Ecology, Biodiversity and Environment

Ecology

Ecology is derived from the Greek words *oikos* (house or living place) and *logos* (study). It is the scientific study of how living organisms interact with each other and with their physical surroundings. The term was first used by Reiter in 1868, and later defined by Ernst Haeckel as the branch of biology concerned with the relationships between organisms and their environment. In India, Prof. R. Misra is regarded as the Father of Ecology.

Ecology can be studied under two broad branches:

- **Autecology – the study of individual species in relation to their environment. It examines how one species adapts to temperature, water, light, and food availability.**

- **Synecology – the study of groups of organisms and their interrelationships within a region. It includes population ecology, community ecology, and ecosystem ecology.**

Ecosystem

The concept of the ecosystem was first introduced by A.G. Tansley in 1935. An ecosystem is a functional unit where living organisms (biotic components) interact with the non-living environment (abiotic components) to form a self-sustaining system.

1. Abiotic Components include physical factors like temperature, light, air, and water; inorganic nutrients such as nitrogen, carbon, and potassium; and organic substances like proteins, lipids, and carbohydrates.
2. Biotic Components are all living organisms, grouped as:

- **Producers (Autotrophs) – green plants and algae that synthesize food using sunlight and chlorophyll.**

- **Consumers (Heterotrophs) – animals that depend on producers or other consumers for food. These include:**

- ***Primary consumers*** **(herbivores)**
- ***Secondary consumers*** **(carnivores feeding on herbivores)**
- ***Tertiary consumers*** **(top carnivores)**
- ***Omnivores*** **(organisms feeding on both plants and animals)**

- **Decomposers (Reducers) – bacteria and fungi that break down dead organisms and organic waste, releasing nutrients back into the soil.**

Types of Ecosystem

Ecosystems can be natural or artificial. Natural ecosystems include forests, deserts, grasslands, ponds, lakes, rivers, and oceans. Aquatic ecosystems can be further classified as lentic (standing water like lakes), lotic (running water like rivers), and marine (oceans and seas). Artificial ecosystems are human-made, such as crop fields, aquariums, and gardens.

Energy Flow in Ecosystems

Energy enters an ecosystem through sunlight, which is captured by producers during photosynthesis. This energy is transferred through the food chain to consumers and finally decomposers. However, at every transfer, a significant portion of energy is lost as heat. The flow of energy is always unidirectional.

According to Lindeman's 10% law (1942), only about 10% of energy is passed on from one trophic level to the next, while the remaining is lost in metabolic processes. This principle explains why food chains are rarely more than four or five steps long.

Food Chain, Food Web, and Trophic Levels

A food chain is the linear sequence of organisms where energy flows from producers to various levels of consumers. For example: *Grass* → *Rabbit* → *Snake* → *Hawk*. There are three main types of food chains:

1. **Grazing food chain – begins with plants eaten by herbivores and then by carnivores.**

2. **Detritus food chain – starts with dead organic matter broken down by decomposers.**

3. **Parasitic food chain – involves parasites feeding on larger organisms.**

In nature, food chains rarely exist in isolation. Instead, they interconnect to form a food web, which maintains ecosystem balance and stability.

The trophic level refers to the feeding position of organisms in a food chain. Producers occupy the first level, herbivores the second, carnivores the third, and so on.

Ecological Pyramids

The concept of ecological pyramids was introduced by Charles Elton in 1927. Pyramids graphically represent the structure of ecosystems by showing the distribution of energy, biomass, or number of organisms across trophic levels.

- **Pyramid of Number – shows the number of organisms. It is usually upright (as in grasslands), but can be inverted in cases like parasitic chains.**

- **Pyramid of Biomass – depicts the total biomass at each level. Upright in terrestrial ecosystems, but inverted in aquatic ecosystems where plankton biomass is lower than consumer biomass.**

- **Pyramid of Energy – represents energy flow, and is always upright, as energy decreases at higher trophic levels.**

Ecological Succession

Ecological succession is the natural, gradual process by which ecosystems change and develop over time. Initially studied by King (1685) and Buffon (1742), it occurs in two forms:

- **Primary succession – takes place in lifeless areas where organisms never existed before (e.g., bare rocks, sandy soil).**

- **Secondary succession – occurs in areas previously occupied by life but disturbed by events like fire or floods.**

Succession ensures that ecosystems evolve toward a stable climax community.

Productivity of Ecosystems

- **Gross Primary Productivity (GPP) – total organic matter produced by plants during photosynthesis.**

- **Net Primary Productivity (NPP) – the energy left after respiration, i.e., *NPP = GPP – Respiration*.**

- **Secondary Productivity – organic matter generated by consumers.**
  The Earth's total annual NPP is estimated at around 170 billion tons of organic matter.

Ecological Interactions

Organisms interact in several ways:

- **Positive interactions:**
    - ***Commensalism*** **– one benefits, the other is unaffected (orchids on trees).**
    - ***Mutualism*** **– both benefit (lichens, coralloid roots of Cycas).**
- **Negative interactions:**
    - ***Parasitism*** **– parasite benefits, host harmed (Cuscuta on plants).**
    - ***Predation*** **– predator feeds on prey.**
    - ***Competition*** **– struggle for resources.**
    - ***Amensalism*** **– one harmed, other unaffected.**

Biogeochemical Cycles

Nutrients circulate in ecosystems through biogeochemical cycles:

1. **Nitrogen cycle – nitrogen fixation by Rhizobium, assimilation by plants, ammonification, nitrification, and denitrification.**
2. **Carbon cycle – exchange of carbon through photosynthesis, respiration, and fossil fuels.**

3. **Oxygen cycle – circulation between atmosphere, biosphere, and lithosphere.**

4. **Phosphorus cycle – limited to soil and water; no atmospheric component.**

5. **Sulphur cycle – movement of sulphur compounds between rocks, soil, and organisms.**

6. **Water cycle – evaporation, condensation, precipitation; influenced by human activities like deforestation and damming.**

Biodiversity

Biodiversity refers to the variety of living organisms and ecosystems on Earth. It exists at three levels: genetic diversity, species diversity, and ecosystem diversity. The term was popularised by Edward Wilson.

The 1992 Earth Summit in Rio de Janeiro emphasized global biodiversity conservation.

Biodiversity provides vital resources such as food, medicine, raw materials, and ecological services like pollination, soil fertility, and waste recycling.

Loss of Biodiversity

IUCN's Red List (2004) documented over 784 species extinctions in the past 500 years. Species like the dodo and several subspecies of tigers have disappeared. The main reasons, known as the Evil Quartet, include:

1. **Habitat loss and fragmentation**

2. **Overexploitation**

3. **Alien species invasions**

4. **Co-extinctions**

Conservation of Biodiversity

- **In-situ Conservation – protecting species within their natural habitats through National Parks (e.g., Corbett), Sanctuaries, and Biosphere Reserves (Nilgiri was India's first).**

- **Ex-situ Conservation – conserving species outside their habitats through zoos, botanical gardens, seed banks, cryopreservation, and gene banks.**

India is home to two biodiversity hotspots: the Eastern Himalayas and the Western Ghats.

Environment and Pollution

The environment includes physical surroundings (air, water, land) and biological factors (plants, animals, microbes). The Earth's atmosphere is layered into the troposphere, stratosphere (ozone layer), mesosphere, and ionosphere.

Pollution, as defined by Odum, is any undesirable change in the physical, chemical, or biological characteristics of air, water, and soil.

Types of Pollution:

- **Air Pollution – caused by SO_2, NO_2, CO, particulates; leads to acid rain, smog, and respiratory diseases.**

- **Water Pollution – caused by sewage, chemicals, heavy metals; measured by Biological Oxygen Demand (BOD). Diseases include Minamata (Hg) and Itai-Itai (Cd).**

- **Soil Pollution – due to fertilizers, pesticides, and waste dumping.**

- **Noise Pollution – unwanted sound (>80 dB); leads to stress, hearing loss.**

- **Radioactive Pollution – fallout from nuclear tests (Chernobyl, Hiroshima, Nagasaki).**

- **Thermal Pollution – rise in temperature of water bodies affecting aquatic life.**

Global Environmental Issues

- **Greenhouse Effect and Global Warming – caused by CO_2, CH_4, CFCs, and N_2O, leading to climate change.**

- **Ozone Layer Depletion – thinning of ozone due to CFCs and halons, resulting in the Antarctic ozone hole.**