14.3 Population Density and Distribution

**KEY CONCEPT** Each population has a density, a dispersion, and a reproductive strategy.

**MAIN IDEAS**

- Population density is the number of individuals that live in a defined area.
- Geographic dispersion of a population shows how individuals in a population are spaced.
- Survivorship curves help to describe the reproductive strategy of a species.

**VOCABULARY**

- **population density**, p. 436
- **population dispersion**, p. 437
- **survivorship curve**, p. 438

**Connect** If you have ever traveled from a rural area into a city, you may have noticed a change in population density. Cities have more dense populations, while rural areas have more widely dispersed populations. Scientists measure species populations in a similar way. What can we learn from population data?

**Illinois Standards**

- **12.11.32** Know that fluctuations in population size are determined by the relative rates of birth, immigration, emigration, and death.
- **12.11.36** Understand the effects upon the population of a species caused by various ecological factors, particularly (a) the presence of another species with competitive feeding habits, (b) the presence (or absence) of and number of predators, (c) the abundance or scarcity of food sources.

**MAIN IDEA**

**Population density is the number of individuals that live in a defined area.**

The wandering albatross may fly over open ocean waters for days or weeks at a time without ever encountering another bird. In contrast to this solitary lifestyle, elephant seals may gather in groups of a thousand or more on California beaches. By collecting data about a population in a particular area, scientists can calculate the density of a population. Population density is a measurement of the number of individuals living in a defined space.

Calculating an accurate population density can tell scientists a great deal about a species. When scientists notice changes in population densities over time, they work to determine whether the changes are the result of environmental factors or are simply due to normal variation in the life history of a species. In this way a wildlife biologist can work to make changes that will help to keep the population healthy. One way to calculate population density is to create a ratio of the number of individuals that live in a particular area to the size of the area. This formula is simplified as follows:

\[
\text{Population density} = \frac{\text{# of individuals}}{\text{area (units}^2\text{)}}
\]

For example, if scientists sampling a population of deer counted 200 individuals in an area of 10 square kilometers, the density of this deer population would be 20 deer per square kilometer.

**Connect** What might a decrease in the density of a deer population over a specific time period tell scientists about the habitat in the area?
Geographic dispersion of a population shows how individuals in a population are spaced.

Other information can be gained from population density measurements. Patterns of geographical dispersion give us ideas of how individuals of the same species interact and how different species interact with one another.

**Population dispersion** is the way in which individuals of a population are spread in an area or a volume. **FIGURE 14.7** shows the three types of population dispersion.

- **Clumped dispersion** Individuals may live close together in groups in order to facilitate mating, gain protection, or access food resources.
- **Uniform dispersion** Territoriality and intraspecies competition for limited resources lead to individuals living at specific distances from one another.
- **Random dispersion** Individuals are spread randomly within an area or a volume.

**Infer** What type of intraspecies interaction might cause uniform dispersion?
QUICK LAB

INTERPRETING DATA

Survivorship Curves

In this lab, you will make a type 1 survivorship curve using data from the obituary section of a newspaper.

PROBLEM What is the trend in data for type 1 survivorship curves?

PROCEDURE

1. Obtain the obituary section of the newspaper.
2. Create a data table like the one at right that extends to include five-year age groups up to 91–95 years.
3. For 35 obituaries, place a tally next to the age group in which the individual died.
4. Subtract the number of individuals that died from the number of remaining survivors, and record the answer in the third column of your data table. Calculate the percent surviving in each age group by dividing the number of survivors by 35 and multiplying by 100. Repeat this step for all age groups.

ANALYZE AND CONCLUDE

1. Graph Data Draw a survivorship curve by plotting the age group on the x-axis, and the percent survivors on the y-axis.
2. Analyze Explain the trend in the data.

<table>
<thead>
<tr>
<th>TABLE 1. SURVIVORSHIP DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>0–5</td>
</tr>
<tr>
<td>6–10</td>
</tr>
<tr>
<td>11–15</td>
</tr>
<tr>
<td>16–20</td>
</tr>
<tr>
<td>21–25</td>
</tr>
</tbody>
</table>

MATERIALS

• obituary section of a newspaper
• graph paper

MAIN IDEA

Survivorship curves help to describe the reproductive strategy of a species.

The California red-legged frog of the western United States is an amphibian that reproduces by laying 2000 to 5000 eggs in late winter and early spring. In one to two weeks, these eggs hatch, and over the next four to seven months, the tadpoles grow into frogs. If so many eggs are laid, why is this frog a threatened species in much of the western United States?

Many predators feed on the eggs of the red-legged frog, so of the thousands of eggs laid, only a small number of offspring will survive to adulthood. This type of reproductive strategy is to produce a lot of offspring. Species use many other reproductive strategies as well. Survivorship curves illustrate how offspring survival from birth to death fits in with the survival strategies of a particular species.

A survivorship curve is a generalized diagram showing the number of surviving members over time from a measured set of births. By measuring the number of offspring born in a year and following those offspring through until death, survivorship curves give information about the life history of a species. For example, we will begin with 100 coyotes born in year zero. After one year, 10 of those baby coyotes died from disease or predation. Of the original 100, 90 are left. During year two, 4 more coyotes die, leaving 86 of...
The original 100. In year three, 3 more die, leaving 83 of
the original 100. The number of individuals surviving
from year to year decreases, but a substantial portion of
the group will live a full life and reproduce. In Figure 14.8,
you can see the three basic patterns of animal survivor-
ship curves.

Type I The graph shows a type I survivorship curve in
orange. Type I survivorship represents a life history that is
common among large mammals, including humans. The
curve shows a low level of infant mortality and a popula-
tion that generally will survive until old age. A behavior
that most organisms showing type I survivorship share is
parental care for the young. Most infant organisms are
unable to care for themselves. By protecting their young, parents are better able
to ensure that their offspring stay alive until they can survive on their own.

Type II Organisms such as birds, small mammals, and some reptiles show
a survivorship rate that is roughly equal at all ages of an organism’s life. At all
times, these species have equal chances of living and dying, whether from
disease or as a result of predation. A type II survivorship curve is shown in
green on the graph.

Type III Organisms with type III survivorship (shown in blue) have a very high
birth rate and also a very high infant mortality rate. Species with type III
survivorship are generally invertebrates, fish, amphibians, and plants. Many of
their offspring will die from predation, but inevitably a few will survive to
adulthood and be able to pass their genes on to the next generation. Though
the California red-legged frogs are threatened largely because of habitat loss
and pollution, the frogs are also targets of high levels of predation at an early
age, making recovery for this species especially difficult.

**Synthesize** Is there any connection between survivorship curves and reproductive
strategies? Explain.

### 14.3 ASSESSMENT

#### REVIEWING MAIN IDEAS

1. A shoreline mussel species has a population density of one organism per square meter. Will all mussels be found one meter apart? Explain.
2. Draw and label a diagram showing the three population dispersion patterns.
3. How do survivorship curves show three types of reproductive strategies?

#### CRITICAL THINKING

4. **Analyze** What might be the advantages of having a clumped dispersal pattern?

5. **Infer** An organism has ten offspring. Two of these offspring die each year over a five-year period. Is the organism more likely to be a bird or an insect? Explain.

6. **Abiotic Factors** On the African savannah, what types of abiotic factors may lead to high population density and clumped dispersion patterns?
Population Growth Patterns

**KEY CONCEPT** Populations grow in predictable patterns.

**MAIN IDEAS**
- Changes in a population’s size are determined by immigration, births, emigration, and deaths.
- Population growth is based on available resources.
- Ecological factors limit population growth.

**VOCABULARY**
- immigration, p. 440
- emigration, p. 440
- exponential growth, p. 441
- logistic growth, p. 441
- carrying capacity, p. 442
- population crash, p. 440
- limiting factor, p. 443
- density-dependent limiting factor, p. 443
- density-independent limiting factor, p. 444

**Connect** That banana you left in your backpack did not go unnoticed. After one week, you open your bag and dozens of tiny insects swarm out. The smell of rotting fruit follows close behind. Only a week ago, the population of fruit flies in your backpack was zero. Just before you opened it, the population had grown to several dozen. How did this population grow so quickly?

**MAIN IDEA**

Changes in a population’s size are determined by immigration, births, emigration, and deaths.

The size of a population is usually changing. If resources such as food and water are abundant, or plentiful, a population may grow. On the other hand, if resources are in short supply, the population may decrease in size. Hopefully, the normal fruit fly population in your backpack is zero. But if an abundance of resources, such as an overripe banana, becomes available, the population will increase dramatically. However, when the resources are removed, the fruit fly population in your backpack will once again return to zero. Four factors affect the size of a population.

- **Immigration** When one or two fruit flies found the banana, they immigrated into your backpack. **Immigration** is the movement of individuals into a population from another population.
- **Births** Additional fruit flies were born in your backpack. Births increase the number of individuals in a population.
- **Emigration** After you opened your backpack, some fruit flies flew out and left to find other rotting fruit. **Emigration** is the movement of individuals out of a population and into another population.
- **Deaths** You might have squashed a couple of unlucky fruit flies as you were opening your backpack. The size of a population decreases when individuals die.

**Apply** When a population is declining, what two factors are likely outpacing what other two factors?
Population growth is based on available resources.

Population growth is a function of the environment. The rate of growth for a population is directly determined by the amount of resources available. A population may grow very rapidly, or it may take a bit of time to grow. There are two distinct types of population growth.

**Exponential Growth**
When resources are abundant, a population has the opportunity to grow rapidly. This type of growth, called exponential growth, occurs when a population size increases dramatically over a period of time. In **FIGURE 14.9**, you can see that exponential growth appears as a J-shaped curve.

Exponential growth may occur when a species moves to a previously uninhabited area. For example, in 1859 an Australian landowner returning home from England brought 24 European rabbits to the country for the purpose of sport hunting. The rabbits were introduced into an environment that had abundant space and food and no predators fast enough to catch them. The initial population of 24 rabbits grew exponentially and spread across the country. After many attempts to control the population, today there are between 200 million and 300 million rabbits in Australia.

**Logistic Growth**
Most populations face limited resources and thus show a logistic growth rate. During logistic growth, a population begins with a period of slow growth followed by a brief period of exponential growth before leveling off at a stable size. A graph of logistic growth takes the form of an S-shaped curve and can be seen in **FIGURE 14.11**, which models a population’s change in size over time. During initial growth, resources are abundant, and the population is able to grow. Over time, resources begin to deplete, and growth starts to slow. As resources become limited, the population levels off at a size the environment can support.
Carrying Capacity

The environment determines how many individuals of the species can be supported based on natural cycles and species diversity. An environment, therefore, has a carrying capacity for each species living in it. The carrying capacity of an environment is the maximum number of individuals of a particular species that the environment can normally and consistently support.

In nature, a carrying capacity can change when the environment changes. Consider a population of grasshoppers that feed on meadow grasses. If a fire burns part of the meadow, the insects’ food resources diminish, and the carrying capacity declines. But during years with plentiful rain, the meadow grasses flourish, and the carrying capacity rises.

The actual size of the population usually is higher or lower than the carrying capacity. Populations will rise and fall as a result of natural changes in the supply of resources. In this way, the environment naturally controls the size of a population.

Population Crash

When the carrying capacity for a population suddenly drops, the population experiences a crash. A population crash is a dramatic decline in the size of a population over a short period of time. There are many reasons why a population might experience a crash.

DATA ANALYSIS

READING COMBINATION GRAPHS

Combination graphs show two sets of data on the same graph. One set of data may be shown as a bar graph, while the other set may be shown as a line graph. The two data sets must share the same independent variable on the x-axis. Scientists can then interpret the data to determine if a relationship exists between the variables.

This combination graph displays data about fish kill events, during which many fish died at once, and average monthly rainfall in Florida from 1991–2001.

- The y-axis on the left side represents the total number of fish kill events.
- The y-axis on the right side represents average monthly rainfall during that time.
- The x-axis shows the month of data collection.

The graph shows that in January there were four fish kill events and an average of 2.7 inches of rain.

1. Analyze  An increase in fish kills and a decrease in rainfall occurs in what months?
2. Analyze  Describe the trend in the fish kill events throughout the year. Describe the trend in rainfall data throughout the year.
3. Hypothesize  What relationship might exist between fish kill events and rainfall?

**GRAPH 1. FLORIDA FISH KILLS 1991–2001**

Source: The University of Florida Extension Information Circular 107. Used by permission.
For example, in 1944, 29 reindeer were introduced to St. Matthew Island off the coast of Alaska. At the time of the introduction, the entire island was covered with a rich mat of lichens. Plenty of good food allowed the reindeer herd to grow at an exponential rate. By the summer of 1963, the island population had grown to 6000 reindeer. However, over the winter, large amounts of snow fell on food resources that had already become greatly depleted by the large herd. By the spring of 1964, only 50 reindeer remained. The population crash on St. Matthew Island came as the result of two factors that limited resources: the harsh winter and the scarcity of food.

**Predict** What would have eventually happened to the reindeer herd if the winter had not made foraging so difficult? Explain.

**MAIN IDEA**

**Ecological factors limit population growth.**

Many factors can affect the carrying capacity of an environment for a population of organisms. The factor that has the greatest effect in keeping down the size of a population is called the *limiting factor*. There are two categories of limiting factors—density dependent and density independent.

**Density-Dependent Limiting Factors**

Density-dependent limiting factors are limiting factors that are affected by the number of individuals in a given area. Density-dependent limiting factors include many different types of species interactions.

- **Competition** Members of populations compete with one another for resources such as food and shelter. As a population becomes denser, the resources are used up, limiting how large the population can grow.

- **Predation** The population of a predator can be limited by the available prey, and the population of prey can be limited by being caught for food. On Isle Royale in Michigan, changes in wolf and moose populations, shown in **FIGURE 14.13**, provide an example. As the moose population grows, so does the wolf population. But at a certain point, the wolves eat so many moose that there are not enough left to feed all the wolves. The result is a decrease in the wolf population. Over time, the two populations rise and fall in a pattern, shown in **FIGURE 14.13**.

- **Parasitism and disease** Parasites and diseases can spread more quickly through dense populations. The more crowded an area becomes, the easier it is for parasites or diseases to spread. The parasites or diseases can then cause the size of the population to decrease.

**Analyze** How does the wolf population on Isle Royale affect the carrying capacity of the moose population?

**FIGURE 14.12** Taking down prey as large as a moose requires that the members of a pack work together. As many as ten wolves may take hours or even days to wear down this moose.

**FIGURE 14.13 DENSITY-DEPENDENT LIMITING FACTORS**

Source: Isle Royale Research Data
FIGURE 14.14 The storm surge accompanying a hurricane can cause dangerous flooding.

Density-Independent Limiting Factors

Density-independent limiting factors are the aspects of the environment that limit a population’s growth regardless of the density of the population.

Unusual weather Weather can affect the size of a population regardless of its density. For example, along the western coast of the United States, a lack of southerly winds can prevent nutrient-poor warm water from being replaced, as it normally is, with nutrient-rich cold water. The lack of nutrients in the water along the coast can prevent phytoplankton, which form the base of the marine ecosystem, from growing in their usual large numbers. In turn, zooplankton, tiny organisms that feed on phytoplankton, have smaller populations. The effects are felt all the way up the food chain, with smaller populations of fish and birds.

Natural disasters Volcanoes, tsunamis, tornados, and hurricanes, shown in FIGURE 14.14, can wipe out populations regardless of density. For example, the large wave of a tsunami can damage fragile coral reefs, knock down entire mangrove forests, and destroy sea turtle nesting beaches.

Human activities Destruction of a wetland habitat along the Platte River in Nebraska has threatened an important feeding ground for the sandhill crane. Urbanization in this area is depleting the resources these migratory birds need during their trek to nesting grounds in northern Canada and in Alaska. By clearing forests, filling wetlands, and polluting the air, land, and water, humans threaten habitats and the organisms that live in them. As we will discuss in Chapter 16, human influence as a limiting factor has had a profound effect on populations. For example, the introduction of nonnative species has caused population crashes in many parts of the world where biodiversity is an important part of the ecosystem’s functioning.

Apply A population of algae in a pond is limited in size by the amount of sunlight that strikes the pond’s surface. Is sunlight a density-dependent or density-independent limiting factor for the algae population?

14.4 ASSESSMENT

REVIEWING MAIN IDEAS

1. What four factors determine the growth rate of a population?
2. How does carrying capacity affect the size of a population?
3. What is the main difference between a density-dependent limiting factor and a density-independent limiting factor? Give examples of each.

CRITICAL THINKING

4. Apply What might cause exponential growth to occur only for a short period when a new species is introduced to a resource-filled environment?
5. Synthesize How might density-dependent limiting factors be affected by a flood or some other natural disaster?

6. Symbiosis Give an example of how a symbiotic relationship could cause a population crash.