CHAPTER 6 POPULATION BIOLOGY

Chapter Overview

An AP student needs to be competent in exponential and logistic growth curves, and the implications of each, including the concept of carrying capacity. Type I, II and III survivorship curves, characteristics of *r*- and *K* -selected species, and examples of each should be learned. Students need to know biotic and abiotic factors in the environment and their role in determining population size. Applications to conservation biology should be understood.

Topics and Key Concepts

The Living World

- Summarize the theory of island biogeography.

Population

- Explain the relationship between logistic and exponential growth; include the role of the carrying capacity in your discussion.
- Classify *r*-selected versus *K*-selected species characteristics. Link the types of survivorship curves to the two groups of species.
- Explain and cite examples of density dependent and density independent factors.
- Differentiate between genetic drift and demographic bottleneck.

Key Terms

abiotic
biotic
carrying capacity
demographic bottleneck
density-dependent
density-independent
exponential growth
founder effect
genetic drift
island biogeography
K-selected species
*lag time
logistic growth
metapopulation
minimum viable population size
population crash
r-selected species
stress-related diseases

** These key terms are not boldfaced in the chapter text, but are still important for the AP Exam.*

Pacing Guide

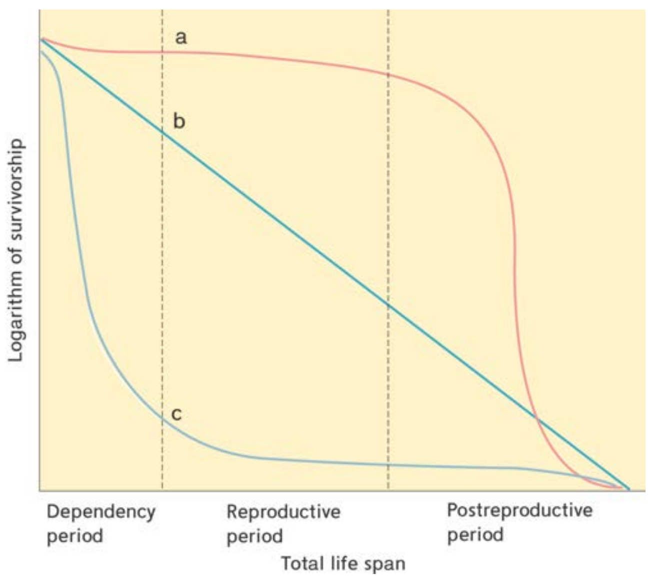
Plan on spending 5-7 days on this chapter.

Approach and Tips

Students are not allowed to use calculators on the AP exam, so make sure they can perform all mathematical operations without this tool. Have students practice the Rule of 70 to learn the doubling time of different populations.

Diagrams of both exponential (*J* curve) growth and logistic (*S* or sigmoid*)* growth curves should be used to explain the differences, noting that exponential growth has no limits and is unrestricted, while logistic growth levels off at the carrying capacity.

Figure 6.8 (p. 123) illustrates the three basic types of survivorship curves. Discuss each curve using the specific organism given, or have students name a different organism that fits the pattern. Make sure students are able to give specific units of time for humans.



Use specific examples of *r*-selected species and *K*-selected species. Using these examples, have the students give characteristics of each species that illustrate their reproductive strategy. Also, stress the importance of reproductive strategy and survival/extinction of species. Type I, II and III survivorship curves should be discussed with application to both reproductive strategies.

Type I (curve a) is a late-loss curve. The likelihood of survival increases with age resulting in more deaths in older organisms. These organisms frequently top consumers and *K*-strategists. A human lifespan is illustrated by a Type I curve. Type II (curve b) represents a constant-loss curve. The likelihood of death does not change with age, as death is equal in all age groups. Examples include sea gulls, rodents, and some plants. In Type III (curve c), or early-loss curve, organisms

experience early life mortality rates. The probability of survival increases as these organisms age. There are many offspring with high mortality, but if they survive, they are likely to live their entire life span. Examples include sea turtles, oysters, and redwood trees.

Discuss the reproductive strategies of *r*-selected and *K*-selected species. Students should be able to provide information on at least one plant and animal of each type. Discuss the differences between r-strategists and *K*-strategists. *K*-strategists are more likely to become endangered, and subsequently extinct, due to the characteristics listed below. Examples of *K*-strategists include elephants, bald eagles, and elk. The definition of *r* or *K* is dependent upon a stable environment. In some cases a species can be either an *r*- or a *K*-strategist, depending upon their environment.

***r*-selected**	***K*-selected**
1. Short life	1. Long life
2. Rapid growth	2. Slower growth
3. Early maturity	3. Late maturity
4. Many small offspring	4. Fewer large offspring
5. Little parental care and protection	5. High parental care and protection
6. Little investment in individual offspring	6. High investment in individual offspring
7. Adapted to unstable environment	7. Adapted to stable environment
8. Pioneers, colonizers	8. Later stages of succession
9. Niche generalists	9. Niche specialists
10. Prey	10. Predators
11. Regulated mainly by extrinsic factors	11. Regulated mainly by intrinsic factors
12. Low-trophic level	12. High-trophic level

Basic terminology of population growth needs to be examined. Four factors that contribute to the rate of growth, r, are **B**irths, **I**mmigration, **D**eaths and **E**migration, often abbreviated as BIDE (Births + Immigration – Deaths – Emigration). Some students prefer to learn to calculate r using the formula r=INS- OUTS. Therefore, r= {(BR+IR) – (DR+ER)}100. Students need to remember that rates are per 1000, so if the population is greater than 1000, reduce the BR, DR, IR, and ER to match 1000 in the denominator. Natality is the production of new individuals by birth, hatching, germination, or cloning. It is the primary way in which populations increase.

Fecundity is the physical ability to reproduce, whereas fertility is a measure of the number of offspring produced by a female. Migration also affects population size. Immigration is movement into a population and emigration is movement out of a population. Mortality is the number of organisms that die in a particular time frame divided by the number living at the beginning of the time frame. Life expectancy is the probable number of years of survival for an individual of a certain age. Your life expectancy increases for every year you live. Life span is the longest period of life reached by a given organism.

Using specific examples of natural disasters and diseases, have the students determine whether the population density, or the amount of the population in a given area, is a determining factor in these situations. This should help the students discover the meanings of both density-dependent and density-independent factors. With respect to biotic and abiotic factors have the students use the etymology (bio and a-bio) of the words to find the meanings. The students should be able to give examples of both types of factors in an ecosystem. If there is significant understanding, they should also be able to explain how these factors limit populations.

Carrying capacity is the maximum number of individuals that the ecosystem can support. Ask the students why there is a carrying capacity and explain that carrying capacity is not a fixed value; it is altered based on seasons, environmental conditions, and any adverse severe weather conditions. This should lead to a discussion of several factors that limit population growth, both biotic (living) and abiotic (non-living). Population overshoot should be addressed as well, since the resultant environmental degradation can lower the carrying capacity.

The importance of conservation biology especially in reference to endangered species should be examined. A critical question in conservation biology is the minimum population size of a rare and endangered species required for long-term viability. Students should be able to critically analyze the theory of island biogeography with specific reference to population size and biodiversity. Have students calculate doubling time using the Rule of 70. Cite specific growth rates and tell the students to calculate doubling time without a calculator. In addition, give the students the doubling time and have them calculate growth rate.

Common Mistakes and Misconceptions

Make sure that the students can solve the Rule of 70 without a calculator. The Rule of 70 is almost certain to be a question they will be asked on the AP exam. Have students solve it by giving them the growth rate and have them determine the doubling time and also by giving them doubling time and having them determine the growth rate. Also, make sure the students understand that the

growth rate is given in a percent and that the percent is used in the equation. They are NOT to convert the percent to a decimal.
The formula is:

$$70/r = \text{doubling time (in years)}$$

Students should also be able to answer a question that has BR, IR, ER, and DR as well as doubling times given. For example, if a population of 10,000 elk has 320 births, 150 emigrants, 200 immigrants, and 100 deaths, calculate the elk population. Or, City Y has a population of 10 million. If the growth rate is 3.5%, determine the population of City Y in 40 years if the current growth rate remains the same.

Activities

Duckweed Lab Activity

A population count using duckweed is an easy lab. Duckweed (*Lemna major* or *Lemna minor* (common duckweed)) is a small, plant that looks like a mini lily pad. It can be found in some local ponds and lakes. Duckweed can be ordered from supply catalogs or you may find it by calling around to local plant nurseries that sell water garden supplies and have it taking over their ponds. These nurseries are usually happy to give you all that you can carry home for free. Some local fish supply stores will also get it in with their aquatic plant shipments and will allow you to remove it from the aquariums for them.

Take large test tubes and have each group of students (2-4 in a group) pick out with forceps four individual duckweed to place into their test tubes. Duckweed reproduces both sexually and asexually and will reproduce until it completely covers the container. As it continues to reproduce, some will be forced down under the water and will die. This lab is perfect for demonstrating exponential growth and carrying capacity.

Have the students record the number of duckweed found in the test tube using the worksheet located at the end of this teacher's manual chapter. It will take about 2 to 3 weeks for the duckweed to grow exponentially and then reach the carrying capacity. You can then have the students graph the data and answer conclusion questions also found on the worksheet.

- One way to incorporate abiotic factors into this lab is to have the students brainstorm different factors that may add to or inhibit growth of the *Lemna minor*. Several factors for them to consider could be light, pH, nitrates, and temperature. The original format could serve as the control.

Population Sampling Methods

1. Mark and Recapture – Students must estimate the size of a bean population. Students collect 20 beans and mark them. Students place beans back into the bag and mix the sample. The second catch, students capture another 20 beans and record how many are marked from the previous marking and how many total are caught. The steps should be repeated and the following equation should be used.

$$\text{Population Estimate} = \frac{\text{(number of beans marked)(number of beans caught)}}{\text{(number of beans captured with mark)}}$$

2. The Great Elephant Census Modeling Activity - Alternately, students can model counting methods using HHMI's Biointeractive lab, which can be found at https://www.hhmi.org/biointeractive/great-elephant-census-modeling-activity

3. Quadrant Sampling – Create small quadrants using PVC pipe or hula hoop. Students should sample for various types of a plants or animals (grasshoppers, ants, pill bugs). Students will record their data in charts and calculate for density, species richness, and abundance. Students should practice a variety of population math problems to ensure they can manipulate the variables necessary to solve population problems.

Questions for Review

1. What is carrying capacity? How do biotic and abiotic factors play a role in carrying capacity? Give an example of each factor and its impact on a specific population.
   Carrying capacity is the number or biomass of a species that can be supported in a certain area without depleting resources. Biotic and abiotic factors limit growth due to their limited availability. Biotic factors include living entities, such as predators. While abiotic factors include non-living entities, such as habitat, sunlight, nutrients.

2. What is the doubling time for a population with a growth rate of 3.5%? *20 years*

3. A population of a particular species doubles every 35 years. What is the growth rate?
   2%

4. A population has a growth rate of 2.0%. If the initial population of a particular species is 50 individuals, how many years before the population is 200?
   70 years

5. A female cockroach can have 80 offspring every 6 months. What factors would limit the growth of the population? Is this population a *K*-selected species or an *r*-selected species? Explain why.
   Limiting factors include food, water, habitat and predators. Cockroaches are r-selected species that have a high reproductive rate and are considered a generalist species.

6. Abiotic factors tend to be density-independent. A collection of plants that is successful when receiving 10 hours of sunlight per day is placed in a location that receives only 6 hours of sunlight per day. What will happen to the population over time? Explain your reasoning.
   The population of plants will probably diminish in time and may eventually die off since the sunlight is a limiting factor and the plants are not getting the amount of sunlight necessary.

Practice Questions

<u>Multiple Choice:</u>

Directions for questions 1-5: The lettered choices below correspond to the descriptions given in questions 1-5. Select the one lettered choice that best fits each statement. Each choice may be used once, more than once, or not at all.

(A) exponential growth
(B) logistic growth
(C) carrying capacity
(D) population crash
(E) survivorship curve

1. *S* shaped curve

2. *J* shaped curve

3. rapid die back

4. the top level portion of a sigmoid population graph

5. signifies growth of natural populations due to limiting factors

Directions: For each of the following questions, select the one lettered choice that best answers the question.

6. Which of the following is an *r*-selected species?
   (A) humans
   (B) giant panda
   (C) African elephant
   (D) cockroach
   (E) elk

7. Which of the following is a density dependent factor in population growth?
   (A) fire
   (B) disease
   (C) volcanic eruption
   (D) flood
   (E) hurricane

8. A population of bald eagles exhibit which of the following characteristics?
    I. they are predators
    II. upper trophic level species
    III. produce many small offspring
    (A) I only
    (B) II only
    (C) III only
    (D) I and II
    (E) I, II and III

9. The number or biomass of a species that can be supported in a certain area without depleting resources is defined as the ______________.
    (A) population crash
    (B) logistic growth
    (C) exponential growth population
    (D) natural increase
    (E) carrying capacity

10. A type III survivorship curve exhibits all of the following characteristics except
    (A) late loss
    (B) many offspring with high mortality
    (C) those that survive live their entire life span
    (D) early loss
    (E) produce many offspring

Free-Response Question

Directions: Answer all parts of the following question. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. When a calculation is required, be sure to show how you arrived at your answer.

1. The giant panda is an endangered species that lives in China. Answer the following questions with regard to this endangered species.
   (a) Identify and describe TWO reasons why the giant panda is endangered.

   (b) Is the giant panda a *K*-selected species or *r*-selected species? Explain your reasoning.

   (c) In 2004, the population of giant pandas in the wild in China was 1600 individuals. If their growth rate is 1.0%, in what year will their population exceed 3200 individuals?

   (d) Describe TWO strategies that the Chinese government could employ to insure that the population of giant pandas will continue to rise.

Practice Questions Answers

Multiple Choice:

1. B
2. A
3. D
4. C
5. B
6. D
7. B
8. D
9. E
10. A

Free-Response Question:

This question is based on 10 points.

1. (a)4 points total. 1 point for each identification and 1 point for each description. Some identifications and descriptions include: it is endemic—only found in one place in the world which would make it more susceptible to extinction, it is a specialist species—only eats bamboo so if the bamboo forest is destroyed, extinction is possible, it does not reproduce quickly, so numbers cannot be added to the population quickly, if habitat is destroyed then possible extinction for either reason (endemic or specialist species)

   (b) 2 points total. 1 point for identifying that the giant panda is a *K*-selected species and 1 point for explanation. Explanation can include any characteristic of *K*-selected species including, but not limited to, slow reproductive rate, specialist species, and high investment in individual offspring.

   (c) 2 points total. 1 point for calculating doubling time and 1 point for indicating after 2074 as the date when the population will exceed 3200.

   Doubling time = 70/1.0= 70 years

   2004 + 70 = 2074

   (d) 2 points total. 1 point for each strategy.

Strategy
captive breeding program
establishing wildlife sanctuaries for the giant panda
fines and jail time for poaching/illegally hunting the giant panda

Answers to questions in the Student Edition:

Case Study AP Document-Based Question (page 117)

(A) Answers will vary but two options are fish aggregating devices and sonar buoys. Fish aggregating devices are floating objects that have been used by fishermen for centuries, but today's high tech devices can be equipped with satellite and sonar so they can tell a boat captain almost exactly what is swimming beneath it. Sonar buoys transmit similar data directly to boat captains, so they can go directly to where they know the fish will be. Other answers may include the use of spotter planes, fish cages, and advances in mobile fish processing.

(B) The largest increase in bluefin tuna catches were from 1990-1995. East Atlantic bluefin tuna catches increased by 6,000 metric tons per year and Mediterranean bluefin tuna catches increased by 4,400 metric tons per year.

(C) The rate of increase for East Atlantic bluefin is 4,500 metric tons/year (47,500-25,000/5). The rate of increase for Mediterranean bluefin tuna is 3,500 metric tons/year ((37,500-20,000)/5).

Use the Math (page 121)

The Rule of 70 is a simple way to calculate how long a population takes to double in size. Simply divide 70 by the rate of growth in percentage. In other words, 70/x% = doubling time.

Doubling time is 23.3 years for a cockroach population growing at a rate of 3% per year to double in size.

Use the Math (page 123)

Answers will vary but three ways in which these data deviate from a model include: in the 1870's the hare and lynx populations peaked around the same time. The strength of response in the number of lynx pelts does not match well with the number of hare pelts on many occasions, and in some years (e.g. after 1850, around 1870, and 1890) the hare population has two peaks without a crash, whereas in other years (e.g. 1860's) there is one peak and a big crash. If we were to gather these data today, a better option might be videography, which could remove some of the bias from the pelt collections (skills of the hunters, hunter preference, etc.) without killing the animals. Another option could be mark-recapture studies, which also do not kill the animals (but could introduce observer bias based on the ability to trap and collect samples).

AP Connections Review Answers (pages 129-130)

Multiple-Choice

1. e. This is density independent because all animals in the stream are affected equally.

2. c. Logistic growth maintains a population near the carrying capacity for the population. The curve for logistic growth is shaped like an S, and these populations are affected by environmental resistance. Exponential growth results in growth at a constant rate of increase per unit time. Logistic growth occurs in part because organisms are densely distributed.

3. b. Birds tends to have a linear survivorship graph, because they have equal mortality at all age groups.

4. c. ZPG occurs when the birth rate equals the death rate.

5. d. large number of offspring.

6. b. have long life spans

Data Analysis and Free-Response Questions

1A This is an example of exponential growth.

1B N at t_5, t_6, and t_7 are 200,000; 2 million; and 20 million, respectively.

1C There is a 900% increase between time points (e.g. [20 – 2]/2 * 100 = 900). The doubling time is 4 and 2/3 days (70/900 * 60).

2A Density-dependent factors include x, x, and x. Density-independent factors include x, x, and x.

2B Species grow faster when they are r-selected because their reproductive strategy ensures that some of their young will survive, even in unstable environments –they are often either in low trophic levels, or they are successional species. K-selected species grow slowly in a stable environment and so do not overshoot their ecosystem’s carrying capacity. This makes them appear to have intrinsic growth limits.

Duckweed Activity/Lab Worksheet

*Student:*____

Date	Days Elapsed	Number of Individuals

Conclusions:

1. Has this population reached the carrying capacity of the test tube?

2. What are the limiting factors for population growth of duckweed?

3. What would happen in a lake or pond if duckweed completely covered the surface? What environmental effects might this have?

4. Can any organism exhibit exponential population growth forever? What happens to a population that is above its carrying capacity?

5. Do you believe there will be a point when the human population, which is growing exponentially, will reach the carrying capacity of the earth? Why or why not?