Population Ecology (part 1)

I. Demographic Rates
II. Models of Population Growth
III. Density Dependence
IV. Population Regulation

What causes populations to grow or decline?

I. Demographic Rates:
- Births
- Immigration
- Deaths
- Emigration

\[ \text{Gains (+)} \text{ } \rightarrow \text{movement into a population} \]
\[ \text{Losses (-)} \text{ } \rightarrow \text{movement out of a population} \]

- expressed as rates per individual (per capita)

⇒ the balance of these 4 rates determines whether a population will grow, shrink, or stay the same

II. Models of Population Growth

- discrete growth -- demographic events occur in discrete units of time (no overlap of generations)
- continuous growth -- demographic events occur continuously

- most organisms don't fit either type perfectly (e.g., seasonal reproduction in long-lived species)

Exponential Growth -- growth in an unlimited environment

- unrealistic, but a good starting point

\[
\begin{align*}
\text{Discrete model: } N_t &= N_0 R_0^t \\
\text{Continuous model: } N_t &= N_0 e^{rt}
\end{align*}
\]

\[ N_0 = \text{initial population size} \]
\[ N_t = \text{population size at time } t \]
\[ R_0 = \text{“Net Reproductive Rate”: # of offspring produced per individual alive at time 0} \]

- includes probability of dying before reproducing
**Discrete model:**

\[ N_t = N_0 R_0^t \]

- \( R_0 = 1 \) -- population stays same size
- \( R_0 > 1 \) -- population grows
- \( R_0 < 1 \) -- population shrinks

**Assumptions:**
- no overlap of generations
- constant environment
- all individuals identical
- immigration = emigration

**Continuous model:**

\[ N_t = N_0 e^{rt} \]

- \( r = 0 \) -- population stays same size
- \( r > 0 \) -- population grows
- \( r < 0 \) -- population shrinks

**Assumptions:**
- constant environment
- all individuals identical
- immigration = emigration

**But what about reality?**

no population grows without hitting some limit

**Exponential Growth -- why is growth unlimited?**

The assumption of these models is that the per capita growth rate \( r \) is unrelated to population size \( N \). This means:

1) Birth rates are unaffected by population size, and
2) Death rates are unaffected by population size

\[ r = b - d \]

Does this make sense?

**III. Density Dependence**

**Limited Growth**

**Assumptions:**

1) Resources become limited as populations increase
2) Thus, per capita rate of growth must decrease with increasing population
Limited Growth – caused by changes to birth and death rates that are \textit{density dependent}.

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

- \( K \) is carrying capacity; upper limit to population size; equilibrium density.
- Assumptions:
  - \( K \) is constant
  - all individuals identical
  - immigration = emigration
  - no time lags
  - relationship between \( r \) & \( N \) is linear

In this model, \( r \) never changes, but in nature, that is exactly what happens: birth or death rates change as resources become scarce.

IV. Population Regulation

Key consequence of density dependence:

\textit{Population regulation:} when population fluctuations are bounded so as not to increase indefinitely or decrease to extinction.
without regulation populations go extinct or increase to infinity

Tight population regulation: return to K after perturbation

Ecological causes of population regulation

• Intraspecific Competition
• Disease/Parasitism
• Predation

Intraspecific Competition

• resources become limited
  ⇒ mortality increases or birth/settlement declines

Disease/Parasitism

• increased rates of transmission at high densities
  ⇒ causes density-dependent mortality

Predators

• can cause competition for shelter and density-dependent mortality, or
• 4 types of predatory responses cause density-dependent mortality:
  1. functional response
  2. aggregative response
  3. developmental response
  4. numerical response