CHAPTER 53 - POPULATION ECOLOGY

I. POPULATION DENSITY AND DEMOGRAPHICS

- **Population** – individuals of a species within a given area. They are distributed in space, vary in age and size → **population structure**
- Members of the same population rely on the same resources, are influenced by the same environmental factors, interact and reproduce with each other.
- **Population density** – the number of individuals per unit area or volume (can be determined directly by counting or by sampling)
- **Population dispersion** – the pattern of spacing among individuals of the populations.
  - Patterns of distribution of various populations within a geographic range:
    - **Clumped** – the individuals aggregated in patches (ex. Plants, fungi, pack of wolves) because of patchy environmental conditions or food sources, carnivorous animals may be more successful of hunting in packs or herbivorous animals may be more successful of surviving attacks of carnivores in herds, mating behaviors also may call for clumped dispersion
    - **Uniform** – the individuals in the population are evenly spaced (ex. Plants release chemicals that inhibit the germination and growth of other organisms, territoriality among animals, artificially planted trees)
    - **Random** – occurs in the absence of strong attractions or repulsions among individuals of the population. The position of each individual is fairly independent on the other individuals. (ex. Wind blown seed disposal for trees or other plants)

- **Demography** – the study of the vital statistics of populations and how they change over time – is also a useful way of describing populations.
  - **Life tables** – age-specific summaries of the survival pattern of a population. These tables follow the fate of a group of individuals of the same age (cohort) from birth until death. These are hard to construct for wild animals.
  - **Survivorship Curves** – A graph that plots the proportion or number of individuals in a cohort still alive at each age. Although survivorship curves are diverse, they usually follow one of three patterns:
    - **Type I** – flat at the start, reflecting low death rates during the early and middle years, than it drops steeply as death rates increase in old age (large mammals, humans).
    - **Type III** – drops sharply at the start because of high death rates for the young, but than flattens out as death rates decline for those few individuals that have survived to a certain age. Typically, these organisms have large number of offspring and very little care (oysters, many fish species)
- **Type II** – Intermediate, with a constant death rate over the organism’s life span (most rodents, some lizards, annual plants)

- Most organisms have a mix of two types of survivorship curves.

### II. THE EXPONENTIAL GROWTH MODEL

- Although populations have a tremendous capacity for growth, unlimited population growth does not occur indefinitely. Limited resources or other environmental factors will slow growth down.
- The growth of the population can be calculated by using:
  \[ \frac{dN}{dt} = B - D \]  
  (where \( N \) = population size; \( t \) = time; \( B \) = birth rate; \( D \) = death rate)
- In a hypothetical population that consists of only a few individuals with unlimited resources the population will increase with every birth if the immigration and emigration is ignored.
  a. **Zero population growth** occurs when the per capita birth and death rates are equal or \( r = 0 \)
  b. **Exponential population growth** can occur if the population has abundant resources and free to reproduce at their physiological capacity. Under these conditions the per capita rate of increase can reach its maximum for the species. When the population is plotted over time the exponential growth curve has a J-shape.

- This type of exponential growth occurs in populations that are introduced into a new or unfilled environment or whose numbers have been drastically reduced by a catastrophic event and are rebounding.
During exponential growth the population number is:
\[ \frac{dN}{dt} = r_{max}N \] (where \( r_{max} \) = maximum per capita growth rate of the population)

III. THE LOGISTIC GROWTH MODEL

- In nature, there is always a limit to the growth of a population. Because a habitat cannot support unlimited number of individuals. **Carrying capacity (K)** – is the maximum population size that a particular environment can support. It varies over space and time. Limited environmental resources lead to a lower per capita rate of increase (r).
- The **logistic population growth model** accounts for the carrying capacity of the environment when it calculates the per capita rate of increase.

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

IV. SELECTION FOR LIFE HISTORY TRAITS

- High and low population densities require very different reproductive and survival mechanisms (life histories):
  - **K** – selection – density dependent selection acts when population density is high, each individual has few resources. Competitive ability and efficient use of resources is favored.
  - **r** – selection – density independent selection acts when the population density is low, each individual has plenty of resources so rapid reproduction is favored.
- Genotypes that are most fit at low density do not have high fitness at high density.
- The K/r selection concepts have been criticized to be oversimplified.
V. POPULATION REGULATIONS

A. Population Density and Population Change:
   - **Density independent factors** - the birth and death rate changes but independently from the size of the population (natural phenomena/catastrophe)
   - **Density dependent factors** - the birthrate falls with rising density (ex. Lynx population decreases if not enough hares are available)

B. Density Dependent Population Regulation
   - This is an example of negative feedback mechanism (review)—at increased densities the birth rate declines or the death rate increases or both. Mechanisms that cause this:
     a. Competition for resources
     b. Territoriality
     c. Health (increased transmission rate of a disease)
     d. Predation
     e. Toxic metabolic wastes
     f. Intrinsic factors (physiological factors that drop reproduction – later maturation, aggressive interactions among individuals)

C. Population Dynamics – focuses on complex interactions between biotic and abiotic factors that cause variations in population size.
   - Over time all populations show fluctuations in numbers.
   - Fluctuation of numbers of large mammal populations can be caused by harsh winter or increasing predator numbers, but they are usually seem to be relatively stable:
     o Smaller, invertebrate animals can have an even more fluctuating population number. Environmental factors affect them even more, more predators or even in some cases cannibalism can decrease the population while laying very large number of eggs can quickly increase the population numbers:

D. Population Cycles:
   - Many populations increase and decrease at unpredictable intervals, but others go through regular cycles of boom-and-bust cycles (ex. Hare and lynx populations)
VI. HUMAN POPULATION GROWTH

- Human population went through an unprecedented boom in numbers since 1650. This growth cannot be sustained for very long in other populations. Although human population still grows, the rate of growth decreased. This decrease in the rate of growth is due to diseases (AIDS) and voluntary population control.

- Population dynamics vary by region to region or by country to country.
  a. Some populations are stable with high birth rate and high death rate
  b. Others are stable with low birth rate and low death rate
  c. Others go through **demographic transition** from a. to b.

- One important demographic variable in present and future growth trends is a country’s **age structure** – the relative number of individuals of each age

- These age structure diagrams not only predict population growth trends but also predict future employment, education and social issues.

- It is hard to determine the **global carrying capacity** for humans. **Ecological footprint** – the aggregate land and water area needed to sustain the people of a nation, is one measure of how close we are to the carrying capacity of Earth. At more than 6 billion people, the world is already in ecological deficit.