EWCE 131
Ecology and Environmental Pollution

Lecture 3

Instructor

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Lecture outline

Ecosystem Diversity

- Basics on biological diversity
- Benefit from biodiversity Threat to biodiversity

Biological Diversity/ Biodiversity



- Biodiversity indicates variety and diversity of life forms (number of kinds) in an area.
- Biodiversity ***increases the stability*** of an ecosystem and contributes to the health of the biosphere

Biodiversity on Extinction Issues

- Biodiversity is the FOCUS of conservation



- Extinction is a process that happens when an entire species permanently disappears from the biosphere due to the death of the species' last member

Higher Biodiversity – Healthy Ecosystem

- Biodiversity acts as a measurement of how healthy an ecosystems is.
- ***Healthy ecosystem*** supports higher biological diversity.
- ***Stressed ecosystem*** may not have the capacity to support high biological diversity

Biological Diversity

Three kinds of **biodiversity** are essential to preserve the ecological systems:

(1) ***Genetic diversity***

(2) ***Species diversity***

(3) ***Ecological diversity***

Biological Diversity – Genetic Diversity

(1) Genetic Diversity

- Is a measure of the variety of different versions of the same genes within individual species.

- *The variety of genes or inheritable characteristics that are present in a population comprises its genetic diversity.*

- *It indicates the* degree of variation in all the genes for all individuals within a species.

Biological Diversity – Genetic Diversity

- Genetic diversity is considered as basis for evolution.
- Genetic diversity within an interbreeding population *increases the chances of survival* during changing environmental conditions or during the outbreak of disease.
- Example: BANANAS and RICE varieties

Biological Diversity – Genetic Diversity





Biological Diversity – Species Diversity

(2) Species Diversity

- Describes the number of different kinds of organisms within individual communities or ecosystem

- Within species diversity, we can distinguish between –

  ✓ ***species richness*** (the total number of species in a community) and

  ✓ ***species evenness*** (the relative abundance of individuals within each species).

Biological Diversity – Species Diversity

Community - 1

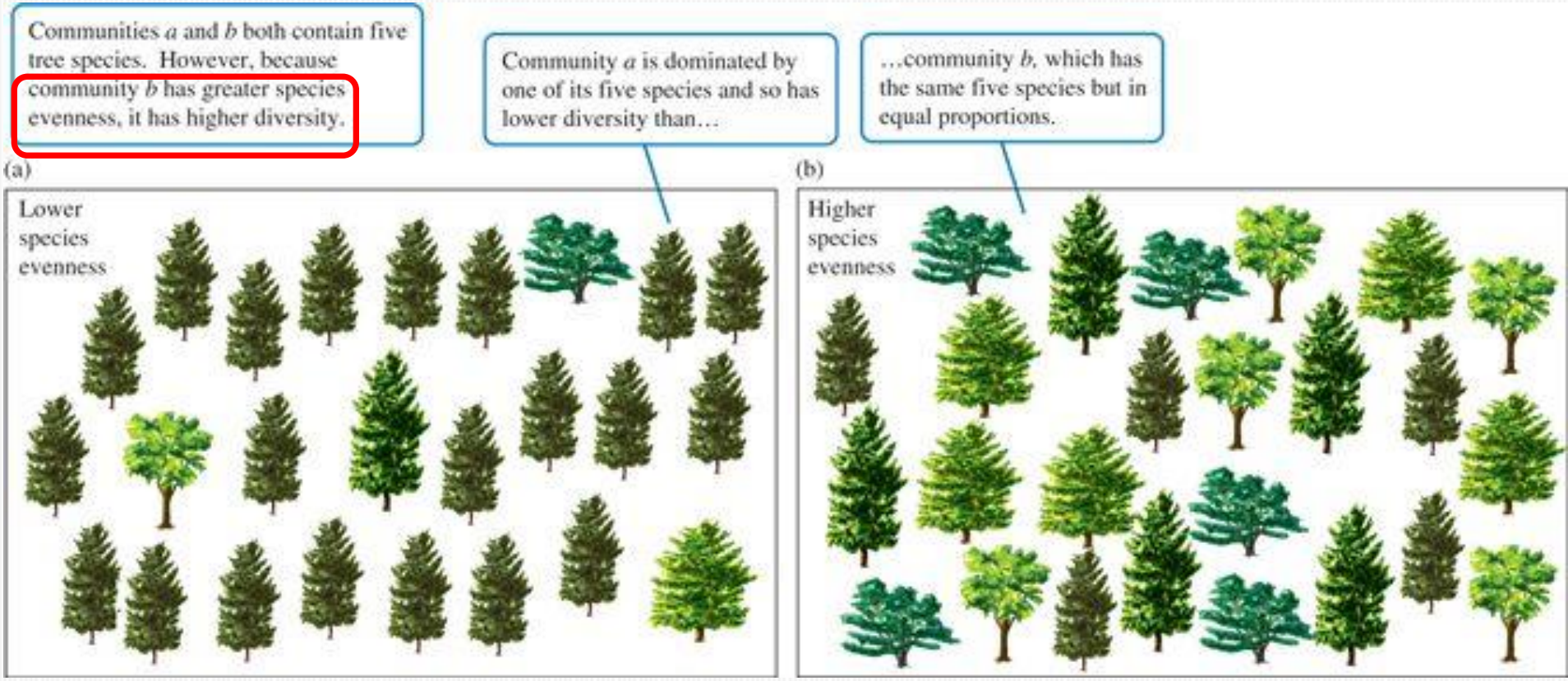
- No of species: 10
- Total plants/ animals: 100
- Individuals of Species 1: 82
- Individuals of other 9 Species : 2× 9 = 18

Community - 2

- No of species: 10
- Total plants/ animals: 100
- Individuals of Species : 10 × 10= 100

- The species richness is the same for two communities.
- But the second one is much more diverse because it is much more likely to encounter a greater variety of organisms there.

Biological Diversity – Species Diversity



Biological Diversity – Ecological Diversity

(3) *Ecological/ Ecosystem Diversity*

- ***Collection of all the plants and animals within a particular area, each differing in species composition, physical structure and function.***

- The variety of ecosystems that are present in the Biosphere, made up of interacting populations and the abiotic factors that support them.

- Example: BIOMES

Biomes

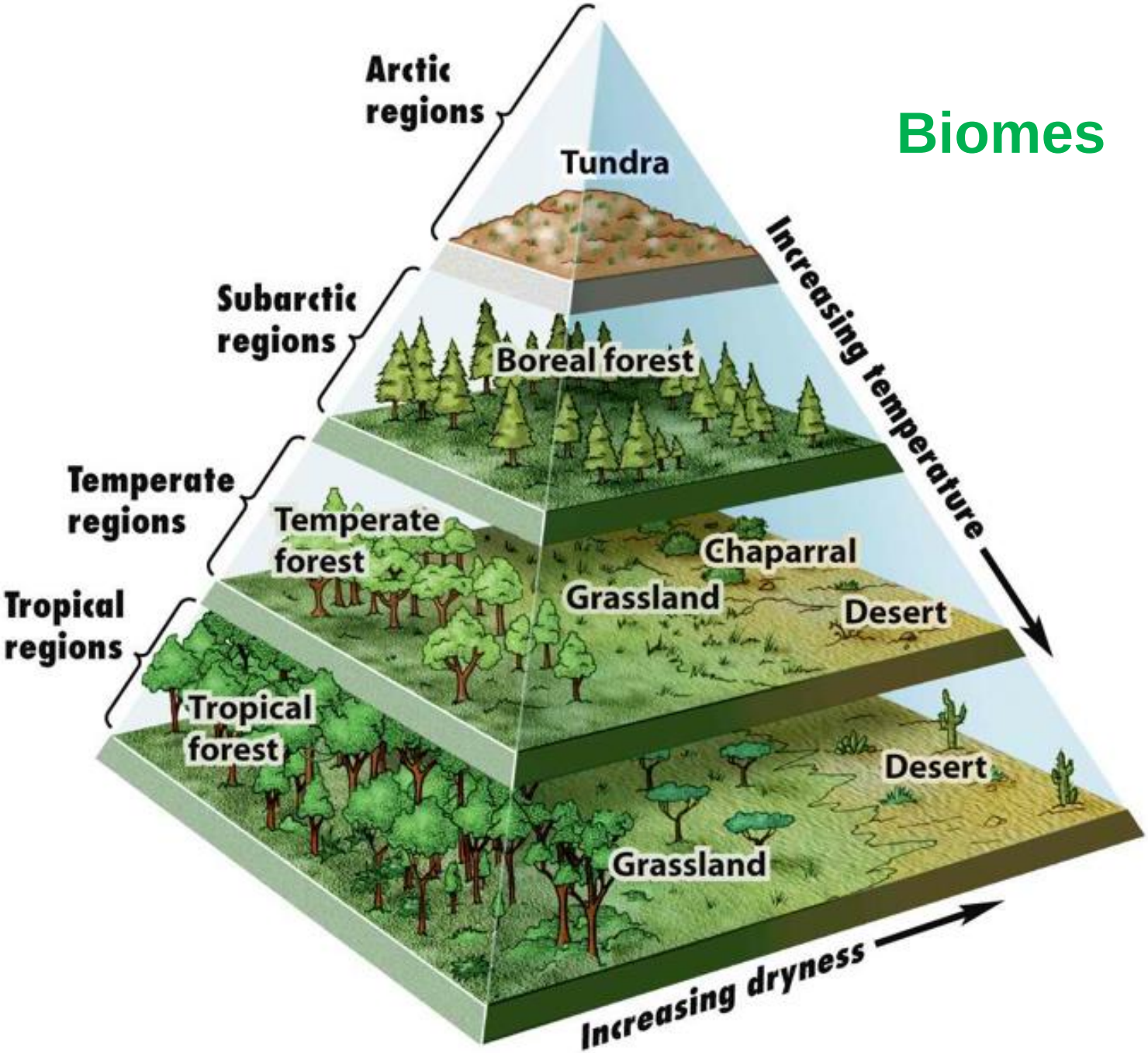


Figure 33-10 Discover Biology 3/e

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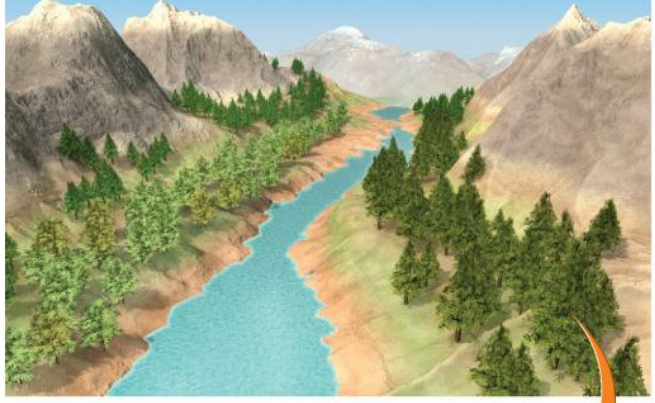
Biological Diversity – Ecological Diversity

(3) *Ecological/ Ecosystem Diversity*

- Assesses the richness and complexity of a biological community

- Includes the number of niches, trophic levels, and ecological processes that capture energy, sustain food webs, and recycle materials within this system.

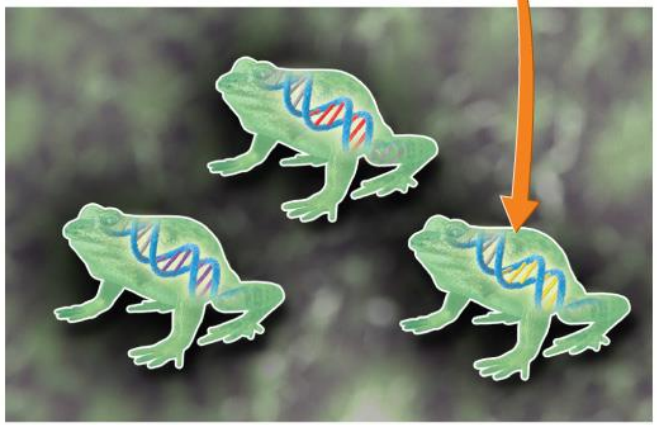
Biodiversity Levels



Ecosystem diversity



Species diversity



Genetic diversity

Biological Diversity Levels

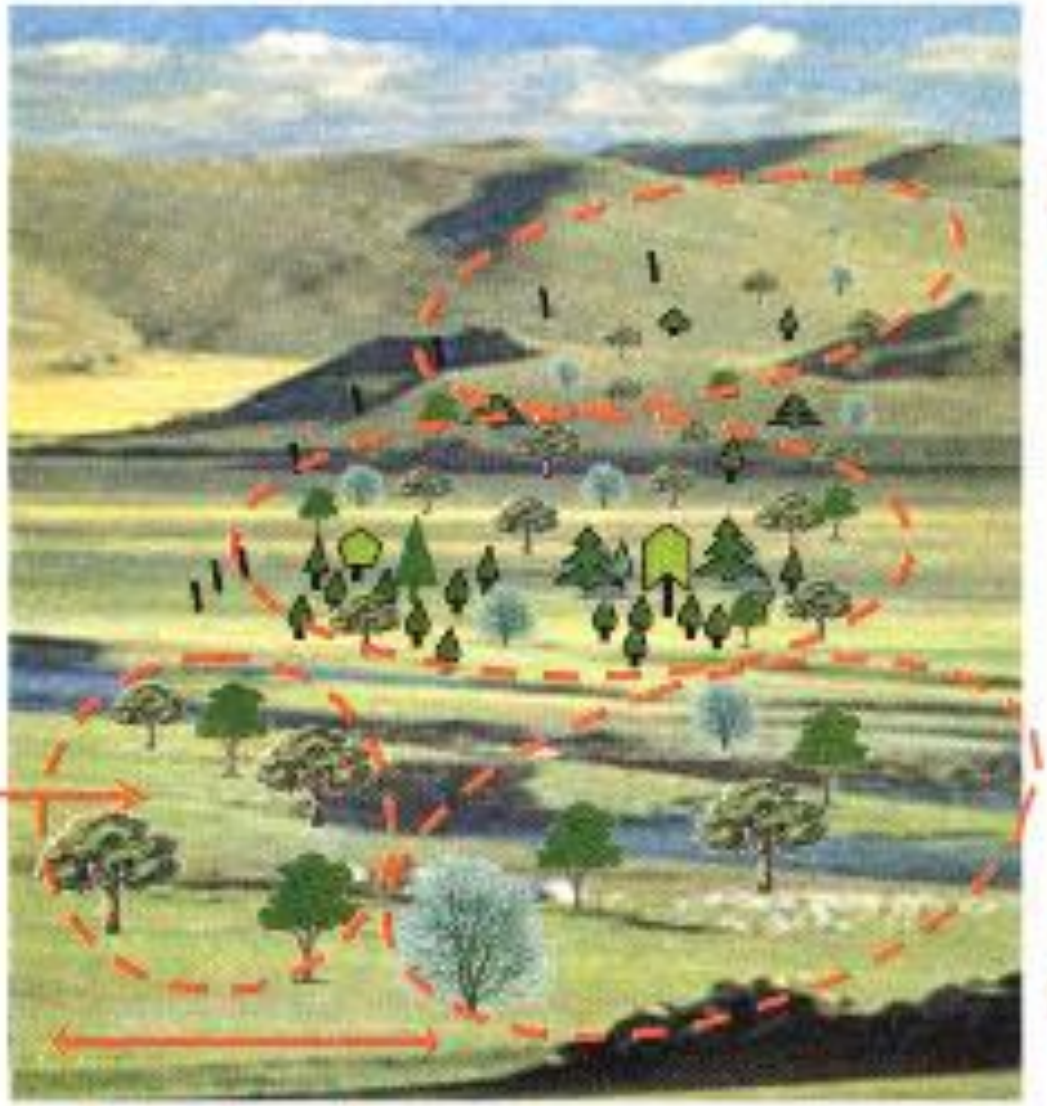
- Diversity at the level of community and ecosystem exists along 3 levels.

  ✓ Within-community diversity (alpha diversity),

  ✓ Between-communities diversity (beta diversity),

  ✓ Diversity of the habitats over the total landscape or geographical area (gamma diversity).

Biological Diversity Levels



Biodiversity Statistics - Biodiversity Index

- A **biodiversity index** is a way of measuring biodiversity.

- **Species Richness**

- The total number of species in an area (add them up)

- **Species Evenness**

- How evenly the species are represented in the area.

- E.g., Do most of the individuals belong to one species?

Biodiversity Index – **Simpson's Index**

- Many diversity indices have been developed that combine different measures of biodiversity.
- One is called the Simpson's Index.
- The Simpson's Index includes both of the species richness and species evenness in a single number.

Biodiversity Index – **Simpson's Index**

D is the Simpson's Index

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

- **n** = total number of individuals/ organisms of a particular species
- **N** = total number of individuals/ organisms of all species

Range of D : **0 to 1**

Higher value – lower diversity, higher dominance

Lower value – Higher diversity

Biodiversity Index – **Simpson's Index**

Example Calculation:

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

Species	No of individuals, n
A	12
B	3
C	7
D	4
E	9

Biodiversity Index – **Simpson's Index**

Example Calculation:

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

Species	No of individuals, n	n-1	n(n-1)
A	12	11	132
B	3	2	6
C	7	6	42
D	4	3	12
E	9	8	72
	N = 35		**Σ= 264**

N(N - 1) = 1190

D = 264/1190 = **0.2218**

Biodiversity Index – **Simpson's Index**

Example Calculation:

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

- This area would score 0.22184 on the Simpson's Index.
- The scale ranges from 0–1, with 1 representing the lowest biodiversity.
- Therefore, the score for this area indicates a high level of biodiversity.

D = 264/1190

= **0.2218**

Biodiversity Index – **Simpson's Index**

- The following calculations are based on sampling conducted in Honduras by Canadian Museum of Nature research scientist Bob Anderson.

Site	N	N(N - 1)	∑ n(n - 1)	D	Species Richness
Cerro Montecristo	2996	7120892	1600002	0.2247	**61**
El Pital 2050 m	233	54056	6856	0.1268	**22**
El Pital 2650 m	5411	29273 510	12873694	**0.4398**	46
Cerro Puca	311	96410	19126	0.1984	27
Santa Barbara	839	703082	55514	**0.0789**	44

Green: Highest **Red: Lowest**

Biodiversity Index – **Margalef's Richness Index**

- Species richness is a measure for the total number of the species in a community.

- This measure is strongly dependent on sampling size and effort.

$$D_{Mg} = \frac{S - 1}{\ln N}$$

- **S** = total number of species
- **N** = total number of individuals in the sample

Biodiversity Index – **Shannon –Weiner Diversity Index**

- The type of diversity used here is α- diversity which is the diversity of species within a community or habitat.

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

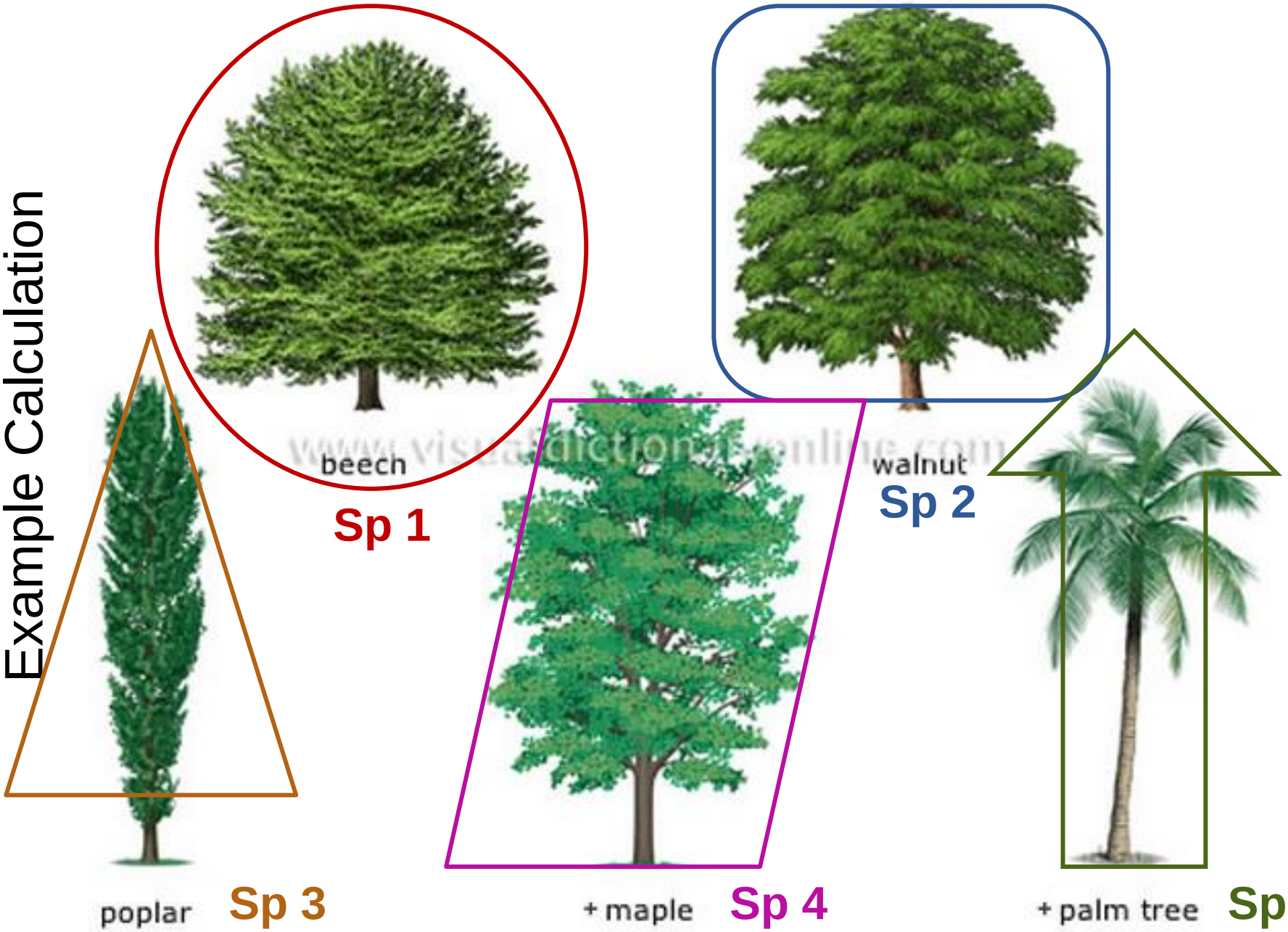
where $\mathbf{P_i = S / N}$

- **S** = number of individuals of one species
- **N** = total number of all individuals in the sample

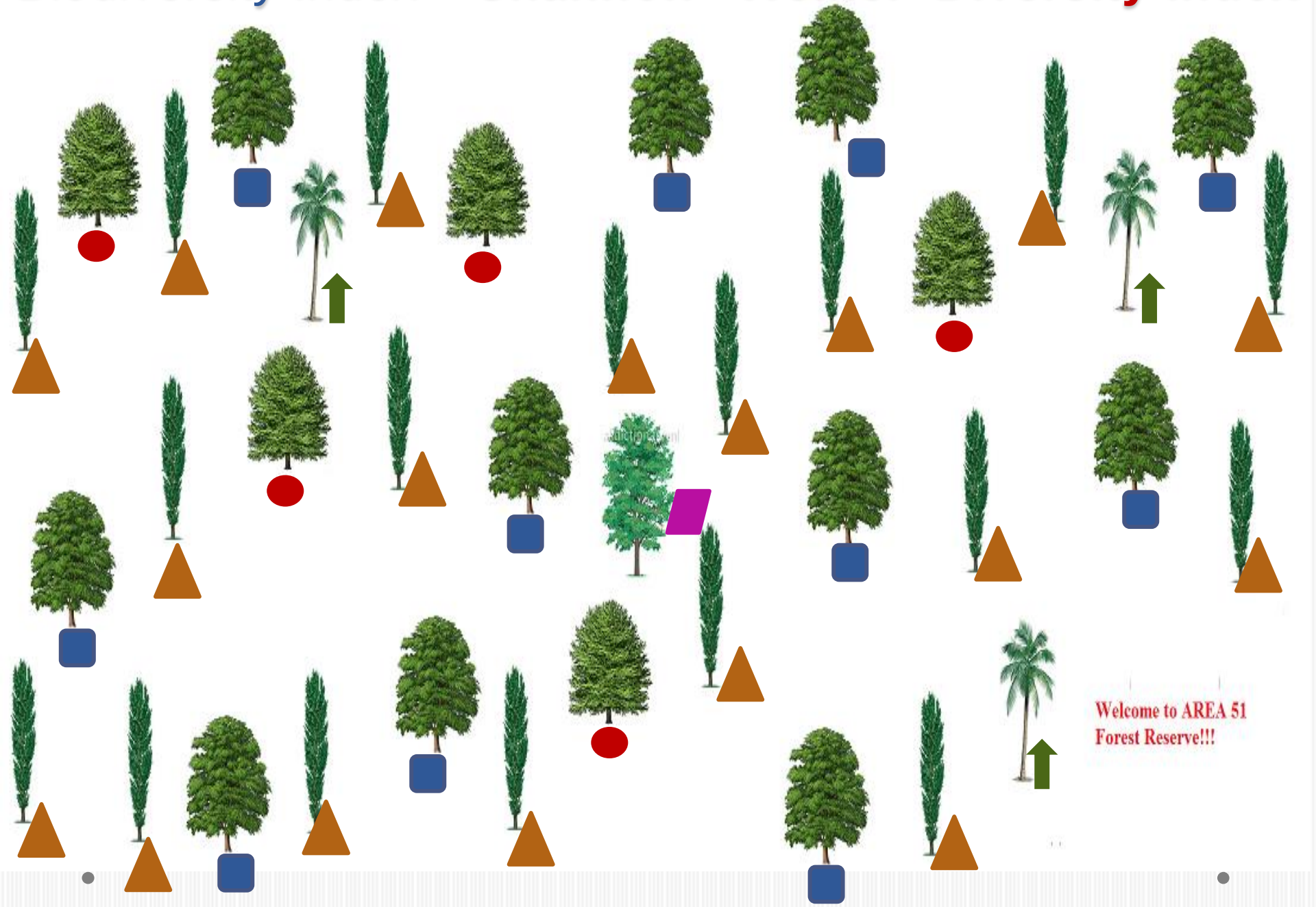
- Varies from 0 for communities with only a single species to high values for communities with many species, each with few individuals

Biodiversity Index – **Shannon –Weiner Diversity Index**

Example Calculation



Biodiversity Index – **Shannon –Weiner Diversity Index**



Biodiversity Index – **Shannon –Weiner Diversity Index**

Species	#Individual	P_i	$\ln P_i$	$P_i (\ln P_i)$
1				
2				
3				
4				
5				
Total =			H=	

Biodiversity Index – **Pielou's Evenness Index**

- For calculating the evenness of species, the Pielou's Evenness Index (e) is used.

- It refers to how close in numbers each species in an environment are.

$$e = \frac{H}{\ln S}$$

here, H = Shannon – Wiener diversity index

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

S = total number of species in the sample

Benefits from Biological Diversity

Biodiversity provides free ecosystem services

- Provides food, fuel, fiber, and shelter
- Purifies air and water and detoxifies wastes
- Stabilizes climate, moderates floods, droughts, wind, temperature
- Cycles nutrients, renews soil fertility
- Pollinates plants and controls pests and disease

Benefits from Biological Diversity

Biodiversity helps maintain ecosystem function

- It increases stability and resilience of natural systems

- Decreased biodiversity reduces a system's ability to function and provide services to our society

- The loss of a species affects ecosystems differently

- If the species can be functionally replaced by others, it may make little difference

- Loss of keystone species, or top predators causes other species to decline or disappear

Benefits from Biological Diversity

Biodiversity enhances food security

- Wild and rare species can improve food security

- Genetic diversity within crops is enormously valuable
  - Turkey's wheat crops received $50 billion worth of disease resistance from wild wheat

- Wild strains provide disease resistance

Potential new food sources

Food Security and Biodiversity: Potential new food sources

Species	Native to…	Potential uses and benefits
Amaranths (three species of *Amaranthus*) 	Tropical and Andean America	Grain and leafy vegetable; livestock feed; rapid growth, drought resistant
Buriti palm *(Mauritia flexuosa)* 	Amazon lowlands	"Tree of life" to Amerindians; vitamin-rich fruit; pith as source for bread; palm heart from shoots
Maca *(Lepidium meyenii)* 	Andes Mountains	Cold-resistant root vegetable resembling radish, with distinctive flavor; near extinction
Tree tomato *(Cyphomandra betacea)* 	South America	Elongated fruit with sweet taste

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Organisms provide drugs and medicines

- Wild species produce $150 billion/year of drugs
- Taxol comes from the Pacific yew tree, which treats cancer
- Every species that goes extinct is a lost opportunity to cure disease

Medicines and Biodiversity: Natural sources of pharmaceuticals

Plant	Drug	Medical application
Pineapple *(Ananas comosus)* 	Bromelain	Controls tissue inflammation
Autumn crocus *(Colchicum autumnale)* 	Colchicine	Anticancer agent
Yellow cinchona *(Cinchona ledgeriana)* 	Quinine	Antimalarial
Common thyme *(Thymus vulgaris)* 	Thymol	Cures fungal infection
Pacific yew *(Taxus brevifolia)* 	Taxol	Anticancer (especially ovarian cancer)
Velvet bean *(Mucuna deeringiana)* 	L-Dopa	Parkinson's disease suppressant
Common foxglove *(Digitalis purpurea)* 	Digitoxin	Cardiac stimulant

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Benefits from Biological Diversity

There are direc and indirect economic, aesthetic, and scientific reasons for preserving biodiversity

Food Security and Biodiversity: Potential new food sources

Species	Native to...	Potential uses and benefits
Babirusa (*Babyrousa babyrussa*) 	Indonesia: Moluccas and Sulawesi	A deep-forest pig; thrives on vegetation high in cellulose and hence less dependent on grain
Capybara (*Hydrochoeris hydrochoeris*) 	South America	World's largest rodent; meat esteemed; easily ranched in open habitats near water
Vicuna (*Lama vicugna*) 	Central Andes	Threatened species related to llama; valuable source of meat, fur, and hides; can be profitably ranched
Chachalacas (*Ortalis*, many species) 	South and Central America	Birds, potentially tropical chickens; thrive in dense populations; adaptable to human habitations; fast-growing
Sand grouse (*Pterocles*, many species) 	Deserts of Africa and Asia	Pigeon-like birds adapted to harshest deserts; domestication a possibility

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Species may go extinct before they can help

Benefits from Biological Diversity

Major types of animals that offer potential medical benefits but that are threatened with extinction of key species

Animal	Potential medical uses	Extinction risks
Amphibians 	• Antibiotics, alkaloids for pain-killers, chemicals for treating heart disease and high blood pressure • Natural adhesives for treating tissue damage • Study of newts and salamanders that can regenerate organs and tissues could suggest how we might, too. • "Antifreeze" compounds that allow frogs to survive freezing might help us preserve organs for transplants.	30% of all species are threatened with extinction (see The Science behind the Story, pp. 294–295).
Bears 	• An acid from bears' gall bladders already treats gallstones and liver disease, and prevents bile buildup during pregnancy. • While hibernating, bears build bone mass. If we learn how they do it, we could treat osteoporosis and hip fractures, which lead to 740,000 deaths per year. • Hibernating bears excrete no waste for months. If we can learn how, this could help treat renal disease, which kills 80,000 people in the U.S. each year.	Nine species are at risk of extinction.
Cone snails 	• Compounds found from these snails include one that may prevent death of brain cells from head injuries or strokes, and a pain-killer 1,000 times more potent than morphine. But so far just a few hundred of the 70,000–140,000 compounds these snails produce have been studied.	Most live in coral reefs, which are threatened ecosystems (pp. 439–442).
Sharks 	• Squalamine from sharks' livers could lead to novel antibiotics, appetite-suppressants, drugs to shrink tumors, and drugs to fight vision loss. • Study of sharks' salt glands is helping address kidney diseases. • Study of sharks' immune systems may shed light on our own.	Overfishing has reduced populations of most species, and some now risk extinction.
Horseshoe crabs 	• A number of antibiotics are being developed. • The compound T140 may be more effective than AZT in treating AIDS, and could also help treat arthritis and several cancers. • Cells from blood can help detect cerebral meningitis in people.	Overfishing is sharply diminishing populations.

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Benefits from Biological Diversity

Biodiversity generates economic benefits

- Biodiversity generates income through tourism

- Especially in developing countries
- Costa Rica: rainforests
- Australia: Great Barrier Reef
- Tanzania: savanna wildlife

- A powerful incentive to preserve natural areas

- But too many visitors to natural areas can degrade the outdoor experience and disturb wildlife

Biodiversity Loss and Species Extinction

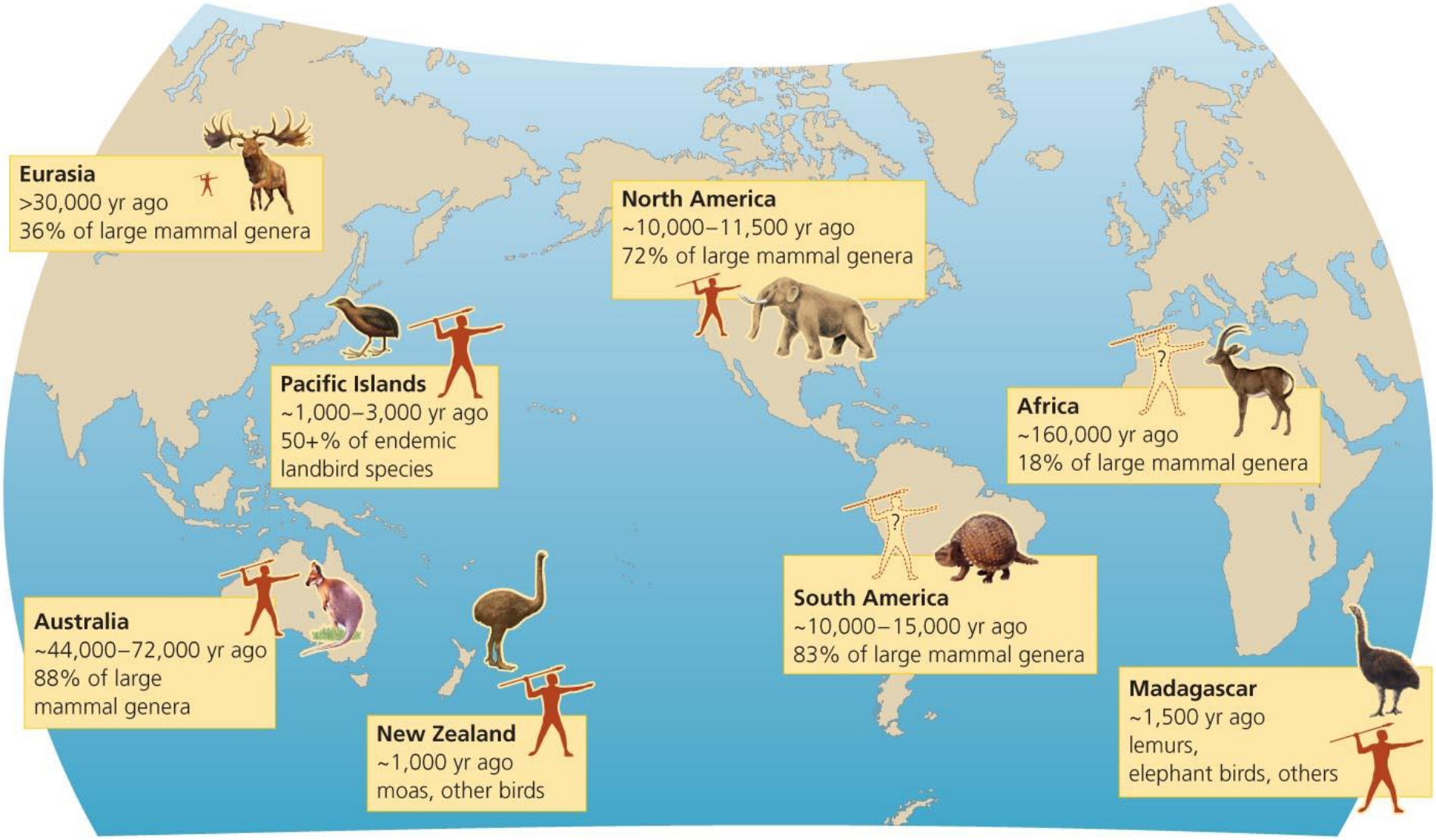
- **Extinction** = occurs when the last member of a species dies and the species ceases to exist

- **Extirpation** = the disappearance of a population from a given area, but not the entire species globally
  - Can lead to extinction

- Extinction is a natural process
  - 99% of all species that ever lived are now extinct

- **Background rate of extinction** = natural extinctions
  - For mammal or marine species: each year 1 species out of every 1–10 million goes extinct

People have Hunted Species to Extinction



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Extinctions followed human arrival on islands and continents

Current Extinction Rates are Higher than Normal

- The current extinction rate is 100 to 1,000 times greater than the background rate
- This rate will increase tenfold in future decades due to -
  - Human population growth and
  - Resource consumption
- **The Red List** = species facing high risks of extinction
  - Mammal species (21%), bird species (12%)
  - 17–74% of all other species

Biodiversity Loss Causes

- Reasons for biodiversity losses are complex and hard to determine
  - Multiple factors interact in causing losses

- Primary causes of population decline are:
  - Habitat alteration
  - Invasive species
  - Pollution
  - Overharvesting
  - Global climate change

Biodiversity Loss - Habitat Alteration

- The greatest cause of biodiversity loss

- Habitats are destroyed, fragmented, and degraded
  - Farming simplifies communities
  - Grazing modifies grassland structure and composition
  - Deforestation removes resources organisms need
  - Hydroelectric dams turn rivers into reservoirs
  - Suburban sprawl replaces natural communities

However, a few species (e.g., pigeons, rats) benefit from changing habitats

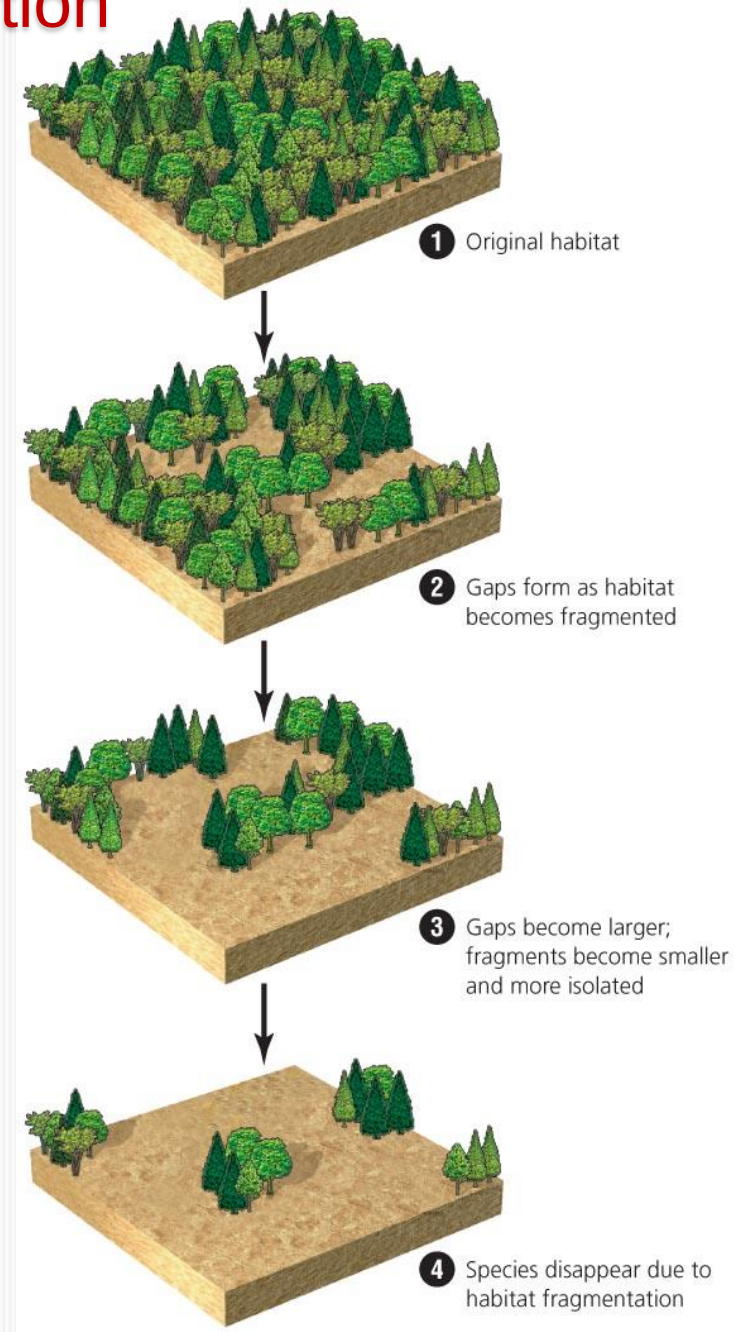


Biodiversity Loss - Habitat fragmentation

- **Habitat fragmentation** = gradual, fractional degradation of habitat
  - Farming, roads, logging, etc.

- Continuous habitats are broken into patches
  - Species dependent on that habitat disappear





Biodiversity Loss - **Pollution**

- Pollution harms organisms in many ways
  - Air pollution degrades forest ecosystems
  - Water pollution impairs fish and amphibians
  - Agricultural runoff harms terrestrial and aquatic species
  - Toxins, garbage, oil, and chemicals impact organisms

- Damage to wildlife and ecosystems caused by pollution can be severe
  - But it is less than the damage caused by habitat alteration or invasive species

Biodiversity Loss – Overharvesting/ Overexploitation

- Vulnerable species: Large, few in number, long-lived, and have few young



- The Siberian tiger is hunted without rules and regulations

- Many other species are affected
  - Whales, sharks, gorillas
  - The oceans contain only 10% of the large animals they once did

Biodiversity Loss - Invasive Species

- Introduction of non-native species to new areas
  - Accidental: zebra mussels, weeds
  - Intentional: food crops, exotic pets, ornamental plants



Zebra Mussel

- Island species are especially vulnerable
- Invaders lack natural predators, competitors, or parasites, therefore are not replaced naturally
- Invaders cost billions of dollars of damage each year

• Biodiversity Loss - Invasive Species

Invasive Species		
Species	**Invasive in…**	**Effects**
Gypsy moth *(Lymantria dispar)* 	Northeastern United States (Native to Eurasia)	In the 1860s, a scientist introduced the gypsy moth to Massachusetts in the belief that it might help produce a commercial-quality silk. The moth failed to start a silk industry, and instead spread through the northeastern United States, where its outbreaks defoliate trees over large regions every few years.
European starling *(Sturnus vulgaris)* 	North America (Native to Europe)	The bird was first introduced to New York City in the late 19th century by Shakespeare devotees intent on bringing every bird mentioned in Shakespeare's plays to America. It only took 75 years for starlings to spread to all corners of North America, becoming one of the continent's most abundant birds. Starlings are thought to outcompete native birds for nest holes.
Cheatgrass *(Bromus tectorum)* 	Western United States (Native to Eurasia)	In just 30 years after its introduction to Washington state in the 1890s, cheatgrass has spread across much of the western United States. It crowds out other plants, uses up the soil's nitrogen, and burns readily. Fire kills many of the native plants, but not cheatgrass, which grows back even stronger amid the lack of competition.
Brown tree snake *(Boiga irregularis)* 	Guam (Native to Southeast Asia)	Nearly all native forest bird species on the South Pacific island of Guam have disappeared. The culprit is the brown tree snake, brought to the island inadvertantly as stowaways in cargo bays of military planes in World War II. Guam's birds had not evolved with tree snakes, and so had no defenses against the snake's nighttime predation. The snakes have spread to other islands where they are repeating their ecological devastation. The arrival of this snake is the greatest fear of conservation biologists in Hawaii.
Kudzu *(Pueraria montana)* 	Southeastern United States (Native to Japan)	Kudzu is a vine that can grow 30 m (100 ft) in a single season. The U.S. Soil Conservation Service introduced kudzu in the 1930s to help control erosion. Adaptable and extraordinarily fast-growing, kudzu has taken over thousands of hectares of forests, fields, and roadsides.
Asian long-horned beetles *(Anoplophora glabripennis)* 	United States (Native to Asia)	Having arrived in imported lumber in the 1990s, these beetles burrow into trees and interfere with the trees' ability to absorb and process water and nutrients. They may wipe out the majority of hardwood trees in an area. Several U.S. cities, including Chicago and Seattle, have cleared thousands of trees after detecting these invaders.
Rosy wolfsnail *(Euglandina rosea)* 	Hawaii (Native to Southeastern United States and Latin America)	In the 1950s, well-meaning scientists introduced the rosy wolfsnail to Hawaii to prey upon and reduce the population of another invasive species, the giant African land snail. Within a few decades, however, the carnivorous rosy wolfsnail had instead driven more than half of Hawaii's native species of banded tree snails to extinction.

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Biodiversity Loss - Climate change

- Human manipulation of Earth's climate system has global impacts on biodiversity
- Emission of greenhouse gases is modifying global weather patterns
- The frequency of extreme weather events increases, e.g. draught.





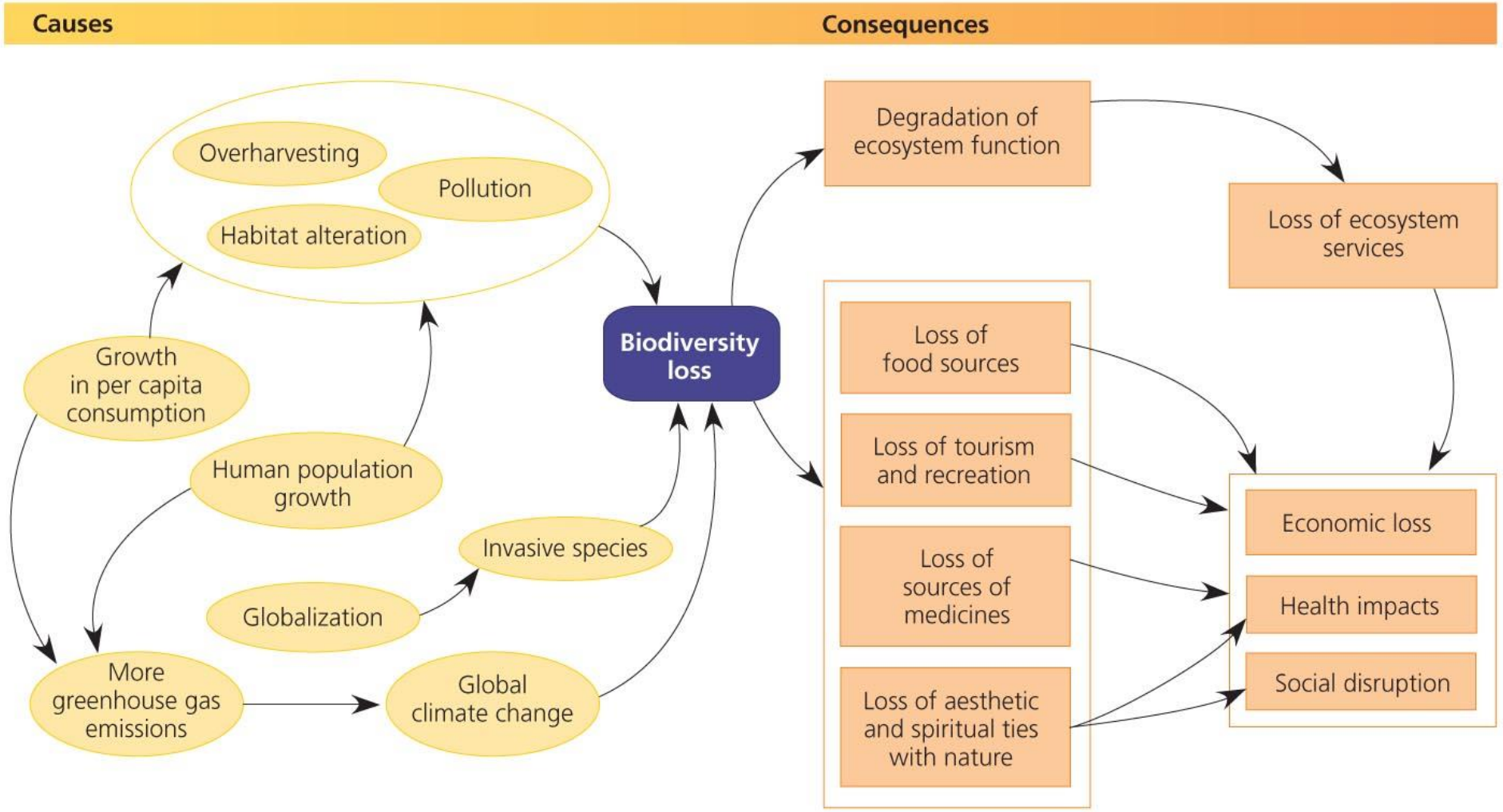
Biodiversity Loss - Climate change

- Increased stress forces organisms to shift their geographic ranges
  - Most animals and plants will not be able to adapt
  - 20–30% of species are at increased risk of extinction

- Because of melting ice, polar bears can't hunt seals, so they were added to the endangered species list in 2008.


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Causes and Consequences of Biodiversity Loss



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