General Biology: Population Ecology And The Distribution Of Organisms

AI-Generated Study Guide

(Based on [lectures delivered by Dr. Ty C.M. Hoffman])

I. Defining Ecology and Levels of Organization
Ecology is the study of interactions between an organism and its environment. The environment encompasses both abiotic (non-living things like rocks, wind) and biotic (living things) surroundings.
Ecological study occurs across various levels of biological organization:
• Organismal Ecology: Focuses on individual organisms.
• Population: A group of individuals of the same species living together and successfully reproducing.
• Community: Includes all the populations of different species living together in an area (only the living things).
• Ecosystem: The community combined with all the non-living (abiotic) factors, such as air, water, and rocks.
• Global Ecology (Biosphere): Ecology pertaining to the entire Earth.
Ecology is considered extremely complex because of the vast number of interacting variables, making it difficult to establish absolute facts.

II. Biophysical Aspects of Ecology (Abiotic Factors)
A. Solar Energy and Intensity Sunlight provides a continuous input of electromagnetic energy to the Earth. Light can be viewed as wavelike or particle-like; a discrete packet of light energy is called a photon. Due to the enormous distance from the Sun, beams of light striking the Earth are considered nearly parallel.
The intensity of solar energy received by a surface is defined as the density (photons per area).
• At the equator, light strikes the surface perpendicularly (normal angle), forming a circular region of illumination, which maximizes energy intensity per unit area.
• At higher latitudes (near the poles), light strikes at an oblique angle, spreading the same amount of energy (same number of photons) over a larger, elongated area (ellipse). This lowers the intensity, explaining why polar regions are colder.
B. Wind and Air Circulation (Convection) Wind is the convection (bulk movement of a fluid) of the gaseous atmosphere, driven by solar intensity:
1. Heating and Rising: Intense sunlight at the equator heats the ground, which transfers heat via conduction to the air above it. The warm air expands, decreasing its density and

causing it to rise. Hot air rises because it is lighter than the surrounding cold air, which descends and pushes it out of the way.
2. Moisture: Warm air is able to hold more water vapor (humidity). Thus, hot, moist air rises from the equator.
3. Condensation and Rain: As the air rises, it cools. Cooling reduces the air's capacity to hold water vapor, causing the vapor to condense (forming clouds) and fall as liquid precipitation. This process dumps water near the tropics, leading to high rainfall.
4. Descending Air and Deserts: The air, now cold and dry, becomes dense and descends back toward the surface at latitudes away from the equator. This cold, dry air scrapes the land, wicking away moisture and creating the world's great deserts in those regions.
5. Global Wind Patterns: The Earth's rotation (spin on its axis) causes these circulating air masses to swirl diagonally, creating major global wind patterns.
C. Seasons and Revolution Revolution is the movement of the Earth around the Sun. Seasons are not caused by changes in the distance between the Earth and the Sun, as the orbit is nearly circular and the distance change is negligible.
• Tilt of the Axis: Seasons are caused by the tilt of the Earth's axis relative to its plane of revolution.
• Effect of Tilt: When a hemisphere is tilted toward the Sun, it receives more direct sunlight (summer). When it is tilted away, it receives more oblique sunlight (winter).
• Solstices: Mark the extremes of day length (longest day in summer, shortest in winter).
• Equinoxes: Occur when the tilt is sideways relative to the Sun, resulting in equal day and night lengths.
D. Ocean Currents and Heat Redistribution Ocean currents move large volumes of water, redistributing massive amounts of heat across the globe.
• Heat vs. Temperature: Heat is an extensive property (total energy content, dependent on sample size), while temperature is an intensive property (average particle speed, independent of sample size). Ocean currents move heat.
• Examples: The Gulf Stream carries warm water from lower latitudes and delivers heat to Western Europe, making it warmer than its latitude would suggest. The California Current cools the West Coast of North America.
E. Mountains and Rain Shadows Moist air flowing inland from the ocean is forced upward by a mountain. The air cools at higher elevations, leading to heavy rainfall on the windward side. By the time the air descends on the opposite, leeward side, it has lost most of its moisture, creating a rain shadow (dry conditions). This results in drastically different ecosystems on opposite sides of the same mountain.

III. Biomes
Biomes are major ecological regions typically defined by the prevailing living conditions and named for the dominant type of vegetation (plants). Plants are emphasized because they are the producers (autotrophs) that form the base of the food web, necessary for consumers (heterotrophs).
A climagraph plots temperature versus precipitation (moisture) to geographically define the conditions associated with different biomes.
A. Terrestrial Biomes

• Tropical Rainforest: Found in warm, wet conditions (high T, high P). Features lush vegetation and the greatest density of biodiversity.
• Desert: Defined by dryness (low P). Can be hot (upper left on climagraph) or cold, like the Tundra (lower left). Plant growth is limited by water.
• Savannah: Grassland with scattered trees; tolerates long periods of drought.
• Chaparral: Dominated by shrubbery; prone to fires.
• Grassland: Dominated by grass; can withstand long droughts.
• Coniferous Forest: Dominated by conifers (gymnosperms/evergreens). Found in colder regions (high latitude or high elevation).
• Temperate Broadleaf Forest: Characterized by broad-leafed, deciduous trees. Leaves drop (abscission) seasonally to conserve water and heat during cold, low-light periods.
• Tundra: A cold desert (low T, low P). Vegetation is sparse and low to the ground to retain heat and avoid strong winds.

B. Aquatic Biomes and Salinity Aquatic biomes are categorized by water type: Aquatic (freshwater, like lakes and rivers) versus Marine (saltwater/ocean). Organisms cannot easily switch between these environments due to differing salinity: freshwater environments are hypotonic (causing continuous water uptake), while saltwater environments are hypertonic (causing continuous desiccation).
• Wetlands: Areas characterized by being wet; crucial stopovers for migrating animals and biodiversity hotspots, often damaged by human activity.
• Headwater Stream: The beginning of a river, typically originating in high-elevation areas (mountains), with water flow driven by gravity (falling downhill).
• Intertidal Zone: The area between high and low tides. Organisms here must tolerate alternating periods of being submerged (aquatic) and exposed (terrestrial), as well as temperature fluctuations. Tides are caused by the Moon's gravitational pull on ocean water.
• Coral Reefs: Known for high biodiversity, sometimes called the "rainforests of the ocean"; currently highly threatened.
• Open Ocean: Vast and deep; most life is concentrated near the surface.
• Hydrothermal Vents (Deep Sea): Communities existing in total darkness at the ocean floor. The producers here are chemoautotrophs (chemosynthesizers), which utilize the vent energy instead of sunlight.

C. Aquatic Zonation

• Photic Zone: The surface layer receiving light penetration sufficient for photosynthesis.
• Aphotic Zone: The dark layer below the photic zone where light is insufficient for photosynthesis.
• Pelagic Zone: Refers to the entire depth and volume of the water.
• Benthic Zone: The floor or bottom (benthos) of the body of water.
• Littoral Zone: The shallow area right up against the land (a horizontal definition).
• Limnetic Zone: The area farther out from the shore.

IV. Population Ecology and Dynamics

A. Limits to Species Distribution The absence of a species from a particular area can be attributed to three main categories:

1. Dispersal Limitation: Something physically prevents the species from reaching the area (e.g., a geographic barrier).
2. Biotic Factors: Interactions with other living organisms (e.g., predation, parasitism).
3. Abiotic Factors: Non-living constraints, which can be chemical (e.g., water, oxygen, pH) or physical (e.g., temperature, light).
B. Population Size and Distribution Population size changes based on four factors: births, deaths, immigration (entering), and emigration (leaving).
Populations exhibit three major distribution patterns:
- **Clumped: Individuals are grouped intentionally (e.g., seeking resources or safety).**
- **Uniform: Individuals are equally spaced, typically intentional (e.g., maximizing personal distance or defending territory).**
- **Random: Spacing is accidental (e.g., wind-scattered seeds).**

C. Survivorship Curves These curves graph the number of survivors against the percentage of maximum lifespan.
- **Type I (e.g., Humans): High survival rate early in life, with mortality increasing sharply in older age. Species invest heavily in a few offspring.**
- **Type III (e.g., Oyster, Dandelion): High mortality rate early in life; few individuals survive the initial period, but those who do tend to live longer. Species produce many small, cheap offspring.**
- **Type II (e.g., Intermediate): Mortality rate is relatively constant across all ages (a straight line).**

D. Population Growth Models Population growth rate is represented by dN/dt (change in population size over time).
1. Exponential Growth (J-shaped Curve)
  ◦ **Formula: $dN/dt=R_{max}N$.**
  ◦ **Rate: The growth rate increases continuously because it is proportional to the current population size (N).**
  ◦ **Limitation: Cannot occur indefinitely in real populations because resources are finite.**

2. Logistic Growth (S-shaped or Sigmoid Curve)
  ◦ **Formula: $dN/dt=R_{max}N(K-N)/K$.**
  ◦ **Carrying Capacity (\mathbf{K}): The maximum stable population size the environment can sustain.**
  ◦ **Behavior: Growth starts fast (like exponential growth) when N is small, but slows down as N approaches K.**
  ◦ **Maximum Rate: The maximum growth rate (inflection point) occurs when N is exactly K/2.**

E. Density Dependent Regulation Density dependent factors limit population growth more strongly as population density (crowding) increases, stabilizing the population near K.
- **Competition for Resources: Increased density leads to depletion of finite resources (food, light, space).**
- **Predation: High prey density makes it easier for predators to locate and consume them.**
- **Disease: High density facilitates the rapid spread of pathogens (viruses, bacteria).**

• Toxic Wastes: Population growth can be limited by the accumulation of waste products (e.g., yeast killed by high alcohol concentration).
• Territoriality: High density increases confrontations between territorial animals, leading to injury and death.
• Intrinsic Factors: Physiological changes inside crowded organisms that reduce reproductive output (e.g., less mating, smaller litters).
F. Predator-Prey Dynamics The populations of predators and their prey (e.g., wolves and moose) often oscillate over time in cyclical patterns. An increase in prey leads to an increase in predators, which then causes the prey population to crash, followed by the predator population crashing due to starvation, allowing the cycle to repeat.