

Introduction to Population Dynamics

Introduction to Population Dynamics

Key concepts, models, and applications

1. What Is Population Dynamics?

- **Definition:** The study of how the size and composition of biological populations change over time and space.
 - **Scope:** Includes births, deaths, immigration, emigration, and interactions with the environment (resources, predators, disease, etc.).
 - **Disciplines Involved:** Ecology, evolutionary biology, conservation biology, epidemiology, resource management, and mathematical modeling.
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2. Fundamental Terms

Term	Meaning
Population	A group of individuals of the same species that live in a defined area and interbreed.
Growth Rate (r)	Net change per individual per unit time (births?–?deaths).
Carrying Capacity (K)	Maximum sustainable population size that the environment can support.
Density?dependent factors	Processes whose intensity changes with population density (e.g., competition, disease).
Density?independent factors	Processes that affect populations regardless of density (e.g., weather, natural disasters).
Age structure	Distribution of individuals among age classes; influences reproductive output and mortality.
Life table	Tabular summary of survival and fecundity by age or stage.
Leslie matrix	A matrix model that projects age?structured populations forward in time.

3. Basic Mathematical Models

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3.1 Exponential Growth (Unlimited Resources)

$$\left[\frac{dN}{dt} = rN \quad \Longleftrightarrow \quad N(t) = N_0 e^{rt} \right]$$

- **Assumptions:** Constant per-capita birth and death rates, no resource limitation.
- **Typical Use:** Early colonization, laboratory cultures, short-term projections.

3.2 Logistic Growth (Limited Resources)

$$\left[\frac{dN}{dt} = rN \left(1 - \frac{N}{K} \right) \right]$$

- **Key Features**
 - Growth slows as (N) approaches (K).
 - Inflection point at (N = K/2).
- **Graphical Shape:** S-shaped (sigmoidal) curve.

3.3 Discrete-time Models

- **Geometric (Ricker) Model**

$$\left[N_{t+1} = N_t e^{r \left(1 - \frac{N_t}{K} \right)} \right]$$

- **Beverton-Holt Model** (common in fisheries)

$$\left[N_{t+1} = \frac{R_0 N_t}{1 + (R_0 - 1) N_t / K} \right]$$

- **Why Discrete?**

- Species with distinct breeding seasons or generations (e.g., insects, annual plants).

3.4 Age-structured Models (Leslie Matrix)

$$\left[\mathbf{n}_{t+1} = \mathbf{L} \mathbf{n}_t \right]$$

- **($\mathbf{L}$)** = Leslie matrix (fertility in the first row, survival probabilities on the sub-diagonal).
- **Eigenvalue (λ)** = long-term growth rate; dominant eigenvector = stable age distribution.

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4. Factors Influencing Population Dynamics

Category	Examples	Typical Effect
Biotic	Competition, predation, parasitism, mutualism	Usually density?dependent; can regulate (N).
Abiotic	Temperature, precipitation, habitat loss, pollutants	Often