Chapter 53

Population Ecology

Population ecology is the study of populations in relation to their environment, including environmental influences on density and distribution, age structure, and population size

A **population** is a group of individuals of a single species living in the same general area

Populations are described by their boundaries and size

Density and Dispersion

Density is the number of individuals per unit area or volume

Dispersion is the pattern of spacing among individuals within the boundaries of the population

Density is the result of an interplay between processes that add individuals to a population and those that remove individuals

Immigration is the influx of new individuals from other areas

Emigration is the movement of individuals out of a population

Patterns of Dispersion

Environmental and social factors influence the spacing of individuals in a population

In a clumped dispersion, individuals aggregate in patches

A clumped dispersion may be influenced by resource availability and behavior

A uniform dispersion is one in which individuals are evenly distributed

It may be influenced by social interactions such as **territoriality**, the defense of a bounded space against other individuals

In a random dispersion, the position of each individual is independent of other individuals

It occurs in the absence of strong attractions or repulsions

Demographics

Demography is the study of the vital statistics of a population and how they change over time

Death rates and birth rates are of particular interest to demographers

Survivorship Curves

A **survivorship curve** is a graphic way of representing the data in a life table

The survivorship curve for Belding's ground squirrels shows a relatively constant death rate

Reproductive Rates

For species with sexual reproduction, demographers often concentrate on females in a population

A **reproductive table**, or fertility schedule, is an age-specific summary of the reproductive rates in a population

It describes the reproductive patterns of a population

Per Capita Rate of Increase

Change in population size = Births + Immigrants entering population – Deaths – Emigrants leaving population

- If immigration and emigration are ignored, a population's growth rate (per capita increase) equals birth rate minus death rate

Zero population growth (ZPG) occurs when the birth rate equals the death rate ($r = 0$)

Exponential Growth

- **Exponential population growth** is population increase under idealized conditions
- Under these conditions, the rate of increase is at its maximum, denoted as r_{max}
- The equation of exponential population growth is

$$\frac{dN}{dt} = r_{max}N$$

- Exponential population growth results in a J-shaped curve

The logistic model describes how a population grows more slowly as it nears its carrying capacity

Exponential growth cannot be sustained for long in any population

A more realistic population model limits growth by incorporating carrying capacity

Carrying capacity (*K*) is the maximum population size the environment can support

Carrying capacity varies with the abundance of limiting resources

The Logistic Growth Model

- In the **logistic population growth** model, the per capita rate of increase declines as carrying capacity is reached
- The logistic model starts with the exponential model and adds an expression that reduces per capita rate of increase as *N* approaches *K*

$$\frac{dN}{dt} = r_{\max} N \frac{(K - N)}{K}$$

The logistic model of population growth produces a sigmoid (S-shaped) curve

The Logistic Model and Real Populations

The growth of laboratory populations of paramecia fits an S-shaped curve

These organisms are grown in a constant environment lacking predators and competitors

Some populations overshoot *K* before settling down to a relatively stable density

Some populations fluctuate greatly and make it difficult to define *K*

Some populations show an Allee effect, in which individuals have a more difficult time surviving or reproducing if the population size is too small

The logistic model fits few real populations but is useful for estimating possible growth

Conservation biologists can use the model to estimate the critical size below which populations may become extinct

Life history traits are products of natural selection

An organism's **life history** comprises the traits that affect its schedule of reproduction and survival

- The age at which reproduction begins
- How often the organism reproduces
- How many offspring are produced during each reproductive cycle

Life history traits are evolutionary outcomes reflected in the development, physiology, and behavior of an organism

Evolution and Life History Diversity

Species that exhibit **semelparity**, or **big-bang reproduction**, reproduce once and die

Species that exhibit **iteroparity**, or **repeated reproduction**, produce offspring repeatedly

Highly variable or unpredictable environments likely favor big-bang reproduction, while dependable environments may favor repeated reproduction

“Trade-offs” and Life Histories

- Organisms have finite resources, which may lead to trade-offs between survival and reproduction
  - For example, there is a trade-off between survival and paternal care in European kestrels

Some plants produce a large number of small seeds, ensuring that at least some of them will grow and eventually reproduce

Other types of plants produce a moderate number of large seeds that provide a large store of energy that will help seedlings become established

***K*-selection**, or density-dependent selection, selects for life history traits that are sensitive to population density

***r*-selection**, or density-independent selection, selects for life history traits that maximize reproduction

Many factors that regulate population growth are density dependent

There are two general questions about regulation of population growth

- What environmental factors stop a population from growing indefinitely?
- Why do some populations show radical fluctuations in size over time, while others remain stable?

Population Change and Population Density

In **density-independent** populations, birth rate and death rate do not change with population density

In **density-dependent** populations, birth rates fall and death rates rise with population density

Mechanisms of Density-Dependent Population Regulation

Density-dependent birth and death rates are an example of negative feedback that regulates population growth

Density-dependent birth and death rates are affected by many factors, such as competition for resources, territoriality, disease, predation, toxic wastes, and intrinsic factors

Competition for Resources

In crowded populations, increasing population density intensifies competition for resources and results in a lower birth rate

Toxic Wastes

Accumulation of toxic wastes can contribute to

density-dependent regulation of population size

Predation

As a prey population builds up, predators may feed preferentially on that species

Intrinsic Factors

For some populations, intrinsic (physiological)

factors appear to regulate population size

Territoriality

In many vertebrates and some invertebrates,

competition for territory may limit density

Disease

Population density can influence the health and survival of organisms

In dense populations, pathogens can spread more rapidly

Population Dynamics

The study of **population dynamics** focuses on the complex interactions between biotic and abiotic factors that cause variation in population size

Metapopulations are groups of populations linked

by immigration and emigration

High levels of immigration combined with higher

survival can result in greater stability in populations

The human population is no longer growing exponentially but is still increasing rapidly

No population can grow indefinitely, and humans are no exception

The Global Human Population

- The human population increased relatively slowly until about 1650 and then began to grow exponentially

Global Carrying Capacity

How many humans can the biosphere support?

Population ecologists predict a global population of

7.8–10.8 billion people in 2050

Estimates of Carrying Capacity

The carrying capacity of Earth for humans is

uncertain

The average estimate is 10–15 billion

Limits on Human Population Size

The **ecological footprint** concept summarizes the aggregate land and water area needed to sustain the people of a nation

It is one measure of how close we are to the carrying capacity of Earth

Countries vary greatly in footprint size and available ecological capacity

Our carrying capacity could potentially be limited by food, space, nonrenewable resources, or buildup of wastes

Unlike other organisms, we can regulate our population growth through social changes