

POPULATION ECOLOGY

The study of populations in relation to their environment. This includes understanding:

- Environmental influences on population density and distribution.
- Age structure of populations.
- Variations in population size.

Why Study Population Ecology?

Scientific Goals:

1. Understanding the factors that influence population size.
2. Developing general principles and analyzing specific cases.

Practical Goals:

1. Population Management:
 - Increasing population size (e.g., for endangered species).
 - Decreasing population size (e.g., for pests).
2. Maintaining Population Size:
 - Fisheries management (maintaining and maximizing sustained yield).

Population

Group of individuals of the same species living in the same area at same time.

Characteristics of a Population

1. Geographic Distribution (Range)

- The area inhabited by the population.
- Geographical limitations are determined by abiotic (e.g., temperature, rainfall) and biotic (food, predators habitat) factors.
- The habitat must be suitable for the species.

2. Population Size

- Population size can change due to four fundamental factors.
 - **Natality (Births):** The birth rate is the ratio of total live births to the total population in a specific area over a given time. Natality is the recruitment to a population through reproduction.
 - **Mortality (Deaths):** The death rate is the ratio of the total number of deaths to the total population. Mortality can be from any source, such as predation or disease.
 - **Immigration:** The movement of individuals into an area occupied by the population.
 - **Emigration:** The movement of individuals out of an area occupied by the population.
- **Factors that Increase Population Size:**
 - Natality (reproduction).
 - Immigration (individuals moving in from other populations).

- **Factors that Decrease Population Size:**
 - Mortality (death).
 - Emigration (individuals moving out to other populations).
- **Other Factors Affecting Population Size:**
 - **Abiotic Factors:** Sunlight, temperature, precipitation, water availability, soil nutrients.
 - **Biotic Factors:** Predators, prey (food), competitors, parasites, disease.
 - **Intrinsic Factors:** Adaptations of the species.

3. Population Density

- The number of individuals per unit area.
- Formula:

$$\text{Population Density} = \frac{\text{Number of Individuals}}{\text{Area (units}^2\text{)}}$$

- Density varies depending on the species and ecosystem.
- **Measuring Population Density:**
 - **Total Count Method:**
 - Directly counting all individuals in a population.
 - Feasible for a limited number of species (e.g., human censuses, counting trees in a specific area).
 - Breeding colonies can sometimes be photographed and counted later.
 - **Sampling Method**
 - Used when a total count is impractical. The method depends on the organism's abundance and distribution.
 - **Plot-based (Quadrat) Methods:**
 - Used for stationary organisms like plants.
 - Formula:
$$\text{Total Population} = \text{Average number per quadrat} \times \frac{\text{Total Area}}{\text{Area of Quadrat}}$$
 - **Capture-based Methods (Mark Recapture):**
 - Used for mobile or elusive species.
 - Formula:
$$N = \frac{M \times C}{R}$$
 - N = Estimated population size
 - M = Number of individuals marked and released
 - C = Total number of individuals captured in the second sample
 - R = Number of marked individuals recaptured in the second sample

4. Population Dispersion

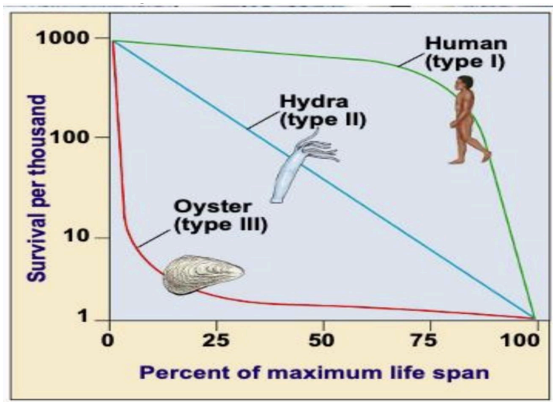
- The spatial arrangement of individuals within a population.
- **Clumped Dispersion:**
 - Individuals are clustered together in patches.
 - Most common pattern.
 - Occurs when resources are clumped, mating or due to social behavior (e.g., mating, group hunting, protection).
 - Examples: Herding animals, flocks of birds, schools of fish, hives of bees.
- **Uniform dispersion:**
 - Evenly spaced individuals, maintaining a minimum distance from each other.
 - Results from strong territoriality or competition for limited resources.
 - Examples: Creosote bushes in the desert, desert lizards defending territories.
- **Random Dispersion:**
 - Spacing is unpredictable; the location of one individual is independent of others.
 - Least common pattern.
 - Occurs when individuals do not interact strongly and are not heavily influenced by microenvironments.
 - Examples: Wind-disperse seeds.

Life Tables

- A table showing the probability of individuals of a certain age dying before their next birthday.
- Can be used to infer the probability of surviving any particular year and remaining life expectancy.
- Often separated for males and females due to differing mortality rates.

Survivorship Curve

- A graph showing the number or proportion of individuals at each age for a given species.
- Graphic representation of life table data for a specific cohort (group of individuals of the same age).
- **Three Types:**
 - **Type I:** High survival rates throughout early and middle life, with steep drop in survival in older age groups (e.g., humans, large mammals). Characterized by low early mortality and extensive parental care.
 - **Type II:** Constant mortality rate throughout the lifespan (e.g., hydra, some birds, rodents).
 - **Type III:** Very high early mortality rates, with few survivors living long lives (e.g., oysters, many plants, insects). Characterized by high early mortality and little to no parental care.



Reproductive Strategies

- **K-Selected Populations (Equilibrial):**
 - Late reproduction.
 - Few offspring.
 - Extensive parental care.
 - Longer lifespan.
 - Often found in stable environments where competition is high.
 - Examples: Primates, coconuts.
- **r-Selected Populations (Opportunistic):**
 - Early reproduction.
 - Many offspring.
 - Little to no parental care.
 - Shorter lifespan.
 - Often found in unstable environments or when colonizing new areas.
 - Examples: Insects, many plants.

Population Growth

- **Population Growth Rate**
 - The change in population size over a given time.
 - Influenced by sex ratio, generation time, and age structure.
 - Mathematically:
 - Change in population size = Births - Deaths
 - Per capita birth rate = b
 - Per capita death rate = d
 - Rate of population growth = $r = b - d$
- **Population Growth Models**
 - **Exponential Growth (Unrestricted Growth):**
 - Occurs when a population has a constant birth rate and is not limited by resources, predation, or disease.
 - Growth rate increases as population size increases.

- Characteristics of populations introduced to a new environment or rebounding from a catastrophe.
- Mathematically:
 - Continuous growth: $\frac{dN}{dt} = r_{\max}N$
 - Population size at time t : $N_t = N_0e^{r_{\max}t}$
 - N_t = number of individuals at time t
 - N_0 = initial number of individuals
 - e = base of natural logarithms
 - r_{\max} = maximum per capita rate of increase
 - t = number of time intervals
- **Logistic Growth (Restricted Growth):**
 - Occurs when environmental constraints (limited resources, increased competition, predation) slow down population growth.
 - The growth rate accelerates initially and then slows as it approaches the carrying capacity.
 - Results in a sigmoid (S-shaped) curve.
 - **Carrying Capacity (K):** The maximum population size that an environment can sustainably support without degradation.
 - Mathematically:

$$\frac{dN}{dt} = r_{\max}N \left(\frac{K - N}{K} \right)$$
 - r_{\max} = maximum per capita rate of increase
 - N = population size
 - K = carrying capacity
 - The growth rate is highest when $N = K/2$. as N approaches K , the growth rate approaches zero.
- **Limits to Population Growth**
 - Environmental factors limit population growth by affecting birth and death rates.
 - **Density-Dependent Factors**
 - Factors whose effects on the size or growth of the population vary with the population density.
 - Examples: Disease, parasite, resource competition (food, nesting sites), predation.
 - As population density increases, these factors typically have a stronger negative impact, slowing growth.
 - **Density-Independent Factors**
 - Factors that affect population size regardless of its density.
 - Often abiotic.
 - Examples: Natural disasters (floods, fires), climate changes (temperature, rainfall).

Human Population

- **Demography**
 - The statistical analysis of human population, including their size distribution, structure, and changes over time.
 - **Population Structure:** The proportion of people by age, ethnicity, education, etc.
 - **Demographic Processes:**
 1. **Fertility:** Actual production of offspring, influenced by health, culture, economics, etc.
 2. **Mortality Rate:** Number of deaths in a population, influenced by age and gender distribution.
 3. **Migration:** Movement of people; influenced by push (unfavorable conditions) and pull (favorable conditions) factors.
- **Population Growth History**
 - For most of human, population growth was very slow due to limiting factors like food scarcity and rampant disease.
 - About 500 years ago, growth began to accelerate due to:
 1. Advancements in agriculture and industry.
 2. More consistent food availability.
 3. Improved sanitation and living conditions.
 4. Decreased death rates while birth rates remained high.
- **Population Pyramid (Age Structure Diagram)**
 - A graphical illustration showing the distribution of various age groups and the sex ratio in a population.
 - **Three Age Categories:**
 1. Prereproductive (ages 0-14)
 2. Reproductive (ages 15-44)
 3. Postreproductive (ages 45 and up)
 - The shape of the pyramid indicates growth trends:
 - Wide base: Rapid growth (many young individuals).
 - More even distribution: Slow growth.
 - Narrower base or inverted shape: Zero or negative growth.