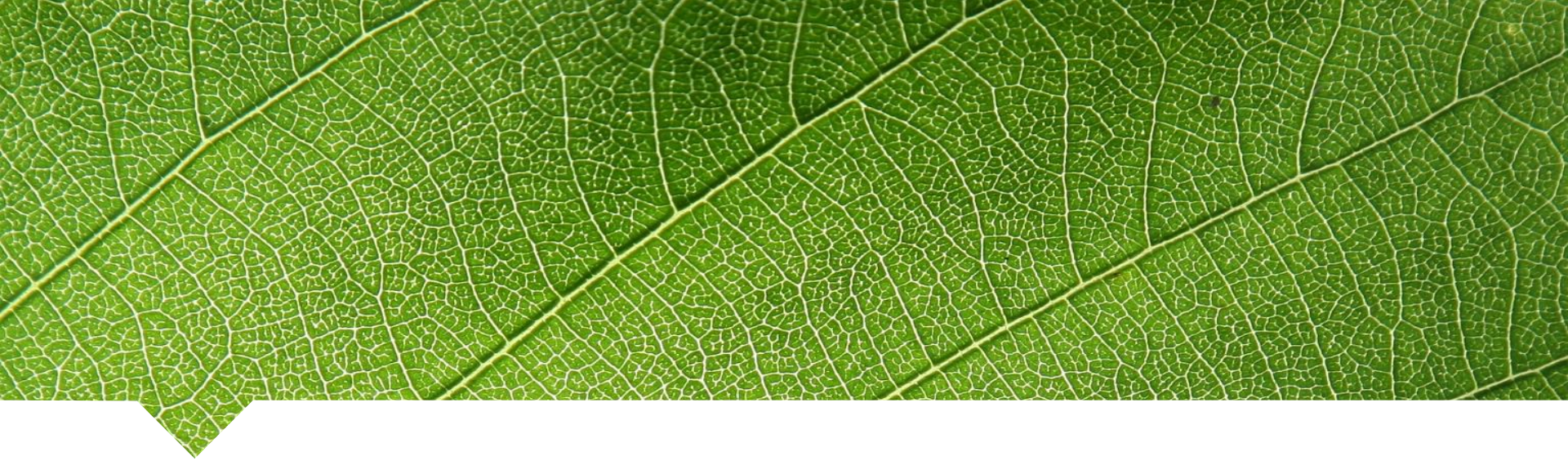


Advanced Animal Ecology and Pollution (ZOO-671)

CONTENT

Species Diversity, Community structure and diversity, Predators and predation, Aquatic community regulation, Habitat types, Feeding mechanisms, factors controlling diversity, Freshwater wetlands, Mangrove mangles, Inorganic and Organic pollutants, Biological and Physical pollutants.



Introduction to Ecology

Lena Hassen
ZOO671.48638.KSU

Key Concepts

- **Ecology** focuses on how organisms interact with their environment. Because its goal is to understand the distribution and abundance of organisms, ecology provides a scientific foundation for the conservation of species and natural areas.

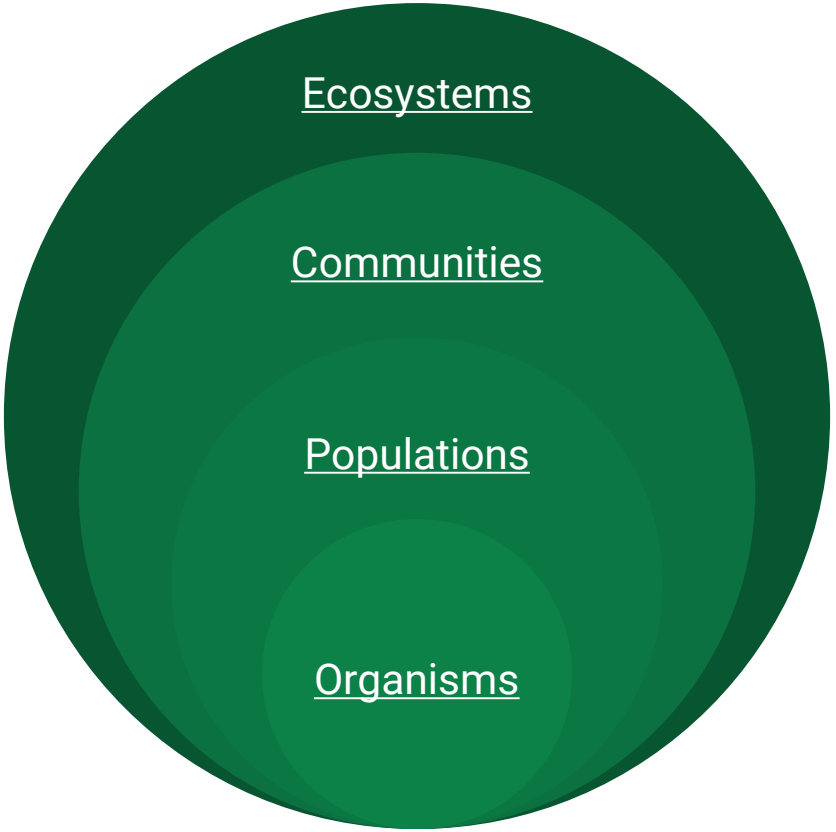
- An **organism's environment** consists of **abiotic**, or physical factors and **biotic** factors, meaning other organisms.

- **On land**, environments are defined by **climate**--specifically, both the average value and annual variation in temperature and in moisture. I**n aquatic habitats**, environments are defined by **physical structure**--particularly water depth.

- A **species distribution** is constrained by a combination of historical, abiotic, and biotic factors.

Introduction

In ecology, researchers work at four main levels:





Organismal Ecology

How do individuals interact with each other and their physical environment?

Example:
Male salmon fight over females during the breeding season.



Population Ecology

How do individuals interact with each other and their physical environment?

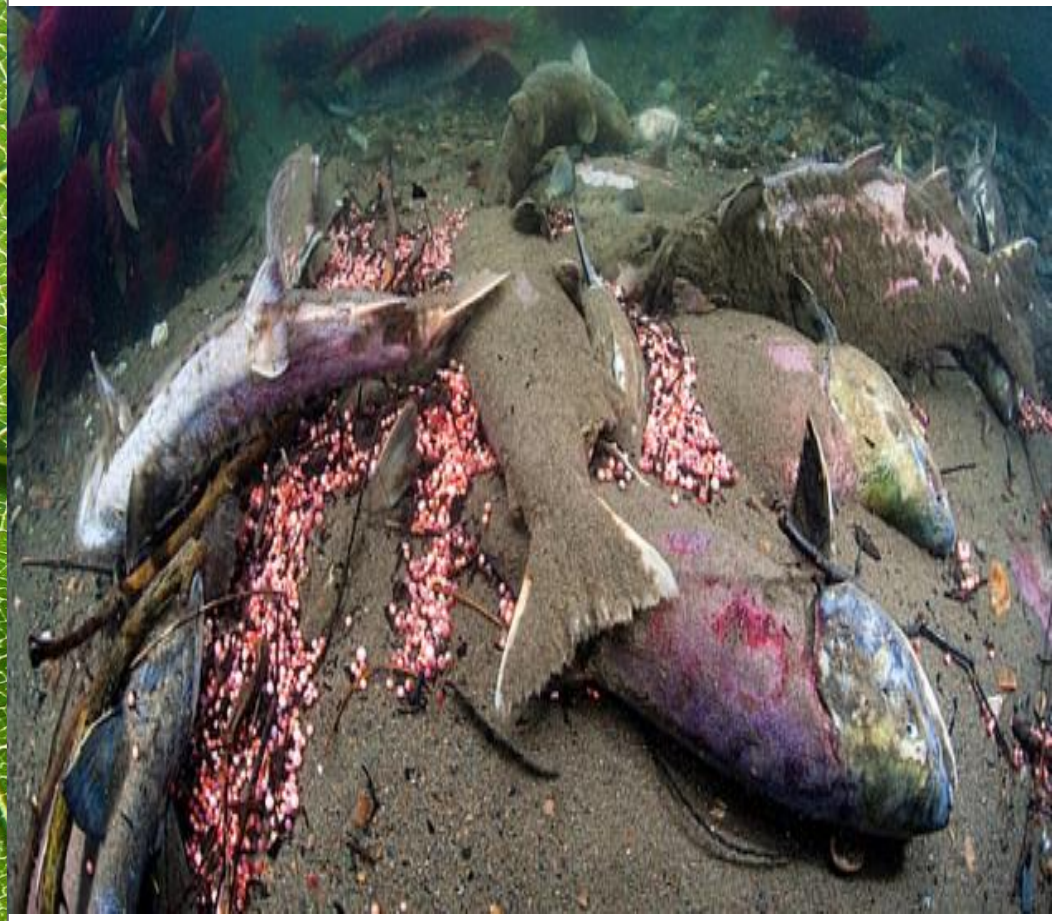
Example:
Each female salmon produces thousands of eggs. Only a few will survive to adulthood. On average, only two will return to the stream of their birth to breed.



Community Ecology

How do species interact, and what are the consequences?

Example:
Salmon are prey as well as predators.



Ecosystem Ecology

How do energy and nutrients cycle through the environment?

Example:
When salmon die and decompose, the nutrients that are released are used by bacteria, archaea, plants, protists, young salmon, and other organisms.



Biodiversity

What is biodiversity??

The word **"biodiversity**" is a contracted version of "biological diversity". The Convention on Biological Diversity defines biodiversity as:"the variability among living organisms from all sources including, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species, and of ecosystems."

Thus, biodiversity includes genetic variation within species, the variety of species in an area, and the variety of habitat types within a landscape.

What is Biodiversity?

In a fundamental sense, biodiversity can be thought of as the tips of the branches on the tree of life--meaning all distinctive populations and species living today.

More formally, biologist recognize and analyze biodiversity on three levels:

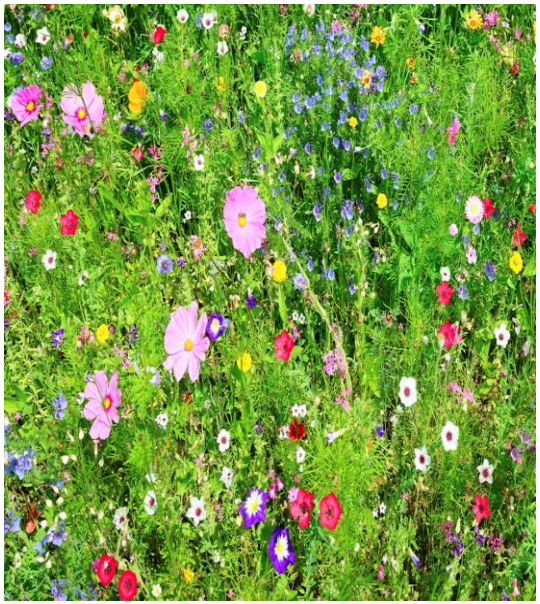
1. **Genetic diversity** is the total genetic information contained within all individuals of a species and is measured as the number and relative frequency of all alleles present in a species.

2. **Species diversity** represents the variety of life-forms on Earth--the twigs on the the tree of life. In practice, species diversity if measured as the number and relative frequency of species in a particular region.

3. **Ecosystem diversity** is the variety of biotic communities in a region along with abiotic components, such as soil and water and nutrients. Ecosystem diversity is more difficult to define and measure than genetic diversity or species diversity, because ecosystems do not have sharp boundaries.




1
2
3
4
5
6
7
8
9
10
11
12





What is species diversity?

- Species diversity comprises the number of different species in an ecosystem (the species richness) and the proportion of each species in the ecosystem (the relative abundance).
- Thus Species diversity consists of **two** components

1. Number of species in community – 'species **richness**'
2. Species **evenness** or **equitability** – how the species abundances (e.g. cover, frequency) are distributed among the species.

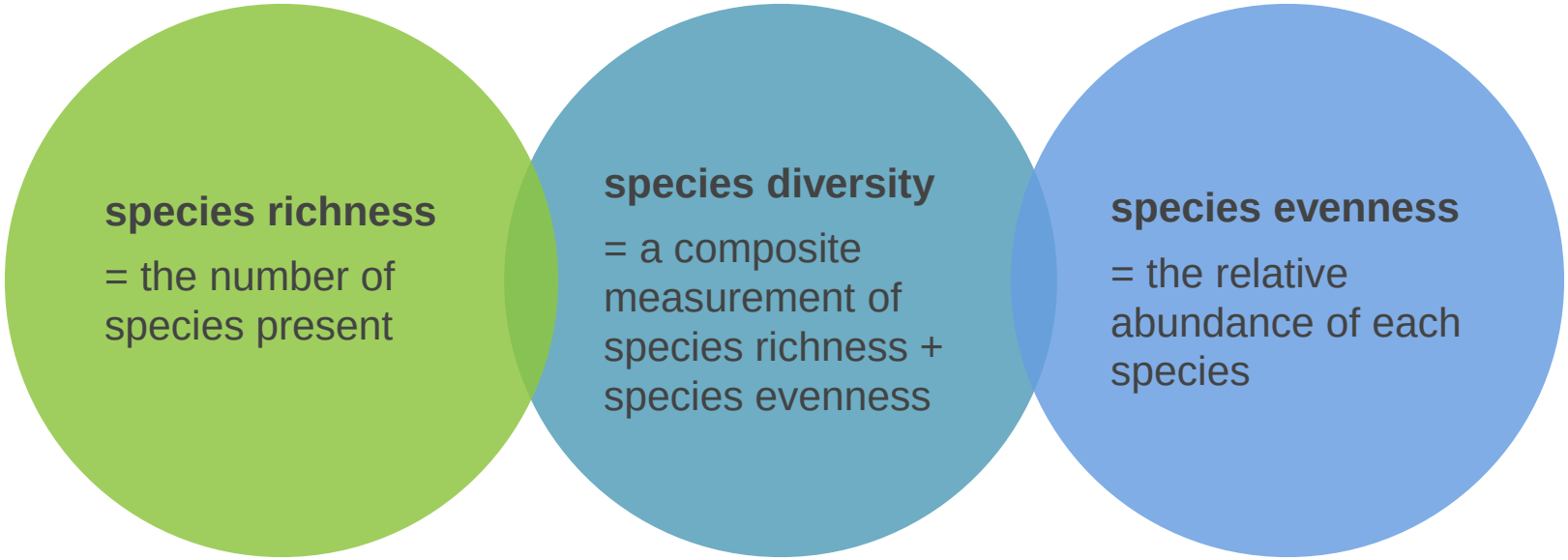
What is Species Diversity?

There is an additional aspect of species diversity, however, that biologist call taxonomic diversity. When biologist assess taxonomic diversity, they attempt to incorporate the evolutionary relationships among the species present.

For example, some lineages on the tree of life are extremely species rich, which others may be represented by only a single living species. African cichlid fish, and the 35,000 species of orchids are examples of **species-rich** lineages. In contrast, the red panda and the Indian river dolphin have few relatives. They are examples of **species-poor** lineages.

Some biologists argue that it is particularly important to preserve populations from species-poor lineages. While measure of species diversity focus on the number and relative abundance of species present, measures of taxonomic diversity incorporate how distinct each species is in its evolutionary history.

How to measure species diversity?

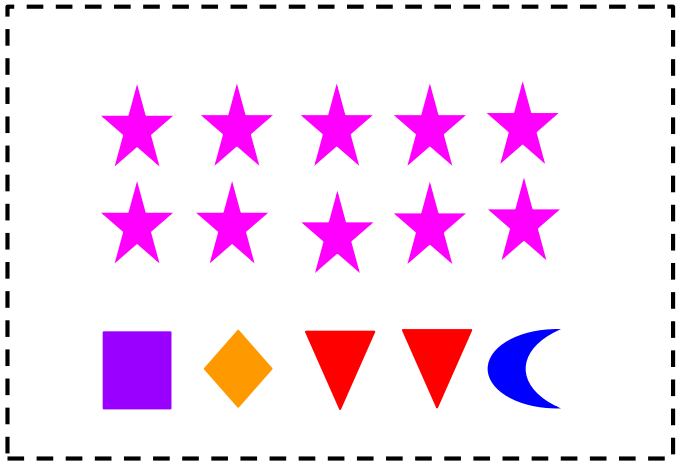


Example

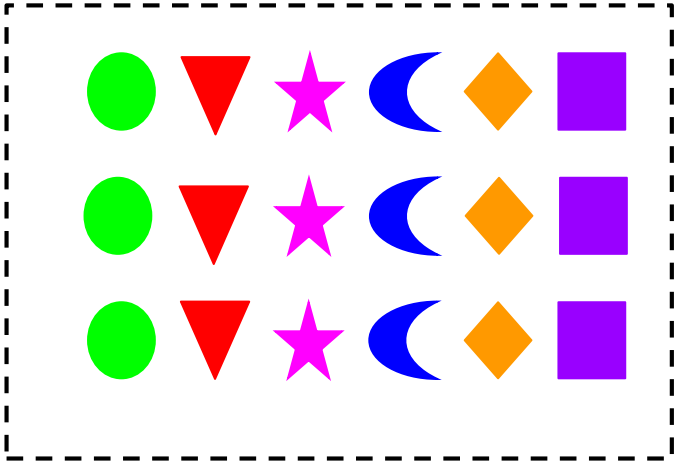
Which group is species rich?

Which group is species even?

Group 1



Group 2



The greater the species richness and species evenness in an area, the higher the biodiversity

Types of Species Richness

Scale	Inventory Diversity	Differentiation Diversity
Within sample	Point diversity	
Between samples, within habitat		Pattern diversity
Within habitat	**Alpha diversity** (local)	
Between habitats, within landscapes		**Beta diversity** (turnover)
Within landscape	**Gamma diversity** (regional)	
Between landscapes		Delta diversity
Within biogeographic province	Epsilon diversity	

MacArthur 1965 and Whittaker 1977

Exploring patterns of richness.

Biodiversity can be measured and monitored at several spatial scales.

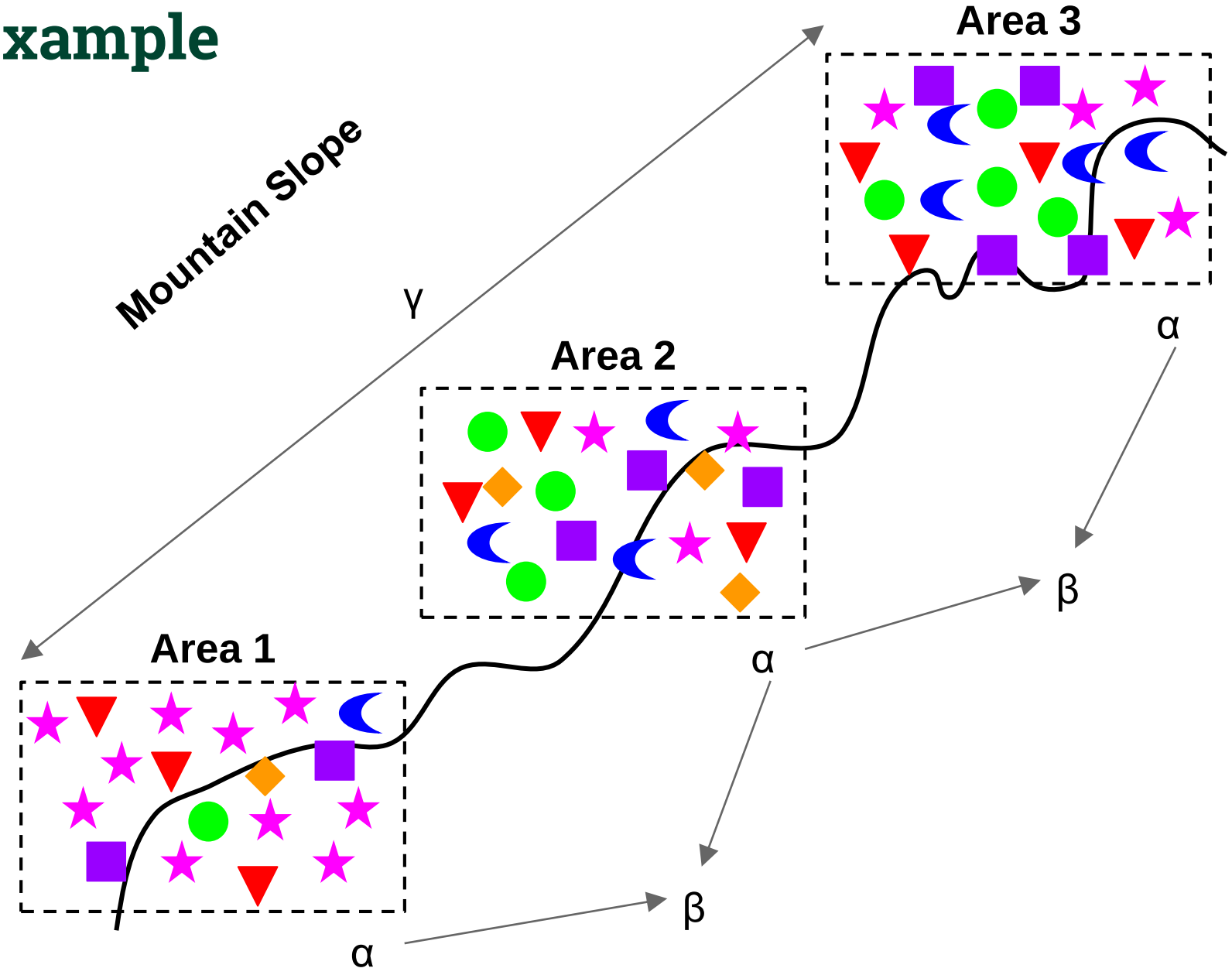
Whittaker (1970) named the spatial measures of richness alpha, beta, Gamma.

Alpha diversity: is the number of species in a locality or habitat i.e. **Alpha** Diversity = richness and evenness of individuals within a habitat unit.

Beta diversity = expression of diversity between habitats.

Gamma diversity = landscape diversity or diversity of habitats within a landscape or region.

Example



Example

Sp	Community 1	Community 2	Community 3
A			
B			
C			
D			
E			
F			

Species Abundance	Highly uneven	High evenness	High evenness
Species Richness	6	6	5

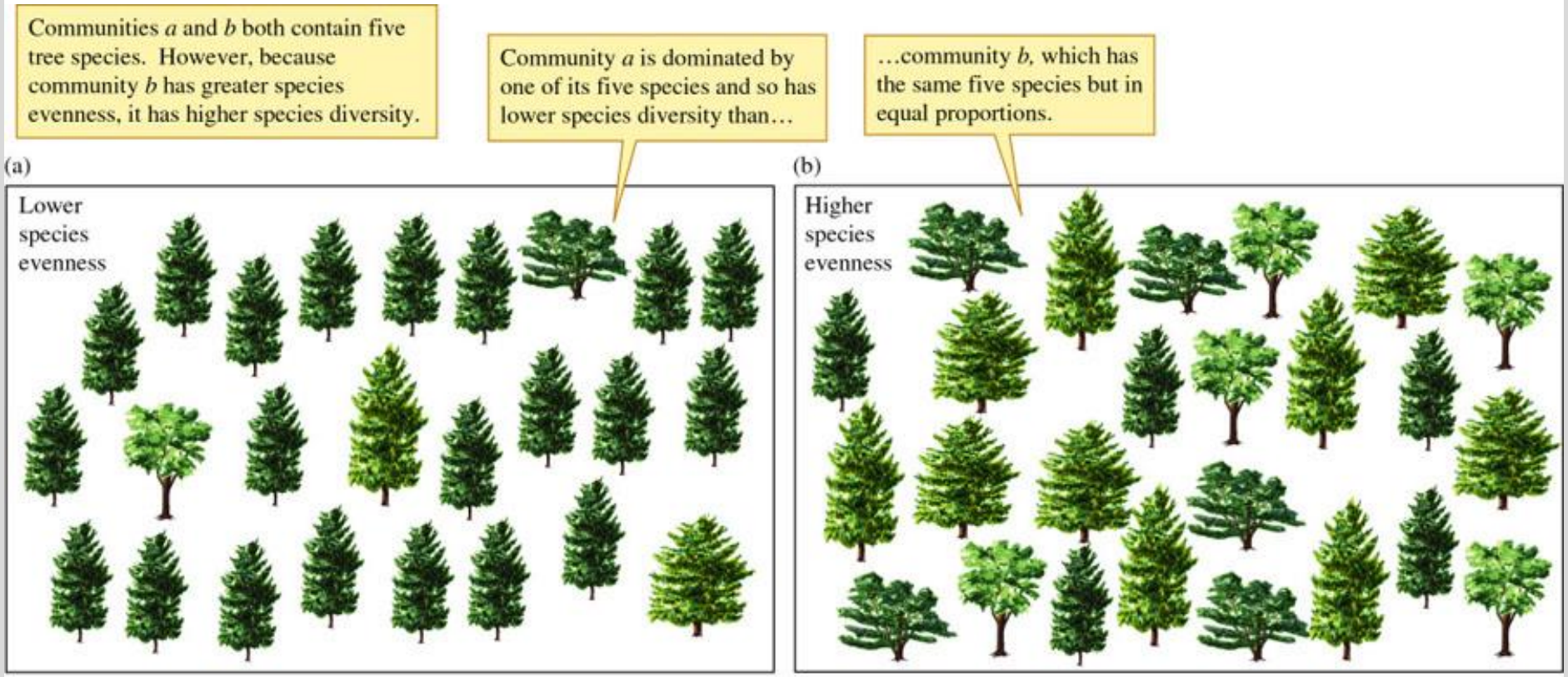
What is the α, β, and γ diversities for these communities?

Example

Sp	Community 1	Community 2	Community 3
A	10	3	4
B	1	3	4
C	1	3	4
D	3	3	4
E	2	3	4
F	1	3	0
Total individuals	18	18	20

Species A in Community 1 = 55.6%
Species A in Community 2 = 16.7%
Species A in Community 3 = 20.0%

Two forests, 5 species only but (b) has higher evenness



5 species; 84% A, 4% B, 4% C, 4% D, 4% E

5 species; A, B, C, D, & E each 20%

Forest (b) more diverse

Species Diversity - Calculations

Simpson's Index

$$D = 1 - \frac{\sum_{i=1}^{S} n_i(n_i - 1)}{N(N-1)}$$

- It takes into account the number of species and the evenness (heterogeneity) of the species.
- D represents the probability that two individuals randomly selected from a sample will belong to different species.
- The index is increased either by having more unique species, or by having a greater species evenness. In other words, heterogeneity is higher in a community where there are more species and when the species are more equally abundant.

Simpson's Index

The Simpson's index is also commonly used to describe species diversity within a community. The basic formula for the Simpson's index of species diversity is,

where **N** = total number of individuals collected of all species

ni = total of individuals of particular species

S = number of species in the sample

i=1 in the absence of any diversity, only one species is present.

Σ = summation, and

D = Simpson's diversity index (no units and ranges from 0 to 1)
High scores (close to 1) indicate rich diversity
Low scores (close to 0) indicate poor diversity

Shannon-Wiener's Index

$$H' = -\sum_{i=1}^{s} P_i \, Ln \, P_i$$

- It takes into account the number of species present, as well as the relative abundance (rare or common) of each species.
- It is a measure of the average degree of uncertainty in predicting what species an individual chosen at random from a collection of S species and N individuals will belong.
- Average uncertainty increase as species number increases and as the distribution of individuals among the species becomes even.

Shannon-Wiener's Index

The Shannon-Wiener index is widely used to describe species diversity within a community. The basic formula for the Shannon-Wiener index of species diversity is,

where **Pi** = proportion of the total sample belonging to species i (Pi=ni/N)

Ln = natural logarithm

S = total number of species in the sample

i=1 in the absence of any diversity, only one species is present.

Σ = summation, and

H = index of species diversity (no units)
H' = 0 if and only if there is one species present
H' = 1 only when all S species are evenly distributed

Example

Sp	Community 1	Community 2	Community 3
A			
B			
C			
D			
E			
F			

Species Abundance	Highly uneven	High evenness	High evenness
Species Richness	6	6	5
Species Diversity	0.59	0.78	0.69

Not all Species are Equal!

In a functional role, **not** all species in a community appear to be **equal**.

1. Few common species with a high population density or relative abundance. Called **dominants**.

   Dominance is the converse of diversity. Simpson's index is often used as a measure of dominance. A value of 0 would represent total dominance (only one species present).

   Dominance may not be numerical abundance but may be biomass, functional importance, or size of the individuals.

2. Many rare species with a low population density or relative abundance. Called **rarities**.

Factors affecting Species Diversity

1. **High eco-complexity or environmental complexity.**

In general species diversity increases with environmental complexity or heterogeneity.

But one aspect of the environment may be important to one group of organisms but may not be important to another group.

Need to know something about the ecological requirements of species (**niches**) to predict how environment influences their diversity.

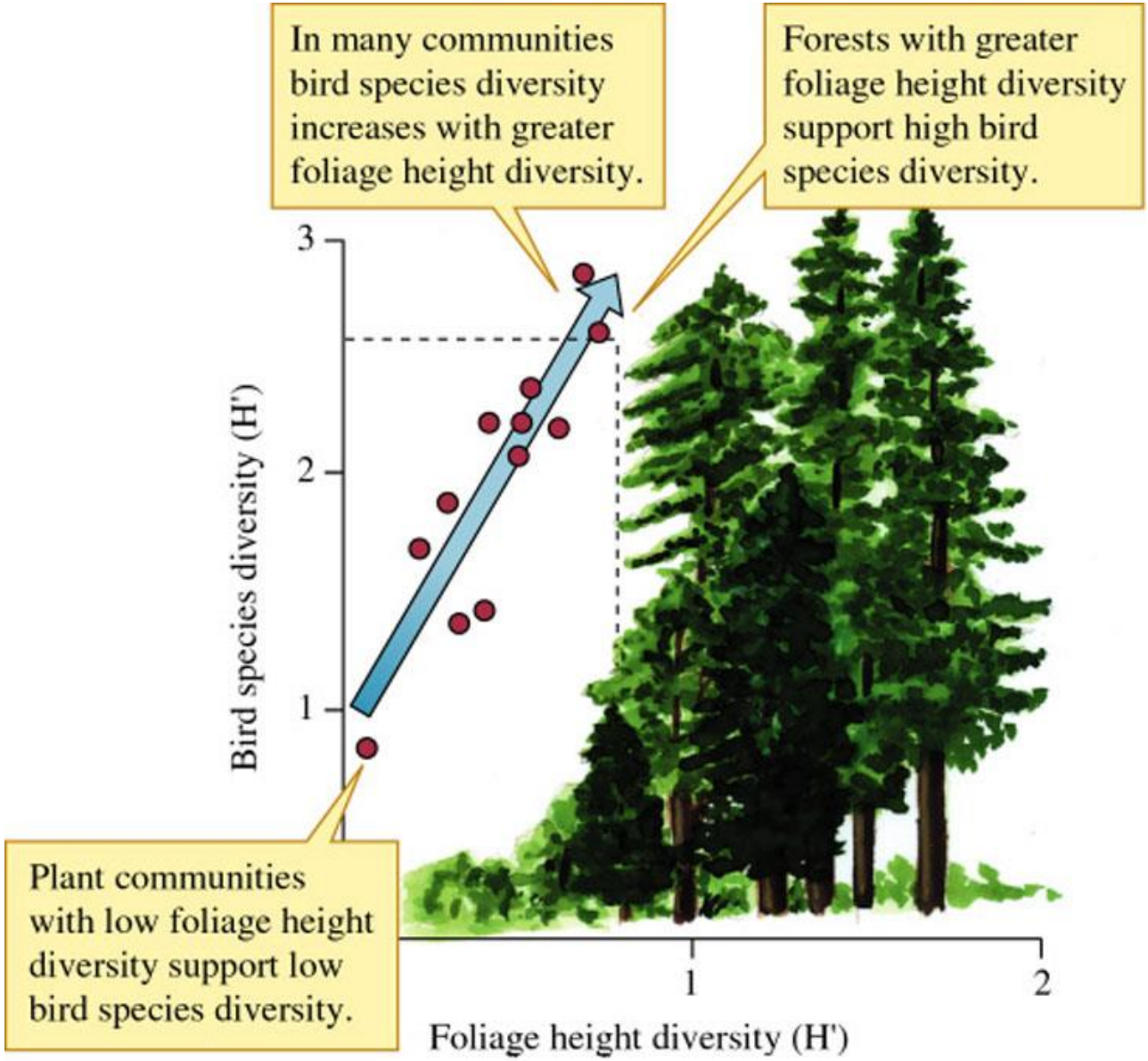
Example:

- MacArthur found warbler diversity increased as vegetation stature increased. Measured environmental complexity as foliage height.

- Many studies have shown positive relationship between environmental complexity and species diversity.

- Forest complexity and bird species diversity
- Competition influences species realised niches.
- Competitive exclusion principle predicts that co-existing species will have different realised niches.

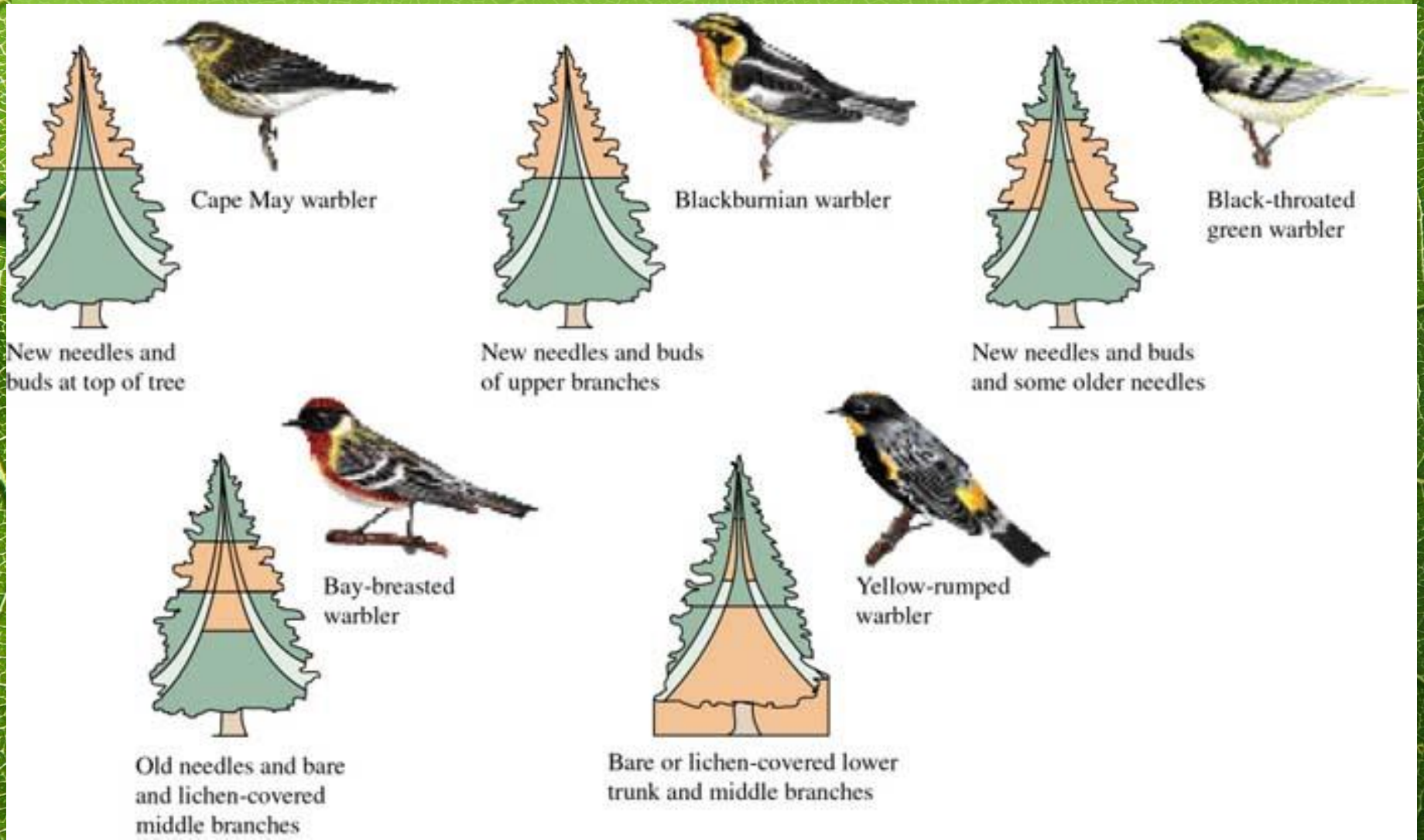
- Warblers in eastern USA forests

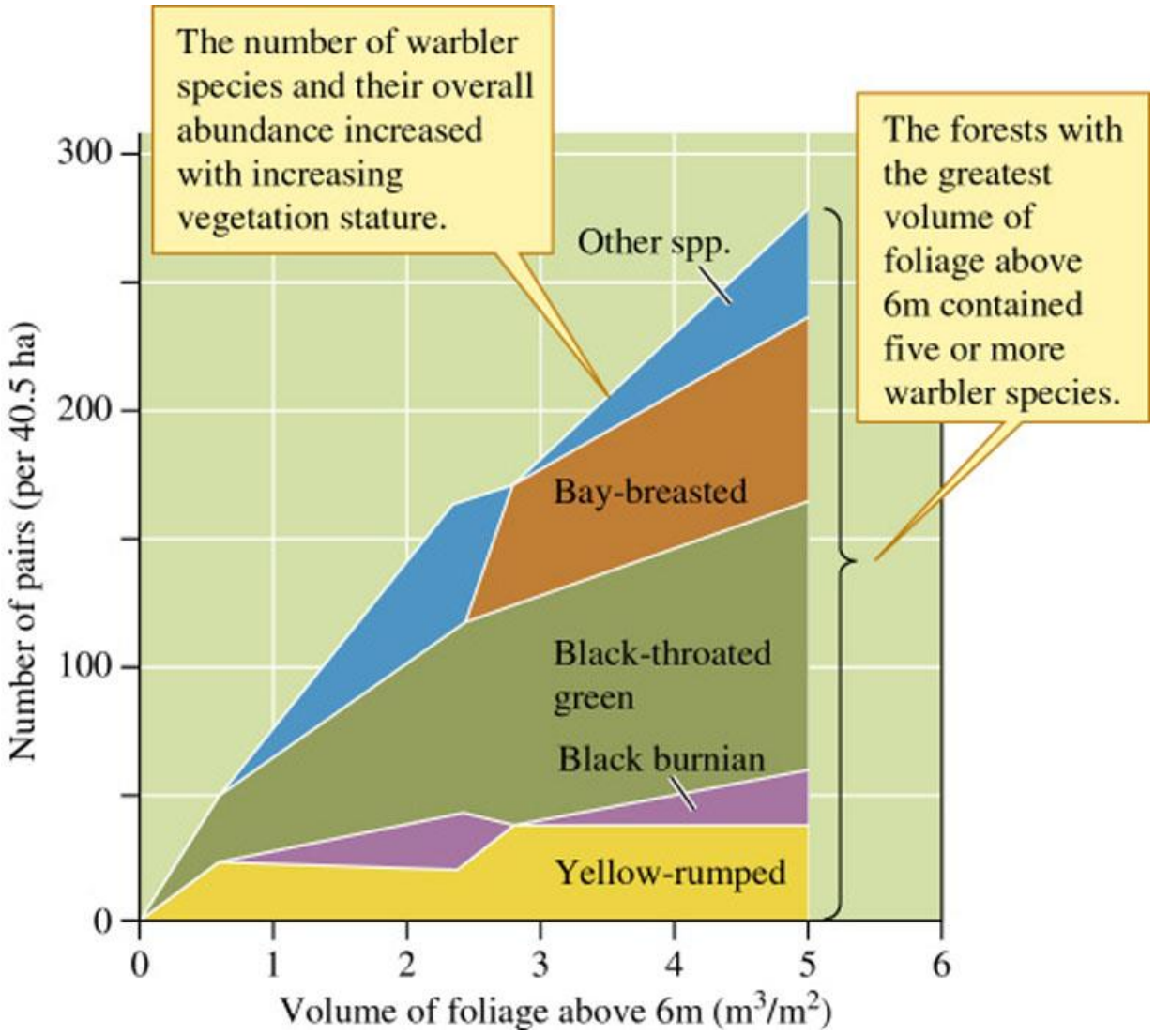


Foliage height and bird species diversity

Five different warblers

Essential to study community structure to provide basis for explaining co-existence of different species of same genus in forests





Stature of vegetation and no. of warbler species

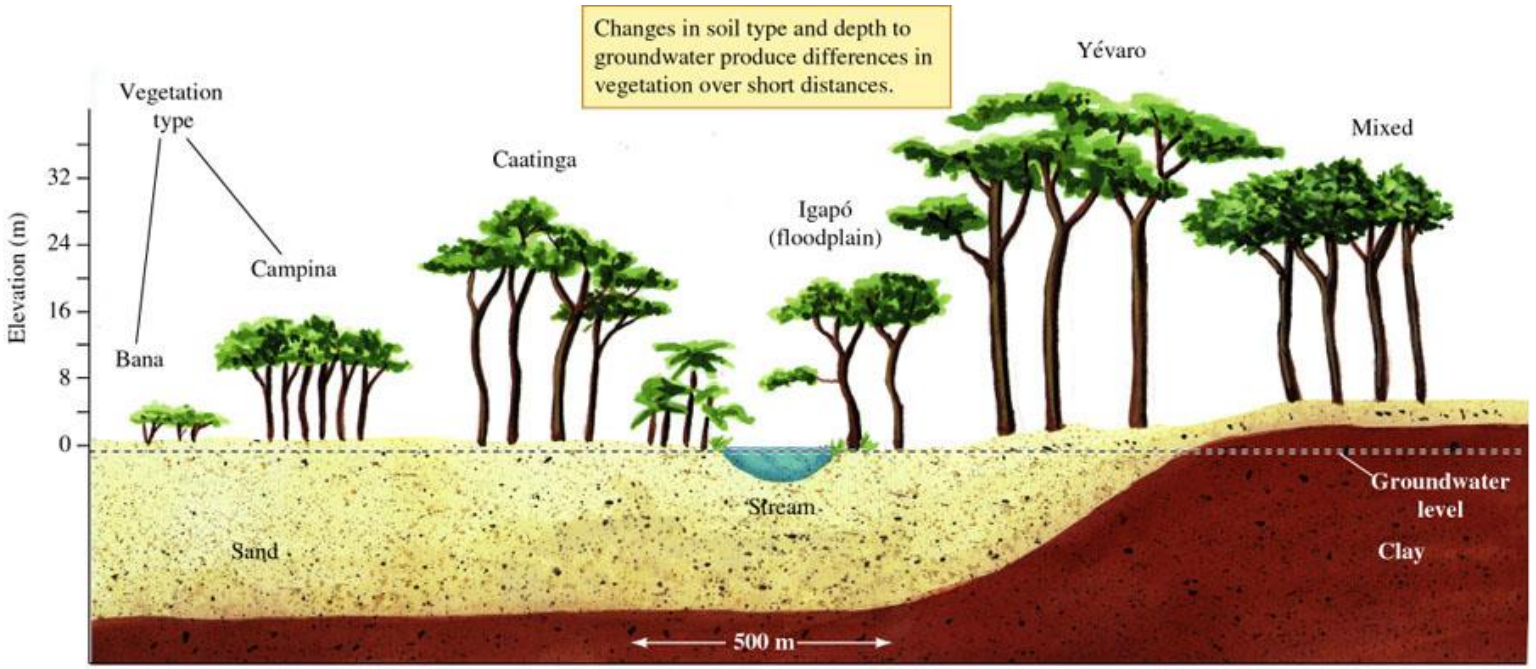
Warbler diversity increased as stature of vegetation increased

i.e. species diversity increased with habitat size.

What about habitat diversity?

Estimated forest habitat diversity by Shannon-Wiener index.

In Terrestrial environments small differences in soil properties result in different plant communities. Six types in 2500m over an elevational range of less than 8 m. Granite bedrock, clay subsoil, varying amounts of sand, small variations in topography determining depth of the soil above the groundwater all contribute to the plant diversity. Subtle changes in physical and chemical environment gives high eco-complexity and hence high biodiversity.



Species Diversity - Hypotheses

High-productivity hypothesis

One hypothesis to explain the gradient is that high productivity in the tropics promotes high diversity by increasing speciation rates and decreasing extinction rates.

The idea is that increased biomass production supports more herbivores and thus more predators and parasites and scavengers. In addition, speciation rates should increase when niche differentiation occurs within populations of herbivores, predators, parasites, and scavengers.

Although this high-productivity hypothesis is supported by the global-scale correlation between productivity and diversity, experimental studies challenge it. For example, researchers who add fertilizers to aquatic or terrestrial communities routinely observe significant increases in productivity but decreases in diversity.

Energy hypothesis

Based on results such as these, researchers have concluded that productivity alone is probably not a sufficient explanation for the higher species diversity in the tropics.

Research continues, however, and investigators have recently begun to focus on a abiotic factors that is correlated with productivity: temperature.

Biologist who analyzed data on gastropods and other marine invertebrates have documented a strong correlation between the temperature of marine waters and species diversity.

This observation has inspired the energy hypothesis: Temperature causes changes in species diversity by influencing productivity and the ability of organisms to tolerate the physical conditions in a region.

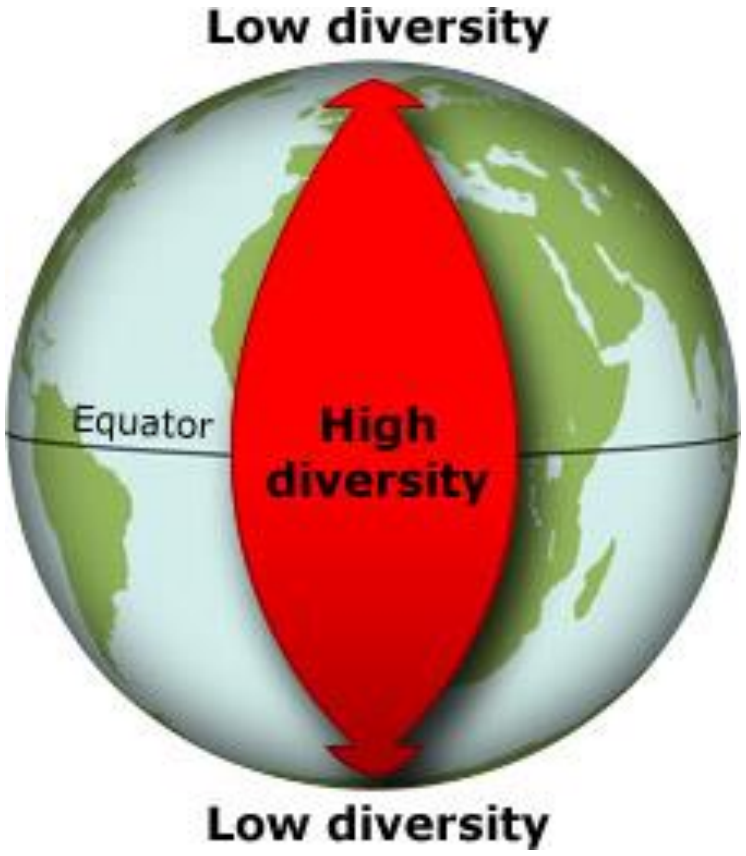
Example

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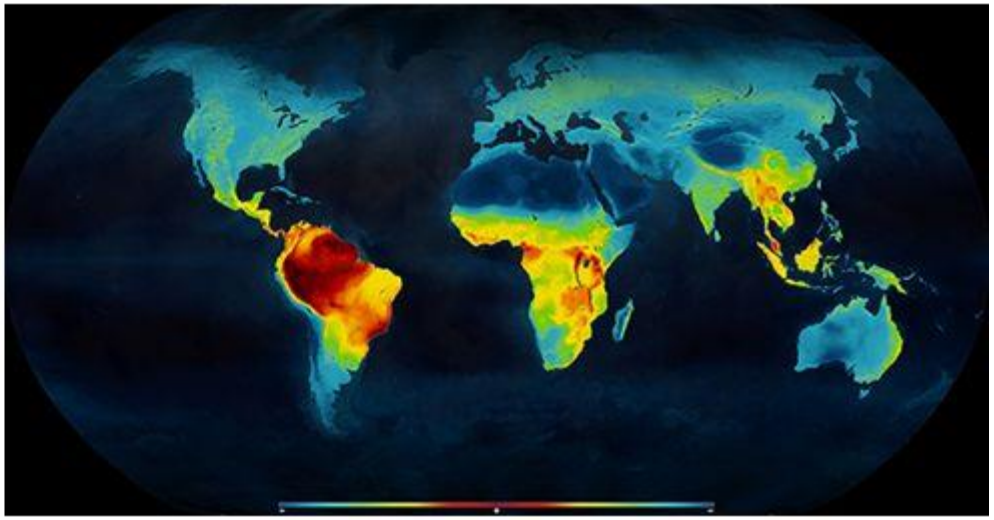
2. Latitude.

This idea is also referred to as the latitudinal diversity gradient, meaning that as you move from the equator towards the poles, diversity lessens. This pattern is one of the oldest observed in ecology.



Biogeographic factors affect community diversity

- Equatorial-Polar Gradients
- Species richness generally declines along an equatorial-polar gradient and is especially great in the tropics
- The greater age, climate, and amount of light found in tropical environments may account for the greater species richness



The causes for latitudinal gradients in biodiversity

- One of the factors proposed as a cause of latitudinal diversity gradients is the area of the climatic zones. Tropical land masses have a larger climatically similar total surface area than land masses at higher latitudes with similarly small temperature fluctuations

This may be related to higher levels of speciation and lower levels of extinction in the tropics

- Moreover, most of the land surface of the Earth was tropical or subtropical during the Tertiary, which could in part explain the greater diversity in the tropics today as an outcome of historical evolutionary processes.

- The higher solar radiation in the tropics increases productivity, which in turn is thought to increase biological diversity.
- Higher temperatures in the tropics may imply shorter generation times and greater mutation rates, thus accelerating speciation in the tropics Speciation may also be accelerated by a higher habitat complexity in the tropics, although this does not apply to freshwater ecosystems.

Historical hypothesis

A third hypothesis is that tropical regions have had more time for speciation to occur that other regions have. Temperate and arctic latitudes were repeatedly scoured by ice sheets over the last 2 million years, but tropical regions were not.

Recent data suggests, however, that tropical forests were dramatically reduced in size by widespread drying trends during the ice ages. Existing forests may be much younger than originally thought. If so, then the contrast in the age of northern and southern habitats may not be enough to explain the dramatic difference in species diversity.

3. Disturbance and Diversity

Ecologists tend to assume environmental conditions remain more or less stable. **Equilibrium**

Lotka-Volterra competition models and predator-prey models **assume** a constant physical environment.

But the physical environment varies continuously in space and time at all scales. As a result, the biotic environment will also vary, as will the frequency and intensity of disturbance. **Non-equilibrium**

Disturbances often occur when there is a **rapid shift** from 'average' conditions (e.g. storms).



Joseph Connell

‘Intermediate disturbance hypothesis'

As all communities experience disturbance and as environment is never stable, proposed that diversity is a result of changing conditions and not competitive accommodation at equilibrium.

Predicts that intermediate levels of disturbance promote higher levels of diversity.

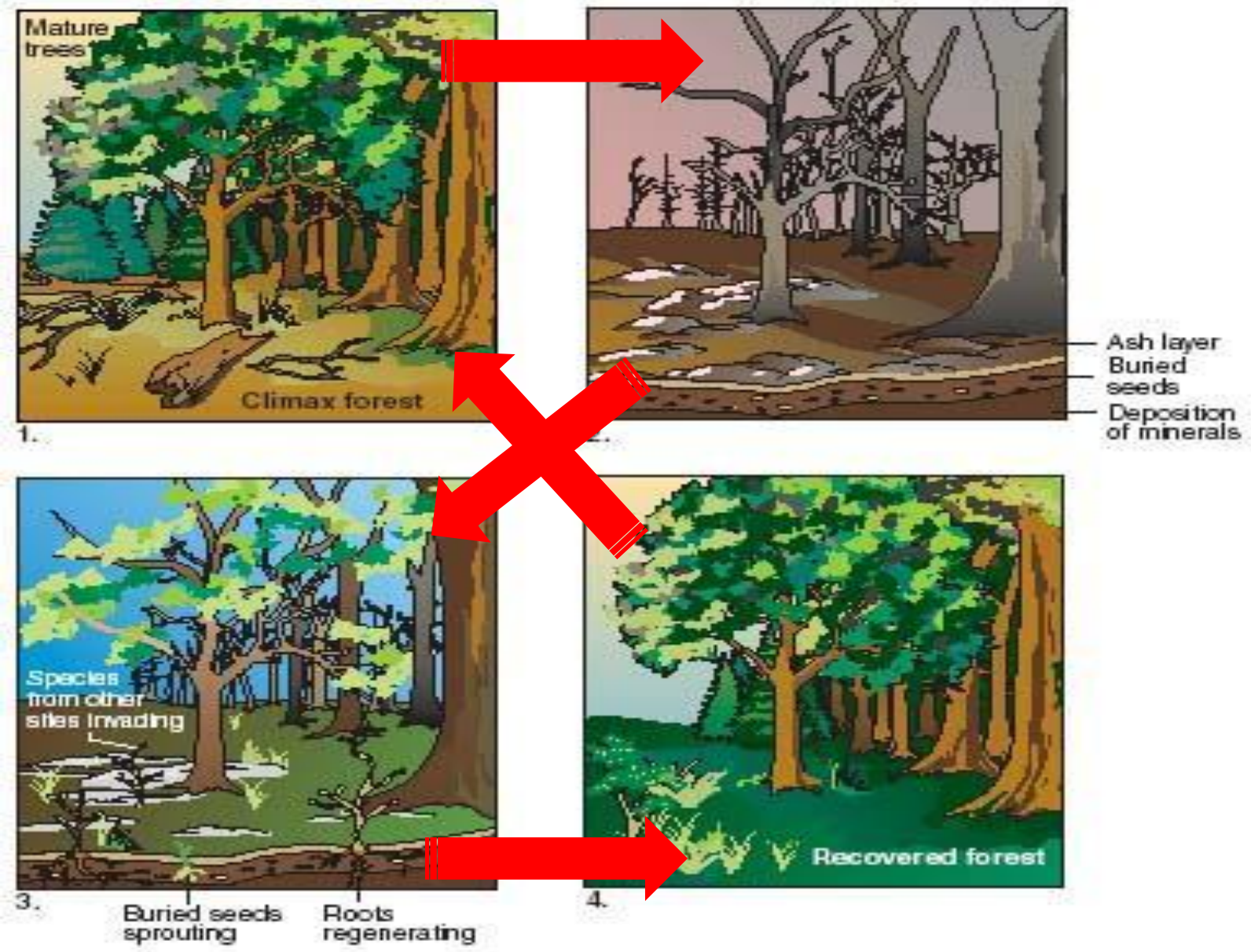
Intermediate disturbance hypothesis

A fourth hypothesis was inspired by the observation that species diversity is much higher in mid-successional communities than in pioneer or mature communities (see next slide)

The intermediate disturbance hypothesis hold that regions with a moderate type, frequency, and severity of disturbance should have high species richness and diversity. The logic here is that intermediate levels of disturbance, communities will contain pioneering species as well as species better adapted to late-successional conditions.

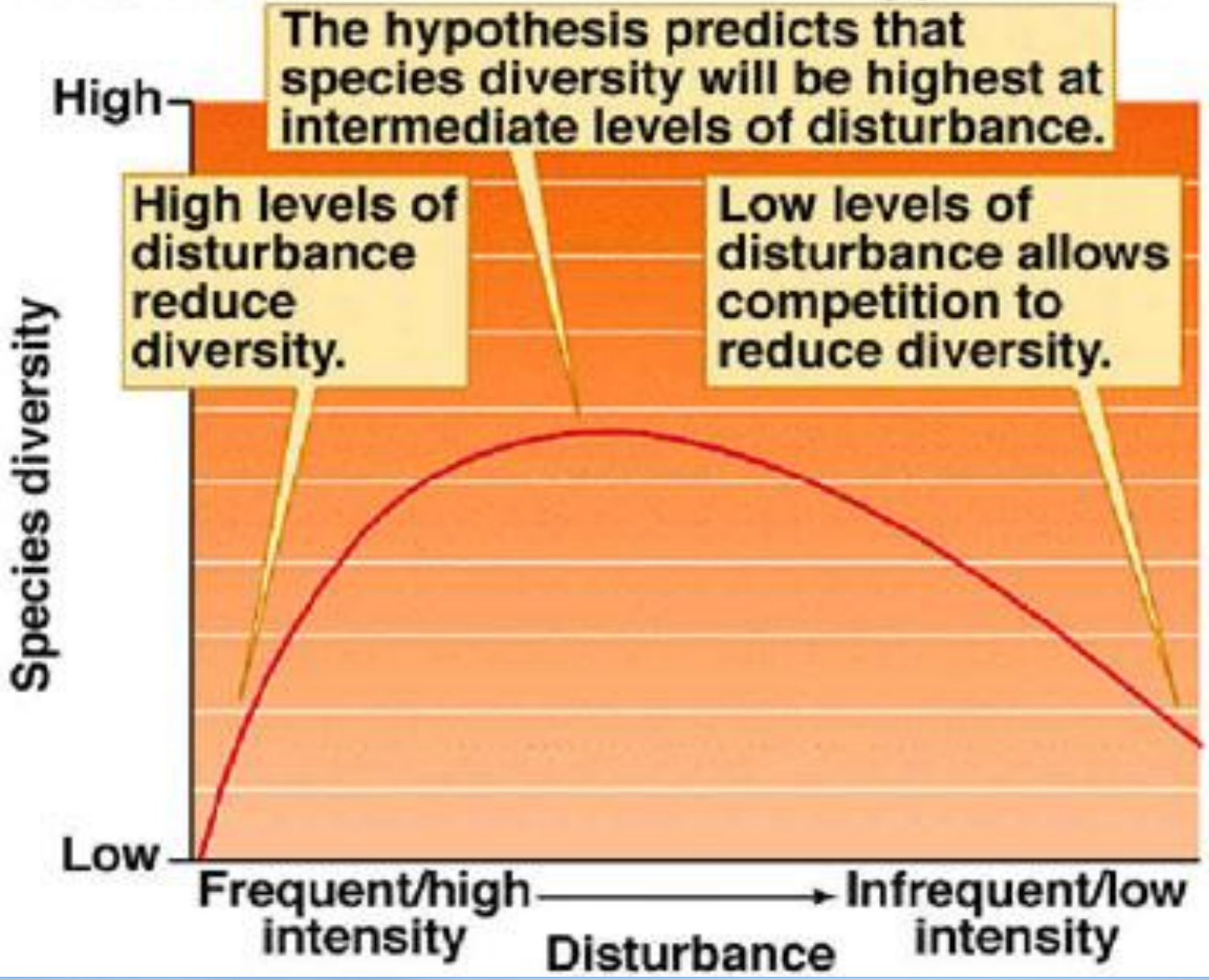
For example, recent studies have confirmed that tree falls and canopy gaps occur regularly in tropical forests and that fires occur in these biomes occasionally.

As yet, however, there are no convincing data showing that intermediate levels of disturbance are more likely to occur in the tropics that they are at higher latitudes.


Mature trees
Climax forest
1.
Ash layer
Buried seeds
Deposition of minerals
Species from other sites invading
3.
Buried seeds sprouting
Roots regenerating
Recovered forest
4.

Manuel C. Molles, Jr., *Ecology: Concepts and Applications*, © 1999 The McGraw-Hill Companies, Inc. All rights reserved.

The intermediate disturbance hypothesis.



EXAMPLE

Intertidal zone

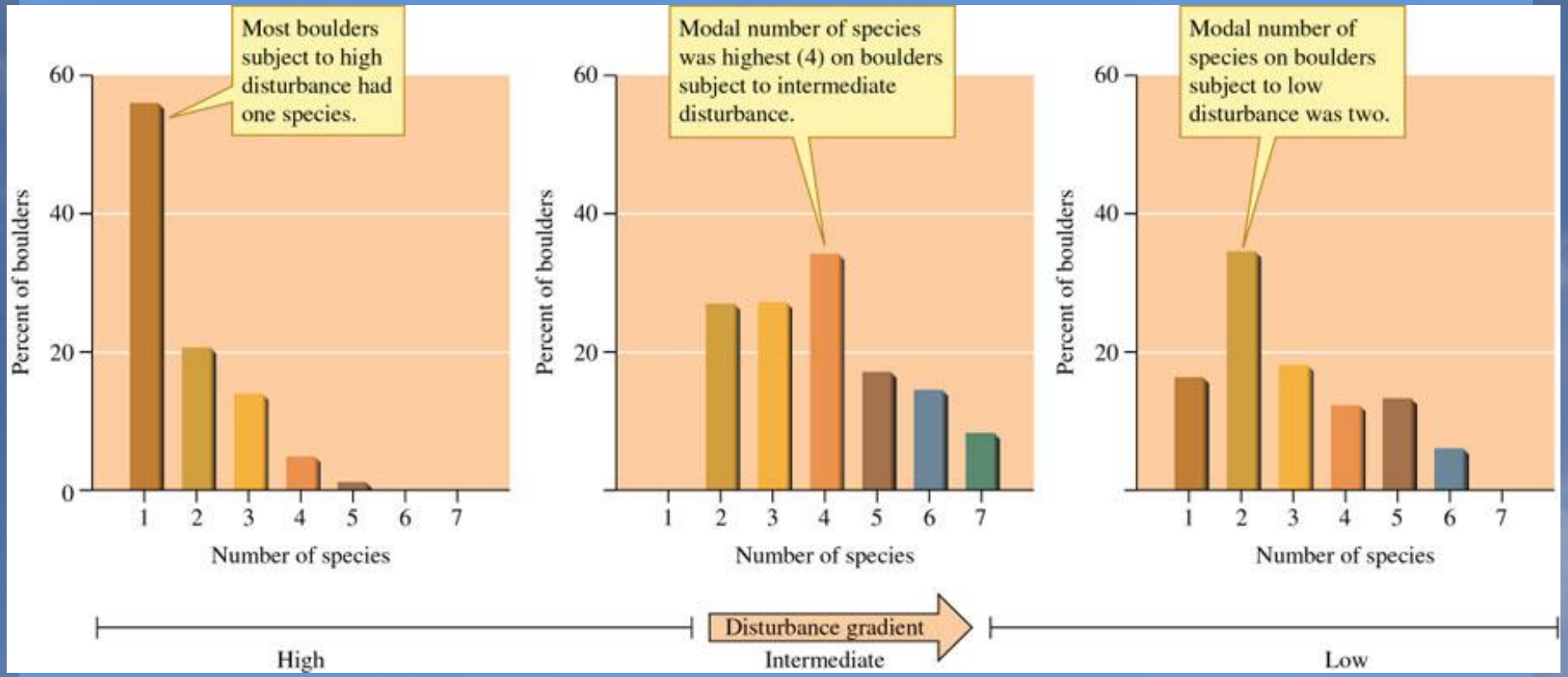
Algae and invertebrates growing on boulders. Small boulders more likely to be disturbed by waves and storms than large boulders.

Estimated wave force needed to move boulders

3 types - frequent movement (42% per month)
intermediate movement (9% per month)
infrequent movement (1% per month)

Number of species recorded

Levels of disturbance and diversity on intertidal boulders



2 species on low-disturbance boulders

4 species on intermediate-disturbance boulders

1 species on high-disturbance boulders

Conclusion

To summarize, there is no simple answer to the question of why some communities are more diverse than others. Each of the factors discussed here may influence diversity, but no single one offers a convincing explanation for the global diversity gradient. According to the data available at present, the presence of high energy inputs seems most responsible for communities with high species diversity.