Ecology

Chapter 5: BASIC ECOLOGICAL CONCEPTS

Learning Objectives: Upon completion of this chapter, students should be able to:

- Define ecology and its importance.
- Understand ecological organization levels from individual to biosphere.
- Differentiate between habitat, ecological niche, and population.
- Explain the concepts of community, biosphere, and ecosystem.
- Describe various population studies techniques.
- Identify abiotic and biotic factors affecting aquatic and terrestrial habitats.
- Explain the measurement of abiotic factors in an ecosystem.

5.1 Defining Ecology and Its Importance

- **Definition of Ecology:** Ecology is the scientific study of the interactions between living organisms and their environment (both living and non-living components). It explores how organisms adapt to their surroundings and how these interactions influence the distribution and abundance of species.
- **Importance of Ecology:**
    - **Understanding Nature:** Helps us comprehend the intricate web of life and the delicate balance within ecosystems.
    - **Environmental Problem Solving:** Provides the scientific basis for addressing environmental issues like pollution, habitat loss, climate change, and resource depletion.
    - **Conservation Biology:** Informs strategies for conserving biodiversity, endangered species, and ecosystems.
    - **Resource Management:** Guides sustainable management of natural resources (e.g., fisheries, forests, water).
    - **Human Health:** Understanding ecological links helps in preventing and controlling diseases (e.g., vector-borne diseases).
    - **Agriculture:** Informs practices that promote healthy soils and pest management.

5.2 Ecological Organization Levels

Ecology studies life at various hierarchical levels of organization, building from the individual to the entire planet.

1. **Individual/Organism:** A single living being capable of independent existence. (e.g., a single lion, a single oak tree).
    - *Study focus:* Adaptations to the environment, behavior, physiology.
2. **Population:** A group of individuals of the *same species* living in the *same geographical area* at the *same time*, capable of interbreeding. (e.g., all the lions in a national park, all the oak trees in a forest).
    - *Study focus:* Population size, density, distribution, growth, birth/death rates.
3. **Community:** All the different populations of *various species* living and interacting within a *defined geographical area*. It includes all biotic (living) components. (e.g., all the plants, animals, fungi, and microorganisms in a forest).
    - *Study focus:* Species diversity, interspecific relationships (predation, competition, mutualism).
4. **Ecosystem:** A biological community of interacting organisms (biotic factors) and their non-living (abiotic) physical environment. It includes energy flow and nutrient cycling. (e.g., a pond, a forest, a desert).
    - *Components:* Biotic (producers, consumers, decomposers) and Abiotic (sunlight, water, soil, temperature, air).
    - *Study focus:* Energy flow, nutrient cycles, productivity.
5. **Biome:** A large naturally occurring community of flora and fauna occupying a major habitat, e.g., forest or tundra. Characterized by distinct climate and dominant plant life. (e.g., Tropical Rainforest, Desert, Tundra, Savanna).
    - *Study focus:* Broad patterns of climate and vegetation.
6. **Biosphere:** The sum of all the ecosystems on Earth; the global ecological system integrating all living beings and their relationships, including their interaction with the elements of the lithosphere (rock), hydrosphere (water), and atmosphere (air). It is the thin layer of Earth where life exists.
    - *Study focus:* Global processes, climate patterns, biogeochemical cycles at a planetary scale.

5.3 Core Ecological Concepts

- **Habitat:** The natural environment or place where an organism normally lives. It provides the necessary resources (food, water, shelter) for survival.
    - *Examples:* A pond is the habitat for a fish; a tree is the habitat for a bird.
    - *Note:* Different species can share the same habitat but have different niches.
- **Ecological Niche:** The role and position a species has in its environment; how it meets its needs for food and shelter, how it survives, and how it reproduces. It encompasses all the interactions of an organism with the biotic and abiotic factors of its environment. It's not just *where* it lives (habitat), but *what* it does.
    - *Example:* For a squirrel, its niche includes what it eats (nuts, seeds), where it nests (tree cavities), when it's active (daytime), and its interactions with other species (seed dispersal, predator avoidance).
- **Environmental Factors:**
    - **Biotic Factors:** Living or once-living components of an ecosystem that affect other organisms.
        - *Examples:* Producers (plants), Consumers (herbivores, carnivores, omnivores), Decomposers (bacteria, fungi), Predators, Prey, Competitors, Parasites.

- **Abiotic Factors:** Non-living physical and chemical components of an ecosystem.
  - *Examples:* Temperature, light intensity, water availability, pH, soil type, humidity, oxygen levels, salinity, wind.

5.4 Conducting Population Studies: Techniques

Studying populations is crucial for understanding dynamics, managing resources, and conservation.

1. **Direct Counting/Census:** Counting every individual in a population.
   - *Applicability:* Small, stationary populations (e.g., trees in a small grove, animals in a confined area).
   - *Limitations:* Impractical for large, mobile populations.
2. **Sampling Techniques:** Estimating population size by counting individuals in a small, representative area and extrapolating.
   - **Quadrat Method:** Used for stationary or slow-moving organisms (plants, slow insects).
     - *Procedure:* A square frame (quadrat) of a known area is randomly placed in the study area. All individuals within the quadrat are counted. This is repeated multiple times, and the average count is used to estimate the total population.
     - *Calculation:* Estimated population = (Average count per quadrat) \times (Total area / Area of one quadrat).
   - **Transect Method:** Used to study changes in vegetation or species distribution across an environmental gradient (e.g., from a forest edge into the forest).
     - *Procedure:* A line (transect) is laid across the study area. Organisms are sampled at regular intervals along the line or within a narrow band along the line.
   - **Line Transect:** Record species touching the line.
   - **Belt Transect:** Record species within a specified width on either side of the line.
3. **Mark-Recapture Method (Capture-Recapture):** Used for mobile animals.
   - *Procedure:*
     1. **Capture:** A sample of individuals (M) is captured, marked (e.g., tag, band), and released into the population.
     2. **Recapture:** After a period (allowing marked individuals to mix), another sample (C) is captured.
     3. **Count Recaptures:** The number of marked individuals in the second sample (R) is counted.
   - *Lincoln-Petersen Index (Formula for estimation):* N = (M \times C) / R Where:
     - N = Estimated total population size
     - M = Number of individuals marked in the first capture
     - C = Total number of individuals captured in the second sample
     - R = Number of marked individuals recaptured in the second sample
   - *Assumptions:*
     - No births, deaths, immigration, or emigration during the study period.
     - Marking does not affect survival or behavior.
     - Marks are not lost.
     - Marked individuals mix randomly with the unmarked population.

5.5 Abiotic Factors Affecting Habitats & Their Measurement

Abiotic factors are crucial in determining which organisms can survive in a particular habitat.

A. Terrestrial Habitat Abiotic Factors:

1. **Temperature:**
    - **Effect:** Influences metabolic rates, enzyme activity, reproductive cycles, and distribution of organisms. Extreme temperatures can be lethal.
    - **Measurement:** Thermometer (degrees Celsius, ^\circ C).
    - **Variation:** Daily (day/night), seasonal, altitude, latitude.
2. **Light Intensity:**
    - **Effect:** Essential for photosynthesis (plants), affects plant growth and distribution (phototropism, photoperiodism), influences animal behavior (e.g., diurnal/nocturnal activity).
    - **Measurement:** Light meter/Lux meter (lux, foot-candles).
    - **Variation:** Time of day, cloud cover, season, canopy cover (in forests).
3. **Humidity:**
    - **Effect:** Amount of water vapor in the air. Affects transpiration rates in plants and water loss (evaporation) in animals.
    - **Measurement:** Hygrometer (relative humidity as a percentage, %).
    - **Variation:** Affected by temperature, proximity to water bodies, vegetation cover.
4. **Wind:**
    - **Effect:** Increases evaporation and transpiration rates, affects plant morphology (e.g., stunted growth), aids seed dispersal and pollination, causes physical damage.
    - **Measurement:** Anemometer (wind speed in m/s or km/h), Wind vane (wind direction).
    - **Variation:** Topography, open areas.
5. **Soil Type:** (Refer to Chapter 4 for detailed properties)
    - **Effect:** Influences water retention, aeration, nutrient availability, and drainage, thus determining plant growth and the types of animals that can live in or on the soil.
    - **Measurement:**
        - **Soil Texture:** Sedimentation test, feel method.
        - **Soil pH:** pH meter or universal indicator solution.
        - **Soil Water Content:** Weighing soil before and after drying.
        - **Soil Temperature:** Soil thermometer.
6. **Rainfall:**
    - **Effect:** Primary source of water for terrestrial organisms; determines vegetation type, influences soil erosion and nutrient leaching.
    - **Measurement:** Rain gauge (mm or cm).
    - **Variation:** Seasonal, geographical.

B. Aquatic Habitat Abiotic Factors:

1. **Temperature:**
    - **Effect:** Influences metabolic rates, dissolved oxygen levels (colder water holds more O2), and species distribution.
    - **Measurement:** Thermometer (^\circ C).
    - **Variation:** Depth, season, sunlight exposure.

2. **Light Penetration:**
    - **Effect:** Determines the depth at which photosynthesis can occur (photic zone). Affects distribution of aquatic plants and algae.
    - **Measurement:** Secchi disc (measures water clarity/transparency), light meter.
    - **Variation:** Depth, turbidity (cloudiness due to suspended particles).
3. **Dissolved Oxygen (DO):**
    - **Effect:** Essential for respiration of aquatic animals (fish, invertebrates) and aerobic microorganisms. Low DO is a major stress factor.
    - **Measurement:** Oxygen meter, Winkler titration method (chemical test).
    - **Variation:** Temperature (inverse relationship), turbulence, presence of aquatic plants (photosynthesis adds O2, respiration consumes O2), organic pollution (decomposition consumes O2).
4. **pH (Acidity/Alkalinity):**
    - **Effect:** Influences solubility of nutrients and toxic substances, affects enzyme activity and survival of aquatic organisms.
    - **Measurement:** pH meter, litmus paper, universal indicator solution.
    - **Variation:** Influenced by bedrock, pollution (acid rain).
5. **Salinity:**
    - **Effect:** Concentration of dissolved salts. Crucial for osmoregulation in aquatic organisms. Differentiates freshwater, brackish, and marine habitats.
    - **Measurement:** Salinometer, conductivity meter (parts per thousand, ppt or % salinity).
    - **Variation:** Evaporation, freshwater inflow.
6. **Water Turbidity:**
    - **Effect:** Cloudiness of water due to suspended particles. Reduces light penetration, can clog gills of aquatic animals.
    - **Measurement:** Secchi disc, turbidimeter.
    - **Variation:** Sediment runoff, algal blooms.
7. **Water Flow/Current:**
    - **Effect:** Important in rivers and streams; affects nutrient distribution, substrate stability, and adaptations of organisms (e.g., attachment structures).
    - **Measurement:** Flow meter, timing a floating object over a known distance.
    - **Variation:** River size, gradient, obstacles.