The Living World: Biodiversity

AP Environmental Science

Introduction to Biodiversity

Biodiversity is the variety of life, measured at three levels:

- **Genetic diversity** – variety of genes *within* a species. More genetic variety means a population can better respond to **environmental stressors**; a **population bottleneck** (a sharp drop in numbers) throws that variety away and leaves the survivors vulnerable.
- **Species diversity** – the number of species (**species richness**) and how evenly individuals are spread among them.
- **Habitat diversity** – the variety of habitats in a region.

More species-rich ecosystems are more **resilient**: they recover from disruption more readily, because varied species can fill roles when conditions change. Habitat loss removes species in a predictable *order* – **specialist** species (narrow needs) go first, then the hardier **generalist** species, and species that need large territories decline as their range shrinks.

Biodiversity has three levels: genetic, species, and habitat

A coral reef: high biodiversity concentrates species and ecosystem services in a small area

Ecosystem Services

Ecosystem services are the free benefits nature gives people, in four categories:

- **Provisioning** – products: food, fresh water, timber, fibre.
- **Regulating** – processes that keep conditions stable: climate regulation, water filtration, pollination, flood control.
- **Cultural** – non-material value: recreation, beauty, spiritual and educational value.
- **Supporting** – the services that make the others possible: nutrient cycling, soil formation, photosynthesis.

Anthropogenic (human-caused) activities can disrupt these services, with real economic *and* ecological costs – for example, losing pollinators forces farmers to pay for pollination that bees once did for free.

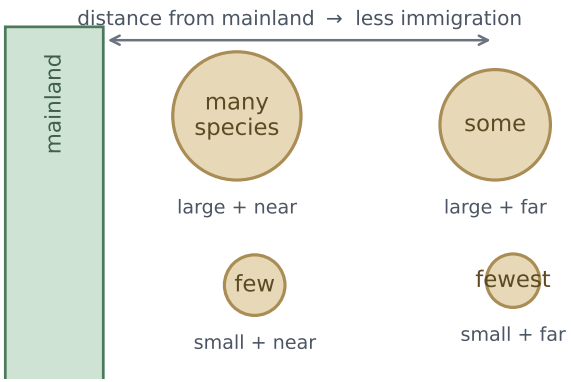
Island Biogeography

Island biogeography studies how many species an island (or any isolated habitat patch) holds. The number settles at a balance between two rates:

- **Immigration** of new species – higher for islands **closer** to the mainland.
- **Extinction** of resident species – lower on **larger** islands.

So big, near islands hold the most species; small, remote ones the fewest. Isolation also drives evolution: island species often become **specialists** because resources are limited, and many are **endemic** – found nowhere else. That makes them fragile.

When an **invasive species** (usually a tough generalist) arrives, it can outcompete the specialists, which have nowhere else to go.

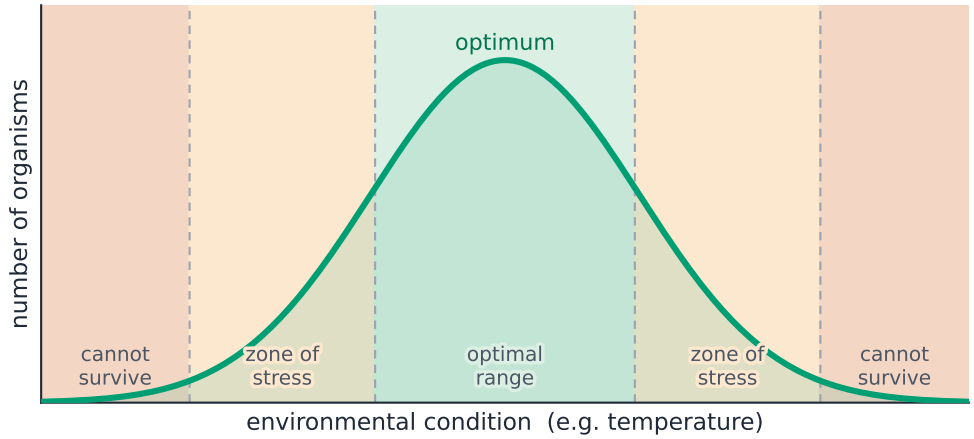


larger area ↑ species · nearer mainland ↑ immigration · equilibrium richness

Larger and nearer islands hold more species, balancing immigration against extinction

Ecological Tolerance

Every species has a **range of tolerance** – the span of conditions (temperature, salinity, pH, sunlight) it can survive. Near the middle is an **optimal range** where individuals thrive; toward the edges are **zones of stress** where they survive but struggle to grow or reproduce; beyond the limits they die. **Ecological tolerance** applies both to a single individual and to a whole species, and it decides where an organism can live and how it copes with change.



range of tolerance: optimum peak · outside = stress or death

Within its optimal range a species thrives; toward the limits it is stressed, then cannot survive

Natural Disruptions to Ecosystems

Natural events disrupt ecosystems across every timescale, and a single natural event can rival or exceed a human-made one. Earth's processes come in three timing patterns:

- **Periodic** – regular cycles (seasons, tides).
- **Episodic** – occasional, irregular events (fires, floods, volcanic eruptions).
- **Random** – no pattern (a meteor strike).

Over geological time, Earth's climate has shifted for many reasons, and sea level has risen and fallen with the amount of glacial ice – each change reshaping large swaths of habitat. Wildlife responds by **migration**, moving short or long distances to follow conditions.

A crown fire sweeping through a forest. Fire is a natural episodic disturbance, and many species are adapted to it

Adaptations

An **adaptation** is an inherited trait that improves survival and reproduction in an environment. Adaptations arise through **natural selection** – incremental genetic change accumulating over generations, not within a single lifetime. When the environment changes, individuals must alter their behaviour, move, or die; if change comes faster than a population can adapt, it declines. A periodic disturbance such as fire is often part of a healthy cycle, and many species are adapted *to* it (some pine cones open only in a fire's heat).

Ecological Succession

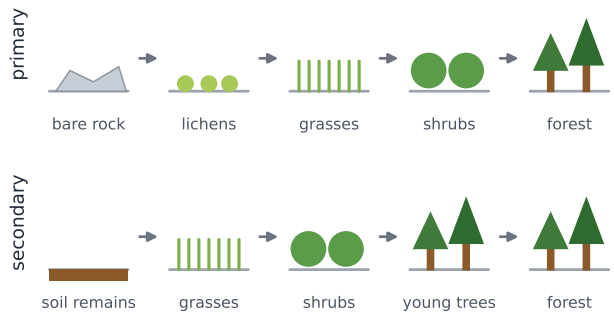
Ecological succession is the gradual, orderly change in a community over time:

- **Primary succession** starts on bare rock with **no soil** – after a glacier retreats or lava cools. **Pioneer species** such as **lichens** arrive first and slowly build soil. It is slow.

Lichens growing straight on bare rock. As pioneer species they slowly break the rock down and build the first thin soil

- **Secondary succession** follows a disturbance that leaves the soil intact – after a fire or abandoned farming – so it is much faster.

Succession tends toward a relatively stable **climax community**. Two special roles shape a community out of proportion to their numbers: a **keystone species**, whose activities hold the community structure together (remove it and the community collapses – sea otters keeping urchins in check), and an **indicator species**, whose presence or health signals the condition of the whole ecosystem (lichens vanish where the air is polluted).



primary: bare substrate (no soil) · secondary: soil remains ⇒ faster recovery

Primary succession builds from bare rock; secondary succession regrows from surviving soil

> **Worked example.** A pond holds 3 fish species with 5, 3, and 2 individuals ($N = 10$). Simpson's Diversity Index $= 1 - \sum \left(\frac{n}{N}\right)^2 = 1 - [(0.5)^2 + (0.3)^2 + (0.2)^2] = 1 - 0.38 = 0.62$. A value near 1 means high diversity; near 0 means one species dominates. Adding a fourth, evenly-sized species would push the index higher.

Exam tips

- Describe biodiversity at three levels: **genetic, species, and habitat**, and link higher diversity to greater **resilience**.
- **Specialist** species (narrow needs) are more vulnerable than **generalists** when a habitat changes.
- Distinguish **primary** succession (bare rock, no soil, slow) from **secondary** (soil intact, faster).
- Explain a **keystone species** (outsized effect) and an **indicator species** (signals ecosystem health).
- Name the four **ecosystem services** (provisioning, regulating, cultural, supporting) with examples.