

INTRODUCTION TO BIODIVERSITY

TOPIC 2.1

Enduring Understanding: Ecosystems have structure and diversity that change over time.

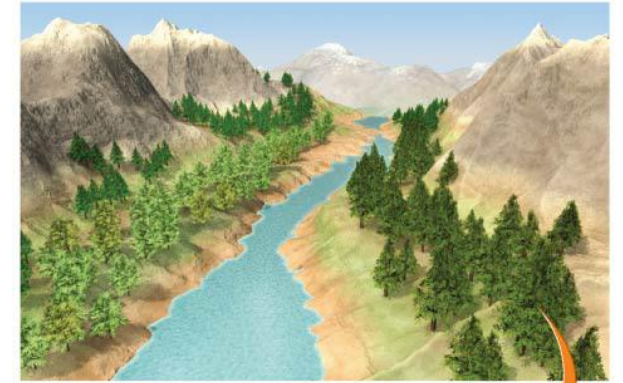
Learning Objective: Explain levels of biodiversity and their importance to ecosystems.

Related Readings: pg. 275 – 280 and 113 -115, “Environment; The Science Behind the Stories” 4th Edition, Withgott, Jay and Laposata, Matthew.

Our Planet of Life

Biodiversity

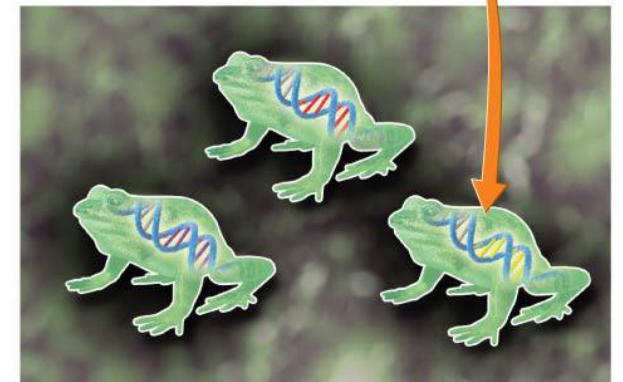
- Biodiversity has several different components, each of equal importance
 - Variety is a function of the number of different types and the number of individuals of a certain type
- Variety of life at all levels
 - *Genetic diversity*
 - *Species diversity*
 - *Habitat / Ecosystem diversity*
- All species in an ecosystem contribute in some way to the functioning of ecosystems
 - Species loss, past a certain point, is likely to have detrimental effects on the functioning of ecosystems and their **stability** (ability to resist change in the future)
- The rate of species **extinction** (biodiversity loss) is increasing.
 - Much of it is due to human activities
 - Loss of biodiversity is causing serious implications for the stability of many ecosystems.



Ecosystem diversity



Species diversity



Genetic diversity

Genetic Diversity

- **Genetic Diversity** is the total number of genetic characteristics in a population or the differences in DNA composition among individuals in a population or species.
- Measured by:
 - **Nucleotide Diversity:** Compares nucleotide sequences in a population. Human Nucleotide diversity is $\approx 0.01\%$ (You and another human have the same nucleotide at 999 out of every 1000 nucleotide sites in your DNA).
 - **Gene Diversity:** Is the average percentage of gene loci that are heterozygous in a population. For humans Gene diversity is $\approx 14\%$



Genetic Diversity

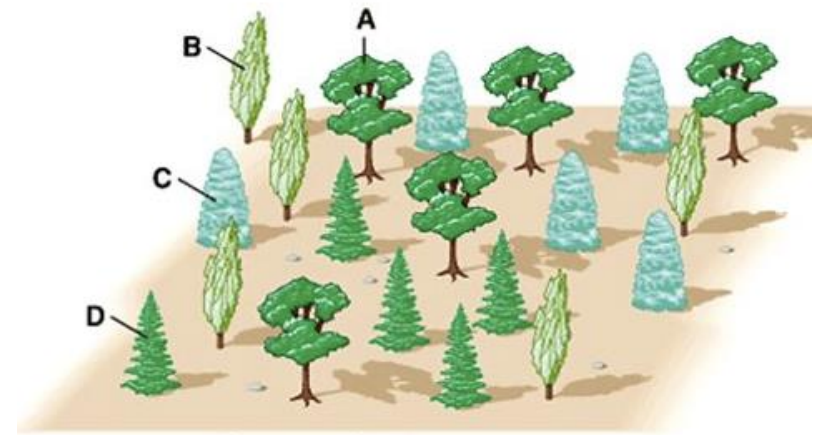
- Genetic Diversity provides the raw material for adaptation to local conditions.
- Populations with more genetic diversity may be more likely to persist because they are more equipped to respond to environmental change through adaptation.
- Populations with little genetic diversity are more vulnerable to environmental change
 - **Bottlenecks** limit the genetic diversity in populations, making them vulnerable to extinction even when overall population size may be quite large
 - **Inbreeding depression** may occur in populations with low levels of genetic diversity

California Elephant Seals experienced a severe bottleneck due to hunting reducing their population to ≈ 20 individuals in 1890. The current population of over 20,000 individuals shows no nucleotide diversity in the 30 gene loci that were studied.



Species Diversity

- **Species Diversity** is the number of different species (**species richness**) represented in a given community and the relative abundance (**species evenness**) of each in the community.
 - High species diversity occurs in communities with large numbers of species and relatively evenly balanced populations of all species present
 - Low species diversity occurs in communities with few species (low richness) and/or which are dominated by one, or a few species, while the populations of other species are relatively small (low evenness).
- **Shannon Index of Biodiversity** quantifies biodiversity at a given time and place allowing for comparisons of biodiversity over time or between two or more biological communities



Community 1
A: 25% B: 25% C: 25% D: 25%



Community 2
A: 80% B: 5% C: 5% D: 10%

Shannon Index of Biodiversity

$$H' = - \sum_{i=1}^s p_i \ln p_i$$

$$P_i = n_i/N$$

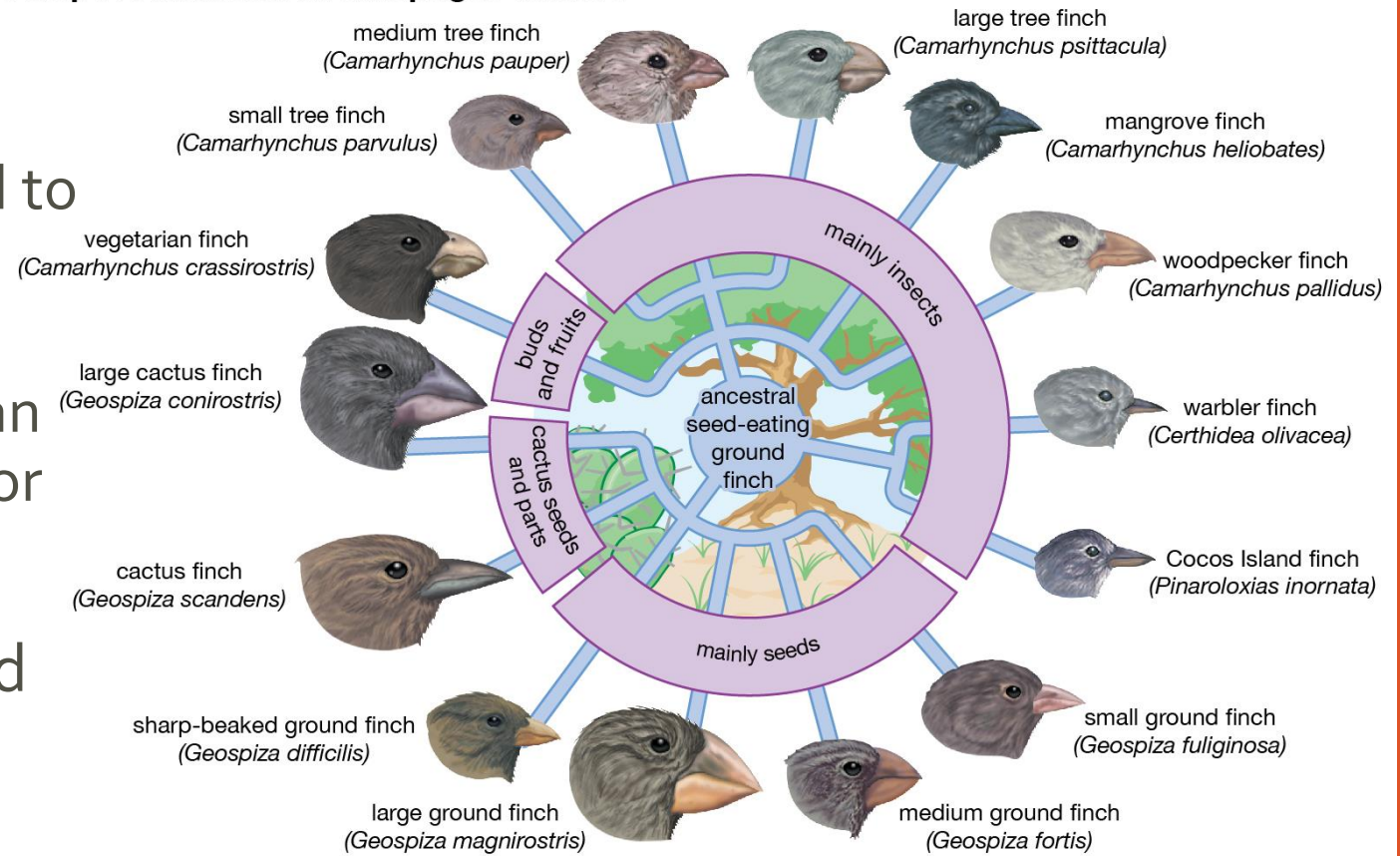
n_i = number of organisms of species i

N = Number of organisms of all species

Species Diversity

- **Speciation** generates new species while **extinction** reduces species richness on a global scale
 - **Background extinction rate** is approximately 1 species in a million per year.
 - Current extinction rate is estimated to 1000x greater
 - **Immigration/emigration** and **extirpation** (localized extinction) can change species diversity on a local or regional scale.
- High Species diversity is associated with stable ecosystems resulting from a large number of biotic interactions

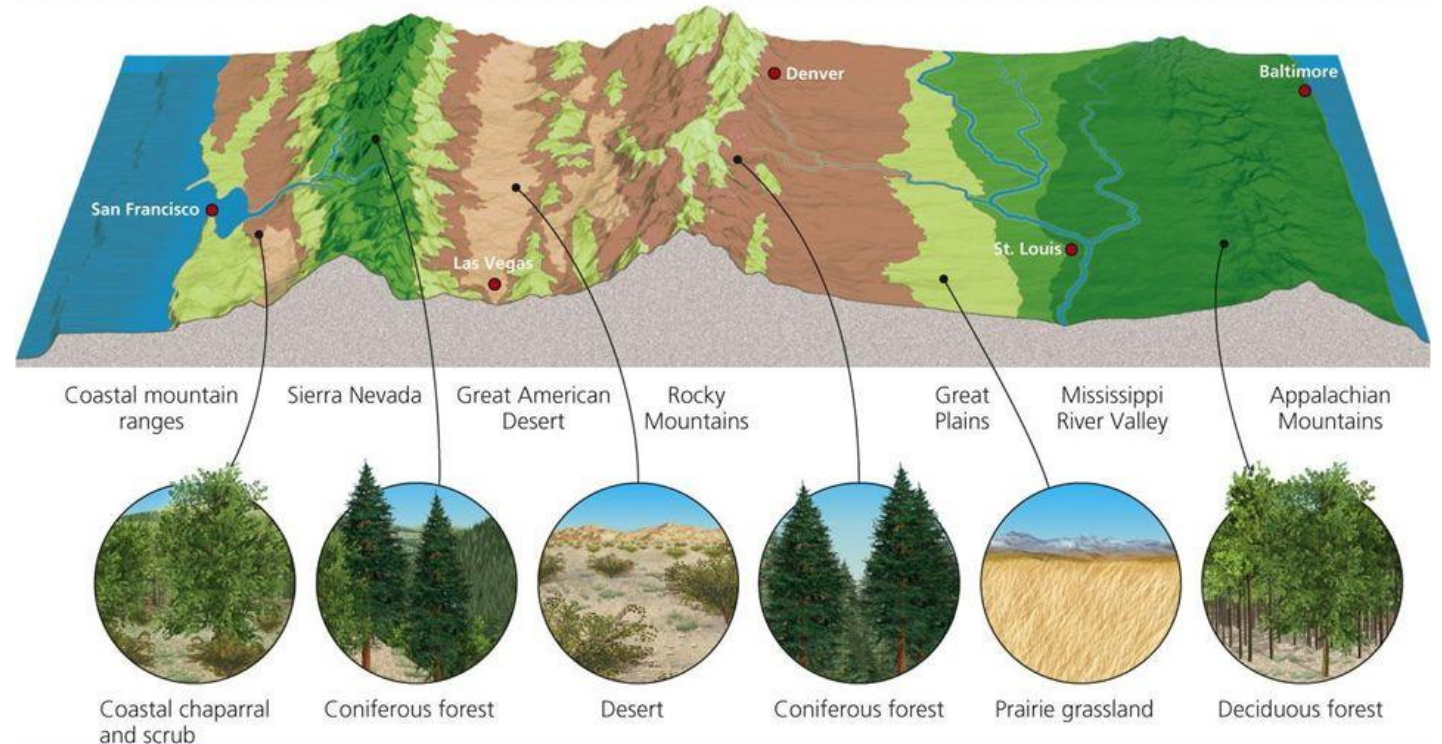
Adaptive radiation in Galapagos finches



Habitat / Ecosystem Diversity

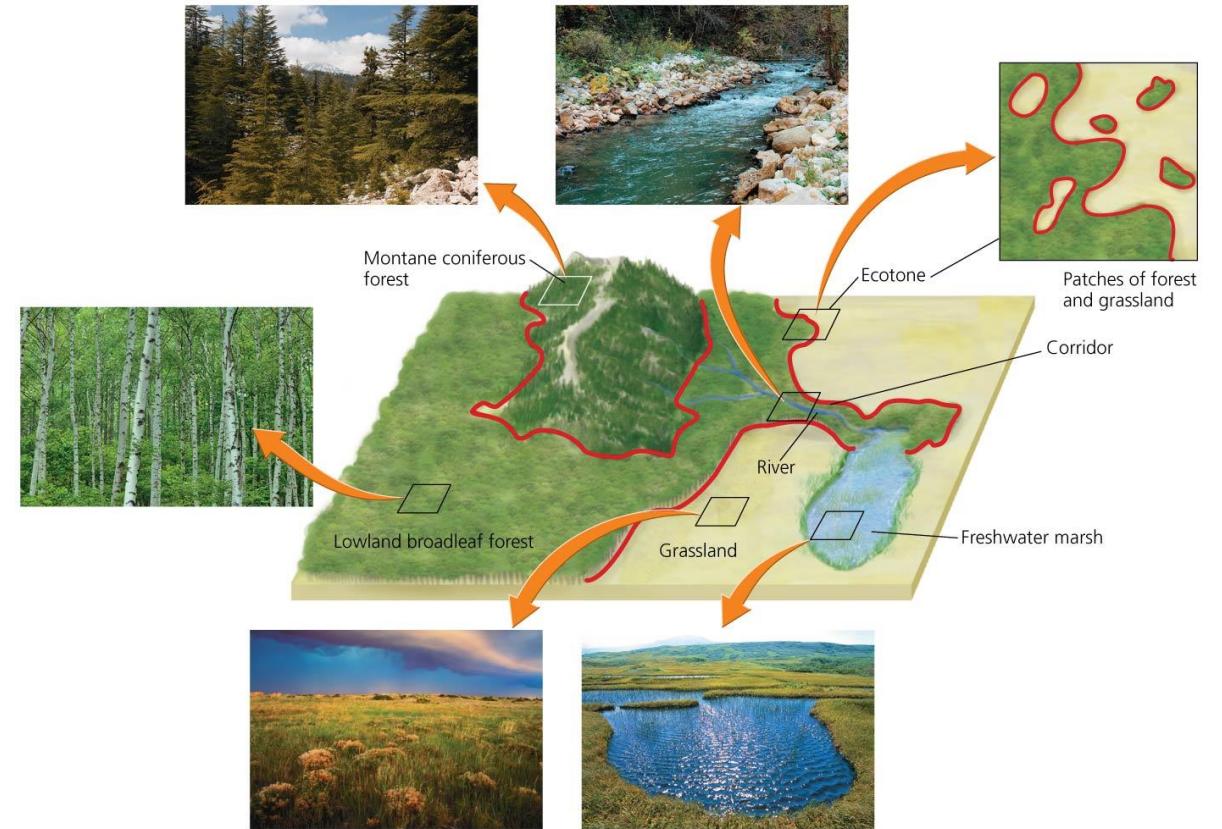
- **Habitat / Ecosystem diversity** describes the number of different habitats provided by a particular landscape.
- Many organisms utilize a variety of different habitats during different seasons or at different periods in their lives. These habitats are spread over a larger landscape.
- Some organisms are more specialized and will spend their entire lives in a single habitat making them extremely dependent on its protection

Ecological Diversity: The Major Biomes Found Along the 39th Parallel Across the U.S.



Habitat / Ecosystem Diversity

- **Landscapes** are made up of **patches** of habitat. The transition from one patch to another is an **ecotone**.
 - More patches within the landscape increase habitat/ecosystem diversity and thus increase overall biodiversity of the landscape.
 - Ecotones are particularly biodiverse and important in conservation due to containing characteristics of two or more habitat types



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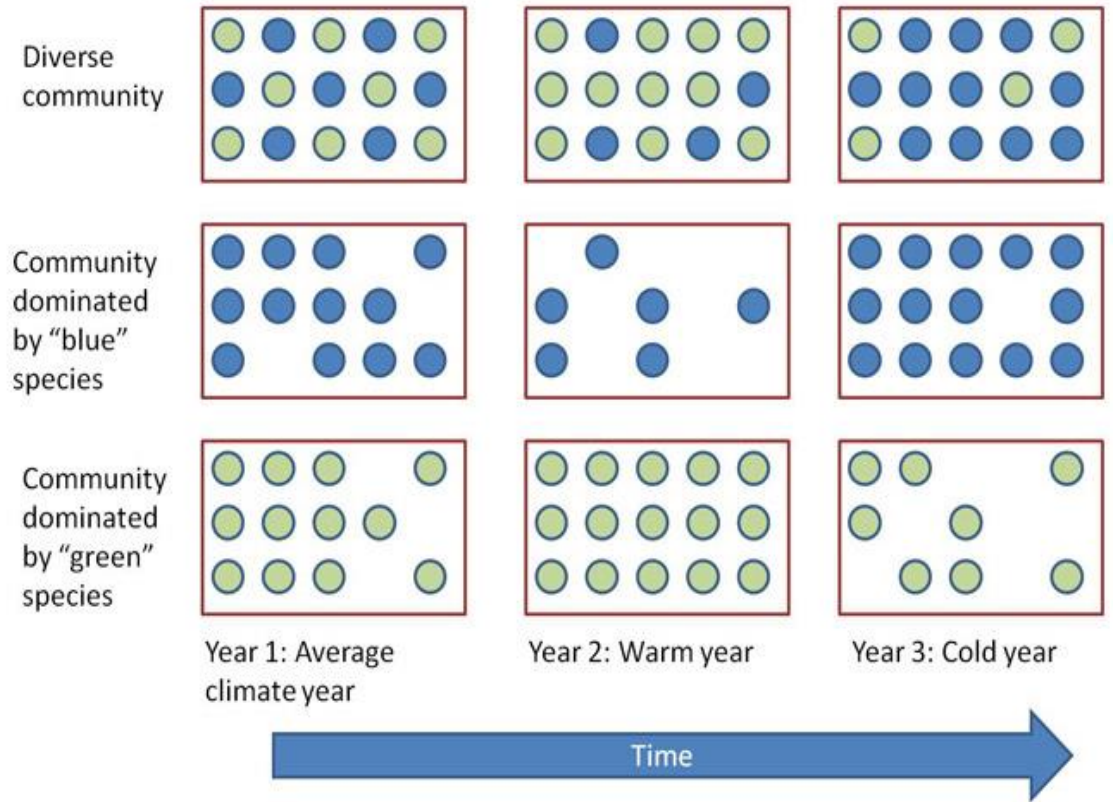
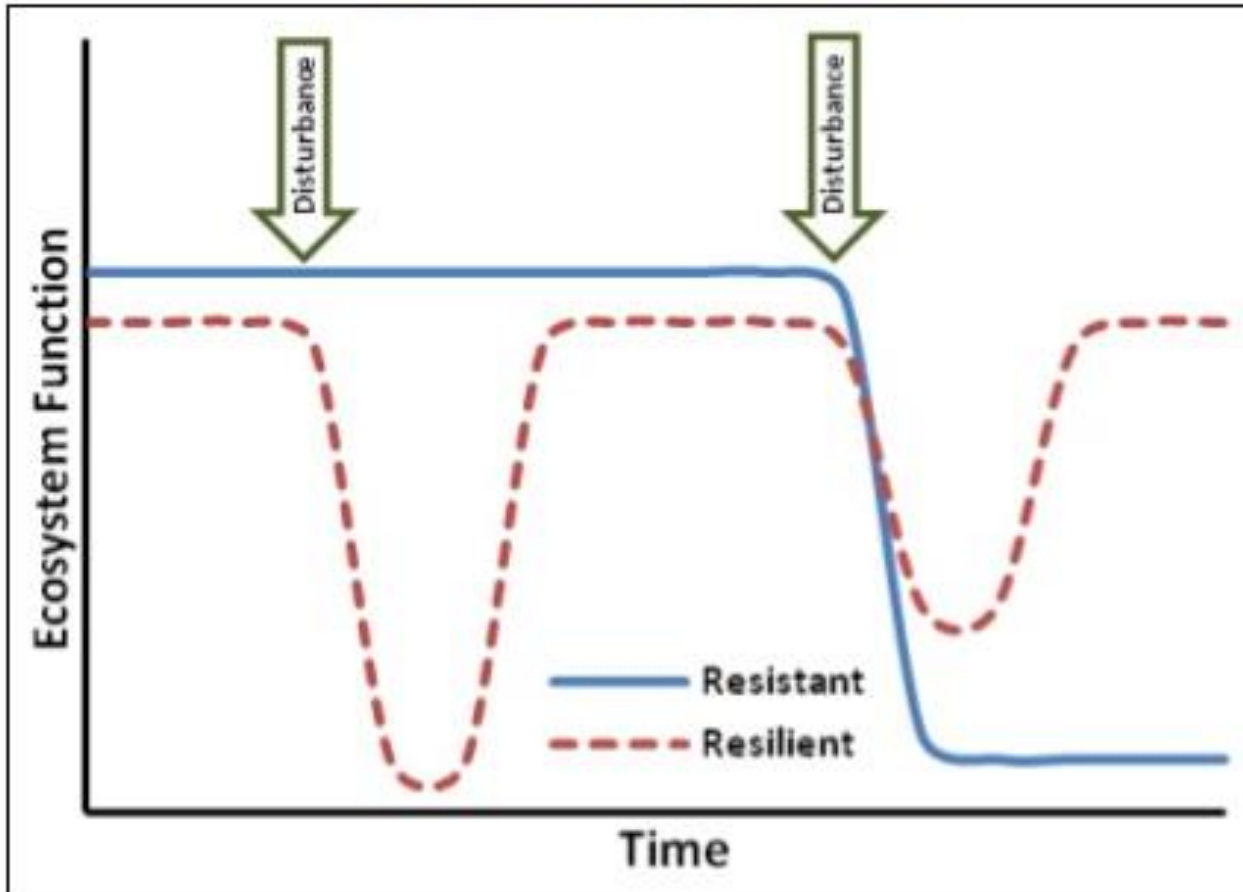
The Serengeti's open plains are vast, but the region holds a diversity of habitat patches, including savanna, woodlands, seasonal wetlands, and rocky outcroppings. This habitat diversity contributes to the rich biodiversity of species in the region

Ecosystem Stability

- **Ecosystem stability** refers to the ability of ecosystems to maintain a state of equilibrium and consistent biodiversity.
 - After a disturbance, the community recovers, species reoccupy their niches, and their population sizes recover.
- Ecosystem stability is achieved through either:
 - **Resistance:** the ability to resist disturbance and remain unchanged.
 - Typified by communities with large biotic structures, such as trees (e.g. forest communities).
 - Large biotic reservoirs of nutrients and energy make these communities resistant to disturbances such as temperature, drought and insect outbreaks
 - **Resilience:** The ability to recover from disturbances. Aquatic ecosystems, which lack large biotic reservoirs of nutrients and energy, are easily disturbed, but tend to be more resilient
- Increased diversity results in more species with partially overlapping fundamental niches, so that even if one species suffers disproportionately from a disturbance, the ecosystem function remains relatively stable as populations of other species grow and compensate

Ecosystem Stability

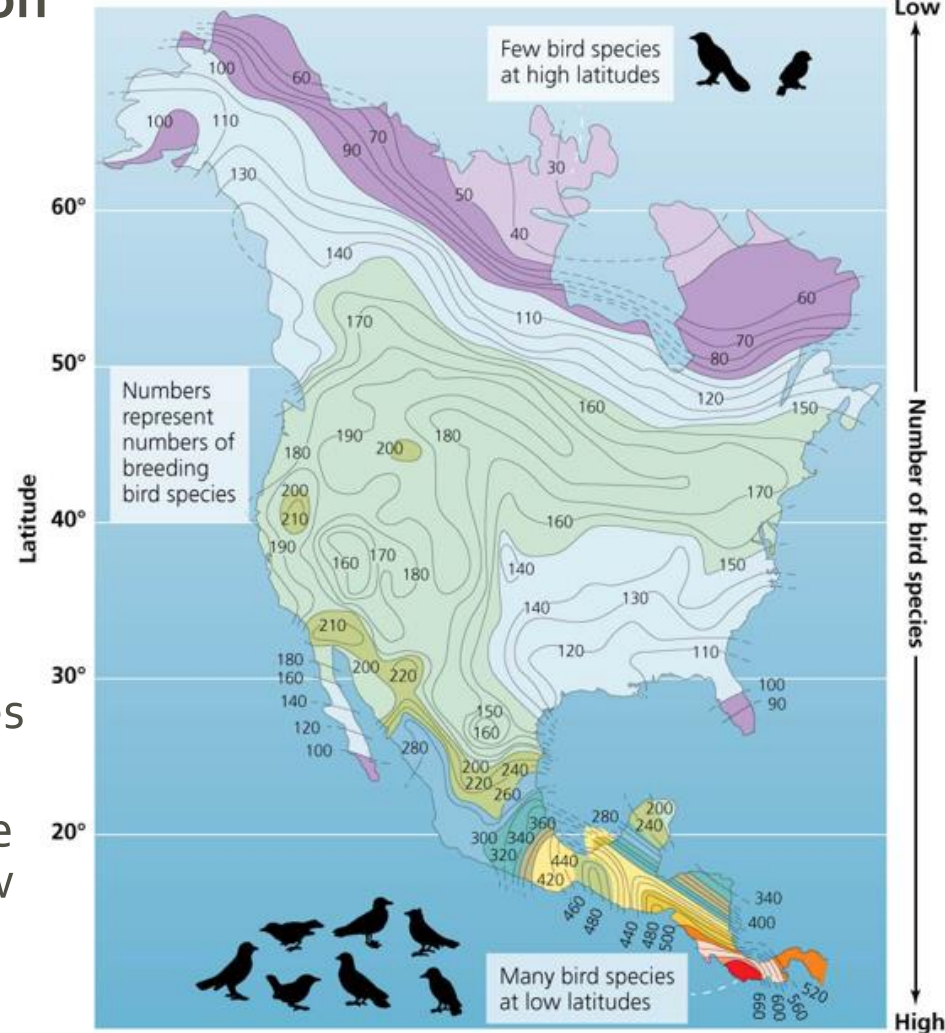
Resistant VS Resilient



Rectangles represent plant communities containing individuals of either blue or green species and the total number of individuals corresponds to the productivity of the ecosystem. A community containing only blue or green species will fluctuate in biomass when there is climate variability. In contrast, in the community containing both green and blue individuals, the decrease in one species is compensated for by an increase in the other species, thus creating stability in ecosystem productivity between years. Note also that, on average, the diverse community exhibits higher productivity than either single-species community.

Biodiversity is Unevenly Distributed

- Living things are not distributed evenly on Earth
 - Habitat diversity increases species diversity
 - Diversity increases with more structurally diverse habitats due to a greater variety of niches (i.e. forests typically have greater diversity than grasslands)
- **Latitudinal gradient: species richness increases with decreasing latitude (toward the equator)**
 - Increasing net primary productivity (NPP) closer to the equator increases resource availability and supports more animal species
 - Climate stability and resource availability favors specialization and species coexistence through resource partitioning leading to new realized niches and character displacement
 - Fewer episodes of glaciation means species have never had to migrate or face extinction/extirpation.



(a) Latitudinal gradient in species richness for birds in North America



Temperate and polar latitudes: Variable climate favors fewer species, and species that are widespread generalists.



Tropical latitudes: Greater solar energy, heat, and humidity promote more plant growth to support more organisms. Stable climate favors specialist species. Together these encourage greater diversity of species.

The Importance of Biodiversity

- Diverse *communities are generally more stable* in their functioning when faced with disturbances compared to less diverse ecosystems.
- Not only is stability intrinsically good for species living in the ecosystem, *diversity maintains ecosystem services* and the continued provisioning of natural resources that humans depend on for our survival.
 - New medicines have been discovered by screening species in diverse ecosystems (rainforests and reefs).
 - Genetic diversity in crop plants and their wild relatives provides breeders with the "raw material" needed to select for traits in response to new agricultural challenges.
 - Biodiversity provides an aesthetic value that humans find appealing.

