42 Populations

Chapter Outline

42.1 – Populations Are Patchy in Space and Dynamic over Time
42.2 – Births Increase and Deaths Decrease Population Size
42.3 – Life Histories Determine Population Growth Rates
42.4 – Populations Grow Multiplicatively, but the Multiplier Can Change
42.5 – Immigration and Emigration Affect Population Dynamics
42.6 – Ecology Provides Tools for Conserving and Managing Populations

Chapter 42 begins with a description of populations of individuals in a species that interact with one another in a given area. Population density and population size are two measures of ecological interest. There are many sampling tools for determining population size, but most involve determining the population density and then multiplying this by the area of the population's habitat.

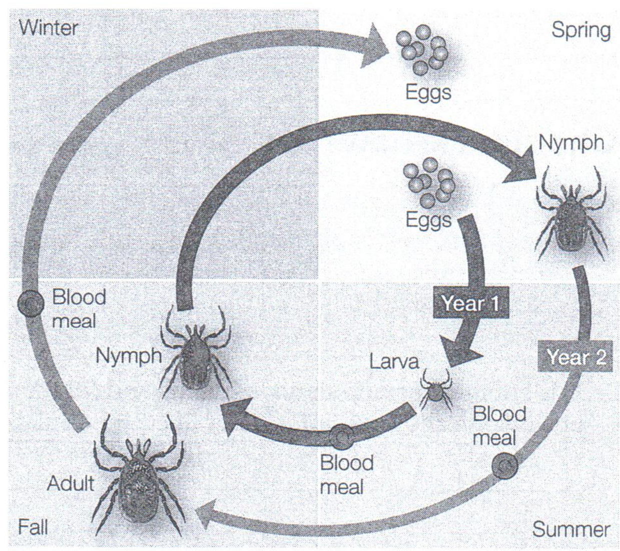
Populations change over time in response to many factors. At a simplistic level, the change in the size of a population (dN) over time (dt), assuming no immigration or emigration, is the number of births (B) less the number of deaths (D), as shown by this equation:

$$\frac{dN}{dt} = B - D$$

Because it is usually impossible to monitor every individual in a population, ecologists calculate per capita birth and death rates (i.e., the average individual's number of offspring and the average individual's chance of dying, in some interval of time). The difference between these birth and death rates is the per capita growth rate (r). By multiplying r by the population size (N), we obtain an estimate of population-growth rate over time. This is expressed by this equation:

$$\frac{dN}{dT} = rN$$

The life history of a species describes growth, development, reproduction, and death. Life histories are represented as circles beginning with eggs or mating parents and ending with the next generation. Below is a diagram showing the life history of the black-legged tick. Life histories can be very complex, particularly if a species relies on blood meals from other species. Other resources, such as light, space, and temperature, must also be considered.



Population growth rates typically fall into two patterns, exponential (multiplicative) and logistic. The equations representing these two models are:

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

Exponential growth — *Logistic growth*

Most species will grow multiplicatively until they reach their carrying capacity (K). At this point, they will fluctuate up or down in response to resource availability or changing environmental conditions. Rarely do we see a species with a consistent population size at its carrying capacity. Most species show frequent increases or decreases in population.

This chapter includes material relevant to **Big Idea 1**, **Big Idea 2**, and **Big Idea 4**. The specific parts of the AP Biology curriculum covering **Big Idea 1:** The process of evolution drives the diversity and unity of life, include:

- **1.A.1**: Natural selection is a major mechanism of evolution.
- **1.C.1**: Speciation and extinction have occurred throughout the Earth's history.

The specific parts covering **Big Idea 2:** Biological systems utilize free energy and molecular building blocks to grow, to reproduce, and to maintain dynamic homeostasis, include:

- **2.A.1**: All living systems require constant input of free energy.
- **2.A.3**: Organisms must exchange matter with the environment to grow, reproduce, and maintain organization.
- **2.D.1**: All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy.
- **2.D.3**: Biological systems are affected by disruptions to their dynamic homeostasis.

The specific parts addressing **Big Idea 4:** Biological systems interact, and these systems and their interactions possess complex properties, include:

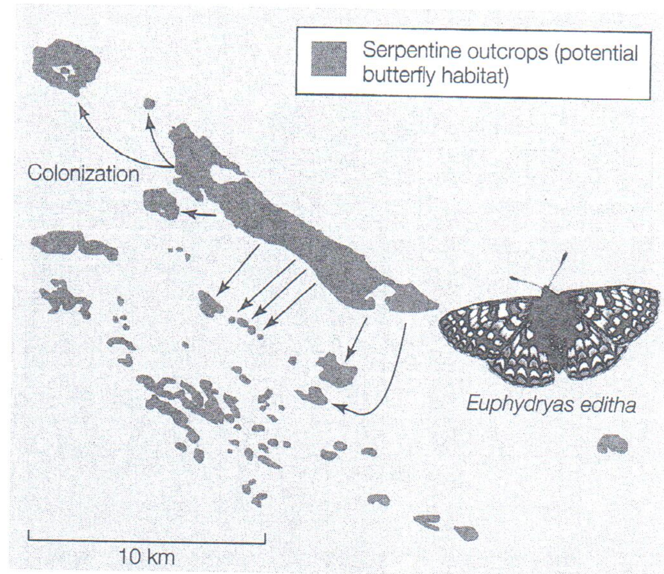
- **4.A.5**: Communities are composed of populations of organisms that interact in complex ways.
- **4.A.6**: Interactions among living systems and with their environment result in the movement of matter and energy.
- **4.B.3**: Interactions between and within populations influence patterns of species distribution and abundance.

Chapter Review

Concept 42.1 *points out that there are many ecological, aesthetic, and ethical dimensions to the study of population dynamics. Humans have long been managing populations, including herds of cattle, fields of crops, schools of fish, and endangered populations of plants and animals.*

1. Identify three populations (plants and/or animals) that are actively managed by humans. Then identify one abiotic and one biotic factor in each population's environment that affect its abundance.

2. Edith's checkerspot butterfly (*Euphydryas editha*) extends from British Columbia and Alberta to Baja California. Many subpopulations of this endangered butterfly went extinct during a severe drought between 1975 and 1977. The only subpopulation that survived was the largest one, on Morgan Hill in the San Francisco Bay Area. The butterfly population is divided into subpopulations, each occupying a patch of suitable habitat. Arrows on the drawing at the right indicate nine colonization events in 1986.

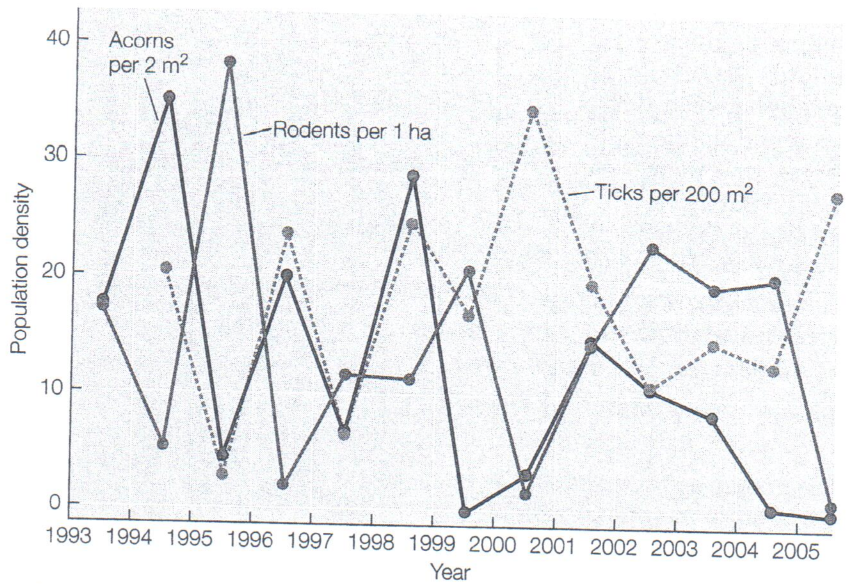


Identify and describe three factors that might prevent this checkerspot butterfly from colonizing an area.

Concepts 42.2 and 42.3 *address the study of demographics, or how populations change over time. Many formulas are given in these sections, but the ones you need to be familiar with are found on the AP Biology Exam equation sheet inside the back cover of this book.*

3. Identify two factors, other than birth and death rates, that affect the size of a population.

4. Below is a graph showing how densities of acorns, rodents (mice and chipmunks), and black-legged tick populations vary over time in a New York State oak forest.



a. Propose and justify the relationship between acorn and rodent densities.

b. Propose and justify the relationship between rodent and tick densities.

c. Ticks are parasites relying on blood meals to reproduce. Propose the effects of changes in one abiotic factor and one biotic factor on tick population numbers.

d. For the year 2000, calculate the number of ticks in the forest if the forest covers 50 square kilometers.

e. Identify two abiotic and two biotic factors that also could influence the population fluctuations seen in the figure.

5. The table below shows the survivorship and fecundity for cactus ground finches born in 1978 on one island in the Galápagos archipelago.

Quantitative Life History for 210 Common Cactus Finches Born in 1978 on Isla Daphne			
Calendar year	**Age of bird (years)**	**Survivorship[a]**	**Fecundity[b]**
1978	0	1.00	0.00
1979	1	0.43	0.05
1980	2	0.37	0.67
1981	3	0.33	1.50
1982	4	0.31	0.66
1983 Increased rain	5	0.30	5.50
1984	6	0.20	0.69
1985 Drought	7	0.11	0.00
1986	8	0.07	0.00
1987 Increased rain	9	0.07	2.20

[a]Survivorship = the proportion of the 210 birds that survived from birth to a given age
[b]Fecundity = the average number of young born per female of a given age

a. Identify the age range when the ground finches in this study were reproducing at their highest rate.

b. Survivorship at age x is the proportion of the original cohort that survived to age x. Calculate how many birds did not make it to one year of age.

c. Propose the relationship between increased rainfall in 1983 and increased fecundity in that year.

d. Fecundity is the average number of young per female. Assume that one-half of the population is female. Calculate the number of young born in 1983.

6. Assume that a population of 25 women and 25 men, all 21 years old, colonizes a previously uninhabited island. Twenty babies are born the following year. In the table at the right, write in possible life table values for these twenty babies.

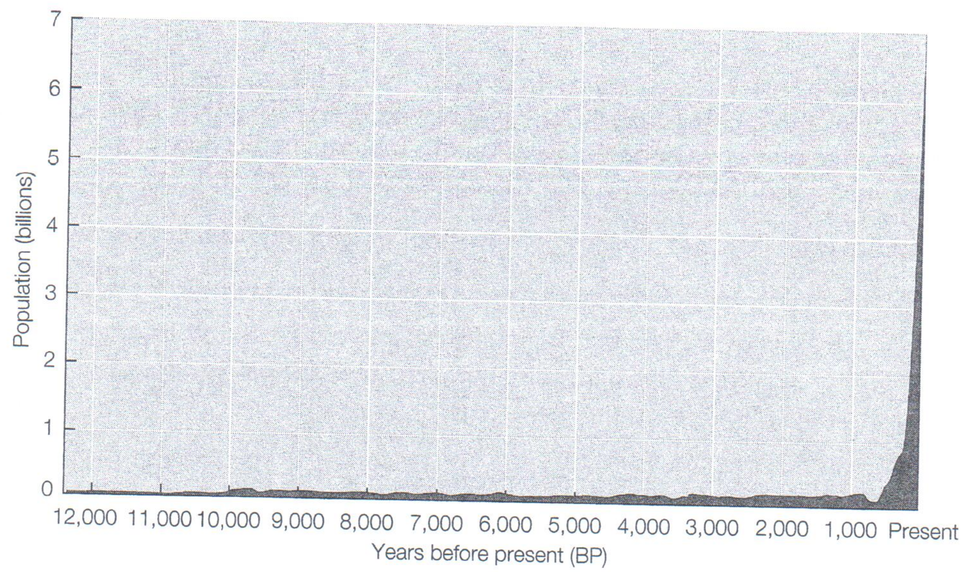
Year	Age	Survivorship	Fecundity
1	0	1.00	0.00
5			
10			
15			
20			
25			
30			
35			
40			
45			
50			
55			
60			
65			
70			

7. Describe the assumptions you made when giving the survivorship and fecundity values in Question 6.

Concept 42.4 *focuses on the dynamics of population growth rates. Most populations tend to grow at either a logistic or an exponential growth rate. Time is a key consideration here, and even if human imagination is not always able to grasp the passage of time, the mathematics make the conclusions clear.*

8. Explain why populations cannot grow multiplicatively for extended periods of time.

9. The graph below shows growth in the human population over more than 12,000 years.



a. Discuss whether the growth in the first 11,500 years should be classified as multiplicative or additive.

b. Discuss whether the growth in the last 500 years on the graph should be classified as multiplicative or additive.

c. Propose an explanation for the fact that the number of human offspring continues to increase over a long period of time.

d. Discuss how the population crash approximately 500 years ago might have affected human genetic diversity.

Questions 10 and 11 refer to an infestation of yellow star-thistle (*Centaurea solstitialis*), a spiny annual plant native to the Mediterranean region. The species, a noxious weed that is unpalatable to livestock, has invaded several regions of the United States, including an imaginary farm operated by Rancher Jane.

10. Jane carefully inspects her ranch every year. In 2012, there was no star-thistle. In 2013, she discovered that one hectare of her ranch's 128-hectare pasture had been invaded. In 2014, she found the weed population had grown to cover two hectares. Based on this pattern, predict how many hectares of her land the star-thistle will infest in 2015, 2016, and 2017 if the pattern is:

   a. growing additively.

   b. growing multiplicatively.

11. Imagine that Jane did not see any star-thistle in 2012, but she discovered in 2013 that the star-thistle population had suddenly infested 32 hectares of her pasture. Calculate how many years she has until the weed completely covers the pasture, if its population is:

   a. growing additively.

   b. growing multiplicatively.

Concept 42.5 *deals with metapopulations, so this section is beyond the scope of the AP Biology Curriculum Framework. Still, it is useful to know that population size of species does change due to more than just births and deaths. Immigration and emigration, as well as habitat fragmentation induced by humans, can be significant factors in population size.*

12. Extinction of populations in small patches can easily occur.

a. Identify a fragmented habitat in your local area.

b. Name the animals found in this habitat, and describe the risks they face.

c. Propose two reasons for the extinction of populations in small patches.

13. Sidewalks can easily divide an area into metapopulations for small organisms, such as snails. Name one organism that might be limited in its distribution because of each of the barriers below, and explain your choice.

a. Parking lot:

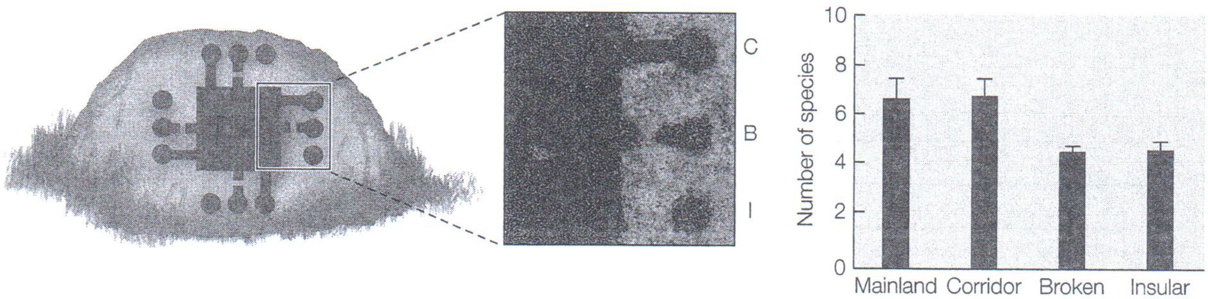
b. Small road:

c. Interstate highway:

d. Housing development:

Concept 42.6 *discusses that the ability to predict the dynamics of populations contributes to our ability to influence the fates of natural populations. On the AP exam, you will most likely not encounter a specific question about the black rockfish or the Edith's checkerspot butterfly that you read about in this chapter, as they are not listed in the AP Biology Curriculum Framework. However, there will be general population data for you to graph or interpret.*

14. In the study below, moss (dark areas) was scraped off of a rock (light areas) in the pattern shown. In the "insular" or island treatment (I), the patches are surrounded by bare rock that is inhospitable to moss-dwelling small arthropods and thus provide a barrier to recolonization. In the "corridor" treatment (C), the patches are connected to the mainland by a 7-by-2 centimeter strip of live moss. In the "broken-corridor" treatment (B), the configuration is the same as the corridor treatment, except that a 2- centimeter strip of bare rock cuts the moss strip.



After six months, the number of species of small arthropods was counted in each of the four areas.

a. Summarize the results shown in the graph.

b. Explain the purpose of the broken-corridor (B) treatment.

c. Explain why the experiment should be replicated multiple times before conclusions are drawn.

Science Practices & Inquiry

In the AP Biology Curriculum Framework, there are seven **Science Practices**. In this chapter, we focus on **Science Practice 5**: The student can perform data analysis and evaluation of evidence. More specifically, we focus on **Science Practice 5.2**: The student can refine observations and measurements based on data analysis.

Question 15 asks you to use data analysis to refine observations and measurements regarding the effect of population interactions on patterns of species distribution and abundance (**Learning Objective 4.19**).

15. Rancher Jane (Questions 10 and 11) is thinking of raising American bison (*Bison bison*) instead of cattle, but she wants to know how well bison will do on her ranch. She buys 50 inseminated female bison and places ten of them, chosen at random, into their own pasture. Using these ten females as a sample, Jane collects demographic data for one year. Use her data in the table at the right to answer the questions below. Show all of your work.

Female #	Alive at end of year?	# of offspring
1	Yes	1
2	Yes	0
3	Yes	1
4	Yes	0
5	No	0
6	Yes	1
7	Yes	1
8	No	0
9	Yes	1
10	Yes	0

a. What is the total number of births and deaths among this sample population?

b. What are the estimated birth and death rates for Jane's entire herd of 50 bison, based on this sample?

c. Based on these estimates, what will the size of Jane's entire herd of bison be at the end of the year?