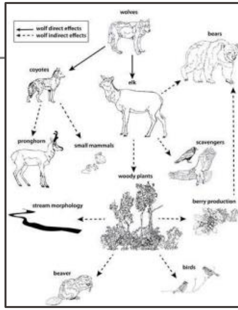
2. Factors influencing the structure of communities

Top-down control – the predator populations control the abundance of prey species, which in turn influences the abundance of their food.

The top-down control with the wolves is a **trophic cascade** – that occurs when a predator suppresses the abundance of their prey such that it increases the abundance of the next lower trophic level.

The other type of control is referred to as **bottom-up control** – the abundance of populations is controlled by the productivity and abundance of populations in the trophic level below them



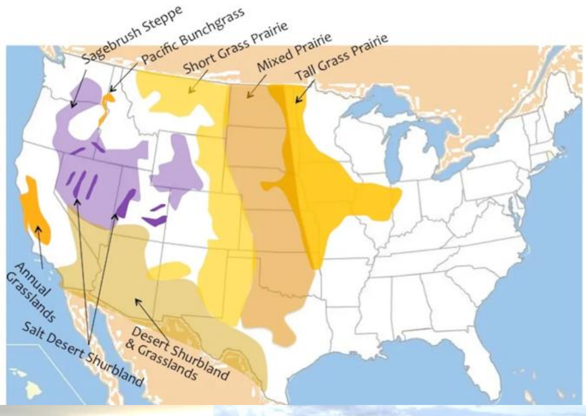


2. Factors influencing the structure of communities

Applications: **Restoration ecology** aims to return a community or ecosystem to a state approaching its condition before disturbance through the application of ecological principles.

It can involve different approaches:

- reintroducing species
- restoring habitats
- reestablishing entire communities.



Example of a success case:

The region west of the Mississippi was unlike anything European settlers were familiar with. The prairies of North America, a vast expanse of grasses, covered a large portion of the continent. This region was transformed, primarily for agriculture. Less than 1 percent of the prairie remains, mainly in small, isolated patches.

2. Factors influencing the structure of communities

First efforts to restore tall-grass prairies began in the 1930s in the Midwest. The goal = reestablishment of native species on degraded pastureland and abandoned croplands.

Restoration process involved:
- destroying the weeds and brush present
- reseeding and replanting native prairie species

(a)

Burning the site once every two or three years to approximate the natural fire regime. After 80 years, the plant community now resembles the original native prairie.

(b)

Photographs of early efforts in the restoration of a prairie community at the University of Wisconsin Arboretum. (a) In 1935, work began on the restoration effort. (b) Early experiments established the critical importance of fire in maintaining the structure and diversity of the prairie community.

2. Factors influencing the structure of communities

Some efforts also failed

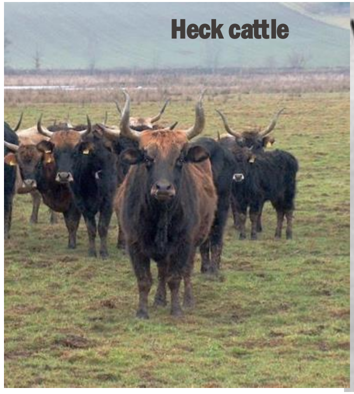
Oostvaardersplassen is a nature reserve in the Netherlands covering 56 km^2. It is a rewilding experiment - restore (an area of land) to its natural uncultivated state.

Before the establishment of the reserve, the dry area was a nursery for willow trees. This led to concern that a dense woodland would develop, significantly reducing the value of the habitat for water birds.

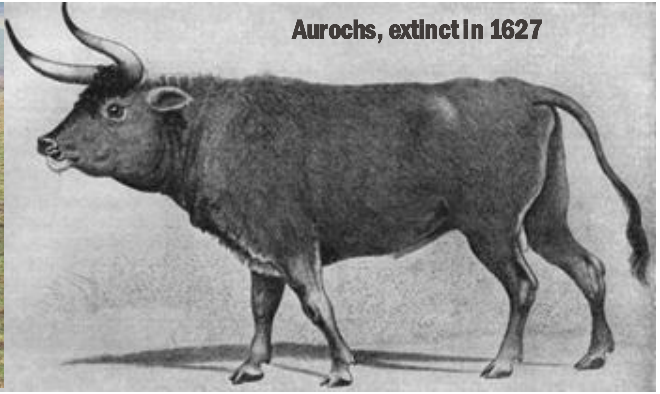
2. Factors influencing the structure of communities

To avoid the development of a dense woodland, the park's managers brought in several large herbivores to keep the area open.

Before they were driven to extinction, large herbivores such as aurochs and tarpans occupied this part of Europe. Other species, such as Konik ponies and heck cattle, were introduced in the reserve because they can act as functional equivalents (occupy the same ecological niche).



Heck cattle



Aurochs, extinct in 1627

The introduced animals rapidly multiplied in the absence of a top predator. However, there is a limit to the number of animals the area can sustain (cf. lecture 4).

Konik ponies

Tarpan, extinct in 1909

2. Factors influencing the structure of communities

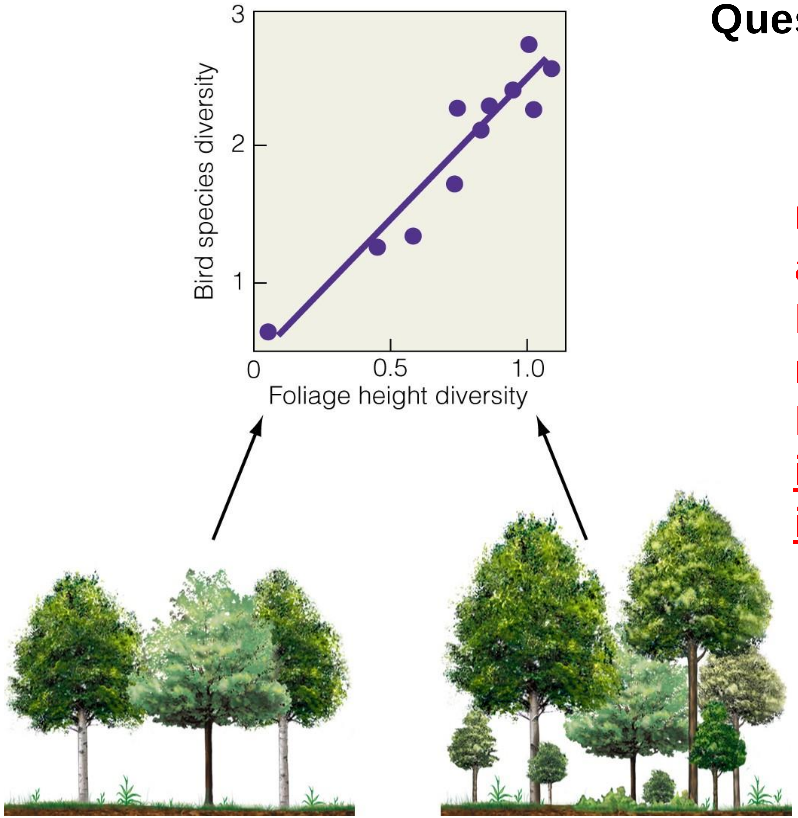
During a particularly harsh winter in 2005, many animals died of starvation, leading to public outcry against alleged animal cruelty.

In the absence of natural predators, the rangers shoot animals that are unlikely to survive (30-60 % of the population).

Effectively the reserve is too small and impoverished to accommodate the natural processes of large herbivores that need to migrate over large distances.

There have been calls by different organizations for a corridor to be created that would allow seasonal small-scale migration and take some strain off the big grazers in winter. However, because of financial and political troubles, the creation of the corridor is still uncertain.

3. Exercices



Question: What does this figure suggest?

Increased heterogeneity in structure generally means greater diversity of potential habitats, and more resources and living space. Different species have specific requirements related to food, cover, and nesting sites. Hence, as can be seen in the figure, **increased foliage height diversity drives increased bird diversity**.

Next week

Community Ecology 2

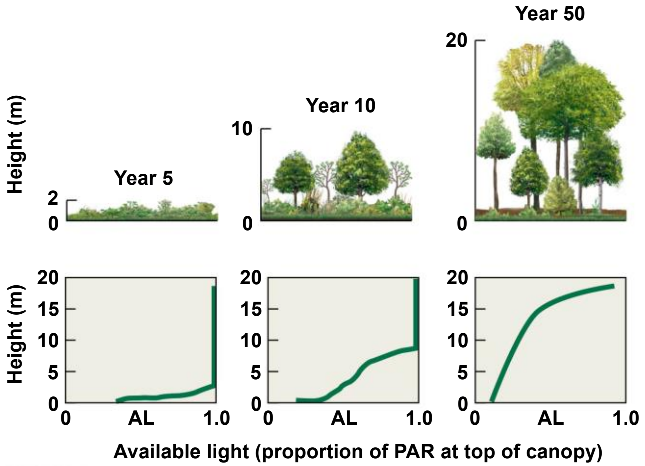



Fig. 7.1a Muir Glacier, 1941


Fig. 7.1b Muir Glacier, 2004