ECOSYSTEMS UNDER STRESS: BIODIVERSITY

WHAT IS BIODIVERSITY?

Defined by the Convention on Biological Diversity (1992), 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.'

MEASURING BIODIVERSITY

Species richness: Number of different species.
Population number: Number of genetically distinct populations of a particular species.
Genetic diversity: The variation in the amount of genetic information within and among individuals of a population, a species, or a community.
Species evenness: Measurement of how evenly individuals are distributed among species.

LOSS OF BIODIVERSITY

Many animal and plant populations have declined in numbers and /or geographical spread. Human activity has increased extinction rate by x100 times compared to the natural rate.
WWF's Living Planet Index (LPI): Widely accepted measure of the state of the world's biological diversity – based on population trends of vertebrate species from terrestrial, freshwater and marine habitats.
1970–2000: Index fell by 40% - the areas experiencing the most rapid decline in biodiversity include the Amazon basin, the Great Lakes region of Eastern Africa, the Indus valley and parts of the Middle East.

CAUSES OF BIODIVERSITY LOSS

Habitat loss and deforestation:

- **Tropical deforestation –** accounts for 17% of the Amazon lost in the last 50 years – as trees are removed, carbon storage capacity decreases, accelerating climate change
- **Mangrove loss –** 35% destroyed in the past two decades for tourism and aquaculture, affecting coastal protection and fish breeding grounds
- **Coral reef destruction –** 20% of reefs have been lost due to overfishing, pollution, and climate change, reducing marine biodiversity and disrupting fisheries

Climate change:

- **Rising global temperatures –** disrupts ecosystems and force species migration, potentially leading to the extinction of species that cannot adapt quickly enough
- **Ocean acidification –** caused by increased CO_2 absorption, weakens calcium carbonate structures, such as corals and shellfish, impacting marine food chains

Pollution:

- **Eutrophication –** fertiliser runoff leads to algal blooms that deplete oxygen levels in water bodies, causing mass fish die-offs
- **Plastic pollution (marine environments) –** kills seabirds, fish, and marine mammals through ingestion and entanglement

Over-exploitation and unsustainable harvesting:

- **Illegal wildlife trade –** the poaching of endangered species like rhinos and pangolins drives them towards extinction
- **Overfishing –** depletes fish stocks, disrupts marine food chains, and threatens the livelihoods of millions dependent on fisheries

RECENT TRENDS – BIODIVERSITY LOSS HAS SLOWED DOWN

- Designation of protected areas – covering nearly 13% of the world's land area
- Increasing recognition of indigenous/local community-managed areas
- Adoption of policies or actions for managing/controlling invasive alien species
- Regulations supporting sustainable harvesting, reduced pollution and habitat restoration
- International financing for biodiversity conservation – grown by about 38% since 1992 and now stands at over US$3 billion per year

ECOSYSTEMS UNDER STRESS: IMPORTANCE OF ECOSYSTEMS

ECOSYSTEM SERVICES

Ecosystems provide a wide range of benefits to humans, which are essential for survival, economic activities, and well-being. These benefits are classified into four key categories…

PROVISIONING SERVICES

(Direct material benefits from ecosystems)
Provisioning services refer to the tangible resources that humans obtain directly from nature. These include:

Food production: Agriculture, fisheries, and wild foods. Over 3 billion people rely on seafood as their primary protein source.

Freshwater supply: Rivers, lakes, and aquifers provide drinking water and irrigation. The Amazon Rainforest, for example, influences rainfall patterns across South America.

Timber and fuel: Forests supply materials for construction, paper, and fuelwood. The global timber industry supports millions of jobs but also contributes to deforestation.

Medicinal resources: 25% of medicines come from rainforest plants, e.g. cancer treatments from the Madagascar periwinkle.

CULTURAL SERVICES

(Non-material benefits contributing to human well-being)
These services enhance quality of life, culture, and mental health:

Recreation and tourism: National parks and marine reserves attract millions of visitors annually, supporting local economies, e.g. Great Barrier Reef generates over $5 billion annually from ecotourism.

Aesthetic and spiritual value: Landscapes hold religious, cultural, and historical significance, e.g. Aboriginal connections to the land in Australia.

Education and scientific discovery: Ecosystems provide opportunities for research and conservation education, such as monitoring biodiversity in tropical rainforests.

SUPPORTING SERVICES

(Essential functions that sustain all other services)
These are fundamental processes that make life on Earth possible:

Nutrient cycling: The movement of essential nutrients (carbon, nitrogen, phosphorus) through the ecosystem and animal life.
The Gersmehl model illustrates this for different biomes.

Soil formation: Microorganisms decompose organic matter, creating fertile soil essential for agriculture and plant growth.

Primary production: Plants convert solar energy into biomass via photosynthesis, forming the base of all food chains.

REGULATING SERVICES

(Natural processes that maintain environmental stability)
These are vital ecosystem functions that regulate climate, air, and water quality:

Climate regulation: Forests, wetlands, and oceans act as carbon sinks, absorbing CO_2 and mitigating climate change. The Amazon rainforest stores approximately 100 billion tonnes of carbon.

Air purification: Trees and plants absorb pollutants and Improve air quality in urban and rural areas.

Water purification: Wetlands and forests filter pollutants before they reach groundwater supplies. For example, the Catskill Watershed in the USA naturally purifies water for New York City, saving billions in treatment costs.

Flood control: Wetlands and mangroves absorb excess rainwater, reducing flood risks in coastal and low-lying areas.

Disease regulation: Biodiverse ecosystems control populations of disease-carrying organisms. For example, intact predator populations keep rodents in check, reducing the spread of Lyme disease.

ECOSYSTEMS UNDER STRESS: ENERGY AND NUTRIENT FLOWS

Ecosystems function by cycling energy and nutrients between their living (biotic) and non-living (abiotic) components. Energy flows through an ecosystem in a one-way direction, from the sun, while nutrients cycle continuously between different parts of the system.

ENERGY FLOW IN ECOSYSTEMS

The sun: Solar radiation provides energy that plants use to convert CO_2 and water into glucose and oxygen through photosynthesis. Only 1-3% of incoming sunlight is used by plants; the rest is either reflected back into space, absorbed by the atmosphere, or lost as heat.

Primary productivity and energy transfer: Plants and algae (producers) capture and store solar energy.

- Gross Primary Productivity (GPP) - total energy captured through photosynthesis (some is used by plants for respiration)
- Net Primary Productivity (NPP) – the remaining energy and is available to herbivores and higher trophic levels.

Ecosystems with high productivity, e.g. tropical rainforests, have abundant warmth, sunlight, and moisture, whereas deserts have much lower productivity due to limited water availability.

Trophic levels and energy loss: Energy moves through ecosystems via food chains and food webs, passing from producers (plants) to primary consumers (herbivores), then to secondary consumers (carnivores), and finally to tertiary consumers (top predators). At each stage, 90% of energy is lost through respiration, movement, heat loss, and excretion, so ecosystems support fewer predators than prey.

Food webs and ecosystem stability: Ecosystems operate as complex food webs, where multiple species interact. Keystone species are critical in maintaining ecosystem balance, e.g. sea otters in kelp forests control sea urchin populations. If sea otters were removed, sea urchins would overgraze the kelp, leading to habitat collapse. The loss of key species can result in trophic cascades, where changes at one level affect the entire ecosystem.

THE GERSMEHL NUTRIENT CYCLE MODEL

Shows how nutrients flow through ecosystems using three major stores:

- Biomass – nutrients stored in living plants and animals
- Litter – dead organic matter, such as fallen leaves and decomposing organisms
- Soil – nutrients stored in the ground that support plant growth

And 3 major processes:

- Littering – leaf fall breaks down into the soil through decomposition
- Plant uptake – allows nutrients to re-enter the biomass store through root absorption
- Leaching – removes nutrients from the soil through water runoff

NUTRIENT CYCLES IN DIFFERENT BIOMES

Tropical rainforests: Most nutrients are stored in the biomass due to rapid plant growth. The litter store is small because decomposition is fast, and heavy rainfall leads to high leaching rates.

Temperate forests: Nutrients are more evenly distributed between biomass, litter, and soil. Decomposition rates are moderate due to seasonal changes.

Deserts: The soil is the largest store, as plant growth is limited. Decomposition is slow, and nutrient cycling is minimal due to low moisture availability.

KEY NUTRIENT CYCLES IN ECOSYSTEMS

The carbon cycle: Carbon is cycled between the atmosphere, land, and oceans. Plants absorb CO_2 during photosynthesis. CO_2 returns to the atmosphere through respiration and decomposition and burning of fossil fuels. Deforestation and industrial emissions disrupt the carbon cycle by increasing atmospheric CO_2 levels.

The nitrogen cycle: Bacteria converts nitrogen into usable forms through nitrogen fixation, making it available to plants. The cycle continues as animals consume plants, excrete waste, and bacteria convert nitrogen back into atmospheric N_2 through denitrification. Fertiliser use and fossil fuel combustion cause nitrogen imbalances, e.g. eutrophication – algae blooms.

The phosphorus cycle: Phosphorus comes from the weathering of rocks, enters the soil, and is absorbed by plants. When organisms die, decomposition returns phosphorus to the soil.

ECOSYSTEMS UNDER STRESS: BIOMES AND THEIR DISTRIBUTION

WHAT ARE BIOMES?

Biomes are large-scale ecosystems that share similar climate, vegetation, and wildlife. They are primarily determined by temperature, precipitation, and latitude, which influence the types of plants and animals that can thrive in each region. The distribution of biomes is closely linked to global climate patterns, including latitude, altitude, and proximity to water bodies.

TROPICAL RAINFORESTS

Location: 5°N-5°S, e.g. South America (Amazon Rainforest), Central Africa (Congo Basin), Southeast Asia (Indonesia, Malaysia), and Northern Australia.
Climate: Hot and humid, with average temperatures around 25–30°C and annual rainfall exceeding 2,000mm.
Vegetation and adaptations: Most biodiverse biome (50% of global species). 4 layers of vegetation. Plants are adapted to high rainfall and competition for sunlight, e.g. buttress roots for stability in nutrient-poor soils, and drip-tip leaves help shed excess water. Epiphytes (plants that grow on other plants) and lianas (woody vines) use vertical space to access sunlight.
Human impact: Deforestation due to agriculture, logging, and infrastructure. 17% of the Amazon has been lost in the last 50 years – biodiversity loss/increased CO_2.

SAVANNA GRASSLANDS

Location: 15°-30° latitude – transition zone between rainforests and deserts, e.g. Africa (Serengeti), South America (Llanos), Australia.
Climate: Seasonal rainfall, with a distinct wet season (summer) and dry season (winter). Annual rainfall ranges from 500mm to 1,500mm, with temperatures averaging 20–30°C.
Vegetation and adaptations: Tall grasses, scattered trees, and drought-resistant shrubs, e.g. acacia and baobab, with adaptations like deep taproots to access groundwater and fire-resistant bark to survive frequent wildfires. Grasses such as elephant grass and red oat grass grow quickly after rainfall.
Human impact: Overgrazing, overcultivation, deforestation, desertification, and poaching pose significant threats. Climate change is causing more extreme droughts.

TEMPERATE DECIDUOUS FORESTS

Location: Mid-latitude regions (40°-60°), mainly in Europe, eastern North America, East Asia, and parts of South America.
Climate: 4 distinct seasons, with warm summers and cool winters. Annual rainfall is between 750 and 1,500mm.
Vegetation and adaptations: Dominated by broadleaf trees, e.g. oak, beech, maple, and ash – shed their leaves in autumn to conserve water during winter. Rich fertile soil – supports a variety of undergrowth plants, e.g. ferns, mosses, and bluebells. The forest is structured into four layers – canopy (tallest trees), sub-canopy (young trees and smaller species), shrub layer (bushes and brambles) and herb layer, e.g. wildflowers.
Human impact: Heavily impacted by urban expansion, agriculture, and deforestation.

HOT DESERTS

Location: Around 30°N and 30°S, including the Sahara (Africa), Arabian Desert, Atacama (South America), and the Australian Outback.
Climate: Receive less than 250mm of rainfall per year and have extreme temperature variations, with scorching daytime highs and cold nights.
Vegetation and adaptations: Few plants – cacti store water in their stems, while succulents have thick, waxy leaves to reduce water loss. Some plants have deep taproots to access underground water, some use rapid germination to complete their life cycle during rare rainfall.
Human impact: Desert ecosystems are fragile, and human activities, e.g. overgrazing, mining, and water extraction are causing desertification – Sahara Desert is expanding southwards, threatening the livelihoods of millions.

TUNDRA

Location: Polar and high-altitude regions, e.g. Alaska, Canada, Scandinavia.
Climate: Long, harsh winters - below -30°C.Permafrost (permanently frozen soil) limits plant growth, and summers are short with low precipitation (200–600mm per year).
Vegetation and adaptations: Limited to mosses, lichens, low shrubs, and dwarf trees. Animals such as caribou, Arctic foxes, and polar bears have adaptations like thick fur, fat reserves, and seasonal migration to cope with extreme conditions.
Human impact: Vulnerable to climate change, as rising temperatures cause permafrost to thaw, releasing stored methane and CO_2 into the atmosphere. Oil and gas exploration in the Arctic also threatens fragile tundra habitats.

ECOSYSTEMS UNDER STRESS: HUMAN IMPACT ON ECOSYSTEMS

Human activities have significantly altered ecosystems, leading to habitat destruction, biodiversity loss, and changes in natural processes. Whilst ecosystems have some capacity for recovery, the scale and intensity of exploitation have led to long-term damage.

DEFORESTATION AND ITS CONSEQUENCES

Agriculture: Cattle ranching, soy/palm oil plantations – biggest cause of forest loss.
Logging: Often illegal with valuable hardwood tree removed at unsustainable rates.
Energy development: Vast areas of forests flooded to make way for HEP.
Mineral exploitation: Mining often leads to river pollution – illegal mining in the DCR has destroyed the habitat of forest elephants.
Impact on biodiversity: Habitat loss, species extinction, and disruptions to food chains, e.g. jaguars in the Amazon are critically endangered due to forest loss.
Impact on climate: Forests act as carbon sinks, absorbing CO_2 from the atmosphere. When trees are cut down or burned, stored carbon is released, contributing to global warming and climate change. The Amazon Rainforest, often called the "lungs of the Earth," is now releasing more carbon than it absorbs due to extensive deforestation.
Soil erosion: Loss of tree roots leaves soils vulnerable to erosion by winds and rain – can lead to landslides and sedimentation in rivers.
Desertification: In dry regions, deforestation accelerates desertification, turning fertile land into unproductive deserts, e.g. Sahel region of Africa.

AGRICULTURAL EXPANSION

Savanna grasslands: E.g. Serengeti – overgrazing (cattle, goats, sheep) has reduced vegetation cover, leading to soil degradation and erosion. Over time, this depletes soil nutrients, making it harder for the land to recover.
Desertification and land degradation: Particularly in semi-arid regions such as the Sahel, parts of Australia, and the southwestern USA. Desertification reduces the availability of grazing land, forcing pastoralist communities to migrate in search of better conditions, often leading to conflicts over land and water resources.
Fertiliser and pesticide overuse: Intensive farming relies heavily on chemicals. While these increase crop yields, they also cause water pollution, soil degradation, and harm to pollinators like bees. Excess fertilisers lead to eutrophication, where nutrient runoff enters rivers and lakes, causing algal blooms that deplete oxygen levels and kill aquatic life.

URBANISATION

Habitat loss: Cleared for housing, roads and industry – displacing of wildlife. In the UK, 97% of wildflower meadows have been lost due to urbanisation and agricultural intensification, impacts pollination.
Impact on local climate: Urban heat island effect – concrete and asphalt absorb and retain heat, making cities warmer than surrounding rural areas. This disrupts local weather patterns and increases energy demand for cooling.
Impact on air quality: Emissions from vehicles and industry contributes to respiratory diseases, acid rain, and climate change.

MARINE ECOSYSTEM COLLAPSE

Overfishing: 90% of global fish stocks either fully exploited or overexploited (e.g. North Atlantic cod). Industrial fishing practices, such as trawling and long-lining, result in bycatch (the unintended capture of non-target species), which includes endangered turtles, dolphins, and sharks.
Destruction of coral reefs: Under threat from destructive fishing techniques such as cyanide fishing and dynamite fishing.
Plastic pollution: Millions of tonnes of plastic waste end up in the oceans each year – ingested by marine species (injury and death). Microplastics in the food chain, have potential long-term consequences for human health.

CLIMATE CHANGE

Rising temperatures and changing weather patterns: E.g. melting glaciers, rising sea levels, and more frequent extreme weather events, e.g. hurricanes, droughts, wildfires.
Species migration and extinction: Many species are forced to migrate to cooler regions, but many can't adapt quickly enough to habitat loss so risk extinction.
Ocean acidification: The ocean absorbs about 30% of CO_2 emissions, leading to ocean acidification, which reduces the ability of marine organisms like corals, molluscs, and plankton to build their calcium carbonate shells – affects marine food chain.
Coral bleaching: Caused by rising sea temperatures – e.g. Great Barrier Reef mass bleaching – at risk of ecological collapse.

ECOSYSTEMS UNDER STRESS: CORAL REEF ECOSYSTEMS

BIODIVERSITY

Among the most diverse and productive ecosystems on Earth, often called the 'rainforests of the sea'. Despite covering only 0.1% of the ocean floor, coral reefs support 25% of all marine species.

CHARACTERISTICS OF CORAL REEFS

Formation: Primarily built by stony corals – marine invertebrates that secrete calcium carbonate to form hard exoskeletons. These structures accumulate over thousands of years, creating complex reef systems.

Conditions: Coral reefs thrive in warm, shallow waters (18-30°C) with clear, nutrient-poor conditions.

Location: Most are found in the tropical and subtropical regions, e.g. the Great Barrier Reef (Australia), the Caribbean, the Coral Triangle (Southeast Asia), and the Red Sea.

NUTRIENT CYCLING IN CORAL REEFS

Role of algae: Unlike most marine environments, coral reefs exist in nutrient-poor waters and rely on highly efficient nutrient cycling to sustain their high biodiversity.

Coral-Algae Symbiosis: One of the most important ecological relationships in coral reefs is the symbiotic relationship between corals and zooxanthellae (microscopic algae)…

- Zooxanthellae live within coral tissues and provide corals with up to 90% of their energy through photosynthesis
- In return, corals supply the algae with nutrients and a safe habitat
- This relationship is crucial for reef growth and survival, as it enables corals to build massive reef structures

Other ways that corals obtain nutrients:

- Filtering plankton and organic matter from the water
- Through the interactions between fish, sponges, bacteria, and detritivores (recycle waste products and prevent excess nutrient buildup)

TYPES OF CORAL REEF

The reef ecosystem is structured into three main types:

Fringing reefs: Found along coastlines, directly attached to land.

Barrier reefs: Located further offshore, separated from land by a lagoon.

Atolls: Ring-shaped coral reefs that surround a central lagoon, often forming over sunken volcanic islands.

ECOSYSTEM SERVICES PROVIDED BY CORAL REEFS

Coral reefs offer numerous ecological and economic benefits:

Biodiversity support: Home to thousands of species, including fish, molluscs, crustaceans, and marine mammals. They provide breeding and nursery grounds for commercially important fish species.

Coastal protection: Act as natural barriers, absorbing wave energy and reducing coastal erosion – without them coastal communities would face higher risks of storm surges, flooding, and tsunami damage.

Fisheries and food security: Coral reef fisheries support the livelihoods of over 500 million people worldwide, providing an important source of protein for coastal populations.

Tourism and economy: Attract millions of tourists each year, generating billions of dollars for local economies and jobs through activities such as diving, snorkelling, and recreational fishing.

Medical and scientific research: Many marine organisms found in coral reefs produce bioactive compounds used in medicine, including treatments for cancer, bacterial infections, and pain relief.

ECOSYSTEMS UNDER STRESS: CORAL REEFS UNDER THREAT

CLIMATE CHANGE AND CORAL BLEACHING

Coral bleaching: Sea temperatures above 30°C cause corals to become stressed and expel their symbiotic zooxanthellae, causing them to turn white. Without the algae, corals lose their primary source of energy and become vulnerable to disease and death.

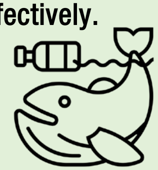
Mass bleaching events: The Great Barrier Reef has experienced three major bleaching events (2016, 2017, and 2020), affecting over 50% of its corals – if global temperatures continue to rise, mass bleaching events could become more frequent and severe.

Ocean acidification: The ocean absorbs 30% of human CO_2 emissions, which lowers pH levels and makes it harder for corals to build their calcium carbonate skeletons. Acidification also affects shell-forming marine species like molluscs and plankton, disrupting entire marine food chains.

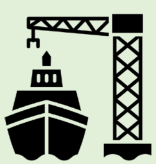
POLLUTION AND COASTAL DEVELOPMENT

Agricultural runoff: Fertilisers and pesticides enters oceans through river systems, leads o eutrophication and algal blooms. Excessive algae growth blocks sunlight, preventing corals from photosynthesising effectively.

Plastic pollution: Coral reefs are highly vulnerable to plastic waste – corals covered in plastic debris are 20 times more likely to suffer from disease than those in unpolluted waters.



Coastal development: Port, resort and city construction near coral reefs leads to habitat destruction, increased sedimentation, and water contamination. Reefs near densely populated areas, e.g. South-east Asia, have significant damage from tourism-related pollution.



OVERFISHING AND DESTRUCTIVE FISHING PRACTICES

Overfishing disrupts the balance of coral reef ecosystems by removing key species that help maintain reef health.

Loss of herbivorous fish: Fish such as parrotfish and surgeonfish graze on algae, preventing it from overgrowing and smothering corals. When these species are overfished, reefs become overrun with algae, reducing coral growth.

Destructive fishing methods:

- **Blast fishing** – the use of explosives to stun or kill fish destroys large sections of coral reefs
- **Cyanide fishing** – poison is used to capture live fish for the aquarium trade, killing corals in the process
- **Trawling** – large nets drag across the seabed, destroying fragile coral structures and reducing fish populations

CORAL MINING AND TOURISM PRESSURE

Coral mining: Corals can be extracted for construction materials, souvenirs, and aquariums, leading to reef destruction – this is particularly common in parts of India, Indonesia, and the Philippines.

Unregulated tourism: While ecotourism provides economic benefits, mass tourism can damage coral reefs through boat anchors, diver contact, and pollution. Popular destinations like Maya Bay (Thailand) have been temporarily closed to allow reef recovery after excessive damage from tourism.

EXAMPLE: ANDROS BARRIER REEF, BAHAMAS

The 3rd largest barrier reef in the world, stretching over 200km along the Bahamian coastline.

Threats to the Andros Barrier Reef:

- **Climate Change** – rising sea temperatures have led to coral bleaching and reduced reef resilience
- **Overfishing** – the removal of predatory fish-like groupers has caused an imbalance in reef ecosystems, increasing populations of coral-eating species
- **Pollution** – coastal development and sewage discharge introduce pollutants that harm coral growth

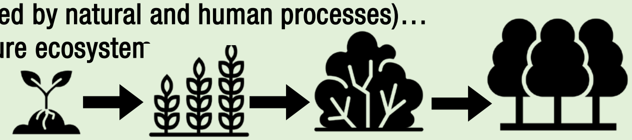
Conservation strategies:

- **Marine Protected Areas (MPAs)** – established to regulate fishing and tourism
- **Sustainable fishing practices** – e.g. banning destructive fishing methods
- **Community-led conservation** – e.g. to promote coral reef restoration and reef-friendly tourism

ECOSYSTEMS UNDER THREAT: SUCCESSION AND ECOSYSTEM CHANGE

Succession: The process by which ecosystems develop and change over time (affected by natural and human processes)…

- Occurs in a series of stages, leading to the gradual establishment of a stable, mature ecosystem
- Process can be disrupted by human activities, e.g. deforestation, agriculture, and urbanisation – prevents ecosystems from reaching their natural climax stage



PRIMARY SUCCESSION

Occurs in environments where no previous life existed and where the land is initially barren, e.g. newly formed volcanic islands, glacial retreat areas, sand dunes, and bare rock surfaces. Because there is no pre-existing soil, the first species to colonise these environments must be able to survive in extreme conditions.

1) Pioneer species colonisation: The first organisms to arrive, e.g. lichens and mosses – specially adapted to survive in harsh conditions, extracting nutrients from rocks and breaking them down to form the first thin layer of soil.

2) Soil formation and plant growth: As pioneer species die and decompose, they contribute organic matter to the soil, making it more fertile, allowing small plants, e.g. grasses and ferns, to establish themselves.

3) Increased biodiversity and complex communities: Over time, shrubs and small trees begin to grow, attracting herbivores and other animals, which further enrich the soil through decomposition.

4) Climax community: After 100s or 1000s of years, a stable and mature ecosystem develops, e.g. deciduous woodland in temperate regions, or tropical rainforest in equatorial areas.

Example – Surtsey Island, Iceland:

Emerged in 1963 due to an underwater volcanic eruption. Initially barren but within a few decades pioneer species of moss and lichens colonised the land. Birds the arrived – led to seed dispersal and now is a thriving habitat.

SECONDARY SUCCESSION

Occurs in areas where an existing ecosystem has been disturbed or destroyed, but where soil is still present, e.g. after natural disasters such as wildfires, or human activities like deforestation. Since soil is already available, secondary succession occurs faster than primary succession, often reaching a climax community within 100–200 years.

1) Colonisation of fast-growing species: The first plants to grow back are grasses and fast-growing weeds, e.g. thistles – these species quickly cover the disturbed land, preventing further soil erosion.

2) Shrub and tree establishment: As organic matter accumulates, shrubs and small trees like birch and willow begin to take root. These species help stabilise the soil and provide shelter for animals.

3) Increased biodiversity: Over time, larger trees such as oak and beech grow, providing food and habitat for a diverse range of animal species.

4) Climax community: Eventually, the area returns to a stable forest ecosystem, similar to the one that existed before the disturbance.

Example – Mount St Helens, USA:

Erupted in 1980 destroyed everything nearby – but the soil remained intact so plants such as fireweed recolonised quickly. Within a few decades, grasses, shrubs, and small trees had returned, along with animal species, e.g. birds and elk.

PLAGIOCLIMAX COMMUNITIES

Occur when human activity interrupts natural succession, preventing ecosystems from reaching climax stage – results in stable but artificial ecosystems with reduced biodiversity, that need managing, such as…

Moorland and heathland: In the UK, large areas of moorland exist because humans have grazed livestock and managed land through controlled burning – stopping them naturally reverting to woodland.

Managed grasslands: Farmland and pastures are maintained through grazing, ploughing, and mowing, preventing natural tree growth.

Urban green spaces: Parks and gardens are artificially maintained through mowing, planting, and removing unwanted species.

Habitat restoration: This can occur through…

- **Afforestation –** of native tree species
- **Wetland restoration –** reintroducing native plants and reducing pollution
- **Heathland/moorland management –** controlled grazing and fire prevention
- **Rewilding –** e.g. letting old farmland generate naturally without human influence

ECOSYSTEMS UNDER THREAT: IN-SITU AND EX-SITU CONSERVATION

CONSERVATION

Plays a crucial role in maintaining biodiversity, protecting ecosystems, and ensuring that natural resources are available for future generations. As human activities continue to exert pressure on the environment, conservation strategies have become more important than ever.
In-situ conservation: Protects species within their natural habitats.
Ex-situ conservation: Involves protecting species outside their natural environments, e.g. in zoos and seed banks.
Both strategies are essential for preventing species extinction and maintaining ecosystem stability

IN-SITU CONSERVATION: NATIONAL PARKS AND NATURE RESERVES

One of the most effective ways to conserve biodiversity is through the establishment of protected areas, such as national parks, nature reserves, and marine conservation zones. These areas provide safe habitats for wildlife, prevent habitat destruction, and regulate human activities to minimise environmental impact.
Examples: Kruger National Park in South Africa protects diverse ecosystems and endangered species such as rhinos, elephants, and leopards; The Great Barrier Reef Marine Park helps conserve coral reef biodiversity by restricting fishing, tourism, and industrial activities.
Limitations Despite their importance, protected areas face challenges, e.g. illegal poaching, deforestation, lack of funding. In some cases, local communities are displaced to create conservation zones, leading to conflicts between conservationists and indigenous people.

IN-SITU CONSERVATION: HABITAT RESTORATION AND REWILDING

In some cases, conservation involves restoring degraded ecosystems through reforestation, wetland rehabilitation, and soil conservation. Rewilding aims to let ecosystems recover naturally by reintroducing keystone species and reducing human intervention.
Example: Yellowstone National Park Wolf Reintroduction Project in the USA. Wolves, which had been hunted to extinction in the park, were reintroduced in 1995. Their presence controlled elk populations, allowing vegetation to recover and improving biodiversity – showing the importance of maintaining top predators in ecosystems.

EX-SITU CONSERVATION: PROTECTING SPECIES OUTSIDE NATURAL HABITATS

Zoos, aquariums, and botanical gardens play an essential role in breeding endangered species, conducting research, and educating the public about conservation.
Examples: The Giant Panda Breeding Program in China has successfully increased panda populations through captive breeding and habitat restoration; Kew Gardens in London houses over 30,000 plant species, many of which are endangered in the wild.
Limitations: Animals kept in captivity often struggle to adapt when reintroduced into the wild, and ethical concerns arise regarding keeping animals in confined spaces. Additionally, maintaining zoo and aquarium facilities can be expensive, limiting their long-term effectiveness.

EX-SITU CONSERVATION: SEED BANKS

Critical for preserving plant biodiversity and ensuring that crops can be restored after a natural disaster or climate change-related crisis.
Example: The Svalbard Global Seed Vault in Norway stores millions of seeds from around the world to protect genetic diversity for future agriculture.

EX-SITU CONSERVATION: GENETIC CONSERVATION

Cryo-preservation: Genetic material from endangered species is frozen for future cloning or breeding programs. This technology could be essential for saving critically endangered species, e.g. northern white rhino, which has only two remaining individuals.

ECOSYSTEMS UNDER THREAT: CHALLENGES AND SUSTAINABLE SOLUTIONS

CLIMATE CHANGE AND HABITAT DESTRUCTION

Rising temperatures, extreme weather events, and changing rainfall patterns are altering ecosystems and pushing species towards extinction. Many species cannot adapt quickly enough, leading to habitat loss and population decline. If global temperatures continue to rise, many ecosystems will become uninhabitable.

Example: Polar bears in the Arctic are struggling to find food as sea ice melts; Increased ocean temperatures and acidification has led to mass bleaching of coral reefs.

HUMAN-WILDLIFE CONFLICT

As human populations grow, people and wildlife compete for space/resources, leading to conflict. Farmers often kill predators like lions and wolves, to protect livestock, and elephants to protect crops. Conservationists have introduced community-based programs to address this issue.

Example: In Kenya, farmers who lose livestock to predators get financial compensation, reducing retaliatory killings; Ecotourism also helps by giving local communities with an incentive to protect wildlife rather than hunt it.

ILLEGAL WILDLIFE TRADE AND POACHING

Animals such as rhinos, elephants, pangolins, and tigers are often hunted for their skins, horns, or medicinal value. The illegal wildlife trade is worth $23 billion per year. Efforts to combat poaching include anti-poaching patrols, stricter law enforcement, and international agreements like CITES. Countries such as Botswana have deployed armed rangers and drone surveillance to protect elephants and rhinos from poachers.

LACK OF FUNDING AND POLITICAL WILL

Many conservation projects require long-term funding, but governments often prioritise short-term economic gains over environmental protection. Also, corruption and weak enforcement mean that even when environmental laws exist, they are not always followed, e.g. logging, mining, and industrial expansion continue to destroy ecosystems despite regulations aimed at protecting them.

SOLUTION: ECOTOURISM AND SUSTAINABLE DEVELOPMENT

Ecotourism: Generating income for local communities while protecting biodiversity.

Example: Costa Rica has successfully used ecotourism to conserve their rainforests while creating jobs and boosting the economy.

Sustainable development: Balancing economic growth with environmental conservation, e.g. promoting sustainable agriculture, renewable energy, and responsible resource management.

SOLUTION: REFORESTATION AND CARBON OFFSETTING

Reforestation: Restoring degraded forests by planting native tree species and preventing further deforestation.

Carbon offsetting: E.g. companies/governments plant trees or invest in conservation projects to compensate for their carbon emissions.

Example of large-scale reforestation: China's Great Green Wall project, which aims to combat desertification by planting trees across the country's northern regions.

SOLUTION: INTERNATIONAL AGREEMENTS AND CONSERVATION POLICIES

Global cooperation is essential for conservation success. International agreements such as:

- CITES (Convention on International Trade in Endangered Species) – helps regulate the global wildlife trade
- Paris Agreement – aims to reduce global carbon emissions to combat climate change
- Convention on Biological Diversity (CBD) – works to protect global biodiversity through legally binding conservation targets

Despite these efforts, enforcement remains a challenge, and many countries struggle to meet their conservation commitments.