CHAPTER 9

POPULATION ECOLOGY

Objectives

1. Describe the various types of population distribution patterns that can occur in nature and comment on which is most common and why.
2. Define birth rate, death rate, immigration, and emigration. Write an equation to mathematically describe the relationship between these rates and the rate of population change.
3. Define limiting factor. Give an example of a resource that would be limiting in an ecosystem.
4. Define exponential growth.
5. Compare a J-shaped growth curve with an S-shaped growth curve and comment on the factors that produce the sigmoid (S-shaped) curve.
6. Define carrying capacity and explain what determines the carrying capacity of an ecosystem.
7. Explain density-dependent population controls and density-independent population controls.
8. List the four general types of population fluctuations in nature. Indicate which of these is most common.
9. Discuss the relationships between predators and prey and the possible interactions upon each other.
10. Define r-selected species and K-selected species and compare the two. Give an example for each type of species reproductive pattern.
11. Describe the three general types of survivorship curves in nature.
12. Explain the genetic effects on a population that has undergone bottleneck, genetic drift, or inbreeding due to isolation of the population.
13. List the nine major ways that humans have altered natural ecosystems and comment on the effects of these alterations for the future of the planet.

Key Terms  (Terms are listed in the same font as they appear in the text.)

<table>
<thead>
<tr>
<th>population dynamics (p. 164)</th>
<th>environmental resistance (p. 165)</th>
</tr>
</thead>
<tbody>
<tr>
<td>size (p. 164)</td>
<td>r-selected species (p. 169)</td>
</tr>
<tr>
<td>density (p. 164)</td>
<td>opportunists (p. 169)</td>
</tr>
<tr>
<td>age distribution (p. 164)</td>
<td>sexual reproduction (p. 169)</td>
</tr>
<tr>
<td>population distribution (p. 164)</td>
<td>K-selected species (p. 169)</td>
</tr>
<tr>
<td>dispersion (p. 164)</td>
<td>life expectancies (p. 170)</td>
</tr>
<tr>
<td>clumping (p. 164)</td>
<td>survivorship curve (p. 170)</td>
</tr>
<tr>
<td>uniform dispersion (p. 164)</td>
<td>late loss curves (p. 170)</td>
</tr>
<tr>
<td>random dispersion (p. 164)</td>
<td>early loss curves (p. 170)</td>
</tr>
<tr>
<td>births (p. 164)</td>
<td>constant loss curves (p. 170)</td>
</tr>
<tr>
<td>deaths (p. 164)</td>
<td>life table (p. 170)</td>
</tr>
<tr>
<td>immigration (p. 164)</td>
<td>founder effect (p. 171)</td>
</tr>
<tr>
<td>emigration (p. 164)</td>
<td>demographic bottleneck (p. 171)</td>
</tr>
<tr>
<td>age structure (p. 164)</td>
<td>genetic drift (p. 171)</td>
</tr>
<tr>
<td>prereproductive stage (p. 164)</td>
<td>inbreeding (p. 171)</td>
</tr>
<tr>
<td>reproductive stage (p. 164)</td>
<td>metapopulations (p. 171)</td>
</tr>
<tr>
<td>postreproductive stage (p. 164)</td>
<td>monoculture (p. 172)</td>
</tr>
<tr>
<td>biotic potential (p. 165)</td>
<td>opportunist species (p. 172)</td>
</tr>
<tr>
<td>intrinsic rate of increase (r)</td>
<td>pests (p. 172)</td>
</tr>
<tr>
<td>(p. 165)</td>
<td>pathogens (p. 172)</td>
</tr>
<tr>
<td>exponential growth (p. 166)</td>
<td></td>
</tr>
<tr>
<td>logistic growth (p. 166)</td>
<td></td>
</tr>
<tr>
<td>overshoots (p. 166)</td>
<td></td>
</tr>
<tr>
<td>reproductive time lag (p. 166)</td>
<td></td>
</tr>
<tr>
<td>dieback (crash) (p. 166)</td>
<td></td>
</tr>
<tr>
<td>population density (p. 167)</td>
<td></td>
</tr>
<tr>
<td>density-independent population controls (p. 167)</td>
<td></td>
</tr>
<tr>
<td>density-dependent population controls (p. 167)</td>
<td></td>
</tr>
<tr>
<td>bubonic plaque (p. 167)</td>
<td></td>
</tr>
<tr>
<td>stable population fluctuations (p. 167)</td>
<td></td>
</tr>
<tr>
<td>eruptive population fluctuations (p. 167)</td>
<td></td>
</tr>
<tr>
<td>cyclic fluctuations (p. 167)</td>
<td></td>
</tr>
<tr>
<td>irregular fluctuations (p. 167)</td>
<td></td>
</tr>
<tr>
<td>top-down control (p. 168)</td>
<td></td>
</tr>
<tr>
<td>bottom-up control (p. 168)</td>
<td></td>
</tr>
<tr>
<td>asexual reproduction (p. 169)</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 9: Learning Log: Answer questions 2-18 on a separate piece of paper for extra credit points on population test.

1. Define the boldfaced terms in this chapter. (OMIT)

2. Explain how the populations of southern sea otters and kelp interact and why the southern sea otter is considered a keystone species.

3. What is population dynamics? Why are the populations of most species found in clumps or groups?

4. What four factors affect population change? Write an equation showing how population change is related to births, deaths, immigration, and emigration.

5. What is the biotic potential of a population? What are four characteristics of a population with a high intrinsic rate of increase (r)?

6. What are environmental resistance and carrying capacity? How do biotic potential and environmental resistance interact to determine carrying capacity?

7. Distinguish between exponential and logistic growth of a population, and give an example of each type.

8. How can a population overshoot its carrying capacity, and what are the consequences of doing this?

9. Distinguish between density-dependent and density-independent factors that affect a population’s size, and give an example of each.

10. Distinguish among stable, irruptive, irregular, and cyclic forms of population change.

11. Distinguish between top-down control and bottom-up control of a population’s size. Use these concepts to describe the effects of the predator–prey interactions between the snowshoe hare and the Canadian lynx on the population of each species.

12. Distinguish between asexual reproduction and sexual reproduction. What are the disadvantages and advantages of sexual reproduction?

13. List the characteristics of (a) r-selected or opportunist species and (b) K-selected or competitor species, and give two examples of each type. Under what environmental conditions are you most likely to find (a) r-selected species and (b) K-selected species?

14. What is a survivorship curve, and how is it used? List three general types of survivorship curves, and give an example of a species with each type.

15. How can genetic diversity affect the survival of small, isolated populations? Distinguish between the founder effect, demographic bottleneck, and genetic drift. What is a metapopulation?

16. List nine potentially harmful ways in which humans modify natural ecosystems.

17. List four principles of sustainability observed in natural systems and describe how they can be adapted for developing more sustainable human societies.

18. List four guidelines we could use to help us live more sustainably.
9-1 Population Dynamics and Carrying Capacity

A. Populations change in size, density, and age distribution; most members of populations live together in clumps or groups.
   1. Three general patterns of population distribution occur in a habitat: clumping, uniform distribution, and random dispersion. Most species live in clumps or groups.
      a. Availability of resources varies from place to place.
      b. Living in groups offers better protection from predators.
      c. Some predator species live in packs to better have a chance to get a meal.
      d. Temporary groups may form for mating and caring for young.
   2. Uniform pattern distribution may occur where a resource, such as water, is scarce.

B. Four variables influence/govern population size: births, deaths, immigration, and emigration.
   1. Increase in population occurs by birth and immigration.
   2. Decrease in population occurs by death and emigration.
   3. Age structure of a population is usually described as the pre-reproductive stage, the reproductive stage and the post-reproductive stage. A population with a large reproductive stage is likely to increase, while a population with a large post-reproductive stage is likely to decrease.

C. No population can grow indefinitely due to limited resources such as light, water, and nutrients and also due to competitors and/or predators.
   1. The biotic potential is the population’s capacity for growth.
   2. The intrinsic rate of increase (r) is the rate of population growth with unlimited resources.
   3. Rapidly growing populations have four characteristics.
      a. Individuals in the population reproduce early in life.
      b. Individuals have short periods between generations.
      c. Individuals have long reproductive lives.
      d. Individuals produce multiple offspring each time they reproduce.

D. Environmental resistance consists of factors that limit population growth.
   1. Carrying capacity (K) is determined by biotic potential and environmental resistance. This is the number of a species’ individuals that can be sustained indefinitely in a specific space.
   2. As a population reaches its carrying capacity, its growth rate will decrease because resources become more scarce.

E. A population can grow rapidly with ample resources.
   1. With few resource limitations, a population will have exponential growth. This is a fixed rate of growth that will take be a J-shaped growth curve as the base size of population increases. This represents its intrinsic rate of increase (r) or biotic potential.
   2. This exponential growth is converted to logistic growth when the populations get larger and face environmental resistance. In logistic growth, the growth rate levels off as population size reaches or nears carrying capacity.
   3. The sigmoid (s-shaped) population growth curve shows that the population size is stable, at or near its carrying capacity.

F. When population size exceeds its carrying capacity, organisms die unless they move or switch to new resources.
   1. Exponential growth leads to logistic growth and may lead to the population overshooting the environment’s carrying capacity.
      a. Overshooting an environment’s resources often is a result of a reproductive time lag.
      b. The reproductive time lag can produce a dieback/crash of organisms unless the organisms can find new resources or move to an area with more resources.
   2. If the carrying capacity of an area is exceeded, changes in the area itself can reduce future carrying capacity. Reducing grass cover by overgrazing allows sagebrush to move in and reduces the number of cattle that the land can support.
   3. Technological, social, and cultural changes have extended the earth’s carrying capacity for human beings, for the time being.

G. The density of a population may or may not affect how rapidly it can grow.
   1. Density-independent population controls affect a population’s size regardless of its density. These are abiotic factors in the community.
   2. Density-dependent factors or population controls have a greater affect on the population as its density increases. Infectious disease is an example of density-dependent population control.
H. Population sizes may stay about the same, suddenly increase and then decrease, vary in regular cycles, or change erratically.
   1. Four general types of population fluctuations in nature are: stable, irruptive, cyclic, and irregular.
   2. A stable population fluctuates slightly above and below carrying capacity and is characteristic of many species living under fairly constant environmental conditions.
   3. Some species have a fairly stable population size that may occasionally irrupt to a high peak and then crash to below carrying capacity. This is characteristic of short-lived, rapidly reproducing species.
   4. Cyclic fluctuations occur over a regular time period, generally a multiple year cycle.
   5. Irregular behavior is poorly understood. Some scientists attribute irregular behavior to chaos in the system; others disagree.
I. Interactions between predators and their prey change in cycles and appear to be caused by species interactions, but other factors may be involved.
   1. The hypothesis of top-down control of prey by predators may not be the only explanation for the boom-and-bust cycles seen in these populations. This may also be related to the food supply of prey.
   2. The bottom-up control hypothesis states that plants are consumed too rapidly by prey for replacement to keep up. This may lead to a crash of plant predators, and that may lead to a crash of higher predators of the herbivores.
   3. These are not mutually exclusive hypotheses; more probably have interaction between predation and food supplies.

9-2 Reproductive Patterns and Survival
A. Some species reproduce without having sex, and others reproduce by having sex.
   1. Asexual reproduction does not utilize sex; each cell can divide and produce two identical cells that are replicas of the original cell.
   2. Sexual reproduction occurs when gametes from each parent combine to produce offspring with a combination of genetic traits from each parent.
   3. There are three disadvantages to sexual reproduction.
      a. Males do not give birth; females have to produce twice the offspring to maintain the same number of young as an asexual organism.
      c. Courtship/mating consume energy and time, transmit disease, and inflict injury on males in some cases.
   4. Two important advantages are genetic diversity for survival of species in the face of changes in environment and males may help with food gathering and/or rearing of young.
B. Reproductive patterns can be classified into two fundamental reproductive patterns: r-selected and K-selected species.
   1. r-Selected species have a high rate of reproduction with little parental care. They have many, usually small offspring. The massive loss of offspring is compensated for by the large numbers of offspring in each reproductive cycle.
   2. r-Selected species are opportunists and reproduce when conditions are favorable or when disturbance opens a niche for invasion. Most species of this type go through irregular and unstable boom-and-bust cycles in population size.
   3. Competitor or K-selected species are at the other extreme. They produce later in life, have a small number of offspring, are born fairly large, are cared for and protected by parents, and mature more slowly.
   4. K-selected species generally follow a logistic growth curve. Many of the larger species with long generation times and a low reproductive rate are prone to extinction.
   5. Availability of a suitable habitat for individuals of a population ultimately determines the population size.
C. Populations of different species vary in how long individual members typically live.
   1. A survivorship curve is one way to represent age structure of a population.
   2. Three generalized types of survivorship curves are: late loss, early loss, and constant loss.
   3. A life table shows the numbers of individuals at each age on a survivorship curve. Insurance companies use life tables to determine the cost of insurance policies.
9-3 Effects of Genetic Variations on Population Size

A. Variations in genetic diversity can affect the survival of small, isolated populations.
   1. Several factors can play a role in loss of genetic diversity and survival of a small population.
   2. The founder effect is when a few individuals move to a new location that is isolated from the
      original population. There is limited genetic diversity in such a population.
   3. A demographic bottleneck occurs when only a few individuals survive a catastrophe.
   4. Genetic drift is a third factor and involves random changes in gene frequencies in a population.
      This may help or hurt the survival of the population.
   5. Inbreeding occurs when members of a small population mate one another; this may increase the
      numbers of defective genes in a population.

B. Metapopulations occur where some mobile populations occasionally exchange genes when some
   members get together. Conservation biologists use this information to establish migration routes that
   will enhance population size, genetic diversity, and survival of related local populations.

9-4 Human Impacts on Natural Systems: Learning from Nature

A. Humans have altered nature in ways that threaten the survival of many species, including our own
   species.
   1. Humans have directly affected changes on about 83% of the earth’s land surface.
   2. Humans have altered nature to meet needs and wants in nine major ways.
      a. Destruction, fragmentation, and degrading of wildlife habitats have reduced biodiversity.
      b. The simplification and homogenization of natural ecosystems by clearing land and planting a
         single species (monoculture) reduces numbers of species and interactions. Opportunistic
         species and pest organisms are costing time, energy, and money to control. Invasion of
         pathogenic organisms is another threat.
      c. Destruction of the earth’s net primary productivity is a third type of alteration.
      d. Certain types of intervention have unintentionally strengthened pest species and disease-
         causing bacteria.
      e. Some predator species have been deliberately eliminated from ranching areas.
      f. Alterations have occurred due to the introduction of nonnative or new species into an
         ecosystem.
      g. A number of renewable resources have been over-harvested, such as overgrazing of
         grasslands, over-hunting of wildlife, and pumping out aquifers for freshwater faster than they
         can recharge.
      h. Some human activities also interfere with normal chemical cycling and energy flows in
         ecosystems.
      i. Human-dominated ecosystems are increasingly dependent on nonrenewable energy from
         fossil fuels that produce pollution and add greenhouse gases to the atmosphere.
   3. Alteration of natural ecosystems needs to be slowed down, and we need to maintain a balance
      between simplified, human-altered ecosystems and more complex, natural ecosystems.

B. By mimicking four major ways that nature has adapted and sustained itself, we can develop more
   sustainable economies.
   1. We are totally dependent on the sun and Earth for life. We are an expendable species.
   2. Everything is interconnected and interdependent. What connections are strongest, most important,
      and most vulnerable are those that we must discover.
   3. Any intrusion into nature has unexpected and unintended side effects. We must not deplete and
      degrade the earth’s natural capital.
Summary

1. Population changes in size, density, makeup, and distribution in response to environmental stress, but there is no direct relationship between the stressors and the population characteristics. Populations distributed throughout a habitat vary from species to species. The age of a population may influence its size directly. The carrying capacity is determined by biotic potential and environmental resistance.

2. Reproductive patterns in species are influenced by ample resources and limited resources. Once resources become limited, the population must decrease over time. The patterns among specific species vary, but there are four general types of population fluctuations: stable, irruptive, cyclic, and irregular.

3. If a population is fairly large, genetic diversity will be fairly constant, and the size of the population will be maintained. If a population is small and/or isolated, limited genetic diversity will threaten it. If a few individuals survive a catastrophe, they may be unable to rebuild the population. Inbreeding and genetic drift also influence a population’s viability.

4. Human activities and the use of technology now threaten the survival of many species and may affect our own quality of life. We have reduced biodiversity, homogenized natural ecosystems, wasted/destroyed the earth’s net primary productivity, strengthened some pest species and disease-causing bacteria, eliminated most predators, introduced nonnative species into ecosystems, overharvested renewable resources, interfered with chemical cycling and energy flows in ecosystems, and become dependent on nonrenewable resources.

5. We must maintain a balance between human-altered ecosystems and natural ecosystems. We must implement and live the spirit of these four guidelines:
   …We are totally dependent on the sun and the earth.
   …Everything is interdependent.
   …Anything we do will have consequences.
   …We must live off the biological income of the earth’s natural capital, not squander it.