

iii. Concept of ecosystem...

iii. Concept of ecosystem, structure, function and types of ecosystem, energy flow in an ecosystem: food chain, food web and ecological succession

Concept of Ecosystems

Definition and Historical Context

1. Ecosystem

- First defined by A.G. Tansley (1935) as the combined complex of **biotic (living)** communities and their **abiotic (non-living)** environment, interacting as a functional unit.
- Encompasses **energy flow**, **nutrient cycling**, and **community dynamics** within discrete spatial boundaries (though boundaries can be flexible).

2. Systems Perspective

- Approaches the study of **ecology** from a holistic viewpoint, where processes such as **production**, **respiration**, and **decomposition** link living organisms with geophysical processes (soil formation, hydrology, climate).
- Integrates multiple scales (microcosms to global biomes) and disciplines (soil science, physiology, climatology).

Fundamental Principles

1. Functional Complexity

- Ecosystems are maintained via **feedback loops** (e.g., predator-prey population cycles), **self-organization**, and **homeostatic** tendencies (resilience to disturbances).

2. Material Cycling

- Closed loops of major elements (C, N, P, S) and micronutrients circulate between living organisms (bioaccumulation) and abiotic reservoirs (soil, water, atmosphere).

3. Emergent Properties

- Ecosystem-level phenomena (e.g., stability, diversity maintenance) arise from interactions among numerous species and environmental processes, not predictable by studying components in isolation.

Structure and Function of Ecosystems

Structural Components

1. Biotic Components

- Producers (Autotrophs):** Photosynthetic or chemosynthetic organisms (plants, algae, some bacteria) converting solar or chemical energy into organic matter.
- Consumers (Heterotrophs):** Herbivores, carnivores, omnivores feeding on living organic matter.
- Decomposers (Detritivores, Saprophytes):** Fungi, bacteria breaking down dead organic matter, releasing nutrients for reuse.

2. Abiotic Components

- Physical and chemical factors: **Climate** (temperature, precipitation), **substrate** (soil, water chemistry), **topography**, **light availability**.
- Nutrient regimes (N, P, K, micronutrients) essential for primary productivity.

Functional Processes

1. Primary Production

- Rate at which autotrophs fix inorganic carbon (CO_2) into organic forms (carbohydrates). Measured as **Gross Primary Productivity (GPP)**.
- Net Primary Productivity (NPP)** = GPP - Autotrophic Respiration. NPP represents biomass accumulation available to consumers.

2. Respiration and Decomposition

- Organisms utilize organic matter for energy, releasing CO₂ back to the atmosphere.
- **Decomposers** transform complex organic molecules into simpler inorganic forms, completing nutrient cycles.

3. Nutrient Cycling

- **Biogeochemical cycles** (C, N, P) facilitate ecosystem productivity.
- **Nitrogen Fixation** by symbiotic bacteria, **denitrification** by microbes returning N₂ to the atmosphere, etc.

4. Homeostasis and Feedback

- Negative feedback loops (e.g., plant growth balancing CO₂ uptake, herbivory limiting plant biomass) can stabilize ecosystems.
- Positive feedbacks may drive regime shifts (e.g., desertification if vegetation cover diminishes beyond a threshold).

Types of Ecosystems

Ecosystems are often classified based on **dominant vegetation**, **climatic conditions**, or **physical environment**. Major categories span terrestrial (forest, grassland, desert) to aquatic (freshwater, marine), each with distinctive structural and functional traits.

Terrestrial Ecosystems

1. Forests

- Characterized by a closed canopy of trees, high biomass.
- Subtypes: tropical rainforests (high biodiversity, rapid decomposition), temperate deciduous forests (pronounced seasonal changes), boreal forests (conifer-dominated, cold, less decomposition).

2. Grasslands

- Dominant grasses, few woody plants.
- Productivity is often linked to rainfall gradients (prairies, savannas, steppes). Support large herbivore populations, significant grazing pressure.

3. Deserts

- Low precipitation, sparse vegetation, high temperature extremes (hot or cold deserts).
- Adaptations of flora and fauna revolve around water conservation and ephemeral growth cycles.

4. Tundra

- Cold climate, permafrost-laden soils, short growing season.
- Vegetation mostly lichens, mosses, low shrubs. Sensitive to climate warming.

Aquatic Ecosystems

1. Freshwater

- Lentic (standing water: lakes, ponds) vs. lotic (flowing water: rivers, streams).
- Stratification by temperature (thermocline) or oxygen affects species distributions, nutrient cycling.

2. Marine

- Coastal (estuaries, mangroves, coral reefs) vs. open ocean (pelagic, benthic).
- Productivity often highest in **upwelling** zones or shallow continental shelves. Coral reefs host high biodiversity, sensitive to temperature and pH shifts.

Transitional Ecosystems

1. Wetlands

- Interface between terrestrial and aquatic realms, e.g., swamps, marshes, bogs.
- Provide critical ecosystem services (water purification, flood control, high productivity).

2. Mangroves and Salt Marshes

- Coastal wetlands adapted to saline or brackish conditions.
- Serve as nursery habitats, protect shorelines from erosion.

3. Urban Ecosystems

- Human-dominated landscapes, interplay of built environment and remnant green spaces.
- Novel ecological processes influenced by pollution, invasive species, fragmented habitats.

Energy Flow in an Ecosystem

Energy in ecosystems is **unidirectional**—entering primarily via photosynthetic fixation of sunlight (or chemosynthesis in certain deep-sea vents) and moving through successive **trophic levels**. Understanding these flows is foundational to ecology.

Food Chain

1. Linear Trophic Pathways

- Representation: **Producers** (plants/algae) → **Primary Consumers** (herbivores) → **Secondary Consumers** (carnivores) → **Tertiary Consumers** (top predators).
- Simplified depiction; real ecosystems typically exhibit multiple, interconnected feeding links.
- **Energy Transfer Efficiency**: Often 5–20% of energy passes from one trophic level to the next (Lindeman's 10% law).

2. Grazing vs. Detritus Food Chains

- **Grazing**: Living plant biomass consumed by herbivores.
- **Detritus**: Decomposers breaking down dead organic material, contributing significantly to nutrient cycling.

Food Web

1. Network of Interconnected Food Chains

- More realistic representation of species feeding relationships.
- Demonstrates **omnivory**, **predator switching**, and **trophic omnipresence** (organisms feeding across multiple levels).
- Complexity can lend ecosystem **stability** (redundancy of energy pathways) or vulnerability if keystone species are lost.

2. Trophic Cascade Effects

- Changes at one level (e.g., apex predator removal) can ripple through the web (mesopredator release, herbivore overgrazing, plant community shifts).
- Important for ecosystem management, rewilding strategies.

Ecological Succession

1. Definition

- **Ecological succession** is the **gradual process of change** in species composition and community structure over time, often following disturbances or newly exposed substrates.

2. Primary Succession

- Occurs on substrates lacking soil or previous life (e.g., lava flows, glacial retreat).
- Pioneer species (lichens, mosses) colonize, modify substrate, eventually allowing more complex plant communities to develop.
- Soil formation is a critical milestone.

3. Secondary Succession

- Follows disturbances (fire, floods, deforestation) that do not completely remove soil or seed banks.
- Faster than primary succession; pioneer species are typically annuals or r-strategists, progressing to a more stable, climax community.

4. Climax Community?

- Classic concept that succession culminates in a stable, self-perpetuating community (e.g., mature forest).
- Modern ecology recognizes that dynamism, intermediate disturbance, and climate shifts often prevent strict equilibrium.

5. Successional Mechanisms

- **Facilitation**: early colonists modify habitat, enabling later arrivals.
- **Inhibition**: competition, allelopathy can hamper subsequent species.
- **Tolerance**: certain species can endure conditions at different successional stages, coexisting with new arrivals.



Concluding Remarks

The **concept of ecosystems** as integrated networks of **biotic** and **abiotic** components underpins much of ecological theory and conservation practice. By understanding **structure** (community composition, trophic organization) and **function** (productivity, nutrient cycling, energy flow), researchers and resource managers can better predict ecosystem responses to **disturbances** (climate change, land-use shifts) and design strategies to maintain **biodiversity** and **ecosystem services**. **Energy flow**—mapped via **food chains** and **food webs**—reveals how solar energy is converted into chemical energy by producers and subsequently partitioned among consumers and decomposers, while **ecological succession** describes how communities dynamically reorganize following disturbances. These classical topics remain central to advanced ecological inquiry, informing sustainable resource management, restoration ecology, and biodiversity conservation at local through global scales.