Chapter 46 Ecology of Populations

Chapter Outline

46.1 Scope of Ecology

A. **Ecology**
   1. Ecology is the study of interactions of organisms with their environment.
   2. Concept of ecology was first voiced by German zoologist Ernst Haeckel.
   3. Ecology studies how environmental factors determine the distribution and abundance of populations.
   4. Ecology and evolution are related because ecological interactions are natural selection pressures that have long-term effects.
   5. A **habitat** is the place where an organism exists.
   6. A **population** is a group of the same species occupying a certain area.
   7. A **community** consists of all populations at one locale (e.g., a coral reef population).
   8. An **ecosystem** contains the community organisms and abiotic factors (e.g., energy flow, chemical cycling).
   9. The **biosphere** is the layer on the earth where living organisms can live.
   10. Modern ecology is both descriptive and predictive, with applications to wildlife management, agriculture, and many other problems.

B. Density and Distribution of Populations
   1. The **population density** of organisms refers to how many live per unit of area or volume.
   2. The population **distribution** is the pattern of dispersal; it varies from uniform to random to clumped.
   3. Ecologists study the causes for any “patchiness” of organisms across space and through time.
   4. Distribution can be due to both **biotic** (living) and **abiotic** (physical) factors.
   5. The physical (abiotic) factors include types of precipitation and amounts, averages, and daily and seasonal variations in temperature, type of soil or nutrients; moisture or temperature may serve as **limiting factors**.
   6. Biotic factors can be illustrated by red kangaroos that are limited to inland Australia by the grasses that grow there.

46.2 Characteristics of Populations

A. Population Size
   1. The **population size** is the number of individuals contributing to the gene pool of the population.
   2. At any one point in time, a population has a certain size.
   3. Future population size depends on natality and mortality (births and deaths), and immigration and emigration (although immigration and emigration are often presumed equal).
   4. Birthrate and death rate are used to calculate the intrinsic rate of natural increase.
   5. The **intrinsic rate of natural increase** is used to calculate the growth of a population per unit time.

B. Population Growth Models
   1. There are two patterns of population growth.
      a. In discrete breeding, organisms reproduce once and cease to grow as adults; they expend energy in reproduction and die.
      b. In continuous breeding, organisms reproduce throughout their lifetime, which invests energy in their future survival.
   2. Most organisms do not exactly fit these two patterns.
      a. Aphids can switch between sexual and asexual reproduction according to the season.
      b. Annual plants can reproduce both by seeds and by vegetative extensions.

D. Exponential Growth
   1. The J-shaped **exponential growth curve** has two phases.
      a. In the **lag phase**, growth is slow because the population is small.
      b. In the **exponential growth phase**, growth is accelerating.

2. A mathematical equation can be used to calculate the exponential growth and size for any population that has discrete generations.
3. **Biotic Potential**
    a. Biotic potential is exhibited during exponential growth, this is the maximum population growth under ideal circumstances.
    b. These circumstances include plenty of room for each member, unlimited resources (e.g., food, water), and no hindrances (e.g., predators).
4. **Environmental resistance** curbs exponential growth; it includes all of the environmental factors that limit population size.

D. Logistic Growth
1. When growth encounters environmental resistance, populations experience an **S**-shaped or **logistic growth curve**.
2. In 1930, Raymond Pearl estimated the growth in yeast and arrived at a graph and formula for logistic growth.
3. In addition to the **lag phase** and **exponential growth**, there is a **deceleration phase** where the rate of population growth slows down and a **stable equilibrium phase** with little if any growth, because births equal deaths.
4. This curve is called "logistic" because the exponential portion of the curve would plot as a straight line as log of *N*.
5. A mathematical equation calculates logistic growth.
6. Environmental resistance results in the deceleration phase and the stable equilibrium phase; population is at the carrying capacity of the environment.

E. Carrying Capacity
1. The **carrying capacity** (***K***) is the maximum number of individuals of a species that can be supported by the environment.
2. The closer population size gets to the carrying capacity, the greater is the environmental resistance.
3. When *N* is small, a large portion of the carrying capacity has not been utilized, but as *N* approaches *K*, population growth slows down because $\frac{K-N}{K}$ is nearing zero.
4. For example, over-fishing drives a population into the lag phase.
5. It is best to maintain desirable populations in the exponential phase of the logistic growth curve.
6. However, reducing crop pests also places them in exponential phase again.
7. Farmers can reduce the carrying capacity for a pest by alternating rows of different crops.

F. Mortality Patterns
1. A **life table** shows how many members of a **cohort**, a group born at one time, are surviving to different ages.
2. **Survivorship** is the percentage of remaining survivors of a population over time; usually this is shown graphically.
    a. In the **Type I survivorship curve**, most individuals live out their life span and die of old age (e.g., humans).
    b. In the **Type II survivorship curve**, individuals die at a constant rate across their lifespan (e.g., birds, rodents, and perennial plants).
    c. In the **Type III survivorship curve**, most individuals die early in life (e.g., fishes, invertebrates, and plants).
3. The grass *Poa annua* is intermediate; most survive till 6–9 months and then chances of surviving diminish.

G. Age Distribution
1. From the perspective of population growth, there are three major age groups in a population: prereproductive, reproductive and postreproductive.
2. An **age structure diagram** is a representation of the number of individuals in each age group in a population.
3. A **pyramid-shape** indicates the population has high birthrates; the population is undergoing exponential growth.

4. A **bell-shape** indicates that prereproductive and reproductive age groups are more nearly equal, with the postreproductive group being smallest due to mortality; this is characteristic of stable populations.
5. An **urn-shaped** diagram indicates the postreproductive group is largest and the prereproductive group is smallest, a result of the birthrate falling below the death rate; this is characteristic of declining populations.

46.3 Regulation of Population Size

A. The J-shaped and S-shaped growth curve models do not always predict real populations.
   1. In the winter moth, many eggs did not survive the winter and exponential growth did not occur.
   2. The growth curve of a reindeer herd introduced to St. Paul Island in Alaska overshot its carrying capacity and crashed.

B. Populations do not increase in size year after year because environmental resistance, including both **density-independent** and **density-dependent** factors, regulates the number of organisms.
   1. Some populations are considered to be regulated primarily by density-independent factors.
      a. The number of organisms present does not affect the influence of the factor.
      b. The damage to a population from an accidental fire does not change with or depend on the number of organisms present.
      c. Density-independent factors show no correlation with the size of the population.
   2. Populations regulated by density-dependent factors are affected by the number of organisms present.
      a. Predation, parasitism, competition are considered density-dependent; the more these organisms crowd together, the more damaging are the food shortages, the parasites, and the predators.
      b. Density-dependent factors have some effect relative to the size of the population.
   3. Weather, food, other animals, pathogens, and habitat are important extrinsic factors.
   4. Intrinsic factors (e.g., anatomy, behavior) can also influence population size: territoriality, recruitment, immigration and emigration.
   5. Populations may also be inherently unstable and deviate from simple models.
   6. New theories on chaos help us understand some of the severe fluctuations over time.

46.4 Life History Patterns

A. The logistic population model predicts two main life history patterns.
   1. ***r*-Selection**
      a. Species that underwent selection to maximize their rate of natural increase are categorized as *r*-selected.
      b. These populations are often **opportunistic species**, and tend to be colonizers.
      c. Their strategy for continued existence is based on individuals having the following traits:
         1) small size,
         2) short life span,
         3) mature fast,
         4) produce many offspring, and
         5) engage in little care of offspring.
      d. Thus, they rely on rapid dispersal to new unoccupied environments.
   2. ***K*-Selection**
      a. Species that hold their populations fairly constant near the carrying capacity are called *K*-selected.
      b. Such populations are **equilibrium species**; they are strong competitors, tend to be specialists rather than colonizers, and may become extinct when their evolved way of life is disrupted (e.g., the grizzly bear, Florida panther, etc.).
      c. Their overall strategy for continued existence is based on having the following traits:
         1) large size,
         2) long life span,
         3) slow to mature,
         4) produce few offspring, and
         5) expend considerable energy in care.

B. Most populations cannot be characterized as either *r*- or *K*-strategists; they have intermediate characteristics.

46.5 Human Population Growth

A. The Human Population Is Growing
    1. The human population is now in an exponential part of a J-shaped growth curve.
    2. World population increases the equivalent of one medium-sized city (225,000) per day and 82 million per year.
    3. The **doubling time** is the length of time for a population size to double, now 47 years.
    4. Zero population growth is when the birthrate equals the death rate and the population size remains steady.
    5. The world population may level off at 8, 10.5 or 14.2 billion, depending on the decline in net reproductive rate.

B. More-Developed Versus Less-Developed Countries
    1. The more developed countries underwent a **demographic transition** from 1950–1975; their growth rate is now low.
        a. The more **developed countries (MDCs)** (e.g., Europe, North America, Japan, etc.) Have low population growth and people enjoy a good standard of living.
        b. **Less developed countries** (**LDCs**) (e.g., countries in Africa, Asia, Latin America) are those in which population growth is expanding rapidly and the majority of people live in poverty.
        c. LDC growth rate peaked at 2.5% between 1960–1965; it has declining slowly to about 1.9%.
        d. **Demographic transition** is decline in death rate followed by declining birthrate; results in slower growth, about 0.1%.
    2. The less developed countries (LDCs) are now undergoing demographic transition.
    3. Most of the explosive growth will occur in Africa, Asia and Latin America unless
        a. family planning or birth control are strengthened,
        b. the desire for more children is reduced, and
        c. the onset of childbearing is delayed.

C. Age Distributions
    1. Age structure diagrams divide populations into: dependency, reproductive, and postreproductive.
    2. *Replacement reproduction*, or each couple having just two children, will still cause population growth to continue due to the age structure of the population.
    3. Mere replacement does not produce zero population growth because more women enter reproductive years than leave them.
    4. The LDCs have a higher growth rate because of a youthful age structure and more women entering reproductive ages than leaving.
    5. The MDCs have a low growth rate because of a stabilized age structure.

D. Population Growth and Environmental Impact
    1. Both the growing populations of LDCs and the high consumption of MDCs stress the environment.
    2. An average American family, in terms of consumption and waste production, is equal to thirty people in India.
    3. MDCs account for one-fourth the world population but provide 90% of the hazardous waste production.
    4. Resource consumption affects the cycling of chemicals and contributes to pollution and extinction of species.
    5. Conservation biology seeks sustainable practices to prevent mass extinction of species..