BLY 122 **C. S. Major**

Chapter 52 Population Ecology

I. Demography

A. Population Dynamics

1. A population is a group of individuals from the same species that live in the same area at the same time.
2. Population ecology is the study of how and why the number of individuals in a population changes over time.
3. Demography is the study of factors that determine the size and structure of populations through time. Analyzing birth rates, death rates, immigration rates, and emigration rates is fundamental to demography.

B. Life Tables

1. Formal demographic analyses of populations are based on a type of data set called a life table, which summarizes the probability that an individual will survive and reproduce in any given year over the course of its lifetime.
   a. Example: Researchers set out to estimate the life table of a low-elevation population of *Lacerta vivipara* in the Netherlands compared with the life table of a high-elevation population. (**Fig. 52.1**)
2. Survivorship
   a. Definition: Survivorship is the proportion of offspring produced that survive, on average, to a particular age (l_x, where x represents the age class being considered. It is calculated by dividing the number of individuals in that age class by the number of individuals in the first age class.
   b. $l_x = N_x / N_0$ (**Box 52.1, Eq. 52.1**)
   c. Type I curve—survivorship throughout life is high. (**Fig. 52.2a**)
   d. Type II curve—constant mortality throughout life. (**Fig. 52.2a**)
   e. Type III curve—high death rate early in life. (**Fig. 52.2a**)
3. Fecundity
   a. Definition: Fecundity is the number of female offspring produced by each female in the population. (**Box 52.1**)
   b. $R_0 = \sum l_x m_x$ (**Box 52.1, Eq. 52.2**)
   c. Lifetime reproduction is a function of fecundity at each age (m_x) and survivorship to each age class (l_x). If R_0 is greater than 1, the population is increasing. If R_0 is less than 1, the population is declining.

C. The Role of Life History

1. An organism's life history consists of how the organism allocates resources to growth, reproduction, and activities related to survival.
2. Example: It is not possible to achieve both high fecundity and high survivorship. A trade-off exists between survival and reproduction. (**Fig. 52.3**)
3. Example: An *Arabidopsis* plant and an oak tree represent two ends of a broad continuum that exists in life-history characteristics. (**Fig. 52.4**)

II. Population Growth

A. The fate of any population depends on four factors:

1. Birth rate
2. Death rate

3. Immigration rate
4. Emigration rate

B. Exponential Growth
1. Exponential growth occurs when *r* does not change over time. It does not depend on the number of individuals in the population. Therefore, it is density independent.
2. Example: In *Arabidopsis* and fruit flies, which breed at a young age and produce many offspring each year, r_{max} is high. In contrast, r_{max} is low in species such as giant pandas and oak trees, which take years to produce few offspring each year. (**Fig. 52.5**)
3. In reality, it is not possible for growth to continue indefinitely. Eventually, the habitat would not have enough resources for the number of individuals present. When a population stabilizes at the maximum number that can be supported by the resources available, that population has reached the habitat's carrying capacity.

C. Logistic Growth
1. Examples
   a. The logistic growth equation describes logistic population growth, or changes in growth rate that occur as a function of population size. Just as exponential growth is density dependent, logistic growth is density dependent. (**Box 52.2**)
   b. Density-dependent graphs have three sections. (**Fig. 52.6a**)
   c. Example: Both species of *Paramecia* exhibited logistic growth, but the carrying capacity differed. (**Fig. 52.6b**)
2. Discrete growth
   a. Biologists use *N* to symbolize population size. N_0 is the population size at time zero, and N_1 is the population size one breeding interval later.
   b. $N_1/N_0 = \lambda$ (**Box 52.2, Eq. 52.3**)
   λ is the finite rate of increase
   c. $N_t = N_0\lambda^t$ (**Box 52.2, Eq. 52.5**)
   This equation summarizes how populations grow when breeding takes place seasonally.
3. Continuous growth
   a. A population's per capita increase is symbolized *r* and is defined as the per capita birth rate minus the per capita death rate.
   b. $\lambda = e^r$ (**Box 52.2, Eq. 52.6**)
   where *e* is the natural logarithm, or about 2.72.
   c. $N_t = N_0e^{rt}$ (**Box 52.2, Eq. 52.7**)
   This equation summarizes how populations grow when they breed continuously. Because *r* represents the growth rate at any given time and because *r* and λ are so closely related, biologists routinely calculate *r*, even for species that breed seasonally.

D. What Limits Growth Rates and Population Sizes?
1. Density-independent factors change birth rates and death rates irrespective of the number of individuals in a population.
2. Density-dependent factors are usually biotic in nature and change in intensity as a function of population size.
3. Researchers studied the bridled goby, a coral-reef fish. They stocked artificial reefs with varying densities of adult gobies; and after 2.5 months, they captured all the gobies and computed the growth rate of individuals, the survival rate, and the immigration rate. (**Fig. 52.7**)
4. Adult gobies survive better when population density is low. More juvenile gobies immigrate successfully when population density is low. Higher rates of predation and disease might occur in dense populations.

III. Population Dynamics

A. Example: Researchers have studied plots of land in the Park Grass study in Rothamsted, U.K, and looked at populations of plant species. (**Fig. 52.8**)

B. Population Cycles: The Case of the Red Grouse
  1. Population cycles are regular fluctuations in size that some populations exhibit.
  2. Hypothesis: The roundworm is responsible for population fluctuations seen in red grouse. Control populations showed a dramatic four-year cycle, whereas populations treated with a drug that kills roundworms maintained high population densities. (**Fig. 52.9**)

C. Age Structure
  1. Definition: A population's age structure—meaning the proportion of individuals that are at each possible age—has a dramatic influence on the population's growth over time.
  2. Age structure in a woodland herb
    a. The common primrose has a complex population dynamic: (**Fig. 52.10**)
      (1) Populations dominated by juveniles experience rapid growth, then are limited by the shading of larger trees.
      (2) The long-term trajectory of the primrose population seems dependent on the frequency and severity of windstorms.
      (3) This species seems to live in small, isolated populations of populations—or metapopulations.
  3. Age structure in human populations
    a. In nations where industrial and technological development is advanced and average incomes are relatively high, the age distribution of the population tends to be even.
    b. The predicted population structure in 2050 highlights a major policy concern in developed countries: how to care for an increasingly aged population. (**Fig. 52.11a**)
    c. In contrast, the age distribution is bottom-heavy in the less-developed countries. (**Fig. 52.11b**)
    d. The projected age distribution in 2050 illustrates the major public policy concerns in these countries: providing education and jobs for an enormous influx of young people who will want to be starting families.

D. Analyzing Change in the Growth Rate of Human Populations
  1. The growth rate for humans has increased over time since about 1750, leading to a very steeply rising curve over the past few centuries. The highest values occurred between 1965 and 1970, when population growth averaged 2.04% per year. (**Fig. 52.12**)
  2. The population growth has slowed over the past few years; it is now 1.2% per year. Humans are ending a period of rapid growth that lasted well over 500 years. How quickly growth rates decline and the maximum population size ultimately reached will be decided by changes in fertility rates and the course of the AIDS epidemic.
  3. Extrapolating the world's population to the year 2050 is based on three different fertility rates: (**Fig. 52.13**)
    a. High fertility = nearly 11 billion
    b. Medium fertility = about 9 billion
    c. Low fertility = 7.4 billion

IV. How Can Population Ecology Help Endangered Species?

A. Preserving Metapopulations

1. Over time, each population within the larger metapopulation is likely to be wiped out. Migration from nearby populations can reestablish populations in these empty habitats, thereby stabilizing the overall population.
2. Example: Ilkka Hanski and colleagues have shown that metapopulations exist in nature. They performed a mark-recapture study on the Glanville fritillary butterfly. The researchers found a migration rate of 9%, which was high enough to recolonize extinct populations. They also confirmed that some populations had gone extinct, while others had been created. (**Fig. 52.14**) (**Box 52.3**)
3. A small, isolated population—even one within a nature reserve—is unlikely to survive over the long term. Based on this realization, conservation biologists are attempting to design reserves for threatened species that are sizable enough to maintain large populations. When this is not possible, an alternative is to establish systems of small reserves that are connected by corridors of habitat, so that migration between patches is possible. Hanski emphasizes that it is also crucial to preserve at least some patches of currently unoccupied habitat as well, to provide future homes for immigrants in the metapopulation.

B. Using Life-Table Data to Make Population Projections
   1. Population projections allow biologists to alter values for survivorship and fecundity at particular ages and assess the consequences.
   2. Studies performed on this aspect support some general conclusions: (**Fig. 52.15**)
      a. Whooping cranes, sea turtles, spotted owls, and many other endangered species have high juvenile mortality, low adult mortality, and low fecundity.
      b. In humans and species with high survivorship in most age classes, rates of population growth are extremely sensitive to changes in age-specific fecundity.

C. Population Viability Analysis
   1. Population viability analysis (PVA) is a model that estimates the likelihood that a population will avoid extinction for a given time period. PVAs attempt to combine basic demographic models for the species in question with data on geographic structure and the rate and severity of habitat disturbance.
   2. Researchers made PVAs for an endangered marsupial, Leadbeater's possum. Their analysis allowed them to assess the impact of migration and to simulate the effects of logging, fires, storms, and other types of disturbances. (**Fig.52.16**)