Fundamentals in Ecology

Week 9

Biodiversity and conservation ecology

Grossiord Charlotte

Schedule of the lectures

Room for all lectures:

ELD020

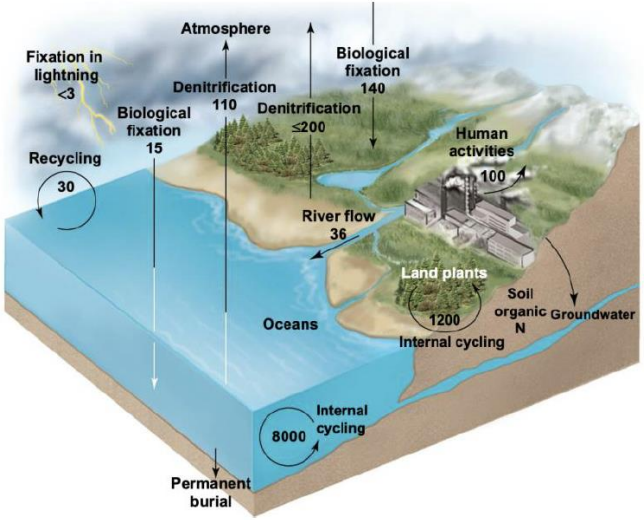
WEDNESDAY - LECTURES - ENV 220			Week	Teacher
19/2/2025	10h15-12h	The nature of ecology (introduction)	1	T. Battin
26/2/2025	10h15-12h	The physical environment	2	T. Battin
5/3/25	10h15-12h	Adaptations to the environment/Physiological ecology	3	C. Grossiord
12/3/25	10h15-12h	Population structure, dynamics, 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

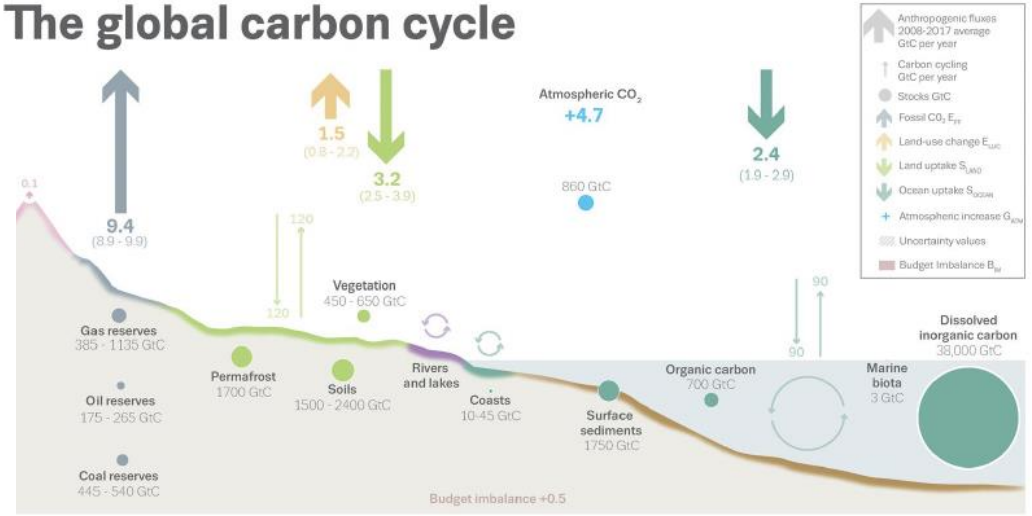
THURSDAY - PRACTICALS - ENV 220			Week	Important deadlines
20/02/25	11h15-13h	Introduction to practicals	1	
27/02/25	11h15-13h	Setting up experiments	2	Inform the experimental setup to TAs by email by 26/02/25
6/3/25	11h15-13h	How to write a report	3	
13/03/25	11h15-13h	Introduction to R	4	
20/03/25	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

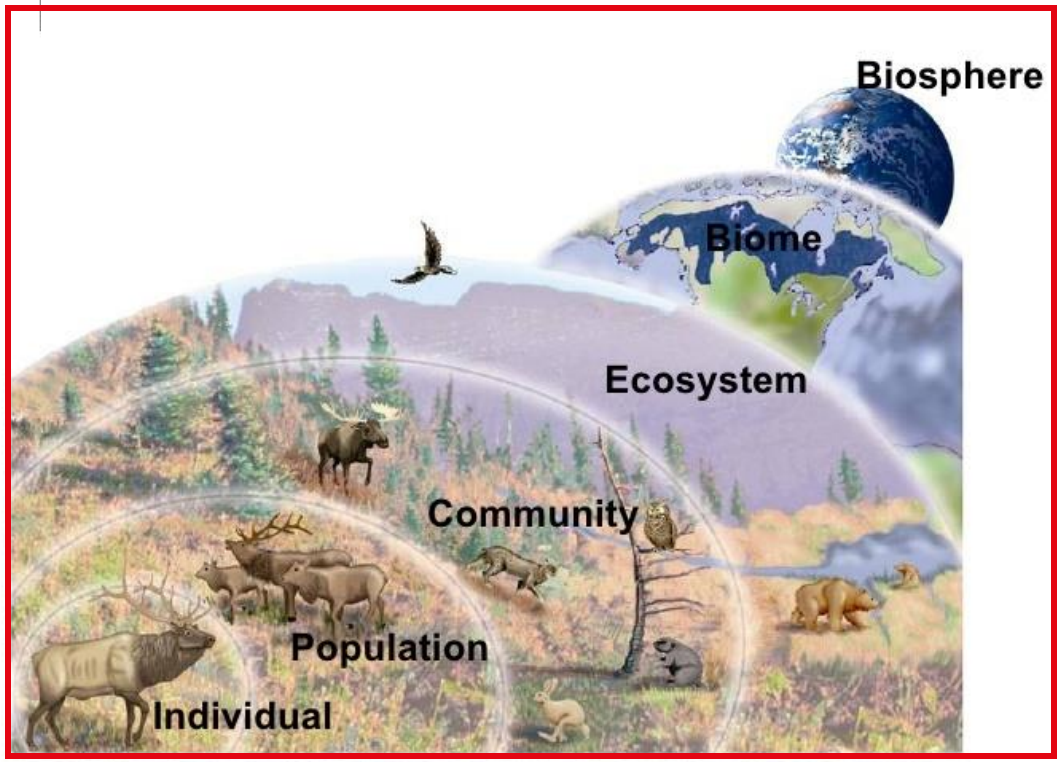
Ecosystem Ecology 1-2



The global nitrogen cycle. Each flux is shown in units of 10^{12} g N/yr.



Overview of today's class



Biodiversity and conservation ecology

I. What is biodiversity and how do we measure it?

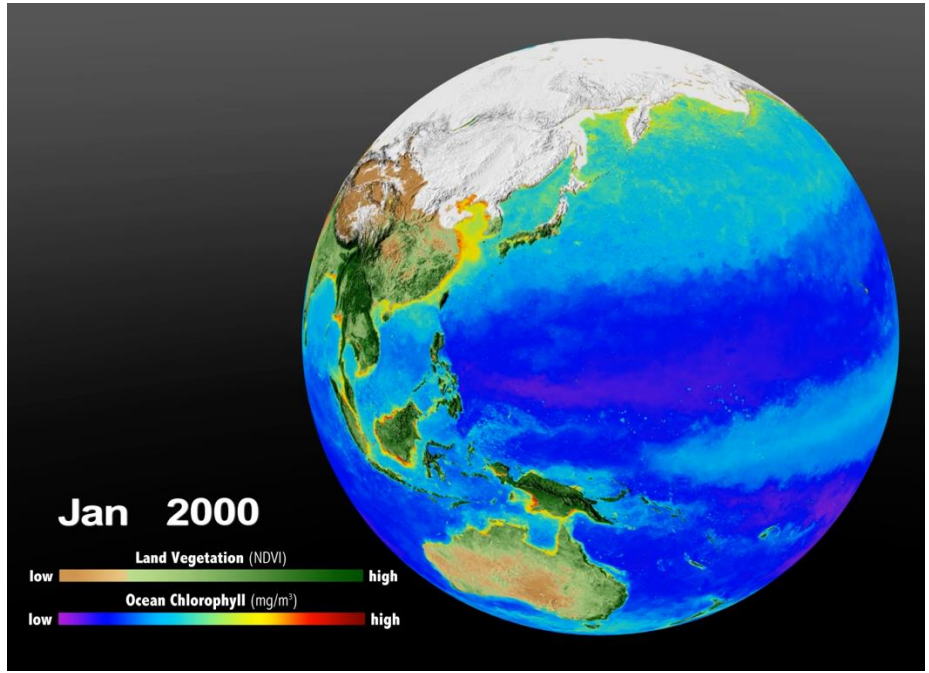
II. How is biodiversity distributed globally?

III. How does biodiversity influence the way that ecosystems are functioning?

1. What is biodiversity and how to measure it?

- The biosphere represents all living organisms and their living environments, including the lithosphere, the hydrosphere, and the atmosphere.

- Biodiversity is a component of the biosphere. Although the term first appeared in 1985, it entered common language at the Earth Summit in Rio de Janeiro in 1992.

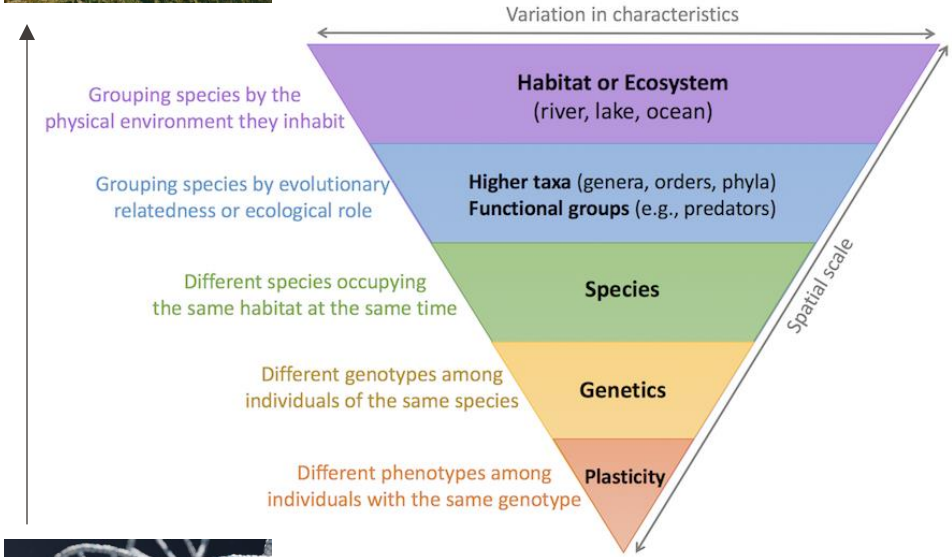


NASA. “Earth Day 2020: Biosphere”

IN OUR HANDS
EARTH SUMMIT ‘92

1. What is biodiversity and how to measure it?

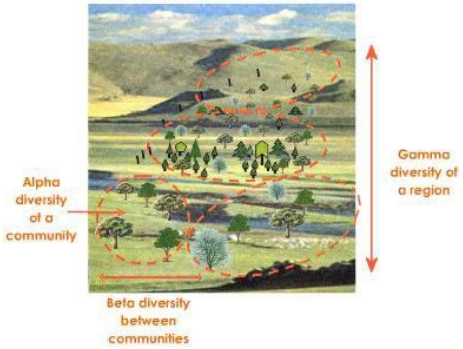
Schematic of the magnitude and type of diversity exhibited at different scales.



The term biodiversity encompasses **a broad spectrum of biotic scales**, from phenotypic variation within genotypes to ecosystems and biomes on the planet.

Biodiversity can be described in terms of **numbers of entities** (how many genotypes, species, or ecosystems), **the evenness** of their distribution, the **differences in their functional traits** (functional groups), and **their interactions**.

1. What is biodiversity and how to measure it?



When referring to ecosystem or community diversity, biodiversity can also be separated into **alpha, beta, and gamma diversity** depending on the scales considered.

- **Local (alpha) diversity** is the species diversity of individual communities

Quantifying alpha diversity is problematic:

(1) It isn't easy to define community boundaries

(2) The relationship between diversity and area makes it difficult to compare patterns of species diversity between communities/ecosystems that differ in size

(3) Local patterns of diversity change over time during succession

1. What is biodiversity and how to measure it?

- **Beta diversity** is the variation in species composition among sites (communities) within a geographic area or region.

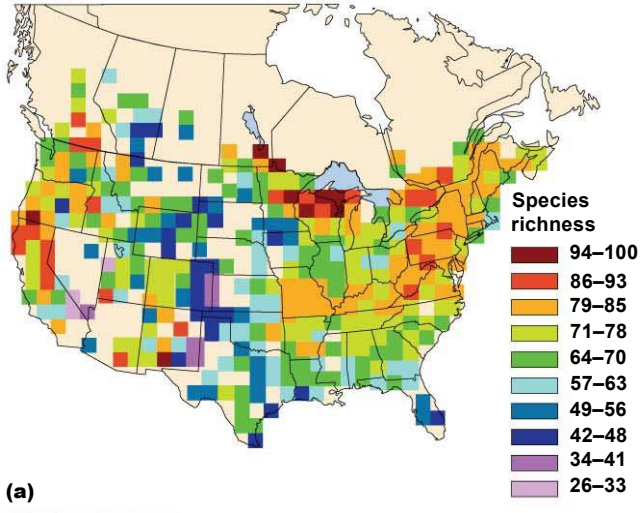
Increasing environmental heterogeneity within a region usually results in increasing beta diversity.

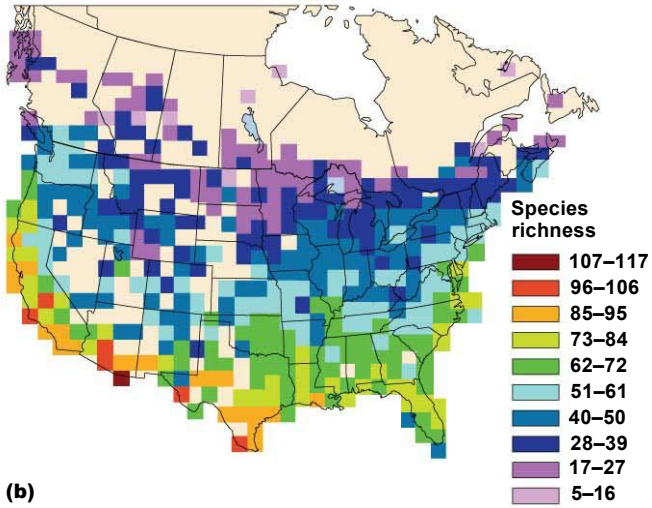
For example, a mountainous region generally has more diverse habitats and communities than a flatland. This leads to an increase in regional diversity patterns.

1. What is biodiversity and how to measure it?

- **Gamma (regional) diversity** is the total species diversity across all communities within a large geographic area (e.g., continent), decreasing worldwide.

A comparison of broad-scale diversity patterns can be confounded by time (seasonal changes that affect water temperature, migration patterns), even under geological timescales (emergence and extinctions of species)





Bird species richness patterns in North America change from summer (a) to winter (b)

1. What is biodiversity and how to measure it?

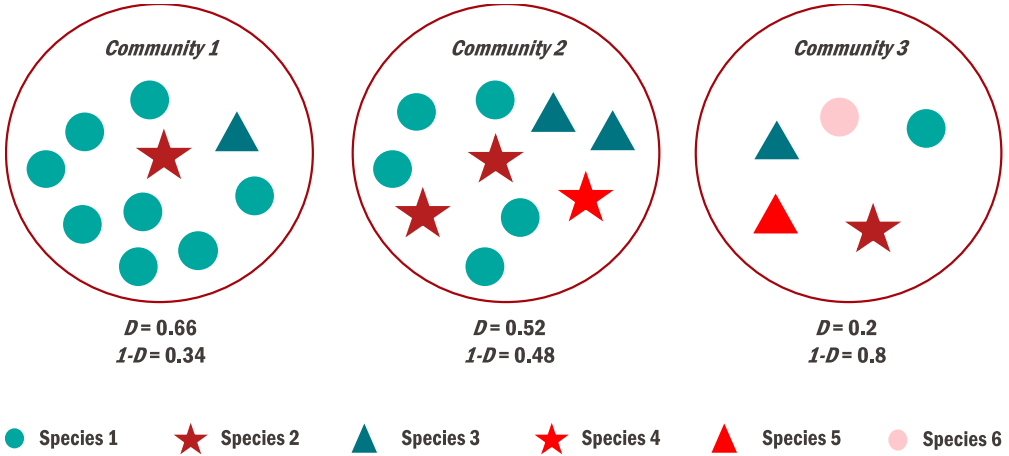
How can we calculate the diversity of a community?

Simpson's diversity index (*D*) measures the probability that two randomly selected individuals from the community will belong to the same species:

$$D = \sum p_i^2$$

P_i=proportion of species i

Values range between 0 and 1. But this range seems counterintuitive as *D* = 1 with no diversity (with one species). *D* approaches zero with higher diversity.



D is thus often subtracted from 1 to give the **Simpson's reciprocal index** = 1 – *D*

1. What is biodiversity and how to measure it?

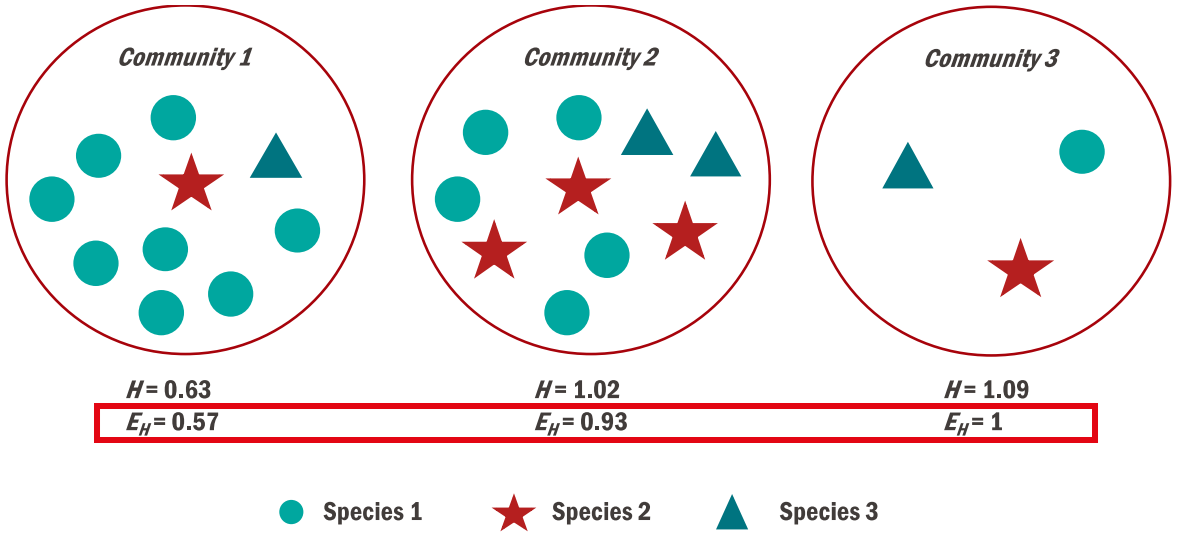
The **Shannon index *H*** (or Shannon-Weiner index) is another widely used index of diversity that also considers species richness and evenness:

$H = -\Sigma(p_i)(\ln p_i)$

p_i = proportion of the total individuals in the community represented by species *i*
minimum value = 0 (one species present)
maximum value = ln *S* (*S* is the total number of species, i.e. **species richness**)

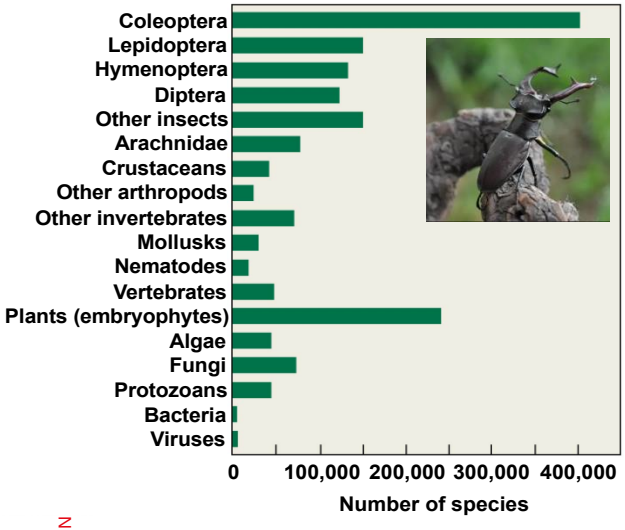
An index of species **evenness** can be calculated using *H*:

$E_H = H / H_{max}$

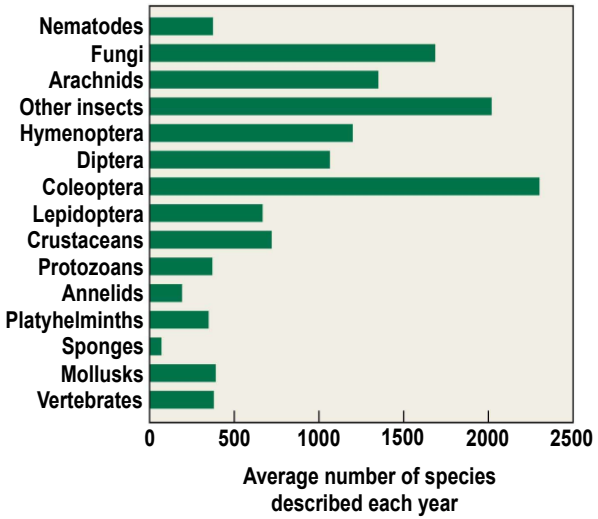


2. How is biodiversity distributed globally?

About **1.8 million species** have been identified and named. It is estimated that about 10 million species live on Earth. Many species are discovered each year, mostly insects.



Number of living species of all kinds of organisms currently known. Species are classified into major taxonomic groups.

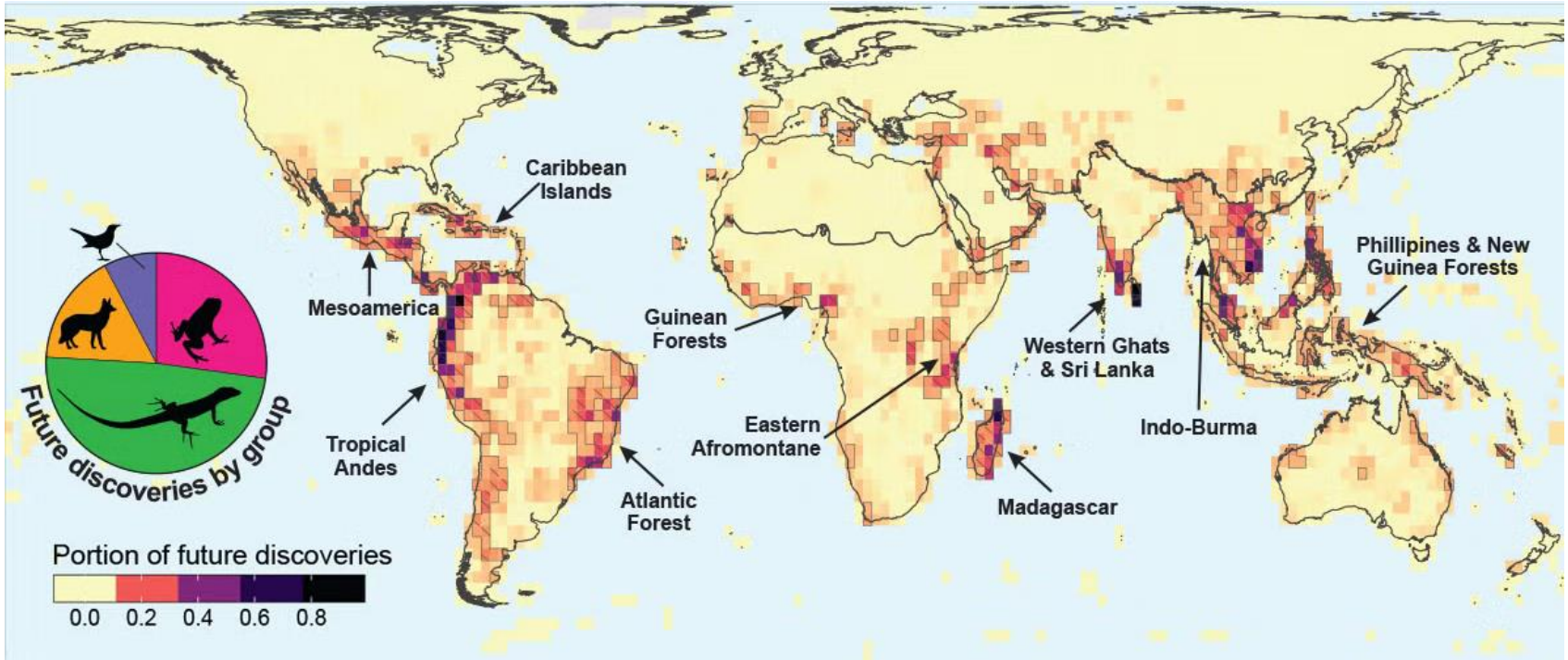


Many new species are discovered each year. Most of these species belong to taxonomic groups that are relatively small in size.

Calamagrostis lonana **(Poaceae) was discovered in the Swiss Alps in 2023.**

2. How is biodiversity distributed globally?

Brazil, Indonesia, Madagascar, and Colombia hold the greatest discovery opportunities, with a quarter of potential discoveries estimated.

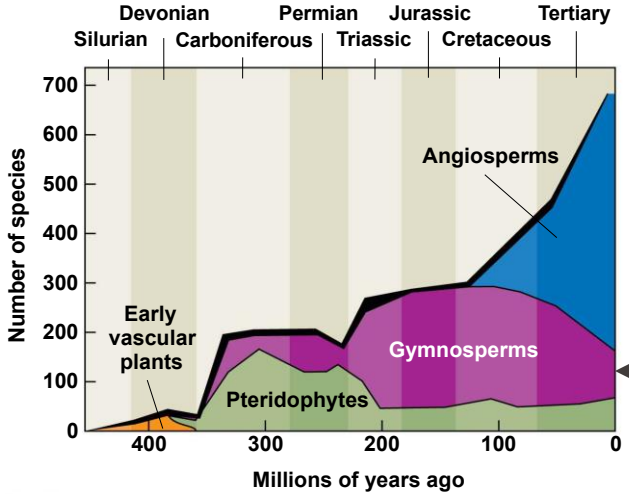


Moura & Jetz, 2021, Nature Ecology & Evolution

2. How is biodiversity distributed globally?

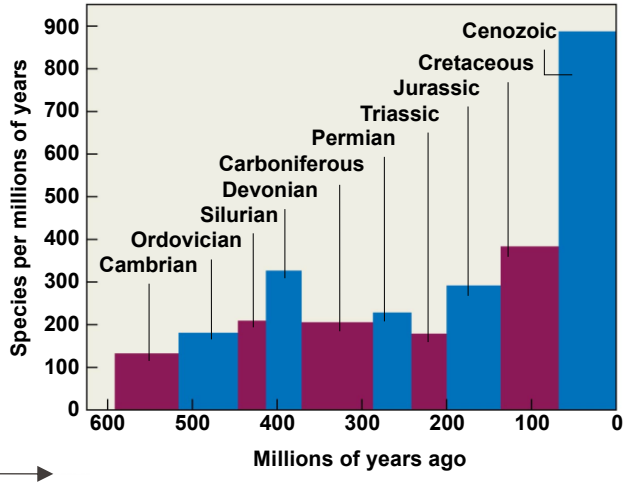
Environmental conditions have influenced species' evolution and the resulting biological diversity in various geographic regions around the world.

Long-term evolutionary changes in global diversity have largely been the result of speciation and extinction.



Pattern of expansion and reduction of major terrestrial plant groups during 400 million years of plant evolution.

The number of species has been increasing for the past 600 million years.



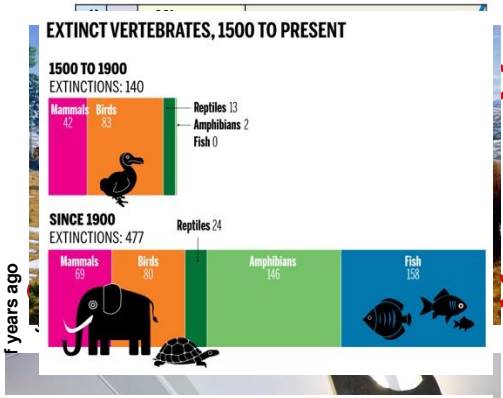
Estimated species richness of fossilized invertebrates over geologic time.

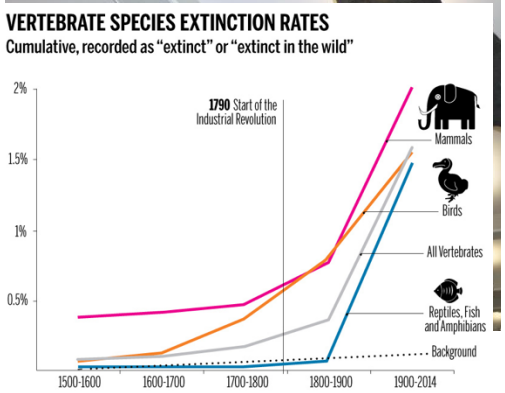
Though the number of terrestrial vascular plants has continuously increased for the past 400 million years, the dominant groups have shifted dramatically.

2. How is biodiversity distributed globally?

Several mass extinction events have accompanied the pattern of increasing diversity through geologic time:

- **End of the Permian (225 mya):** 90 % of shallow-water marine invertebrates lost and 50% overall.
- **End of the Cretaceous (65 mya):** Dinosaurs and many other species went extinct (half of all). It was likely caused by an asteroid impact that altered climate, interrupted oceanic circulation, and increased volcanic and other tectonic activity.
- **During the Pleistocene (10,000 years ago):** Ice-age mammals went extinct (woolly mammoth, giant sloth, giant deer). Caused by movement of ice sheets and/or hunting by humans
  - **Modern extinctions:** 75 % of extinctions since 1600 are the result of human activity





record profiles mass extinctions during geological times.

2. How is biodiversity distributed globally?

Five main anthropogenic factors responsible for the current biodiversity crisis

Habitat loss & fragmentation
(Urbanization, deforestation, seafloor dredging…)

Overexploitation
(Intensive agriculture, overfishing…)

Pollution
(Nitrates, phosphates, plastics…)

Invasive species

Climate change
(warming, drought…)

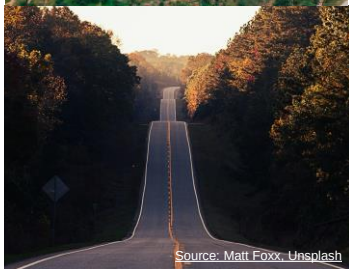

Source: Pok Rie, CC0, Pexels


Source: no one cares, Unsplash


Source: Naja Bertolt JensenUnsplash


Source: Shannon Kunkle, Unsplash


Source: Anders Jilden, Unsplash


Source: Matt Foxx, Unsplash


Source: Gryffyn m, Unsplash


Source: Arjun MJ, Unsplash


Source: Fresh water mussels shells, DSKEO, CC-BY-SA 4.


Source: Matt Palmer, Unsplash

2. How is biodiversity distributed globally?

Factors contributing to enhancing species' vulnerability to extinction

Large body size

Feeding at high trophic level

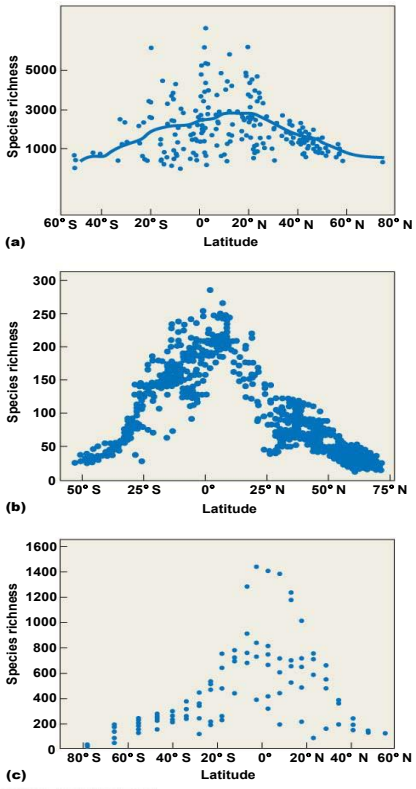
Small population size and low fecundity

Fixed migratory routes

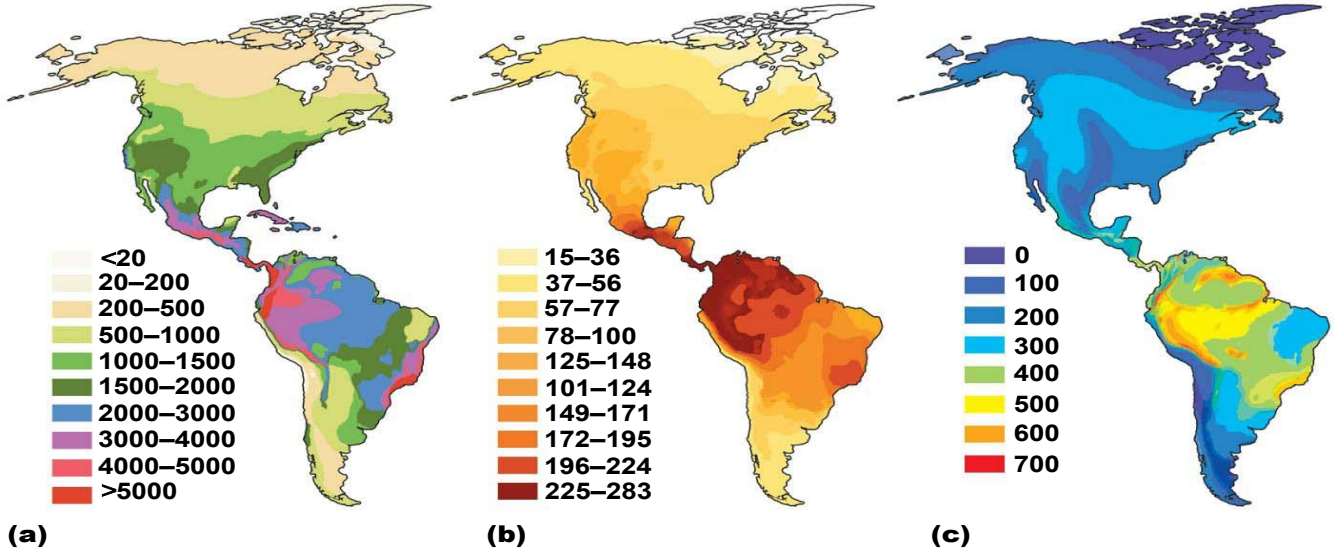
Localized and narrow distribution (endemism)

2. How is biodiversity distributed globally?

Globally, species diversity declines as you move northward and southward from the equator.



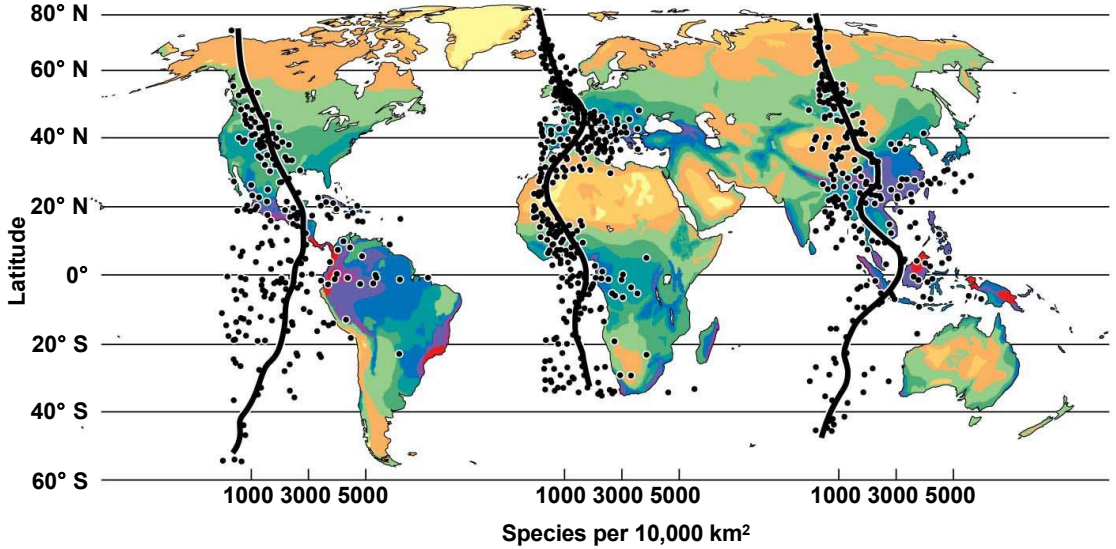
Geographic patterns of species richness for (a) vascular plants, (b) mammals, and (c) birds in North and South America.



2. How is biodiversity distributed globally?

While this is a general pattern, the underlying mechanism is often more complex and disrupted by other variables.

- For plants, deviations can be seen between continents.
- Two latitudinal peaks in the belt are Europe and Africa, one at the equator and one in the Mediterranean. The Mediterranean region has high species diversity and endemism, with lower diversity in subtropical deserts.

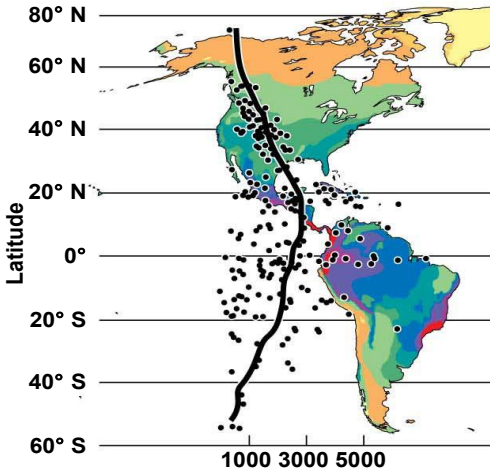


Latitudinal gradients of vascular plant species richness for three different longitudinal bands associated with the major continental regions (North and South America, Europe and Africa, and Asia and Australia). Each dot represents mean species richness plotted against the latitude of the geographic midpoint of the grid cell (approximately 10,000 km²).

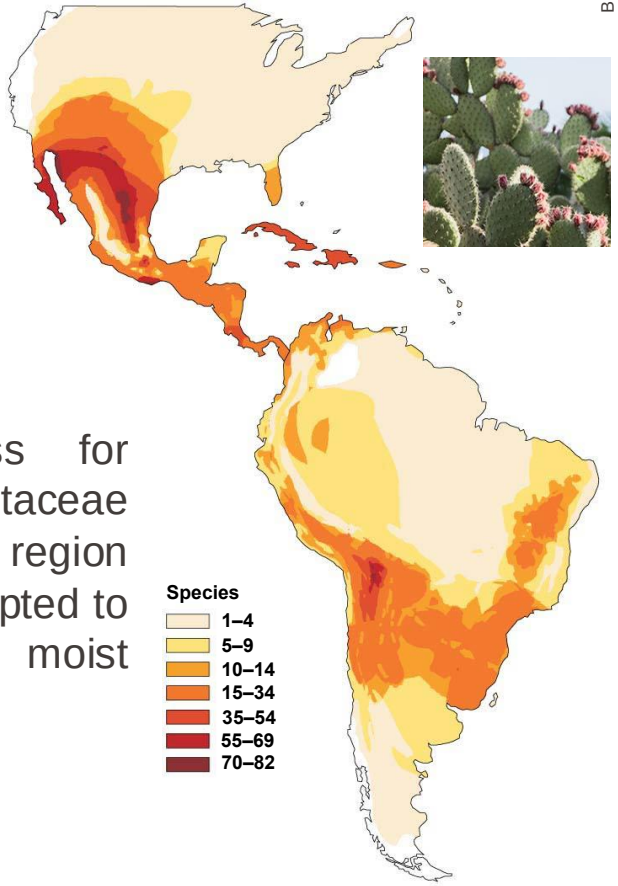
2. How is biodiversity distributed globally?

Deviations can also be seen for specific taxonomic groups associated with particular environments or resources.

Latitudinal patterns for species richness for South and North American vascular plants show peak diversity around the equator region.



However, species richness for members of the family Cactaceae (cacti) is low in the equatorial region because these plants are adapted to desert regions rather than moist environments.



2. How is biodiversity distributed globally?

Over 25 different mechanisms have been proposed to explain the relationship between latitude and species richness, including the **age of the community and climate stability, the surface area, and the available energy and ecosystem productivity**.

Age of community and climate stability:

- Tree species and plant communities in North America during periods of glacial expansion and retreat can be examined regarding their role in community age and climate stability.
- During expansion, tree species distribution shifted south and again northward during the retreat. In contrast, tropical regions did not see the same patterns of displacement.

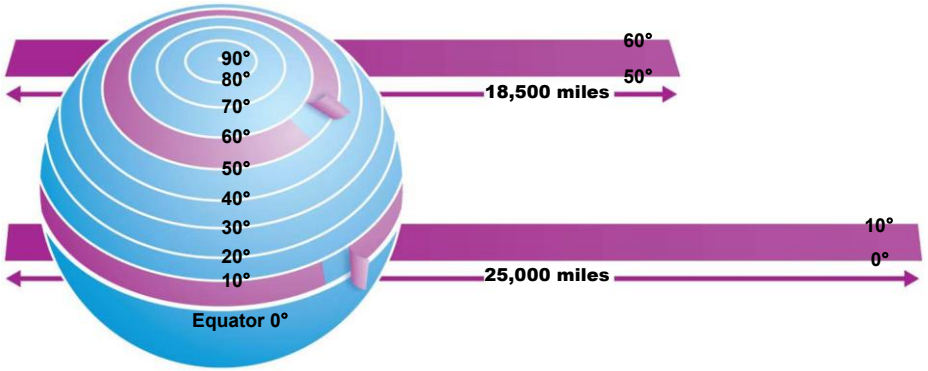
Today, Europe has fewer tree species than North America or eastern Asia. Based on fossils, Europe had a much richer flora before the Pleistocene, including genera that are now found only in temperate regions of North America and Asia. These species were eliminated from Europe during the Pleistocene and may not have recolonized because they did not reach refugia during the glacial phase.

2. How is biodiversity distributed globally?

Surface area:

Another possible mechanism is **the relationship between the area and species diversity**. In general, species richness tends to increase with increasing area.

Surface area decreases when moving to the poles. ⟶

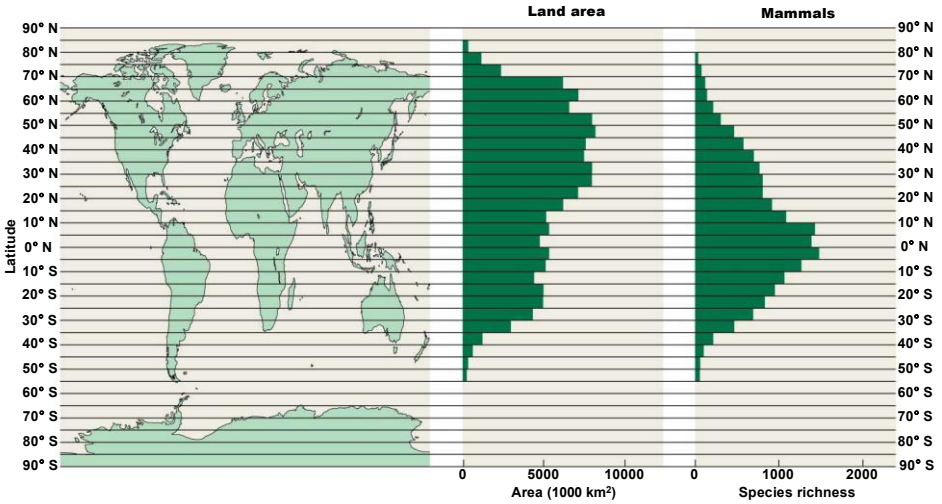


There is a greater surface between 0 and 10° north latitude than there is between 50 and 60° north. This is because Earth's circumference is largest at the equator. The circumference of Earth at the equator is 25,000 miles (40,000 km), whereas at 50° latitude it is 18,500 miles (30,000 km).

2. How is biodiversity distributed globally?

Surface area:

However, when examined for mammals, the gradients do not align. There is more landmass at higher latitudes in the north but great species richness at the equator.



Comparison of variation in land area and species richness of mammals across 5° bands of latitude.

However, although this is the case for the Pacific, it is not for the Atlantic Ocean. →

The surface area of the oceans is greatest in the tropics and is thus positively correlated with patterns of marine species diversity.

(a) Percentage of total ocean surface area by latitude. (b) Map of Pacific and (c) Atlantic Ocean basins.

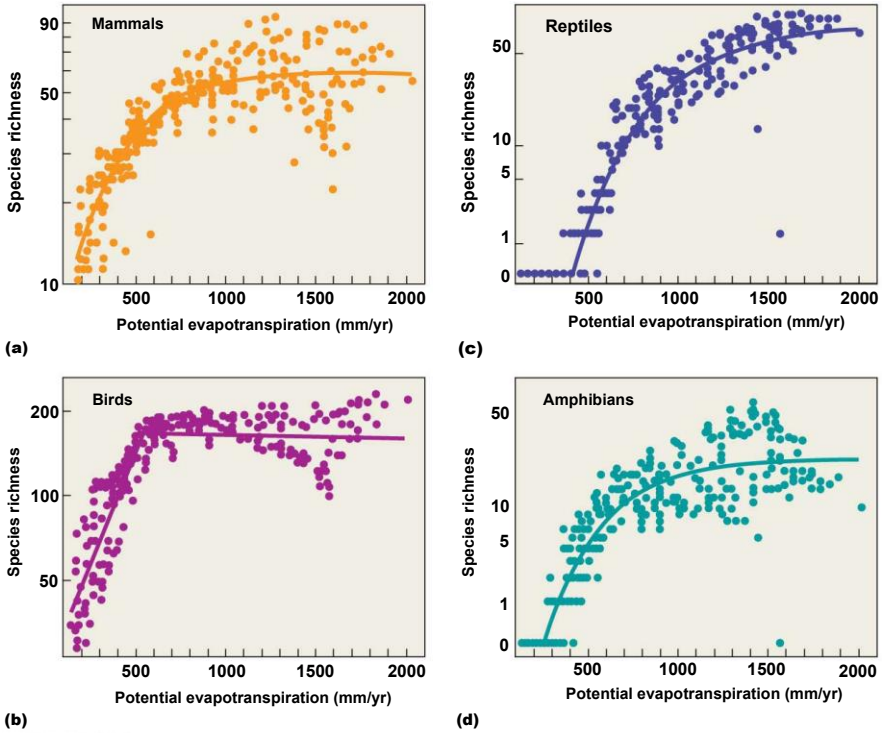
2. How is biodiversity distributed globally?

Among the various hypotheses proposed to account for global diversity patterns, the most accepted are those related to **available energy**.

Thermal energy is associated with climate and the availability of essential resources, which are known to influence animal and plant processes.

It is assumed that greater energy availability enables the support of a greater biomass = more individual organisms to coexist.

Thus, more species at abundances that are viable population sizes can co-exist in higher energy environments.



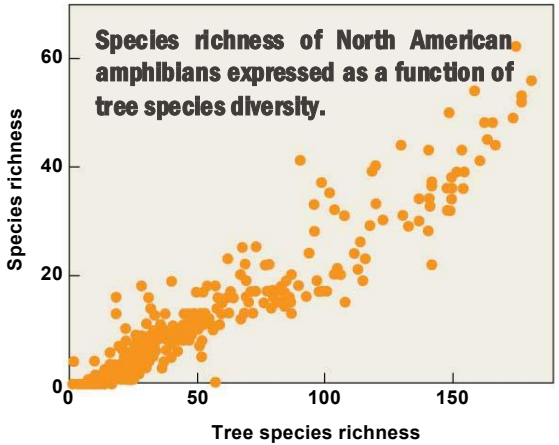
Relationship between the annual estimate of potential evapotranspiration (PET) and species richness of (a) mammals, (b) birds, (c) reptiles, and (d) amphibians in North America.

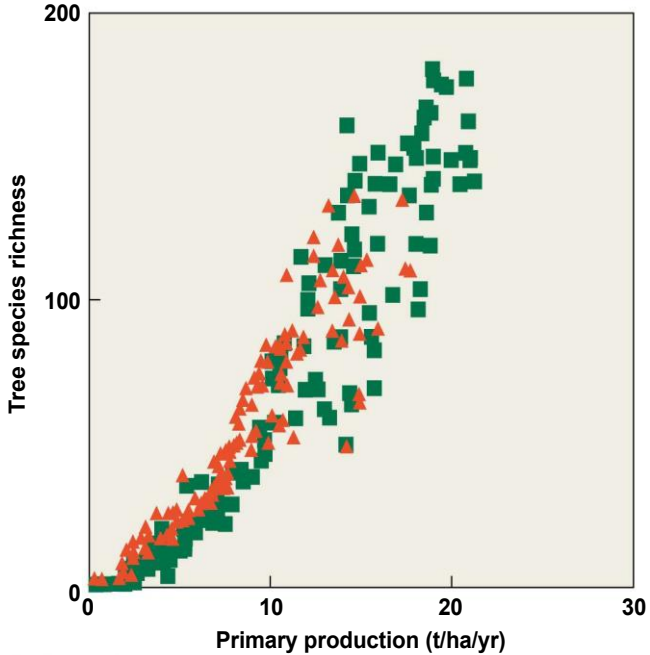
2. How is biodiversity distributed globally?

Researchers have found significant relationships between primary productivity and species richness for plants and animals at global scales (e.g., with tree species to the right).

Species diversity of the plant community is positively correlated with animal species diversity.

Evaluating which parameter provides the best mechanistic understanding is complicated as most indices are correlated with each other.





Relationship between tree species richness and net primary productivity for North America (squares) and Europe (triangles). This relationship partially suggests that environmental conditions favorable for photosynthesis and plant growth can support more tree species.

2. How is biodiversity distributed globally?

Regions of high species diversity are crucial to conservation efforts (protecting nature where it thrives!)

Many of Earth's species are **endemic**. They have small, restricted geographic ranges.

- Of the approximately 10,000 bird species, more than 2500 are endemic (restricted to a range < 50,000 km^2)
- Species of flora endemic to a single country are 46 to 62 % of the world flora

This restricted distribution makes them especially vulnerable to human activities.

2. How is biodiversity distributed globally?

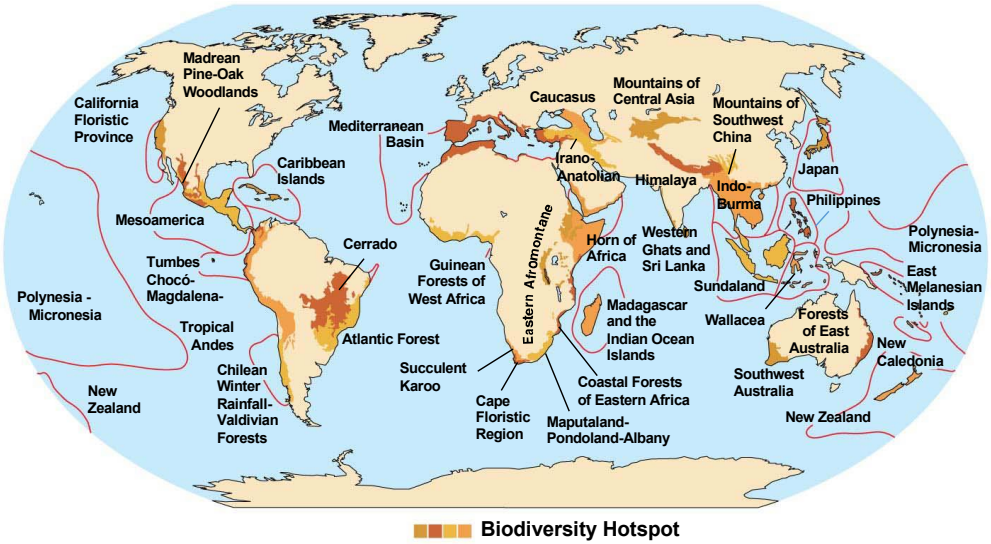
Hotspots are regions of high species richness and endemism:

- A region must support 1500 or more endemic plant species
- A region must have lost more than 70 % of its original habitat.

36 biodiversity regions were designated as **hotspots** by the IUCN*

Contain 44 % of all plant species and 35 % of all terrestrial vertebrate species in **1.4 % of Earth's land area**

Currently, the average protected area of hotspots is 10 % of their original extent



The International Union for Conservation of Nature has designated thirty-six areas of the world as biodiversity hotspots.

2. How is biodiversity distributed globally?

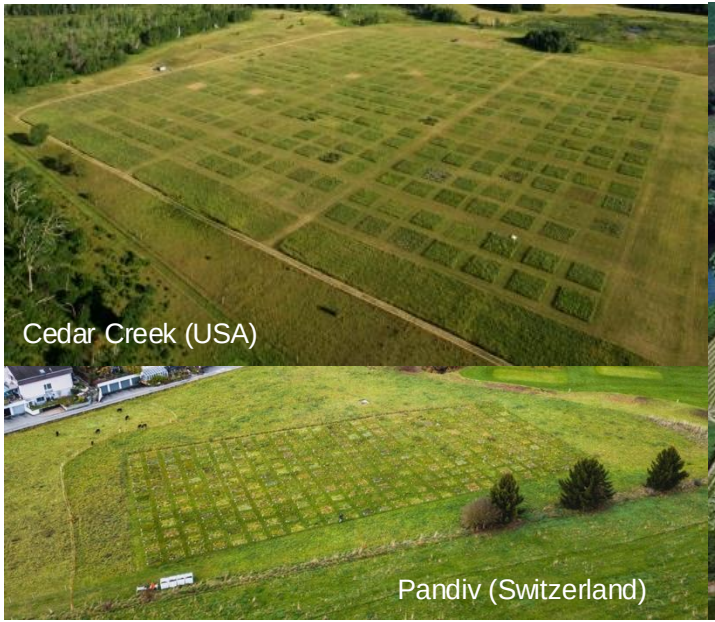
Ex-situ conservation strategies can complement the *in-situ* approaches

- Zoos and wildlife reserves
- Botanical gardens and seed banks
- Captive breeding programs
- Cryopreservation and genetic banks
- Conservation sanctuaries and rescue centers

3. How does biodiversity influence ecosystem functions?

Relationships between species richness and ecosystem functions

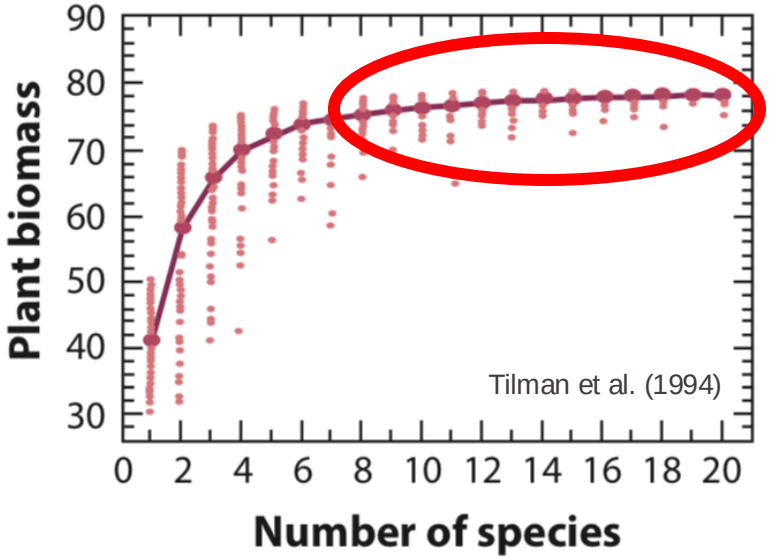
Most work has been conducted in simple systems (e.g., grasslands) and on growth/productivity



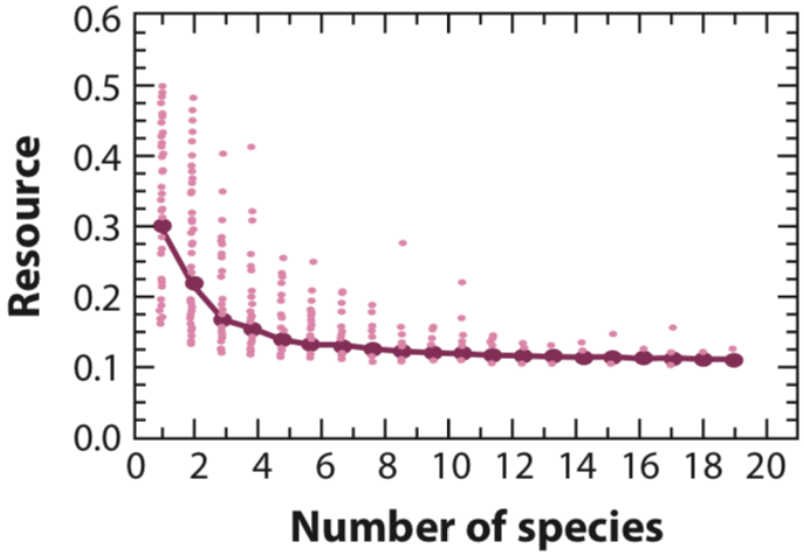
3. How does biodiversity influence ecosystem functions?

Relationships between species richness and ecosystem functions

Most work found a positive effect of richness on productivity

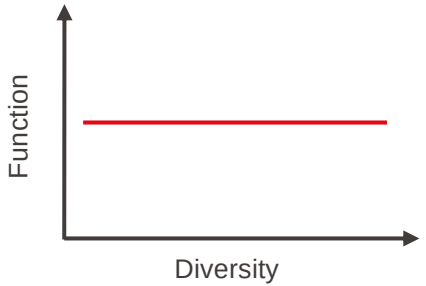


Saturation has been attributed to redundancy between species.



3. How does biodiversity influence ecosystem functions?

What type of relationships can be found and why ?



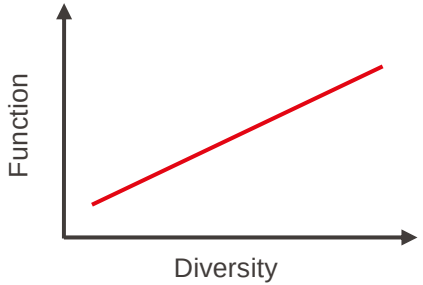
(1) Diversity might have no effect: changing relative abundance or species richness might not change process rates or pool sizes.

Lack of response could occur for several reasons, such as primary control by abiotic factors (e.g., areas where resources are severely lacking)

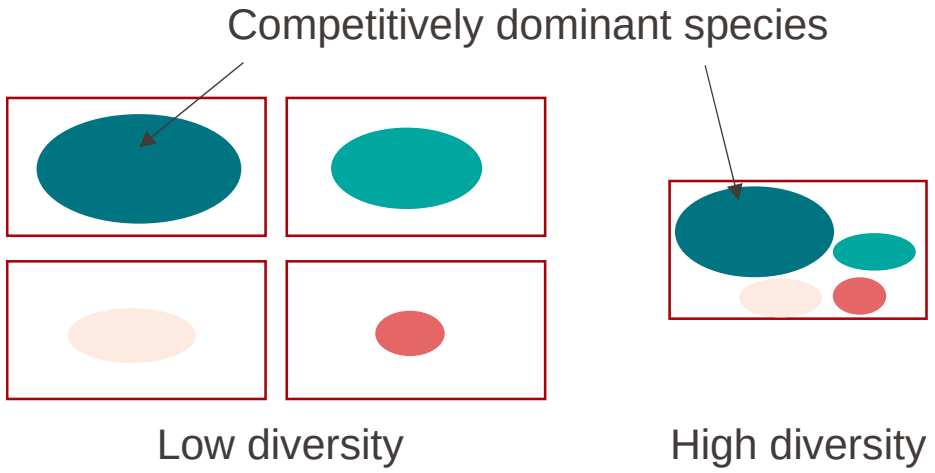
3. How does biodiversity influence ecosystem functions?

What type of relationships can be found and why ?

(2) Increases in ecosystem functioning with increasing diversity could arise from two primary mechanisms



Only one or a few species might have a large effect on any given ecosystem property. Increasing species richness increases the likelihood that those key species would be present. This is known as **the selection effect**



3. How does biodiversity influence ecosystem functions?

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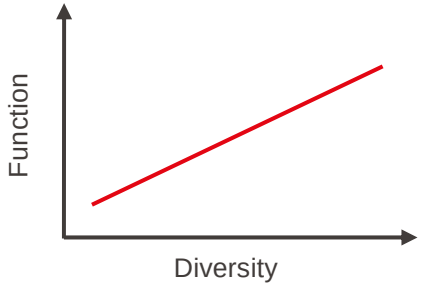
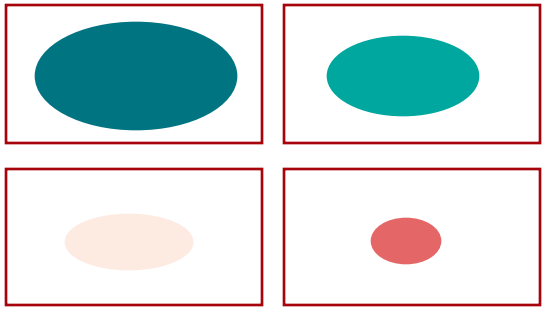
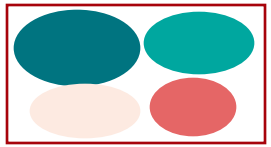


Second, species or functional richness could increase ecosystem properties through positive interactions among species: **complementarity** and **facilitation**.



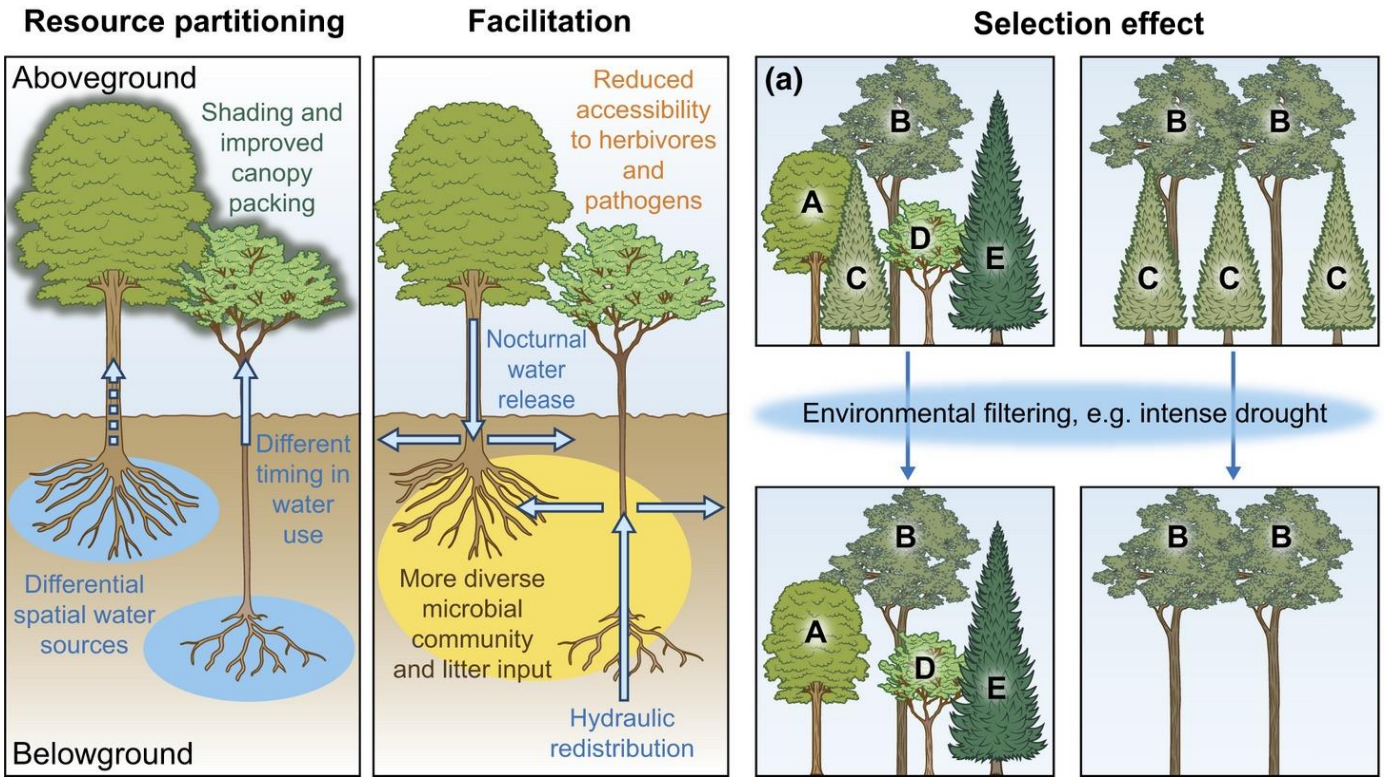
Low diversity



High diversity

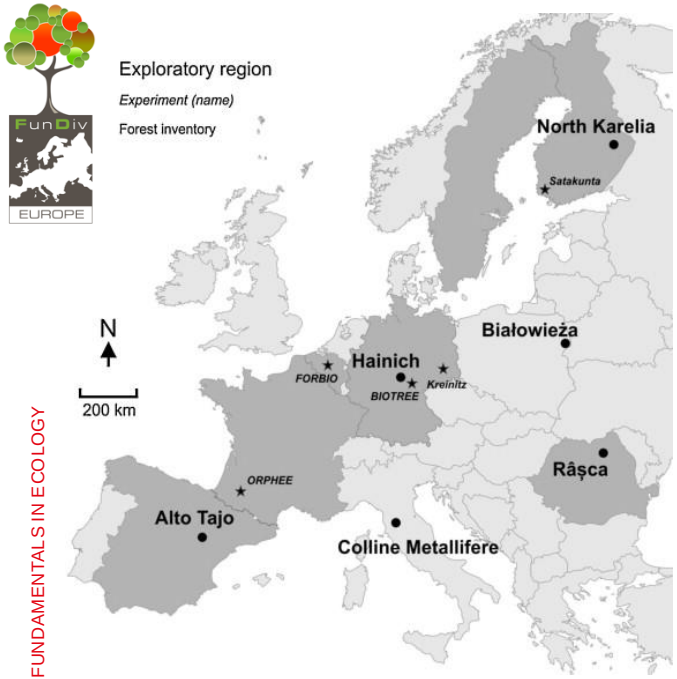
3. How does biodiversity influence ecosystem functions?

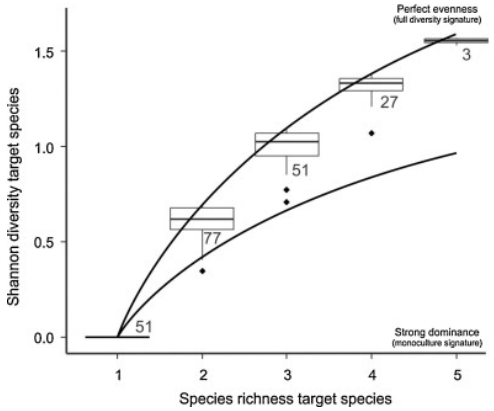
Examples of underlying mechanisms in forests



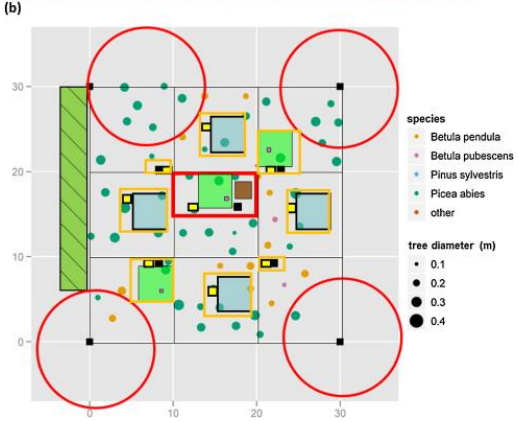
3. How does biodiversity influence ecosystem functions?

More recently, work has started to focus on more natural ecosystems



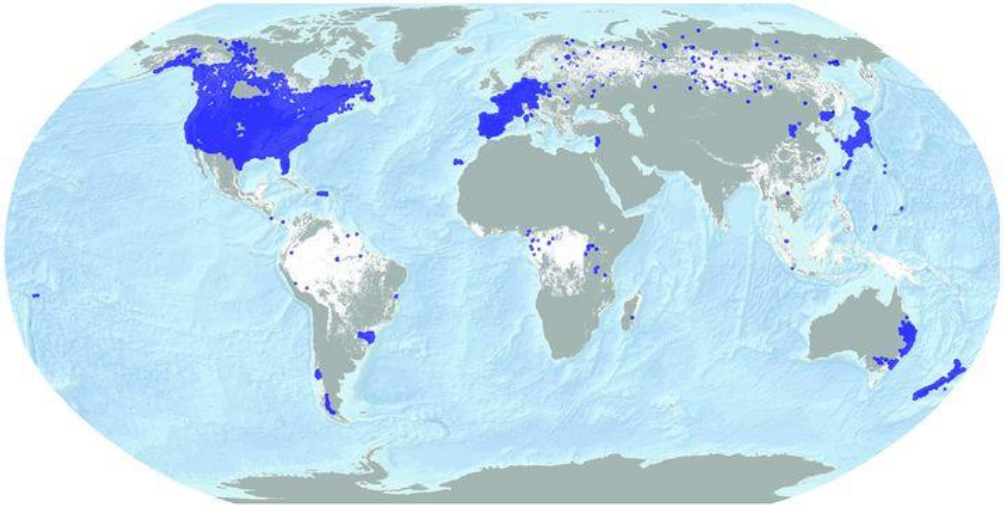


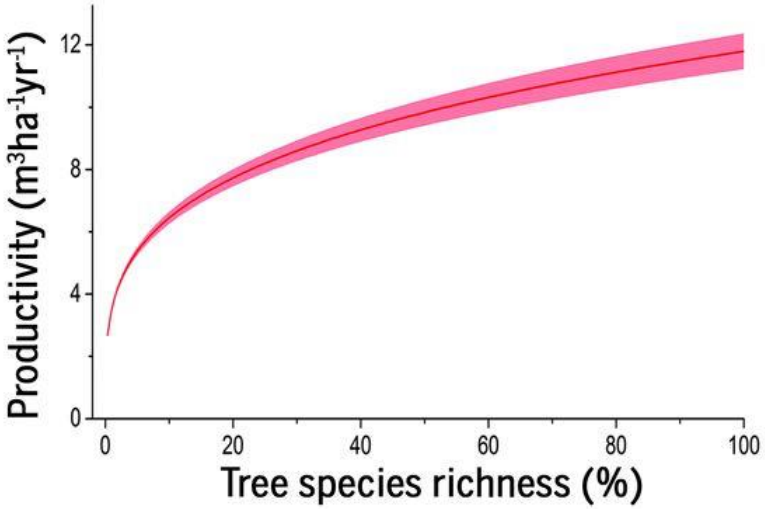
Network of forest plots along tree species diversity gradients in six major European forest types



3. How does biodiversity influence ecosystem functions?

The same positive relationship has been observed in global forests

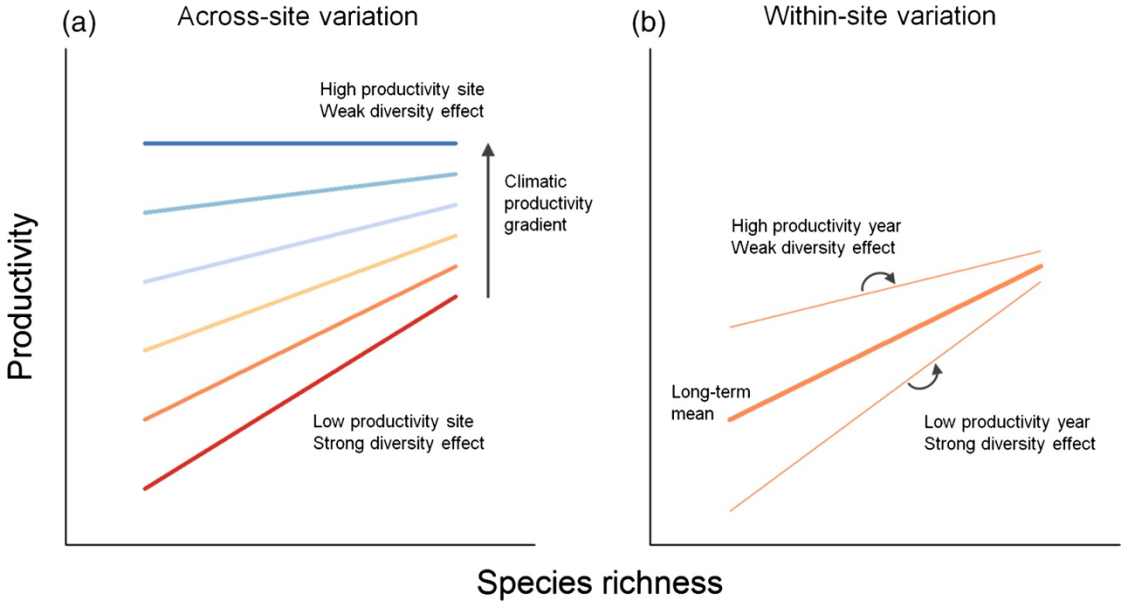


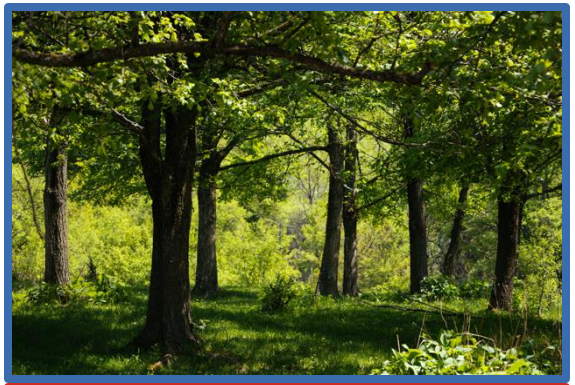


Liang et al. (2016), Nature

3. How does biodiversity influence ecosystem functions?

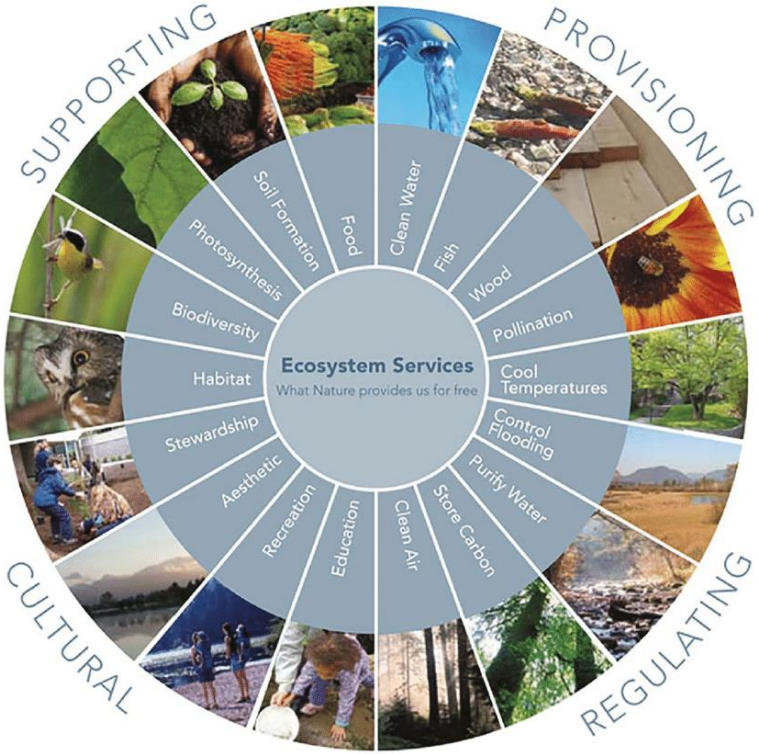
But the effects of diversity depend on the environmental context





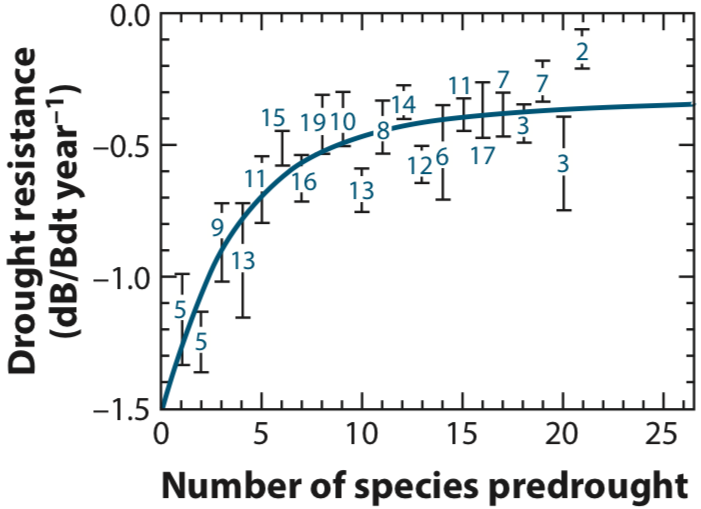
Jucker et al. (2016)

3. How does biodiversity influence ecosystem functions?



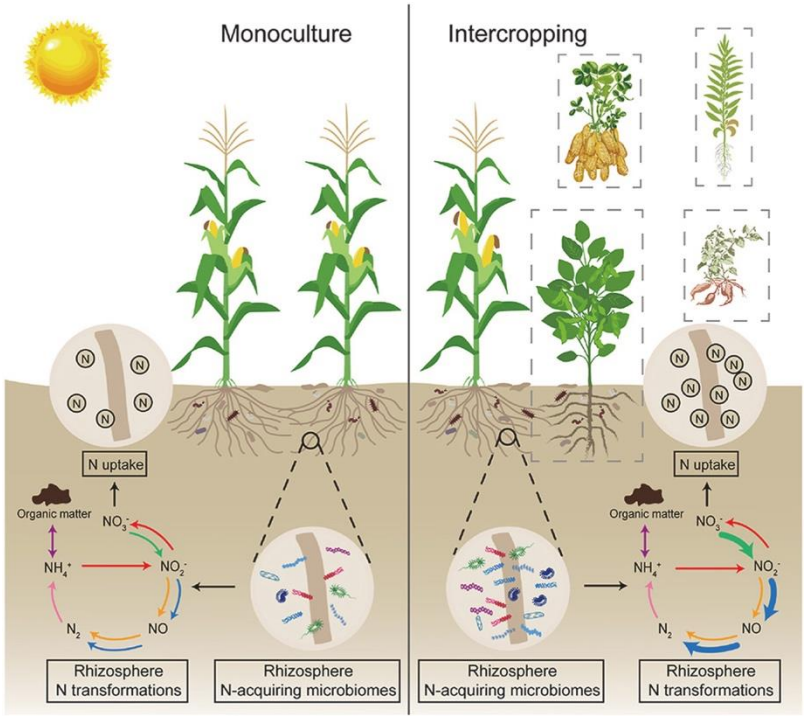
More recently, work has also started to focus on wider ecosystem functions and services:

- Wood quality
- Drought and pathogen resistance…



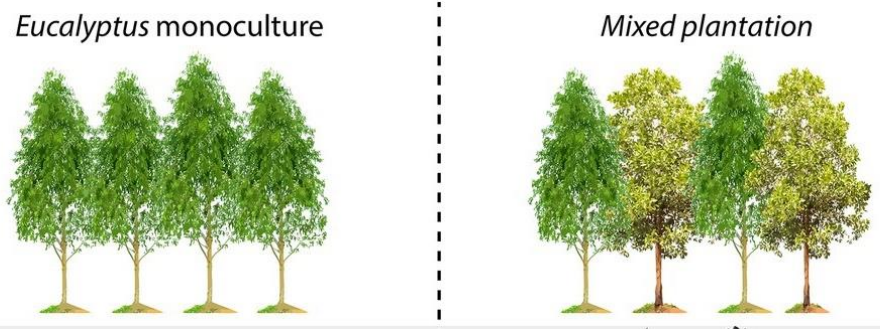
3. How does biodiversity influence ecosystem functions?

Example: Intercropping maize and beans



3. How does biodiversity influence ecosystem functions?

Example: Acacia and Eucalyptus plantations



3. How does biodiversity influence ecosystem functions?

Example: Mangrove restoration

3. How does biodiversity influence ecosystem functions?

Example: Wildflower strips in agriculture

3. Exercices

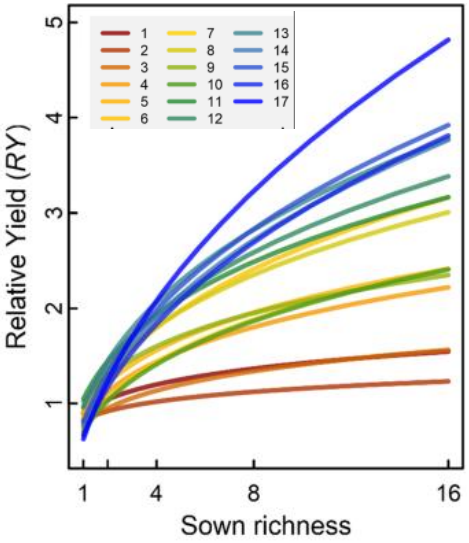
Question: What are the different indexes used to calculate the biodiversity of a community, and why are these indexes different? ***At the exam in 2023***

Answer: To measure the biodiversity in a community, we can use the Simpson's diversity index (D) or the Shannon's diversity index (H). D measures the probability that two randomly selected individuals from a community belong to the same species. It is calculated as $D = \sum 1 \; pi2$. Pi the proportion of total individuals in the community represented by species i (i.e., the relative abundance). H considers the species richness and the evenness, and it is calculated as $H = - \sum 1 \; pi \times (\ln pi)$.

D is a dominance index because it gives more weight to common or dominant species and a few rare species with only a few individuals present will not affect D. In contrast, H is based on randomness present at a site and considers both species richness and equitability in distribution between species, hence it emphasizes the richness component of diversity, especially the rarity and commonness of species in a community.

3. Exercices

Relationships between sown species richness and relative yield of grassland communities at the Jena experiment for each passing year (1 = 2003, 17 = 2019).



At the Jena Biodiversity experiment, scientists assessed the change in species richness-productivity over 17 years. Describe the figure to the right, highlighting their findings and hypothesize on the underlying mechanisms driving the relationships and their change over time.

Answer: Greater sown species richness consistently resulted in greater yield. The positive effect of species richness on yield increased over the 17-year period with less and less saturation with time. This could be explained by potentially less niche overlap between species.
This trend could indicate that the underlying driver of this relationship is complementarity between species whereby a strengthening of the complementarity effect through time increases in niche segregation among species to avoid competition.

Climate change impacts on terrestrial ecosystems