Lecture Outline: Population Ecology And The Distribution Of Organisms

I. **Ecology: Definitions and Complexity**
   A. Definition of Ecology
      1. The study of interactions between an organism and its environment.
      2. The environment includes **abiotic** (non-living) surroundings and **biotic** (other organisms) factors.
   B. Levels of Ecological Study
      1. Begins at the level of individual **organisms**.
      2. **Population**: A group of individuals of the same species successfully reproducing together.
      3. **Community**: All the populations (different species) living together in an area (only the organisms/living things).
      4. **Ecosystem**: The community plus all the non-living (abiotic) factors (e.g., rocks, air, water).
      5. **Global Ecology**: Study of the entire biosphere.
   C. Complexity of Ecology
      1. Involves numerous variables and complex interactions.
      2. Absolute facts and precise measurements are difficult to obtain, especially at higher levels.

II. **Biophysical Aspects and Climate Determinants**
   A. Solar Energy Input
      1. Sunlight is a continuous input of electromagnetic energy (photons).
      2. Energy intensity received depends on the angle of incidence.
         a. Light strikes the equator at a **normal (perpendicular) angle**, concentrating energy into a circular region (high intensity).
         b. Light strikes regions away from the equator at an **oblique angle**, spreading the same energy over a larger (elliptical) area (lower intensity).
         c. Lower solar intensity explains why the Earth's poles are colder.
   B. Global Wind Patterns (Convection)
      1. Wind is an example of **convection** (bulk movement of a fluid) that transfers heat.
      2. Air rises at the equator because intense sunlight heats the ground, which heats the air through conduction.
         a. Hot air **expands** (decreases density) and is forced upward by heavier, colder air.
         b. Warmer air is able to pick up a lot of **water vapor**, creating hot, moist air.

3. As air rises, it cools down.
    a. Cooling air reduces its capacity to hold water vapor, leading to condensation (clouds) and **precipitation** (rain).
    b. This process explains why the tropics (near the equator) are very wet.
4. Cold, dry air descends in surrounding latitudes, creating high pressure and **wicking moisture away** from the surface.
    a. These regions typically contain the world's great deserts.
5. The **rotation (spin)** of the Earth causes the swirling pattern of rising and falling air to become **diagonal** (large-scale wind patterns).

C. Revolution and Seasonality
1. **Rotation** (spinning on axis) determines the daily cycle (day and night).
2. **Revolution** (orbiting the sun) determines seasonality.
3. Seasonal temperature changes are **not** due to changes in distance between the Earth and the Sun, as the difference in distance is negligible.
    a. If distance were the cause, both hemispheres would experience the same season simultaneously.
4. Seasonality results from the **tilt** of the Earth's axis relative to the plane of revolution.
    a. When a hemisphere is tilted toward the sun, it receives more direct sunlight (summer).
    b. When tilted away, it receives more oblique sunlight (winter).
5. Key seasonal days:
    a. **Solstices** (Winter and Summer): Extremes of day length (shortest and longest, respectively).
    b. **Equinoxes** (Spring and Fall): Equal day and night lengths.

D. Major Ocean Currents
1. Ocean currents redistribute massive amounts of water and **heat** across the globe.
2. **Heat** is an **extensive property** (depends on the amount of sample).
3. **Temperature** is an **intensive property** (average speed of particles).
4. Example: The **Gulf Stream** is a warm current that moves heat toward Western Europe, making that region warmer than expected based on its latitude.
5. Example: The California Current cools the West Coast of North America.

E. Mountain Effects (Rain Shadows)
1. Air flowing inland from the ocean is **moist** (humidified).
2. The mountain forces the moist air **upward**, causing it to cool significantly due to elevation.
3. The cooling air loses water vapor, resulting in heavy rain on the **windward side** of the mountain.
4. The air descending the **leeward side** is dry, creating a **rain shadow** with arid conditions.

III. **Biomes and Limiting Factors for Distribution**

A. Biome Definitions and Types

1. **Terrestrial Biomes** are found on land.
2. **Aquatic Biomes** are in water.
   a. **Marine**: Saltwater (ocean, seas).
   b. **Aquatic (Freshwater)**: Lakes and rivers.
3. Terrestrial biomes are often defined by the **predominant vegetation**.
   a. Plants are the major **producers** (autotrophs) and are vital because consumers (heterotrophs) depend on them.

B. Climagraphs and Biome Characteristics

1. A **climagraph** graphs temperature versus precipitation (moisture) to show where specific biomes occur.
   a. **Climate** refers to broad-scale patterns (e.g., annual rainfall), distinct from day-to-day **weather**.
2. Biome examples:
   a. **Tropical Rainforest**: Warm and wet (high T, high P); greatest density of biodiversity; light and water are generally not limiting factors.
   b. **Savannah**: Grassland with some trees; tolerates long periods of drought.
   c. **Hot Desert**: Limited primarily by water; sparse vegetation; defining feature is dryness.
   d. **Chaparral**: Dominated by shrubbery; prone to fires.
   e. **Coniferous Forest**: Dominated by conifers (gymnosperms); adapted for cold, high-latitude or high-elevation areas.
   f. **Temperate Broadleaf Forest**: Features deciduous trees (broad leaves) that undergo **abscission** (leaf fall) seasonally to prevent water loss and conserve energy during cold, low-light periods.
   g. **Tundra** (Cold Desert): Very dry, high latitude; sparse, low-to-the-ground vegetation; limited by water and cold.

C. Aquatic Biome Examples

1. **Wetlands**: Wet areas important for biodiversity and migrating animals; often damaged by human activity.
2. **Lakes** (Freshwater): Organisms face a **hypotonic** environment, risking continuous water uptake.
3. **Marine Environments** (Saltwater): Organisms face a **hypertonic** environment, risking continuous desiccation (water loss).
4. **Headwater Stream**: The beginning of a river, starting in high places (mountains) due to rainfall moving downhill.

5. **Intertidal Zone**: Area between high and low tides; organisms must tolerate both aquatic and terrestrial conditions, and drastic temperature changes.
    a. Tides are caused by the gravitational pull of the Moon.
6. **Coral Reefs**: High biodiversity concentration (rainforests of the ocean); threatened globally.
7. **Open Ocean**: Sparsely populated; most life is concentrated near the surface.
    a. The **photic zone** (surface zone receiving light) supports photosynthetic producers.
8. **Deep Sea (Hydrothermal Vents)**: Found in total darkness.
    a. Producers are **chemoautotrophs** (unicellular organisms) that use chemosynthesis, drawing energy from the vent rather than light.

D. Water Zonation Terms

1. Vertical Definitions (Depth):
    a. **Photic Zone**: Surface layer where light penetrates; supports photosynthesis.
    b. **Aphotic Zone**: Deeper layer, dark; organisms rely on falling organic material.
    c. **Pelagic Zone**: The combination of the entire depth (Photic + Aphotic).
    d. **Benthic Zone**: The floor (benthos) of the body of water.
2. Horizontal Definitions (Distance from Land):
    a. **Littoral Zone**: The shallow part of the surface right up against the land.
    b. **Limnetic Zone**: Farther out from the shore.

E. Limiting Factors for Species Distribution

1. **Dispersal**: Limitations due to barriers preventing a species from spreading to an area.
2. **Biotic Factors** (Living): Includes predation, parasitism, and competition.
3. **Abiotic Factors** (Non-living):
    a. Chemical factors (Water, oxygen, pH).
    b. Physical factors (Temperature, light, moisture).

IV. **Population Ecology and Growth**

A. Population Size

1. Population size is affected by: births, deaths, **immigration** (entering), and **emigration** (leaving).
2. The health of a population impacts the overall stability of the community.

B. Distribution Patterns

1. **Clumped**: Individuals grouped together in clusters (intentional).
2. **Uniform**: Individuals equally spaced apart, maximizing personal space (intentional avoidance).
3. **Random**: Individuals located without pattern (accidental).

C. Survivorship Curves

1. Graphs the number of survivors versus the percentage of maximum lifetime.
2. Three types based on shape:
    a. **Type I (Convex)**: High survival early in life; die-off occurs mainly late in life (e.g., Humans).
    b. **Type III (Concave)**: Very high die-off early in life; those who survive early challenges tend to live long (e.g., Oysters, Dandelions).
    c. **Type II (Linear)**: Continuous, constant rate of die-off regardless of age (straight slope).
3. Reproductive Strategies related to Survivorship:
    a. Type I species invest **high energy** into a small number of expensive offspring.
    b. Type III species produce a large number of **cheap, small** offspring with low survival probability.

D. Population Growth Models

1. Growth Rate (dN/dt) is the derivative (slope) of the population size curve over time, representing population size per unit time.
2. **Exponential Growth (J-shaped)**:
    a. Formula: $$ \frac{dN}{dt} = r_{max}N $$ (where r_{max} is a constant and N is population size).
    b. The growth rate itself continually increases because it depends on the current population size (N).
    c. This growth cannot be sustained indefinitely in real populations.
3. **Logistic Growth (S-shaped or Sigmoid)**:
    a. Formula: $$ \frac{dN}{dt} = r_{max}N \frac{(K - N)}{K} $$
    b. Growth levels off and approaches the **Carrying Capacity (K)**, the maximum sustainable population size.
    c. When N is small, growth is nearly exponential ($\frac{K-N}{K} \approx 1$).
    d. When N approaches K, growth slows down ($\frac{K-N}{K} \approx 0$).
    e. The **maximum growth rate (inflection point)** occurs exactly when the population size (N) is equal to $K/2$ (half the carrying capacity).

E. Density Dependent Population Regulation

1. **Population Density** refers to the number of individuals per area (crowding).
2. An **Equilibrium Point** is reached when the birth rate equals the death rate, stabilizing the population density.
3. A **Density Dependent Rate** is one where the rate (e.g., birth or death) changes depending on the crowding level.
4. Density Dependent Factors (constraining population growth):
    a. **Competition for Resources**: Finite resources (food, light) run out as the population

grows.

b. **Predation**: High prey density makes it easier for predators to hunt, increasing the death rate.
c. **Disease**: High density increases the spread of illness (biotic agents like viruses) due to close proximity.
d. **Toxic Wastes**: Waste products (e.g., ethanol produced by yeast) accumulate to toxic levels, killing off the organisms when density is high.
e. **Territoriality**: Overcrowding leads to confrontations, injury, and death among animals defending their space.
f. **Intrinsic Factors**: Physiological changes within organisms due to high density (e.g., rats reducing mating behavior or litter size).

F. Predator-Prey Cycles

1. The populations of predators (e.g., wolves) and prey (e.g., moose) oscillate over time.
2. The increase in prey population is followed by an increase in the predator population.
3. The high predator population then causes the prey population to drop sharply.
4. The resulting lack of food (prey) causes the predator population to drop, allowing the cycle to repeat, oscillating out of phase.